JIPS

THE JOURNAL OF INDIAN PROSTHODONTIC SOCIETY

Official publication of Indian Prosthodontic Society

Vol. 22 | Issue 3 | July-September 2022

Print ISSN 0972-4052
E-ISSN 1998-4057

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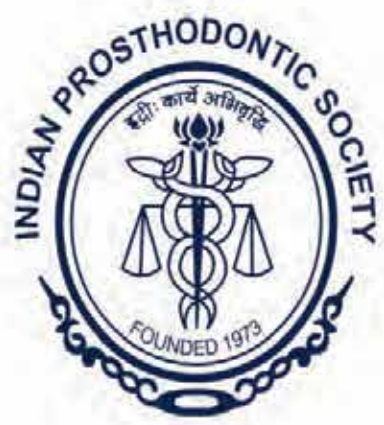

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The Journal of Indian Prosthodontic Society

Official Publication of Indian Prosthodontic Society

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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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  USD 185.00 for outside India
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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.

The Journal of Indian Prosthodontic Society

Official Publication of Indian Prosthodontic Society

Volume 22 ▪ Issue 3 ▪ July-September 2022

CONTENTS

CASE REPORTS

Finite element analysis – Concepts for knowledge and implementation in dental research

Finite element analysis (FEA) helps to visualize the location, direction, and magnitude of the applied force, and the stress evolved the three-dimensional anatomic structure, which may not be otherwise feasible in a clinical scenario.[1] The advantage is that the physical property of the material is unchanged by the applied force, and the tests can be done multiple times until there is no skewing of the results from the mean values. FEA is frequently used in dentistry by undergraduates and postgraduates for their short-term research, and the outcome solely depends on the analyst's perspective of understanding the clinical situation. Errors could occur during the stages, from designing a virtual model to the analysis of the results, and the researcher compiles this erroneous data for submission of the outcome. Literature in dentistry has defined the application of FEA, while this editorial will enable the researcher to provide clinicians' insight into finite element research to minimize errors for higher quality results.

At the **preprocessing stage**, based on the clinical scenario, the researcher could choose a one-dimensional (1D) element for a lengthy and thin structure such as wires, a two-dimensional (2D) element for plate or shell-like structures, and a three-dimension (3D) element for a structure that is solid and has complex geometry that cannot be simplified for analysis [Figure 1].[2] The researcher also needs to understand that analyzing the property of an implant in 1D or 2D could reveal a false outcome as the vertical impact of force at a point could create shear stress on another point of a solid body. Similarly, assessing a maxillary major connector in three dimensions could add an extra element to the dimension that may hamper the speed of processing. However, the false outcome will be minimal in a three-dimensional model design when real-time data are captured through cone-beam computed tomography. Planning to analyze a 2D element in 3D space gives a better in-depth output, provided the design requires the third space. Especially when assumptions are made for idealized geometry that would enable us to understand the material better at each cross sections.

Elastic modulus and Poisson's ratio of an element are available in the literature for isotropic and anisotropic models based on the complex anatomy of the human body or the device. Isotropic mineral crystals have the same and consistent characteristics throughout the material due to their uniform composition, and they are not direction-dimension dependent. Whereas, human tissues are anisotropic, with the mineral crystal related to the compositional differences having varying properties

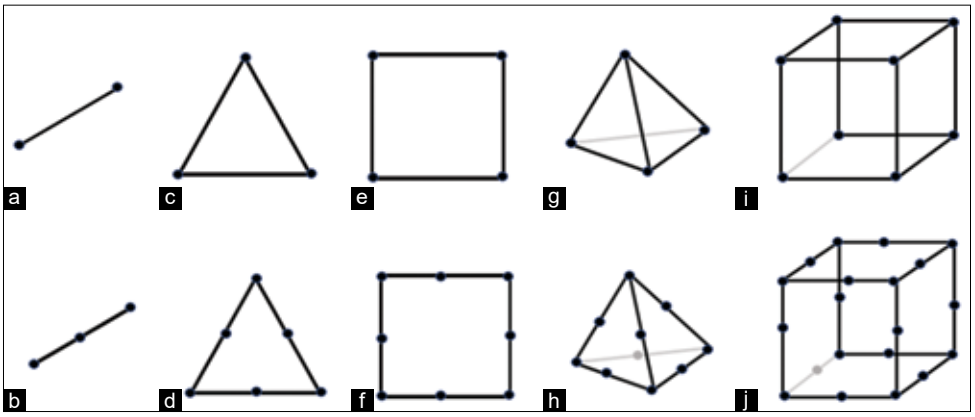

Figure 1: (a) 1D first order; (b) 1D second order; (c) 2D tri 3 (first order); (d) 2D tri 6 (second order); (e) 2D quad 4 (first order); (f) 2D quad 8 (second order); (g) 3D tet 4 (first order); (h) 3D tet 10 (second order); (i) 3D hex 8 (first order); (j) 3D hex 20 (second order), 1D: One dimensional, 2D: Two dimensional, 3D: Three dimensional

in different orientations of the mineral surface. These are direction-dimension dependent and hence, the researcher should assign appropriate values accordingly to the element.

An element can be meshed into triangular elements (TRI/TET), or more robust quadratic elements (QUAD/HEX) based on the first order or second order or third order. A 2D or 3D model can be a linear element, also called first order, whereas a quadratic element is referred to as second order.[3] The first order has the nodes only at the ends of a line [Figure 1a], whereas the second order and third order have additional nodes in between the lines to help in capturing the deformation in detail during an analysis [Figure 1b]. The presence of nodes at the center in second-order or third-order elements helps to model either a concave or convex shape and can show deformation on mapping to curvilinear geometry with ease. The second-order or third-order elements are advantageous when handling nonlinear elastoplastic or hyperelastic materials. However, the computational effort and duration taken for the output are higher than when using first-order elements. Most commonly, first-order elements are used for meshing, but high precision is obtained only with higher orders, especially when bending movement needs to be analyzed.

Nodes decide the mesh density that confirms the accuracy to yield a better output at minimal time consumption. A 2D mesh could be triangular with three nodes (first order) [Figure 1c], or six nodes (second order) [Figure 1d], or quadrilateral with four nodes (first order) [Figure 1e] or eight nodes (second order) [Figure 1f].[4,5] The triangular nodes are not better choices compared to the latter as they may give less detailed output, and a quadrilateral mesh is preferred, especially the eight nodes when modeling a 2D element for better strain output. A 3D mesh could be tetrahedral with four nodes (first order) [Figure 1 g], 10 nodes (second order) [Figure 1 h], or hexahedron with eight nodes (first order) [Figure 1i], 20 nodes (second order) [Figure 1j].[4,5] Similar to the 2D element, the second-order element is better for a 3D mesh, but computing a hex with a 20-node model would consume time. Hybrid meshing (hex-pyram-tetra) is a very special option where different mesh densities are used simultaneously in one single model, and not all software supports its application.[6] It is better to begin with a coarse mesh to monitor the time and accuracy, and later the mesh fineness can be improved. The mesh refinement methods include the h-method (MesH), which refers to reducing the size of the mesh; the p-method, which relates to an increase of the polynomial order in the element that is good for regions with a low-stress gradient; and the r-method, which relocates the position of a node.[7] The combinations of the methods, for example, "hr" is good for regions with a large stress gradient, "hp" for a low-stress gradient.[7]

The **processing stage** of biological structures is affected by the dynamic nature, and the models should be fixed by setting the boundary conditions of the environment to avoid inconsistent results. The researcher needs to decide whether to analyze the 2D element in 2D space or in 3D space or the 3D element in 3D space [Figure 2], as each inclusion of space adds extra data to the dimension. To avoid or minimize discretion errors in this process, the researchers can use higher-order shape functions or smaller elements. A 2D object should be fixed and stable in 3D space with the addition of a support element to the model [Figure 2c].[8] Evaluating the 2D object in 2D space would decrease the added data and fastens the outcome as the degree of freedom is reduced. However, the deformation (or buckling) of a 2D element out of space would not be considered [Figure 3]. For example, when an endodontic post material is evaluated at the point of impact for vertical loading in 2D space, the oblique loading beyond the point of impact may not be measurable. Hence, a 3D space is required that would increase the number of elements, and delay the process. Moreover, misinterpretation of multiple numerical data would also occur if the elements are not defined precisely.

Load applications in FEA are determined based on specific events such as a thermal cycle, shock from a drop, vibration, or static flexure.[9] The researchers should not simplify complex loads or reduce the number of loads from the optimum required for a test. Similarly, if the load is applied at two different regions which are at sufficiently large distances from the point of measurement, the effect of the load becomes insignificantly small at the area of analysis and may not represent the clinical situation. A static load would be time independent, whereas a dynamic load is time dependent. In a static load, the board-level displacement and elastic stresses/strains are analyzed and not the creep strains/energies, which is time-dependent plastic deformation. It is also essential to capture the inertial effect of an object in a dynamic load since the counteracting force that inhibits the motion of the object would alter the output. Hence, for a dynamic load, as in the investigation of solder fatigue, creep properties must be included, which are modeled by simulated cycles.

