THE JOURNAL OF INDIAN PROSTHODONTIC SOCIETY

Official publication of Indian Prosthodontic Society

Vol. 23 | Issue 1 | January-March 2023

Print ISSN 0972-4052
E-ISSN 1998-4057

Wolters Kluwer

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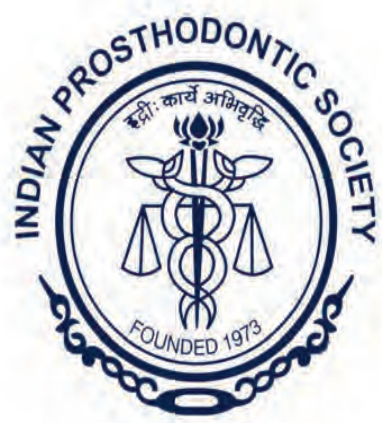

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The Journal of Indian Prosthodontic Society is the official publication of The Indian Prosthodontic Society. Published quarterly, this journal serves as a platform for the exchange of interesting case reports, scientific studies, literature reviews and valuable tips for the common benefit of the prosthodontics community. The journal also aims to bring evidence-based dentistry to the forefront and highlight its importance.

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To serve as a medium for continued prosthodontics education and quantitative scientific publications on clinical trials, basic science related to the biological aspects of prosthodontics, basic science related to prosthodontics techniques as well as orofacial pain that will ultimately improve the prosthodontics research and patient's health and psychological comfort.

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IPS EXECUTIVE COUNCIL 2022-23

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The Journal of Indian Prosthodontic Society (JIPS) (ISSN: 0972-4052, Online 1998-4057) is a peer-reviewed journal published on behalf of the publication of Indian Prosthodontic Society. The journal publishes articles relating to Prosthodontics and restorative dentistry including implants, esthetic, ceramics and reconstructive dentistry. The Journal is published in March, June, September and December.

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Copies are sent to the members of Indian Prosthodontic Society free of cost. A subscription to The Journal of Indian Prosthodontic Society comprises 4 issues. Prices include postage. Annual Subscription Rate for non-members-

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  USD 185.00 for outside India
- Personal: INR 6500.00 for India
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E-mail: editorjips2021@gmail.com, anandkumar.v@sriramachandra.edu.in
Website: www.j-ips.org

Published by

Wolters Kluwer India Private Limited
A-202, 2nd Floor, The Qube,
C.T.S. No.1498A/2 Village Marol,
Andheri (East),
Mumbai - 400 059, India.
Phone: 91-22-66491818
Website: www.medknow.com

Printed at

Nikeda Art Printers Pvt. Ltd.,
Building No. C/3 - 14,15,16,
Shree Balaji Complex, Vehele Road, Village Bhatale, Taluka Bhiwandi,
District Thane - 421302, India.

The Journal of Indian Prosthodontic Society

Official Publication of Indian Prosthodontic Society

Volume 23 ▪ Issue 1 ▪ January-March 2023

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CLINICAL TECHNIQUES

Survey questionnaires in dental research

The pandemic has resulted in the submission of numerous self-developed nonvalidated questionnaire-based manuscripts by authors. These nonvalidated questionnaires may deviate from the outcome and provide a false interpretation of the described study objective. A questionnaire for survey-based research contains a set of questions that are developed to collect data related to demography, health-related information, or opinions from respondents.[1]

The development of a new questionnaire is nonessential when a validated questionnaire is available in the literature. Authors should have a thorough knowledge of framing a questionnaire if a void exists in the literature. It needs to be reinforced that a questionnaire in the English language must be validated when administered in a regional language to the regional participant. For example, an oral health impact profile-14 questionnaire administered in a regional language to an individual would alter the meaning or intended objective of the questionnaire. The author should also consider performing both forward (from English to Regional language) and backward (from translated Regional language to English) translations. The forward translation of the regional language is reliable only if the backward translation provides the same meaning as the original questionnaire. Blinding the backward translators about the intended idea/objective of the research would prevent bias. Apart from language, the questionnaire that has been intended for a particular age, sex, or social group will not match the other subdivision of the group, and hence these also require revalidation based on the objective of the study design. Authors should understand that exhibiting their high proficiency in the language while framing questions and lack of training with the administrator, especially in interview-based questions, makes the participant misunderstand the actual meaning of the questions.

Development/validation of a new questionnaire begins with a literature review to identify the void that necessitates the framing of questions. The essential aspect of framing a survey-based research questionnaire is shown in Figure 1. An observation or interview with a few participants by the focus group method helps identify the problem from the population's perspective.[2,3] Literature search being an imminent part of any research, obtaining an expert interview specialized in the field is an essential aspect before framing questions. Based on focus group discussion and expert opinion, the researcher should synthesize the questions correlating to his/her objective; each objective becomes a domain with a set of questionnaires.

Validation of each question begins with a preliminary cognitive interview of 10 participants and checking the participant's way of understanding the question. The question should be selected based on the analogous outcome of these participants, followed by the removal of unwanted questions, or modifying the language of the question. After cutting the clutter, the researcher should redo the cognitive interview with another set of 20 participants in two sets, with 10 in each, to confirm cognitive validation.

The reliability of the questionnaire follows cognitive interview and should involve checking with at least 30 participants. It is judged by the reproducibility of similar answers when the questionnaire is administered at different intervals of time, with a minimum of 15 days gap between the interviews. However, it is difficult to evaluate the reliability of pain at different intervals since the patient experiences pain at different levels with time. Reliability also helps to determine errors present in content sampling, variations in demographic characteristics of respondents, measurement scales, etc. There are multiple aspects in evaluating reliability; internal consistency, test–retest reliability, inter-rater reliability, parallel form reliability, and split-half reliability. *Internal consistency,* measured by Cronbach alpha co-efficient that evaluates the inter-correlation of items in the questionnaire, and the reliability of 0.7 is adequate to check the validity to a wider population. *Test-retest* reliability is administering the questionnaire to the same respondents at a different period of research and measuring the Pearson correlation. *Parallel*

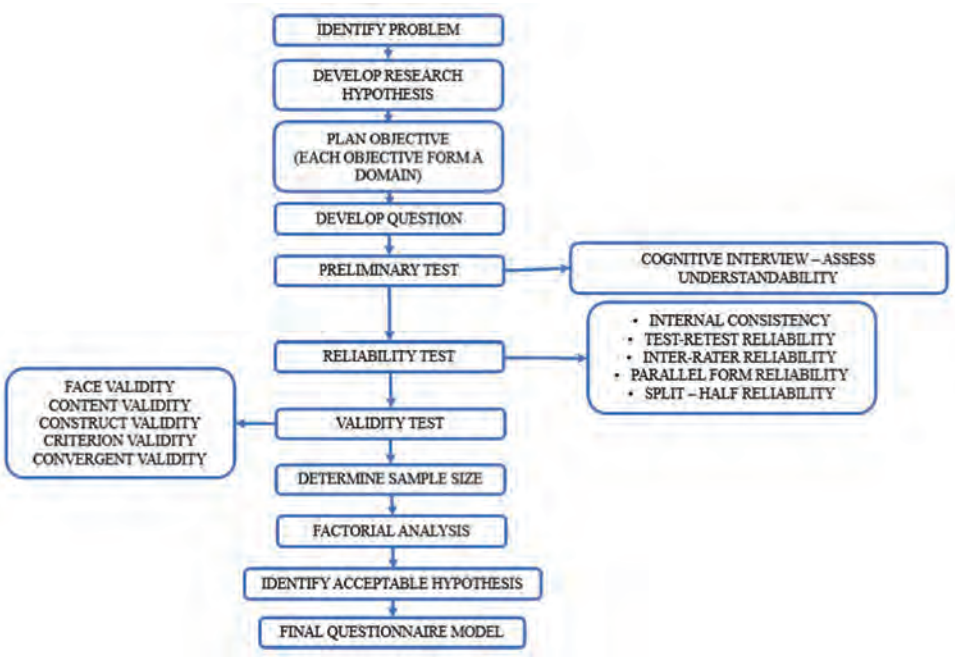

Figure 1: Sequence of questionnaire validation

form reliability is the evaluation of two different domains of a questionnaire by the same participant, responding to the first domain followed by the second domain. *Split-half reliability* is the evaluation of two different domains of a questionnaire by splitting the participants and providing the questions of each domain to each of the groups simultaneously. We also need to check the *Inter-rater reliability* between different questionnaire administrators and a kappa coefficient above 0.61 is an acceptable agreement.[4] The researcher should understand that it is an unethical practice to increase the number of questions to increase the reliability. A participant will ignore the "*n*" number of questions and responds without even reading the questions, especially in online mode.

Validation is done after reliability to confirm the constructed questions measure the intended objective of the study. For example., assessing the oral health quality of life specific to cardiac disease measures the output of oral health from cardiac disease and not because of their social status or health issues. Validity also has several phases: face validity, content validity, construct validity, criterion validity, and convergent validity. *Face validity* is the linguistic analysis, and the response from each person depends on the IQ or understanding ability of the respondent. The response also depends on their age, educational, and socioeconomic status and is assessed by the Cohens kappa index. *Content validity* is the expertise given by the panelist to evaluate the efficiency of the chosen items to measure the variables in a domain measured by Lawshe's Method.[5,6] *Construct validity* determines the set/sequence of a question under each domain that correlates with the objective. It is considered small if the correlation coefficient observed is 0.1, moderate if it is observed as 0.3, and large if it is observed as 0.5. *Criterion validity* is validating with gold standard questionnaires or experts from that field to ensure the test measures the intended objective. It is also called concrete validity and measures the outcome of a questionnaire-based survey in different situations such as past, present, and future. Convergent validity tests the questionnaire for correlation with the previously validated tool that had been constructed for the same objective.

The magnitude of the sample size is critical for the research. Larger samples will waste the resources of the researcher and the organization, and smaller samples may not correctly represent the population under study. The sample size is computed by using a sample size calculator or use of qualitative guidelines like 5:1 (50 samples for 10 questions), 10:1, 15:1, or 30:1. A minimum of 300 patients should be assessed, and the value of 0.5 obtained from factorial analysis to validate the questionnaire the question matches an appropriate domain. A value of <0.5 requires repetition of the reliability test by framing new questions. The researcher may either discard the question or get an expert opinion on the necessity of retaining the question.

A researcher cannot use any question available online, as it may lead to copyright issues. The researcher should seek permission from the primary author to use it in their research without any commercial motive.

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Submitted: 28-Nov-2022, **Revised:** 16-Dec-2022, **Accepted:** 17-Dec-2022, **Published:** ***

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Quick Response Code:

Website: www.j-ips.org

DOI: 10.4103/jips.jips_519_22

How to cite this article: Vaidyanathan AK, Banu FR. Survey questionnaires in dental research. J Indian Prosthodont Soc 2023;23:1-3.

Review

A narrative review on techniques of iris replication in an ocular prosthesis

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Abstract

The disfigurement associated due to the loss of an eye can cause a significant physical and psychological disturbance. Psychological distress among such unfortunate patients can be reduced by providing an artificial eye. Rehabilitating such patients with an ocular defects is the most challenging task for a prosthodontist. The custom-made ocular prostheses are preferred over the prefabricated stock eye shells as it provides intimate contact with the tissue bed, enabling an ideal fit. For an esthetic ocular prosthesis, the precise positioning of an iris is a primary requirement to avoid the squint eye appearance. Various case reports are documented in the literature for centralizing the iris in the prosthetic eye. This review article explores the established methods and techniques for positioning the iris in a custom-made ocular prosthesis.

Keywords: Customized scale, facial measurements, graph grid, iris positioning, ocular prosthesis, prosthetic eye

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Submitted: 18-May-2022, **Revised:** 13-Oct-2022, **Accepted:** 22-Oct-2022, **Published:** ***

INTRODUCTION

The eyes are the first features of the face to be noted. The unfortunate loss or absence of an eye may be caused by a congenital defect, irreparable trauma, or tumors. The disfigurement due to the loss of an eye can cause significant physical and emotional problems.[1] Therefore providing an artificial substitute to restore the form and functions is the mandatory reason for such disability. Prosthodontic rehabilitation of such patients has therefore become the treatment option to restore esthetics and comfort and also elevate the psychological status of such patients.[2]

In terms of anatomy, the iris is the muscular, pigmented curtain that covers the area in front of the eye between the cornea and the lens and is punctured by the pupil. The iris is situated behind the cornea and in front of the lens and ciliary body. Iris positioning in a prosthetic eye is critical as the complete success of maxillofacial prosthesis depends on the esthetics offered, which in turn lifts the patient's quality of life. The esthetics mainly depends on positioning the iris along with proper shade selection and contouring. Various factors affecting iris positioning are the appropriate selection of shape, size, contour, and color of the iris.[3]

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_252_22

How to cite this article: Nimonkar SV, Belkhode VM, Dahihandekar C, Nimonkar PV, Pisulkar S. A narrative review on techniques of iris replication in an ocular prosthesis. J Indian Prosthodont Soc 2023;23:4-11.

Many methods for the precise positioning of the iris have been described in the literature, such as an ocular locator, fixed calipers, grids, dividers, inverted anatomic tracings, and visual assessment.[4] The present literature review aims to highlight all the proposed techniques for iris positioning in a prosthetic eye with their pros and cons. This study will help the maxillofacial prosthodontist select the appropriate iris positioning technique to enhance the prosthetic eye's esthetics.

METHODOLOGY

The present narrative review used the Preferred Reporting Items For Systematic Review and Meta-Analyses guidelines for the literature search, including all the relevant articles. The search strategy is in Table 1 with an assessment based on the Population, Intervention, control, and outcomes study criteria.

LITERATURE SEARCH

The dental literature in English was searched electronically to find scientific articles that applied to the methods of iris positioning in patients with ocular and orbital defects. The following index word searches were used in PubMed, Google Scholar, and Cochrane: Iris positioning and patients with ocular and orbital defects. The publication year ranged from January 1969 to February 2022, allowing the quest to encompass all of the papers in that database. The abstracts were read first, followed by the full-text documents that had been preselected.

Articles with full text were collected and reviewed further for research that met the inclusion criterion. The inclusion criteria include all the case reports, which are in the English language from 1969 to February 2022. The titles and abstracts of all screened papers were evaluated and checked for appropriateness. Finally, a manual search was conducted to enhance the electronic search, which included the citations of the documents that were eventually retrieved. Newcastle–Ottawa Quality Assessment scale was used for assessing the risk of bias in prospective studies. AXIS tool was used for bias assessment of cross-sectional studies. Examples of times in the AXIS tool include assessing the appropriateness of the study design for the stated aims, sample size justification, the reliability of survey instruments, and evaluating whether the response rate raises concerns.

Table 1: Systematic search strategy

Search strategy	Protocol followed
Focus question	Population: Patients with ocular defects seeking prosthetic rehabilitation in the form of ocular prosthesis Intervention: Various techniques for iris positioning in an ocular prosthesis Comparison: Advantages of newer techniques over earlier techniques for iris positioning Outcome: To select the best technique available for the orientation of the iris accurately in a particular case
Search combination	"Positioning," "Iris," and "Ocular Prosthesis"
Electronic database searched	PubMed, Google Scholar, and Cochrane
Inclusion criteria	All articles in the English language Articles from 1969 to February 2022
Exclusion criteria	Articles other than the English language

RESULT OF LITERATURE SEARCH

The electronic search in the GoogleScholar and PubMed databases provided a total of 25 articles that were considered potentially relevant. The text found using the "and" Boolean operator in between the search words: Positioning, Iris, and ocular Prosthesis were 25. In the second phase of article selection, one article was excluded as it was not found to be in the English language. Another 1 article was excluded as the complete text was not found. After reading the full text, 24 articles were selected for the present review. After reading the full text out of 24 articles, three articles were excluded due to duplication of method and material. A total of 21 articles were selected for the narrative review, as described in Figures 1 and 2. The Newcastle–Ottawa Scale and AXIS Tool showed that the study design was appropriate, with a proper selection of articles for generating the best results.

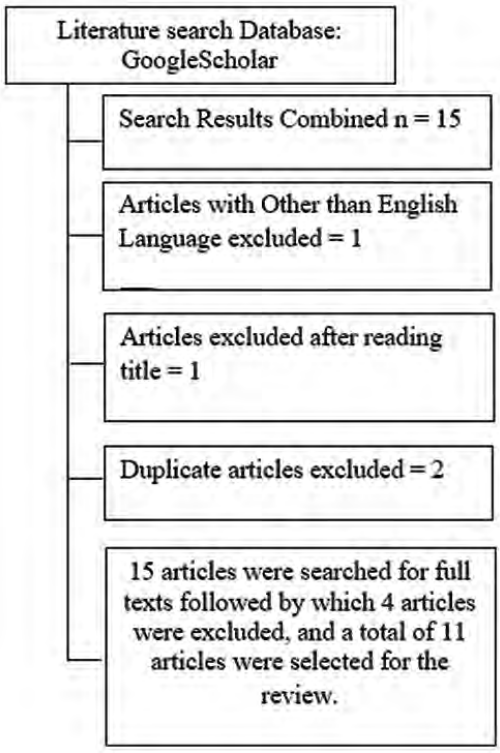

Figure 1: Inclusion of articles from Google Scholar Search

RESULT OF INCLUDED ARTICLES

The methods and techniques involved for iris positioning in an ocular prosthesis that were included in this review were pupillometers by Roberts,[5] facial measurements using anatomic landmarks by Brown,[6] window light by Joneja *et al*.,[7] visual assessment by James *et al*.,[8] ocular locator by McArthur,[9] inverted anatomic tracings by Nusinov *et al*.,[10] graph grid method by Guttal *et al*.,[11] Boleys gauge by Manvi *et al*.,[12] grid cutouts placed on spectacle frame by Pai *et al*.,[13] customized scale computer-aided designing/computer-aided manufacturing (CAD/CAM) by Gupta *et al*.,[14] modified Hanau wide-view spring bow by Shetty *et al*.,[15] customized frame spring bow assembly by Chamaria *et al*.,[16] pupillary distance (PD) ruler by Bhochhibhoya *et al*.,[17] digital photograph by Dasgupta *et al*.,[18] and optical Vernier interpupillary distance (IPD) ruler by Chicago and Syafrinani,[19] a laser pointer technique by Belkhode *et al*.[20] and digital imaging by Lanzara *et al*.,[21] and Naes' ruler by Atwal *et al*.[22] were included in the present review.

DISCUSSION

A prosthetic eye is frequently used to replace an eye lost or removed due to a congenital deformity, accident, or malignancy. The physical and psychological effects of evisceration, enucleation, or exenteration of an eye influence the patient's quality of life. In such unhappy individuals, rehabilitation in the form of a prosthetic eye reestablishes shape, improves psychological status, and restores esthetics and comforts.[23-25]

The most critical stage in creating a prosthetic eye is positioning the iris. A correctly positioned iris gives the patient's face realism and symmetry. The exact location of the iris has been widely established in the literature using a variety of approaches and procedures.[26] Subjective and objective techniques can be used to classify these methods. Ocular locator, fixed calipers, grids, divisions, inverted anatomic tracings, and visual evaluation are examples of subjective procedures. They manipulate the operator's perception for the iris to be precisely positioned. The list of subjective and objective techniques used for iris positioning is listed in Table 2. Objective techniques were developed and published to solve the issues associated with subjective methods. Table 3 lists the advantages and disadvantages of objective procedures over subjective ones.

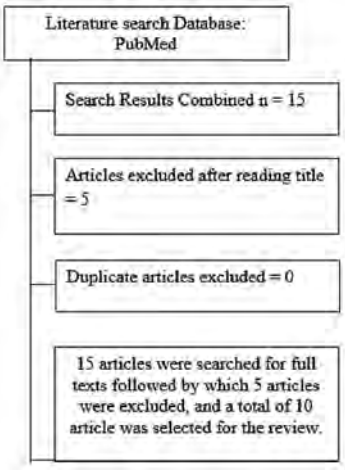

Figure 2: Inclusion of articles from PubMed Search

In 1968, Roberts developed a device consisting of cylindrical tubes with parallel axes, each with a positive lens.[5] The instrument was created with the pupil as a fixation point, with two plastic rotating discs with scale marks sitting on the bridge of the nose. The Pupillometer was designed to be utilized during the wax-up stage of construction. This pupil segment is aligned in the wax sclera for prosthetic eye replacement alone, without replacement of the surrounding orbital region. The Pupillometer was found helpful in

Table 2: List of objective and subjective techniques of iris positioning

Subjective techniques	Objective techniques
Facial measurements using anatomic landmarks by Brown[6]	Pupillometer by Roberts[5]
	Ocular locator by Arthur[9]
Window light by Joneja *et al*.[7]	Graph grid method by Guttal *et al*.[11]
	Boley's gauge by Manvi *et al*.[12]
Visual assessment by James *et al*.[8]	Grid cutouts placed on spectacle frame by Pai *et al*.[13]
	Customized scale for iris positioning by Gupta *et al*.[14]
Inverted anatomic tracings by Nusinov *et al*.[10]	Modified Hanau wide-view spring bow by Shetty *et al*.[15]
	Customized frame spring bow assembly by Chamaria *et al*.[16]
	PD ruler by Bhochhibhoya *et al*.[17]
	Digital photograph by Dasgupta *et al*.[18]
	Optical Vernier IPD ruler by Chihargo and Syafrinani[19]
	Laser pointer apparatus by Belkhode *et al*.[20]
	Photoshop software by Lanzara *et al*.[21]

PD: Pupillary distance, IPD: Inter-PD

Table 3: Pros of objective methods over subjective methods

Properties	Objective methods	Subjective methods
Standardized readings, which are common to all	√	X
Accuracy in measurements	√	X
Easy communication with technicians	√	X
Inter-observer errors	X	√
Lesser accuracy when compared to the objective methods	X	√
The measurements cannot be communicated with the technician	X	√

√: Yes, X: No

identifying the precise location of the artificial eye in the whole prosthesis when the prosthetic eye was to be put in an orbital prosthesis. This is true for both types of applicators. The Pupillometer is used to provide a natural esthetic effect by providing an exact final registration of the position and alignment of an eye prosthesis.[5]

Brown recommended moving measurements from the normal contralateral eye to the problem location in the 1970 publication.[6] This was utilized to mimic the size and form of a typical anatomical eye. To orient the iris in the prosthetic globe, Brown proposed collecting the facial measurements of several facial anatomic features concerning the relationship of the normal eye with the neighboring anatomic structures.[6]

In a 1976 publication, Joneja *et al.* presented a verification procedure for appropriate iris placement.[7] He stated that the measurements should be taken such that the pupil's center is at the same distance from the bridge of the nose as a normal eye. The patient is next instructed to stare straight ahead in the direction of a well-lit window. The picture of window glass may be observed symmetrically in both eyes if the eyes are correctly aligned. To obtain appropriate alignment, the location of the acrylic resin eye may be changed. The "Window Light Technique" is the name given to this technique.[7]

In a 1976 study published in Glasgow, James *et al.* described a method including a wax replica of the prosthesis into which a plastic disc was placed to show the location of the iris and pupil.[8] The artificial eye's primary body is made to fit the wax model perfectly. After adding vascular and other marks to the sclera, a circular hole is drilled onto its anterior surface to receive a painted plastic disc mimicking the iris. Then, a clear acrylic cornea is put anteriorly (lensing). Then a clear acrylic cornea is put anteriorly (lensing). While the transfer of information between the fitter and manufacturer often results in a sufficient prosthesis, there are inherent issues in adequately interpreting the fitting's instructions and the regularly utilized production procedures.[8]

With his novel Ocular Locator, McArthur devised a grid approach. An X and Y-axis and a mirror image of the axes were drawn on graph paper with a grid side of 1 mm × 1 mm.[9] The division and subdivision pattern was repeated for all intervals on the X-axis. The Y-axis was labeled 1 through 9 and split and subdivided in the same way as the X-axis was divided and subdivided. The black-and-white film was used to photograph the grid. The negative was reproduced and expanded to the exact size of the original grid on photographic film. The finished device consisted of a black grid on a transparent backdrop between two sheets of 1/8th-inch Plexiglas with a nose aperture in the center. A line was scribed into the Plexiglas from top to bottom along the middle of the grid, splitting the right set of coordinates from their mirror copy on the left. A pair of horizontal lines were also scribed into the Plexiglas, one at the top and one at the bottom of the grid. The distance between the two horizontal scribed lines was reproduced using a stiff caliper. The scribe midline and intersecting set of horizontal lines on the ocular locator are superimposed over the marks on the patient's face when the locator is put on the patient's face. The ocular locator is applied to the stone moulage as it was to the patient's face. Before the prosthesis is processed, all indirectly produced facial prostheses must be directly verified on the patient's face.[9]

Nusinov *et al.* suggest a technique termed "Inverted Anatomic Tracings" for iris location and centricity in this study.[10] On a 5 × 5-inch acetate sheet (0.020 inches thick), trace the orbital architecture of the remaining eye and the orientation lines with a wax pencil. Making the tracing when the patient is staring straight ahead in a conversational gaze is critical. To ensure that all orientation lines are overlaid, invert the anatomic tracing over the surgical defect.[10]

In 2007, Guttal *et al.* employed the Graph grid approach to locate the iris.[11] Anatomical landmarks such as the midline (passing through the forehead crease, glabella, tip of the nose, and chin), medial canthus, lateral canthus, and the horizontal lines referring to the center, inferior, and superior limits of the iris were marked on the patient's face with an indelible pencil in this method. The clear grid template was used to transfer the markings. The iris was affixed to the wax pattern after the marks were put onto the sculpted scleral wax pattern.[11]

Manvi *et al.* proposed a mechanism for accurately verifying iris location in a study.[12] The ocular prosthesis was adjusted to mimic the healthy eye's location, with the patient gazing at a distant point immediately ahead. A reference mark was placed at the midline, and the mediolateral location was confirmed using a Boley gauge. The prosthesis was precisely positioned mediolaterally, anteroposteriorly, and inferosuperiorly to mirror the location of the native eye.[12]

Pai *et al.* employed grid cut on spectacle frames to position the iris in 2010.[13] On the lens of the glass eyeglasses, two grid cuts of identical size were put. The patient was told to maintain a normal conversational gaze by looking forward. An indelible ink marker was used to outline and trace the iris. This grid is removed and put on the inner surface of the afflicted eye's eyeglasses lens, aligning with the horizontal

and vertical lines of the affected eye's grid cuts. On the glassware's afflicted side, the iris's image is reflected on the grid cutout on the outside surface of the lens.[13]

In 2013, Guptal *et al*. used a customized scale to locate the iris.[14] From left to right at the top and right to left at the bottom, the custom scale was marked from 0 to 4 cm. The iris was placed mediolaterally, superior-inferiorly, and anteroposteriorly using this bespoke scale. As a reference point, the vertical line on the customized scale was aligned with the medial canthus of the eye. The mediolateral dimension of the iris and the distance from the medial outline of the natural iris to the medial canthus of the eye were measured using a bespoke scale. The measured distance was transferred to the scleral wax pattern using the tailored scale after the wax pattern was placed.[14] The patients were requested to sit up straight and maintain a normal expression, and their facial morphology was evaluated. The 3D facial models were then aligned to the standard head position. The healthy side of the mirrored model covered the fault region in the original model, which was mirrored according to the midplane. The prosthetic margin was designed to encompass the defect area's boundary, with the red circle as a guide. After the nonessential parts of the mirrored model were eliminated, a preliminary simulated prosthetic pattern was developed. The final prosthesis might be manufactured directly and swiftly using a CAD/CAM negative mold. The orbital defect was rebuilt precisely, and the ocular prosthesis was placed correctly.

In 2017, Shetty *et al*. employed a Modified Hanau wide-view spring bow to place the iris.[15] The orbital pointer is supported on the bottom border of the ala of the nose by the Hanau wide-view spring bow's frame, which has been inverted. The edentulous facebow fork was joined to the reversed frame with the transfer clamp assembly. With double-sided tape, a metal-graded scale measuring the width of the fork is affixed horizontally to the fork. Two paper clips were placed on the scale to measure the mediolateral breadth of the eye.[15]

Chamaria *et al*. used a customized frame spring bow assembly to place the iris in 2017.[16] This device consisted of a heat-cure acrylic resin frame on which a graph grid with equal lines on either side of the scale's midline was affixed. Ballpoint pen caps were used to fasten the scale to the spring bow. A Hanau Spring bow was used to attach this frame. The spring bow's graph grid and assigned scale aided in the proper alignment of the iris.[16]

In 2018, Chicago *et al*. employed an Optical Vernier IPD to locate the iris. The millimeter-scale optical Vernier IPD ruler has a moveable frame to adjust and record the distance between the eyes.[19]

In 2019, Bhochhibhoya *et al*. utilized a PD ruler to place the iris.[17] The instrument was composed of graded scales positioned in a horizontal plane relative to the patient's nose's axis. The notch on the bridge of the nose is utilized to situate the instrument in the patient, and the eye is then inserted into the ocular opening. The patient is instructed to grasp their eye in a conversational look, and the graduated scale is used to record the measurements. The sculpted scleral wax pattern is then transferred using these measurements.[17]

For iris placement, Dasgupta *et al*. in 2019 employed digital images and spectacles gridded with an mm scale.[18] A DSLR camera was used to get a shot of the entire face for digital photography. The patient was told to sit up straight without using a headrest. The patient was requested to stare straight and at eye level while the image was being taken, and the lens was held such that the flashlight's reflection was visible in the middle of the pupil. An indelible pencil was used to transfer all of the anatomical markers from the pictures on the patient's face. Both subjective and objective verification is used in this strategy.[18]

He also advocated a gridded spectacle approach by adding a gridded translucent paper to the front parallel acrylic glasses to create custom-made eyeglasses. The face marks were produced using this gridded spectacle to identify the natural eye's pupil location and corneal plane. The faulty site was then marked with these markers. The installation of a transparent grid boosted patient participation.

Belkhode *et al*. employed laser pointer equipment to locate the iris in 2020.[20] This device comprises an occlusal plane analyzer, web camera, laser pointer, and software. An "L"-the shaped metal frame was attached to the horizontal plate to the side of the typical eye to shift the occlusal plane analyzer. The laser pointer and web camera were attached to the "L" plate through holes. The horizontal plate was fastened by one more moveable vertical plate. The iris distances were measured using this adjustable vertical metal plate and a laser pointer. The web camera was connected to the laptop. It used the program "laser range finder" to precisely measure the distances between the iris and the corner of the eyes. These measurements were taken from the healthy eyewear and then repeated on the damaged eye.[20] The installation of a transparent grid boosted patient participation.

Lanzara *et al*. used photoshop software to locate the iris on a digital image in 2019.[21] The iris of a typical eye was

Table 4: Pros and Cons of subjective techniques of iris positioning

Techniques	Pros	Cons
Facial measurements using anatomic landmarks by Brown, 1969[6]	Easy to perform Does not require any specific instrument Gives esthetic results	Technique sensitive It cannot be carried out in a completely disfigured face with no scope of neighboring structure's measurements
Window light by Joneja *et al*., 1976[7]	Easy to perform It does not require any specific instrument	Technique sensitive It cannot be carried out at all times of the day
Visual assessment by James *et al*., 1976[8]	Easy communication between the dentist and the technician	Fouls the upper lid margin, which makes centralization difficult The plastic former is difficult to place
Inverted anatomic tracings by Nusinov *et al*., 1988[10]	Easy to perform Does not require any specific instrument Gives esthetic results	Technique sensitive It cannot be carried out in a completely disfigured face with no scope of neighboring structure's measurements

Table 5: Pros and Cons of objective techniques of iris positioning

Techniques	Pros	Cons
Pupillometer by Roberts, 1969[5]	Accurate iris positioning	Futile in patients with facial asymmetry Cannot be used in small clinical settings
Ocular locator by Arthur, 1977[9]	Easy and accurate iris positioning and centralization of iris	-
Graph grid method by Guttal *et al*., 2008[11]	Easy to perform and accurate Can be performed in small clinical settings	Needs subjective verification Accurate scribing of the iris can lead to subjective errors
Boley's gauge by Manvi *et al*., 2008[12]	Reduces the fabrication time	The mechanism of the use of Boley's gauge is complicated
Customized scale for iris positioning by Gupta *et al*., 2014[14]	It can be used in cases of facial asymmetry Requires minimal skill Less time Very economical Easy to fabricate	The limitation of the technique includes its subjective nature due to variation in the operator's perception The scale was fabricated with heat-polymerizing resin, so the processing errors may occur during acrylization
Modified Hanau wide-view spring bow by Shetty *et al*., 2018[15]	Uses mathematically correct method Uses readily available equipment	It cannot be used for patients without ears as it is not possible to stabilize the facebow Technique sensitive method
Customized frame spring bow assembly by Chamaria *et al*., 2017[16]	The established reference plane provides precise registration of the iris disc Less time-consuming Requires minimal skill No need for assistance Allows repeated checking of iris position It can be used for multiple patients Easy to use in the clinical setup	Cannot be used in patients without bilateral symmetry
PD ruler by Bhochhibhoya *et al*., 2019[17]	Ease of use as the construction of a customized scale is difficult and has a possibility of errors during its fabrication The technique requires less armamentarium Reduced chairside time lessens the inconvenience caused due to lengthy clinical appointments	It cannot be used in patients with facial asymmetry and hypertelorism as both eyes cannot fit within the aperture of the PD ruler
Digital photograph by Dasgupta *et al*., 2019[18]	Digital method Increased patient cooperation Avoids movement of the contralateral eye Avoids complex armamentarium Transparent grid template Increased patient cooperation More standardized than the conventional graph grid technique Spectacle helps to reproduce the same measurements in every appointment	Digital method Use of DSLR camera High precision is required while shooting the photo Technique sensitive Transparent grid template It can be used only in bilaterally symmetrical cases Proper handling of spectacles needs to avoid errors
Laser pointer apparatus by Belkhode *et al*., 2020[20]	The need for assistance is eliminated Less time-consuming Not a technique-sensitive method The device is portable and can be easily customized Can be used in multiple patients, can be used in small setups, and allows repeated checking of the iris positioning Can be used in dentulous and edentulous patients and patients with facial asymmetry	Need for additional armamentarium
Photoshop software by Lanzara *et al*., 2019[21]	The advantage of this method is its simplicity, practicality, and time efficiency	Technique sensitive
Nae's ruler by Atwal *et al*., 2020[22]	Utilizes a simple yet innovative technique Measurements of iris as well as IPD are done with ease owing to its flexibility	Requires the need of the specific instrument

PD: Pupillary distance, IPD: Inter-PD

photographed digitally. After that, the image was transferred to Photoshop software and printed on high-quality photo paper. To preserve the image of the scleral blank from the staining impact of acrylic resin, it was then veneered with a laminating bag. On the afflicted side, the scleral blank was modified and altered.[21]

Nae's ruler is a flexible ruler made of plastic, consisting of a notch for a nasal bridge and two eye boxes one on each side of the notch. The eye boxes are placed equidistant from the nasal notch bridge center. The labeling of 30 in each of the two boxes created an interpupillary distance (IPD) of 60mm, which lies in the average range of the Indian Population for both gender. On the opposite side of the ruler, there are measurements for the iris and pupil size, which helps to choose the right iris for a particular patient. Due to the flexibility of this multifunctional ruler, measurements of the iris and IPD may be done with ease. It is not complicated like other systems and provides several readings on a single ruler while being user-friendly.[22]

Newer objective techniques have overcome the shortcomings of prior subjective procedures. None of the documented techniques of iris positioning is free of lacunae. They do have some pros and cons that are listed in Tables 4 and 5. A comment on the lifespan in terms of the outcome of the various procedures for iris centering can barely be made due to a lack of well-structured and long-term prospective research. The different commonly used techniques are the Guttal *et al*.'s Grid method,[11] the Reverse anatomic tracing method by Nusinov *et al*.[10] and the laser pointer method by Belkhode *et al*.,[20] etc. The other techniques which are seldom used are the pupilometer by Roberts,[5] Ocular Locator by McArthur *et al*.[10] and Naev's ruler[22] because of the unavailability of their instruments.

SUMMARY

The success of an ocular prosthesis largely depends on the precise orientation of the iris. An attempt is made to call attention to the published articles on iris positioning. It can be concluded that the objective techniques for iris positioning making use of a simple armamentarium, without the need for patient cooperation and assistance that best suits the case, should be opted to get the best esthetic results such as techniques given by Dasgupta *et al*., Lanzara *et al*., and Pai *et al*. It depends on the proper knowledge of all the techniques with future advancements. The void for the availability of a recent theoretical review on iris positioning techniques has been filled with the compilation of all the available literature. The digital approach, such as digital photography, offers an advantage over traditional methods for iris location. However, well-structured and long-term prospective studies are recommended to comment on the longevity in terms of the outcome of the various techniques for iris positioning.

Acknowledgment

The authors would like to acknowledge the help and support of all the teaching and nonteaching staff of the Department of Prosthodontics, Sharad Pawar Dental College and Hospital.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Research

Comparative evaluation of the antibacterial activity of red diode laser therapy and 0.2% chlorhexidine against *Aggregatibacter actinomycetemcomitans* on implant healing abutments: An *ex vivo* study

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Abstract

Aims: The intraoral microbiota has a high potential to undergo dysbiosis, causing inflammatory changes with respect to the tissues surrounding either a natural tooth or an implant. Thus, the longevity of implant prosthesis depends on a thorough implant decontamination protocol. Among all the techniques available for doing so, laser is garnering increasing popularity, owing to minimal bleeding, high efficiency, and faster healing. However, limited literature exists regarding the superiority of lasers over chlorhexidine (CHX), the indisputable gold standard antibacterial chemical agent. The aim of this study was to compare the percentage of bacterial reduction of Aggregatibacter actinomycetemcomitans from implant healing abutments post red diode laser therapy versus 0.2% CHX treatment.

Settings and Design: The current study had an *ex vivo*, observational, case–control design.

Materials and Methods: Patients reporting for the second stage of the implant surgery were taken as the source of data and the healing abutments, the clinical samples. Eleven patients were chosen with one intraoral implant serving as the test site for laser treatment and another, the control site for CHX treatment. Microbiological analysis was performed via quantitative real time polymerase chain reaction to compare the bacterial reduction percentage after each treatment.

Statistical Analysis Used: Repeated measures ANOVA and independent sample *t* test were used.

Results: The mean bacterial viability of the test group (laser) was 1.2%–1.6%, and 0.6%–1.4% for the control group (CHX). The former caused a mean bacterial reduction of 96.1% while the latter, 96.3%. Both the treatments caused a highly statistically significant reduction of viable bacterial counts ($P = 0.001$). However, when compared, there was no statistically significant difference in the bacterial reduction, when compared in between the two ($P = 0.902$).

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Submitted: 31-Mar-2022, **Revised:** 28-May-2022, **Accepted:** 17-Jun-2022, **Published:** ***

Access this article online	
Quick Response Code:	**Website:** www.j-ips.org
	DOI: 10.4103/jips.jips_158_22

How to cite this article: Sengupta S, Ganesh S, Meenakshi S, Bettahalli AS, Rao RM, Swamy KN. Comparative evaluation of the antibacterial activity of red diode laser therapy and 0.2% chlorhexidine against *Aggregatibacter actinomycetemcomitans* on implant healing abutments: An *ex vivo* study. J Indian Prosthodont Soc 2023;23:12-20.

Conclusion: Laser treatment is at par with chemical implant surface decontamination. It can help bypass the complications of CHX and revolutionize the protocols for implant surface decontamination.

Keywords: Chlorhexidine, diode laser, implant surface decontamination

INTRODUCTION

Owing to its successful and predictable outcome, there has been a profound inclination toward implant dentistry over the past few decades.[1] Considering the crucial requirement of harmony between the various host- and implant-related factors, the basis of appraisal of the longevity of an implant has taken a gradual yet definitive shift of focus from earlier concepts such as implant surgical planning and osseointegration toward a long-term comprehensive maintenance of the implant and its associated peri-implant tissues.[2] This has led to the emergence of implant surface decontamination.

The topography of an implant surface has historically been in the spotlight as it can modulate the colonization of different microorganisms.[3] The constant salivary submergence during its entire period of function exposes the implant to a complex microbial biofilm. This biofilm may initially consist of commensals, under certain deleterious variables such as an unfavorable pH shift, systemic illnesses, or local inflammatory conditions, may undergo a dysbiotic shift to more Gram negative, anaerobic, fusiform pathogenic taxa. Various authors postulate that the peri-implant biofilm harbors a similar microbiota as that of the adjacent teeth, indicating that the residual teeth serve as the reservoir for bacterial accumulation in the biofilm surrounding the implants. Such pathobionts, combined with the host immunity response, can induce enzymatic tissue destruction and challenge the maintenance of the integrity of the attachment and functioning of the osseointegrated implant.[4,5] One such putative bacterium is *Aggregatibacter actinomycetemcomitans*, present in high numbers at the intracoronal compartment and peri-implant sulcus of healthy implant surfaces.[6] This bacterium not only has a strong association with intraoral lesions like localized aggressive periodontitis but also, in rare cases, can show systemic seeding and cause brain abscess, endocarditis, etc.[7,8] However, it is essential to keep this bacterial load within a critical threshold for an effective implant decontamination regimen. The literature documents various nonsurgical and surgical methods, among which, in recent times, laser therapy and chemical disinfection strategies are the most sought-after ones.[9,10] However, there is insufficiency of literature to consider either as the preliminary conservative mainstay. Thus, the purpose of the current study was to compare the antibacterial activity of red diode laser therapy of wavelength 808 nm, with that of 0.2% chlorhexidine (CHX) treatment for the reduction of the bacterial load of *A. actinomycetemcomitans*, as detected from surfaces of implant healing abutments.

MATERIALS AND METHODS

The current *ex vivo*, observational, case–control study was carried out in the Department of Prosthodontics and Crown and Bridge, in collaboration with the Department of Periodontology and the Department of Microbiology, and was approved by the Institutional Ethical Committee (Research Protocol Number 38/2019). The selection criteria were established after purposive sampling in a way that 11 systemically healthy partially edentulous patients, having undergone prior implant placement surgery for at least two intraoral sites [Figure 1a], and now reporting to the outpatient department for the prosthetic phase, were included [Figure 1b]. Pregnant and lactating mothers; subjects under any anti-inflammatory drugs, antibiotics, and/or analgesics; subjects presenting with any other lesion not pertaining to the scope of the study; and subjects undergoing periodontal therapy at the time of recruitment were excluded.

There were three phases to the current study, explained as follows:

Phase X: Patient recruitment phase

Patients undergoing the second-stage implant surgery for at least two sites intraorally were recruited for the study after obtaining written informed consent. Healing abutments were placed at the two sites, as per the standard treatment care decided by the clinician.

Phase A: Pretreatment sample collection

Collection of clinical samples

After 14 days of placement, the two healing abutments were removed, put into two microcentrifuge tubes, and allocated to the test/control group via simple randomization to avoid the risk of selection bias [Figure 1a-c]. After appropriate coding of both the groups, microbiological analysis was performed for the pretreatment bacterial load of *A.*

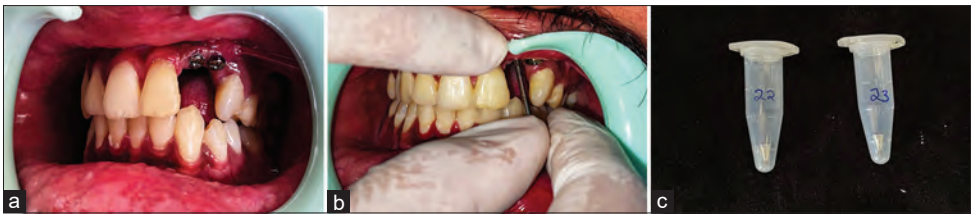


Figure 1: Clinical sample collection from oral cavity of study subject. (a) Intraoral left lateral view of subject post second-stage surgery of implant placement at two intraoral sites. (b) Removal of the two healing abutments with the implant hex driver. (c) Collection of the two healing abutments into sterile microcentrifuge tubes prior to simple randomization for allotment to test and control groups

actinomycetemcomitans from the clinical samples, without having undergone any kind of treatment. The steps for doing so have been mentioned as follows.