The researcher should perform a patch or single element test to determine the response to different loads before final processing and analyze different states of stress and strain to check the validity and inconsistency of the designed

model.[8] The researcher should choose plane strain to simulate the interior of a very thick component loaded in a single plane [Figure 4], and plane stress to simulate a very thin component and also the surface behavior of thick plates.[10] The presence of too small or large element aspect ratios (width and length ratio in the FEA model) and corner angles, warped elements, large Poisson's ratio, and increased curved shell element spans need to be analyzed before receiving the final output.[7] The researcher should ask the analyst to verify the coincident nodes (i.e., two nodes meeting at the same point when two elements are joined) and a proper mesh application along with the material property. An inbuilt automated adaptive solution in the software proceeds by refining the mesh until the maximum error is below the optimal limit.[8] The current research on polyhedral meshing and mesh-less (or mesh-free) analysis for reducing the meshing time is being experimented.[6] They are also highly accurate, with fewer degrees of freedom.

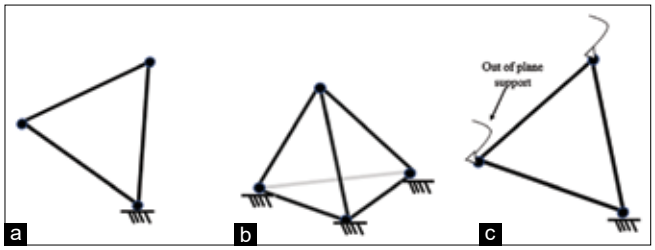

Figure 2: (a) 2D structure in 2D space; (b) 3D structure in 3D space; (c) 2D structure in 3D space, 2D: Two dimension, 3D: Three dimension

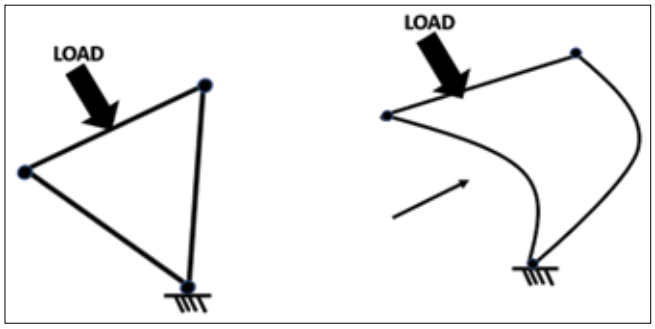

Figure 3: The buckling effect was seen in load application on 2D structure in 3D space, 1D: One dimension, 2D: Two dimension, 3D: Three dimension

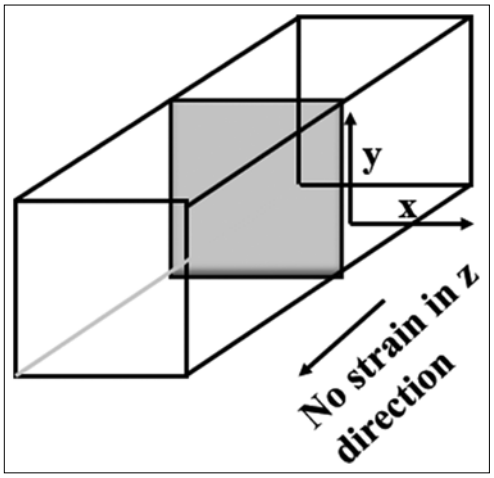

Figure 4: Plane strain for thick components assessed at x and y plane

Postprocessing stage to reduce the numerical error, a modified nonlinear iterative can be formulated; and to reduce the computing time, an adaptive time step size algorithm can be undertaken.[11] Integration errors caused by Gauss integration lead to numerical instabilities. To counteract, increasing the Gauss points is an option, but it is expensive.[7] Similarly, rounding off numerical data (such as 1.1567–1.2) for one element leads to the cumulative effect of appreciable error throughout the model. Hence, rounding should be done with caution.[7] The principle stresses should be zero at an unloaded boundary and the displayed stress, for example, principle stress versus shear stress versus Von Mises stress, should be closer to the standard model in literature or less skewed during the repetition of loading conditions. There should not be large displacements to cause a change in the force directions, especially when soft-tissue or periodontal ligament models are used, and this could be prevented by considering a nonlinear analysis. Nonlinear analysis helps in processing the dynamic behavior of the model like tooth movement and transient and residual stresses in dental materials.[6]

Innovative proposals that cannot be done through *in vivo* and *in vitro* studies make us rely on FEA, which has its own limitations in medical research to simulate a biomechanical environment. The limitations can be limited only if the researcher has a greater role in understanding the FEA model. Furthermore, the outcome of FEA should be accompanied by *in vitro* and/or *in vivo* models to confirm that the published design is effective.

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Submitted: 17-Jun-2022, **Revised:** 01-Jul-2022, **Accepted:** 01-Jul-2022, **Published:** ***

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Quick Response Code:

Website: www.j-ips.org

DOI: 10.4103/jips.jips_299_22

How to cite this article: Vaidyanathan AK, Banu RF. Finite element analysis – Concepts for knowledge and implementation in dental research. J Indian Prosthodont Soc 2022;22:211-4.

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Review

Survival rate of dental implant placed using various maxillary sinus floor elevation techniques: A systematic review and meta-analysis

Darshana Shah, Chirag Chauhan, Rajal Shah

Department of Prosthodontics, Ahmedabad Dental College and Hospital, Ahmedabad, Gujarat, India

Abstract

Aim: The aim of this systematic review is to evaluate the survival rate of dental implant placed using different maxillary sinus floor elevation techniques.

Setting and Design: PRISMA guidelines were used for this systematic review and meta-analysis.

Materials and Methods: Relevant articles were searched from Medline, PubMed, Google Scholar, ScienceDirect, and Cochrane trials. Articles published in English language were selected. Hand search was further conducted. For risk of bias, two tools were used, i.e., Cochrane tool for randomized controlled trials (RCTs) and new castle Ottawa quality assessment tool for non-RCTs.

Statistical Analysis: For statistical meta-analysis RevMan 5.4 software was used.

Results: Seventeen studies were finalized. All studies were included in the meta-analysis to check the implant survival rate. There is no statistical difference between direct and indirect techniques, and forest plot was derived for direct approach ($P = 0.688$, 95% confidence interval [CI] 0.9691) and for indirect approach ($P = 0.686$ and 95% CI 0.970).

Conclusion: There is no statistically significant difference in the survival rate of implant placed using direct or indirect sinus lift approach procedures. Hence, the technique is selected as per the indications given for each direct and indirect procedure.

Keywords: Bone grafting, crestal sinus lift and lateral window approach, dental implants, maxillary sinus, sinus floor elevation technique

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Submitted: 06-Jun-2022, **Accepted:** 06-Jun-2022, **Published:** ***

INTRODUCTION

The rehabilitation of missing or lost teeth by means of implant reconstruction is a predictable treatment option. Implant placement in the posterior maxilla is the most challenging. Poor bone quality and quantity are limiting factors, for which different methods have been proposed.[1-3]

The maxillary sinus is a pyramidal-shaped cavity in the maxilla with a volume of 12–15 ml. Its anterior border

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_283_22

How to cite this article: Shah D, Chauhan C, Shah R. Survival rate of dental implant placed using various maxillary sinus floor elevation techniques: A systematic review and meta-analysis. J Indian Prosthodont Soc 2022;22:215-24.

extends into the pre-molar roots or distal surface of canine roots, and the posterior border reaches the maxillary tuberosity.[4] Due to its structure and location, the maxillary sinus sometimes challenges the proper placement of the implant.[5]

Techniques used for vertical bone augmentation are direct, indirect and combination of both the techniques.[6]

Autogenous bone is the most commonly used grafting material and is considered gold standard.[7,8] SFE from a lateral window approach is most commonly used technique, which was first proposed by Tatum in 1977 and first published by Boyne and James in 1980.[1]

In comparison to SFE with a lateral window approach, the osteotome procedures are less invasive to elevate the membrane, reduces the operation time, and minimum postoperative discomfort,[10] was introduced by Summers in 1994.[7,9]

Selection of the techniques depends on the anatomy of sinus floor and lateral wall of sinus and the residual bone height (RBH). For bone height <5 mm, lateral window approach is performed and for height ≥5 mm crestal approach is performed. Hence, RBH is the deciding factor between the two methods.[11] The use of piezoelectric technique, preserves soft tissue and maintains precision and a clear surgical site without blood during bone cutting.[12] Antral membrane balloon elevation technique is a modification of bone-added osteotome sinus floor elevation technique. In this technique, antral membrane balloon elevation is carried out through the osteotomy site.[13-15]

Hence, various maxillary sinus lift techniques with different modifications are studied based on the availability of type and amount of bone. The aim of this systematic review is to evaluate the survival rate of implants placed with different maxillary sinus lift procedures through a meta-analysis.

MATERIALS AND METHODS

To carry out this review PRISMA guidelines and population, intervention, comparison, outcome, and study design (PICOS) structure were used to develop the search strategy.

Population, intervention, comparison, outcome, and study design framework

According to PICOS strategy, *P* represents patients having maxillary edentulous space in the posterior region requiring sinus floor elevation for implant placement, I represents maxillary sinus floor elevation for dental implant placement, C represents different sinus floor elevation techniques, O represents survival rate of dental implants and S represents combination of *in vivo* studies including randomized controlled trial (RCT), prospective, retrospective, and clinical studies.

Search strategy

An electronic literature search focusing on the purposes was performed using PubMed, Medline, Embase, and Cochrane from 1997 to 2020. The search methodology applied was combination of MeSH terms and keywords such as maxillary sinus, bone grafting, dental implants, sinus floor elevation technique, crestal sinus lift, lateral window approach, and survival rates. The searches were limited to articles written in English with an associated abstract. The studies found after hand search was also included.

Inclusion criteria

1. Prospective and retrospective studies
2. Cohort studies and randomized control trial
3. Studies on human
4. ≥6 months to ≤5 years of follow-up period
5. Studies with all different sinus floor elevation techniques.