Preparation of clinical sample solution

Two hundred microliters of 0.9% normal saline solution was pipetted to each of the two microcentrifuge tubes and vortexed to mechanically disperse the biofilm adhered to the samples into the entire volume of the saline solution. Then, the entire volume from each microcentrifuge tube was divided into two further parts. Thus, each subject yielded four microcentrifuge tubes in the pretreatment phase, each containing 100 μL of the initial sample solutions having the biofilm collected from the subject's intraoral sites:

1. Test sample (laser, L)
    a. 100 μL aliquot, for quantification of total target bacteria present in that sample, L_{Dx}^{Ua}
    b. 100 μL aliquot, for quantification of viable target bacteria present in that sample, $L_{D✓}^{Ua}$
2. Control sample (CHX)
    a. 100 μL aliquot, for quantification of total target bacteria present in that sample, CHX_{Dx}^{Ua}
    b. 100 μL aliquot, for quantification of viable target bacteria present in that sample, $CHX_{D✓}^{Ua}$

Application of viability dye, propidium monoazide, PMAxx

PMAxx dye concentrate 20 mM, in H_2O (Biotium, Fremont, California, United States of America), was diluted to a stock solution of 5 mM in H_2O.

The sample solutions, coded $CHX_{D✓}^{Ua}$ and $L_{D✓}^{Ua}$, were pipetted with 1 μL of the 25 μM dye solution. They were then covered with an opaque foil to prevent exposure to ambient light, thoroughly hand-mixed, incubated in dark for 10 min, and exposed to blue light-emitting diode (LED) light of λ = 466 nm (spectral property of dye, λ_{abs} = 464 nm) for 15 min.

The dye was expected to cross-link with and cause permanent selective alteration of only the dead target bacterial deoxyribonucleic acid (DNA), which would aid in conducting quantitative real-time viability polymerase chain reaction (qRT-vPCR) for the pretreatment sample solutions for just the live cells.

Genomic deoxyribonucleic acid extraction and quantification by real-time polymerase chain reaction

HumqPCR real-time *A. actinomycetemcomitans* test kit (Lote RTq-H710-100D111220, BioIngentech Corporation, Concepcion, Chile) was procured for extraction of genomic DNA and carrying out qRT-PCR in Rotor-Gene Q PCR instrument.

The entirety of the four fractions prepared was used individually for bacterial DNA extraction before carrying out qRT-vPCR.

All the steps carried out were in conformity with the manufacturer's instructions given in the PCR test kit, and thus, the viable and total bacterial DNAs present in the pretreatment samples were quantified.

Phase B: Posttreatment sample collection

After removing the two healing abutments in the pretreatment phase of the study methodology, two new healing abutments were placed back in the oral cavity. Post 14 days, those two healing abutments were again removed, placed in two sterile microcentrifuge tubes, and aptly coded and steps were commenced for the red diode laser treatment (test site) and treatment with 0.2% CHX (control site).

Laser versus chlorhexidine treatment

Quantification parameters for carrying out laser and CHX treatments were as per Tantivitayakul *et al*., having had a similar study design.[11]

Red diode laser (λ = 808 nm) was irradiated on each laser group sample for episodes of 30 s each, to reach a power output of 2.5 W and energy density of 703.125 J/cm^2 with a gap of 30 s in between each episode [Figure 2a and b].

Each control group sample was dipped in 1 ml of 0.2% CHX digluconate solution for 30 s before swishing it gently

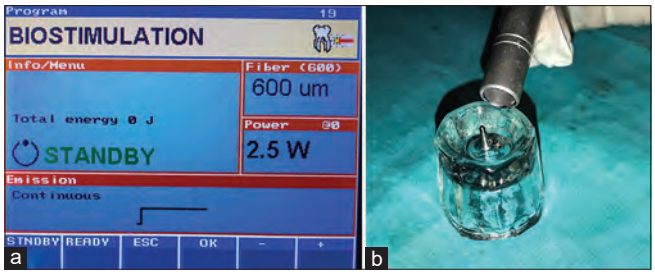


Figure 2: Procedure for carrying out laser treatment on test sample. (a) Protocol of laser treatment followed with initial energy output of 0 J/cm² reaching a maximum of 703.125 J/cm² by the end of Phase B for samples from test site undergoing laser treatment. (b) Healing abutment from test site kept stable; dappen dish manually rotated slowly for uniform exposure of laser light to all the surfaces of the healing abutment

in 0.9% normal saline solution for removal of traces of CHX [Figure 3a and b].

This was followed by microbiological analysis for the posttreatment load of target bacteria from the samples.

Preparation of clinical sample solutions

Four sample solutions were prepared from the two posttreatment samples, in steps similar to the pretreatment sample solutions:

1. Test sample (laser, L)
   a. 100 µL aliquot, for quantification of total target bacteria present in that sample, L_{Dx}^{Tb}
   b. 100 µL aliquot, for quantification of viable target bacteria present in that sample, $L_{D\checkmark}^{Tb}$
2. Control sample (CHX)
   a. 100 µL aliquot, for quantification of total target bacteria present in that sample, CHX_{Dx}^{Tb}
   b. 100 µL aliquot, for quantification of viable target bacteria present in that sample, $CHX_{D\checkmark}^{Tb}$.

Thus, each patient yielded a total of eight sample solutions, four from the pretreatment phase and four from the posttreatment phase [Figure 4].

Application of viability dye, PMAxx

One microliter of 25 µM dye solution was added to the solutions, coded $CHX_{D\checkmark}^{Ua}$ and $L_{D\checkmark}^{Ua}$, followed by dark incubation and blue LED light exposure in steps similar to the pretreatment sample solutions. This would help in carrying out qRT-vPCR for the treated sample solutions for just the live cells [Figure 5].

Genomic deoxyribonucleic acid extraction and quantification by real-time polymerase chain reaction

Extraction and quantification of the viable and total bacterial DNAs present in the treated samples was done similar to the steps followed for the pretreatment samples.

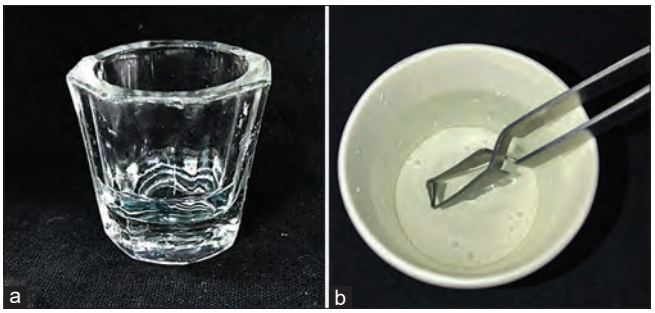


Figure 3: Procedure for carrying out chlorhexidine treatment on control sample. (a) Sample from control site submerged in 1 mL of 0.2% chlorhexidine digluconate. (b) After 30 seconds, sample held gently with a sterile bracket holder and washed with water lightly to remove traces of CHX. CHX: Chlorhexidine

RESULTS

After verification of the validity of the experimental setup, qRT-vPCR was carried out for all the coded clinical samples. Raw data were acquired by the Rotor-Gene Q Analysis Software for quantification of the template bacterial DNA present in all the samples which was then analyzed using IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. (Armonk, NY: IBM Corp.).

This mean total reduction of 322296.13 copies/µL was found to be highly statistically significant ($F = 42.812$, $P = 0.001$) [Table 1]

Before treatment, the mean total viable bacterial count (VBC) was 325967.93 copies/µL which had been reduced to 3671.80 copies/µL, irrespective of the groups. This mean total reduction of 322296.13 copies/µL was found to be highly statistically significant ($F = 42.812$, $P = 0.001$).

However, when analyzed across the laser and CHX groups, the reduction in the mean total VBC in the laser group was 325361.28 copies/µL and in the CHX group was 319230.97 copies/µL, which were statistically insignificant ($F = 0.004$; $P = 0.951$) [Graph 1].

The mean total reduction in the BVR of 96.23 was found to be highly statistically significant ($F = 22580.893$, $P = 0.001$) [Table 2]

Before treatment, the mean total bacterial viability ratio (BVR) was 97.38 which had been reduced to 1.15, irrespective of the groups. The mean total reduction in the BVR of 96.23 was found to be highly statistically significant ($F = 22580.893$, $P = 0.001$).

However, when analyzed across the laser and CHX groups, the mean reduction of the BVR in the laser group was 96.14, and in the CHX group was 96.3, which were statistically insignificant ($F = 0.015$; $P = 0.902$) [Graph 2].

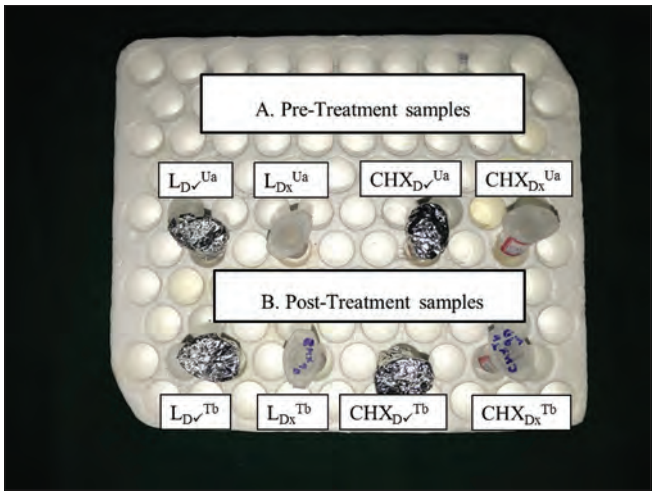


Figure 4: The final sample solutions from each patient. Phase A: $L_{D\checkmark}^{Ua}$, L_{Dx}^{Ua}, $CHX_{D\checkmark}^{Ua}$, CHX_{Dx}^{Ua}. Phase B: $L_{D\checkmark}^{Tb}$, L_{Dx}^{Tb}, $CHX_{D\checkmark}^{Tb}$, CHX_{Dx}^{Tb}. CHX: Chlorhexidine

Figure 5: Exposure of sample solutions to blue LED light after application of viability dye, PMAxx. LED: Light-emitting diode

Table 1: Mean viable bacterial counts before and after treatment of laser and chlorhexidine groups with descriptive statistics and results of repeated measures analysis of variance

Groups	VBC				Change*
	BT		AT		
	Mean	SD	Mean	SD	
Laser	329531.28	245199.84	4170.00	2847.54	325361.28
CHX	322404.58	221116.83	3173.61	2207.23	319230.97
Total	325967.93	227871.68	3671.80	2537.94	322296.13

*The change from the mean total viability count in the before and after treatment groups has been given as the difference between the two groups, Test statistics: *F* (change before to after, overall)=42.812; *P*=0.001, *F* (change with reference to groups)=0.004; *P*=0.951. BT: Before treatment, AT: After treatment, VBC: Viable bacterial count, SD: Standard deviation, CHX: Chlorhexidine

Table 2: Mean bacterial viability ratio before and after treatment of laser and chlorhexidine groups with descriptive statistics and results of repeated measures analysis of variance

Groups	BVR				Change*
	BT		AT		
	Mean	SD	Mean	SD	
Laser	97.62	3.16	1.32	0.16	96.30
CHX	97.13	2.73	0.99	0.27	96.14
Total	97.38	2.89	1.15	0.27	96.23

*The change from the mean bacterial viability ratio in the before and after treatment groups has been given as the difference between the two groups, Test statistics: *F* (change before to after, overall)=22580.893; *P*=0.001, *F* (change with reference to groups)=0.015; *P*=0.902. BT: Before treatment, AT: After treatment, SD: Standard deviation, CHX: Chlorhexidine, BVR: Bacterial viability ratio

Independent sample t test revealed that the ratio differences between the two groups were statistically insignificant ($t = 0.124$; $P = 0.902$) [Graph 3] [Table 3]

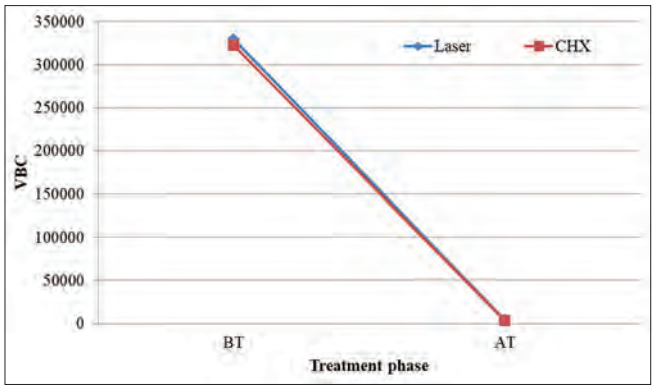
The mean bacterial percentage difference between the before treatment and after treatment groups was 96.14 for the laser group, whereas it was 96.30 for the CHX group. Independent sample *t*-test revealed that the ratio differences between the two groups were statistically insignificant ($t = 0.124$; $P = 0.902$) [Graph 3].

The ratio between the viable and the total counts after treatment for the laser group was 1.32, whereas it was 0.99 for the CHX group. The independent sample *t*-test revealed a significant mean difference in the BVR values of after treatment values with the $t = 3.458$, significance level being 0.002 [Graph 4].

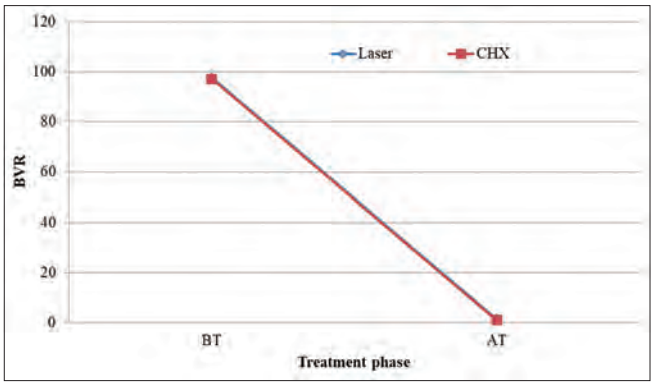
DISCUSSION

Pokrowiecki *et al.* state that the lack of periodontal ligament, the origination from postoperative scar tissue, reduced vascularity, and an increased sulcus depth make peri-implant tissues more susceptible to bacterial penetration as compared to periodontal tissues.[4,12] Hence, it may be equated that these fundamental differences and the lack of complete resolution of any inflammatory condition, warrants a sustained and thorough implant maintenance regimen.

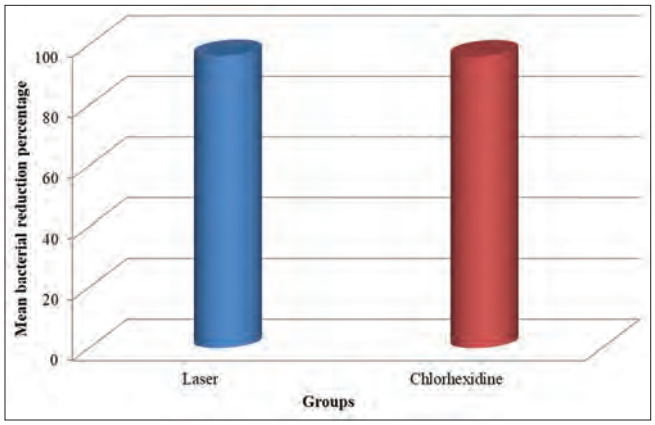
The constant exposure to the oral cavity brings an implant in contact with a bacterial biofilm composed of a community of commensals that generally help the host in maintaining homeostasis.[5] Certain concomitant factors pertaining to the patient systemic history (uncontrolled diabetes mellitus, head and neck radiotherapy), local parameters (dental plaque, calculus, and overhanging restorations), any drug induced pH alteration (antacids and antihypertensives), deleterious habit history like smoking or alcohol consumption, etc.; may cause a dysbacteriosis to a more pathological, Gram negative, anaerobic taxa, leading to the breakdown of the surrounding peri- implant tissues.[13]



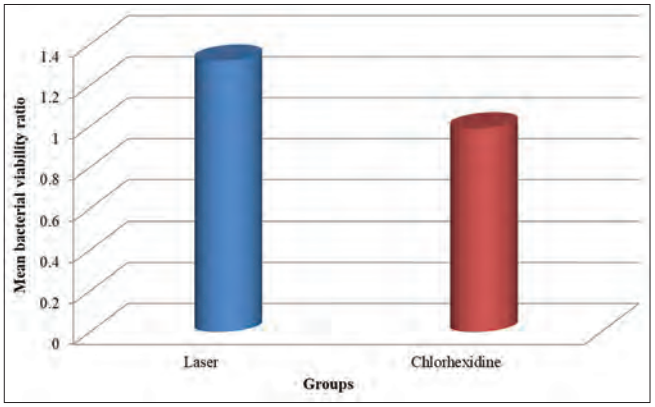
Graph 1: Mean VBC of laser and CHX groups before and after treatment. VBC: Viable bacterial count, CHX: Chlorhexidine



Graph 2: Mean BVR of laser and CHX groups before and after treatment. BVR: Bacterial viability ratio, CHX: Chlorhexidine



Graph 3: Mean difference in the bacterial reduction percentage between laser and CHX treatments. CHX: Chlorhexidine



Graph 4: Mean bacterial viability ratio of samples after laser and CHX treatments. CHX: Chlorhexidine

Various authors have affirmed the persistent presence of *A. actinomycetemcomitans* in and around healthy and diseased peri-implant sites, which, unlike the red and orange complex microbes, may not be a polymicrobial conglomerate, but can still pose a latent bacterial challenge to the health of implant and its associated tissues.[14-16] It resists and dodges host defense and interferes with tissue repair mechanisms. The combined infectious pattern of multiple serotypes may exhibit a difference in the individual antibiotic susceptibility rates.[17,18] Moreover, Di Murro *et al*. correlated compromised systemic health and the prevalence of peri-implantitis and noted pronounced higher bacterial loads of *A. actinomycetemcomitans* in patients with systemic comorbidities as compared to healthy patients.[19] Thus, regular surface decontamination from this spp. is imperative toward the overall success of the maintenance of the implant.

Conventional nonsurgical techniques for doing so include mechanical methods such as implantoplasty, air-powder abrasives, chemical disinfectants (bis-biguanides, essential oils etc.), antibiotics and lasers.

Table 3: Mean bacterial percentage reduction and bacterial viability ratio of laser and chlorhexidine groups and the results of independent sample *t*-test

Variable	Groups	Mean	SD	SE	*t*	*P*
Bacterial percentage reduction	CHX	96.30	3.18	0.96	0.124	0.902
	Laser	96.14	2.82	0.85		
BVR	Laser	1.32	0.16	0.05	3.458	0.002
	CHX	0.99	0.27	0.08		

CHX: Chlorhexidine, SD: Standard deviation, SE: Standard error, BVR: Bacterial viability ratio

Literature states that implantoplasty has adverse effects such as embedment of debris within surrounding tissues and postoperative marginal recession. Air-powder abrasives, despite being an excellent noninvasive technique, have the possibility of persistent attachment of the powder particles to the implant surface and subcutaneous emphysema. Metallic-tipped scalers can cause extensive surface texture alteration that can serve as the niche for further bacterial accumulation. On the other hand, nonmetallic scalers have a questionable surface decontamination and re-osseointegration.[20-22]

CHX is considered the gold standard antibacterial chemical disinfectant and has been reported to cause a

significant decrease of aerobic and anaerobic bacteria.[23] This was substantiated by Kadkhoda *et al.* after having checked the antibacterial effect of 0.2% CHX against *A. actinomycetemcomitans*, isolated from peri-implantitis sites.[10] However, it is said to have certain rising complications both at a macro-local level, such as staining of restorations and tissues, mucosal ulcerations, taste alteration, an elevation of supragingival calculus, and parotid swellings, and at the microcellular level, such as detrimental effects on cellular proliferation, growth, enzymatic activity, polymorphonuclear leukocyte disruption, and apoptotic and necrotic cell deaths.[23-26]

Lasers, owing to their thermal energy based degradation have a pronounced fungicidal and bactericidal effect. They also promote rapid wound healing and repair, have a low possibility of developing bacterial resistance, can showcase selective targeting of microflora and cause minimal tissue damage without any surface texture alteration.[9,27-30] This was in concordance with Aimetti *et al.*, who concluded that lasers brought about a decrease in clinical parameters such as bleeding on probing, plaque index, and probing pocket depth that was comparable to the conventional mechanical debridement alone.[31]

With respect to the results derived from the current study, both kinds of treatments, laser and CHX, brought about a major bacterial reduction of viable *A. actinomycetemcomitans* [Tables 1 and 2]. This mean total reduction of 322296.13 copies/μL was found to be highly statistically significant ($F = 42.812$, $P = 0.001$). However, when analyzed across the laser and CHX groups, the reduction in the mean total VBC in the laser group was 325361.28 copies/μL and in the CHX group was 319230.97 copies/μL, which were statistically insignificant ($F = 0.004$; $P = 0.951$) [Graph 1].

Laser treatment resulted in the postoperative bacterial viability of 1.2%–1.6% and CHX resulted in the postoperative bacterial viability of 0.6%–1.4%. Conversely, laser treatment caused a mean bacterial reduction of 96.1%, while CHX caused a mean bacterial reduction of 96.3% of *A. actinomycetemcomitans* [Table 3]. Independent sample *t*-test revealed that the ratio differences between the two groups were statistically insignificant ($t = 0.124$; $P = 0.902$) [Graph 3].

The ratio between the viable and the total counts after treatment for the laser group was 1.32, whereas it was 0.99 for the CHX group. Independent sample *t*-test revealed a significant mean difference in the BVR values of after treatment values ($t = 3.458$, $P = 0.002$) [Graph 4].

The above three statistical results implied that even though CHX was more potent in reducing the total VBC, laser therapy was also equally effective.

This study validated the results of an *in vitro* study conducted by Tantivitayakul *et al.* having used red diode laser and 0.2% CHX digluconate solution against *A. actinomycetemcomitans* cultured on natural teeth *in vitro*. Red diode laser had shown 93.425% of bacterial reduction, and CHX, 99.994%.[11]

The clinical implications and recommendations from this study include the mandatory need for regular systemic and oral health checkups for a constant vigil over clinical and radiographic parameters of the implant and the prosthesis. For in-office debridement of the implant site, both the lasers and CHX can be provided to the patient. Keeping in mind the clinical scenario and the financial aspect involved, the final call can be made.

Misch states that the first decontamination appointment should be succeeded by a follow-up visit after about 1 month. This can be followed by regular 3-month recalls. In case of a good intraoral health and condition, a 3–6-month recall system can be established. Patient education and motivation about a stringent home care regimen is also equally essential. This can include a combination of tooth brushing aids, auxiliary hygiene devices, and antibacterial mouthwashes.[32]

The strengths of the current study included the conservative target approach for implant maintenance. All the steps were in compliance with good clinical practices. Culture-independent techniques increased the speed and sensitivity of microbiological analysis and the viability dye gave the accurate quantification of the viable bacteria on the samples before and after laser and CHX treatments.

However, further research can be done with larger sample sizes, *in vivo* study designs, other causative microorganisms of peri-implantitis, and further in-depth research regarding the effect of lasers on different surface designs and characteristics of an implant fixture and prosthesis.

CONCLUSION

1. Contemporary times call for the need of early detection and conservative management of peri-implant diseases. Out of all the documented conservative treatment protocols for implant detoxification, laser and CHX were two treatments that have been under the radar for recognition as the relatively superior one among the two

2. The results of the current study showed that both diode laser treatment and CHX disinfection treatment gave a similarly high degree of antibacterial efficacy against *A. actinomycetemcomitans*, present on implant healing abutments. However, when compared in between the two, laser treatment gave a postoperative BVR of *A. actinomycetemcomitans* that was marginally higher as compared to the one observed after CHX treatment
3. Consequently, laser and CHX treatments gave similar high percentages of overall bacterial reduction of *A. actinomycetemcomitans* present on implant healing abutments. However, on drawing a comparative evaluation, it was seen that CHX brought about a bacterial reduction that was marginally higher as compared to the one seen after laser treatment
4. Laser therapy is garnering increasing popularity among all fields on dentistry, owing to minimal bleeding, high efficiency, and faster healing. Hence, it can also be considered to be an efficient treatment modality for implant surface decontamination and implant maintenance that is at par with other conventional nonsurgical mechanical and chemical options for carrying out similar procedures.

Acknowledgment

We sincerely acknowledge and express our heartfelt gratitude toward the Indian Council of Medical Research (ICMR) for having provided us with the financial aid for the current study in the form of the annual ICMR PG Thesis Research Grant for MDS students, June 2020 (Ref No. 3/2/June-2020/PG-Thesis-HRD (48D). The amount has been duly used for the smooth conduct of our study.

Financial support and sponsorship

This study was financially supported by the Indian Council of Medical Research (ICMR) Annual Thesis Financial Assistance for MDS students (Ref No. 3/2/June-2020/PG-Thesis-HRD (48D).

Conflicts of interest

There are no conflicts of interest.

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Research

Comparison of accuracy of hexed and nonhexed pickup impression copings in a multiple variable impression setup for recording multiple straight and angulated implant positions: An *in vitro* study

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Abstract

Aim: The aim of this study was to evaluate and compare the accuracy of hexed and nonhexed pickup impression copings with and without splinting using polyether (PE) and polyvinyl siloxane (PVS) impression materials in open-tray technique in recording multiple straight and angulated implant positions.

Settings and Design: An accurate impression results in an accurate definitive cast, thus minimizing the incidence of prosthesis misfit. The critical aspect is to record the three-dimensional location of the implant in bone rather than reproducing fine surface details. Precise fit of a fixed implant-supported prosthesis depends on the accuracy of the implant analog location within the definitive cast. Factors which affect impression accuracy include implant angulation, impression material, impression copings, technique, and splinting.

Materials and Methods: A sample size of 80 study models fabricated from the impression of different groups was included. A reference master model based on All-on-4 implant concept with two parallel (implants 1 and 2) and two angulated (implant 3 at 17° and implant 4 at 30°) was fabricated using implant angulation guide. All impressions were recorded using open-tray impression technique. The groups were divided into two main groups of 40 samples each. Group A used hexed open-tray impression copings and Group B used nonhexed open-tray impression copings. Both the groups involved impression recording using splinted (Subgroup I) and nonsplinted impression copings (Subgroup II). Further, impressions in each subgroup were made using PE (Subsubgroups a) and PVS (Subsubgroup b). A total of eight subsubgroups with ten samples each were included. Impressions were recorded for each group and poured into Type IV die stone for fabrication of study models. After 24 h, the study models and reference master model were fitted with implant abutments for measurement with coordinate measuring machine.

Statistical Analysis Used: The mean differences of the interimplant distance R1 (1–2), R2 (1–3), R3 (2–4), and R4 (3–4) between the reference model and sample models in different subsubgroups were calculated and three-way analysis of variance test was applied with Tukey's *post hoc* tests.

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Submitted: 29-Apr-2022, **Revised:** 17-Jul-2022, **Accepted:** 25-Aug-2022, **Published:** ***

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_218_22

How to cite this article: Kaur T, Singla S, Kumar L. Comparison of accuracy of hexed and nonhexed pickup impression copings in a multiple variable impression setup for recording multiple straight and angulated implant positions: An *in vitro* study. J Indian Prosthodont Soc 2023;23:21-9.

Results: No significant difference was found in mean coronal deviations for distance R1, R2, and R3 ($P > 0.05$) between different study groups. $P = 0.02$ for R4 (distance between 17° and 30° implants) between impression materials subsubgroups suggested that significantly less distortion was created in location of highly angulated implants (>30°) using PVS impression material. Splinting and type of coping did not have a significant influence on impression accuracy. Increasing angulation decreased the accuracy.

Conclusion: PVS was found equivalent in accuracy to rigid PE for recording parallel or angulated implants. Impressions of implants with higher angulations were recorded more accurately with PVS. The study found no difference in accuracy with or without splinting. Furthermore, nonhexed impression copings facilitate easier and accurate recording of multiple angulated implant location in bone.

Keywords: Accuracy, hexed and nonhexed impression copings, implant angulation, implant impression, splinting

INTRODUCTION

Osseointegrated implants have been established as a successful alternative to conventional prosthesis in the replacement of missing teeth. The fixed dental prosthesis, the osseointegrated implants, and the bone act as a unified structure without any resiliency.

One of the critical factors in its success is a passive fit of the prosthesis. Lack of passive fit may lead to strain and movement between components which acts as a precursor to many biological and mechanical complications.[1] In case of multiple implant-supported prostheses, apart from accurate record of individual implant position, precise recording of their three-dimensional inter-relation is critical. Other factors such as type of impression coping, splinting technique, and splinting material also influence the impression. Vigolo *et al*. and Akalin *et al*. reported that the most important criterion for accuracy of impression is the magnitude of angulation of implants.[2,3] To minimize the errors of multiple angulated implants, direct transfer technique for impression has been advocated.[4] The choice of impression material depends on the presence of undercuts, state of edentulous arch, number of implants, angulation, and impression copings of implant system. The most widely used materials are polyvinyl siloxane (PVS) and polyether (PE).[5] Impression material in open-tray technique is required to be sufficiently rigid to maintain position and prevent movement of impression copings during the procedure. Splinting (S) of impression copings has been advocated to prevent positional distortion of copings.[6-8]

In internal hexed implants, the hexed (H) pickup impression copings are difficult to draw from multiple divergent implants, especially when rigidly splinted together. Shallow nonhexed (NH) internal connection impression copings require less maneuvering while drawing, thus minimizing distortion of impression. The risk of distortion during removal increases when rigid impression material along with splinted long connection impression copings is used.[8-10] Studies by Lee *et al*. and Richi *et al*. have reported superior accuracy with nonhexed splinted impression copings in multiple angulated implant impressions.[8,11]

Numerous studies have compared the influence of impression variables on accuracy of implant-level impression with varying results. Available literature indicates a need to study the influence of factor variation simultaneously, especially on multiple straight and angulated implants.[12] The aim of this study was to evaluate the effect of hexed and nonhexed open impression coping, splinting, and impression material on accuracy of recording by multiple straight and angulated implants in an edentulous situation. Null hypothesis was that there was no significant difference in impression accuracy of multiple angulated implants with different variables including impression material, splinting, and coping type.

MATERIALS AND METHODS

The comparison of accuracy of the study model obtained with direct impression technique using hexed and nonhexed impression copings (variable G1), with and without splinting (variable G2), utilizing two different impression materials, PVS and PE (variable G3), was done in this study. Direct/open-tray/pickup impression technique was used in all groups. This study approved by Institute RDC. IRB number - HSJ/19/291 DATED 6/2/19.

Study groups

Ten models were made for each subsubgroup ($n = 10$). The division of the groups is shown in Figure 1.

Methodology

Model preparation

A vertical milling machine and an implant angulation guide (Institut Straumann AG, Switzerland) were used to place

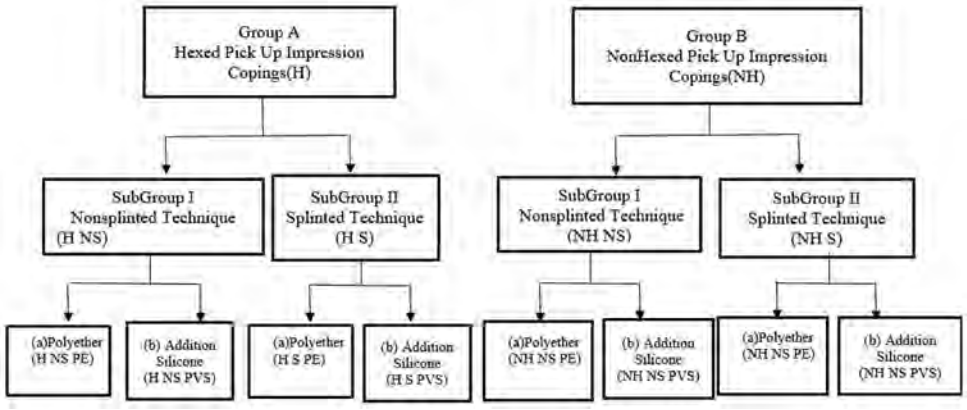

Figure 1: Study groups

two parallel implants (BioHorizons™ Tapered Internal, 3.5 mm × 12 mm, USA) in canine region bilaterally, one at 17° distal and another at 30° distal angulation in premolar region in an acrylic resin maxillary edentulous model [Figures 2 and 3]. The implants were secured with self-cure acrylic resin (DPI RR, Dental Products of India Ltd.), and the region around the implants was substituted with a 2 mm thickness gingival mask (Gingifast Elastic, Zhermack) to simulate oral mucosa.

Custom tray fabrication

Reference model was duplicated after adaptation of 3 mm wax spacer to accommodate open-tray impression copings. This duplicated spaced model was used to fabricate open impression custom trays of light-cure resin (Plaque Photo®, WP Dental, Willmann and Pein GmbH). Two types of custom open impression trays were prepared. Forty impression trays were fabricated with four openings/windows for individual implants [Figure 4] for recording impressions in Subgroup II (NS impression copings) The other forty open custom impression trays were prepared with continuous window extending from the distal-most implant on one side to the other for Subgroup I to accommodate splinted copings [Figure 5]. The opening was covered with wax sheet to prevent the extrusion of impression material during impression making. The trays were left at room temperature for 24 h before use.[13]

Impression procedure

A standard procedure was followed for all impressions. Respective hexed (Group A) and nonhexed (Group B) impression copings were tightened to the implants with the help of a hex driver at 10 N cm torque. Tray adhesive (3M ESPE™) was painted on all the trays for 15 min prior to each procedure to obtain adequate tensile bonding strength, before recording the impressions. For splinting, impression copings were tied with dental floss and pattern resin (GC Corporation, Japan) was applied in 2 mm thickness [Figures 6 and 7]. After 17 min, the splint was sectioned into four pieces with a diamond disk and resplinted, to minimize polymerization shrinkage.[14] There were total eight subsubgroups with ten study

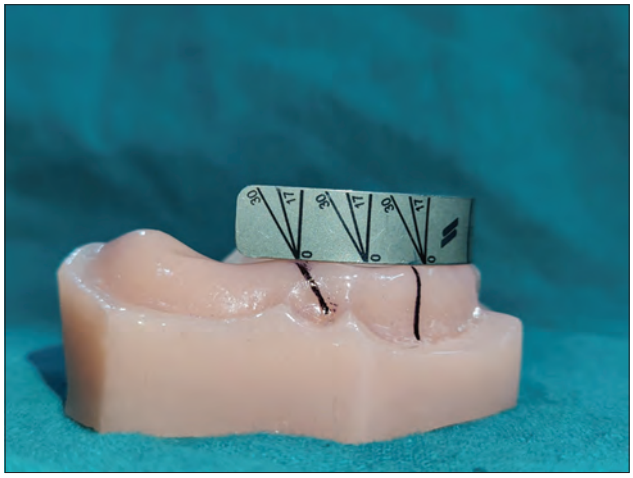

Figure 2: Implant angulation guide used for placing implants in reference model

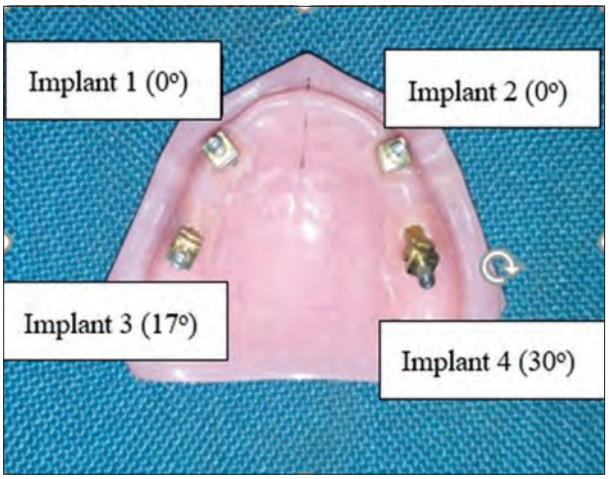

Figure 3: Reference model with implants

Figure 4: Four-holed custom tray for nonsplinted impression subgroups

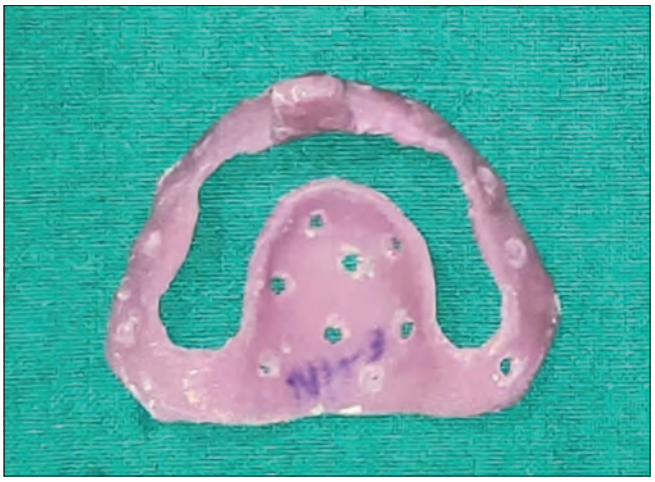

Figure 5: Continuous window custom tray for the splinted impression subgroups

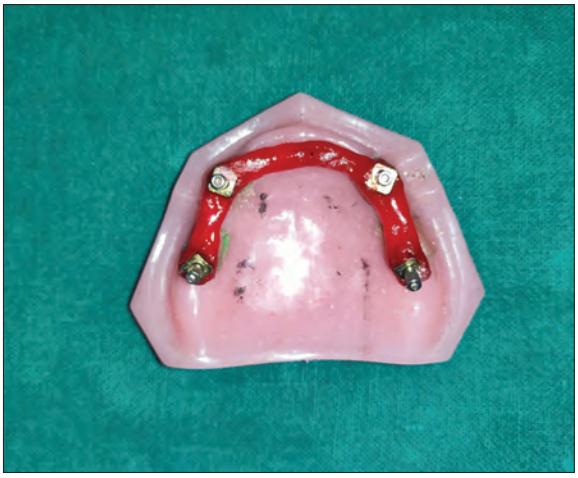

Figure 6: Open-tray impression copings splinted with pattern resin

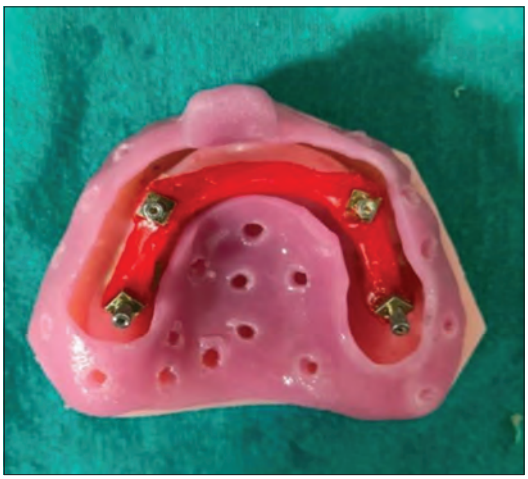

Figure 7: Continuous window tray placed on the resin-splinted impression copings in a study model

models each [Figure 1]. Twenty impressions were recorded for each subgroup, i.e., splinted (Subgroup I) and nonsplinted (Subgroup II) with respective impression material in each subsubgroup (a and b) [Figures 8 and 9]. PE (Monophase, 3M ESPE) auto mixed with Pentamix Lite and PVS putty and light body consistencies (President, Coltene/Whaledent) were used for Subsubgroups a and b, respectively.

Cast production

Once the impression material had been set, the impression copings were loosened with the aid of a hex driver and the recorded impression was retrieved with impression copings embedded within the impression material. The implant analogs were tightened onto the impression copings with a hex driver manually. Gingival mask (Gingifast Elastic, Zhermack SpA, Italy) was applied around the impression copings and analogs, and once set, the impression was poured in a vacuum-mixed Type IV dental stone (Kalrock, Kalabhai, Mumbai). The impressions were separated from the cast after 1 h. All the casts were stored at room temperature for 24 h.

Measurement

BioHorizons™ (3.5 diameter, regular) standard abutments were screwed onto the implants in reference model to get reference measurements for each distance R1, R2, R3, and R4 [Figure 10]. In each study model also, BioHorizons™ (3.5 diameter, regular) standard abutments were screwed onto the analogs. A single examiner measured the distance between abutment heads (R1, R2, R3, and R4) using a coordinate measuring machine (CMM) (Mitutoyo, Japan) in reference and study models [Figure 11]. The flowchart for measurement procedure is depicted in Figure 12. The formula for Euclidean distance for each measurement in three axes was $R = \sqrt{(\Delta x^2 + \Delta y^2 + \Delta z^2)}$. Differences of mean distances in each subsubgroup from respective distance on reference model were taken as coronal deviation from accuracy and compared.

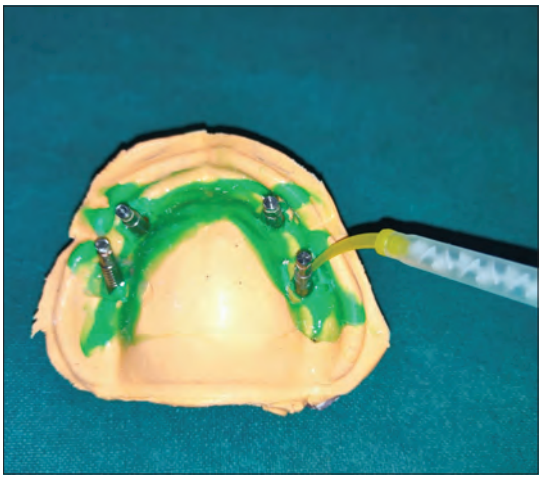

Figure 8: PE impression with open-tray impression copings. PE: Polyether

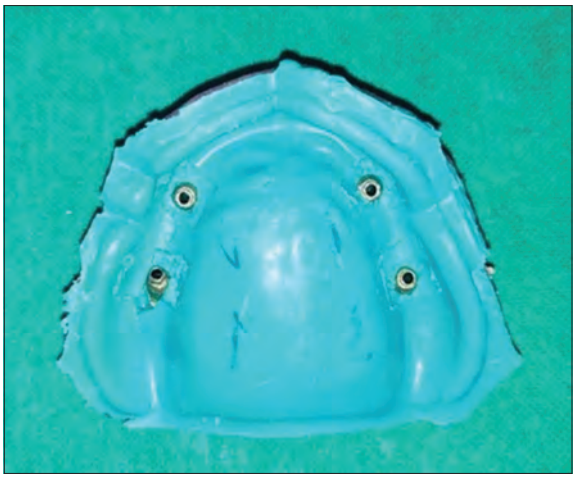

Figure 9: PVS impression with gingival silicone being placed around the impression copings. PVS: Polyvinyl siloxane

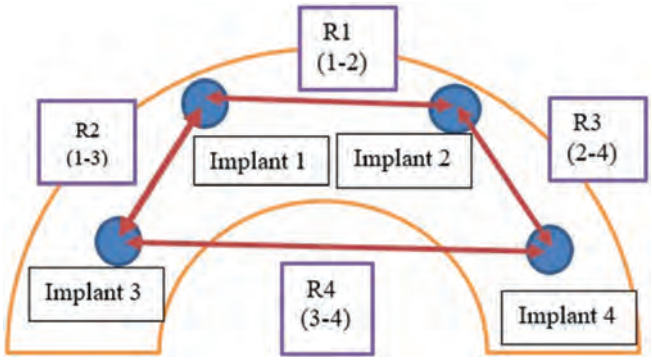

Figure 10: Schematic diagram of the measurements made. R1 denotes anterior interpositional difference of parallel implants in anterior region, R2 denotes interpositional difference of the straight (implant 1) and 17° angulated implant (implant 3), R3 denotes interpositional difference of a straight (implant 2) and 30° angulated implant (implant 4), R4 denotes interpositional difference of a 17° (implant 3) and a 30° angulated implant (implant 4)

Figure 11: Stone cast being measured with standard abutments in place on the CMM machine. CMM: Coordinate measuring machine

RESULTS

The mean differences of Euclidean distances R1, R2, R3, and R4 between the reference model and each study cast in every subsubgroup, along with the standard deviations, was statistically analysed by three-way analysis of variance (ANOVA) as depicted in Tables 1 and 2.

Statistical analysis revealed that implant angulation and impression material had a significant effect on mean coronal deviations of copings [Table 2]. Figure 13 depicts the mean box plots for all groups.