Exclusion criteria

1. Case reports
2. Non-clinical studies
3. Animal studies
4. Inadequate data
5. Systematic reviews and meta-analyses already undertaken.

Screening for selection

The titles and abstracts were examined by two investigators. The complete text of relevant research articles was given to each investigator to review independently. The third investigator resolved the disagreement and conflict regarding the inclusion of the articles.

Risk of bias

For randomized control trials, Cochrane risk of bias tool was used and for non-randomized trials new castle Ottawa scale was used [Tables 1, 2 and Graph 1].

Statistical analysis

The statistical analysis was carried out for included studies according to the data, on survival rate of implant placement using various sinus lift procedures through meta-analysis. For this, all the data according to inclusion criteria were taken into consideration. Mean value, *P* value, and heterogeneity values were obtained and the forest plots were obtained for both direct and indirect sinus lift techniques, RevMan 5.4 software was used.

Table 1: Risk of bias based on new castle Ottawa Quality Assessment Scale for cohort study

Study	Selection				Comparability	Outcome			Total quality score
	Representativeness of the exposed cohort	Selection of the nonexposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis controlled for confounders	Assessment of outcome	Was follow-up long enough for outcomes to occur	Adequacy of follow-up of cohorts	
Zitzmann and Schiirer[16]	1	1	1	1	1	0	1	1	7
Tawil and Mawla[17]	1	0	1	1	1	0	1	1	6
Fugazzotto and Paoli[18]	0	0	1	1	1	0	1	1	5
Fugazzotto[19]	1	1	1	1	1	0	1	1	7
Leblebicioglu *et al*.[20]	1	0	1	1	1	0	1	1	6
Bornstein *et al*.[21]	1	0	1	1	1	0	1	0	5
Baldi *et al*.[23]	1	0	1	1	1	1	1	1	7
Mazor *et al*.[24]	1	0	1	1	1	0	1	1	6
Fermergård and Åstrand[25]	1	0	1	0	1	0	1	1	5
Li *et al*.[26]	1	0	1	1	1	0	1	1	6
Gu *et al*.[27]	1	0	1	1	1	1	1	1	7
Brizeula *et al*.[28]	1	0	1	1	1	0	1	1	6
Rao and Reddy[29]	1	0	1	1	1	0	1	1	6
Cara-Fuentes *et al*.[30]	1	1	1	0	1	0	1	1	6
Hussein and Hassan *et al*.[31]	1	1	1	1	1	0	1	1	7
Molemans *et al*.[32]	1	0	1	1	0	0	0	1	4

Table 2: Determining the Quality of Studies Based on Newcastle-Ottawa Scale

Study	Selection	Comparability	Outcome	Total quality score	Quality of Study
Zitzmann and Schiirer[16]	4	1	2	7	Good
Tawil and Mawla[17]	3	1	2	6	Good
Fugazzotto and Paoli[18]	2	1	2	5	Fair
Fugazzotto[19]	4	1	2	7	Good
Leblebicioglu *et al*.[20]	4	1	2	6	Good
Bornstein *et al*.[21]	3	1	1	5	Good
Baldi *et al*.[23]	3	1	3	7	Good
Mazor *et al*.[24]	3	1	2	6	Good
Fermergård and Åstrand[25]	2	1	2	5	Fair
Li *et al*.[26]	3	1	2	6	Good
Gu *et al*.[27]	3	1	3	7	Good
Brizeula *et al*.[28]	3	1	2	6	Good
Rao and Reddy[29]	3	1	2	6	Good
Cara-Fuentes *et al*.[30]	3	1	2	6	Good
Hussein and Hassan *et al*.[31]	4	1	2	7	Good
Molemans *et al*.[32]	3	0	1	4	Good

According to Newcastle-Ottawa Scale: The study was classified as good quality (''3 or 4 stars in selection domain,'' ''1 or 2 stars in comparability domain,'' and ''2 or 3 stars in outcome/exposure domain''), fair quality (''2 stars in selection domain,'' ''1 or 2 stars in comparability domain,'' and ''2 or 3 stars in outcome/exposure domain.'') and poor (''0 or 1 star in selection domain,'' ''0 stars in comparability domain,'' or ''0 or 1 star in outcome/exposure domain)

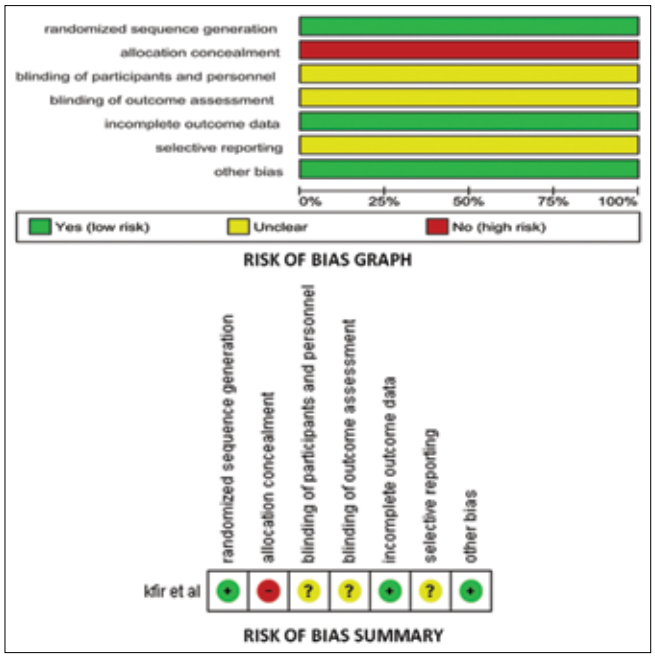
RESULTS

Study selection

The search identified 895 titles on maxillary sinus lift techniques, out of which 835 were excluded on the basis of titles. Out the 60 titles selected, only 37 articles were selected on the bases of abstract. After full-text analysis, 19 articles were selected and further two more articles were excluded as per inclusion–exclusion criteria and inappropriate data. Thus, 17 articles were selected for the present systematic review [Figure 1].

Study characteristics

The 17 articles selected were published between 1998 and 2020. The research comprised nine clinical studies, five prospective,



Graph 1: Kfir *et al.* 2009 randomized control trial (cochrane risk of bias tool)

two retrospective studies, and one RCT study in the present study, a total of 337 implants were placed using direct approach and 922 implants were placed using indirect approach [Table 3].

Meta-analysis

Follow-up period ≥6 months was considered after implant placement and meta-analysis was obtained for both direct and indirect approach [Tables 4-6 and Figures 2-4]. A forest plot was fabricated [Figures 2-4].

Figure 2, forest plot for studies using direct approach[16,17,21,29,30,32] depicted $P = 0.688$, 95% confidence interval [CI] 0.969.

Figures 3 and 4, forest plot for studies using indirect approach[16,18-20,22-28,31,32] depicted $P = 0.686$ and 95% CI 0.970.

Graph result

The survival rate of each technique was calculated and given [Tables 7, 8 and Figures 5, 6].

Overall survival rate for direct approach is 95.98% and for indirect approach is 95.79%.

There was no major mean difference in the survival rate of direct approach and indirect approach.

DISCUSSION

Systematic reviews are considered as best evidence from the scientific literature. Different techniques have been

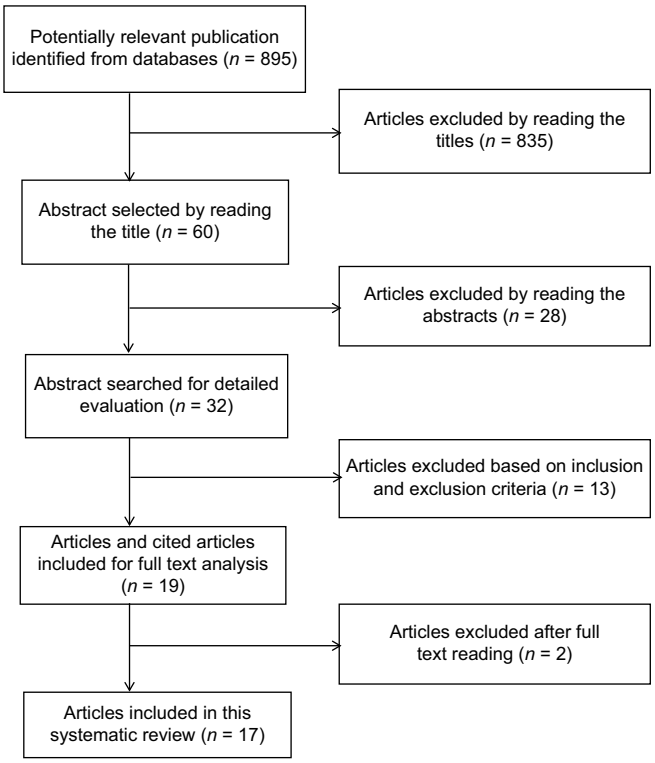


Figure 1: Flow-chart of the search strategy

used for maxillary sinus lift procedures for implant placement in the posterior maxilla region based on the availability of RBH. Thus, this systematic review was carried out to evaluate the available data on various maxillary sinus floor elevation. Analyzing survival outcomes of implant placed through various direct and indirect sinus lift techniques was one of the primary objectives of this systematic review. Nine clinical studies, six prospective, and two retrospective studies were identified and included in this systematic review. In this review, *in vivo* studies were included because they are well accepted for supplying basic scientific knowledge and for their clinical relevance.

Sinus lift techniques are most commonly used and highly predictable surgical procedure to overcome bone height deficiencies in the posterior maxilla (Wallace *et al.* 2007).[15] RBH for all lateral antrostomy procedure was <5 mm and >5 mm for crestal approach [Table 3]. Complications that occurred during sinus floor elevation are: bleeding from sinus membrane or from lateral bony window (Solar *et al.* 1999), laceration of the buccal flap, injury to infra-orbital nerve, and accidental membrane perforation (Pikos 2006). Modifications with direct as well as indirect techniques used reduced the complications during the procedures. Bone grafting done using bio-Oss and autogenous bone increased the implant survival rate. Furthermore, pre- and post-surgical antibiotic administration helped in

Table 3: Summary of all maxillary sinus floor elevation techniques in included studies

Study year	Study type	Number of patients	Number of implants (L, D and S.T)	Sinus augmentation techniques	With or W/O graft	Residual bone height	Gained bone height	Prosthetic solution	Follow up period (years)	Number of failure	Survival rate
Zitzmann and Schiirer, 1998[16]	Clinical report	30	79 L: 8.5–10 mm	20 I: Lateral approach (DI) 59 I: Osteotome (IN)	Bio-oss Bio-gide	DI: 2.3–5 mm IN: 8.8 mm	DI: 12.7 mm IN: 3.5 mm	-	2–3	3 (bio)	96% overall DI: 100% IN: 95%
Tawil and Mawla, 2001[17]	Clinical report	29	61 41 immediate 20 delayed L: 8–15 mm D: 3.75 mm	Lateral approach (DI) by elevation osteotomy	Bio-oss	Delayed: <5 mm IMM: >5 mm	-	PFM	1.5–2 years	9	93.1%
Fugazzotto and Paoli 2002[18]	Clinical report	150	167 D: 4.8 mm or 5 mm L: 10–11.5 mm	Osteotome with modified trephine (IN)	Bioabso-rbable	-	-	-	3 years	3 (bio)	97.8
Fugazzotto, 2002[19]	Clinical report	103	116 D: 3.75–4.8 mm L: 7–11 mm	Osteotome with modified trephine (IN)	-	4–5 mm	-	PFM, FPD, IRRPD	4 years	2 (bio)	98.3%
Leblebicioglu *et al.*, 2005[20]	Clinical report	40	75 29 I: L: 11±1.7 mm 46 I: 13.5±1.06 mm	Osteotome (IN)	No graft	<9 mm or 9 mm	29 I: 3.9±1.9 mm 46 I: 2.9±1.2 mm	SC: 33 I FPD: 40 I	2 years	2 (bio)	97.3%
Bornstein *et al.*, 2008[21]	Prospective study	56	111 TPS/SLA L: 8–12 mm D: 4.1 or 4.8 mm	Lateral approach (DI) with hinge technique	Autogenous	<4 mm	-	FPD: 40 I SSC: 71 I	Upto 5 years	2 (bio) 11 I dropouts	98% (SLA - 100%) (TPS - 89%)
Kfir *et al.*, 2009[22]	RCT	112	219 D: 3.75–5 mm L: 13–17.1 mm	Indirect using antral membrane balloon elevation	With graft	≤6 mm	≥10 mm	-	0.5–1 year	11 (bio + tech)	95%
Baldi *et al.*, 2011[23]	Prospective study	25	36 D: 3.75–5 mm L: 10–11.5 mm DAE	Crestal approach (IN) with piezosurgery and osteotome	Bio-oss	3–7.5 mm	6.78 mm	Fixed	Upto 5 years Minimum 1 year	1 2 dropouts	97%
Mazor *et al.*, 2011[24]	Clinical report	20	37 L: 13 mm D: 5 mm	Indirect using antral membrane balloon elevation (flapless)	With graft	2–6 mm	-	PFM crowns	1.5 years	0	100%
Fermergård and Åstrand, 2012[25]	Retrospective study	36	53 L: 9–13 mm D: 4.5 mm	Osteotome (IN)	W/O graft	6.3±0.3 mm	4.4±0.2 mm	-	Upto 3 years	3 (tech)	94%
Li *et al.*, 2013[26]	Clinical report	23	33 D: 4.1–4.5 mm L: 10–12 mm	Piezo with hydraulic pressure	Bio-oss	2–5 mm	7.5±0.9 mm	-	2–3 years	0	100%
Gu *et al.*, 2016[27]	Prospective study	25	37: SLA	Indirect approach	W/O graft	≤4 mm (2.81)	-	-	Upto 5 years	2 (bio)	94.6%
Brizeula *et al.*, 2014[28]	Prospective study	37	36 D: 3.5 and 4.1 mm L: 10 and 8 mm	Osteotome (IN)	W/O graft	4–9 mm (7.4±0.4 mm)	1.8±0.3 mm 4 I: >3 mm	Fixed	Upto 2 years	1 (bio) 1 PT drop out	91.6%
Rao and Reddy 2014[29]	Clinical report	34	62	Lateral approach with AMBE	Autogenous	4.2 mm (1.8–6.4 mm)	7.5 mm (5.2–10.5 mm)	-	Upto 3 years	2	96.8%

Contd...

Table 3: Contd...

Study year	Study type	Number of patients	Number of implants (L, D and S.T)	Sinus augmentation techniques	With or W/O graft	Residual bone height	Gained bone height	Prosthetic solution	Follow up period (years)	Number of failure	Survival rate
Cara-Fuentes *et al*., 2016[30]	Retrospective study	51	76 L: 11.1–11.2 mm D: 4–4.1 mm	Direct with piezo	With and W/O graft	4–7 mm	2.7±0.9 mm 2.6±0.9 mm	-	2–2.5 years 924 days - with 1177 days - W/O graft	With graft: 2 W/O: 1	93% (with) 97% (W/O)
Hussein and Hassan, 2017[31]	Prospective study	24	32 SLA Study group: 16 Control group: 16	Osteotome with AMBE	ORC graft	≤6 mm	6.48 mm	-	1 year	3	90.62%
Molemans *et al*., 2019[32]	Cohort	26	29 SLA Indirect: 22 Direct: 7 L: 9.61–10 mm D: 4.2–4.8 mm	Indirect with osteotome and direct with piezosurgery	With PRF	6.2±1.5 mm (IN) 4.6±1.8 mm (DI)	3.4±1.2 mm 5.4±1.5 mm	-	0.5 year	2 (bio) (IN)	97.8% (IN) 100% (DI)

DI: Direct, IN: Indirect, FPD: Fixed partial dentures, RCT: Randomized controlled trial, PRF: Platelet rich fibrin, TPS: Ti plasma sprayed, SLA: Sand blasting, large grit and acid etch, W/O: Without, IMM: Immediate, PFM: Porcelain fused to metal, IRRPD: Implant retained removable partial denture, DAE: Dual acid etching, AMBE: Antral membrane balloon elevation, SC: Single crown, SSC: Stainless steel crown, IN: Indirect, DI: Direct, S.T: Surface treatment

Table 4: Direct sinus lift technique

Author	Year	*n*	*N*	Proportion	95% LL	95% UL
Zitsm Ann *et al*.	1998	76	79	0.962	0.920	1.004
Tawil *et al*.	2001	57	61	0.934	0.872	0.997
Bornstein *et al*.	2008	109	111	0.982	0.957	1.007
Rao *et al*.	2014	60	62	0.968	0.924	1.012
Carafuentes *et al*.	2016	72	76	0.947	0.897	0.998
Molemans *et al*.	2019	28	29	0.966	0.899	1.032

Binary random-effects model			
Estimate proportion	95% LL	95% UL	SE	*P*
0.969	0.952	0.985	0.009	<0.001

Heterogeneity			
T^2	Q (df=8)	Heterogeneity *P*	I^2
0	3.076	0.688	0%

LL: Lower limit, UL: Upper limit, SE: Standard error

infection-free field for surgery and also reduced discomfort to the patient postsurgery.

It is difficult to compare the large number of studies on maxillary sinus lift techniques due to differences in type of implants used, the patient's follow-up and quantity of residual bone present, techniques used, and evaluation methods.[33]

In the present study, a total of 337 implants were placed using direct approach from six included studies. Modifications such as piezosurgery and antral membrane balloon elevation were used in three studies by direct approach. Two studies were carried out using piezosurgery that provided advantage of atraumatic sinus elevation and clear surgical site. Although studies that used Piezosurgery preparation for lateral window approach showed sinus perforation rate of 3.6%.[34]

One study with subantral membrane elevation via balloon was included along with direct approach, which is considered less technique sensitive, proposed by Soltan and Smiler.[35] Few studies[35,36] have documented antral balloon elevation method. Kfir *et al*.[22] achieved success in 91.6% for initial 12 patients and 100% success in second series of 12 patients, without complications. In antral balloon elevation method along with direct approach, initial procedural success was 100% and implant survival rate 96.8% after 6 months of follow-up.[29] Major advantages of antral balloon protocol are low incidence of infection and bleeding and low risk of perforation of sinus membrane, even in anatomically complex conditions.[37]

A lateral window approach is considered to be performed with a residual bone <5 mm. One-step and two-step lateral antrostomies are performed where one step was performed with RBH 4–6 mm in which simultaneous

implant placement was done along with elevation. Moreover, majorly two-step is performed where bone graft material is placed and waited and implant placement is done after 6–8 months.[16] More bone gain was obtained nearly 10–12.7 mm through lateral window approach compared to osteotome technique (Zitzmann *et al*., 1998).[16]