Table 1: Descriptive Statistics for R1, R2, R3, and R4

G1	G2	G3	Mean±SD (mm)			
			R1	R2	R3	R4
A (H)	I (NS)	a	0.95±0.96	0.88±0.29	1.42±0.89	1.15±0.55
		b	0.45±0.21	0.77±0.43	0.92±0.80	0.51±0.84
	II (S)	a	0.46±0.28	0.88±0.39	1.61±0.90	1.60±1.18
		b	0.45±0.24	0.67±0.35	0.87±0.62	0.50±0.32
B (NH)	I (NS)	a	0.56±0.322	0.88±0.53	1.38±1.12	1.06±0.189
		b	0.56±0.37	0.88±0.48	1.38±0.73	0.50±0.36
	II (S)	a	0.72±0.44	0.78±0.33	1.30±0.90	1.04±0.47
		b	0.42±0.28	0.59±0.38	0.81±0.35	0.44±0.21

G1: Variable 1, i.e., hexed and nonhexed impression copings, G2: Variable 2, i.e., splinting and nonsplinting of impression copings, G3: Variable 3, i.e., impression materials. SD: Standard deviation

Mean deviations in each study group increased with increasing angulation, i.e., from R1 (two parallel implants) to R4 (implants angulated at 17° and 30°). R3 with one posterior 30° distal angulation implant gave maximum coronal deviation in each subsubgroup [Figure 13]. Furthermore, mean deviations in each subgroup were significantly lesser with PVS impression material [Table 1]. In the present study, subgroup in nonhexed impression coping group (Group B) revealed lesser mean deviation across all subsubgroup as compared to hexed impression coping group (Group A) except in nonhexed nonsplinted PVS subsubgroup (Group BIb) which showed higher coronal

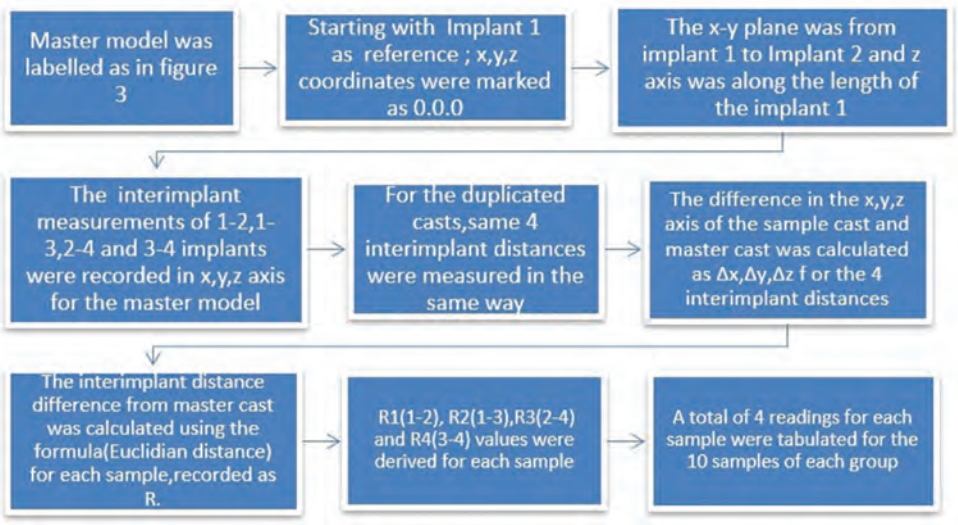

Figure 12: Flowchart for measurement calculations

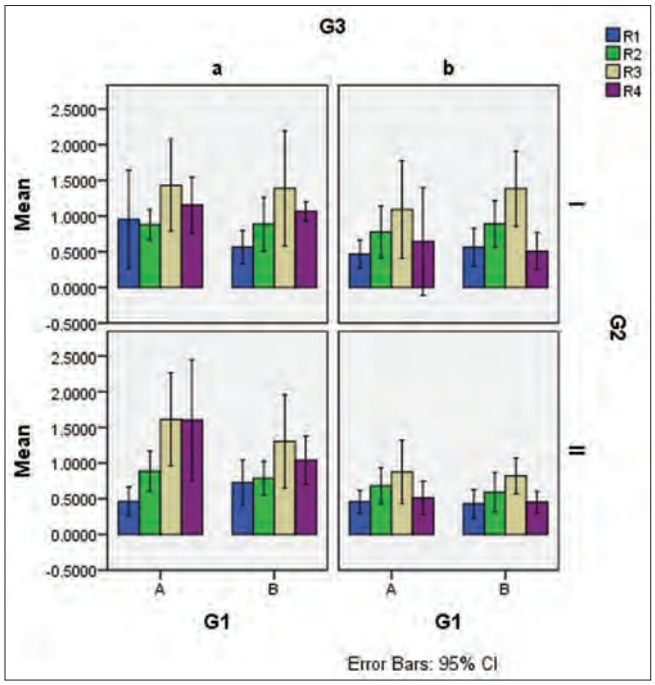

Figure 13: Boxplot showing final results where G1 is the impression coping variable, G2 is the splinting technique variable, and G3 is the impression material variable. CI: Confidence interval

deviation for all angulations in comparison to corresponding hexed coping group (Group AIb) [Figure 13].

Maximum mean deviation in parallel implant distance (R1) was reported with hexed nonsplinted PE impression (Group AIa), whereas maximum mean deviation in angulated implants (R3 and R4) was reported with hexed splinted PE group (Group AIIa).

Impressions made with nonhexed splinted PVS group (Group BIIb) showed the least coronal deviation

Table 2: Three-way ANOVA *P* values

Source	*P* value R1	*P* value R2	*P* value R3	*P* value R4
Model	0.138	0.606	0.252	0.00
G1	0.902	0.855	0.942	0.190
G2	0.253	0.185	0.479	0.519
G3	0.048	0.172	0.022	0.00
G1×G2	0.204	0.408	0.293	0.337
G1×G3	0.619	0.743	0.307	0.290
G2×G3	0.610	0.405	0.334	0.376
G1×G2×G3	0.052	0.801	0.738	0.441

G1: Variable 1, i.e., hexed and nonhexed impression copings, G2: Variable 2, i.e., splinting and nonsplinting of impression copings, G3: Variable 3, i.e., impression materials

for all angulation groups, followed by hexed splinted PVS group, but the difference was not found statistically significant.

DISCUSSION

Accurate implant-level impression is a critical step to achieve success in multiple implant prosthesis. Variables such as impression material, impression techniques, type of impression coping, splinting/nonsplinting of impression copings, and number and angle of implants influence the accuracy of implant impression.[15,16] Very few studies have reported cumulative influence of these variables on implant impression. The present study evaluated multiple parallel and angulated implant impression accuracy in multiple variable impression setup and observed that increasing angulation inversely affects the accuracy of impression [Table 1]. PVS was reported to have significantly higher accuracy in multiple angulated implants. Splinting did not have any significant effect on impression accuracy. NH impression copings were found to provide an easy and viable alternative for recording multiple angulated implants with no significant difference from H impression copings [Table 2].

In multiple implant impressions, impression copings are aligned at different angles and there can be pronounced rotational movement of copings leading to inaccuracy. Further, deep wide connection area (hex) in internal connection implants is more engaging and may cause movement of impression copings and hence distortion within impression necessitating the use of nonhexed copings.[6,8]

The impression procedure in our study was standardized by using light-cure custom trays of uniform thickness fabricated on the same duplicated cast and with same-sized stops for the accurate positioning of the tray on the reference model each time an impression was made. The pickup impression copings were hand tightened with a hex driver by the same operator, eliminating the difference in force used for tightening to simulate a clinical situation. The PE impressions were separated from the cast after more than 6 min and PVS impressions were separated more than 4 min to compensate the difference in room and oral cavity temperature. For pouring the stone casts, die stone was vacuum mixed to ensure standard W: P ratio and avoid the incorporation of air bubbles. The stone casts were separated from the impressions after 1 h to allow the stone to reach a certain strength, and measurements were made after 24 h to allow the die stone to reach its full dry strength. The accuracy of the readings measured by the CMM was up to 0.001 mm. The operator of the machine was blinded to avoid observation bias.

In the present study, NH impression coping groups revealed lesser mean deviation across all groups as compared to H impression coping groups except nonhexed, nonsplinted PVS group (Group BIb) which showed higher coronal deviation for all angulation in comparison to corresponding hexed coping group (Group AIb) [Figure 13].

Long internal connection of hexed implant and impression coping makes withdrawal of impression difficult, especially in multiple and angulated implants.[8,17,18] A nonhexed pickup impression coping that has a shorter connection area permits a greater angle of draw during impression withdrawal reducing the withdrawal stress and also eases retrievability from mouth.[6,8] In the present study, nonhexed group B reported a lower mean deviation for parallel implants (R1) and angulated implants, thus recommending nonhexed copings as a viable and easier alternative for recording multiple nonparallel implant positions of up to 30° angulations. Richi *et al*., in a recent study, have also favored the use of nonhexed copings for multiple angulated implants up to 20° angulation.[8] Nonsplinted nonhexed copings recorded with PVS (Group Bib) impression material gave higher coronal deviation because of more maneuverability and movement allowed with nonsplinted copings in resilient PVS impression material. Although hexed impression copings provide better positional accuracy than nonhexed impression copings, especially in fewer implants with straight angulation, this study found that NH impression copings are more accurate and easier alternatives for multiple angulated implants.

Splinting the impression copings did not cause a significant lowering influence on mean deviations in any of the subgroups for parallel as well as angulated implant positions [Table 2]. To manage shrinkage or fracture of splint material, in this study, pattern resin used for splinting of impression copings was sectioned from midline with diamond disc. The sections were rejoined after 17 min to compensate polymerization shrinkage.[9,14] Our results are in accordance with studies by Hsu *et al*., Phillips, Chang *et al*., and Buzayan *et al*.[10,19-21] Del'Acqua and Baig *et al*. and Tsagkalidis *et al*. also reported no significant advantage of splinting the impression copings.[22-24]

Conflicting results exist in the literature regarding cast accuracy using PE and PVS impression materials. PE has been reported to cause lesser deviation in impression recording because of its rigidity and dimensional stability.[3,12,22,25,26] Some studies reported PVS to be better due to its high elastic recovery, hence reduced permanent distortion, maybe due to decreased stress between impression copings and impression material.[11,17,27,28] In the present study, one-way multivariant ANOVA gave an insignificant *P* value for difference in performance of PVS and PE in various study groups for straight as well as angulated implants [Table 1]. However, application of three-way ANOVA gave a significant *P* value (0.00129) for parallel as well as angulated implant [Table 2]. This result points to a better accuracy with PVS, especially in multiple implants with higher angulations. Between straight and up to 30° angulation, a significant difference was found between PVS and PE in open-tray impression technique. Assuncao *et al*. had reported an insignificant difference between PE and PVS in recording implant angulation up to 25°.[4] Many authors have reported an insignificant difference in impression accuracy with PVS and PE for straight and varying angulated implants.[23,29-31] Our study is in accordance with Vojdani *et al*. (2015) who reported the advantage of PVS over PE as impression material for implants angulated up to 20° mesially/distally.[13] However, the present study is the first to establish the superiority of PVS for recording up to 30° of divergence between two implants with minimal deviation, thus partially rejecting the null hypothesis, i.e., significantly lower mean coronal

deviation was found with PVS impression for multiple parallel and angulated implants.

It was observed that during tightening, open-tray impression copings in the PE material did not rotate as easily it did in PVS impressions accounting for higher accuracy in PE group with nonhexed nonsplinted impression copings (Group BIa) than hexed nonsplinted PE group (Group AIa). In the latter group, H copings in combination with rigid PE material generated higher stresses during withdrawal leading to higher coronal deviation. The splinting material broke in a few samples as the withdrawal force had to be increased to separate the impression from the master model generating stresses. In a few cases of hexed splinted impression groups, the custom tray fractured as well, indicating the requirement of higher degree of maneuverability as compared to nonhexed splinted impression copings. Higher mean coronal deviations in the present study were comparable to those in a recent study by Richi *et al*. comparing the accuracy of hexed and nonhexed impression copings for implant angulation up to 20°.[8] Mean coronal deviation for R3 was higher in all groups maybe because 30° distal tilted posterior implant, compared to straight anterior implant, altered their planes of withdrawal to the maximum. The study also made a unique observation that with a greater number of rigid impression variables, manipulation and stresses increase during tray withdrawal leading to increased coronal deviation in recording multiple angulated implant positions. Group BIIb using splinted NH impression copings recorded with PVS material gave minimal coronal deviation for all measured distances, but splinting in combination with other rigid variables such as H impression coping and PE material gave higher coronal deviation for angulated implants.

In vitro setup is the possible limitation of this study since oral cavity conditions including humidity, temperature, and presence of saliva were not reproduced in this case. Furthermore, only linear measurements were made, rotational discrepancy was not tested. Machining tolerance in mismatch of implant component (22–100 μm) was not taken into consideration.[16] There is a need for *in vivo* studies as the angle of removal of impression varies in mouth compared to that of an *in vitro* model. Impression technique with digital scanning needs to be explored and assessed for accuracy so as to avoid errors in conventional techniques and enhance the chances of prosthesis success.

CONCLUSION

The present study concluded that edentulous arches with parallel implants can utilize PE on account of its low strain of compression, but PVS is more accurate in areas of undercuts or multiple angulated implants. No significant difference was found between the use of hexed and nonhexed impression copings with or without splinting in multiple parallel and angulated implants.

Within the limitations of this study, it can be concluded that:

1. Nonhexed impression copings are an easy and viable alternative for recording multiple angulated implants
2. Both PE and PVS have acceptable accuracy for impression in multiple implants, but PVS is recommended for higher angulations (>30°), as the withdrawal of PE impression gets difficult in higher angulated implants and increased undercuts
3. Splinting does not significantly affect the impression accuracy
4. Increasing angulation inversely affects the accuracy of impression.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Research

An evaluation of the effect of wearing complete dentures on temporomandibular joint vibrations over time using the joint vibration analyzer

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Abstract

Aim: To evaluate the changes in temporomandibular joint (TMJ) vibrations after insertion of the complete denture in edentulous patients.

Settings and Design: An observational *in vivo* study conducted to evaluate the changes in maximum mouth opening, total integrals, peak amplitude, and peak frequency in TMJ vibrations on the day of complete denture insertion and 6 months of follow up.

Materials and Methods: Twenty patients (male: 12 and female: 8) were selected for the fabrication of balanced complete dentures following conventional procedure. Joint vibration analysis was recorded using the joint vibration analyzer. The patients were instructed to open as wide as possible and close to the intercuspal position with rhythmic speed following the metronome projected on the screen. The TMJ vibrations were amplified and displayed as waveforms in a graphical representation by system software.

Statistical Analysis Used: Wilcoxon test.

Results: A significant decrease in the total integral ($P = 0.001$) and peak amplitude ($P = 0.044$) for opening and closing movements of the left and right joints was observed. There was no significant change in maximum mouth opening ($P = 0.624$). A decrease in peak frequency was noted only at left opening movements between the day of insertion and at 6 months ($P = 0.025$).

Conclusion: The function of TMJ mechanics was improved till 6 months after insertion of complete denture with balanced articulation (BA).

Keywords: Complete denture, joint vibration analysis, temporomandibular joint, vertical dimension

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Submitted: 28-Apr-2022, **Revised:** 14-Oct-2022, **Accepted:** 22-Oct-2022, **Published:** ***

Access this article online	
Quick Response Code:	**Website:** www.j-ips.org
	DOI: 10.4103/jips.jips_215_22

How to cite this article: Vasavi M, Ramaraju AV, Sajjan MC, Rao DB, Manikyamba YJ, Thorreti VS. An evaluation of the effect of wearing complete dentures on temporomandibular joint vibrations over time using the joint vibration analyzer. J Indian Prosthodont Soc 2023;23:30-7.

INTRODUCTION

The temporomandibular joint (TMJ) is a ginglymoarthrodial joint with well-lubricated surfaces that glide over one another in function. Any change in the surface due to degeneration, perforation, or mechanical displacement creates friction between the articulating surfaces. The friction is often heard as crepitus.[1] The intensity and timing of vibrations differ due to different disorders.[2]

The vertical dimension of the lower third of the face is maintained by the posterior teeth in natural dentition.[3] This also limits the rotation of the condyle to locate on the anterior slope of the glenoid fossa. The loss of teeth eliminates the vertical stop during the closure of the mandible allowing the mandible to move excessively superior to bring the ridges into contact with the anterior region to mash the food. This excessive movement results in a backward rotation of the condyles, thus increasing the duration of friction between the articulating surfaces. The backward rotation may also compress the retrodiscal tissue and strain the articular disk. In the long run, this may induce changes in the TMJ.

The loss of vertical stop forces the elevator muscles to contract more for bringing the ridges together and TMJ structure and introduces a heavier burden during the function.[4] Any change in the position of the condyle would disturb the joint spaces bringing in friction between articulating surfaces and the disk.

The frictional sounds of the TMJ are conventionally evaluated by palpation and auscultation.[5] Palpation of the joint requires excellent tactile sensitivity. A stethoscope is used to listen for abnormal TMJ sounds like crepitus. The outcomes of the palpation and auscultation are subject to the operator's interpretation and are not measurable. Clinical detection of TMJ sounds is shown to provide inaccurate data.[6]

Complex objective methods to document TMJ sounds include Doppler ultrasound, thermography, and sonography. These examinations include the involvement of specially trained individuals and are also of high cost.

The joint vibration analyzer (JVA) provides a dynamic analysis of the joint. It is used in various fields of the stomatognathic system both dentulous and edentulous conditions. JVA objectively records all the vibrations from the TMJ during mandibular movement and distinguishes the side of the origin. JVA provides data on maximum mouth opening (mm), and the vibrations in the joint are recorded by transducers positioned on the joint and expressed in terms of total integrals, peak amplitude, and peak frequency by the software. The software also provides the signature waveforms to be correlated with the flowchart provided by the company to determine the condition of the TMJ.

Total integrals indicate the total amount of vibration energy in the TMJ joint. Peak amplitude indicates the point of highest vibration intensity, which was measured in Pascals. Peak Frequency indicates the point at which the highest intensity of energy of vibration occurred, which was measured in Hz. It is a noninvasive diagnostic method, supplementing essential clinical examination and elucidating the structural abnormalities of the TMJ.

Occlusal instability contributes to TMJ disorders among complete denture wearers.[7] A harmonious relationship can be established in complete dentures by establishing a balanced articulation (BA) to restore healthy conditions to the TMJs.

There is limited literature available regarding the effect of wearing complete dentures on changes in TMJ with time using JVA. The present study was formulated to evaluate the changes in the extent of maximum mouth opening (mm), total integrals, peak amplitude, and peak frequency of the TMJ with complete dentures with BA on the day of insertion till 6 months in asymptomatic individuals. The null hypothesis adapted was that there will not be any significant difference in the TMJ vibrations on the day of complete denture insertion and 6 months after postinsertion of complete denture.

MATERIALS AND METHODS

An observational study was planned to evaluate the changes in the joint vibrations from insertion up to 6 months. Approval for the study was obtained from the Institutional Review Board and Ethics Committee (VDC/IEC/2018/42). All patients were given detailed information about the investigation and written informed consent was obtained for their participation. A simple random sampling technique was employed to select the study population.

Twenty edentulous patients reported to the department of prosthodontics from December 2018 to November 2019 fulfilling the inclusion criteria and who consented to report for the follow-up were included in the study. The recruitment period was 1 year with the follow-up of 6 months.

Twenty (male: 12 and female: 8) volunteered edentulous participants of age between 40 and 70 years having moderately formed alveolar ridges (ACP class I and II) with an edentulous period of >3 months and first time denture wearers were included. Patients expressing signs and symptoms of TMJ disorder, orofacial myalgia, poor neuromuscular coordination, and compromised ridges (ACP class III and IV) were excluded.

The sample size was calculated using software program (G*Power 3.0.10; Heinrich Heine University Dusseldorf). The effect size was kept at 0.36, an alpha error probability of 5% and power was 80%. The final sample size was calculated as 20 with a dropout rate estimated as 20%.

To standardize the procedure and reduce the number of variables, patients with TMJ disorder were not included. Variables such as duration of denture wearing per day and tolerance threshold were not considered in our study. The duration of edentulous period and personality of the individual can be confounding factors. However, since evaluation in the present study was within the same patient for a period of 6 months, it would not be relevant. All the data acquisition was done by the single operator to minimize the interoperator bias.

Procedure

A detailed case history was recorded and conventional maxillary and mandibular removable complete dentures were fabricated in BA for each participant. Postfabrication, a laboratory remount procedure and selective grinding were followed to eliminate the processing errors and maintain the achieved BA. The dentures were verified clinically for bilateral simultaneous occlusal contact without any glide in centric relation and without any interferences during excursive movements. Clinical remount and occlusal adjustment was done to refine the occlusal balance before final insertion.

Each patient underwent JVA (BioResearch, Inc. Milwaukee, WI, USA) recording once at the time of denture insertion and at 6-month follow-up. All patients were instructed to remove their ear jewelry, spectacles, and hearing aids to avoid errors when recording JVA.

To record JVA, the participant was seated in an upright position, with the Frankfurt plane parallel to the floor. The skin in front of the tragus of the ear was wiped with an alcohol swab before mounting the headset carrying the transducer for good tissue contact and accurate recording. The transducers were positioned on the skin over TMJ. The transducers were connected to a signal amplifier and to the computer equipped with BIOPAK software program (BioResearch, Inc., Milwaukee, WI, USA) [Figure 1].

The range of maximum mouth opening, deviation in excursive movements of the mandible were measured. These data were entered into the program as prompted by the software when registering the patient. The patient was trained to follow the metronome on the computer screen to do maximum unassisted wide opening and to tap the teeth while closure. These data were entered into the program as prompted by the software when registering the patient. The patients were instructed and trained to follow the metronome on the computer screen and do maximum unassisted wide opening and closing movements of the mandible, and to tap the teeth.

The patients were trained to synchronize with the metronome for uniform cycles of movement when recording. Six cycles of the mouth opening and closing were recorded.

Graphical recordings of the left and right TMJ vibrations were displayed in real time as acoustic waveform graphs, suggesting the relationship between time and vibration amplitude[7] at the selected point of the cycle. Graphical waveform is evaluated with JVA flowchart. Three uniform cycles were selected for evaluation in acoustic form window.

The sounds in the joint are displayed in the form of vibrations for both the condyles separately. Three vibrations corresponding to the similar timing were selected manually. The vibrations either at the time of opening or closing have to be considered individually. The center of opening of the selected three cycles was marked. The mean values at

Figure 1: Patient mounted with BIO-JVA and amplifier. BIO-JVA: BIO-Joint vibration analyzer

the selected points of the three waves were calculated and displayed by the software program [Figure 2]. The same procedure was followed for all the participants. These values were tabulated for further analysis. BioResearch, Inc., provides a JVA flowchart with signature wave patterns for the interpretation of the data.

All obtained mean values were tabulated and statistically analyzed using SPSS software (IBM SPSS, Version 21.0. Armonk, NY, USA: IBM Corp).

Due to the nonnormal distribution of mean values, the Wilcoxon test was used to compare the pairwise tests for maximum mouth opening, total integrals of the right and left TMJ, and peak amplitude and peak frequency. $P < 0.05$ was considered statistically significant, and the confidence interval was 95%.

RESULTS

All twenty cases presented vibrations during opening or closing. Twenty percent ($n = 4$) of the patients showed small vibrations and they remained the same for 6 months. Eighty percent of the patients showed medium vibrations. Forty percent ($n = 8$) remained the same at follow-up, while 40% ($n = 8$) of the patients showed a reduction in the vibrations, however remained within the range of medium intensity vibrations at the 6–month follow-up for total integrals and peak amplitude, suggesting an improvement in the health of their TMJs.

The range of mouth opening (min 44 mm–max 45 mm) did not show any significant change between denture insertion and after 6 months of follow-up ($P = 0.624$) [Table 1].

A comparison of the total integrals from insertion and follow-up showed a statistically significant reduction for the opening and closing movements of both left and right joints ($P = 0.001$*) [Table 2].

A statistically significant decrease was observed in opening movements for both the left joint ($P = 0.008$*) and the right joint ($P = 0.001$*) and closing of the left joint ($P = 0.008$*),

Table 1: Comparison between mean maximum mouth opening (mm) within the samples obtained at insertion and after 6 months of follow-up

JVA recording	Median	Mean	SD	Mean difference	*Z*	*P*
Insertion	44.0	45.4500	6.41934	−0.4500	−0.490	0.624
Follow-up	44.5	45.9000	6.52848			

SD: Standard deviation, JVA: Joint vibration analyzer

Table 2: Comparison of the total integrals peak amplitude (Hz) during opening and closing movements after complete dentures insertion and 6 months of follow-up

JVA recording	Median	Mean	SD	Mean difference	*Z*	*P*
Opening movement						
Left TMJ						
At insertion	33.85	42.78	33.26	19.525	−3.659	0.001*
After 6 months	15.50	23.25	26.74			
Right TMJ						
At insertion	28.60	41.78	35.96	29.660	−3.920	0.001*
After 6 months	10.75	12.12	9.69			
Closing movement						
Left TMJ						
At insertion	36.65	44.68	28.04	21.960	−3.920	0.001*
At 6 months	20.30	22.72	18.69			
Right TMJ						
Insertion	41.30	47.77	36.12	21.255	−2.782	0.005*
Follow-up	18.70	26.51	25.22			

*$P < 0.05$ was considered statistically significant. JVA: Joint vibration analyzer, TMJ: Temporomandibular joint, SD: Standard deviation

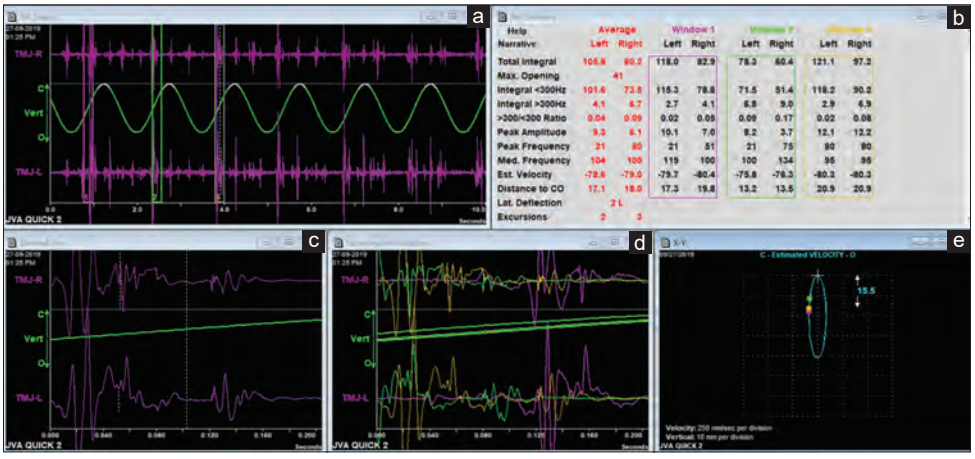

Figure 2: Components of JVA. (a) JVA sweep indicates vibrations and the timing of the vibrations during opening and closing waveform has white color indicating teeth coming in occlusion. High-intensity vibrations indicate a tapping of teeth. (b) JVA summary indicate average values of three selected vibrations either at opening or closure of both right and left joints. (c) Average of vibrations. (d) Superimposed image of selected vibrations. (e) X-Y view indicating the cycle of movement and location of the selected vibration in the cycle. JVA: Joint vibration analyzer

while the right joint's peak amplitude was also decreased ($P = 0.044$*) [Table 3].

A comparison of peak frequency showed a statistically significant decrease between insertion and 6 months only for opening movements of the left joint *(P* = 0.025*) [Table 4].

Based on the gender issues, it was observed that the difference in change of intensity between males and females was significant.

DISCUSSION

The loss of teeth usually brings in an essential change in the stomatognathic system, the bone structure, the oral mucosa, and the masticatory muscles. TMJ disorder symptoms are more common in conditions of multiple teeth lost than with a few teeth lost.[8] The TMJ is a complex joint with the condyle articulating with the glenoid fossa. A fibrocartilage articular disk is located between the condyle and the glenoid fossa.

Synovial fluid facilitates smooth gliding movement with no friction in a healthy joint. Any form of changes in the articular disk and synovial fluid would result in friction and experienced as sounds. Sounds are caused by conditions such as degeneration, perforation, or mechanical displacement of the articular disk. TMJ sounds may be described as clicking or cracking, by the patient.[5,9]

TMJ dysfunction has been documented as a prevalent condition among complete denture wearers, with most estimates ranging between 15% and 25%.[10] Differences in prevalence by age and sex have been reported, and these associations remain equivocal. One of the potential risk factors for mandibular dysfunction among complete denture wearers was the existence of an unstable occlusion.[11]

Balanced articulation (BA) is the bilateral, simultaneous occlusal contact of the anterior and posterior teeth in excursive movements (GPT 9).

BA maintains the stability of the dentures when the mandible moves from centric to eccentric positions. An

Table 3: Comparison of the peak amplitude during opening and closing movements after complete dentures insertion and 6 months of follow-up

JVA recording	Median	Mean	SD	Mean difference	*Z*	*P*
Opening movement						
Left TMJ						
At insertion	2.70	4.06	3.32	1.960	−2.633	0.008*
After 6 months	1.60	2.10	2.28			
Right TMJ						
At insertion	3.25	4.68	4.67	3.555	−3.681	0.001*
After 6 months	1.00	1.13	1.00			
Closing movement						
Left TMJ						
At insertion	4.10	5.20	4.38	2.120	−2.632	0.008*
After 6 months	2.55	3.08	2.55			
Right TMJ						
At insertion	3.55	5.73	5.11	2.99	−2.016	0.044*
After 6 months	3.20	3.92	3.94			

* $P<0.05$ was considered statistically significant. JVA: Joint vibration analyzer, TMJ: Temporomandibular joint, SD: Standard deviation

Table 4: Comparison of the peak frequency (Hz) during opening and closing movements after complete dentures insertion and 6 months of follow-up

JVA recording	Median	Mean	SD	Mean difference	*Z*	*P*
Opening movement						
Left TMJ						
At insertion	41.00	54.25	30.64	19.850	−2.235	0.025*
After 6 months	26.00	34.40	18.92			
Right TMJ						
At insertion	38.50	43.80	22.68	−0.100	−0.240	0.810
After 6 months	45.50	43.90	22.18			
Closing movement						
Left TMJ						
At insertion	21.00	29.85	17.10	2.850	−0.285	0.776
After 6 months	23.50	27.00	16.00			
Right TMJ						
At insertion	26.00	35.05	20.24	−1.200	−0.227	0.820
After 6 months		36.25	20.57			

* $P<0.05$ was considered statistically significant. JVA: Joint vibration analyzer, TMJ: Temporomandibular joint, SD: Standard deviation

unbalanced articulation disturbs the stability of the denture during eccentric movement, resulting in malposition and change in TMJ conditions.[3]

JVA is a passive device that works on the simple principles of motion and friction. It includes a headset with transducers encompassing accelerometers on each side. The accelerometer consists of a piezoelectric crystal in a metal case connected to an amplifier. This crystal responds to acceleration by producing a minute electric charge directly proportional to the acceleration. The electric charge then passes through an amplifier of high input impedance before being recorded as a vibration signal. During opening and closing movements, the characteristic vibrations produced by the joint will be detected by the accelerometers and the data will be transferred to the computer.

The software program then interprets the data and displays it in graphical form. The highest amplitude consistently occurring in each joint recording either at opening or closing movements will be used to calculate the frequency spectrum computed by the fast Fourier transform algorithm. Three vibrations are marked for evaluation.

All the vibrations marked should be either during opening vibrations or closing movements. It can record inaudible sounds below 20 Hz, creates an image of the vibration patterns, distinguishes mild or moderate TMJ dysfunctions from severe disorders, precisely quantifies the frequency content, and provides a permanent record for future comparison.[12]

In the present study, no significant change was seen in the maximum mouth opening range with an average range of 45 mm [Figure 3]. Intrasubject comparison of mean maximum mouth opening values within the samples was not statistically significant between insertion and follow-up. In accordance with the study by Olivieri and Garcia, we obtained similar results that the vibratory energy without mandibular position change is minor and remains stable at the analyzed positions.[5,13] After denture placement and re-establishment of vertical stop during masticatory function, the elevator muscles will be reconditioned. The vibrations (Hz) no longer occur, or their intensity would be diminished from insertion to follow-up. This could eliminate the inflammatory process and the TMJ vibrations due to stabilized occlusion, improving the occlusal force redistribution and improving the disk's lubrication mechanism.

Comparison of total integral (PaHz) and peak amplitude (Pa) for the opening and closing movements of the left and right joints showed a significant reduction of total integrals between insertion of the dentures and 6-month follow-up. In the present experimental study, the total integrals of the vibrations analyzed using JVA showed that four patients (20%) had total integrals below 20 PaHz (small vibrations), and they remained the same after follow-up. Eight patients (40%) presented with large-intensity vibrations (120 PaHz) at insertion, and there was a reduction in the intensity of the vibrations (50 PaHz) after 6 months of follow-up [Figure 4].

Eight patients (e.g., 40%) presented with medium vibrations (60 PaHz) during insertion, and there was a reduction in the intensity of the vibrations (30 PaHz) after 6 months of follow-up; however, they were still within the range of medium vibrations (20–80 PaHz).

The increase in the edentulous period in posterior teeth increases the burden on the TMJs to alter the smoothness of the joint tissue surface and can produce changes such as disk shifting and degenerative joint disorders.[10] The loss of teeth eliminates the vertical stop during the closure of the mandible allowing the mandible to move excessively superior to bring the ridges into contact with the anterior

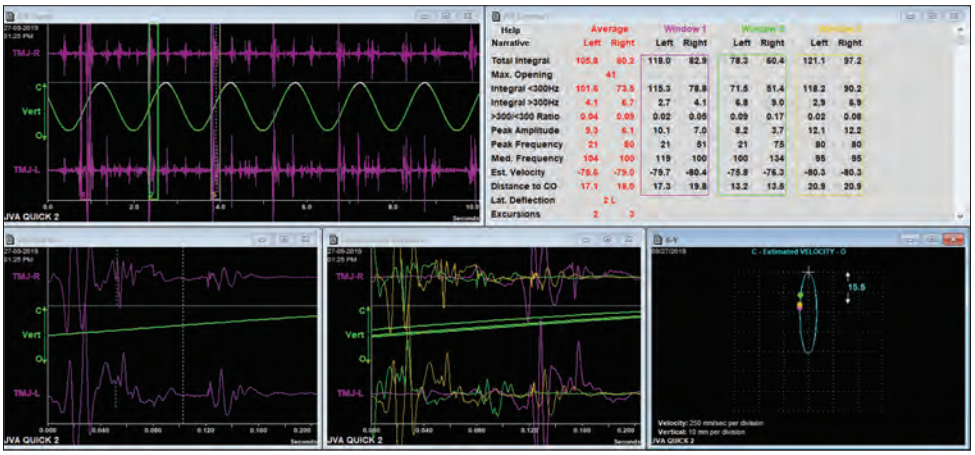

Figure 3: JVA sweep showing closing cycles present in both the right and left joint on the day of insertion. JVA: Joint vibration analyzer

Figure 4: JVA sweep showing in closing cycles present in both the right and left joint at six months of follow-up. JVA: Joint vibration analyzer

region to mash the food. The backward rotation of the condyles during excessive movement may induce changes in the TMJs. The loss of vertical support makes the elevator muscles contract more to bring the ridges together and introduces a heavier burden during the function.[4]

In the present study, after insertion of the dentures, the occlusal vertical dimension (OVD) was re-established, and the vibrations' intensity varied in TMJ. Significant diminished vibrations were found in most of the subjects (80%) with new dentures for opening and closing movements during the observation period. Patients with low intensity (20%) did not show any change in TMJ vibrations with new denture insertion.

Intragroup comparison of the total integrals' means during the opening and closing movements of both the left and right joint vibrations, with complete dentures on the day of insertion and after 6 months, demonstrated a significant reduction. Higher frequency vibrations indicate a more progressive degenerative condition.[14,15] The authors[7] found improvement in TMD signs and also observed reduced vibrations after new dentures were put in place due to the correct re-establishment of OVD, in correlation with the present study. The frequency spectra view in the JVA software plots the amplitude (vertical axis) versus the frequency (horizontal axis) [Figure 2]. The height of the curve is directly proportional to the energy of the spectrum at each frequency. The thick line represents the average spectrum of all the marked vibration spectra. Two spectra are plotted for each side, the smaller of the two represents the absolute magnitude of the vibrations' spectra as recorded (N/m^2), and the larger one has been scaled to the maximum range (at the recorded amplification) and is known as the relative plot.[16-18] The relative plot accentuates features that may not be visible in the absolute plot.

Intragroup comparison of mean peak amplitude during the opening and closing movements of both left and right joint vibrations, with complete dentures on the day of insertion and after 6 months, demonstrated marked reduction (statistically significant). A larger amplitude of 25 dB from symptomatic subjects was noted compared to asymptomatic subjects with 15 dB.[19]

The peak amplitude is the intensity or "loudness" of the dominant frequency (values >6 Pa are usually audible TM joint noises). The significant change suggests that a decrease in the amplitude of the vibrations from denture insertion to follow-up suggests an improvement in the health of TMJ.

Intragroup comparison of mean peak frequency (Hz) did not show a statistically significant difference in opening of right joint and closing of left and right joint peak frequency except during opening movement of the left joint. The numeric values that are calculated and displayed in the JVA summary view are based on the absolute frequency spectra. The frequency spectrums showed similar patterns of joint vibrations before and after the 6 month recording suggesting that there were no changes in the degree of internal derangement and shape of the disk.[9,15,20]

The results inferred that the loss of posterior teeth causes anatomical, physiological, and biochemical changes in the TMJs.

Rehabilitation of lost vertical dimension with removable prostheses brought about significant changes to the TMJ structural vibrations [Tables 2 and 3].

The reduced vibrations were seen as smaller total integrals. Less energy below 300 Hz typically due to reduced disk hyper mobility, lowered peak amplitudes (loudness), and

lower peak frequencies observed at the opening movement of the left joint, indicating that there was less aberrant disk movement. This is a indicative of a definitive improvement in disk function during mandibular motion.

Limitations

Use of electromyographical data to substantiate the muscular activity along with JVA analysis provide, would substantiate the effect of vertical jaw relations and effect on TMJ. Parameters did not include gender variation due to the smaller sample size.

CONCLUSION

Within the limitations of the study, from the BIO-JVA evaluation of removable complete dentures, the following conclusions can be drawn:

1. The fabrication of complete dentures with corrected vertical dimensions showed a decrease in the total integral of the vibrations and peak amplitude in opening and closing movements of the TM joints from the time of denture insertion to 6 months
2. The values verified through analysis of the peak frequency showed a decrease in peak frequency only at left opening movements from the day of insertion and at 6 months
3. The analysis of the maximum mouth opening did not show any statistically significant difference between the denture insertion and at 6 months.

The function of TMJ mechanics was improved till 6 months could be due to BA and maintenance of vertical dimension. The authors[7] found that vertical rotation of condyle is limited during the closure from edentulous to after wearing of complete denture due to the correct vertical dimension. The present study shows that Bio-JVA can be an effective tool for evaluating TMJ function in individuals.

Declaration of patient consent

The authors declare that they have obtained consent from patients. Patients have given their consent for their images and other clinical information to be reported in the journal. Patients understand that their names will not be published and due efforts will be made to conceal their identity but anonymity cannot be guaranteed.

Acknowledgment

I would like to acknowledge my special thanks of gratitude to Dr. John Radke for his able guidance and support for the study.

Financial support and sponsorship

This study was self-funded.

Conflicts of interest

There are no conflicts of interest.

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Research

In vitro comparison of the color degradation of two computer-aided design/computer-aided manufacturing provisional materials: A 12-month simulation

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Abstract

Aim: This study evaluated the color aging of two computer aided design/computer aided manufacturing (CAD/CAM) provisional materials of different compositions (polymethyl methacrylate and composite resin) after exposure to thermal aging and immersion in coffee for 3, 6, and 12 intraoral months.

Setting and Design: The current in vitro study was conducted from September to December 2021 at the Craniofacial laboratory at the Saint Joseph University in Beirut, Lebanon.

Materials and Methods: The shades of 2.0 mm thick, 10.0 mm in diameter disk shaped specimens of VITA CAD Temp® and Ceramill® TEMP were measured using the VITA Linearguide 3D MASTER® and a conversion table to extract the CIE L*a*b* values on a white background ($n = 30$).

Statistical Analysis Used: The color differences ΔE at 3, 6, and 12 months were calculated and analyzed by repeated measures ANOVA followed by Bonferroni multiple comparisons, univariate analyses, and one sample *t* tests.

Results: The mean $\Delta E_{T1/T0}$, $\Delta E_{T2/T0}$, and $\Delta E_{T3/T0}$ values were significantly higher than the cutoff values for acceptability and perceptibility for the VITA CAD Temp® and the Ceramill® TEMP groups. In addition, the increase in ΔE overtime was significantly greater in the Ceramill® TEMP group compared to the VITA CAD Temp® group.

Conclusions: The Ceramill® TEMP changed color more and faster than the VITA CAD Temp®. In addition, whether at 3, 6, or 12 months, the color variations of both materials are not only perceptible but also unacceptable compared to the initial shade.

Keywords: Color, composite resin, computer-aided manufacturing/computer-aided manufacturing, *in vitro*, materials, polymethyl methacrylate, stability, temporary

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Submitted: 07-Mar-2022, **Revised:** 15-Jul-2022, **Accepted:** 29-Jul-2022, **Published:** ***

INTRODUCTION

In fixed prostheses, the temporization phase is the most important,[1] especially because of its role in restoring esthetics, its diagnostic value, restoring function (chewing and phonation), and protection of underlying and surrounding structures.[2] Whether for the patient or for the practitioner, the provisional will make it possible to

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Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_119_22

How to cite this article: Sayegh SM, Daou M, Najjar G, Zebouni E. *In vitro* comparison of the color degradation of two computer-aided design/computer-aided manufacturing provisional materials: A 12-month simulation. J Indian Prosthodont Soc 2023;23:38-44.

choose the best permanent crowns as wisely as possible at the end of treatment.[1] Discoloration of these temporary teeth would lead to patient dissatisfaction, the need to replace them, and the surge of additional costs on the practitioner. It is therefore based on this reasoning that the quest for temporization materials[2] that combine mechanical resistance, biocompatibility, and esthetic longevity has been intensified.[3] When treatment plans are long and require long temporization periods of up to 12 months, practitioners then resort to materials manufactured industrially under optimal conditions: computer-aided design/computer-aided manufacturing (CAD/CAM)-manufactured materials, more stable mechanically and chemically,[4-7] and available mainly in two types: methacrylic resins and composite resins.

The aim of this study was first, to confirm or refute the theory that claims that composite materials are more vulnerable than others to color change, to determine which of the two materials (PMMA and composite) changes color more and quicker, to determine whether this change in color is perceptible or not and acceptable or not by the patient, and finally, to deduce which of the two materials should be chosen for provisional restorations for long term prosthetic treatments in an esthetic region.

The answers to the above were found after calculating and analyzing the color changes (ΔE) after thermal aging and immersion in coffee[7-12] of two CAD/CAM-manufactured materials: the VITA CAD-Temp® (Bad Säckingen, Germany) from VITA, a microfiller-reinforced polyacrylic (MRP) composed of a matrix of cross-linked acrylate polymer, exempt of fibers and supplemented with microfillers, and the Ceramill® TEMP (Koblach, Austria) from Amann Girrbach made of polymethyl methacrylate (PMMA) and methacrylic acid ester-based cross-linked polymers.

MATERIALS AND METHODS

In the present study and as aforementioned, two CAD/CAM materials used for the fabrication of temporary crowns were compared, one made of PMMA resin, the Ceramill® TEMP (Koblach, Austria) PMMA from Amann Girrbach, and the other a composite resin, the Vita CAD-Temp® (Bad Säckingen, Germany) from VITA. Both materials, manufactured in the same way, were exposed to the same staining factor, the most dreaded according to previous studies:[7-11,13] coffee. Ethical Committee approval reference number, it's the following: USJ-2020-236.

Materials and specimens' fabrication

VITA CAD-Temp® is a material consisting of a high-molecular-weight cross-linked acrylate polymer matrix supplemented with microfillers; this material is called MRP. VITA CAD-Temp® is used for the fabrication of multiunit provisional bridges in cases requiring long-term temporization. Ceramill® TEMP is a PMMA that is also suitable for long-term temporary restorations with a wearing time of up to 3 years. According to the recommendations of their respective manufacturers, both materials have the same indications for use.

Thirty specimens of each material, both of shade 1M2 ($n = 30$, $n = 60$), were milled according to the ISO recommendations for this kind of experiment, i.e., 1 cm diameter and 2 mm thick discs [Figure 1] with the Ceramill® Motion 2 (Koblach, Austria) milling machine from Amann Girrbach AG [Figure 2]. The 60 specimens were numbered from 101 to 130 (VITA CAD-Temp®) and from 201 to 230 (Ceramill TEMP®) on one side (by engraving) and polished on the other side by the same operator using a diamond polishing paste (Renfert Polish® by Renfert). Specimens were polished for 15 s with a polishing disc mounted on an electric handpiece at 15,000 rpm using the diamond polishing paste. Before initial color measurement, visual observation of the respective polished surfaces of all specimens was made to ensure that surfaces were exempt of any porosity. This was followed by washing and storing the discs in distilled water.

Preparation of the staining solution

Coffee is one of the most popular drinks in the world. In Lebanon, Turkish coffee is the most consumed, with 65%[14] of the total consumption, whereas instant coffee is only 35% of the total consumption (Espresso 0.34% and filter coffee almost 0%).[14] To prepare the coffee solution and to standardize it, the preparation was done with the Raqwa® (Beirut, Lebanon) machine of Café Najjar, which allowed to obtain the exact same solution each time by the capsule system.

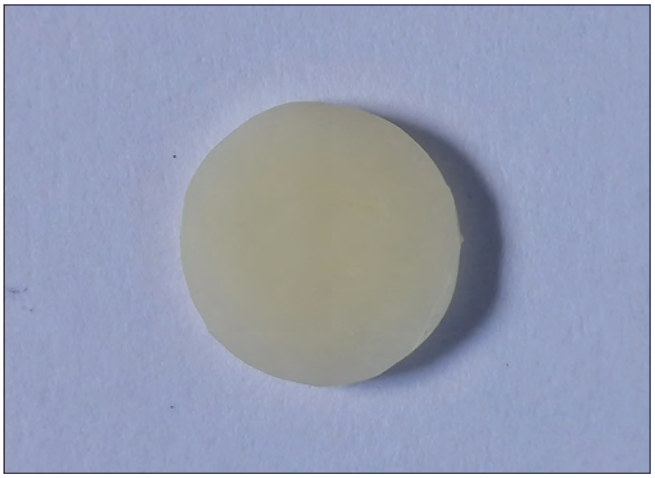

Figure 1: One centimeter diameter and 2 mm thick disc-shaped specimens

Implementation of the protocol

The specimens were artificially aged by thermocycling (each cycle = 30 s in the −5°C tray, 5 s of rest, and 30 s in the 55°C tray) [Figure 3]. After each thermocycling step (2500, 5000, and 10,000 cycles, respectively, equivalent to 3, 6, and 12 months[15]), soaking was performed to simulate the consumption of three cups of coffee per day over 3, 6, and 12 months (24 h of soaking being equivalent to 1 month of consumption; therefore, 72 h for 3 months, 144 h for 6 months, and 288 h for 12 months.[16-18]).

Color measurements [Figure 4] were performed after each pair of manipulations (thermocycling + soaking) using the VITA Linearguide 3D-MASTER® (Bad Säckingen, Germany) and after rinsing the specimens for 3 min using distilled water and drying them with absorbent paper towels. First of all, the initial shade of the specimens was double-checked before soaking, and the baseline color values at T_0 were noted down. Moreover, since visual color examination is influenced by the light environment and the visual fatigue of the practitioner, the specimens were positioned on a white background, allowing better visualization of color changes in addition to a better accentuation of the nuances.[19,20] This was done on the same working surface, and facing the same window, between noon and 3 o'clock, every single time. These precautions aimed to lessen, as much as possible, the bias related to the light environment. Furthermore, the color was measured twice each time, 1 h apart, and by a practitioner with a trained eye and good eyesight (no glasses worn), to eliminate any bias that might be caused by visual fatigue of the practitioner. The color difference (ΔE) after 3, 6, and 12 months was then calculated.

Figure 5 concretizes the chronology of the manipulations and the measurements in time.

Statistical analyses

Statistical analyses were performed using IBM SPSS Statistics for Windows (IBM Corp., Armonk, NY, USA) (version 25.0). The level of significance was set at – $P \leq 0.05$. The primary outcome variable of this study was the variation of ΔE within time.

Repeated measures analysis of variance with one within-subject factor (time) and one between-subject factor (VITA and AG) was applied to compare the mean Δ E between the groups. This test was followed by univariate analyses and Bonferroni multiple comparisons. The 95% confidence interval of the mean Δ E values was calculated in each group. One-sample *t*-tests were used to compare the mean ΔE with the cutoffs of 1.2, 2.767, and 3.368.

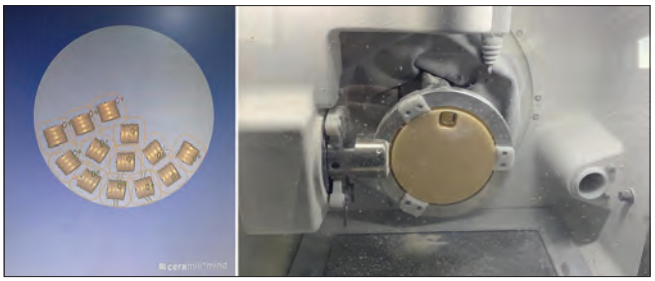

Figure 2: Specimens' design and milling

Figure 3: Thermocycling step

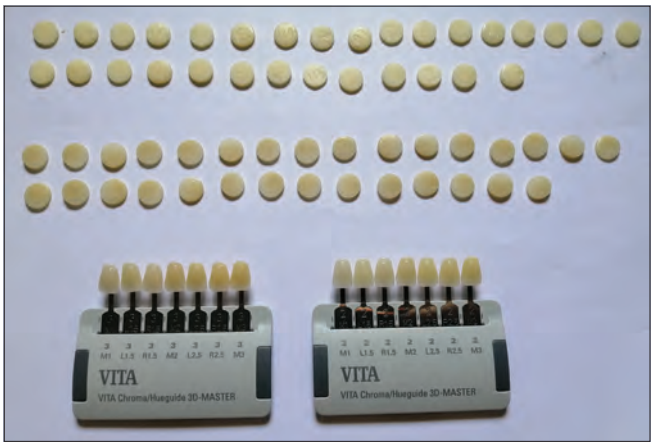

Figure 4: Specimens and shade guides on the white background used for color measurement

RESULTS

As shown in Table 1, the mean $\Delta E_{T1/T0}$, $\Delta E_{T2/T0,}$ and $\Delta E_{T3/T0}$ values were significantly higher than the cutoff of acceptability and perceptibility for the VITA ($P < 0.001$) and AG groups ($P < 0.001$).

These ΔE values significantly increased over time for the VITA ($P < 0.001$) and AG groups ($P < 0.001$); however, the increase in ΔE over time was significantly greater in the AG group compared to the VITA group (statistical interaction: $P < 0.001$).

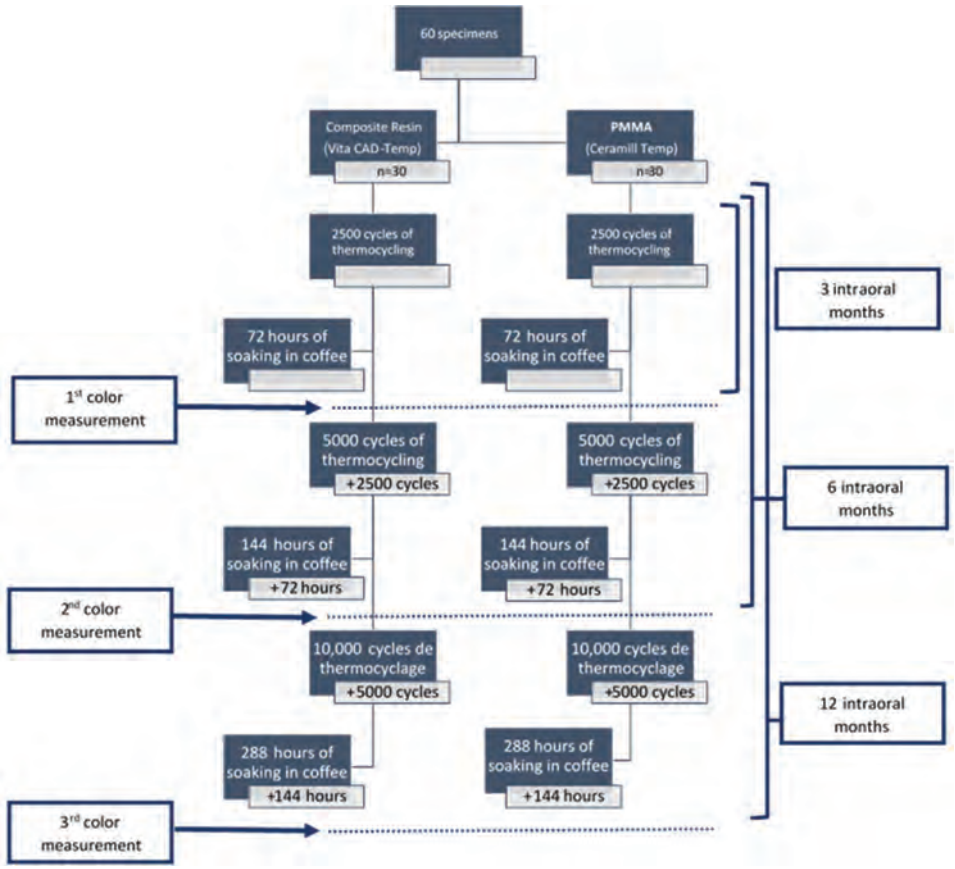

Figure 5: Chronology of the applied protocol

Table 1: MeanΔE variation among groups (VITA and Amann Girrbach [AG])

	n	Mean	SD	95% CI		Minimum	Maximum
				Lower	Upper		
$\Delta E_{T1/T0}$							
VITA	30	6.068	0.842	5.754	6.382	4.57	6.52
AG	30	7.059	1.052	6.666	7.452	4.75	7.52
$\Delta E_{T2/T0}$							
VITA	30	7.409	0.512	7.218	7.601	6.57	7.71
AG	30	8.840	0.001	8.840	8.840	8.84	8.84
$\Delta E_{T3/T0}$							
VITA	30	10.803	0.798	10.504	11.101	9.03	11.19
AG	30	12.820	0.001	12.820	12.820	12.82	12.82

SD: Standard deviation, CI: Confidence interval

Hence, for VITA, the ΔE has significantly increased between T1/T0 and T2/T0 by +1.341 ($P < 0.001$), between T2/T0 and T3/T0 by +3.394 ($P < 0.001$), and between T1/T0 and T3/T0 by +4.735 ($P < 0.001$). The increase of +1.341 was not perceptible ($P = 0.342$), the increase of +3.394 was perceptible ($P < 0.001$) and acceptable ($P = 0.882$), and the increase of +4.735 was perceptible ($P < 0.001$) but not acceptable ($P < 0.001$).

For the AG group, the Δ E has significantly increased between T1/T0 and T2/T0 by +1.781 ($P < 0.001$), between T2/T0 and T3/T0 by +3.98 ($P < 0.001$), and between T1/T0 and T3/T0 by +5.761 ($P < 0.001$). The increase of +1.781 was perceptible ($P = 0.005$). The increase of +3.980 was perceptible ($P < 0.001$) but not acceptable ($P < 0.001$), and the increase of +5.761 was perceptible ($P < 0.001$) but not acceptable ($P < 0.001$).

DISCUSSION

This study's primary aim was to compare the color stability of two provisional CAD/CAM materials of two different compositions, the Vita CAD-Temp® from VITA and the Ceramill® TEMP from Amann Girrbach, after exposure to thermal aging and immersion in coffee for 3, 6, and 12 intraoral months.

First, statistical analysis showed that the Ceramill® TEMP changed color more and faster than VITA CAD-TEMP®, making the latter a better choice for long-term esthetic provisional restorations, thus invalidating the theory stating that composite materials are more prone than others to color change[21,22] and thereby refuting the hypothesis of the current study. The aforementioned results are in line with the ones of another recently published study by Kul *et al*. that compared these two materials.[8]

However, whether at T1, T2, or T3, the color variations of both materials were shown to be not only perceptible

but also unacceptable compared to the initial shade when the temporary crowns were placed in the mouth. This was deduced after comparing the ΔEs obtained to perceptibility and acceptability thresholds, the perceptibility threshold (3368) being the visually detectable color difference, and the acceptability threshold[1,2] being the magnitude of color difference that is acceptable by the patient for esthetic outcomes.[16] Practically, this means that after 3 months in the mouth, the patient could complain about the change in color of the provisional crowns and demand their replacement, and the situation would deteriorate further 3 and 9 months later (at 6 and 12 months).

This allows to deduce that first, after 3 months in the mouth in a patient drinking three cups of coffee a day, even these high-performance materials are not ideal from an esthetic point of view since their color change is already perceptible and unacceptable at 3 months, and that second, the color stability of prefabricated temporary blocks for CAD/CAM systems still needs to be improved, as also mentioned by Kul *et al*.[8]

Nevertheless, going into the details of the results, it is noticeable that between T1 and T2, during the period extending between the 3rd and 6th months after the delivery of the provisional crowns, the color change is not perceptible with the VITA CAD-Temp® and is perceptible and acceptable with the Ceramill® TEMP. Furthermore, between T2 and T3, during the 6 months extended from the 6th to the 12th month after delivery of the provisional crowns, the color change is perceptible and acceptable for VITA CAD-Temp® but perceptible and not acceptable for Ceramill® TEMP.

The above two results suggest a lesser degradation of the materials after 3 intraoral months, thus a less important color change than during the first 3 months. Further studies analyzing the changes affecting the materials in particular at the level of their sorption and thus of their capacity of absorption of the coloring substances at shorter intervals are necessary to confirm this hypothesis, as it was done in a previous study.[16] This hypothesis is also supported by another study which underlines the fact that the degradation of color during the first 4 weeks of simulation is less important than that appearing after 8 weeks;[4] the time factor would therefore be quite delicate after the 1st month of manipulation,[23] and it would have been interesting to have included measurements at 1 month of simulation in the present study.

Moreover, it can then be deduced that when planning for treatments including long-term temporization in an esthetic region, the VITA CAD-Temp® is a better choice than the Ceramill® TEMP, without omitting the fact that the color stability of CAD/CAM blocks must be further improved in future to meet the expectations of practitioners and patients, since the color change in both materials was noticeable and not acceptable after 3, 6, and 12 months.

In addition, this study provided more precise results than several other studies (sometimes even very recent) of the same kind,[8] given several facts. First, most studies only soaked specimens without prior thermocycling,[7-9,12] which does not accurately reproduce the intraoral conditions. Second, in other studies,[8,9] the color measurements are made with spectrophotometers on the VITA CAD-Temp® specimens, knowing that the values given by the most advanced dental spectrophotometers on the market are not validated on this material (according to the scientific research team of VITA Zahnfabrik who were contacted). Third, the coffee staining solutions used in this study are highly standardized since they were prepared through a capsule system (Raqwa® from Café Najjar). Fourth, the population represented was poorly included in previous studies, since the type of coffee used in the vast majority if not all of the previous studies is filter coffee or instant coffee, types of coffee that are far from being the most popular in the Arab region. A last important advantage is the fact that the manipulations simulated 12 intraoral months, a duration exceeding those simulated in similar studies. This makes this study a continuation of previous ones that have underlined the limitation due to short simulation periods.[4]

It is nevertheless important to underline the fact that, in the oral environment, apart from exposure to coffee and temperature variations, restorative materials are also exposed to many other liquids and coloring substances, as well as to functional and parafunctional load constraints and toothbrushing. One of the limitations of this *in vitro* study would therefore be that the clinical environment and its effect on the discoloration of the CAD/CAM blocks have not been fully reproduced. Therefore, further investigation and more sophisticated handling is recommended to assess the effect of all the exogenous factors contributing to the long-term discoloration of CAD/CAM materials.[16,24] Furthermore, a detailed dissection of the filler and resin matrix composition of each material and an analysis of the surface quality and composition-related properties of the materials after each soaking cycle would have possibly brought clarifications as to the influence of endogenous factors on color aging, as it was highlighted in other studies.[12,13,16,24] Therefore, a

more comprehensive strategy should be developed to test the exogenous and endogenous influences on the color stability of provisional prosthetic materials. Although combining factors will not provide information on the influence of any single factor, it might better mimic intraoral conditions and provide valuable supplementary findings.

An additional limitation of the present study is the fact that the color measurement was done twice, but by a single observer, it is recommended for it to be done by at least two different observers.

Finally, it would be interesting to investigate starting how many weeks this deterioration becomes perceptible and unacceptable in order to be able to predict the maximum duration of acceptability of the provisional by the patient. An analysis of the modification of the surface properties of the materials, in particular the modifications of their water sorption,[25] would provide further explanation as to the dynamics and intensity of color aging of the materials studied.

CONCLUSIONS

Within the limitations of this study, it was concluded that:

1. "Composite" does not automatically mean less efficient, quite the contrary: on the basis of the results obtained, it is concluded that the VITA CAD-Temp® composite material from VITA Zahnfabrik exhibited a less important color aging than the noncomposite Ceramill TEMP® PMMA material from Amann Girrbach
2. The Ceramill TEMP® PMMA aged more and quicker than the VITA CAD-Temp® composite material
3. The color change is both perceptible and not acceptable by the patient whether it is after the simulation of 3, 6, or 12 intraoral months
4. Despite all the technological advances with regard to dental materials, in particular materials for temporary restorations, improvements in physical properties still need to be made in order to obtain materials whose color stability is sufficient for long-term treatments to avoid the need for their replacement due to patient dissatisfaction. Nevertheless, if a choice has to be made between the two materials used in this study, the VITA CAD-Temp® would be preferred
5. The spectrophotometers on the market are not yet ideal, their measurements not being validated with certain materials including composite ones. Improvements in these instruments can still be made.

Acknowledgments

The authors would like to thank VITA Zahnfabrik for the donation of their materials, Zirconnet Dental Laboratory (Mr. Marwan Khoury and Ms. Laureine Hamdar) for the milling of the specimens, and Pr. Maha Daou and Dr. Georges Najjar for their assistance and guidance in the laboratory work.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Research

Chemical characterization of silanized silver nanoparticles impregnated in poly (methyl methacrylate) resin: An *in vitro* study

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Abstract

Aim: The intention was to determine the chemical interaction of silanized AgNPs with PMMA by Fourier transform infrared (FTIR) spectroscopy.

Settings and Design: *In-vitro* comparative study.

Materials and Methods: This study is composed of four groups – 0.75% AgNP, 1.0% AgNP, 1.5% AgNP impregnated with PMMA, and nonimpregnated PMMA as control. The chemical nature of silanized AgNPs was studied using FTIR study.

Results: The results showed the appearance of new peak between 1727/cm and 1436/cm, i.e., 1636.476/ cm, 1645.886/cm, and 1646.885/cm, representing the C = C stretch in the experimental groups, i.e., 2, 3, and 4, respectively. This peak confirms that coupling agent has chemically interacted with PMMA.

Conclusion: It can be concluded that the AgNPs coated with the silane coupling agent TMSPM has chemically reacted with PMMA.

Keywords: Denture base resin, silane coupling agent, silver nanoparticles

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Submitted: 22-Apr-2022, **Revised:** 09-Jul-2022, **Accepted:** 13-Jul-2022, **Published:** ***

INTRODUCTION

Dr. Walter Wright and Vernon Brothers in Philadelphia launched acrylic resins as transparent resin in 1936 and as acrylic powder in 1937. Poly (methyl methacrylate) (PMMA) is of great importance for its superior esthetics, biocompatibility, low cost, solidity in oral environment, convenient processing and repair.[1] It has good mechanical properties such as high hardness, rigidity, discontinuity deformation, and biological properties. However, it has high adhesion of microorganism causing denture stomatitis.

Silver nanoparticle (AgNP) form incorporated in PMMA reduced the adherence and inhibited the growth of microorganism. The properties of silver-impregnated polymer depend on the size, shape, and concentration and its reaction with the polymer matrix. Silver is the

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	DOI: 10.4103/jips.jips_203_22

How to cite this article: Nayaki VT, Karthigeyan S, Ali SA, Kalarani G, Ranganathan K, Ranganathan A. Chemical characterization of silanized silver nanoparticles impregnated in poly (methyl methacrylate) resin: An *in vitro* study. J Indian Prosthodont Soc 2023;23:45-9.

most widely used polymer additive due to its antimicrobial properties.

The problem associated with AgNPs is its incapability to homogeneously disperse within the polymer (PMMA) powder causing the agglomeration of nanoparticles, thus preventing its high surface area being realized for antibacterial action.

The dispersibility of AgNPs in polymer matrix is a significant factor which dominates the enhancement ability of properties of the nanocomposites. To increase the dispersibility as well as decrease the agglomeration of AgNPs in polymer matrix, surface modification of AgNPs is the core method.[2]

To overcome this, a silane coupling agent is added to AgNP to enhance its bonding with PMMA. Silane coupling agents upgrade the mechanical properties of composites by easier and better adhesion of inorganic filler particles to the polymer matrix.[3]

Silane coupling agents act in the interphase region between organic and inorganic substrate and act as bridging, bonding, and to improve adhesion between two dissimilar materials.[4] Silane coupling agent bears alkoxy silane groups and a large number of functional groups which ensure good compatibility between the reinforcing element and the polymer matrix [Figure 1].

In this study, a silane coupling agent named 3-(trimethoxysilyl) propyl methacrylate (TMSPM) containing a alkoxy hydrolyzable group that reacts with hydroxyl group present on the surface of AgNPs was tried.

The coupling agent trimethoxymethylsilane cannot be used as there is no linker and an organofunctional group that reacts with functional group present in the heat cure denture base resin. The TMSPM with two functional groups (C = C and O–C = O) can work more effectively and interact more strongly with hydroxyl groups on the surface of nanoparticles. The intention of this modification was to enhance the hydrophobic property of nanoparticles as compared to the noncoated ones, leading to improved dispersion and interaction of modified nanoparticles in a resin matrix, thus uplifting AgNP properties.

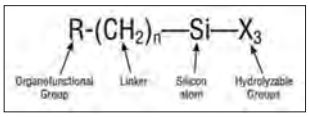

Figure 1: Structure of silane coupling agent

MATERIALS AND METHODS

This was an *in vitro* study done to characterize the chemical interaction of silanized AgNPs impregnated in denture base resins with that of the control group.

Study groups

For this study, four groups were formed and, in each group, one acrylic resin sample was made of AgNP-impregnated PMMA resin.

Preparation of silanized silver nanoparticles

AgNPs of size 10–20 nm (Amnium Technologies, Pune) and a coupling agent TMSPM (Sigma Aldrich) were used. One hundred milliliters of ethanol aqueous solution (70 vol%) was prepared using 99.8 vol% ethanol and deionized water (30 vol%). The pH of ethanol was maintained at 4.8. Five milliliters of ethanol was added to 5 ml of coupling agent, and this mixture was then added to 5 g of AgNPs. The mixture was then placed in magnetic stirrer for 20 min and sonicated in probe sonicator apparatus for 20 min, and left to dry at room temperature for 14 days.[5]

Preparation of experimental groups

For the fabrication of experimental groups, a specified percentage of AgNPs (0.75%, 1.0%, and 1.5%) and polymer is ball milled for 1 h to achieve homogeneous mixing.

Preparation of mold space

Steel dies of size 10 mm × 2 mm were prepared according to the dimension quoted by Ramakrishna Alla in the year 2019.[6] Vernier caliper was used to measure the dimension of the dies. The standardized steel dies of 10 mm × 2 mm thickness were used to prepare the mold space for acrylic samples. The dental flask was filled with dental plaster and coring was done using putty elastomer and the dies were pressed and closed for 5 min.

Preparation of experimental group

For the fabrication of discs in the experimental group, the polymer containing the silanized AgNPs and unmodified monomer were proportioned at 3:1 ratio in a porcelain jar. Once the dough stage is formed, the polymer containing the silanized AgNPs and monomer mixture were then packed in the molds and placed under mechanical press for 10 min. The heat-curing cycle of 74°C for 90 min and at 100°C for 30 min was followed. After curing, the flasks were bench cooled and the disks which were formed were trimmed and polished.

Fourier transform infrared study

Samples were tested by Fourier transform infrared (FTIR) spectrophotometer to determine if the functional groups

present in the silane coupling agent have been coupled to PMMA resin by scrutinizing characteristic vibrations of functional groups.

RESULTS

Fourier transform infrared–chemical interaction study

To study the chemical interaction of AgNPs coated with TMSPM with that of PMMA, FTIR study was done for both control group and experimental groups.

The peaks from 2956.350/cm to 2921.475/cm represent methylene stretch (C–H), the peaks from 1727.186/cm to 1719.858/cm represent the carbonyl stretch (C = O), the peaks from 1646.885/cm to 1636.476/cm represent TMSPM substituted stretch (C = C), the peaks from 1436.865 to 1433.961 represent C–H deformation, the peaks from 1387.157/cm to 1375.267/cm represent CH_3 deformation, the peaks 1271.418/cm, 1238.620/cm, 1139.415/cm, and 985.859/cm represent C–O stretching, and the peaks 680.096/cm–670.086/cm represent the presence of AgNPs[7] [Figures 2-5 and Table 1].

DISCUSSION

This is an *in vitro* study done to characterize the chemical interaction of silanized AgNPs impregnated in denture base resins with that of the control group.

In this study, it was found that the coupling agent added to the AgNPs has chemically interacted with the PMMA when compared to the control group. Earlier, the same procedure was done using titanium nanoparticles; however, no studies have been reported on AgNPs.

FTIR method is nondestructive, faster than older techniques, sensitive, and precise with simultaneous quantification of many compounds. FTIR detects functional groups, and a molecule's covalent bonds will selectively absorb the radiation of specific wavelength which changes the vibrational energy in the bond. When FTIR study was done to study the characterization of silanized AgNPs impregnated in PMMA, the results showed the appearance of new peak between 1727/cm and 1436/cm, i.e., 1636.476/cm, 1645.886/cm, and 1646.885/cm, representing the C = C stretch in the experimental groups, i.e., 2, 3, and 4, respectively. This peak confirms that TMSPM has chemically interacted with PMMA. This new peak between 1727/cm and 1436/cm was absent in the control group. The peaks 670/cm and 681/cm confirm the presence of AgNPs.

Vodnik *et al*. in 2009 studied the characterization of AgNP in PMMA. When IR measurements were done to check if chemical bonding has occurred, the results of the study showed that there was a weak and physical interaction between the polymer matrix and nanofiller particles.[8]

Kassaee *et al*. in 2010 studied the characterization of AgNPs in PMMA using FTIR study for pure PMMA and PMMA stabilized AgNPs. The results were similar which

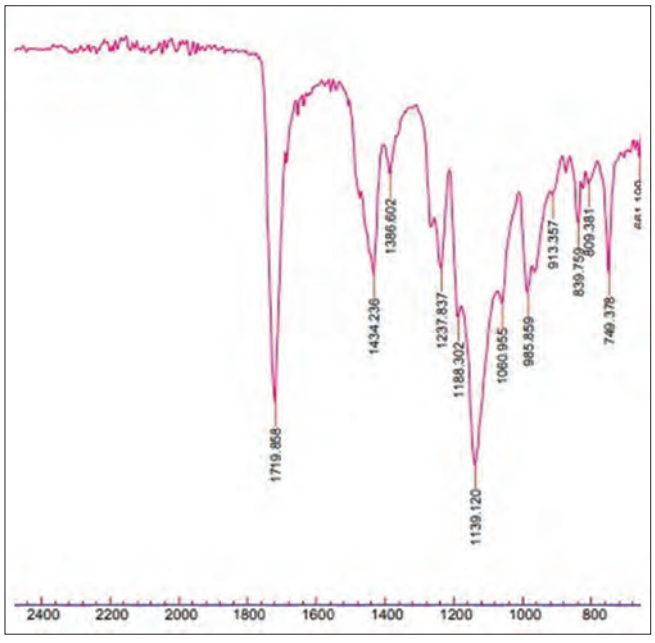

Figure 2: FTIR Group I – Control group. FTIR: Fourier transform infrared

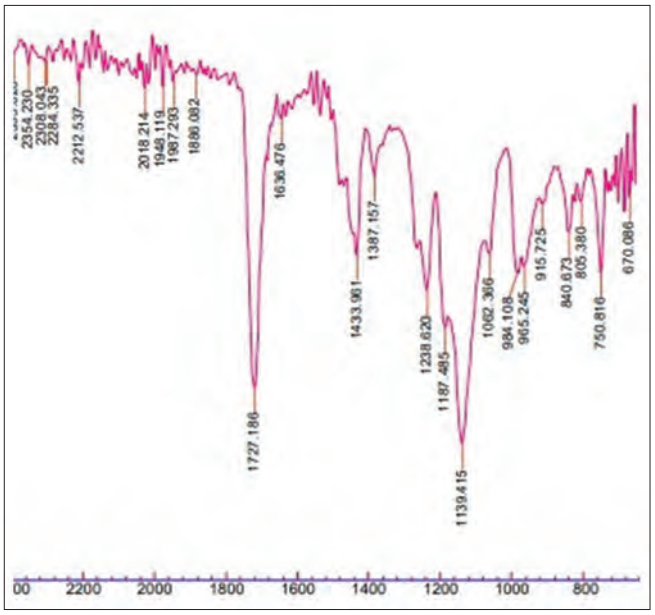

Figure 3: FTIR Group II – 0.75% AgNP impregnated in PMMA. FTIR: Fourier transform infrared, AgNP: Silver nanoparticle, PMMA: Poly(methyl methacrylate)

Table 1: Spectral wavelength of functional groups

Wave number (per cm)	Functional group	Groups			
		I. Control	II. 0.75% AgNP	III. 1.0% AgNP	IV. 1.5% AgNP
2956.350-2921.475 (C–H)	Methylene stretch	Present	Present	Present	Present
1727.186-1719.858 (C=O)	Carbonyl stretch	Present	Present	Present	Present
1646.885-1636.476 (C=C)	TMSPM substituted stretch	Absent	Present	Present	Present
1436.865-1433.961	C-H deformation	Present	Present	Present	Present
1387.157-1375.267	$-CH_3$ deformation	Present	Present	Present	Present
1271.418, 1238.620, 1139.415, 985.859	C-O stretching	Present	Present	Present	Present
680.096-670.086	AgNP	Absent	Present	Present	Present

AgNP: Silver nanoparticle, TMSPM: 3-(trimethoxysilyl) propyl methacrylate

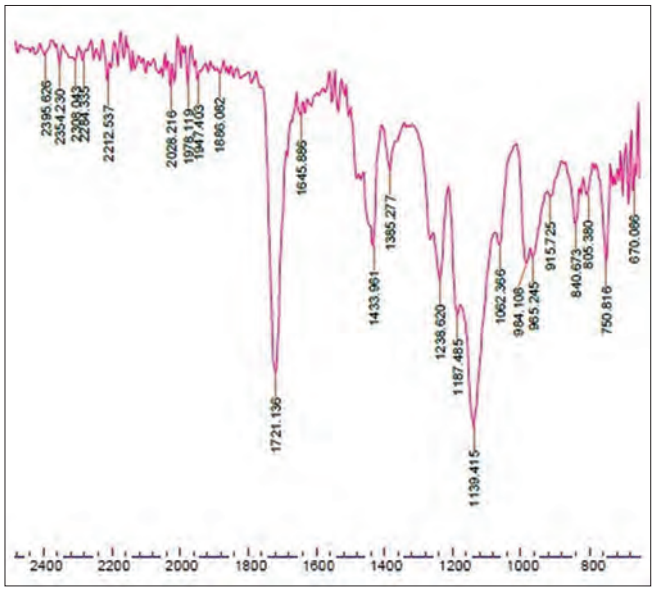

Figure 4: FTIR – Group III -– 1.0% AgNP impregnated in PMMA. FTIR: Fourier transforminfrared , AgNP: Silver nanoparticles, PMMA: Poly (methyl methacrylate)

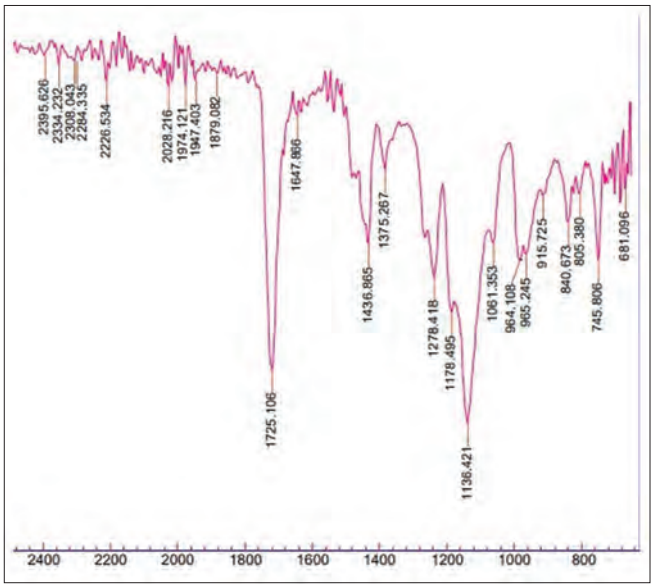

Figure 5: FTIR - Group IV -– 1.5% AgNP impregnated in PMMA. FTIR: Fourier transforminfrared , AgNP: Silver nanoparticles, PMMA: Poly (methyl methacrylate)

states that the bond is physical and not chemical between nanoparticles and resin matrix.[9]

A study by Siddiqui *et al.* in 2015 prepared AgNPs by dissolving $AgNO_3$ silver nitrate in dimethylfuran solvent and compared. Characterization of the control group with experimental groups was evaluated by FTIR study that showed no appearance of peaks 1724/cm and 1436/cm, indicating that the reaction between AgNPs and resin is physical.[10]

In this study, we have attempted to coat the AgNPs with silane coupling agent TMSPM.

On heating, the initiator benzoyl peroxide is converted to free radicals that cleave the double bond present in methyl methacrylate and in silane coupling agent TMSPM to single bond. The silane group present in the coupling agent joins with the inorganic filler and forms the matrix.

This reaction was confirmed by the appearance of peaks at 1636.476/cm, 1645.886/cm, and 1646.885/cm in the FTIR study representing the C = C stretch.

Biofilm formation and bacterial growth are common in dentures. The addition of AgNPs in PMMA significantly inhibits the growth of *Candida albicans* in denture stomatitis.[11] However, achieving full utilization of AgNPs in PMMA has remained a concern due to agglomeration and prevention of dispersibility of the material. To improve its dispersibility when incorporated in PMMA, an attempt was made to coat the AgNPs with a silane coupling agent.

Hence, in contrast to the above-cited studies, the AgNPs coated with the coupling agent TMSPM formed a chemical bond with the heat-polymerized denture base resin in our study. Therefore, it is expected to improve its dispersibility and prevent agglomeration. Since it is chemically reacted, it can be a part of denture base resin leading to less agglomeration and availability of more silver for antimicrobial action.

CONCLUSION

Thus, from the findings of the present *in vitro* study, it was concluded that the silane coupling agent TMSPM

used to coat the AgNPs has chemically reacted with the AgNP-impregnated PMMA and this can prevent the agglomeration between AgNP and PMMA.

Limitations

This is an *in-vitro* study, future studies on *in vivo* study is recommended.

The color of AgNPs causes discoloration to denture base resin.

This study was limited to only one strain of fungus.

Future recommendations

Studies on mechanical properties of PMMA such as surface hardness and abrasion resistance with larger sample size is recommended.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Research

An *in vitro* study of a custom-made device for thermoregulation of the mixing slab on the setting properties of zinc oxide eugenol impression paste

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Abstract

Aim: The present study was aimed to investigate the functional relationship between the mixing temperature and properties of a commercially available zinc oxide eugenol impression paste (ZnOE paste).

Settings and Design: *In-vitro* study.

Materials and Methods: A custom-made simulated mixing device was indigenously designed to maintain different mixing temperatures, simulating cold, ambient, and hot weather. A commercially available ZnOE paste was mixed according to the manufacturer's instructions in the simulated mixing device at the temperatures ranging from 10°C to 50°C. Initial setting time and consistency were measured according to A. D. A. Specification No. 16 ($n = 8$). A stainless-steel die having 25, 50, and 75 µm lines was used for surface detail reproduction. Detail reproduction of the stone casts of the impressions was evaluated with a stereomicroscope at 30 magnification ($n = 8$). The shear bond strength of ZnOE paste to self-cure acrylic tray resin was measured by using the UTM at a crosshead speed of 0.5 mm/min ($n = 8$).

Statistical Analysis Used: Data were analyzed by using one-way analysis of variance (ANOVA) and Tukey's post hoc tests at a confidence interval of 95% (alpha =0.05)

Results: Initial setting time, consistency, and detail reproduction of the ZnOE paste were affected by the mixing temperature ($P < 0.001$). Mixing ZnOE paste at a lower temperature of 10°C and higher temperatures of 40°C and 50°C resulted in shorter initial setting time, thicker consistency, and poor detail reproduction. However, no significant difference was obtained in the shear bond strength among the different mixing temperatures evaluated ($P > 0.05$).

Conclusion: Based on this *in vitro* study, it is advisable to perform the manipulation of ZnOE paste at a clinical/laboratory temperature of 30°C for optimum performance. The simulated mixing device used in this study can be an alternative for extreme climatic conditions.

Keywords: Zinc oxide eugenol impression paste, mixing temperature, initial setting time, consistency, detail reproduction, bond strength, mixing device

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Submitted: 12-Jul-2022, **Revised:** 13-Oct-2022, **Accepted:** 22-Oct-2022, **Published:** ***

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_337_22

How to cite this article: Sinha D, Shettigar LS, Ginjupalli K, Upadhya NP, Bhagat A. An *in vitro* study of a custom-made device for thermoregulation of the mixing slab on the setting properties of zinc oxide eugenol impression paste. J Indian Prosthodont Soc 2023;23:50-6.

INTRODUCTION

Zinc oxide eugenol impression paste (ZnOE paste) is an old, rigid as well as irreversible impression material used for recording secondary impressions of edentulous arches. It has been popular as a secondary impression paste due to its unique properties such as good surface accuracy, detail reproduction, dimensional stability, adequate working time, and good adherence to dried surfaces of resin custom trays without using any tray adhesive.[1] It has been considered as the gold standard impression material for recording complete denture impressions.[2] It is dispensed as a two-paste system with a base paste containing zinc oxide (ZnO) and a reactor paste containing eugenol/clove oil. Fillers, plasticizers, accelerators, etc., are invariably added to get the required characteristics for a certain application of the impression paste.[2,3] The material sets by a chemical reaction in which the phenolic – OH group present in eugenol provides hydrogen ions, thus, behaving as an acid. It triggers an acid-base neutralization reaction with ZnO. As a result of the reaction, zinc eugenolate salt is formed.[4,5] However, for the initial reaction of forming zinc hydroxide, water is a must. It is needed for the generation of reacting ionic species and to act as a reaction solvent. Upon the formation of zinc eugenolate, water is released as a byproduct and is available for further reaction.[5,6] The set impression consists of grains of unreacted ZnO getting interspersed in a matrix of long, sheath-like crystals of zinc eugenolate matrix, together with an excess of eugenol being absorbed by both ZnO and zinc eugenolate particles.[5,7]

Usually, ZnOE paste is available with a wide range of properties that have been carefully and skillfully compounded by the manufacturer. The factors such as type and particle size of ZnO, addition of chemical modifiers to one or both pastes are solely under the control of the manufacturer to control the rate of the reaction.[4,5,8] Improper handling of the material like mixing ratio and mixing time alters the properties of the ZnOE paste. Previous studies have reported that a change in the ZnO to eugenol mixing ratio influenced the consistency and setting of the products.[9,10] Similarly, longer spatulation time, within practical limits, shortened the setting time of the product.[11] Further, studies on commercially available ZnOE paste indicated variation in the properties due to disparities in setting characteristics, viscosity, wettability, and quality of the mix.[9,12]

It is important to note that the manufacturers formulate the ZnOE paste and optimize its performance under standard laboratory conditions with temperature and humidity control. However, during the clinical use of the material, these factors are likely to be significantly different than the standard conditions. Such deviations in manipulative and environmental conditions may affect the setting characteristics of the material and thus its clinical performance. The initial viscosity of the mixed paste governs its ease of handling and is also related to the initial setting time, detail reproduction, and adhesion to the custom tray. In this regard, the existing literature indicates that changes in humidity and temperature significantly influence the rate of setting of ZnOE paste.[11,13-15] However, it is not clear if these changes affect the clinical performance of the material. In this regard, it would be logical to investigate the effect of mixing temperature on the clinically relevant properties of ZnOE paste such as initial setting time, consistency, detail reproduction, and its bond strength to self-cure acrylic tray resins. The main aim of the present study was to establish a simple indigenous, reproducible, cost-effective simulated mixing device for the manipulation of ZnOE paste and to investigate the functional relationship between the variable mixing temperature and properties of the ZnOE paste such as initial setting time, consistency, detail reproduction, and shear bond strength. The hypothesis of the study was that the mixing temperature would influence the properties of ZnOE paste.

MATERIALS AND METHODS

In this study, a commercially available ZnOE paste (Dental Products of India, Batch number 8173, India) was manipulated as per the manufacturer's instructions at various temperatures. The desired temperature during the manipulation was maintained by using a custom-made simulated mixing device. A schematic drawing of the simulated mixing device is shown in Figure 1a and b and the original image is shown in Figure 1c.

The simulated mixing device was constructed by using two thick Thermocol blocks for the upper and lower layers.[16] A cuboid of the exact size of the glass slab was cut into the upper layer to fit the glass slab snugly into the cavity. A smaller and deeper cavity was then cut, that acted as the reservoir for water. The configured upper layer was then placed on the lower layer and then glued together. A total of five temperatures simulating cold (10°C and 20°C), ambient (30°C) and hot climatic conditions (40°C and 50°C) were selected. Water at the desired temperature was taken in a container in which a spatula made of rigid stainless steel and a glass slab were kept immersed for 5 min to attain the temperature same as that of water, before using them for mixing the ZnOE

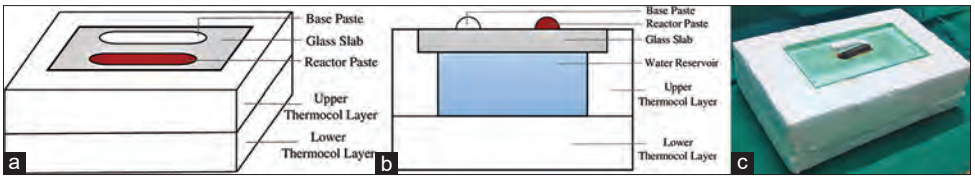

Figure 1: (a) Simulated mixing device. (b) Simulated mixing device - lateral view. (c) Clinical image of simulated mixing device

paste. The temperature of water was monitored regularly with a laboratory thermometer. Water from the container was then poured into the apparatus and the glass slab was snugly fit into the reservoir such that the lower surface of the glass slab was in contact with temperature-controlled water. Any debris or water condensation was gently dabbed away with cotton before dispensing the material onto the glass slab.

According to the manufacturer's guidelines, equal lengths of base and reactor pastes were dispensed on the glass slab positioned in the simulated mixing device and mixed for 45 s. The initial setting time and consistency were measured according to American Dental Association Specification No. 16.[17]

Initial setting time

A metal ring of 25-mm diameter having a depth of 3 mm was taken and the freshly mixed paste was placed, and then was leveled off at the top. A steel rod of 2.4 mm in diameter with rounded ends weighing 10 g was applied to the surface of the paste at 20-s intervals. Initial setting time was measured as the time from the start of mixing until the material ceases to string out upon withdrawing the rod (n = 8).