Table 5: Indirect sinus lift technique using osteotome

Author	Year	*n*	*N*	Proportion	95% LL	95% UL
Zitsmann *et al*.	1998	76	79	0.962	0.92	1.004
Fugazzotto *et al*.	2002	163	167	0.976	0.953	0.999
Fugazzotto *et al*.	2002	114	116	0.983	0.959	1.006
Leblebicioglu *et al*.	2005	73	75	0.973	0.937	1.01
Fermergard *et al*.	2012	50	53	0.943	0.881	1.006
Xin Gu *et al*.	2014	35	37	0.946	0.873	1.019
Brizuela *et al*.	2014	33	36	0.917	0.826	1.007
Hussien and Hassan *et al*.	2017	29	32	0.906	0.805	1.007
Molemans *et al*.	2019	28	29	0.966	0.899	1.032
Binary random-effects model Metric: Proportion						
Estimate proportion	**95% LL**		**95% UL**		**SE**	***P***
0.971	0.958		0.984		0.007	<0.001
Heterogeneity						
T^2	**Q (df=8)**		**Heterogeneity *P***		I^2	
0	5.525		0.700		0%	
Author	**Year**	***n***	***N***	**Proportion**	**95% LL**	**95% UL**
Indirect sinus lift technique using piezosurgery						
Baldi *et al*.	2011	35	37	0.946	0.873	1.019
Li *et al*.	2013	33	33	0.985	0.945	1.026
Indirect sinus lift technique using antral membrane balloon elevation						
Kfir *et al*.	2009	208	219	0.950	0.921	0.979
Mazor *et al*.	2011	37	37	1.000	0.951	1.023

LL: Lower limit, UL: Upper limit, SE: Standard error

Out of 337 implants placed, 18 implants failure resulted using direct approach with overall survival rate of 96.9%.

A total of 13 studies are included of maxillary sinus floor elevation using osteotome technique, in which total of 922 implants are placed. The osteotome technique was most frequently performed a study to elevate antral membrane. The advantage of this technique, as contrasted with lateral approach, are that it is less invasive and that it has shorter healing and waiting period. The increase of 3.5 mm of bone was noticed which is slightly below the values reported by summers.[12]

When 4 to 5 mm of alveolar bone is available below the sinus floor, the use of osteotomes is considered less traumatic than repeated malleating to the patients. The author has utilized a formula of 2 × 2 as the maximum size of the implant to be placed following trephine and osteotome core implosion. If 5 mm residual bone is present, maximum of 8 mm implant length will be contemplated. If a longer implant is desirable osteotome with modified trephine technique is imploded.[38]

Out of 13 studies included with indirect approach, nine studies performed osteotome technique in indirect approach with the overall survival rate of 97.1% of osteotome technique. Two studies were performed with indirect approach using Piezosurgery with survival rate 94.6% and 98.5%. Moreover, two studies were performed with antral membrane balloon elevation method with survival rate of 95% and 100%.

Table 6: Indirect sinus lift techniques (overall)

Author	Year	*n*	*N*	Proportion	95% LL	95% UL
Zitsmann *et al*.	1998	76	79	0.962	0.92	1.004
Fuggazotto *et al*.	2002	163	167	0.976	0.953	0.999
Fugazzotto *et al*.	2002	114	116	0.983	0.959	1.006
Leblebicioglu *et al*.	2005	73	75	0.973	0.937	1.01
Kfir *et al*.	2009	208	219	0.950	0.921	0.979
Baldi *et al*.	2011	35	37	0.946	0.873	1.019
Maxor *et al*.	2011	37	37	1.000	0.951	1.023
Fermergard *et al*.	2012	50	53	0.943	0.881	1.006
Li *et al*.	2013	33	33	1.000	0.945	1.026
Xin Gu *et al*.	2014	35	37	0.946	0.873	1.019
Brizuela *et al*.	2014	33	36	0.917	0.826	1.007
Hussien and Hassan *et al*.	2017	29	32	0.906	0.805	1.007
Molemans *et al*.	2019	28	29	0.966	0.899	1.032
Binary random-effects model						
Estimate proportion	**95% LL**		**95% UL**	**SE**		***P***
0.970	0.959		0.981	0.006		<0.001
Heterogeneity						
T^2	**Q (df=8)**		**Heterogeneity *P***	I^2		
0	9.193		0.686	0%		

LL: Lower limit, UL: Upper limit, SE: Standard error

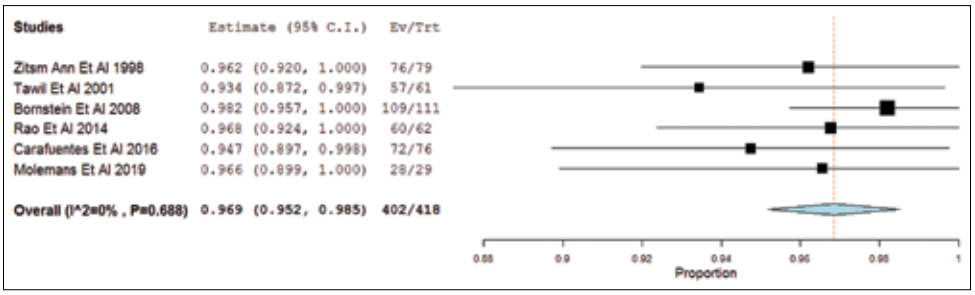


Figure 2: Forest plot for direct technique

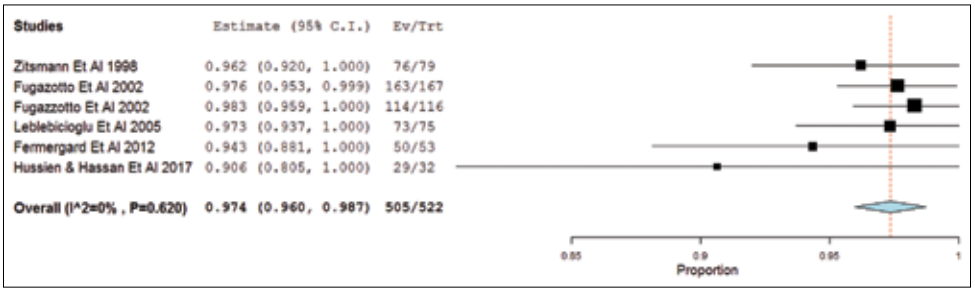


Figure 3: Forest plot for indirect technique using osteotome

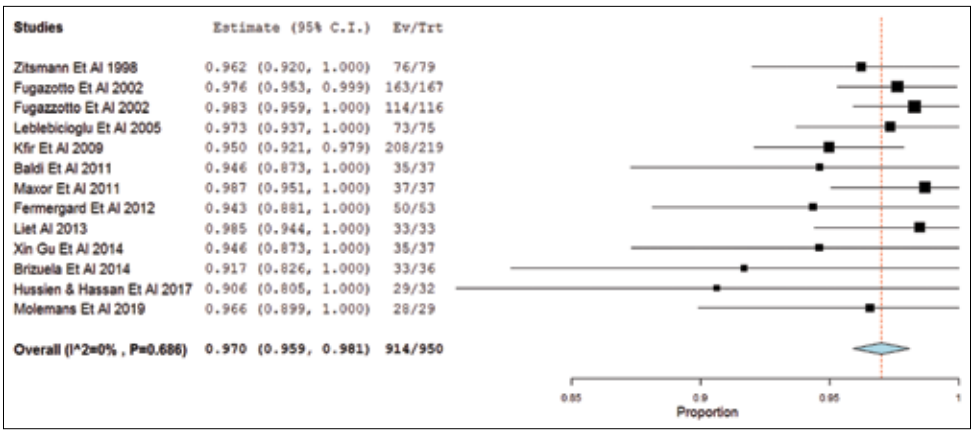


Figure 4: Forest plot all indirect techniques

Table 7: Survival rate of direct approach procedures (%)

Study and year	Sinus floor elevation technique	Survival rate (%)
Zitzmann and Schiirer, 1998[16]	Direct approach with modified Caldwell–Luc	96.2
Tawil and Mawla, 2001[17]	Direct approach with elevation osteotomy	93.4
Bornstein *et al*., 2008[21]	Direct approach with hinge technique	98.2
Rao and Reddy, 2014[29]	Direct approach with antral membrane balloon elevation	96.8
Cara-Fuentes *et al*., 2016[30]	Direct approach with piezosurgery	94.7
Molemans *et al*., 2019[32]	Direct approach with piezosurgery	96.6
Total mean		95.98

Bio-oss graft material showed good clinical results, reported by Hallman and Nordin[39,40] who used it in connection with a conventional sinus lift and Brägger *et al*.[41] who used it with osteotome sinus floor elevation.

Even there are very limited studies with hydraulic sinus floor elevation that fulfilled the inclusion criteria of the study conducted. Hydraulic forces avoided the rupture of the sinus membrane using osteotome techniques. One study by Li *et al*. in 2013[26] showed 100% survival rate of implant using hydraulic pressure technique.

Hence, a total of 35 implants failed out of 922 implants placed using indirect techniques with the overall survival rate of 97%.