Consistency

0.5ml of the mixed material was injected onto a glass plate. Exactly 1.5 min after the beginning of the mixing, another glass plate weighing 20 g and a 500 g weight were carefully placed. After 10 min, the weight was removed, and the average diameter of the resulting disc was noted in millimeters (mm) with a traveling microscope (n = 8).

Detail reproduction

A round stainless–steel die containing 3 parallel lines of 20, 50, and 75 μm width and 25 mm in length with 2.5 mm spacing was used for evaluating the detail reproduction of the impression. A specially designed tray that fits the die was used and was loaded with freshly mixed ZnOE paste. The loaded tray was then placed on the die and a load of 1 kg was applied. After setting, the impression was retrieved and subsequently cast with dental stone under vibration. The cast was retrieved from the impression after an hour. Subsequently, the cast was allowed to dry in air for 24 h and then evaluated for detail reproduction. Surface detail reproduction of the stone casts (n = 8) was evaluated by using a stereomicroscope at ×30 magnification.[18] The details of the lines reproduced in the cast were assessed and graded as follows.

- Grade 1 – Continuous well-defined lines with accurate details
- Grade 2 – Lines are continuous, with little loss of accuracy
- Grade 3 – Noncontinuous lines or marked loss of detail
- Grade 4 – Absence of lines.

Shear bond strength

Rectangular custom trays of dimensions 4 cm × 2cm × 1 cm were made with self–cure acrylic tray resins. After 24 h of aging, freshly mixed ZnOE paste was extruded onto the custom tray to form a cylinder of radius 0.8cm and length 1.5cm and was allowed to set for 7 min (n = 8). After setting, the acrylic tray was attached to the lower platform of a universal testing machine (INSTRON 3366, UK), and loaded at the impression paste-acrylic resin interface at a crosshead speed of 0.5mm/min until debonding. The peak load observed during the test divided by the total bonded surface area of the specimen computed the shear bond strength in MPa.

Statistical analysis

The data were analyzed using the one-way ANOVA and Tukey *post hoc* analysis (GraphPad Prism) at a 95% confidence interval (α = 0.05).

RESULTS

The effect of temperature on the initial setting time of ZnOE paste is shown in Figure 2. The results showed that a gradual decrease in initial setting time was observed with increasing slab temperature from 30°C to 50°C. The effect was reversed by reducing mixing slab temperature from 30°C to 20°C. One-way ANOVA showed a significant difference in the initial setting time at various temperatures studied ($P < 0.001$). However, the initial setting time at 10°C and 50°C was not significantly different ($P = 0.0582$) [Table 1].

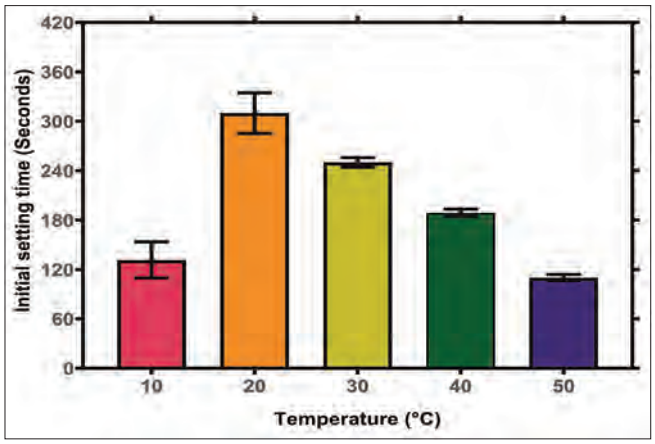

Figure 2: Initial setting time of zinc oxide eugenol impression paste

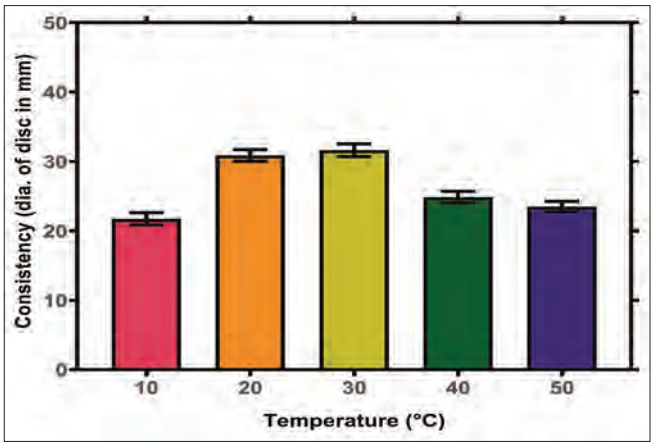

Figure 3: Consistency of zinc oxide eugenol impression paste

Figure 3 demonstrates the consistency of ZnOE paste manipulated at various temperatures. The ZnOE paste manipulated at ambient temperature 30°C showed maximum flow. Temperatures deviating on either side from 30°C were seen to reduce the amount of flow. The consistency values measured at different temperatures were significantly different from each other except between 20°C and 30°C ($P = 0.4063$) [Table 2].

The detail reproduction at various temperatures is shown in Figure 4. The ZnOE paste manipulated at 20°C and 30°C showed better reproduction of details compared to other temperatures. The casts obtained from the impressions manipulated at both lower and higher temperatures namely 10°C, 40°C, and 50°C showed grades of 3 or 4. There were no significant differences in the detail reproduction between 10°C and 40°C ($P = 0.6133$); 10°C and 50°C ($P = 0.9963$); 20°C and 30°C ($P = 0.8194$); 30°C and 40°C ($P = 0.0519$); 40°C and 50°C ($P = 0.8194$) [Table 3].

Figure 5 depicts the shear bond strength of ZnOE paste manipulated at three different temperatures to acrylic resin tray. ZnOE paste manipulated at 30°C exhibited the highest shear bond strength. However, the shear bond strength of ZnOE paste mixed at different temperatures with acrylic resin was not found to be significantly different ($P = 0.1328$, 0.3407, 0.8077 between 20°C and 30°C; 20°C and 40°C; 30°C and 40°C) [Table 4]. Visual examination of the fracture mode indicated the adhesive type of fracture at the acrylic resin tray-impression paste interface.

Table 1: Results for Tukey's *post hoc* test for initial setting time between the temperatures (10°C, 20°C, 30°C, 40°C and 50°C)

Variable	Mean difference	95.00% CI of difference		*P*
		Lower bound	Upper bound	
Temperature				
10 versus 20	−178.4	−200.3	−156.5	<0.0001*
10 versus 30	−118.5	−140.4	−96.62	<0.0001*
10 versus 40	−57.25	−79.13	−35.37	<0.0001*
10 versus 50	21.38	−0.5063	43.26	0.0582
20 versus 30	59.88	37.99	81.76	<0.0001*
20 versus 40	121.1	99.24	143.0	<0.0001*
20 versus 50	199.8	177.9	221.6	<0.0001*
30 versus 40	61.25	39.37	83.13	<0.0001*
30 versus 50	139.9	118.0	161.8	<0.0001*
40 versus 50	78.63	56.74	100.5	<0.0001*

*$P<0.05$ significant. CI: Confidence interval

Table 2: Results for Tukey's *post hoc* test for consistency between the temperatures (10°C, 20°C, 30°C, 40°C and 50°C)

Variable	Mean difference	95.00% CI of difference		*P*
		Lower bound	Upper bound	
Temperature				
10 versus 20	−9.125	−10.34	−7.907	<0.0001*
10 versus 30	−9.875	−11.09	−8.657	<0.0001*
10 versus 40	−3.125	−4.343	−1.907	<0.0001*
10 versus 50	−1.750	−2.968	−0.5320	0.0019*
20 versus 30	−0.7500	−1.968	0.4680	0.4063
20 versus 40	6.000	4.782	7.218	<0.0001*
20 versus 50	7.375	6.157	8.593	<0.0001*
30 versus 40	6.750	5.532	7.968	<0.0001*
30 versus 50	8.125	6.907	9.343	<0.0001*
40 versus 50	1.375	0.1570	2.593	0.0204*

*$P<0.05$ significant. CI: Confidence interval

DISCUSSION

This study was conducted to determine the impact of mixing temperature on the initial setting time, consistency, detail reproduction, and bond strength of commercially available ZnOE paste. The hypothesis that the mixing temperature affects the properties of ZnOE paste was accepted except for its bond strength when loaded onto self-cure acrylic resins.

The temperature of the mixing slab and spatula/environment plays an important part in the evaluation of the properties of ZnOE paste. The American Dental Association Specification No. 16 for impression paste stipulates the

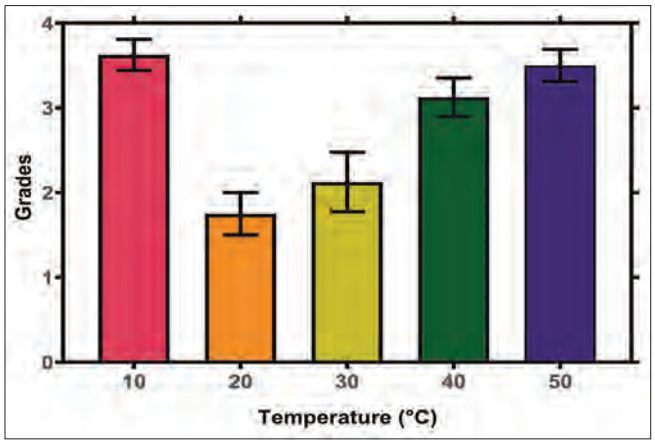

Figure 4: Detail reproduction grades of zinc oxide eugenol impression paste

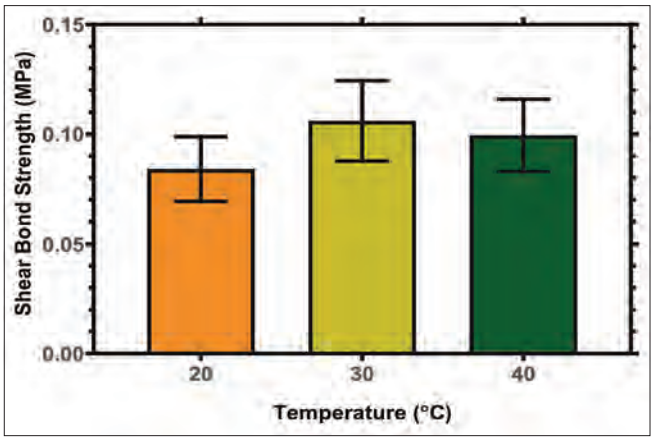

Figure 5: Shear bond strength of zinc oxide eugenol impression paste

importance of temperature control (23.0 ± 2.0°C) during the manipulation.[17] Clinically, best possible impressions can be obtained by manipulating ZnOE paste at ambient temperature. Any increase or decrease in the temperature of the mixing slab/spatula could alter the kinetics of the setting of the mixed ZnOE paste, thereby leading to compromised quality of the patient's impression. In the present study, a custom-made mixing device was prepared for thermoregulation of the mixing slab and spatula using two thick Thermocol blocks and water at the desired temperature. Thermocol was selected as the material of choice since it acts as a thermal insulator and would prevent any change of temperature of the water during the time taken for mixing the paste.[16] The temperature of the mixing slab and spatula were controlled (10°C to 50°C) during the manipulation of the ZnOE Paste.

Initial setting time or working time is one of the important properties to be considered during the initial handling of the ZnOE paste. During the initial setting, both physical and chemical changes occur simultaneously. The initial viscosity of the mixed paste governs its ease of handling. Ideally, the impression material must have enough manipulation time for mixing, filling the tray, and seating the impression in the mouth.[12] The improper handling during the manipulation phase could compromise their properties on subsequent placement into the mouth.

The initial setting time measurements obtained in a simulated mixing device indicated that the greatest decrease in initial setting time occurred at 10°C and 50°C. ZnOE paste mixed at these two temperatures did not comply with the minimum specification requirement of 180 s.[17] There was an inverse relationship between the mixing temperature and initial setting time that can be attributed to increased/decreased ionic mobility due to increased/

Table 3: Results for Tukey's *post hoc* test for detail reproduction between the temperatures (10°C, 20°C, 30°C, 40°C and 50°C)

Variable	Mean difference	95.00% CI of difference		*P*
		Lower bound	Upper bound	
Temperature				
10 versus 20	1.875	0.8695	2.881	<0.0001*
10 versus 30	1.500	0.4945	2.506	0.0012*
10 versus 40	0.5000	−0.5055	1.506	0.6133
10 versus 50	0.1250	−0.8805	1.131	0.9963
20 versus 30	−0.3750	−1.381	0.6305	0.8194
20 versus 40	−1.375	−2.381	−0.3695	0.0033*
20 versus 50	−1.750	−2.756	−0.7445	0.0001*
30 versus 40	−1.000	−2.006	0.005537	0.0519
30 versus 50	−1.375	−2.381	−0.3695	0.0033*
40 versus 50	−0.3750	−1.381	0.6305	0.8194

*$P<0.05$ significant. CI: Confidence interval

Table 4: Results for Tukey's *post hoc* test for shear bond strength between the temperatures (20°C, 30°C, and 40°C)

Variable	Mean difference	95.00% CI of difference		*P*
		Lower bound	Upper bound	
Temperature				
20 versus 30	−0.02200	−0.05003	0.006028	0.1328
20 versus 40	−0.01540	−0.04343	0.01263	0.3407
30 versus 40	0.006600	−0.02143	0.03463	0.8077

*$P<0.05$ significant. CI: Confidence interval

decreased kinetic energy of the ions. This corroborates the findings reported in the earlier investigations.[9,11,15] The observation of this study has shown that a reduction in temperature below 20°C led to a shorter setting time. This anomalous behavior of the paste can be attributed to the possible incorporation of condensed water on the glass slab at a lower temperature. The addition of water increases the polar and ionic character of the material. An increase in the polar character favors the hydration of the ZnO to form Zn $(OH)^+$ as the reacting species at a faster rate, whereas the ionic character favors the salt formation between zinc ions and eugenolate ions at a faster rate. The reaction occurs in two steps, i.e., generation of ions, followed by recombination of ions as shown below: [5,19,20]

$ZnO + H_2O \rightleftharpoons ZnOH^+ + OH^-$

$ZnOH^+ \rightleftharpoons Zn^{2+} + OH^-$ $HE \rightleftharpoons H^+ + E^-$

Recombination of ions

$Zn^{2+} + 2E^- \rightleftharpoons ZnE_2$ $H^+ + OH^- \rightleftharpoons H_2O$

$ZnE_2 + H_2O \rightleftharpoons ZnE_2.H_2O$

To validate the above findings, the entire simulated mixing device was transferred to a refrigerator where the temperature was maintained at 10°C. Refrigerators provide cooling with relatively less humidity than the environment by working on the principle of dry cooling. This resulted in little to no water condensation on the surface of the glass slab. The average initial setting time increased to around 215 (±15.4) s compared to the earlier reading of 131.5 (±21.9) s, as shown in Figure 2. This confirms that water condensation has a significant function to help the material set.

Consistency is the relative mobility of freshly mixed material to flow. It is related to the rheological changes occurring within the mixed paste during the mixing to setting time intervals. There is a gradual change in the consistency as the mixed material approaches a set condition. The consistency of the ZnOE paste is controlled by the rheology of the product, amount of pressure applied, the kinetics of the setting reaction, the nature of the environment i.e., temperature and humidity.[21,22] In this study, the diameter of the disc formed at various temperatures was in the range of 20–50 mm.[17] However, a correlation was observed between consistency and setting time.[9,12] The ZnOE paste that showed less consistency or flow at 10°C, 40°C, 50°C temperatures also exhibited a shorter initial setting time. This could be attributed to the incorporation of water at 10°C and higher activation energy at 40°C and 50°C, leading to a rapid increase in viscosity, thus, limiting the spread of the material under load.[23,24] However, better consistency was observed at 40°C and 50°C compared to 10°C. Although the material showed a faster setting, an increase in the consistency can be attributed to the plasticizing component such as thermoplastic substances present in the material. The softening temperature of these substances is slightly higher than the oral temperature of 37°C, which facilitated the increased flow.[11,14]

Detail reproduction plays a vital role in the fabrication of any prosthesis. The factors such as viscosity, wettability, setting characteristics, and the presence of voids can influence the degree of surface detail obtained in the impression.[25] In the present study, the casts obtained at 20°C and 30°C displayed good surface details, whereas poor detail reproduction was observed at 10°C and 50°C. It was observed that ZnOE paste appears to adhere to the stone cast at all the temperatures studied.[9,12] The ZnOE paste manipulated at 20°C and 30°C exhibited a gradual increase in the viscosity during the initial phase of the setting thus facilitating the flow of the material into the details. Detail reproduction deteriorated as the temperature decreased below 20°C and increased over 30°C due to accelerated setting, grainy nature of the mix, and incorporation of air voids.

The impression material must remain attached to the impression tray during placement and removal, hence the bond strength of the impression material to the tray becomes paramount.[2,16] Only three temperatures were selected as the ZnOE paste manipulated at 10°C and 50°C did not yield any promising result. The shear bond strength of ZnOE paste mixed at different temperatures with the acrylic resin did not show any significant differences. The ZnOE paste mixed at ambient temperature exhibited the highest shear bond strength. The low shear bond strength of the paste mixed at 20°C could be due to the slow rate of reaction, whereas at 40°C, it could be due to a faster rate of reaction that prevented the paste from adhering properly to the tray.

CONCLUSION

Conclusions drawn from the findings of the present *in vitro* study are listed below:

1. The properties of ZnOE paste were significantly affected by the temperature of the mixing slab
2. When it is not possible to achieve the ideal room or ambient temperature of 25°−30°C, it is advisable to follow the simulated custom-made mixing device to achieve consistent results
3. Extreme mixing temperatures of 10°C and 50°C did not yield clinically promising results and are not advised to be used.

Further clinical and laboratory experiments incorporating humidity are needed to illustrate the efficacy of this custom-made device.

CLINICAL IMPLICATIONS

For consistent and optimum clinical performance, it is advisable to manipulate ZnOE paste at ambient temperature.

Financial support and sponsorship
Nil.

Conflicts of interest

There are no conflicts of interest.

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Research

Effect of sintering procedures on optical properties, chemical composition, and grain size of monolithic zirconia ceramic at different thicknesses after hydrothermal aging: An *in vitro* study

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Abstract

Aim: The purpose of the present study was to examine the optical properties, chemical composition, and grain size (GS) of monolithic zirconia (MZ) ceramic at different thicknesses sintered using different procedures after hydrothermal aging.

Settings and Design: An *in vitro* study.

Materials and Methods: Forty MZ discs (0.5-mm thickness [Group-0.5] and 1-mm thickness [Group-1]; 12 mm diameter) were milled and divided according to standard (Group-ST) and speed (Group-SP) sintering procedures. All specimens were hydrothermally aged at 134°C after sintering. Translucency (TP), opalescence (OP), and fluorescence (ΔE_{ab^*}-FL) parameters were calculated using the color coordinates (L^*, a^*, b^*, respectively) of the discs. The chemical composition and the GS of the specimens were characterized using X-ray fluorescence spectroscopy and a scanning electron microscopy, respectively.

Statistical Analysis Used: TPs and ΔE_{ab^*}-FLs were analyzed using independent samples *t*-tests and Mann–Whitney U-tests while a two-way analysis of variance (ANOVA) was used for OPs.

Results: Group-1 showed significantly lower TP than Group-0.5 ($P < 0.001$) but a significantly higher OP ($P = 0.014$). Group-SP showed significantly higher OP ($P = 0.00003$) and ΔE_{ab^*}-FL ($P = 0.0026$) values than Group-ST without considering the thickness. Group-SP (0.29 ± 0.119 μm) had a smaller GS than Group-ST (0.306 ± 0.142 μm). Compared to Group-ST, Group-SP had a lower percentage of Y_2O_3 and a higher percentage of Al_2O_3.

Conclusion: The effect of the sintering procedure on TP and OP of MZ was not perceived by the naked eye. The speed sintering procedure may increase ΔE_{ab^*}-FL of MZ to higher values than natural teeth when compared with standard sintering. The speed sintering may cause minor changes in GS and the chemical composition of MZ.

Keywords: 3 Mol% yttria-stabilized tetragonal zirconia polycrystal, fluorescence parameter, grain size, sintering procedure

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Submitted: 15-Jul-2022, **Revised:** 09-Oct-2022, **Accepted:** 21-Nov-2022, **Published:** ***

Access this article online	
Quick Response Code:	**Website:** www.j-ips.org
	DOI: 10.4103/jips.jips_345_22

How to cite this article: Albayrak H, Eraslan R, Aydinlioglu Ö. Effect of sintering procedures on optical properties, chemical composition, and grain size of monolithic zirconia ceramic at different thicknesses after hydrothermal aging: An *in vitro* study. J Indian Prosthodont Soc 2023;23:57-64.

INTRODUCTION

Monolithic zirconia (MZ) restorations have become widely preferred in prosthetic dentistry because of advantages including favorable fracture strength, biocompatibility, production simplicity, reduced tooth preparation, reduced fracture risk of veneering porcelain, and acceptable esthetic appearance.[1] MZ crown restorations with different thicknesses may be needed depending on intraoral requirements.[2] Therefore, evaluating the optical properties of MZ restorations of different thicknesses is crucial.

A dental material should be similar optical properties to the intact dental tissue to succeed in esthetic restorations.[3] Translucency (TP), opalescence, and fluorescence are the most critical optical properties for controlling the esthetic outcome of dental restorations.[3] The TP is a reliable method used in many studies to assess the transparency of dental materials.[4-9] TP of dental materials is calculated as a color difference against a black and white backgrounds.[2,10,11] The opalescence parameter (OP) has usually been used to estimate the opalescence of dental materials. The OP of a restorative materials is calculated from the difference in the chromas determined under reflected light and transmitted light or a black-and-white background.[3] Natural teeth appear whiter and lighter under daylight while they have a bluish-white fluorescence under ultraviolet (UV) light.[3,12] The fluorescence property of a dental material can be determined by the color difference (fluorescence parameter [ΔE_{ab^*}-FL]) in the presence and absence of UV light using a spectrophotometer.[12]

MZ restorations are commonly fabricated with a soft milling process of a partially sintered zirconia block. The milled MZ restorations must be sintered to gain final density and final strength. There are slow, standard, speed and high-speed sintering procedures with the parameters (final temperature, dwell time, heating and cooling rate) varying according to the manufacturer.[13] Previous studies reported that the speed sintering procedure increased,[4] decreased.[5,9] or did not.[6-8] affect the TP values compared to standard sintering among the studies that examined 3 Mol% Yttria-Stabilized Tetragonal Zirconia Polycrystals (3Y-TZPs). It has also been reported that the OP value of the standard sintering procedure was similar to speed sintering[7,8] but lower than high-speed sintering[14] procedure considering the study including 3Y-TZP. Therefore, the effect of the sintering procedure on the TP and OP is still controversial. Although the fluorescence property of MZ has been investigated,[15,16] no study has yet been found that investigated the effect of the sintering procedure on the fluorescence property of MZ. There is a lacuna of research on the fluorescence of MZ in this area. Moreover, the effect of the sintering procedure on the optical properties of MZ may be related to the change in grain size (GS)[5,8,9] and chemical composition.[13]

MZ restorations are exposed to oral fluids, which leads to hydrothermal aging[17] and may affect the optical properties of MZ restoration.[18] Therefore, MZ specimens should be subject to hydrothermal aging to predict the long-term results of the restorations. Only one[5] of the previous studies[4-9,14] examining the effect of the sintering procedure on the optical properties of MZ (3Y-TZP) includes hydrothermal aging. The present study aimed to assess the impact of sintering procedures and thicknesses, on the optical properties, chemical composition, and GS of MZ after hydrothermal aging. The null hypotheses were that no differences were found between the TP, OP, or ΔE_{ab^*}-FL values of tested thicknesses (first) and sintering procedures (second) after the aging.

MATERIALS AND METHODS

The total sample size was 40 (n = 10). Power analysis was done using G Power 3.1.9 software (Franz Faul University, Kiel, Germany), according to the effect size (f) was 1.33, and power was 0.80 (two tails).[19]

Fabrication of zirconia discs

A zirconia ceramic brand was tested in the present study [Table 1]. Disk-shaped (diameter = 12 mm) solid models were created with two different thicknesses (0.5 mm and 1 mm) in a three-dimensional software program (SolidWorks 2018; Dassault System SolidWorks Corp, Vélizy-Villacoublay, France) and saved in the standard triangle language (STL) file format. To compensate for volume shrinkage of the presintered zirconia block, the STL files were resized by a computer-aided manufacturing software program (DWOS; Dental Wings, Montréal, Canada) according to the magnification factor of the corresponding block. Forty specimens (n = 40) were milled from presintered blanks on a milling machine (Yenadent D40; Yenadent, ZenoTec, Istanbul, Turkey) using the resized

Table 1: Main properties of zirconia block

Compounds	Katana HT (HT10)
Chemical composition	
ZrO_2+$Y2O_3$+HfO_2	>99.0%
$Y2O_3$	4.5%<-<6%
HfO_2	≤5%
Other oxides (Al_2O_3, SiO_2, Fe_2O_3, Na_2O)	≤1%
Manufacturer	Kuraray Noritake Inc., Tokyo, Japan
Batch Code	BWHTC, BWFRZ
Stability	Partially stabilized, Yttria-stabilized tetragonal zirconia polycrystal

files. New burs were attached to the holder of the milling machine after the production of every 20 specimens was completed. The specimens were divided into two groups according to thicknesses: Group-0.5 (0.5 mm, $n = 20$) and Group-1 (1 mm, $n = 20$). Each group was divided into two subgroups according to the standard (Group-ST) sintering and speed (Group-SP) sintering procedures [Table 2]. The final dimensions of all discs were gauged (293-821-30, Mitutoyo Micrometer, Kanagawa, Japan) with an accuracy of ± 0.01 mm after sintering. Any discs with unsuitable dimensions were excluded from the present study, and new discs were produced.

Hydrothermal aging

After sintering, each specimen was placed in a sterilization pack labeled with brand, sintering procedure, and specimen number. All specimens were hydrothermally aged in an autoclave[16] (Lina, W&H, Brusaporto, Italy) at 134°C under two bars for 5 h[17] and then were cleaned ultrasonically in distilled water at 40°C for 15 min (Sonorex, Bandelin, Berlin, Germany). All specimens were dried with compressed air.

Determination of optical parameters

The Commission Internationale de l'Eclairage (CIE) color coordinates (L*, a*, b*) of the specimens were measured over black (L*=94.171, a*=−0.65, and b*=2.19) and white (L*=0.21, a*=0.04, and b*=−0.22) backgrounds using a spectrophotometer (Lovibond RT 400, Tintometer Inc., Florida USA). Measurements were performed with 10°standard observer angle and D_{65} standard illuminant.[4] The specular component was excluded. The spectrophotometer had an 8-mm diameter aperture. The average value of the three measurements for each specimen was recorded. The spectrophotometer was calibrated as stated by the user guides before measuring per specimen.

The TP was calculated as the difference in L*, a*, b * measurements on white (L_W*, a_W*, b_W*) and black (L_B*, a_B*, b_B*) backgrounds using the following formula:[3]

Table 2: Details of standard and speed sintering procedures

Sintering procedures	ST	SP
Total sintering time	7 h	1 h+ 45 min
Rump up		
Heating rate (C°/min)	10	35
Final temperature (C°)	1500*	1515*
Dwell time (min)	120**	30**
Rump down		
Cooling rate (C°/min)	10	45
Temperature (C°)	Room temperature	Room temperature
Furnace used for sintering	inFire HTC furnace (Sirona, GmbH, Bensheim, Germany)	

*Final sintering temperature, **Dwell time for the final temperature. ST: Standard, SP: Speed

$$TP = [(L_B^* - L_W^*)^2 + (a_B^* - a_W^*)^2 + (b_B^* - b_W^*)^2]^{-1/2}.$$

The difference in chromaticity of the specimens over the white (a_W*, b_W*) and the black (a_B*, b_B*) backgrounds was used to assess the opalescence using the following formula.[3]

$$OP = [(a_B^* - a_W^*)^2 + (b^*_B - b^*_W)^2]^{-1/2}.$$

The color coordinates of each specimen were determined by a spectrophotometer (CM-3600d, Konica Minolta, Osaka, Japan), including (UV 100%) or excluding (UV 0%) the UV component. Measurements were carried out against a white background (l = 95.08, a=-0.52, b = 0.84) using a standard illuminant D_{65} and 10° observer function.[4] Fluorescence was defined as color difference ΔE_{ab^*}-FL in the presence and absence of the UV component. It was calculated using the following formula: $\Delta E_{ab^*}\text{-FL} = [(L_{100}^* - L_0^*)^2 + (a_{100}^* - a_0^*)^2 + (b_{100}^* - b_0^*)^2]^{-1/2}$.[12] The color coordinates of the UV included (100%) and excluded (0%) conditions are shown respectively with the subscripts 100 and 0 in the equation.

Analysis of chemical composition

As previously described, one specimen (1 mm × 12 mm × 12 mm) for each sintering group was produced. Silicon-carbide papers with 400, 600, 800, 1200, 1600, and 2000-grit (Struers, Cleveland, United States) were used for polishing the specimens. The chemical composition (wt %) of one specimen from each sintering group was defined using a wavelength dispersive X-ray fluorescence (WD-XRF; PANalytical AXIOS Advanced, Malvern, United Kingdom) spectrometer operated at 60 kV and 50 mA.

Grain size measurement

After WD-XRF analysis, the same specimens were thermally etched (30 min at 1450°C; Programat S1 Ivoclar, Schaan, Liechtenstein) to reveal the grain boundaries. The microstructures of the same specimens were inspected using field emission scanning electron microscopy (FE-SEM; Zeiss Gemını 500, Oberkochen, Germany) at magnifications of 20000× and 30000× after each specimen was coated with gold/palladium. The average GS of each specimen was determined (at least 200 grains at ten different locations) on FE-SEM micrographs using software (Image J, National Institutes of Health) according to the linear intercept method.[20]

Shapiro–Wilk test is used for testing the normality of optical data. The TP values did not show normal distribution according to sintering procedures only. The

sintering variable was analyzed with a Mann–Whitney U-test, while the thickness factor was analyzed with an independent samples *t*-test for the TP. A two-way ANOVA was used analysis of OP, where the two factors were the sintering procedure and thickness. The homogeneity of variances was assessed using Levene's test. Independent sample tests were used for *post hoc* comparisons. The ΔE_{ab^*}-FL did not show normal distribution according to the thickness factor. ΔE_{ab^*}-FL data were analyzed using an independent samples *t*-test for the sintering procedure and a Mann–Whitney U-test for the thickness factor. All statistical analyses ($\alpha = 0.05$) were carried out using a software program (SPSS, Version 20, Chicago, IL, USA).

RESULTS

Descriptive statistics of TP, OP, and ΔE_{ab^*}-FL values are presented in Tables 3-5, respectively. The effect of the sintering procedure on the TP was not statistically significant ($P = 0.433$) without considering the thickness. The effect of the thickness on the TP was statistically significant ($P < 0.001$). Reducing the thickness of a specimen from 1 mm to 0.5 mm caused a statistically significant increase in all TP values [Figure 1].

OP values were statistically significantly affected by thickness and sintering procedure [Tables 4 and 6]. Speed sintered specimens showed higher OP values than standard sintered specimens, while 1-mm-thick specimens showed higher OP values than 0.5-mm-thick specimens [Figure 2].

ΔE_{ab^*}-FL values were statistically significantly affected by the sintering procedure but not by thickness [Figure 3]. Speed-sintered specimens showed a higher ΔE_{ab^*}-FL value than standard-sintered specimens [Table 5].

The FE-SEM micrographs are presented in Figure 4. The grain boundaries were obviously observable in standard and speed sintering. The pores and voids were not observed at the grain boundaries in all specimens. The mean GS and chemical composition (wt%) of specimens are shown in Table 7.

DISCUSSION

The first null hypothesis was rejected for the TP because the TPs of all specimens with 0.5-mm thickness were significantly higher than those of 1 mm specimens [Table 3]. The present study found an inverse relationship between the TP and thickness. This result is compatible with many studies investigating the optical properties of 3Y-TZP.[2,10,11] Perceptibility and acceptability thresholds of TP were 1.33 and 4.46 CIELab units, respectively.[19] In the present

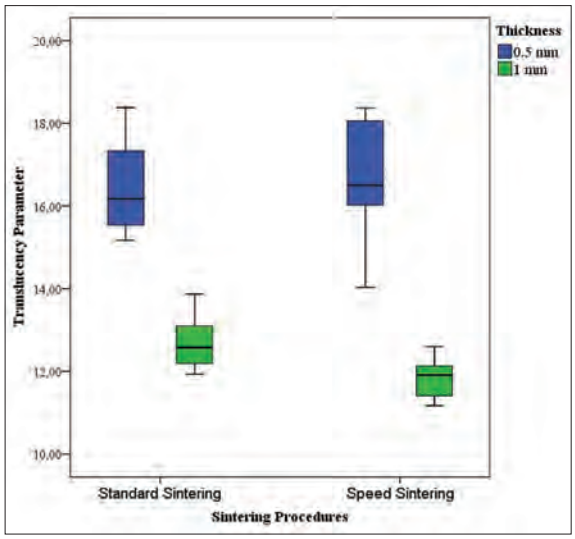

Figure 1: Boxplot of translucency values

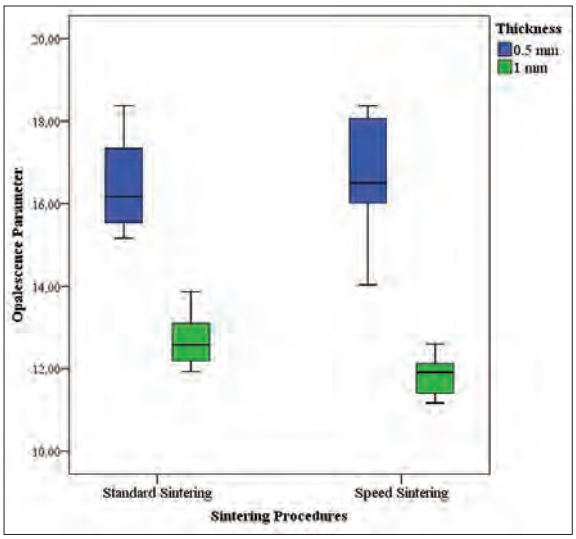

Figure 2: Boxplot of opalescence parameter values

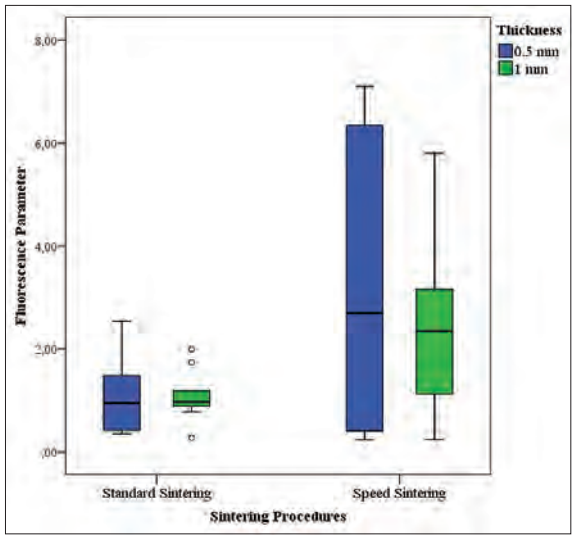

Figure 3: Boxplot of fluorescence parameter values

Table 3: The translucency values: Mean±standard deviation (median, interquartile range) (minimum-maximum)

Sintering procedure	Thickness			
	0.5 mm	1 mm	Total	*P*
ST	16.46±1.09$^{A, a}$ (16.18-1.98) (15.17-18.38)	12.7±0.62$^{B, a}$ (12.58-0.99) (11.93-13.87)	14.58±2.11^{a} (14.52-3.68) (11.93-18.38)	0.445*
SP	16.61±1.35$^{A, a}$ (16.5-2.24) (14.03-18.37)	11.84±0.45$^{B, b}$ (11.91-0.77) (11.17-12.60)	14.22±2.63$^{a,¥}$ (13.32-4.65) (11.17-18.37)	
Total	16.53±1.2^{A} (16.33-2.18) (14.03-18.38)	12.27±0.69^{B} (12.16-0.73) (11.17-13.87)		
TP change (CIE laboratory unit)	4.26			
P	<0.001			

*Significance value for Mann-Whitney *U*-test, ¥Groups that deviate from the normal distribution. Within the same thickness group, different superscript uppercase letters in each row and different superscript lowercase letters in each column denote significant differences. TP: Translucency, CIE: The Commission Internationale de l'Eclairage, ST: Standard, SP: Speed

Table 4: The opalescence parameter values: Mean±standard deviation

Sintering procedure	Thickness			
	0.5 mm	1 mm	Total	*P*
ST	3.2±0.17$^{A, a}$	3.64±0.13$^{B, a}$	3.42±0.27^{a}	0.00003
SP	3.8±0.35$^{A, b}$	3.73±0.19$^{A, a}$	3.76±0.28^{b}	
Total	3.5±0.41^{A}	3.69±0.17^{B}		
P	0.014			

Within the same thickness group, different superscript uppercase letters in each row and different superscript lowercase letters in each column denote significant differences. ST: Standard, SP: Speed

study, the effect of the thickness (4.26 units) on the TP is clinically perceptible by human observers while it is within acceptable limits [Table 3].

MZ restorations replace the enamel layer of the natural tooth structure.[21] Due to this, the TP level of MZ restorations should be similar to the natural tooth's enamel.[21] Yu *et al*. reported the TP of 1-mm thick enamel was 18.7.[22] In the present study, the TP of all specimens with 0.5-mm thickness was in the range of 14.03–18.38 and was significantly higher than those of 1 mm specimens [Table 3]. According to the results, it can be considered that the TP of 0.5-mm-thick specimens was more similar to the natural tooth's enamel than 1-mm-thick specimens.

The second null hypothesis was accepted for the TP because the effect of the sintering procedure on the TP of MZ was not statistically significant ($P = 0.445$) without considering the thickness [Table 3]. This result is consistent with some previous studies,[6-8] but not others.[4,5,9] The shorter (speed and high speed) sintering procedures were defined with changes in heating rate, final temperature, dwell time at the final temperature, and cooling rate.[13] It has been reported that the increase of at least 70°C in the final sintering temperature[23] or a cooling rate of at least 45°C/min[24] causes a statistically significant increase in the TP, but the heating rate[25] did not. A significant increase in the TP values was shown when the final temperature of at least 100°C and dwell time of at least 60 min were increased together.[26] In the present study, the speed sintering

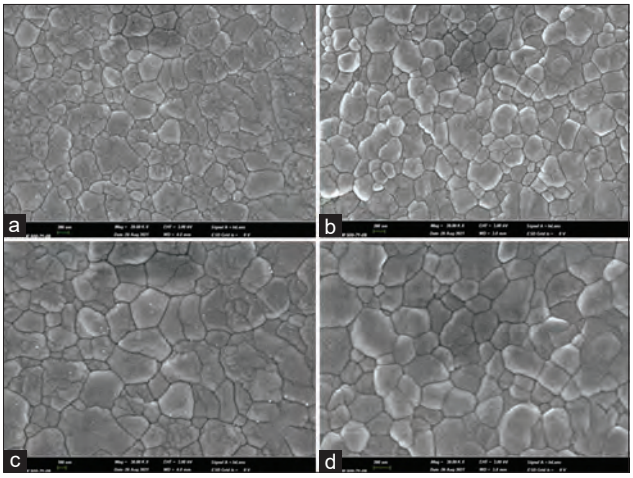

Figure 4: FE-SEM micrographs of standard and speed sintered specimens; (a and c) Indicate standard sintered specimens, and (b and d) indicate speed sintered specimens. Images (a and b) were obtained at magnification of ×20000; (c and d) were ×30000

procedure had a 15°C higher final temperature, 35°C/min higher cooling rate, and a 90-min shorter sintering time than the standard [Table 2]. The final temperature and cooling rate differences between the two sintering procedures in the present study were lower than the values reported in previous studies.[23,24] The shortening of the dwell time may have prevented the statistical difference. This result supports that dwell time significantly affects the TP.

The TP values of the standard sintered specimens were significantly higher ($P = 0.002344$) than the speed specimens within the 1 mm group only [Table 3]. This result is in agreement with most of the studies that compared standard and speed sintering procedures of 3Y-TZP specimens.[4,6,9] However, this TP difference between the sintering procedures was lower than 1.33 CIELab Units[19] in the present study and the reported studies.[4,6,9] Therefore, the effect of the sintering procedure on the TP cannot be clinically perceived by the human eye.

It has been shown that the average GS of 3Y-TZP specimens varies between 0.2 and 0.8 μm.[27] The mean GS calculated in the present study [Table 7] was consistent with

Table 5: The fluorescence parameter values: Mean±standard deviation (median, interquartile range) (minimum-maximum)

Sintering procedure	Thickness			
	0.5 mm	1 mm	Total	*P*
ST	1.07±0.74^{A,a} (0.95-1.18) (0.35-2.54)	1.09±0.49^{A,a} (0.97-0.47) (0.27-1.99)	1.1±0.61^{a} (0.97-0.87) (0.27-2.54)	0.0026
SP	3.14±2.72^{A,b} (2.69-5.98) (0.23-7.1)	2.49±1.61^{A,b} (2.35-2.26) (0.23-5.80)	2.81±2.28^{b} (2.35-3.1) (0.23-7.1)	
Total	2.11±2.22$^{A,¥}$ (1.2-2.65) (0.23-7.1)	1.79±1.36$^{A,¥}$ (1.17-1.52) (0.23-5.8)		
P	0.829*			

*Significance value for Mann-Whitney *U*-test, ¥Groups that deviate from the normal distribution. Within the same thickness group, different superscript uppercase letters in each row and different superscript lowercase letters in each column denote significant differences. ST: Standard, SP: Speed

Table 6: The outcome of two-way analysis of variance for opalescence parameter values

Source	SS	df	MS	*F*	*P*
Corrected model	2.161	3	0.720	14.128	0.000003
Intercept	516.170	1	516.170	10121.705	0.0000000
Sintering	1.159	1	1.159	22.735	0.00003
Thickness	0.344	1	0.344	6.748	0.014
Sintering × thickness	0.658	1	0.658	12.901	0.000973
Error	1.836	36	0.51		
Total	520.168	40			
Corrected total	3.997	39			

df: Degrees of freedom, SS: Sum of squares, MS: Mean square

Table 7: Chemical analysis (weight %) and mean grain size of the different sintered specimens

Sintering procedure	Oxide percentage by weight (weight %)				Grain size (μm)
	ZrO_2	Y_2O_3	HfO_2	Al_2O_3	
ST	90.82	7.33	1.70	0.15	0.306±0.142
SP	90.96	7.04	1.76	0.24	0.29±0.119

ST: Standard, SP: Speed

the previous studies.[5,27] Considering the study including 3Y-TZP, speed sintering procedures usually had smaller GS than standard sintering procedures[5,8,9] with the clinically imperceptible decrease in TP values.[8,9] These results are also consistent with the present study. The reduction in GS of the speed procedure can be explained by decreased Y_2O_3[13] and increased Al_2O_3[28] concentration [Table 7] in the present study.

The first and second null hypotheses were rejected for the OP because the main effect of the thickness and sintering procedure on the OP was statistically significant [Table 6]. The significant increase in OP values as the thickness increases is consistent with some previous studies.[29,30] Speed sintering group had a significantly higher ($P = 0.000125$) OP value than the standard sintering group in the 0.5 mm thickness [Table 4]. However, the effect of sintering on the OP was not statistically significant in the 1 mm thickness ($P = 0.265$). These results support that the main effect of sintering originates in the 0.5 mm group.