Table 8: Survival rate of indirect approach procedures (%)

Study and year	Sinus floor elevation technique	Survival rate (%)
Zitzmann and Schiirer, 1998[16]	Indirect approach with osteotome	96.2
Fugazzotto and Paoli, 2002[18]	Indirect approach with osteotome	97.6
Fugazzotto, 2002[19]	Indirect approach with osteotome	98.3
Leblebicioglu *et al*., 2005[20]	Indirect approach with osteotome	97.3
Kfir *et al*., 2009[22]	Indirect approach with antral membrane balloon elevation	95
Baldi *et al*., 2011[23]	Indirect approach with piezosurgery and osteotome	94.6
Mazor *et al*., 2011[24]	Indirect approach with antral membrane balloon elevation	100
Fermergård and Åstrand, 2012[25]	Indirect approach with osteotome	94.3
Li *et al*., 2013[23]	Indirect approach with piezosurgery	98.5
Gu *et al*., 2016[27]	Indirect approach with osteotome	94.6
Brizeula *et al*., 2014[28]	Indirect approach with osteotome	91.7
Hussein and Hassan, 2017[31]	Indirect approach with antral membrane balloon elevation	90.6
Molemans *et al*., 2019[32]	Indirect approach with osteotome	96.6
Total mean		95.79

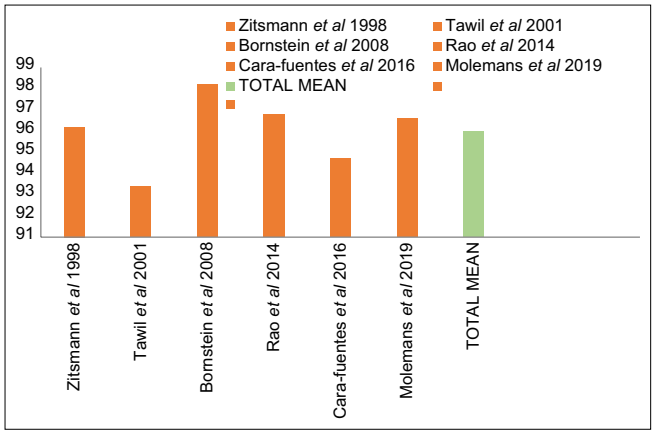


Figure 5: Survival rate of direct approach procedures (%)

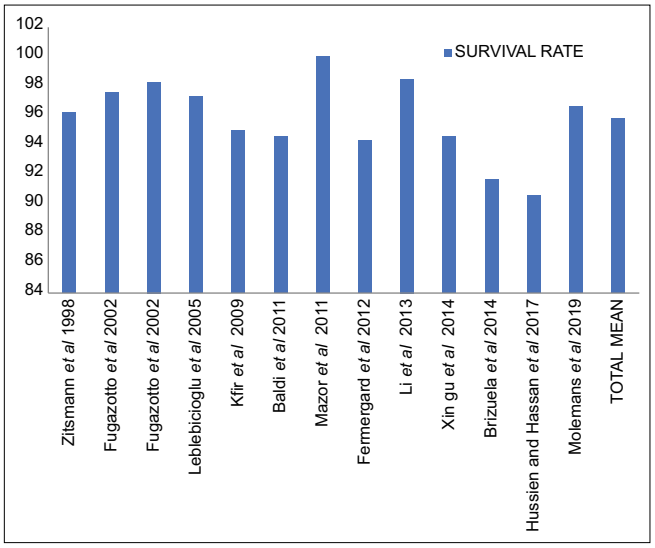


Figure 6: Survival rate of indirect approach procedures (%)

In this review, implants used were surface treated with Ti plasma-sprayed (TPS) and SLA (sandblasting, large grit, and acid etch). According to Bornstein *et al*., in their study, SLA implants showed 100% survival rate and TPS implants showed 89% survival rate.[21]

Biological and mechanical complications might cause failure in implant therapy.[42]

The results of the study showed, furthermore extensive future studies are needed especially a randomized control trial as such studies are lacked in the present research study along with newer modifications involving sinus floor elevation using hydraulic pressure and antral membrane balloon elevation methods.

CONCLUSION

Hence, summarizing and highlighting the findings of this systematic review, the following conclusions are drawn:

- Overall survival rate of implants placed by direct approach is 96.9%
- Overall survival rate of implants placed using indirect approach is 97%.

Due to the limited number of well-performed RCT studies published to date, this systematic review concludes that there is no statistically significant difference in the survival rate of implant placed using direct and indirect approach procedures. Hence, the technique is selected as per the indications given for each direct and indirect technique.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Research

Evaluation of customized cobalt-chromium abutments fabricated with different manufacturing process versus titanium stock abutments on the marginal misfit -An *in vitro* study

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Abstract

Aim: Accurate fit of the abutment to the implant is required for the uniform load distribution throughout the assembly. The study aims to compare the marginal misfit of titanium stock abutments with the cobalt-chromium (CoCr) customized abutments fabricated with the different manufacturing processes in internal hex implant-abutment connection using an appropriate scanning technique.

Setting and Design: *In vitro* comparative study.

Materials and Methods: A total of 40 abutments were included in the study. Ten titanium stock abutments were used as control (Group CN) and 30 CoCr abutments were fabricated and taken as the test group. Stock abutments were scanned and from obtained images test group abutments were fabricated as follows: Ten cast abutments (Group CA), 10 sintered abutments (Group SA), and 10 milled abutments (Group MA). Endosseous implanst having internal hex connections were matched with 10 stock abutments and 30 customized CoCr abutments. Implants were mounted in a clear epoxy resin block and the abutments were then fitted onto the implants with a torque of 30Ncm. The marginal discrepancy at implant-abutment connections was measured with confocal laser scanning microscope.

Statistical Analysis Used: One-way ANOVA and Tukey's *post hoc* test was done for statistical analysis.

Results: One-way ANOVA revealed a significant difference in marginal misfit of abutments. The mean marginal misfit was lowest for stock abutments (0.35 ± 0.009 μm). Among the customized abutments, the mean marginal misfit was highest for cast abutments (2.44 ± 0.445 μm) followed by sintered abutments (1.67 ± 0.232 μm) and least for milled abutments (0.65 ± 0.041 μm). A significant difference was found in marginal misfit with cast abutments and sintered abutments when compared to stock abutments ($P < 0.001$). The difference in marginal misfit was insignificant between stock abutments and milled abutments ($P = 0.052$).

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Submitted: 27-Jul-2021, **Revised:** 26-Dec-2021, **Accepted:** 08-Mar-2022, **Published:** ***

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_381_21

How to cite this article: Sutradhar W, Mishra SK, Chowdhary R. Evaluation of customized cobalt-chromium abutments fabricated with different manufacturing process versus titanium stock abutments on the marginal misfit -An *in vitro* study. J Indian Prosthodont Soc 2022;22:225-32.

Conclusion: Difference in marginal misfit exists between the titanium stock abutments and customized CoCr abutments. Among the customized abutments, milled CoCr abutments have the least marginal discrepancy and cast CoCr abutments have a maximum marginal discrepancy. Milled CoCr abutments can be used as an alternative to titanium stock abutments.

Keywords: Confocal laser scanning microscope, implant-abutment interface, marginal misfit, milled abutment, sintered abutment

INTRODUCTION

Dental implant abutments are of two types: stock abutments supplied by the manufacturers, which matches the respective implant systems; and custom-made abutments made with (computer-aided design and computer-aided manufacturing [CAD/CAM]). The custom-made abutments contoured the soft tissues well around the restorations during the healing stage.[1] These abutments provide a natural emergence profile to the implant prosthesis. Crown margin depth can be customized for better hygiene and esthetics.[2]

The implant-abutment assembly attached with a screw produces an interface between the abutment-implant junction.[3,4] There should not be any vertical misfit between the abutment and implant, a key requirement to secure function and the esthetic requirements for long-term implant success.[5-7] The gap usually created between the abutment and the implant may result in the microleakage of bacteria and their metabolic products causing inflammation of the peri-implant tissues with successive bone loss.[8,9]

The presence of the microgap sometimes causes micromovements and transfers the stresses from the abutment to the implant leading to screw loosening, fracture of the screw, or the abutment with the reduction in the prosthetic screw preload.[10,11] Internal hex abutment-implant interface has been introduced with an attempt to reduce the mechanical drawbacks related to external connection with long-term stability, less screw loosening, and fracture, better aesthetics, and reduced crestal bone loss.[12-15]

Titanium and zirconia are widely used as implant abutments;[16-19] however, the use of cobalt-chromium alloy (CoCr) as abutments is sparse.[19-21] Previously published literature has studied the microgap at the abutment-implant interface using scanning electron microscopy (SEM) and optical microscope. However, these microscopic techniques are not very suitable for accurate measurement of the misfit between the components fabricated with different manufacturing processes.[22-24] Baschong *et al*.[25] stated that a Confocal microscope helps in getting better three-dimensional (3D) images as compared to SEM and it also does not require any additional preparation of the sample to be recorded. This microscope has been already in use for evaluating the surface topography and biofilm formation on dental tissues and implants.[26]

The marginal fit has a key role in the osseointegration and success of dental implants. The manufacturing process for the fabrication of abutment can affect the precision of marginal fit of the abutment with the implant.[21] Hence, the present *in-vitro* research was done to compare the marginal misfit of titanium tock abutments with CoCr customized abutments fabricated with different manufacturing processes (cast, sintered, and milled) in an internal hex implant-abutment connection using an appropriate scanning technique. The null hypothesis was that no difference exists in the marginal misfit of titanium stock abutments and CoCr customized abutments fabricated using different manufacturing processes.

MATERIALS AND METHODS

In this study, a power analysis was established by G * power, version 3.0.1 (Franz Faul universitat, Kiel, Germany). A sample size of 40 samples (10 in each group) which yield 80% power to detect significant differences, with effect size of 0.57 and a significance level at 0.05 were needed. Based on the power analysis, 40 abutments were included in the study. Ten titanium stock abutments were used as control [Group CN, Figure 1a], and 30 CoCr abutments were fabricated and taken as a test group [Figure 1b-d]. Stock abutments were scanned [Figure 2a] and from obtained images test group abutments were fabricated as follows: 10 cast abutments (Group CA), 10 sintered abutments (Group SA), and 10 milled abutments (Group MA). The cast abutments were fabricated from CoCr alloy with the help of milled polymethyl methacrylate patterns [Figure 2b] obtained from the scanned data utilizing the lost wax casting technique. Cobalt chromium sintered abutments were fabricated using the laser beam, in which powdered raw material was placed in a tray (HBD 100D, Guangdong

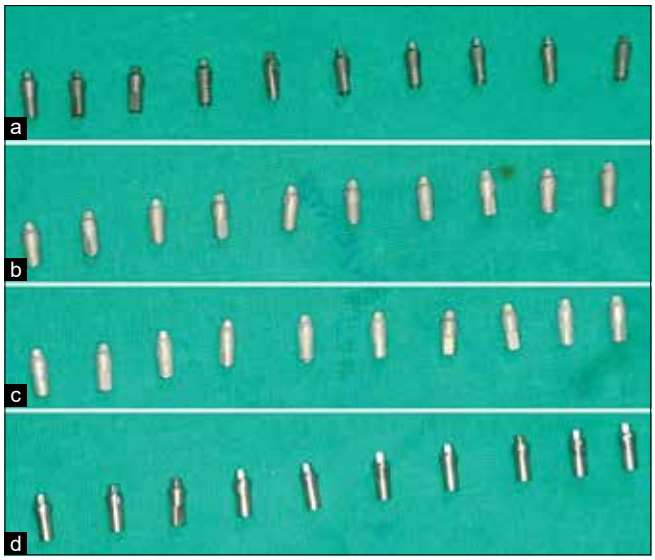


Figure 1: (a) Stock abutments. (b) Cast abutments. (c) Sintered abutments. (d) Milled abutments

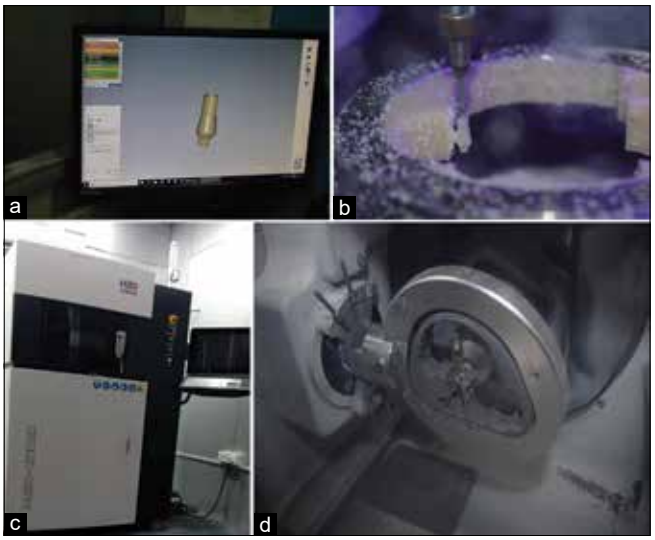


Figure 2: (a) Scanned image of the stock abutment. (b) Milling of polymethyl methacrylate patterns for the fabrication of cast abutments using lost wax casting technique. (c) Fabrication of Sintered abutments with laser sintering machine. (d) Milling of cobalt-chromium alloy for fabrication of milled abutments

Hanbang 3D Tech Co. Ltd, China) [Figure 2c]. A laser beam was spotted over the working tray to increase the temperature of the powder and make the particles bind together layer by layer to obtain the desired shape. Cobalt chromium abutments of the milled group were fabricated utilizing the milling procedure (Ceramill, Amann Girrbach, Austria) where the cutting tools remove the excess material gradually and shape the component [Figure 2d].[19]

Endosseous dental implants (5.0 mm diameter × 10 mm length) with internal hex connection (Alpha Bio Tec, Israel) were matched with 10 titanium stock abutments and 30 CoCr abutments. Clear epoxy resin blocks of 20 mm × 20 mm × 20 mm in dimension were made. A central borehole of 5 mm length × 5 mm diameter was made to place half of the length of an implant as required for scanning.[18,21] The implant was placed in the borehole and fixed with epoxy resin. The abutments were then fitted onto the implant with an abutment screw with a torque of 30Ncm [Figure 3a-d].

Implant-abutment connections were evaluated under SEM for the marginal discrepancy.[21] When the samples were scanned under the SEM, the images obtained could not record the marginal depth because of the curvature of the abutment with that of the implant. The implant used in the study was an internal hex due to which the margins of the implant covered the seated abutment. Hence, it was decided that the samples need to be scanned by an alternative scanner, which can record this curvature.

A confocal laser scanning microscopy (CLSM) (FV1000; Olympus, Finland) was selected for this and after a few initial trial scans, it was found that a CLSM was an appropriate tool for measuring the marginal discrepancy in this situation and so used in the study. This microscope removes the signals which are out-of-focus, with illumination at a single point at a slower speed. With the CLSM technique, the optical resolution and contrast of the micrographs were increased.[27-30]

The analysis was performed with statistical software (IBM Corp. Released 2019. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY, USA: IBM Corp). One-way ANOVA and Tukey's *post hoc* test was done to find significant ($P < 0.05$) difference in between the groups.

RESULTS

Comparison of mean marginal misfit at the implant-abutment junction of the stock abutment, cast abutment, sintered abutment, and milled abutment is presented in Table 1, Graph 1. The marginal misfit at the implant-abutment junction was compared using One-way ANOVA which revealed a significant difference in the marginal misfit of abutments ($P < 0.001$). The mean marginal misfit was lowest for stock abutments (0.35 ± 0.009 μm) [Figure 4a-f]. Among the customized abutments, marginal misfit was highest for cast abutments (2.44 ± 0.445 μm) [Figure 5a-f] followed by sintered abutments (1.67 ± 0.232 μm) [Figure 6 a-f] and least for milled abutments (0.65 ± 0.041 μm) [Figure 7a-f].

Pairwise comparison of mean marginal misfit at the implant-abutment junction was done using Tukey's

Table 1: Comparison of mean marginal misfit at the implant-abutment junction of the stock abutment, cast abutment, sintered abutment, and milled abutment

Group	*n*	Mean±SD	Median	Minimum	Maximum	*F* ratio	*P**
Stock abutment (CN)	10	0.35±0.009	0.35	0.33	0.36	145.29	<0.001*
CA	10	2.44±0.445	2.45	2.00	2.90		
SA	10	1.67±0.232	1.75	1.27	1.90		
MA	10	0.65±0.041	0.65	0.60	0.73		

*One-way ANOVA test $P<0.05$ is statistically significant. SD: Standard deviation, CN: Control, CA: Cast abutment, SA: Sintered abutment, MA: Milled abutment

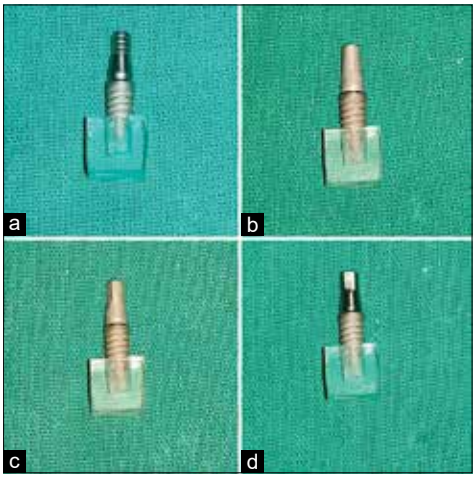


Figure 3: Abutments were screwed to the implants with a torque of 30Ncm. (a) Stock abutment. (b) Cast abutment. (c) Sintered abutment. (d) Milled abutment

post hoc analysis to find the difference between the stock abutment, cast abutment, sintered abutment, and milled abutment [Table 2] Pairwise comparison showed a significant difference in the marginal misfit with cast abutments and sintered abutments when compared to stock abutments ($P < 0.001$). The difference in marginal misfit was insignificant between stock abutments and milled abutments ($P = 0.052$).

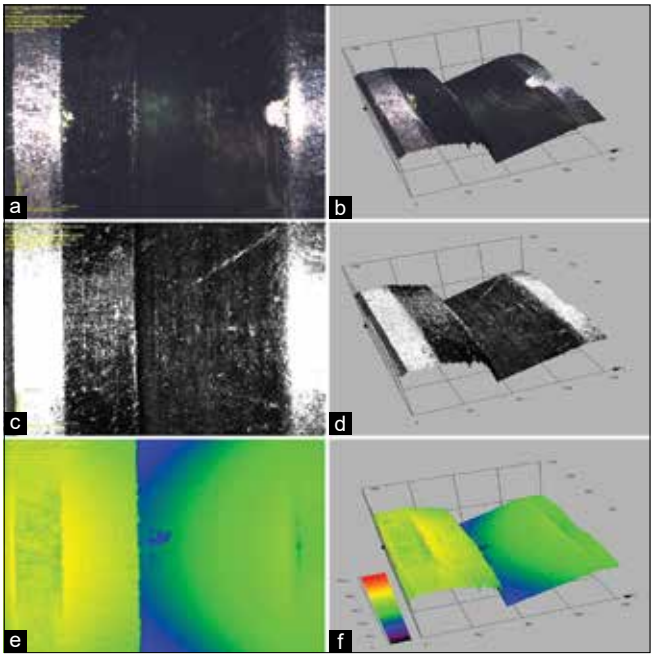


Figure 4: (a) Two-dimensional laser image of scanned stock abutment at the implant-abutment junction. (b) Three-dimensional laser image of scanned stock abutment at the implant-abutment junction. (c) Two-dimensional grayscale scanned image of stock abutment at the implant-abutment junction. (d) Three-dimensional grayscale scanned image of stock abutment at the implant-abutment junction. (e) Two-dimensional colored image showing depth and curvature of the stock abutment at the implant-abutment surface. (f) Three-dimensional colored image showing depth and curvature of the stock abutment at the implant-abutment surface

DISCUSSION

The null hypothesis was rejected as differences exist in the marginal fit of stock implant abutments and customized implant abutments fabricated using different manufacturing processes.