The OP values in the present study were weaker than the enamel-dentin complex (4.8) and the enamel layer of the natural tooth (7.4).[31] The weakest opalescence in the present study may be explained by the small[15] GS [Table 7]. Considering the study including 3Y-TZP, the OP values of standard sintering group were lower than in some previous studies.[8,14,25] High OP values in the previous studies[8,14,25] may be related to an increased amount of oxide materials such as ZrO_2, Y_2O_3,[3,32] SnO_2, V_2O_5,[32] or usage of zirconia blanks with a high chromatic shade.[3]

The first null hypothesis was accepted for ΔE^*_{ab}-FL because the thickness did not cause a significant change in the ΔE^*_{ab}-FL values. The mean ΔE^*_{ab}-FL value of the speed sintered group was greater than that of the standard sintered group with or without considering the thickness [Table 5]. Therefore, the second null hypothesis was rejected for ΔE^*_{ab}-FL. The increase in the Al_2O_3 percentage [Table 7] may explain the statistical difference.

The dentin layer of human teeth has greater fluorescence than the enamel layer, and most of the fluorescence of human teeth arises from the dentin.[33] Lee *et al.* reported that ΔE^*_{ab}-FL value of human dentin was 0.73 ± 0.04.[34] ΔE^*_{ab}-FL values of the standard sintered group in the present study are closer to human dentin than the speed sintered group. Clinicians should consider that the speed sintering procedure may increase the fluorescence of MZ. Therefore, standard sintering may be beneficial in terms of achieving an esthetic result much similar to natural teeth.

The use of nonparametric tests for the analysis of TP and ΔE^*_{ab}-FL values is a main limitation of the present study. The authors of the present study think that if there were a different thickness group (between 0.5 mm and 1 mm) for the TP and a different sintering group for ΔE^*_{ab}-FL, all values would show normal distribution. Additional limitations of the present study include that only one brand of zirconia with one shade and Y_2O_3 ratio was studied. The results may not be suitable for other commercial zirconia blocks with different shades, Y_2O_3 ratios, and manufacturers. In addition, chewing forces,

different surface treatments, and the underlying tooth, and the cement's color could be simulated in further studies. Therefore, future studies, including high-speed sintering, at least three thickness groups, and multi-materials with different Y_2O_3 ratios, would be beneficial to clarify the effects of the sintering procedure on the optical properties (especially fluorescence) of MZ. Further research is advised to determine the optimal sintering procedure that achieves the tooth-like fluorescence property without deteriorating the TP and opalescence properties of MZ. It is a noteworthy issue that the result of the present study requires supporting clinical investigations before final clinical proposals.

CONCLUSIONS

Within the limitations of the present study, the following conclusions were drawn:

- The effect of the sintering procedure on TP and OP of MZ was not perceived by the naked eye
- The speed sintering procedure may increase ΔE_{*ab}-FL of MZ to higher values than natural teeth when compared with standard sintering
- The speed sintering may cause minor changes in the chemical composition and GS of MZ.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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Research

Evaluation of dimensional stability, compressive resistance, and detail reproduction of thermoplastic resin ([BD]IMPRESS), elastomeric and composite bite registration material: An *in vitro* study

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Abstract

Aim: The fabrication of an accurate prosthesis depends mainly on precise recording of the maxillo—mandibular relationship of the patient and transferring it to the articulator. BDIMPRESS is a new thermoplastic material that has been proposed as a potential material to be used as an inter-occlusal registration, but there has been no literature evidence regarding its application as a bite registration. The main purpose of this study is to evaluate and compare the dimensional stability, detail reproduction, and compressive resistance of new interocclusal recording material with other two commonly used materials.

Settings and Design: *In Vitro* Comparative study.

Materials and Methods: The study was conducted according to ADA Specification standards of testing for dimensional stability, detail reproduction and compressive resistance. Specimens were prepared for three different materials (Thermoplastic resin, Polyvinyl siloxane, and Bis- acrylic) with 12 samples each.

Statistical Analysis Used: One way ANOVA was done for statistical analysis.

Results: Polyvinyl siloxane material was dimensionally stable (mean at 1 hr: 24.928 mm; 24 hrs: 24.919 mm & 48 hrs: 24.912 mm) followed by Bis- acrylic material (mean at 1 hr: 24.851 mm; 24 hrs: 24.825 mm & 48 hrs: 24.815 mm). On one way ANOVA, strong significance was observed between groups ($P = 0.00$). Thermoplastic resin showed higher amount of detail reproduction with 10 (out of 12 samples) samples showing satisfactory results. While bis- acrylic material showed the least compressive resistance (Strain %: 0.484%; Displacement-0.0990mm). One-way ANOVA showed presence of significance between the groups ($P = 0.024$).

Conclusion: Polyvinyl siloxane showed superior dimensional stability, thermoplastic resin showed better detail reproduction and bis- acrylic showed high resistance to compression over other materials.

Keywords: Compressive resin, dimensional stability, interocclusal recording material, thermoplastic resin

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Submitted: 24-Mar-2022, **Revised:** 15-May-2022, **Accepted:** 08-Jul-2022, **Published:** ***

Access this article online	
Quick Response Code:	**Website:** www.j-ips.org
	DOI: 10.4103/jips.jips_146_22

How to cite this article: Koppolu SK, Manoharan PS, Rajkumar E, Ezhumalai G. Evaluation of dimensional stability, compressive resistance, and detail reproduction of thermoplastic resin ([BD]IMPRESS), elastomeric and composite bite registration material: An *in vitro* study. J Indian Prosthodont Soc 2023;23:65-70.

INTRODUCTION

The fabrication of an accurate prosthesis depends mainly on precise recording of the maxillomandibular relationship of the patient and transferring it to the articulator. There are high chances of variations occurring during vertical, anteroposterior, and mediolateral positions. To achieve an accurate relation, a medium is essential to articulate the casts in the correct maxilla-mandibular relationship and in programming the articulator. Hence, interocclusal registration materials are essential.[1,2] The interocclusal records are like impression materials that are specially modified to record the occlusal relationship of the human oral cavity and transferring it to the articulator. Interocclusal registration material is mainly indicated in certain conditions such as completely edentulous, worn-out conditions, full mouth rehabilitations, and distal extension-partially edentulous where reference stops are not present. Any inaccuracy in interocclusal records leads to occlusal errors in the final prosthesis.[3,4]

Bite registration is one of the essential steps in obtaining a proper occlusal relation and as well promotes the health of temporomandibular joint and other supporting structures. The main objective of these records is to reproduce the details (i.e., cuspal morphology), withstanding the compressive forces, maintain dimensional stability (during the time of transport), have sufficient wettability and have easy handling properties. Initially, waxes were used; later, zinc oxide-eugenol pastes and elastomeric materials (polyvinyl siloxane [PVS], polyether) were used extensively. Usage of bis-acrylic materials has also been applicable for recording the bite.[5-7]

There are plenty of materials available in the market, and a clinician should be able to choose the right material, for which one should be aware of the composition, techniques, properties, and factors affecting the interocclusal recording materials to produce predictable results. In the past decade, multiple studies were done on properties such as accuracy, viscosity, thermal conductivity, setting characteristics, detail reproduction, elasticity, compressive resistance, and dimensional stability of different interocclusal recording materials.[8-10] The choice of other two materials (Ivoclar CAD-Bite and DMG Luxabite) used for the study was made referring to the previous studies.

With new materials, the accuracy in achieving good results has been increasing. A new thermoplastic material ([BD]IMPRESS) has been proposed to be used as custom impression, custom trays, functional border molding, and as an interocclusal registration. However, there has been no literature evidence regarding its application as a bite registration.[11]

This study was done to evaluate the compressive resistance, dimensional stability, and detail reproduction of three different interocclusal recording materials such as bis-acrylic (DMG Luxabite), PVS (Ivoclar CAD-Bite), and thermoplastic resin ([BD] IMPRESS).

MATERIALS AND METHODS

The equipment and materials used for the study were described in Tables 1 and 2. This study was approved by The Institutional Review Board (IRB reference number-IGIDSIEC2021NRP03PGSKPRI.

Fabrication of die for dimensional stability and detail reproduction

A master die was made according to the Revised American Dental Association specification number19 for nonaqueous, elastomeric dental impression materials.[12] It consists of three stainless steel parts. The first part is described as a ruled block with three vertical lines differing in widths (50, 20, and 75 μm, respectively) and two horizontal lines with 75 μm width. The distance between the intersection of lines (vertical and horizontal) is 25 mm, which is used as a criterion for checking the dimensional stability of the samples. The vertical lines with three widths are essential for assessing the detail reproduction of the samples. The ruled block has a base with 31-mm height, 38-mm diameter and raised the part has 3-mm height and 30-mm diameter. The second part was a hollow impression material mold for the injection of material which is 6 mm in height and 30 mm of inner diameter. When the hollow impression material mold was snuggly fit over the ruled block, it provides space of 3 mm for the material to be injected. This gives an accurate thickness of 3 mm for all the samples fabricated. The final part was the riser which was used to cover the mold after injecting the material into the mold. It was of 3 mm in height and 29.97 mm in diameter.

Table 1: Equipment used

Equipment name	Company name	Testing
MCR 702 with DMA Image Processing Software	AntonPaar, Austria	Compressive resistance Dimensional stability; Detail reproduction

Table 2: Materials used

Composition	Brand name	Manufacturer
Thermoplastic resin	[BD]IMPRESS	Merz dental, Germany
Poly-vinyl siloxane	VIRTUAL CAD-BITE	IVOCALAR, Liechtenstein
Bis-acrylic	LUXABITE	DMG, Germany

Fabrication of die for compressive resistance

A master die was done using a split stainless steel hollow mold. One hollow mold, which has an inner diameter of 12.5 mm and a height of 20 mm, was retained in the second hollow mold, which has a 5° tapering. The second mold has an outer diameter of 35 mm, inner diameter at the base is 22 mm, and inner diameter at the apex is 26 mm. It has a height of 16 mm.

Specimen fabrication

A proper application of lubricating agent was done on the inner surfaces of the molds for easy retrievability of the material once it is set. After the application of adequate lubricating agent over the molds, the impression material mold was snugly fitted into the other split mold. The material was mixed according to the manufacturer's instructions and injected into the impression material mold. After the placement of the material, riser was placed over it for obtaining the proper shape and size of the sample. Polyvinyl silicone material (Ivoclar Vivadent CAD-Bite) was supplied in auto-mixing cartridges of 1:1 ratio, which were dispensed using dispensing gun (1:1/1:2) with the attachment of mixing tips to the cartridge. The tips were placed into the mold, and the material was injected into the impression material mold and covered with riser over it. Bis-acrylic material (DMG Luxabite) was supplied in auto-mixing cartridges of 1:10 ratio and dispensed using a 1:10 dispensing gun with the attachment of mixing tips to the cartridge. The same manipulative method was applied for bis-acrylic material using the cartridge, dispensing gun, and mixing tip. Whereas thermoplastic material (^{BD}IMPRESS) was supplied as small white color beads, which become soft and moldable when placed in boiling water. The adequate number of beads was placed in boiling water, and once it transformed into a clear moldable state, it was taken out with a clear instrument and manipulated with fingers by applying Vaseline to avoid sticking of the material to the fingers. After manipulation, it was placed into the mold, and riser was compressed over the material to make the sample uniform in dimensions. The samples were allowed to set for 3–5 min before retrieving them from the mold. The assembly was then transferred to water bath with 32°C. For each material, 12 samples were made for compression analysis, and another 12 samples were made for dimensional stability measurements using their respective molds.

Testing of the samples for compressive resistance

The testing of samples for compressive resistance involves the application of a series of loads and checking the compressive strain (%). Initially, the length of each sample was measured using a digital Vernier caliper. The testing was done using a Modular Compact Rheometer (MCR) 702 with a linear drive for Dynamic Mechanical Analysis (DMA), AntonPaar, Austria. The fabricated samples were placed in water bath at 32°C until it sets. After setting, the sample was removed from the mold and placed between two 25 mm parallel plates for application of load [Figure 1].

The test was conducted under three intervals and two loads. Initially, a constant load of 100 g/cm^2 (9.8kPa) was applied for 60 s. The first reading (A) of linear compressive strain (%) was recorded after the 30s of initiation of the load. After the 60s, the load was gradually increased to 1000 g/cm^2 (98kPa) in 10 s. The 30s after initiation of second load, second reading (B) was recorded. The compressive strain (%) was calculated by subtracting readings A and B for each sample.

Testing of the specimens for dimensional stability

The fabricated samples were scanned using a scanner EPSON at 2400dpi resolution. The scanned image was analyzed using ImageJ image processing software. The distance between the intersection of vertical and horizontal lines was assessed after 1, 24, and 48 h of sample fabrication. All the three readings were measured to the nearest 0.005 mm.

Testing of the specimens for detail reproduction

Detail reproduction was assessed using the same sample which was fabricated for measuring dimensional change. The reproduction of three lines widths for the full length of 25 mm was assessed using ImageJ image processing software [Figure 2].

RESULTS

The data obtained after testing the samples for compressive resistance, dimensional stability, and detail

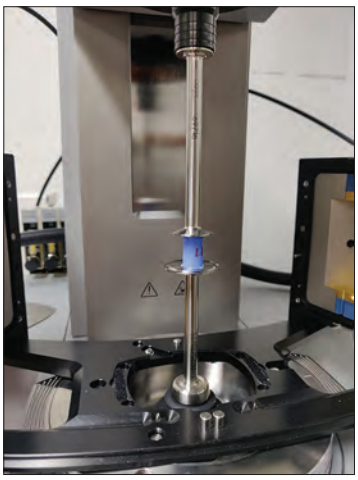

Figure 1: Sample compressed between two parallel plates in MCR 702 with DMA. MCR: Modular Compact Rheometer, DMA: Dynamic mechanical analysis

reproduction were statistically analyzed using one-way analysis of variance (ANOVA). The clinical significance among the groups was also mentioned. Mean, standard deviation, and 95% confidence with upper and lower borders for all the groups were discussed in descriptive tables.

Compression resistance analysis

DMG Luxabite showed better resistance to compression (compressive stain % and displacement [mm]), followed by [BD]IMPRESS, while Ivoclar Virtual CAD Bite showed high values which explain that they had less resistance to compression [Tables 3 and 4].

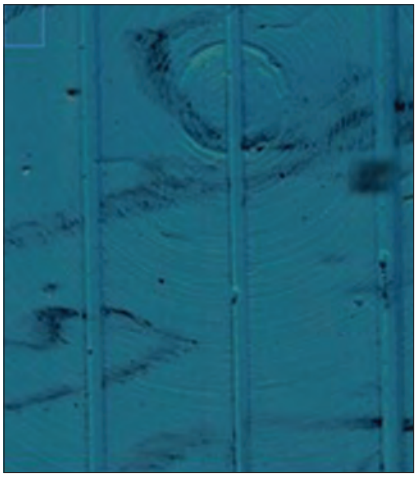

Figure 2: Evaluation of detail reproduction for the samples

Table 3: Comparison of compressive strain (%) of three interocclusal materials using ANOVA

Material	*n*	Mean±SD
[BD]IMPRESS	12	0.602±0.32
Ivoclar Virtual CAD-Bite	12	0.796±0.226
DMG Luxabite	12	0.484±0.245
ANOVA		*F*=4.185; *P*<0.024 (S)

P<0.05 (S). S: Significant, SD: Standard deviation

Table 4: Comparison of displacement on compression (mm) between three interocclusal materials using ANOVA

Material	*n*	Mean (mm)±SD
[BD]IMPRESS	12	0.122±0.065
Ivoclar Virtual CAD-Bite	12	0.162±0.045
DMG Luxabite	12	0.099±0.049
ANOVA		*F*=4.185; *P*<0.024 (S)

P<0.05 (S). S: Significant, SD: Standard deviation

Dimensional stability

Ivoclar Virtual CAD Bite showed better dimensional stability at 1 h, 24 h, and 48 h, followed by DMG Luxabite, while Group I ([BD]IMPRESS) showed the least values of dimensional stability [Table 5].

Detail reproduction

Thermoplastic resin ([BD]IMPRESS) showed good amount of reproduction with 10 (out of 12 samples) samples showed satisfactory results, while Bis- Acrylic (DMG Luxa-Bite) showed least detail reproduction 6 (out of 12 samples) were satisfactory [Table 6].

DISCUSSION

The basic objectives for occlusal rehabilitation are optimum oral health, functional efficiency, oral comfort, and esthetics. The recording medium should be accurate and dimensionally stable to transfer the relationship of jaws to the casts on an articulator. Various methods of recording maxillomandibular relationships are graphic, functional, cephalometric, and direct interocclusal records. Direct interocclusal records are commonly used to record the maxillomandibular relationship of dentulous casts. The recording material, which is soft, initially occupies the spaces between teeth and hardens. The set material, along with the casts, are then transferred onto an articulator.[6,7]

The main purpose of this *in vitro* study was to compare the interocclusal recording materials (thermoplastic resin, poly vinyl siloxane, and bis-acrylic). Two materials (PVS and bis-acrylic) commonly used in the clinical scenario were compared with a new material (thermoplastic resin) which was claimed to have superior properties. The three materials were tested for compressive resistance, dimensional stability, and detail reproduction. The compressive resistance was measured in strain % and displacement (mm). Dimensional stability was assessed at three different time intervals (1 h, 24 h, and 48 h) by calculating the shrinkage of the line (length wise), which was reproduced on the sample. The measurements were assessed in millimeters. Whereas detail reproduction was evaluated by checking the reproducibility of the lines as satisfactory and unsatisfactory among the samples.

Table 5: Statistical analysis for dimensional stability length wise (mm) at different time intervals for three interocclusal materials using ANOVA

Material	*n*	1 h	24 h	48 h
[BD]IMPRESS	12	24.818±0.018	24.804±0.017	24.784±0.018
Ivoclar Virtual CAD-Bite	12	24.929±0.013	24.919±0.021	24.912±0.017
DMG Luxabite	12	24.851±0.031	24.826±0.037	24.815±0.030
ANOVA		*F*=76.335; *P*<0.001 (HS)	*F*=61.677; *P*<0.001 (HS)	*F*=90.277; *P*<0.001 (HS)

P<0.001 (HS). HS: Highly significant

Table 6: Descriptive table on detail reproduction among three interocclusal materials groups

Material	*n*	Satisfatory	Un-satisfactory
[BD]IMPRESS	12	10	2
Ivoclar Virtual CAD-Bite	12	9	3
DMG Luxabite	12	6	6

The samples were assessed using MCR 702 with DMA by AntonPaar for compressive resistance.[13,14] ImageJ is an Image processing software that was used in this study to evaluate dimensional stability and detail reproduction of the samples.[15,16]

A total of 36 samples were fabricated (12 samples per material) for evaluating compressive resistance. Another set of 36 samples was fabricated for evaluation of dimensional stability and detail reproduction. The sample size of 12 in each group was calculated using the sample size formula and by referring to similar study articles.[17,18] The statistical analysis used for the study are mean, standard deviation, one-way ANOVA, and Bonferroni correlation.

The null hypothesis of the study (there is no difference in the dimensional stability, compressive resistance, and detail reproduction between thermoplastic interocclusal registration material ([BD]IMPRESS) and elastomer (Ivoclar Virtual CAD-Bite) and composite (DMG Luxa-bite) bite registration materials) was rejected. Strong significant difference was present among the groups, which indicates the high power for the study. Bis-acrylic material (DMG Luxa bite) showed the least compressive resistance (Strain%−0.484%; Displacement −0.0990 mm), followed by thermoplastic resin ([BD]IMPRESS) (Strain % −0.60253%; Displacement −0.12275 mm). One-way ANOVA showed the presence of significance between the groups (P = 0.024), and Strong significance was observed between bis-acrylic and PVS material. On the other hand, PVS (Ivoclar Virtual CAD-Bite) material was dimensionally more stable with less shrinkage in relation to time (mean at 1 h: 24.928 mm; 24 h: 24.919 mm and 48 h: 24.912 mm), followed by Bis-acrylic (DMG Luxa-Bite) material (mean at 1 h: 24.851 mm; 24 h: 24.825 mmand48 h: 24.815 mm). Thermoplastic resin ([BD] IMPRESS) was the least dimensionally stable among the three materials. On one-way ANOVA, strong significance was observed between groups (P = 0.00), while Bonferroni (*post hoc*) test elaborated strong significance on the comparison of all the groups individually (P < 0.001). Significance was also observed within the groups at three different time intervals. On evaluation for detail reproduction, thermoplastic resin ([BD]IMPRESS) showed a good amount of reproduction with 10 (out of 12 samples) samples showed satisfactory results, while Bis-Acrylic (DMG Luxa-Bite) showed the least detail reproduction (6 out of 12 samples were satisfactory). All the values were statistically significant, but its clinical relevance should be evaluated in future studies.

Similar studies which were done evaluating compressive resistance and dimensional stability are: Nagrath *et al*. compared four interocclusal records for compressive resistance. He concluded that PVS (Virtual CAD-Bite) had greater resistance to compression with the least amount of distortion.[17] Prajapati *et al*.(2018) conducted an *in vitro* study to evaluate dimensional stability among PVS, bite registration wax, and zinc oxide-eugenol bite registration paste. PVS showed less linear change, followed by Zinc oxide eugenol paste and bite registration wax.[18] In 2020, Choudhary evaluated the compressive resistance of Zinc oxide eugenol paste, PVS, and Polyether. Samples were made of three different thicknesses (2 mm, 5 mm, and 10 mm). A constant load of 25 N was applied for 1 min and deformation was measured after 60 s of loading. Clinical significance was observed between the materials. There was a decrease in compressive resistance with an increase in thickness of the material. PVS showed greater resistance to compression compared with other materials.[19] In another study comparing PVS, bis- acrylic and alu-wax for their dimensional stability, it concluded that PVS and bis acrylic had better dimensional stability. It was concluded that PVS and bis-acrylic had better dimensional stability. There are many studies supporting that PVS had better compressive resistance, dimensional stability, and detail reproduction.[17,20-22]

The main strength of this study was the standardization followed for the fabrication of samples and the testing protocol used. The samples were assessed using superior machinery (MCR 702 AntonPaar and ImageJ software) for the evaluation of compressive resistance, dimensional stability, and detail reproduction. Some of the limitations of the study are there was no simulation of intra-oral temperature and saliva during the setting of the materials and no application of nonaxial loading. Hence, there is a need for further clinical trials to evaluate the time needed for setting and how much time is needed after maxillomandibular registration to the articulation of the casts without affecting the dimensional stability of the materials and also to evaluate the compressive resistance in nonaxial loading.[4]

CONCLUSION

Within the limitation of the study, the following conclusions may be drawn:

- Bis-acrylic interocclusal recording material showed high resistance to compression, whereas PVS had the least compressive resistance

- PVS interocclusal recording material is dimensionally more stable. Thermoplastic resin showed the least dimensional stability
- Thermoplastic resin interocclusal recording material showed better detail reproduction, whereas bis-acrylic showed poor detail reproduction.

Clinical implication

This thermoplastic resin can be used as one of the interocclusal recording materials. It has good advantages of precise detail reproduction and good compressive resistance. It can also be compared with other existing materials.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Research

Correlation between gerotranscendence and oral health-related quality of life among elderly population in Davanagere city: A cross-sectional survey

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Abstract

Aim: To assess the relationship between oral health related quality of life (OHRQoL) and gerotranscendence among elderly subjects in Davangere city.

Settings and Design: Field Setting and cross-sectional survey design.

Materials and Methods: Study involved a stratified sample of 400 elderly population aged 60 years and above. Data related to demographic details, systemic and oral health related factors, nutritional status, gerotranscendence level and geriatric oral health related quality of life of study participants was recorded using study proforma, Mini Nutritional Scale Assessment- Short form (MNA-SF) index, Gerotranscendence Scale Type 2 (GST2) questionnaire and GOHAI questionnaire respectively.

Statistical Analysis Used: Significance level was fixed at $P < 0.05$. Chi-square, Pearson's/Spearman's correlation and Multiple linear regression tests were used for analysis.

Results: Participants had good oral health related quality of life (mean GOHAI - 41.33±10.8) and moderate level of gerotranscendence (GST2- 19.5 ± 8.7). The gerotranscendence scores were significantly ($P<0.05$) negatively correlated with socioeconomic status (r = -0.19), education (r = -0.55), self-perceived oral health (r = -0.43), nutritional status (r = -0.64), GOHAI (r = -0.17), utilization of dental services (r = -0.26) and marital status (r = -0.39) and were significantly ($P < 0.05$) positively correlated with age (r = 0.77), systemic problems (r = 0.49), number of missing teeth (r = 0.57), self-perceived need for treatment (r = 0.24), and pan chewing (r = 0.62). Gerotranscendence was not a significant predictor of GOHAI (P = 0.43).

Conclusion: Gerotranscendence was negatively correlated with oral health related quality of life among elderly population in Davanagere city.

Keywords: Correlation, dentistry, geriatric, gerotranscendence, oral health-related quality of life

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Submitted: 15-Dec-2021 **Revised:** 09-Mar-2022 **Accepted:** 06-Jun-2022 **Published:** ***

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_282_22

How to cite this article: Das A, Yavagal PC, Nandeeshwar DB. Correlation between gerotranscendence and oral health-related quality of life among elderly population in Davanagere city: A cross-sectional survey. J Indian Prosthodont Soc 2023;23:71-7.

INTRODUCTION

The aging of the population has awakened the interest of researchers toward health of the elderly. India currently has over 100 million elderly people, which is predicted to rise to 323 million by 2050, accounting for 20% of the entire population.[1] The rate of growth of elderly population of India is much faster than the total population. This rapidly growing population comes with a plethora of general and oral health problems, escalating issues of multi-morbidity and malnutrition. Oral health problems continue to be a major public health issue because they have economic, social, and psychological ramifications impacting quality of life. Oral health is an essential component of general health and well-being as recognized by the Global Oral Health Program of WHO.[2] Geriatric oral health-related quality of life provides critical information when assessing their treatment needs, making clinical decisions, and evaluating treatment services and programs. Hence, it has emerged as an important indicator of their oral health. Understanding the implications of the influence of various factors on oral health-related quality of life (OHRQoL) becomes important to provide quality care to elderly. Several factors such as demographic, socio-economic, self-perceived oral health, prosthetic status, systemic health, nutritional level, have been linked with geriatric OHRQoL.[3,4] Recently, a study done by Mihara *et al*., have identified Gerotranscendence as a major influential factor which can have an impact on geriatric OHRQoL.[5] Psychological dimensions in geriatric health care are a challenging area of research. In 1989, Tornstam proposed the gerotranscendence theory, which states that "with ageing, people slowly develop a transition in perspective, from a materialistic and pragmatic view to a cosmic and transcendent one."[6] According to Erikson's psychoanalytic theory, there is a ninth stage of aging applicable to elderly aged 80 years and above. The despair related with the eighth stage is amplified by the experience of one's deteriorating physical and mental health, resulting in lowered self-esteem and confidence. Gerotranscendence facilitates adaptation and recovery from the despair felt in the eighth stage. Perhaps elderly people with high gerotranscendence levels might be well adapted and contended with their oral health conditions leading to increased self-reported OHRQoL in spite of poor oral health. This might lead to a potential mismatch between clinical indicators and subjective indicators of geriatric oral health. In this context, gerotranscendence may be considered a potential confounding factor when trying to identify the associations between OHRQoL and oral health status indicators. Hence, it might be useful to explore the correlation between geriatric OHRQoL and gerotranscendence. A cross-sectional study was planned to assess the correlation between gerotranscendence and OHRQoL among elderly population aged 60 years above in Davangere city, India.

METHODOLOGY

The study proposal was approved by Institutional Ethical Review Board of Bapuji Dental College and Hospital, Davanagere. (Ref No BDC/467/2018-19). The sample size was calculated using the formula, $n = N z/[(N-1) E^2 + z]$, where, n = sample size, N = population size (Total population of elderly people aged 60 years and above in Davangere = 14,622), Z =1.96, E = Margin of error (5%). The estimated sample size was 375, which was approximated to 400. A multistage stratified random sampling technique was employed to select the study subjects. Elderly people ≥ 60 years old, residing in their home or in old age homes who were present at the site during the study were included in the study whereas, elderly people who had mental disorders affecting communication and memory functions like Alzheimer's disease were not included. After informing the participants about the study objectives and procedures through the participant information form, voluntary informed consent was sought by them.

Procedure for data collection

Survey was conducted in the field setting. Data was collected using self-designed structured pro forma containing both open- and closed-ended questions. Provision was created in the pro forma to collect details regarding socio-demographic characteristics, medical conditions and medications, habits, utilization of dental services, self-perceived oral health and to record Mini-Nutritional Assessment – Short Form index, Gerotranscendence Scale Type 2 questionnaire, Geriatric Oral Health Assessment Index (GOHAI) and clinical oral health status (number of missing teeth and prosthetic status). Oral examination was done by the investigator using CPI probe and mouth mirror. Type III (Inspection) examination was followed to record clinical oral findings. The participants were made to sit upright on a chair under natural light. Body mass index was measured using measuring tape and weight was measured using a calibrated digital weighing scale. A trained assistant was calibrated to record Mini Nutrition Scale-SF, GOHAI, and Gerotranscendence index in local (Kannada) language who had no other role in the survey. Investigator and assistant were trained and calibrated by an expert to administer Mini Nutritional Scale Assessment – Short-Form (MNA-SF), Gerotranscendence, and GOHAI questionnaires in the Department of Public Health Dentistry. Interexaminer reliability (Kappa score) scores were 0.83, 0.85, and 0.80 and intraexaminer reliability scores were k = 0.79, 0.80, 0.82

for MNA-SF, gerotranscendence, and GOHAI respectively, which reflected good inter- and intra-examiner reliability.

Assessment of nutritional status

Nutritional status was recorded using Mini Nutritional Assessment – Short-Form index. It is a six-item questionnaire, which is a widely used and validated questionnaire to assess the nutritional status of elderly population in surveys.[7] It included questions regarding food intake, weight loss, mobility, psychological stress, neuropsychological problems, and body mass index. Specific scores were assigned to responses and total score range from 0 to 14. Scores were interpreted as follows: 0–7: malnourished; 8–11: at risk of malnutrition; and 12–14: normal nutritional status.

Assessment of gerotranscendence level

The degree of gerotranscendence was recorded using Gerotranscendence Scale Type 2 developed by Tornstam in 1995. It is a validated 10 items questionnaire which includes the Cosmic Dimension (five items), the Coherence Dimension (two items), and the Solitude Dimension (three items). The responses were on a 4-point Likert scale: strongly disagree = 1, disagree = 2, agree = 3, and strongly agree = 4. Each response was given a score and gerotranscendence level was calculated by summing up the scores of all the items. The total gerotranscendence score ranged from a minimum of 10 to maximum of 40.[8] The gerotranscendence scale type (GST2) questionnaire was not validated for Indian population; therefore, it was validated by five experts.

Validity of gerotranscendence scale type 2 questionnaire

Gerotranscendence using GST2 questionnaire was tested for content validity by five experts (two psychologists, one public health dentist, one prosthodontist, and one elderly person). Questionnaire was assessed for relevance, simplicity, clarity, and ambiguity based on the criteria established by Yaghmale.[9] The content validity index (CVI) for total scale was computed. A satisfactory level of agreement was found (CVI for: relevance = 0.9, simplicity = 0.8, clarity = 0.8, and ambiguity = 0.8) among the experts. As all the components had a CVI score more than 0.75 and hence validity was established.

Assessment of oral health-related quality of life

OHRQoL was recorded using well-established and validated GOHAI. It consists of 12 items which assess the dimensions of physical functions (eating, speaking, and swallowing), psychosocial functions (worry or concern about oral health, dissatisfaction with appearance, self-consciousness about oral health, avoidance of social contact because of oral problems), and pain or discomfort (use of medication to relieve pain, oral discomfort) for the past 3 months. Responses were rated on a five-point Likert scale interpreted as: Always = 1, Often = 2, Sometimes = 3, Seldom = 4, and Never = 5. The total GOHAI score was calculated by summing of all the scores of questions and the final GOHAI score was in range from 12 to 60.[10] The validity of Hindi (national language) version of GOHAI has already been tested in previous studies but it was not translated into Kannada language. Hence, it was translated into local language and the language validity was checked by back translation method.

Statistical analyses

IBM SPSS Statistics for Windows, version 20 (IBM Corp., Armonk, N.Y., USA) was used for statistical analysis. The significant level was fixed at $P < 0.05$. Descriptive statistics were generated in terms of frequencies or percentages. Data were dichotomized for systemic problems, smoking status, alcohol consumption, pan chewing habit, dental visit in the past 1-year, and self-perceived need for treatment. Data were assessed on ordinal scale for nutritional status and self-perceived oral health. Age, geriatric OHRQoL, nutritional status, gerotranscendence, and missing teeth were on a continuous scale. Chi-square test was used to compare categorical variables. Pearson's and Spearman's correlation tests were used to assess correlation between the test variables. Multiple linear regression analysis was performed to assess predictor variables related to OHRQoL.

RESULTS

Majority of the subjects were male (72.5%), aged between 60 and 75 years (67%). Table 1 depicts demographic and clinical profile of study population. Mean MNF score was 9.99 ± 3.20 suggesting risk of malnutrition among participants. The mean number of missing teeth was 12.26 ± 12.1 with majority being partially edentulous (75.9%). The average gerotranscendence score was 19.5 ± 8.7 which falls on the mid-scale of gerotranscendence reflecting that the gerotranscendence level of participants was neither low nor high [Figure 1]. Gerotranscendence scores were significantly high among unemployed, pensioned, and literate. Participants who had systemic problems, who were on medications, smokers, alcoholics, nonpan chewers, completely edentulous, had no prosthesis, had not visited a dentist in the past 1 year and perceived their oral health as poor had higher gerotranscendence scores compared to others [Table 2]. The GOHAI scores were significantly ($P < 0.05$) negatively correlated with socioeconomic status ($r = –0.26$), systemic problems (r

Table 1: Demographic and clinical profile of study participants

Demographic/clinical variables	*n* (%)	χ^2/*P*
Gender		
Male	302 (72.5)	0.024*
Female	98 (27.5)	
Age		
60–75	268 (67)	0.021*
76–90	132 (33)	
Marital status		
Married	367 (91.75)	0.796
Unmarried/widowed	33 (8.25)	
Occupation		
Unemployed	320 (80)	0.002*
Employed	80 (20)	
SES		
Middle class	195 (48.7)	0.000*
Lower class	205 (51.2)	
Source of income		
Pension	80 (20)	0.586
Depend on child	281 (70.2)	
Other	39 (9.7)	
Living with		
Spouse	272 (70.5)	0.027*
Child	80 (20)	
Alone	32 (8)	
Old age home	16 (4)	
Education		
Illiterate	137 (34.2)	0.005*
Primary school	194 (48.5)	
Secondary school	31 (7.7)	
Graduation and above	38 (9.5)	
Nutritional status		
Malnourished	137 (34.2)	0.686
At risk of malnutrition	97 (24.2)	
Normal	166 (41.5)	
Mean±SD	9.99±3.20	
Median (range)	11.0 (4–14)	
Medical problem		
Yes	305 (76.2)	0.000*
No	95 (23.7)	
Under medication		
Yes	279 (69.5)	0.000*
No	121 (30.5)	
Smoking		
Yes	245 (61)	0.000*
No	155 (39)	
Alcohol		
Yes	304 (75.5)	0.000*
No	96 (24.2)	
Pan		
Yes	234 (59)	0.065
No	166 (41)	
Missing teeth		
Completely edentulous	100 (24.5)	0.007*
Partially edentulous	300 (75.5)	
Mean±SD	12.265±12.30	
Median (range)	5.0 (0–32)	
Prosthetic status		
Nil	307 (76.7)	0.007*
Removable prosthesis	78 (19.5)	
Fixed prosthesis	15 (4.5)	
Last dental visit (year)		
<1	100 (25.75)	0.000*
>1	300 (74.25)	
Self-perceived oral health		
Good	35 (8.75)	0.009*
Fair	189 (47.25)	
Poor	176 (44)	
Self-perceived need for treatment for treatment		
Yes	338 (84.5)	0.097
No	62 (15.5)	

SES: Socioeconomic status, SD: Standard deviation. *Statistically significant at $P<0.05$

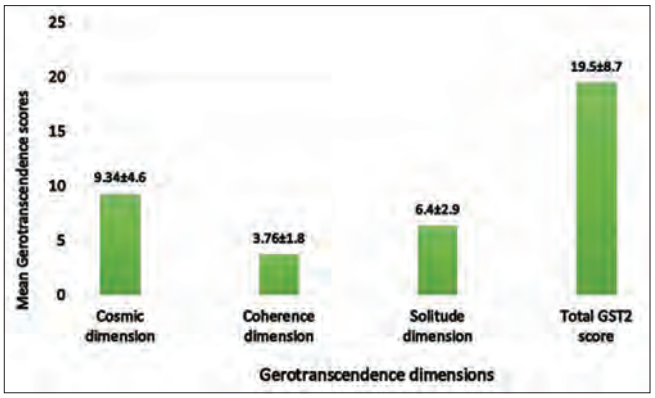

Figure 1: Distribution of mean gerotranscendence scale type 2 scores among the study population

= –0.50), utilization of dental services (r = –0.23), number of missing teeth (r = –0.19), gerotranscendence (r = –0.17), and alcohol consumption (r = –0.36) and were significantly ($P < 0.05$) positively correlated with self-perceived oral health (r = 0.09), nutritional status (r = 0.22), and smoking (r = 0.17) [Table 3]. The gerotranscendence scores were significantly ($P < 0.05$) negatively correlated with socioeconomic status (r = –0.19), education (r = –0.55), self-perceived oral health (r = –0.43), nutritional status (r = –0.64), GOHAI (r = –0.17), utilization of dental services (r = –0.26), and marital status (r = –0.39) and were significantly ($P < 0.05$) positively correlated with age (r = 0.77), systemic problems (r = 0.49), number of missing teeth (r = 0.57), self-perceived need for treatment (r = 0.24), and pan chewing (r = 0.62) [Table 3]. Table 4 shows results of multiple linear regression analysis. Number of missing teeth, gender, nutritional status marital status, socioeconomic status, age, medical problems, self perceived oral health and self perceived need for treatment were significant ($P < 0.05$) predictors of GOHAI (F [13,386] = 18.003, $P < 0.00$, r2 =0.377).

DISCUSSION

Gerotranscendence phase encourages older people to overcome despair related to aging and helps to embrace positivity with aging. Recently, gerotranscendence has been considered as a predictor of OHRQoL.[11] In the present study, gerotranscendence level was negatively correlated with OHRQoL. The possible reason for this could be that the people with low gerotranscendence state may not accept the oral problems as a part of their ageing process and feel the need for dental treatment and seek it which might lead to improve quality of life. In contrary to this, people with high gerotranscendence level may accept the limitations associated with poor oral health as a normal aging phenomenon and do not seek necessary treatment and exhibit poor OHRQoL. However, contradictory

Table 2: Comparison of gerotranscendence scores across different variables

Demographic variables	*n*	Mean rank	df	χ^2	*P*
Gender					
Male	302	201.37	1	14536.500	0.788
Female	98	197.83			
Marital status					
Married	367	220.00	2	0.202	0.904
Unmarried/widowed	33	193.57			
Occupation					
Unemployed	320	212.98	1	8937.000	0.000*
Employed	80	151.33			
SES					
Middle class	195	113.02	2	2.521	0.284
Lower class	205	95.67			
Source of income					
Pension	80	271.04	2	38.144	0.000*
Depend on child	281	183.55			
Other	47	178.91			
Living with					
Spouse	272	201.90	3	3.897	0.273
Child	80	193.39			
Alone	32	182.61			
Old age home	16	248.00			
Education					
Illiterate	137	85.70	3	240.339	0.000*
Primary school	194	269.54			
Secondary school	31	162.82			
Graduation and above	38	297.53			
Medical problem					
Yes	305	231.74	1	4960.500	0.000*
No	95	100.22			
Under medication					
Yes	279	240.96	1	5590.500	0.000*
No	121	107.20			
Smoking					
Yes	245	235.52	1	10408.500	0.000*
No	155	145.15			
Alcohol					
Yes	304	200.12	1	14475.500	0.904
No	96	201.71			
Pan					
Yes	234	140.97	1	5492.500	0.000*
No	166	284.41			
Missing teeth					
Completely edentulous	100	308.32	1	4232.000	0.000*
Partially edentulous	300	165.51			
Prosthetic status					
Nil	307	218.94	2	43.559	0.000*
Removable prosthesis	78	124.82			
Fixed prosthesis	15	216.70			
Last dental visit (year)					
<1	100	148.96	1	9845.500 (Z=−5.273)	0.000*
>1	300	217.68			
Self-perceived oral health					
Good	35	192.05	2	105.880	0.000*
Fair	189	143.16			
Poor	176	265.42			
Self-perceived need for treatment for treatment					
Yes	338	211.74	1	6490.500	0.000*
No	62	136.19			

SES: Socioeconomic status. *Statistically significant at $p<0.05$

findings were observed in a study where people with high gerotranscendence level exhibited improved quality of life.[5] Since this was the first Indian study exploring the relationship between gerotranscendence level and OHRQoL comparison of study results with similar population could not be done. Gerotranscendence Scale Type 2 was used to assess the gerotranscendence level of study population in the present study. Hoshino *et al.* developed the Japanese version of the the GST2 and examined reliability and validity of the scale among Japanese elderly.[8] An exploratory factor

Table 3: Correlation of geriatric oral health assessment index and gerotranscendence scores with different demographic and clinical variables of study population

Study variables	GOHAI		Study variables	Gerotranscendence	
	Correlation value (*r*)	*P*		Correlation value (*r*)	*P*
Age	−0.077	0.125	Age	0.772	0.000*
SES	−0.264	0.000*	SES	−0.194	0.000*
Education	−0.26	0.603	Education	−0.554	0.000*
Systemic problems	−0.502	0.000*	Systemic problems	0.496	0.000*
Missing teeth	−0.194	0.000*	Missing teeth	0.577	0.000*
Self-perceived oral health	0.099	0.049*	Self-perceived oral health	−0.437	0.000*
Self-perceived need for treatment	0.081	0.106	Self-perceived need for treatment	0.244	0.000*
Nutritional scores	0.222	0.000*	Nutritional scores	−0.640	0.000*
Gerotranscendence	−0.172	0.001*	GOHAI	−0.172	0.001*
Marital status	0.013	0.796	Marital status	−0.188	0.000*
Utilization of dental services	−0.236	0.000*	Utilization of dental services	−0.264	0.000*
Smoking	0.178	0.000*	Age	−0.390	0.000*
Alcohol	−0.360	0.000*	Alcohol	0.006	0.904
Pan chewing	−0.092	0.065	Pan chewing	0.627	0.000*

GOHAI: Geriatric oral health assessment index, SES: Socioeconomic status. *Statistically significant at $P<0.05$

Table 4: Results of multiple linear regression analysis highlighting the predictor variables of geriatric oral health assessment index

Coefficients							
Model	Unstandardized coefficients		Standardized coefficients (β)	*t*	*P*	Group label (95.0% CI for *B*)	
	B	SE				Lower bound	Upper bound
Constant	48.76	11.84		4.11	0.00*	25.47	72.06
Gerotranscendence	−0.08	0.10	−0.06	−0.78	0.43	−0.29	0.12
Missing teeth	−0.24	0.07	−0.28	−3.46	0.00*	−0.39	−0.10
Nutritional status	0.85	0.27	0.25	3.16	0.00*	0.32	1.38
Gender	−4.25	1.15	−0.16	−3.68	0.00*	−6.52	−1.98
Marital status	5.19	2.11	0.13	2.45	0.01*	1.02	9.35
Utilization of dental services	−0.09	1.50	−0.00	−0.05	0.95	−3.05	2.87
SES	−6.26	0.95	−0.29	−6.59	0.00*	−8.13	−4.39
Education	0.00	0.85	0.00	0.00	0.99	−1.68	1.69
Adverse habits	−0.60	1.57	−0.02	−0.38	0.70	−3.69	2.49
Age	0.55	0.11	0.45	4.99	0.00*	0.33	0.77
Medical problems	−12.5	1.58	−0.49	−7.92	0.00*	−15.71	−9.47
Self-perceived oral health	−5.20	1.01	−0.30	−5.14	0.00*	−7.19	−3.21
Self-perceived treatment needs	−4.11	1.84	−0.13	−2.22	0.02*	−7.73	−0.48

Model summary					
Model	*R*	R^2	Adjusted R^2	SE of the estimate	Durbin–Watson
1	0.614[a]	0.377	0.356	8.68584	1.213

Dependent variable: GOHAI. Predictors: Constant, self-perceived treatment need, missing teeth, SES, gender, adverse habits, medical problems, utilization of services, marital status, self-perceived oral health, education, GST2, MNASF, age

ANOVA					
Model 1	Sum of squares	df	Mean square	*F*	Significance
Regression	17656.716	13	1358.209	18.003	0.000[b]
Residual	29121.284	386	75.444		
Total	46778.000	399			

Dependent variable: GOHAI, [b]Predictors: Constant, self-perceived treatment need, missing teeth, SES, gender, adverse habits, medical problems, utilization of services, marital status, self-perceived oral health, education, GST2, MNASF, age. GOHAI: Geriatric oral health assessment index, SES: Socioeconomic status, GST2: Gerotranscendence Scale Type 2, SE: Standard error, CI: Confidence interval

analysis of the Japanese version of the GST2 revealed the three-factor structure including the dimensions of the cosmic, the coherence, and the solitude, which had been reported by Tornstam. Reliability and construct validity of the Japanese version of the GST2 were confirmed. Since the validity of this questionnaire was not tested among Indian population, the questionnaire was translated to local language (Kannada) and validated. The average gerotranscendence score was 19.5 ± 8.7 which falls on the mid-scale of gerotranscendence reflecting that the gerotranscendence level of participants was neither low nor high. A study assessing the gerotranscendence and life satisfaction of elderly pilgrims attending Maha Kumbha Mela revealed high gerotranscendence levels among elderly population.[12] However, the high level of gerotranscendence level among pilgrims cannot be generalized to general population since the pilgrims are spiritually inclined and gerotranscendence is strongly correlated with spirituality

and life satisfaction.[12] Age was positively correlated with gerotranscendence in the present study. Similar result was seen in few studies.[12] Older people are more likely to have a cosmic perspective as observed in few studies. This could be due to shifts in how time, space, life, and death are perceived or defined. In a similar vein, older persons showed a larger preference for isolation which was linked to a shift in the meaning and importance of social relationships between individuals.[12] Although gerotranscendence was not a significant predictor of GOHAI, it was negatively correlated with OHRQol. Hence, gerotranscendence may be considered as a potential confounding factor by researchers, when trying to identify and interpret the associations between OHRQoL and oral health status indicators. A study by Mihira *et al.* showed that gerotranscendence was a significant predictor of GOHAI.[5]

A study done by Murthy *et al.* concluded that selfefficacy and conscientiousness domain of personality contributed to predicting denture satisfaction and OHRQOL with complete dentures. The authors stressed the importance of assessing patient's psychological status and personality before the start of the treatment toward the improvement of patient acceptability to dentures.[13]

Limitation of the present study was that the oral health status and oral hygiene practices of the study subjects were not assessed which could have been strong predictors of OHRQoL. The study was first of its kind done among Indian population which tested a new variable gerotranscendence as a predictor of GOHAI. The GTS-2 questionnaire used for assessing the gerotranscendence level of study subjects was validated in Kannada language. Majority of demographic and clinical variables were tested in regression analysis. This study provides a strong baseline data regarding OHRQoL and gerotranscendence level of elderly population of local city which will be helpful for public health workers to plan oral health programs and services to the elderly population.The study underlines the potential predictors of OHRQoL among elderly which may be considered by clinicians while planning treatment for such population as well as program planners and policy makers for planning of oral health programs for such population. Gerotranscendence was strongly correlated with various predictors of OHRQoL in the elderly population. Hence, it is recommended to conduct further research to explore the relationship of gerotranscendence and its association with OHRQoL among elderly which may provide useful insights toward patient-centered clinical decision-making.

CONCLUSION

Gerotranscendence was significantly, negatively correlated with OHRQoL among elderly population in Davanagere city. Hence, gerotranscendence could be an important confounder and effect modifier, while estimating the association between various clinical and systemic factors with OHRQoL among elderly population. This study emphasizes the necessity of assessing oral health-related quality of life in conjunction with gerotranscendence level of elderly people.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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Research

Knowledge and awareness of polycaprolactone and its applications as provisional material in prosthodontic practice: A questionnaire-based survey

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Abstract

Aim: The present study was done to evaluate the knowledge and awareness of different provisional materials, especially polycaprolactone (PCL) and their application in prosthodontic practice.

Setting and Design: A questionnaire based survey was carried out to assess the knowledge and awareness of PCL and its applications as provisional material in prosthodontic practice.

Materials and Method: A questionnaire-based descriptive study consisting of 10 questions related to different provisional materials and their applications in prosthodontic practice was formulated on Google Forms. The link was created and circulated among the prosthodontist faculty members of various dental institutes and private practitioners of India with the use of digital platforms such as E-mail and social media. The data were collected and examined using Microsoft Excel software for statistical evaluation.

Statistical Analysis Used: For this descriptive type of study, knowledge and awareness among prosthodontists across India was evaluated using Microsoft Excel software.

Results: The use of PCL was known only to 20.75% of prosthodontists. Moreover, its application and indications are known to only <1% of the study participants. Autopolymerizing resin was most commonly used for the custom tray and temporary base fabrication as well as temporization in crown and bridge prosthesis, while muscle deprogrammer and surgical template were commonly fabricated in heat-cure and clear acrylic resin, respectively. Pattern resin was found to be commonly used in splinting implant impression copings.

Conclusion: The use of PCL as a temporary denture base, custom tray, muscle deprogrammer, implant impression splinting, and provisional for crown and bridge and templates should be encouraged and incorporated to get benefits of its characteristic properties. Considering the overall performance of PCL, its use should be incorporated into prosthodontic research and practice.

Keywords: Polycaprolactone, prosthodontic application, provisional materials, questionnaire study, survey

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Submitted: 03-May-2022, **Revised:** 10-Oct-2022, **Accepted:** 13-Oct-2022, **Published:** ***

Access this article online	
Quick Response Code:	**Website:** www.j-ips.org
	DOI: 10.4103/jips.jips_224_22

How to cite this article: Patel KA, Patel JR, Patel VV, Duseja S, Raval HJ. Knowledge and awareness of polycaprolactone and its applications as provisional material in prosthodontic practice: A questionnaire-based survey. J Indian Prosthodont Soc 2023;23:78-83.

INTRODUCTION

Resins are the combination of monomers or macromolecules which combine with other components to create a material of superior properties. Synthetic resins are described as plastic, which are dimensionally stable in their use and forever reshaped by irreversible deformation. Plastic is molded into different shapes by heat, pressure, or chemical reaction.[1]

Polymers are used in different dental applications such as denture bases, denture teeth, custom trays, impression materials, splints, maxillofacial prostheses, soft liners, core buildup materials, temporary restoratives, and luting materials.[1]

Polycaprolactone (PCL) was among the oldest polymer synthesized by the Carothers group in the 1930s.[2] Later on, it was commercially available with the efforts to recognize synthetic polymers with reduced microorganisms.[3] PCL can be made by either ring-opening polymerization of Ɛ-caprolactone using with anionic, cationic, and coordination catalysts or through free-radical ring-opening polymerization of 2-methylene-1-3-dioxepane.[4]

PCL is a hydrophobic and semicrystalline in nature. The crystallinity of PCL tends to decrease with increasing molecular weight. PCL has low melting point (59°C–64°C), and extraordinary blend compatibility has stimulated extensive research in the biomedical field.[5-7] PCL and its copolymers were used in various drug-delivery devices. Various other groups were also added to make the polymers more adhesive, hydrophilic, and biocompatible in nature. The average molecular weight of PCL may vary from 3000 to 80,000 g/mol. PCL was graded according to molecular weight.[8] It can easily merge with other polymers to manufacture copolymers with different physicochemical properties and biodegradability.[9-15]

Residual monomers in autopolymerizing acrylic resins may cause allergic reactions and biocompatibility issues. The literature regarding the comparison of PCL and autopolymerizing resin does not exist. In the field of prosthodontics, various provisional materials are routinely used, but the use of PCL as a provisional material is seldom known.

This questionnaire was done to evaluate and assess the knowledge and awareness of different provisional materials, especially PCL and their applications in prosthodontic practice.

MATERIALS AND METHOD

It was a descriptive type of study and was conducted across India in 2021 from August 16, 2021 to October 15, 2021, for 2 months. Ethical approval no. NPDCH/IEC/2021/44.

Study population

The study participants were prosthodontists across India.

Inclusion criteria

All the prosthodontics across the country whether they are attached to dental institutes or private practitioner. Inclusion criteria were independent of the institute, gender, postgraduation year, and curriculum content.

Exclusion criteria

Prosthodontists who denied participating in the present study were excluded from the study.

Study method

The study was carried out across India. In the process of validation, the final questionnaire was circulated among experts in the same field, and their responses were recorded. Based on that result, required modifications were done. A survey was formulated with the help of Google Form, and it was circulated among the participants, and data were recorded.

This survey comprised 10 questions. There were six open-ended and four closed-ended questions to know the dentist usage of different provisional materials. Five demographic questions related to E-mail, designation, participant name, college name (if attached), and experience were included [Table 1].

Table 1: Questionnaire

Question
Which material do you use most frequently for fabrication of custom tray?
Which material do you use most frequently for fabrication of temporary denture base?
Which material do you use most frequently for fabrication of temporary crown/bridge?
Which material do you use most frequently for fabrication of muscle deprogrammer?
Which material do you use most frequently for fabrication of diagnostic/surgical template in implant?
Which material do you use most frequently for splinting implant at the time of impression?
Do you know PCL and its application in dentistry? a. Yes b. No
If yes, where do you find its application? Please mention_____
Any significant advantage of PCL? Please mention_____
What was the major drawback of this material? Please mention_____

PCL: Polycaprolactone

In total, 106 prosthodontists across India were included in the survey.

Sample size for descriptive statistics,[16,17]

$n = 4pq/L^2$

10% of $P = 10\times$

where $P = 92.8\%$

$=0.928$

$q = (1 - p)$

$=1–0.928$

$=0.072 = 7.2\%$

L = Allowable error = (5%) = 0.05

$n = 4 \times 0.928 \times 0.072/(0.05)^2$

$n = 106$

The questionnaire was sent to the participants, and the collected responses were included in statistical analysis. The results of the questionnaire were tabulated in Google Sheets. Data were evaluated descriptively with the use of Microsoft Excel software.

RESULTS

The questionnaire study was completed by a total of 106 respondents, which included prosthodontists across India. The following questions were formulated for the participants [Table 1].

78% of participants preferred autopolymerizing acrylic resin for making of custom trays. Self-cure acrylic resin is the most common and preferred material of choice for the making of custom trays [Figure 1].

Similarly, autopolymerizing acrylic resin is preferred by 78% of participants for the fabrication of temporary denture bases. Autopolymerizing acrylic resin is the most common and preferred material of choice for the fabrication of temporary denture base, followed by light-cure resin (14%) and shellac base plate (7%) [Figure 2].

67.9% of participants commonly used autopolymerizing acrylic resin too for the fabrication of temporary crown/bridge. Hence, autopolymerizing acrylic resin is the preferred material of choice for the fabrication of crown/bridge, followed by heat-cure resin (17%) [Figure 3].

It was found that 53.8% of participants preferred autopolymerizing acrylic resin for the fabrication of muscle deprogrammer. Autopolymerizing acrylic resin was followed by heat-cure acrylic resin (30.2%) for use as material for muscle deprogrammer [Figure 4].

The survey reported that 78.3% of participants preferred autopolymerizing acrylic resin commonly for the fabrication of diagnostic/surgical templates. This was followed by thermoplastic polymer (12.3%) [Figure 5a]. Another finding was that 83% of participants used pattern resin for

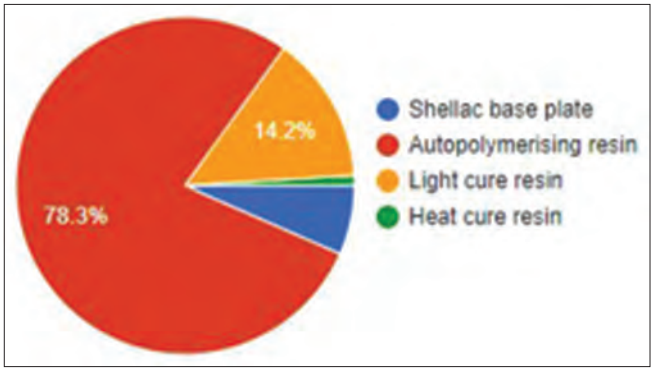


Figure 1: Frequently used material for fabrication of custom tray

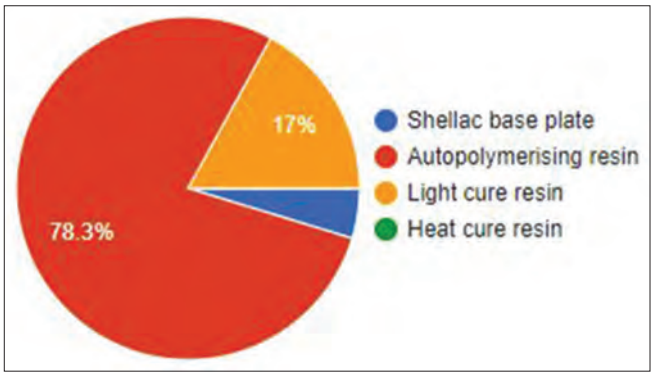


Figure 2: Frequently used material for fabrication of temporary denture base

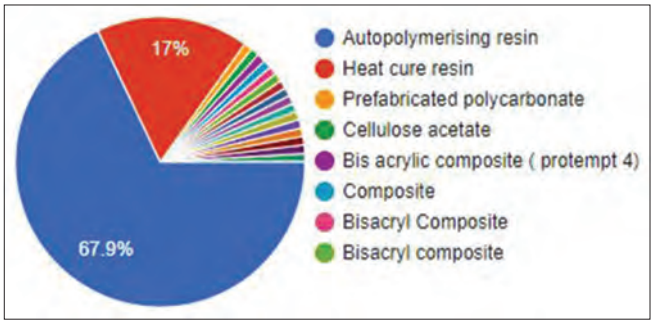


Figure 3: Frequently used material for fabrication of temporary crown/bridge

splinting implants at the time of impression [Figure 5b]. 67% of participants knew about PCL and its application in dentistry, while 33% of prosthodontists were unaware of it [Figure 6].

Graph 1 shows the participants' responses about the application of PCL and its application in various dental treatments. Graph 2 shows the participants' responses about any drawback related to PCL, while 14 participants (out of 67%) did not find any drawback related to PCL.

DISCUSSION

The PCL was widely used as drug-delivery system, tissue engineering, textile technologies, medical appliances like sutures, contraceptive devices, wound dressings, fixation instruments, etc., Nowadays, it gains its popularity as a forgotten polymer in the field of dentistry. In dentistry, earlier, it was used as a root canal filling material.

PCL has several superior properties compared to self-cure acrylic resin-such as light molecular weight, hydrophobicity, low melting point, and biocompatibility. There are different provisional materials used in dentistry, especially in the field of prosthodontics such as self-cure acrylic resins, composite resin, light-cured resins, BISGMA, and PMMA.

There are no *in vivo* or *in vitro* studies available in the literature, which justified the improved properties of PCL as a provisional material. Hence, this questionnaire-based survey was used to evaluate the knowledge and awareness of different provisional materials, especially PCL and its applications in prosthodontic practice.

In the present study, a total of 106 participants were included across India. Autopolymerizing resin was still a preferred choice of temporary material for the fabrication of custom trays (78%), denture bases (78%), muscle deprogrammer (53.8%), as well as surgical templates in the implant (clear acrylic) (78.3%). The reason may be its easy handling properties and less cost with no special equipment required. 67% of participants knew about PCL and its application in dentistry, while 33% of prosthodontists were unaware of it.

Of 67% of participants, 14 participants did not have any idea of its drawbacks. Most of the participants did not have actual knowledge of its properties, as answers were very random. The PCL is a thermoplastic material which has low viscosity in clean state and good rigidity in cool state, thus facilitating adequate molding of the material. Its melting temperature ranges from about

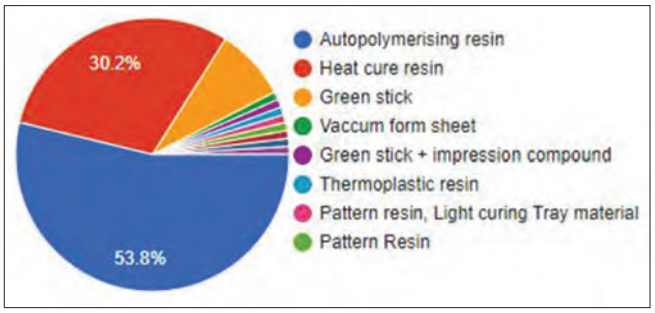


Figure 4: Preferred material for fabrication of muscle deprogrammer

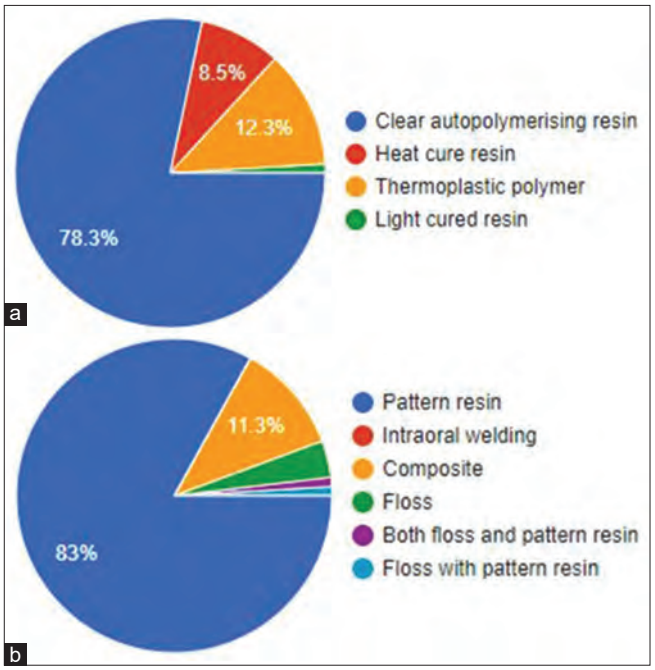


Figure 5: (a) Preferred material for fabrication of diagnostic/surgical template. (b) Preferred material for splinting implants at the time of impression

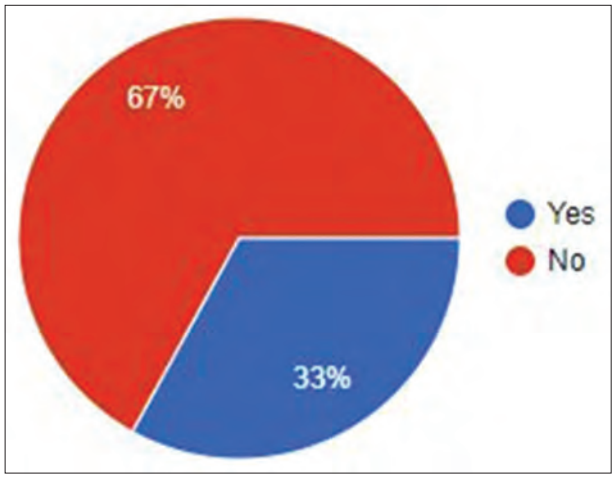
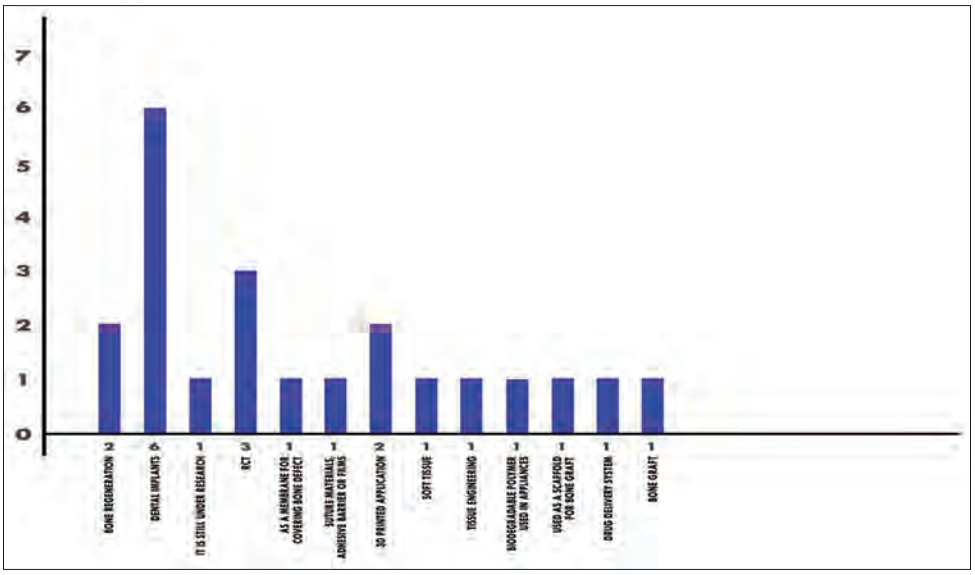
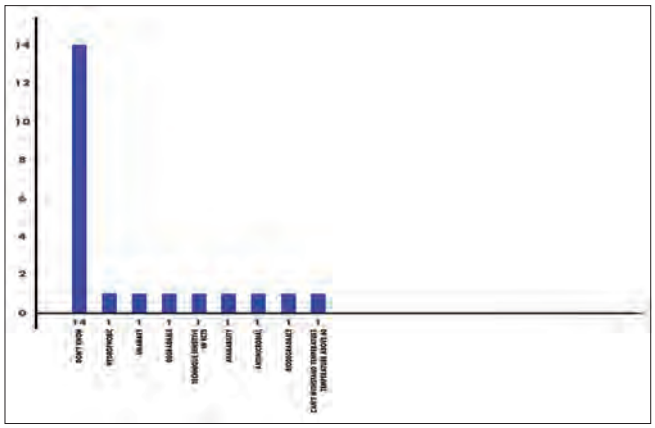


Figure 6: Application of PCL in dentistry. PCL: Polycaprolactone

130°F to about 150°F and it has sufficient strength and stiffness to withstand oral forces. Moreover, because of



Graph 1: Application of PCL in various dental treatments. PCL: Polycaprolactone



Graph 2: Drawback of PCL. PCL: Polycaprolactone

the lack of any residual monomer, no adverse reactions and carcinogenicity have been reported. The limitations of this study were the participants and their time period. In further studies, other fields of practitioners, as well as general dentists, should be included as well as *in vitro* or *in vivo* studies should be conducted to evaluate more physical and mainly mechanical properties of PCL.

The purpose of this survey was to make the prosthodontists familiar with a material with many desirable properties of PCL and their use in routine clinical practice. Since PCL was introduced many years ago, it was obsolete in spite of its many advantages. The survey was designed to revive this unique material in prosthodontics.

Within the limitation of this questionnaire-based survey, the use of PCL should be incorporated into daily use of prosthodontic practice, especially as a temporary material because of its enlisted advantages.

CONCLUSION

The PCL, despite its good handling properties, is not well known to prosthodontists and is a forgotten polymer. Its use as a temporary denture base, custom tray, muscle deprogrammer, implant impression splinting, provisional for crown and bridge, and templates should be encouraged and incorporated to get benefits of its characteristic properties.

Acknowledgments

The author would like to acknowledge Dr. Rahul Patel for the Statistical evaluation.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Research

Using deep learning approaches for coloring silicone maxillofacial prostheses: A comparison of two approaches

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Abstract

Aim: This study aimed to compare the performance of two deep learning algorithms, attention-based gated recurrent unit (GRU), and the artificial neural networks (ANNs) algorithm for coloring silicone maxillofacial prostheses.

Settings and Design: This was an *in vitro* study.

Materials and Methods: A total of 21 silicone samples in different colors were produced with four pigments (white, yellow, red, and blue). The color of the samples was measured with a spectrophotometer, then the L*, a*, and b* values were recorded. The relationship between the L*, a*, and b* values of each sample and the amount of each pigment in the compound of the same sample was used as the training dataset, entered into each algorithm, and the prediction models were obtained. While generating the prediction model for each sample, the data of the corresponding sample assigned as the target color were excluded. L*, a*, and b* values of each target sample were entered into the obtained models separately, and recipes indicating the ratios for mixing the four pigments were predicted. The mean absolute error (MAE) and root mean square error (RMSE) values between the original recipe used in the production of each silicone and the recipe created by both prediction models for the same silicone were calculated.

Statistical Analysis Used: Data were analyzed with the Student *t*-test (α=0.05).

Results: The mean RMSE values and MAE values for the ANN algorithm (0.029 ± 0.0152 and 0.045 ± 0.0235, respectively) were found significantly higher than the attention-based GRU model (0.001 ± 0.0005 and 0.002 ± 0.0008, respectively) ($P < 0.001$).

Conclusions: Attention-based GRU model provided better performance than the ANN algorithm with respect to the MAE and RMSE values.

Keywords: Artificial neural networks, attention-based gated recurrent unit, deep learning, maxillofacial silicone

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Submitted: 25-Mar-2022, **Revised:** 14-Jun-2022, **Accepted:** 30-Jun-2022, **Published:** ***

INTRODUCTION

Maxillofacial defects occur due to cancer, trauma, or congenital deformities. A treatment can be provided with maxillofacial prostheses that protect the defect area from external influences, and satisfies the patients aesthetically.[1,2] It is accepted that the most important factor in the esthetic

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_149_22

How to cite this article: Kurt M, Kurt Z, Işık Ş. Using deep learning approaches for coloring silicone maxillofacial prostheses: A comparison of two approaches. J Indian Prosthodont Soc 2023;23:84-9.

result of the maxillofacial prosthesis is the color match of the prosthesis with the patient's skin.[3]

The most commonly used method for coloring the prosthesis is called the "trial and error method." According to this traditional method, the selected pigments are added to the nonpolymerized silicone in small amounts and mixed, a piece of this mixture is held nearby the patient's skin to evaluate the color match, and the pigment addition is continued until the color match is completed.[4,5] However, this method is entirely subjective because it highly depends on the maxillofacial prosthodontist's experience and color perception, and the illumination of the environment where the coloring is made can also be misleading. A failure in the coloring procedure may cause to repeat the entire production process from the beginning.[5-7]

Today instead of this time-consuming subjective method, studies are continuing on "digital methods" in which pigmentation recipes are created to color the silicone using the data obtained from the patient's skin through color measuring devices.[7] It has been reported that these objective methods eliminate individual failures, are not affected by metamerism, and give reproducible results.[8] Due to the complex characteristics of human skin, a computer-aided color measurement system becomes a necessity in such types of operations. For this reason, a system called the "e-skin system" has been introduced to maxillofacial prosthodontics.[6,9] It has been reported that the e-skin system can provide clinically acceptable color-matched silicone prostheses.[6,10] However, these systems' costs are relatively high, and they are not commonly available since they utilize special color-measuring devices.[9,11] Furthermore, they only operate in the presence of pigments supplied by the manufacturer of the same system, which makes them quite inaccessible and expensive for ordinary specialists as well as patients.[12]

Recently, deep learning has become commonplace with its superiority in terms of prediction and classification tasks. Inspired by the human brain mimics, artificial neural network (ANN), has progressed constantly in recent years. The main motivation is absorbing the nonlinear dependency related to the input data with a combination of linear systems (called convolutions in layers) and nonlinear differentiable activation functions.[13] The previous studies[14,15] have reviewed such potential capability so far; however, the traditional ANN structures suffer from the fact that they are limited in terms of performance when it comes to capturing the correlation between time series observation.[14,15] Considering the limited capability of the conventional ANN family, different methodologies have been proposed. One of the deep learning models for time series sequences, recurrent neural networks (RNNs) was proposed to give insight into relationships.[16,17] Lately, it was found that the RNN has such difficulties remembering inputs for a long period due to the vanishing gradient problem.[16] Therefore, the long short-term memory (LSTM)[18] and gated recurrent units (GRU)[19] studies are designed to constantly remember the long-term dependencies. The GRU is computationally efficient in terms of faster converging; however, when it comes to performance, the GRU is on par with LSTM. In a recent study, the attention-based model is particularly useful in interpreting and capturing the nonlinear relations between sequences.[20]

Deep learning nowadays, as part of artificial intelligence (AI) technology, is on a constant growth path owing to its ability to deal with in-depth analyses and problem cases in various fields, among them the field of medicine. As far as dentistry is concerned, AI assists specialists in examining dental images.[11,21] In this respect, deep learning allows for not only classification but also deciding on the course of treatment and predicting disorders.[11,22,23] However, when it comes to color matching for maxillofacial prosthetics, there is not much research on the use of deep learning tools for such purposes.[11] This is a gap in the literature since compared to the presently – in-use skin color reproduction equipment assessment facilities, the abovestated applications could be far more economical, more publicly accessible, and more convenient for creating the right colors intended for facial prosthetics.[9,11,12]

Against this backdrop, this study aimed to evaluate the performance of two different deep learning approaches for coloring silicone maxillofacial prostheses. The null hypothesis was that there is no difference between two deep learning algorithms, attention-based GRU, and the ANN algorithm.

MATERIALS AND METHODS

Preparation of silicone samples

A total of 21 samples with different colors were produced from room temperature vulcanizing silicone elastomer. These colors were obtained using combinations of four pigments (intrinsic master colors: brilliant white [P105], blue [P116], yellow [P106], and brilliant red [P112]; Technovent Ltd., Newport, U.K.) at different concentrations. The base (M522; Principality Medical Ltd., Newport, U.K.), the catalyst components of the silicone (Original Cosmesil Tin Catalyst and Original

Cosmesil Tin Crosslinker M) were mixed by 1 g: 2 drop ratio as recommended by the manufacturer. The pigments were added by weight measuring on a balance with a weight tolerance of 00.000 g (FZ120i, A&D Company, Ltd., Tokyo, Japan). The mixture was blended thoroughly with a spatula until the color was homogeneously distributed. The compounding ranges of the pigments are shown in Table 1. The colored mixture was placed in square-shaped stone molds of 25 mm × 25 mm × 6 mm dimensions. The molds were closed and allowed to polymerize for 24 h at room temperature. After polymerization, silicone samples were separated from the molds. The irregularities at the edges of the samples were smoothed out with scissors. To remove any remnants of the stone molds, samples were cleaned in distilled water with an ultrasonic cleaner for 10 min.

The color of the silicone samples was measured with a reflectance spectrophotometer (Konica Minolta Cm2300d; Konica Minolta, Tokyo, Japan) on a white background (L: 97.17, a: −0.11, b: 0.16) under standard measurement conditions. The device was set to standard illuminant D65, illumination geometry d/8 degree, 10° colorimetric standard observer, 8 mm in the diameter measurement area, and the average reading function of three consecutive measurements. The L*, a*, and b* values of each sample were recorded. The relationship between L*, a*, and b* values of each produced silicone sample and the amount of each pigment in the compound of the same sample was used as the training dataset and entered into each algorithm to obtain the prediction model.

The attention-based gated recurrent unit model

The approach adopted in this empirical research is a methodology based on an attention model for time series prediction. Since the generalizability of the existing GRU methods fails to draw a relationship between the L* a* b* values and white, red, blue, and yellow channels, the attention-based GRU model was employed to improve the results.

Figure 1 provides an overview of the proposed model, where bidirectional layers were used along with GRU layers. The attention layer was applied before generating predictions using the sigmoid activation function. The proposed model consisted of about 12 million parameters and was trained by setting 300 epochs and 32 batch sizes with early stopping criteria. The same parameters were used for the ANN model, too. The optimization function was the root mean square propagation,[24] while the learning rate was assigned as 1e-4. If the performance was seen to remain unchanged on internal observations, then the learning rate was gradually reduced at 0.7 multiplications down to the minimum learning rate, which was determined as 1e-5 [Table 2].

Data preprocessing stage

The leave-one-out cross-validation technique was applied to analyze the performance of the method. The cross-validation technique is one of the more practical resampling methods to obtain an unbiased estimate of the accuracy of a learned model. In this respect, k-fold cross validation is a commonplace method in terms of better estimation of performance for a model trained on a specific dataset. In the machine learning literature,[25,26] the value of k is usually selected as 5 or 10. However, if the value for k is fixed to the number of samples of a dataset, then each sample is considered a test sample, and the remaining ones are used for training purposes. This type of resampling methodology is called leave-one-out cross validation.[25,26] In the present study, 21 different models were created, one for each sample. Therefore, the test results were analyzed utilizing 21 different models. However, since the data of the remaining 20 samples are very limited as a training dataset, the jittering data augmentation method was used to obtain more reliable results. Jittering is known as a practical way to improve model performance in case of limited data size. The jittering data augmentation method which is commonly used in time series was applied to the training data at each leave-one-out stage. Jittering is considered in terms of integrating the Gaussian noise with determining mean and standard deviation values.[27,28] The sigma value was defined as 1e-4, and the mean values varied between 1e-4 and 1e-3. The training data size became 12,000 + 20 as the original 20 values were also added to the augmented data.[29] Figure 2 shows the jittering-based time series data augmentation. The blue portions indicate the augmented data.

Table 1: The compounding ranges of the pigments

Pigments	Compounding range (g)
White	0.08-0.12
Red	0.03-0.11
Yellow	0.04-0.09
Blue	0.007-0.016

Table 2: The layers of the proposed attention-based gated recurrent unit model

Layer name	Input	Output
Bidirectional (input layer)	None, 1, 3	None, 1, 3
Bidirectional (GRU)	None, 1, 3	None, 1, 1024
Bidirectional (GRU)	None, 1, 1024	None, 1, 1024
Bidirectional (GRU)	None, 1, 1024	None, 1, 1024
Dense	None, 1, 1024	None, 1, 1024
Dropout	None, 1, 1024	None, 1, 1024
Attention	None, 1, 1024	None, 1, 1024
Dense	None, 1, 1024	None, 1, 4

GRU: Gated recurrent unit

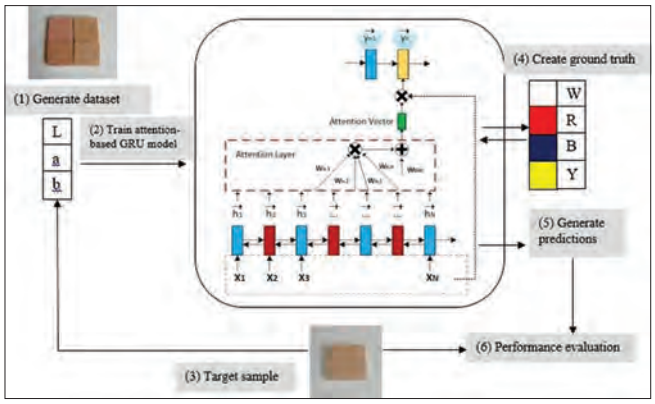

Figure 1: The general framework of the present study. (1) Prepare the dataset by including the L* a* b* values of the silicone samples and the amounts of the four pigments in the compound. (2) Input the training dataset into the attention-based GRU algorithm to generate the prediction model. (3) Input the L* a* b* values of each sample that is assigned as the target color into the obtained prediction model. (4 and 5) Estimate recipe indicating the amount of pigments for target color based on the model (6) Measure MAE and RMSE error values for each sample. GRU: Gated recurrent unit, MAE: Mean absolute error, RMSE: Root mean square error

The L*, a*, and b* values of each silicone sample assigned as target color were used as input data for the prediction models obtained for that sample from both ANN and the attention-based GRU algorithms. The recipe regarding the ratios for mixing white (W), red (R), yellow (Y), and blue (B) pigments was generated as the output data. The mean absolute error (MAE) and root mean square error (RMSE) values between the original recipe used in the production of each silicone and the recipe provided by both prediction models for the same silicone were calculated with the following equations:[30]

$$MAE = \frac{1}{N}\Sigma[|\Delta W| + |\Delta R| + |\Delta Y| + |\Delta B|],$$

and

$$RMSE = [\frac{1}{N}\Sigma(\Delta W)^2 + (\Delta R)^2 + (\Delta Y)^2 + (\Delta B)^2]^{1/2}$$

$$Where\ N = \#silicone\ specimens,\ W = W - \tilde{W},\ R = R - \tilde{R},\ Y = Y - \tilde{Y},\ B = B - \tilde{B}$$

ΔW, ΔR, ΔY, and Δ B indicate the difference between real amounts (W, R, Y, and B) and estimated amounts ($\tilde{W}$, $\tilde{R}$, $\tilde{Y}$, and $\tilde{B}$) of the white, red, yellow, and blue pigments, respectively. The obtained values were analyzed to evaluate the ability to predict the pigment recipe, and lower MAE and RMSE values indicate a better fit.

Statistical analyses

Data analysis was conducted with a statistical software program (IBM SPSS Statistics version 25.0; IBM Corp., Armonk, NY, USA). The normality of the data distribution was evaluated with the Kolmogorov–Smirnov test, and the homogeneity of the variances was investigated by the Levene test. Due to the normal distribution of the data, the Student's *t*-test was performed to compare the attention-based GRU model and the ANN algorithm. A $P < 0.05$ was considered to show a statistically significant result.

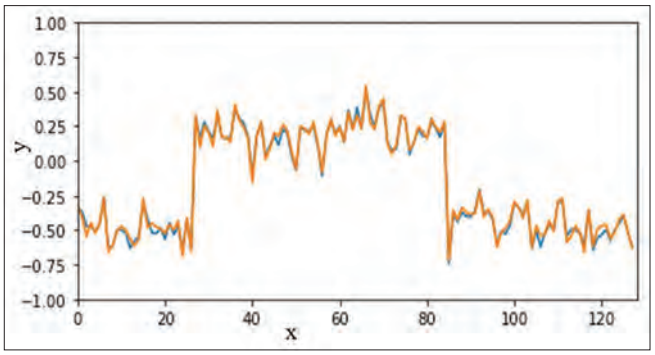

Figure 2: The augmented data after jittering

RESULTS

MAE and RMSE rates achieved by the attention-based GRU model and the ANN algorithms are shown in Table 3. The mean MAE values for the ANN algorithm (0.045 ± 0.0235) were found significantly higher than the attention-based GRU model (0.002 ± 0.0008) ($P < 0.001$). Similarly, the mean RMSE values for the ANN algorithm (0.029 ± 0.0152) were found significantly higher than the attention-based GRU model (0.001 ± 0.0005) ($P < 0.001$). The box plot of the prediction models based on the MAE and RMSE evaluation scores are illustrated in Figures 3 and 4, respectively.

DISCUSSION

In this study, a novel approach of attention-based GRU deep learning model is proposed to predict the pigment recipe, and the results were compared with the ANN deep learning algorithm. The proposed model successfully estimated the pigment volumes very close to the original recipe that was used to manufacture each silicone. The MAE and RMSE rates achieved by the attention-based GRU model were 0.002 ± 0.0008 and 0.001 ± 0.0005, respectively. Accordingly, the results achieved by the proposed model are seen to be clearly and substantially lower than those of the ANN algorithm. With these findings, the hypothesis was rejected because a significant difference was found between the two algorithms.

The MAE and the RMSE have been widely used as standard statistical indicators for assessing model performances. They are used to determine the success of

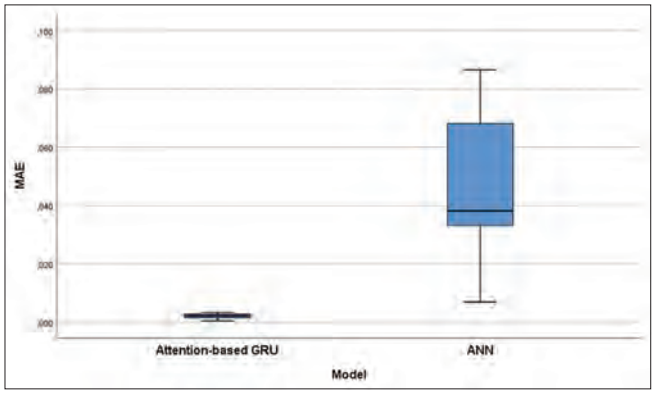

Figure 3: The box plot of the ANN and attention-based GRU models based on the MAE evaluation scores. ANN: Artificial neural network, GRU: Gated recurrent unit, MAE: Mean absolute error

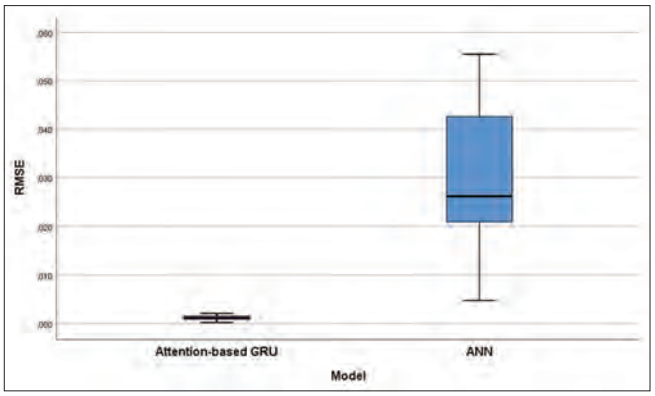

Figure 4: The box plot of the ANN and attention-based GRU models based on the RMSE evaluation scores. ANN: Artificial neural network, GRU: Gated recurrent unit, RMSE: Root mean square error

Table 3: The prediction error rates achieved by attention-based gated recurrent unit and artificial neural network algorithms

Model	Measurement (mean±SD)	
	MAE	RMSE
Attention-based GRU	0.002±0.0008	0.001±0.0005
ANN	0.045±0.0235	0.029±0.0152

MAE: Mean absolute error, RMSE: Root mean square error, SD: Standard deviation, GRU: Gated recurrent unit, ANN: Artificial neural network

the model by calculating the distance between the actual values and the predicted values.[30,31] These two metrics are used in many different fields such as time series analysis, data mining, and machine learning.[32-34] While both have been used to evaluate model performance for a long time, there is still no consensus on the optimal measurement of the model error rates.[30] Thus, both were calculated in the present study.

In a study by Mine *et al*.,[11] two machine learning algorithms, the random forest algorithm, and ANN-based deep learning were compared with respect to skin color reproduction by determining the pigment volumes. They reported that the ANN algorithm was found more successful and promising than the random forest machine learning algorithm for maxillofacial prosthesis coloration.[11] For this reason, in the present study, the ANN method was preferred to compare with the proposed model. However, we did not find a similar study on the performance of the attention-based GRU model on skin color reproduction by predicting the compounding amount of pigments. Therefore, it is not possible to make a one-to-one comparison between the results obtained in the present study with other studies.

Evaluating the clinical outcomes of computerized systems is central in the decision to adopt the right technology in treatment processes. Over the past years, there have been new developments in research concerning skin color assessment and soft-tissue prostheses for individuals. In this direction, entire digital workflows have been published and introduced with regard to the direct printing of colored silicone prostheses.[5,35-37] However, all of these attempts remain subject to further tests concerning their efficiency and applicability.

At present, a key element is to decide on the required pigment volumes in a way that is not only economical but also precise and targeted. To this end, there have been options available in the market, all of which are either too costly or technical. One of the advantages of this attention-based GRU model is that it can be run on a single computer with a standard central processing unit, thus enhancing the availability of the coloration system. The real-time deep learning-based skin color matching technique would further provide more economical and accessible coloration support for maxillofacial prostheses.[11]

The current study offers some important insights into the efficiency and effectiveness of the attention-based GRU model for predicting pigment volumes using L*, a*, and b* values. However, this study has some limitations, among them the inability to apply the model in real time on actual people; hence, the need for Δ E values instead of error rates. For this reason, as in the study of Mine *et al*.,[11] silicone coloring should be performed according to the L*, a*, and b* values measured from the skin of the human subjects. In future work, it is recommended to color the silicone, based on the proposed attention-based GRU model and calculate the color difference between the produced silicone and the human skin. In this way, the validation process of the tested approaches could be performed. Furthermore, the study should be conducted on a larger population as well as with larger training datasets.

CONCLUSIONS

The attention-based GRU model is capable of predicting the pigment volumes more accurately than the ANN algorithm. This GRU model is a promising deep learning technique for the improvement of maxillofacial prostheses coloration.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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Research

Exploratory analysis of demographic data, tobacco habits, and oral health-related quality of life among complete denture patients

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Abstract

Aim: The present study assessed the impact of demographics and tobacco habits on oral health related quality of life (OHRQoL) among complete denture patients.

Setting and Design: Prospective cohort study design.

Materials and Methods: Two hundred and eighty four edentulous patients, aged above 30 years, were chosen as the sample for the study after taking informed consent. Information regarding demographic data and smoking status was obtained from each participant. OHRQoL was evaluated using the Oral Health Impact Profile Edentulousness (OHIP EDENT) quantifying various domains, namely functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability, and handicap.

Statistical Analysis Used: Data were analyzed using the Statistical Package for the Social Sciences version 23.0 (IBM; Chicago, Illinois, USA). Mann–Whitney U test was applied to find significant differences in OHRQoL between gender, age, and smoking status. $P < 0.05$ was considered to be statistically significant.

Results: It was seen that complete denture wearers above 65 years had higher OHIP EDENT scores as compared to younger counterparts suggesting the compromised quality of life in the functional domain which was statistically significant. Psychological discomfort was greater in females while physical disability seemed higher in males. Smoking was found to be a factor associated with decreased OHRQoL.

Conclusion: Older age groups, female gender, and smoking were factors associated with decreased OHRQoL among complete denture patients.

Keywords: Dentures, edentulousness, gender, quality of life, smoking

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Submitted: 07-Sep-2022, **Revised:** 05-Nov-2022, **Accepted:** 23-Nov-2022, **Published:** ***

INTRODUCTION

Edentulism is an inevitable oral health consequence resulting from the accumulated pathology such as dental caries, periodontal disease, or a deficient rehabilitation technique. Literature shows a 4% raise of this condition every decade among young adults and a further 10% by

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_423_22

How to cite this article: Iyer S, Dhaded S, Kaur M, Hegde P. Exploratory analysis of demographic data, tobacco habits, and oral health-related quality of life among complete denture patients. J Indian Prosthodont Soc 2022;23:90-5.

the individual reaches the age of 70.[1] Edentulism has a direct connection to masticatory and nutritional issues, and some authors consider it to be a reliable predictor of mortality.[2] Edentulousness is a serious condition that affects both overall health and quality of life (owing to the lesser consumption of fruits and vegetables and a diet with lesser nutritional value).[3,4] Evidence is overwhelming that edentulism has a detrimental impact on oral health-related quality of life (OHRQoL) in the form of functional, psychological, and social impairment, which has an impact on daily living. Elderly people who have lost their teeth experience low self-esteem, a deterioration in psychological well-being, limited social engagement, and social isolation.

Complete loss of all erupted teeth, has been observed to have a detrimental effect on the OHRQoL.[5] The most popular form of treatment for treating edentulism is a conventional complete denture for rehabilitation of such patients. Even though there have been some reported disadvantages, it would still be the opted choice because of its affordability and in cases where implant placement is contraindicated because of existing illnesses.[6,7]

The Oral Health Impact Profile (OHIP) is one of the most often used evaluation methods for quantifying OHRQoL.[8] In patients with receiving complete dentures, Stober *et al*.[9] found a substantial correlation between overall satisfaction and OHRQoL. OHIP comprises 49 items for assessing OHRQoL.[10] The OHIP-Edentulousness (OHIP-EDENT) is a condensed version of the OHIP, which includes 19 items tailored to measure OHRQoL of edentulous patients.[11] Research exploring various demographic variables and their relationship to OHRQoL among the denture wearers in this region is scantly reported with noteworthy conclusions, which prompted this study.

METHODOLOGY

The study population consisted of 284 first time, complete denture wearers aged 30 years and above recruited within a time period of six months. Based on the study of Limpuangthip *et al*.[12] which showed a 43% impact of complete dentures on OHRQoL, the sample size was determined to be 284, using the below formula, wherein n is the sample size, Z is the statistic corresponding to level of confidence, *P* is expected prevalence, and d is precision:

$$N = \frac{Z^2\ P(1-P)}{d^2}$$

Patients with any type of cognitive disability, systemic disorders, and a history of previous dentures were excluded. The study was carried out in accordance with the ethical standards for medical research involving human subjects set forth in the Helsinki Declaration of the World Medical Association. Informed consent of all participants was taken after explaining them the details of the study and ensuring confidentiality.

The participants were asked to fill out a questionnaire eliciting demographic details such as age and gender. Smoking status was binomially categorized into smokers and nonsmokers. Those who had a history of smoking and have quit were also considered nonsmokers. OHRQoL was assessed using OHIP-EDENT,[11] which was translated into native language. To ensure linguistic validity, the questionnaire was forward translated, reconciled, back translated, and reviewed for the corrected version in the same order. OHIP-EDENT includes seven domains for assessing the quality of life, namely functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability, and handicap. The obtained data were analyzed using the Statistical Package for the Social Sciences version 23.0 (IBM; Chicago, Illinois, USA). One-way analysis of variance was applied to find differences between age groups, gender, smoking, and socioeconomic status on OHRQoL among complete denture wearers. The level of significance was set at 5%.

RESULTS

70.7% of the study participants were males while 29.3% of females participated in the study. 60.9% of the denture wearers fell above 65 years of age, as shown in Table 1.

Table 2 presents OHRQoL and its different domains as related to age. Functional limitation domain in OHRQoL demonstrated a significant difference with age for all its variables. A highly significant difference was noted for difficulty in chewing with >65 years of age having greater impact (1.576 ± 1.160) as compared to <65 years (0.666 ± 1.020). Similarly, a higher mean score was noted in >65 years for food catching and dentures not fitting variables with 0.596 ± 0.495 and 1.384 ± 1.122 values, respectively, which was significant at $P = 0.038$ and

Table 1: Demographic data of study population

Variables	*n* (%)
Age (years)	
<65	111 (39.1)
>65	173 (60.9)
Gender	
Male	201 (70.7)
Female	83 (29.3)
Smoking habit	
Smokers	96 (33.9)
Nonsmokers	188 (66.1)

Table 2: Oral health-related quality of life with age

Domains	Variables	Mean±SD (years)		Total	Mann-Whitney *U*-test	*P*
		<65	>65			
Functional limitation	Difficulty in chewing	0.666±1.020	1.576±1.160	1.223±1.189	484.500	<0.001**
	Food catching	0.363±0.488	0.596±0.495	0.505±0.502	658.500	0.038*
	Dentures not fitting	0.757±1.118	1.384±1.122	1.141±1.156	563.500	0.005**
Physical pain	Painful aching	0.484±0.755	0.714±0.847	0.623±0.816	736.500	0.215 (NS)
	Uncomfortable to eat	0.818±0.768	0.980±1.075	0.917±0.966	834.00	0.817 (NS)
	Sore spots	0.878±0.819	1.134±1.120	1.035±1.017	773.00	0.421 (NS)
	Uncomfortable dentures	1.060±1.197	1.538±1.565	1.352±1.445	744.00	0.280 (NS)
Psychological discomfort	Worried	1.636±1.140	1.634±1.414	1.635±1.307	814.00	0.679 (NS)
	Self-conscious	1.363±1.084	1.365±0.561	1.367±0.799	820.500	0.712 (NS)
Physical disability	Avoid eating	0.878±1.023	1.442±1.092	1.223±1.095	598.500	0.014*
	Unable to eat	0.969±0.728	1.365±0.950	1.211±0.887	663.500	0.059 (NS)
	Interrupts meals	0.606±0.348	0.307±0.728	0.211±0.619	752.00	0.073 (NS)
Psychological disability	Upset	0.424±0.830	0.769±0.982	0.635±0.936	710.00	0.098 (NS)
	Has been embarrassed	0.363±0.783	0.615±0.843	0.517±0.825	708.00	0.095 (NS)
Social disability	Avoids going out	0.424±0.751	0.576±0.871	0.517±0.825	795.50	0.486 (NS)
	Less tolerant of others	0.454±0.564	0.384±0.745	0.411±0.677	742.00	0.197 (NS)
	Irritable with others	1.333±0.989	1.173±1.166	1.235±1.098	753.50	0.322 (NS)
Handicap	Unable to enjoy company	0.969±0.683	1.038±1.047	1.011±0.919	826.50	0.759 (NS)
	Life unsatisfying	1.727±1.179	1.557±1.109	1.623±1.133	785.00	0.494 (NS)

*Significant, **Highly significant. NS: Nothing significant, SD: Standard deviation

0.005. Painful aching, uncomfortable to eat, sore spots, and uncomfortable dentures had slightly higher scores in the age group of above 65 years, but their p-value was not significant. The variables of worried and self-conscious in the psychological domain were almost equally distributed in both ages with no significant difference noted. Higher age group category avoided eating with dentures placed with a mean score of 1.442 ± 1.092 as against lower age group having a mean of 0.878 ± 1.023, which was significant at $P = 0.014$. The other variables of unable to eat and interruption during meals were not significantly different between the age categories. None of the questions in the domain of psychological disability, social disability, and handicap showed any significant difference between age groups. Overall, it was seen that in the domain of functional limitation, denture wearers who were lesser than 65 years of age had lesser mean scores as compared to their older counterparts. This suggested that denture was better adapted in the younger age.

Table 3 presents OHRQoL and its different domains as related to gender. Males exhibited compromised OHRQoL in the domain of functional limitation. The mean scores for difficulty in chewing were much higher in males as compared to females with a mean of 1.600 ± 1.196 versus 0.320 ± 0.476 which was statistically significant at $P < 0.001$. The complaint of food catching was greater in females than males. Denture not fitting variable had a higher score in males with a mean of 1.483 ± 1.185 as against 0.320 ± 0.476 of females. In the physical pain domain, males had greater mean scores for uncomfortable to eat, sore spots, and uncomfortable dentures when compared to females, but their p-value was not significant. Painful aching was significantly higher in females with a mean of 1.506 ± 0.000 versus 0.883 ± 0.845 in males at $P < 0.001$. The domain of psychological discomfort was significantly higher in females at $P = 0.009$ for being worried and $P = 0.049$ for being self-conscious. In the physical disability domain, males significantly exhibited compromised quality with scores of 1.450 ± 1.199 as compared to females at $P = 0.012$.

Smoking status and OHRQoL among completely edentulous patients with dentures are demonstrated in Table 4. No significant differences were noted between smokers and nonsmokers for the variables of functional limitation such as difficulty in chewing, food catching, and dentures not fitting at $P = 0.345$, $P = 0.084$, and $P = 0.246$, respectively. Physical pain characteristics did show changes with smokers having higher mean scores for painful aching (1.040 ± 0.840 vs. 0. 450 ± 0.746) as compared to nonsmokers and for uncomfortable to eat (1.400 ± 1.290 vs. 0.716 ± 0.715) at $P = 0.002$ and $P = 0.037$, respectively. Sore spots were equally distributed in both the groups. Psychological discomfort quality of worried and self-conscious was also not significant. Interruption during meals was higher among smokers with a mean of 0.720 ± 0.978 as compared to. 000 ± 0.000 among nonsmokers which was significant at $P < 0.0001$. Against convention, nonsmokers were significantly more embarrassed with a mean score of 0.733 ± 0.899 when compared to their smoking counterparts. Smokers had compromised quality of life with smokers avoiding to go out to be significantly more as against nonsmokers. Smokers also felt that their life was more unsatisfying with a mean score of 2.040 ± 0.840 as against 1.450 ± 1.199 in

Table 3: Oral health-related quality of life with gender

Domains	Variables	Mean±SD		Total	Mann-Whitney U-test	*P*
		Males	Females			
Functional limitation	Difficulty in chewing	1.600±1.196	0.320±0.476	1.223±1.189	312.500	<0.001**
	Food catching	0.583±0.497	1.088±0.476	0.505±0.054	552.500	0.028*
	Dentures not fitting	1.483±1.185	0.320±0.476	1.163±1.156	332.00	<0.001**
Physical pain	Painful aching	0.883±0.845	1.506±0.000	0.623±0.816	312.50	<0.001**
	Uncomfortable to eat	1.016±1.096	0.680±0.476	0.917±0.966	652.00	0.483 (NS)
	Sore spots	1.050±1.213	1.000±0.000	1.035±1.017	675.00	0.447 (NS)
	Uncomfortable dentures	1.633±1.615	0.680±0.476	1.352±1.445	593.00	0.112 (NS)
Psychological discomfort	Worried	1.000±1.386	1.980±0.816	0.980±0.570	489.00	0.009*
	Self-conscious	1.280±0.717	1.400±0.979	0.120±0.262	732.00	0.049*
Physical disability	Avoid eating	1.450±1.199	0.680±0.476	0.770±1.095	501.500	0.012*
	Unable to eat	1.316±0.892	0.960±0.840	0.356±0.052	608.00	0.140 (NS)
	Interrupts meals	0.300±0.720	0.000±0.000	0.211±0.619	637.500	0.042*
Psychological disability	Upset	0.000±0.000	0.900±1.003	0.900±0.936	412.500	<0.001**
	Has been embarrassed	0.733±0.899	0.000±0.010	0.733±0.825	425.00	<0.001**
Social disability	Avoids going out	0.733±0.899	0.000±0.056	0.733±0.825	425.00	<0.001**
	Less tolerant of others	0.300±0.720	0.680±0.476	0.4118±0.677	429.00	<0.001**
	Irritable with others	1.316±1.185	1.040±0.840	1.235±1.098	682.00	0.491 (NS)
Handicap	Unable to enjoy company	1.016±1.096	1.000±0.000	1.011±0.919	650.00	0.297 (NS)
	Life unsatisfying	1.716±1.059	1.400±1.290	1.623±1.133	635.00	0.250 (NS)

*Significant, **Highly significant. NS: Nothing significant, SD: Standard deviation

Table 4: Oral health-related quality of life with smoking status

Domains	Variables	Mean±SD		Total	Mann-Whitney U-test	*P*
		Smokers	Nonsmokers			
Functional limitation	Difficulty in chewing	1.400±1.290	1.150±1.147	1.223±1.189	656.500	0.345 (NS)
	Food catching	0.360±0.489	0.566±0.499	0.505±0.502	595.00	0.084 (NS)
	Dentures not fitting	1.080±1.469	1.166±1.011	1.141±1.156	635.500	0.246 (NS)
Physical pain	Painful aching	1.040±0.840	0.450±0.746	0.623±0.816	460.500	0.002*
	Uncomfortable to eat	1.400±1.290	0.716±0.715	0.917±0.966	548.00	0.037*
	Sore spots	1.080±1.469	1.015±0.770	1.035±1.017	676.00	0.453 (NS)
	Uncomfortable dentures	1.440±1.959	1.316±1.185	1.352±1.445	673.500	0.442 (NS)
Psychological discomfort	Worried	1.720±0.979	1.600±1.428	1.635±1.307	673.500	0.442 (NS)
	Self-conscious	1.640±0.952	1.250±0.704	1.364±0.799	637.00	0.236 (NS)
Physical disability	Avoid eating	1.400±1.290	1.150±1.005	1.223±1.095	692.500	0.559 (NS)
	Unable to eat	1.720±0.979	1.000±0.759	1.211±0.887	480.00	0.005 (NS)
	Interrupts meals	0.720±0.978	0.000±0.000	0.211±0.619	480.00	<0.001**
Psychological disability	Upset	0.720±0.979	0.600±0.924	0.635±0.936	705.00	0.590 (NS)
	Has been embarrassed	0.000±0.000	0.733±0.899	0.517±0.825	425.00	<0.001**
Social disability	Avoids going out	1.040±0.840	0.300±0.720	0.517±0.825	388.500	<0.001**
	Less tolerant of others	0.720±0.978	0.283±0.454	0.411±0.677	616.00	0.111 (NS)
	Irritable with others	1.400±1.290	1.166±1.011	1.235±1.098	696.500	0.588 (NS)
Handicap	Unable to enjoy company	1.400±1.290	0.850±0.659	1.011±0.919	612.00	0.150 (NS)
	Life unsatisfying	2.040±0.840	1.450±1.199	1.623±1.133	533.00	0.030*

*Significant, **Highly significant. NS: Nothing significant, SD: Standard deviation

the nonsmokers which was significant at $P = 0.030$. Overall, smokers demonstrated decreased quality of oral health as evaluated by OHIP-EDENT.

DISCUSSION

Complete tooth loss and alveolar bone resorption are regarded as oral health impairments that impede the stomatognathic system's ability to eat, speak, and look good. It has detrimental psychological and societal implications. Complete edentulism is becoming less common, although the number of patients who need rehabilitation with complete dentures is still higher than average in several nations. There are several factors that determine whether a denture is acceptable in terms of satisfaction and OHRQoL. Studies[13-16] have discovered a variety of relationships between denture satisfaction and oral anatomy, patient psychology, technical proficiency, and dental communication abilities. Despite these positive and negative full denture success indications, many patients nevertheless find it difficult to adjust to a complete denture. Patients who have trouble accepting their missing teeth are more likely to suffer from sadness. The patient's personality, relationship with the dentist, and attitude toward the dentist and denture are further contributing aspects. These, however, are not often assessed. The patient and the dentist jointly decide on the course of therapy. The accumulated impact of patient satisfaction, socioeconomic

status, psychological status, and physical traits such as age and gender among complete denture wearers in this part of the country is not well documented in the literature.

Higher age group of our study population was affected as compared to their younger counterparts. The findings are contradictory with those of Weinstein *et al*.,[17] who found that among all age categories, those in their 70s and older were the most contented. This conclusion may be connected to the fact that elderly people have a strong need for fulfillment at every level of everyday functioning.[18] Another cause might be that they are reluctant to continuously report issues to the physician and instead try to deal with the small issues on their own. In their investigation of stereognosis in edentulous participants, Mantecchini *et al*.[19] discovered that older subjects' stereognostic abilities are worse than those of younger persons. In comparison to participants with superior stereognostic ability, those with less stereognostic ability displayed higher levels of enjoyment.

On evaluating OHRQoL between genders, a significant difference was noted in the present study for the domain of functional limitation (Q1, Q2, and Q3) at $P < 0.001$. On the contrary, the study of Saddq *et al*.[20] did not show differences in this domain. Males had higher means of functional limitation suggesting greater dissatisfaction among them as compared to females.

Functional limitations, such as mastication and capturing food capacity, were found to be considerably prevalent in the research population regardless of gender or age. The patient was unable to carry out his daily activities. This finding is consistent with earlier studies,[21-23] which link functional limitations to edentulous patients' pain, the feeling of an ill-fitting denture, and food collection under dentures. Complete denture wearers require seven or eight times more chewing strokes than dentulous patients to remove food particles because of decreased masticatory forces as compared to dentate patients.[24]

Psychological discomfort was noticed to be higher in the females of the present study. Q8 (worried) and Q9 (self-conscious) questions of psychological discomfort domain showed higher scores for females than males, which was significant. This is similar to the study of Saddq *et al*.[20] Gender and psychological handicap were found to have a strong relationship; females were more disturbed and ashamed by their denture difficulties. Females appeared to be a little more sensitive than males in this study, preferring to stay at home and avoid going out in public settings in case of denture difficulties. This can be explained by physical or psychological variations between men and women, as well as physiological and hormonal alterations that have been claimed to have a role.

The findings of the current study demonstrated that while male patients complained of physical aspect or functional domain of OHRQoL, females had more troubles with psychological domain. This was not in line with Taylor and Doku's[25] findings, which showed that male patients were happier with their dentures than female patients were. Male patients expressed greater satisfaction with their full dentures in terms of mastication, look, speech, and health, according to Singh *et al*.[26]

Regarding the size, shape, and color of teeth chosen, female participants more frequently experienced esthetic concerns than their male counterparts. In accordance with their current dentures, patients reported increased speaking and esthetic satisfaction levels but higher mastication complaints which matched the findings of our investigation. This implies that healing from mastication issues is most challenging in the areas of mastication, speech, and esthetics. The current study found that smokers demonstrated decreased quality of oral health as evaluated by OHIP-EDENT. The results related to smoking and drinking habits require further research. Shao *et al*. in their study on elderly subjects with a history of smoking and drinking had higher GOHAI scores, which was similar to what we found.[27]

The study poses few limitations. Owing to the cross-sectional pattern of the study design, a causal association between age, gender or smoking status, and OHRQoL cannot be established. When concerning personal choices and opinions, the respondents might not be accurate in their response. But still the study has greater merits considering the larger sample size and elaborateness in the study design.

CONCLUSION

The current study showed a statistically significant difference of OHRQoL with age, gender, and smoking status among edentulous patients rehabilitated with complete denture using OHIP-EDENT. Patients >65 years had higher scores for functional limitation than their younger counterparts. Assessment of OHRQoL could be used as a complementing measure along with clinical examination thus allowing the dental practitioner to make a thorough assessment that includes clinical outcomes and patient's perception towards oral health.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Denture tracker for edentulous Alzheimer's patients

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Abstract

Dementia in Alzheimer's disease complicates the caregivers in tracking the patients. Many options are discussed in the literature. A novel technique is essential to improve the quality of life and to assist in locating the patients. The Global Position System (GPS) trackers are attached to dentures and the movements are observed through a mobile application. This technique discusses on a simple method of tracking Alzheimer's edentulous patients with the support of removable dentures. Denture tracking devices are a secured form of tracking patients. A GPS device in dentures assists in locating the patient's movement and supports the caretakers.

Keywords: Alzheimer's disease, dementia, Global Position System tracker, wandering behavior

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Submitted: 03-May-2022, **Revised:** 08-Jul-2022, **Accepted:** 18-Jul-2022, **Published:** ***

INTRODUCTION

Alzheimer's disease accounts for 60%–80% of dementia patients. Attempts were made across the world to discover the methods to prevent its development, hinder the onset, and to treat the disease.[1] The treatment procedures cannot prevent dementia but it can reduce the progress of symptoms.[2] Among the issues of dementia, there are possibilities of losing the patients due to disorientation and wandering.[3,4] This is a serious problem to the caregivers. Many methods were studied and suggested to overcome this limitation.[5,6]

The World Health Organization and the National Institute on Aging-related tooth loss as a risk factor for Alzheimer's disease. Alzheimer's patients are mostly associated with teeth loss and required prostheses to improve their oral function and quality of life.[7] Attaching a tracker to the dentures and tracing the patients through the Global Position System (GPS) modules can be helpful to the care providers. With the advances in technology, the caregivers can be provided with easy and economic options in tracking these patients. Many mobile devices and techniques operating through GPS were designed.[5] Major issues existing in costing and devices may not be used by the patients.[6] GPS trackers attached to the denture are simple, economic, and convenient to use for the patient. It provides required support to the caregivers in tracking the patients and improves the oral health quality of life.

PROCEDURE

The dentures were fabricated by conventional procedures. The position of the sensors was located and marked on the maxillary denture [Figure 1]. A sheet of light polymerizing acrylic sheet (Profibase; VOCO GmbH) was adapted

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How to cite this article: Chander NG, Reddy DV. Denture tracker for edentulous Alzheimer's patients. J Indian Prosthodont Soc 2023;23:96-8.

over the defined position of the sensors. The sensors were placed on the positioned light polymerized sheet and it was spot cured for 5 s to trim/remove the excess materials. Postremoving the flash material, the denture along with sensors was light polymerized according to the manufacturer's instructions.

A clear thermoforming material (Clear Bioplast® Material; Biostar®, NY, United States) was vacuumed and pressed over the placed sensors. The pressed thermoforming material sheet was shaped to cover and protect the sensors. The extension of thermoplastic sheet over the USB plug of the sensor was removed and sealed with room temperature vulcanizing silicone (M511 Platinum silicone, Technovent) [Figure 2]. The power switch of the sensors was turned on and it was activated in accordance with the manufacturer's instructions. The GPS-attached denture can be used to locate the position of the patient and it can be tracked through the mobile application [Figure 3].

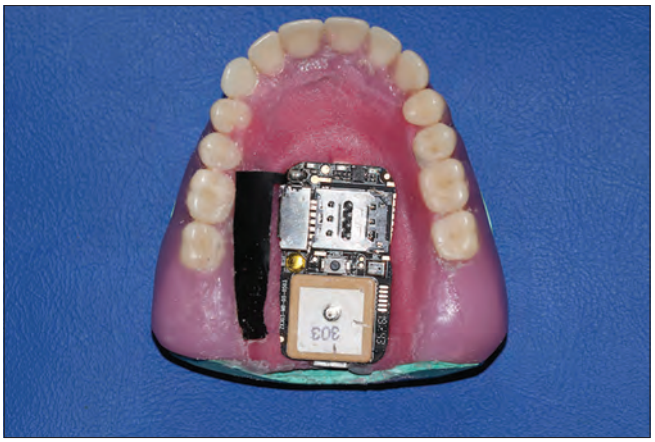

Figure 1: Tentative positioning of tracker on the denture

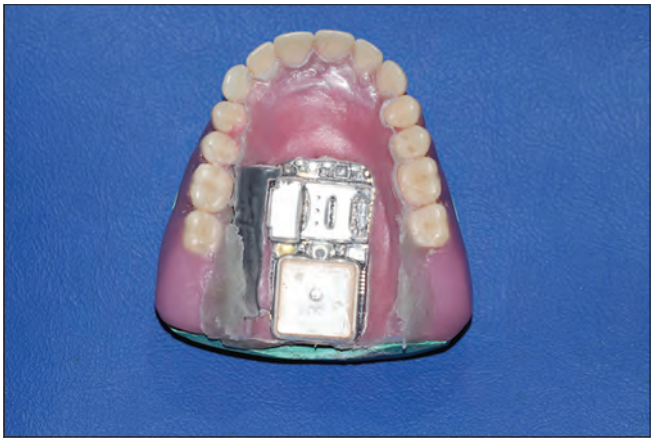

Figure 2: Vacuum-packed denture tracker with thermoforming materials

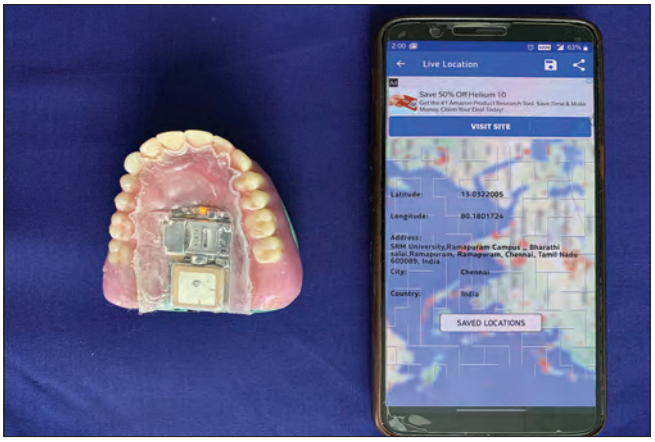

Figure 3: Denture tracking through the mobile application

DISCUSSION

A GPS tracker device is designed to be attached to the maxillary or mandibular denture. The signals sent by the tracker will be received and decoded through the mobile phones. The tracker design works with Android, iPhone, and other applications. The device shall send information on location, speed, distance traveled, and route through the established free mapping systems available on the phone networks. A long-distance accuracy design of tracking shall be adapted and the module allows the device to be tracked even in difficult areas. The tracker was designed to provide auto report position. The username, password, and authorized number facilities shall be provided to enhance accuracy. In addition, the device incorporated the features of low battery alert, remote monitoring, and geofence alert on movement and speed. These features can assist in tracking and checking the patients. The battery life varies between 40 and 48 h and it is rechargeable. In addition, the device is programed to work on a low-power charge. The limitations of bulkiness, phonetics, and difficulty in palatal adaptation can be reduced with advanced technology.

The GPS denture tracker can aid in establishing the contact of wandering Alzheimer's patients. It can improve the quality of life and care both to the patient and caregiver. Many GPS tracking devices such as pocket tracking devices, clothing attachments, and wearable – bracelets, watches, necklaces, and pendants are commercially available; the use of sensor trackers in dentures is simple, novel, and effective approach in edentulous or partially edentulous patients.[5] The technique can be employed in situations where the dentures are fabricated in edentulous patients or in palatal plates for dentulous Alzheimer's patients. It is comparatively economical with the use of open-source platforms. The thought and technique can be used with extensive modifications to benefit the needy. In addition, since the device is attached to the denture, there are lesser chances to forget or lose it in Alzheimer's patients.

The technique described is a prototype and the sensor employed in this technique is slightly bulky. Efforts can be made to use smaller size devices and suitable secured linking platforms. Smaller or nano-GPS sensor options are available but presently they are expensive.

The type of software system used in this technique was open sourced. Many dedicated software systems are available for tracking Alzheimer's patients. The system can be either customized or commercial models can be used in accordance with the needs. An exclusive denture tracking network for Alzheimer's can provide simple and more economic options for tracking participants in future.

CONCLUSION

The technique described provides a simplified approach to track edentulous patients with Alzheimer's disease.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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A novel chairside technique to assess the interocclusal clearance and abutment axial walls during tooth preparation

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Abstract

The importance of a judicious and unerring abutment tooth preparation in the field of prosthodontics has always been paramount. It is not uncommon for many clinicians to face challenges during laboratory fabrication of fixed prostheses, caused due to inappropriate occlusal clearance and over axial wall taper of the abutment tooth. With evolving technologies and methods, the modus operandi for attaining such tooth preparation is varying; however, every technique has its own shortcomings. The technique mentioned in the article is cost-effective as it uses modified Heister mouth gag forceps to achieve the desired objective of evaluating the prepared abutment morphology three-dimensionally with minimum chairside time.

Keywords: Abutment, occlusal clearance, three-dimensional, tooth preparation

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Submitted: 18-Apr-2022, **Accepted:** 24-Aug-2022, **Published:** ***

INTRODUCTION

Occlusal clearance is the space created between two opposing teeth when one or both are being prepared to receive a restoration. The amount of tooth structure lost while preparing the occlusal aspect is prudent and must be done cautiously. If over-prepared, it may contribute to irreversible pulp damage or loss in resistance form, and if underprepared, the structural durability of the restoration may be compromised.[1,2]

Various conventional techniques and their modifications, for verifying the occlusal clearance have been proposed using dental wax or silicone bite registration materials for interocclusal records and evaluating their thickness with an Iwanson gauge caliper or a graduated periodontal probe.[3-8] However, positive replica models have always been more convenient and effective to assess the preparation, in terms of prepared abutment morphology and occlusal clearance, compared to their negative form. Techniques like pouring the check casts with salt incorporated dental plaster have been advocated but require an additional impression, contribute to laboratory workload, and the setting of the plaster mix is time-consuming. Recently, intraoral scanners have been successfully employed to evaluate the occlusal form three-dimensionally, but scanning is not cost-effective for every practitioner.[9] Therefore, the technique proposed in the article is simple and attempts to negate the previous shortcomings of verifying the abutment preparation three-dimensionally.

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	DOI: 10.4103/jips.jips_197_22

How to cite this article: Kaushik A, Chaudhary A, Khurana PR. A novel chairside technique to assess the interocclusal clearance and abutment axial walls during tooth preparation. J Indian Prosthodont Soc 2023;23:99-102.

PROCEDURE

In this technique, a modified Heister mouth gag forceps is used, where two opposing threaded screws of 3 mm width and 5 mm height are attached at the end of forceps arms which are precisely calibrated (up to 0.5 mm) on a curved scale, and a slidable metal stopper block which engages a V-shaped groove in one of the forceps arms near its furcation junction. The metal stopper provides a standardized opening of 13 mm at the forceps end [Figure 1]. This modified instrument acts as a mini-hinged articulator and enables quick mounting of the bite record.

1. Screw the forceps knob up to three turns to slightly open up the forceps arms before the clinical appointment
2. After a tentative occlusal reduction during tooth preparation, record the bite using an addition silicone bite registration material only in the region of prepared abutment [Figure 2]
3. Carefully cut the excess silicone index material adjacent to the abutment margin using a surgical blade number 22/23 [Figure 3]
4. Heat a Type 1 medium inlay wax stick over burner flame, and coat three to four layers on the abutment and opposing occlusal surface of silicone bite index [Figure 4]
5. Heat the threaded screws over the flame, orient the silicone index coated with inlay wax between them, and, immediately clamp the forceps arms until it contacts the metal stopper [Figures 5 and 6]. This enables the inlay wax to flow inside screw threads and mechanically retain on the forceps
6. After allowing the wax to cool down on its own, screw in the forceps knob to separate the silicone index from the inlay wax and clamp the forceps again until the arm rests on the stopper completely [Figure 6]. This is the 0 mm position on the graduated curved scale [Figure 7]
7. Slide the metal stopper sideways along the groove, from the forceps arm and clamp both the forceps arms together until the opposing cusps meet [Figure 8].

Figure 1: Parts of modified Heister mouth gag forceps instrument

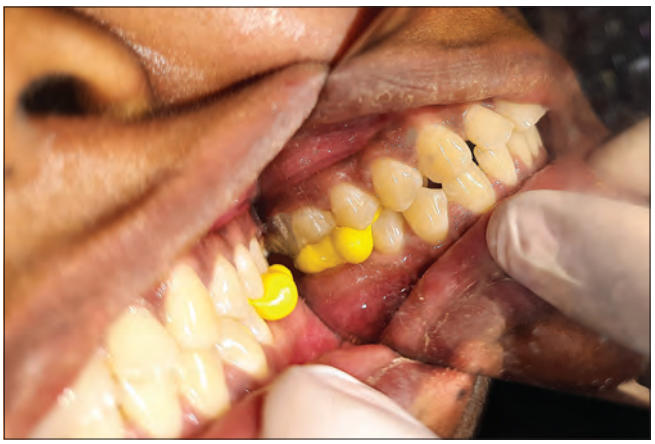

Figure 2: Selective silicone bite registration record of the prepared abutment

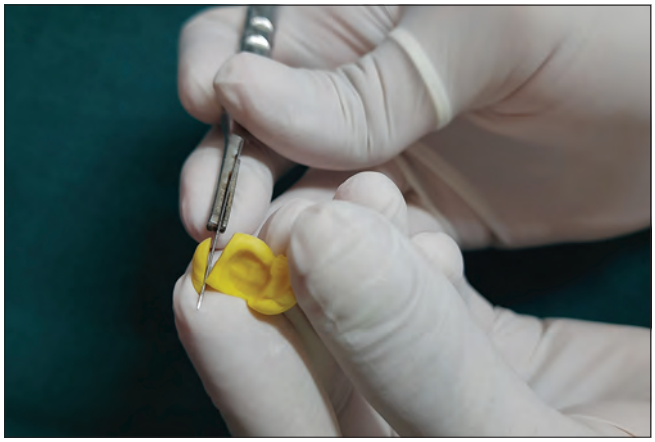

Figure 3: Cutting the excess silicone index material adjacent to the abutment

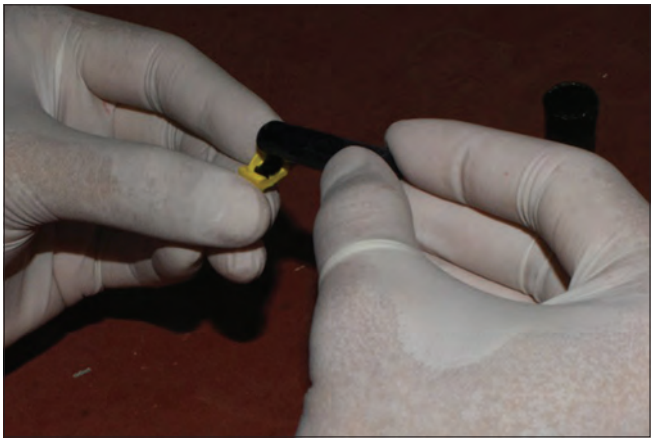

Figure 4: Dripping inlay wax on both sides of bite index

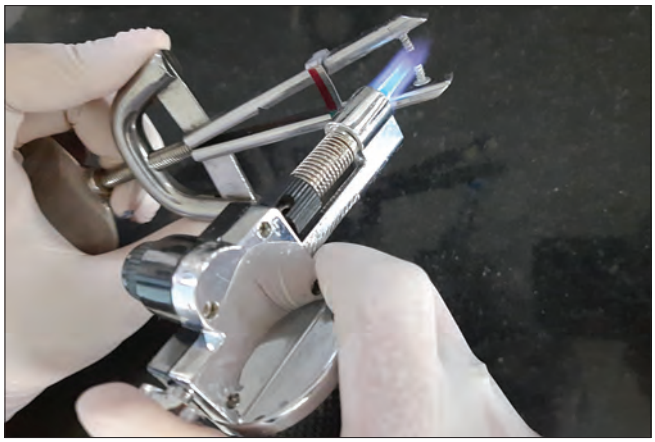

Figure 5: Heating the threaded screws of the instrument using a flame torch

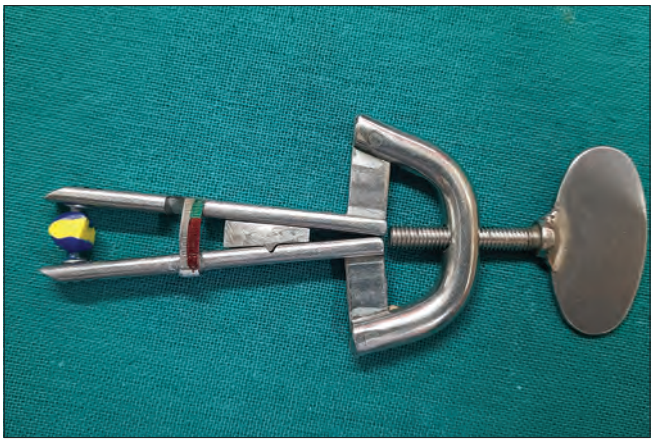

Figure 6: Mounted bite index and inlay wax on the instrument

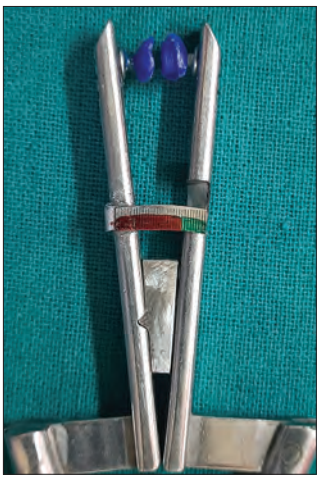

Figure 7: Assessment of abutment occlusal clearance with stopper in place

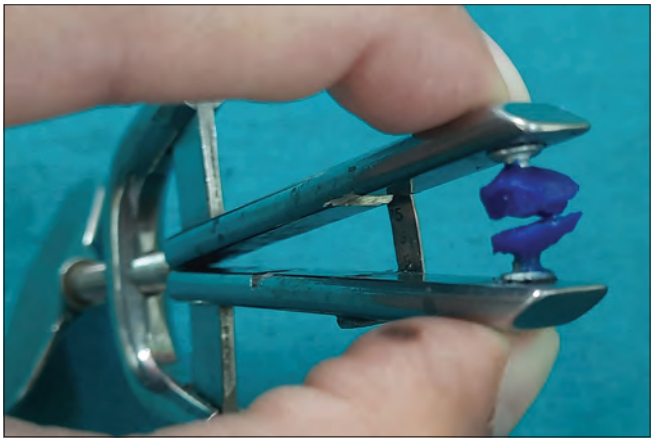

Figure 8: Assessing the first abutment contact after stopper removal

The reading on the scale now obtained, depicts the minimum occlusal clearance achieved in the tooth preparation [Figure 9]

8. Modify the abutment intraorally, in accordance with the measurements obtained on the scale
9. Evaluate the axial morphology of the abutment, after opening the arms of the forceps. Modify the axial walls in accordance with the undercuts, if present.

Clinical Implication: The modified instrument design enables the clinician to visually assess the positive replica of the prepared abutment tooth three-dimensionally, along with accurately measuring its interocclusal clearance, thereby allowing the rectification of abutment morphology chairside.

SUMMARY

The novel technique described using a modified Heister forceps is beneficial, as it would aid the clinician and dental students, in effectively preparing the abutment and be more assertive regarding its laboratory phase assessment including the absence of undercut and adequate occlusal clearance. The basic materials required for the procedure are readily available and cost-effective. The technique when performed takes less than 4 min compared to the standard check cast method and is equivalent to the learning curve of the intraoral scanner.[10] As no carving or shape manipulation of wax, the pattern is done at the formative stage, no force is exerted, and minimal residual stresses are incorporated into the wax used.

Acknowledgments

The authors thank their teachers from Davangere, for their guidance and motivation, and the anonymous reviewers for their insightful suggestions.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

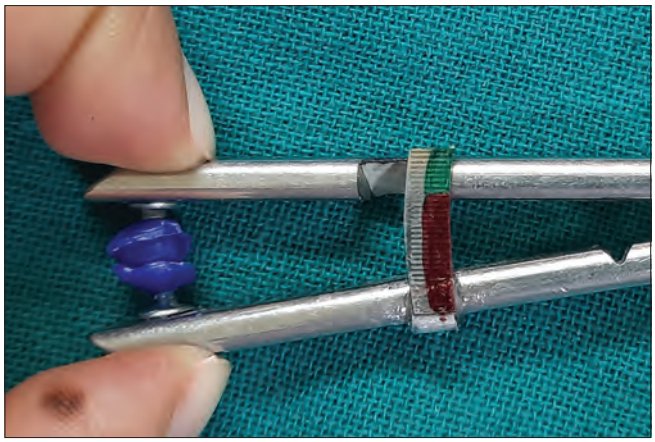

Figure 9: Curved metal scale depicting the minimum occlusal clearance achieved

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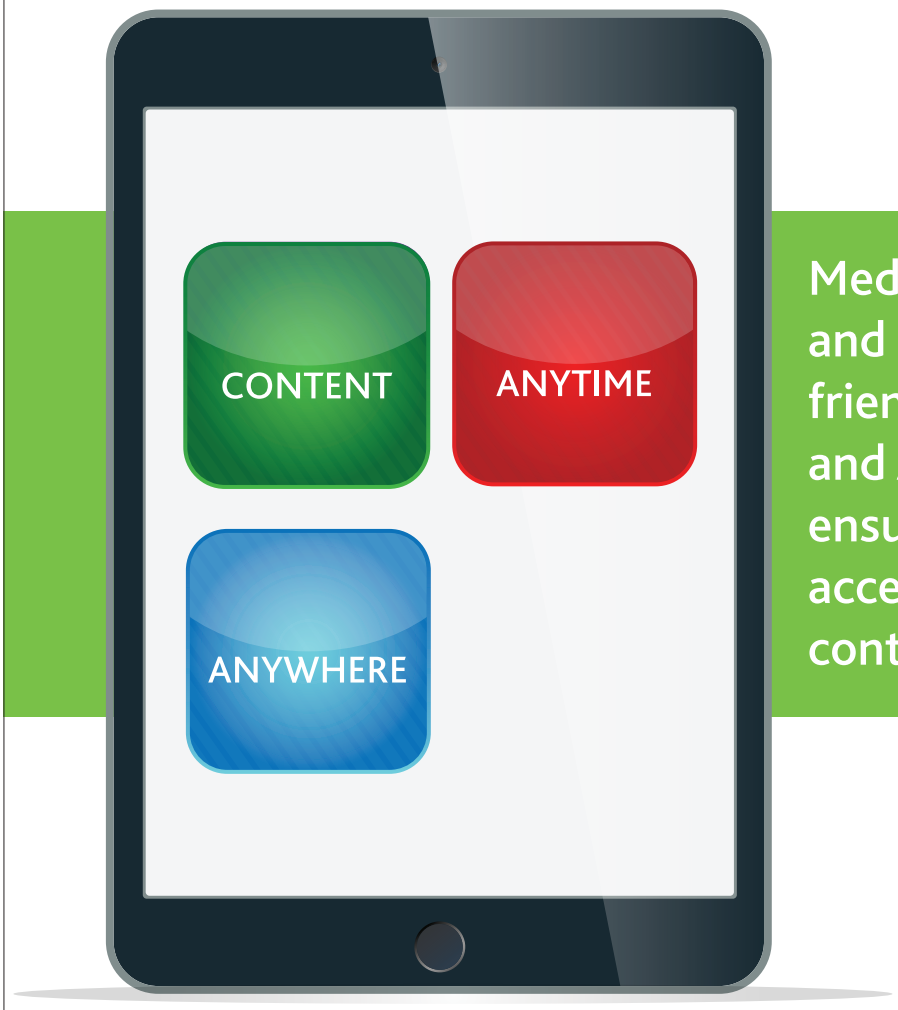

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