In the majority of the implant systems, due to marginal discrepancies, microgaps may present at the implant-abutment connection. The implant platform which is usually presents at the crest level of the alveolar bone causes exposure at the bone-implant connection and leads to the colonization of microbes.[31,32] These cause the passage of fluid at the interface and may lead to potential implant failure.[33-37]

Stock abutments work well for the posterior teeth, which are away from the esthetic zone. However, these abutments cannot control the marginal fit of the crown in a well-précised fashion due to the abutment height and implant depth. This lack of precision might lead to failure of the dental implant due to peri-implantitis.[1,2] Abutments that lack proper surface proximity can also lead to screw loosening. Custom abutments fabricated with CAD/CAM on the other hand are very well customized and specific for the patients. These abutments can be accurately milled to fit the crest of the dental implant and the soft tissue to give a better fit and also improve esthetics.[10]

The roughness at the surface of the abutment usually creates a microgap at the implant-abutment connection and inhibits in obtaining a passive fit.[38-41] Fernández *et al*.[19] in an *in-vitro* study compared the misfit of CoCr custom-made implant

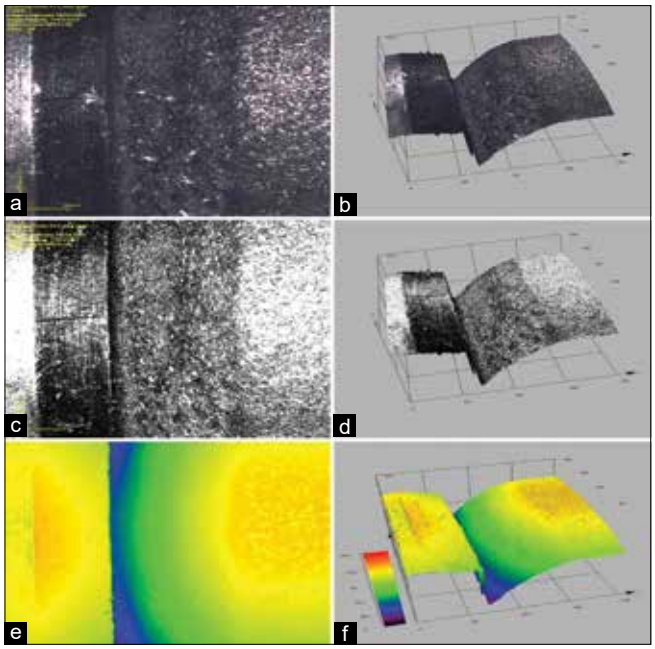


Figure 5: (a) Two-dimensional laser image of scanned cast abutment at the implant-abutment junction. (b) Three-dimensional laser image of scanned cast abutment at the implant-abutment junction. (c) Two-dimensional grayscale scanned image of cast abutment at the implant-abutment junction. (d) Three-dimensional grayscale scanned image of cast abutment at the implant-abutment junction. (e) Two-dimensional colored image showing depth and curvature at the cast abutment at the implant-abutment surface. (f) Three-dimensional colored image showing depth and curvature at the cast abutment at the implant-abutment surface

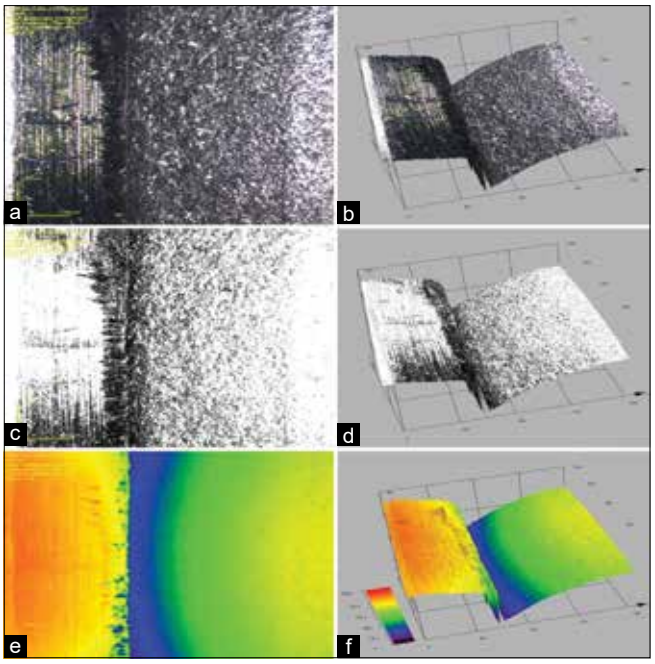


Figure 6: (a) Two-dimensional laser image of scanned sintered abutment at the implant-abutment junction. (b) Three-dimensional laser image of scanned sintered abutment at the implant-abutment junction. (c) Two-dimensional grayscale scanned image of sintered abutment at the implant-abutment junction. (d) Three-dimensional grayscale scanned image of sintered abutment at the implant-abutment junction. (e) Two-dimensional colored image showing depth and curvature of the sintered abutment at the implant-abutment surface. (f) Three-dimensional colored image showing depth and curvature of the Sintered abutment at the implant-abutment surface

Table 2: Pairwise comparison of mean marginal misfit at the implant-abutment junction of the stock abutment, cast abutment, sintered abutment, and milled abutment

Groups	Mean difference	SE of mean difference	*P**
Stock abutment versus CA	−2.09	0.141	0.001*
Stock abutment versus SA	−1.32	0.073	0.001*
Stock abutment versus MA	−0.30	0.013	0.052
CA versus SA	0.77	0.159	0.001*
CA versus MA	1.79	0.141	0.001*
SA versus MA	1.02	0.075	0.001*

*Tukey test $P<0.05$ is statistically significant. SE: Standard error, CA: Cast abutment, SA: Sintered abutment, MA: Milled abutment

abutments with the external hexagonal connection using three different techniques (casting, laser sintering, and milling). They found that the abutments manufactured by the milling process showed the least microgap (0.73 μm), followed by sintered abutments (11.30 μm) and cast abutments (9.09 μm) in the mating surface of the implant-abutment area. Although no significant difference was found between sintered and cast abutment ($P = 0.26$). In the present study, a statistically significant difference was found for the misfit of CoCr custom-made implant abutments with the internal hexagonal connection among all the groups. Milled abutments showed the least marginal discrepancy (0.65 μm), followed by sintered abutments (1.67 μm) and cast abutments (2.44 μm). Milled abutment surface provides a better fit at the implant mating surface with more number of contacts and seals the microgap in a better way.[42,43] Cast abutments had a high degree of marginal discrepancy which might be due to the expansion of investment products used which causes increased misfit.[10,19]

Gonzalo *et al*.[21] compared the misfit among milled titanium versus laser sintered CoCr abutment at the implant-abutment interface with internal hexagon connection design. Regardless of the implant system the mean marginal misfit for the milled titanium abutments was less (0.75 ± 1.27 μm) compared to the CoCr laser sintered abutments (11.83 ± 13.21 μm). Although in the present study CoCr abutments were used for fabrication of both milled and Sintered abutments, still the obtained result was similar with less marginal discrepancy with Milled abutments (0.65 ± 0.041 μm) compared to the sintered abutments (1.67 ± 0.232 μm). Alonso-Pérez *et al*.[20] in an SEM study compared the marginal accuracy of titanium Stock abutments with custom-made CoCr laser sintered abutment and found that marginal accuracy

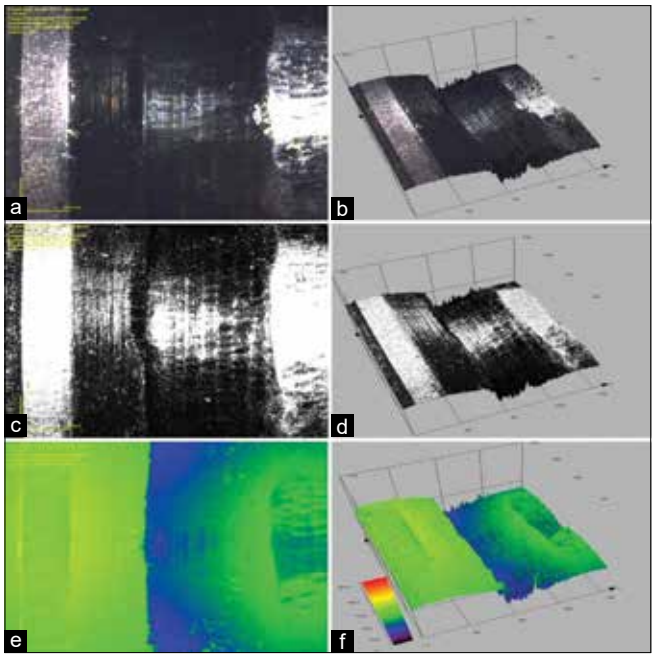
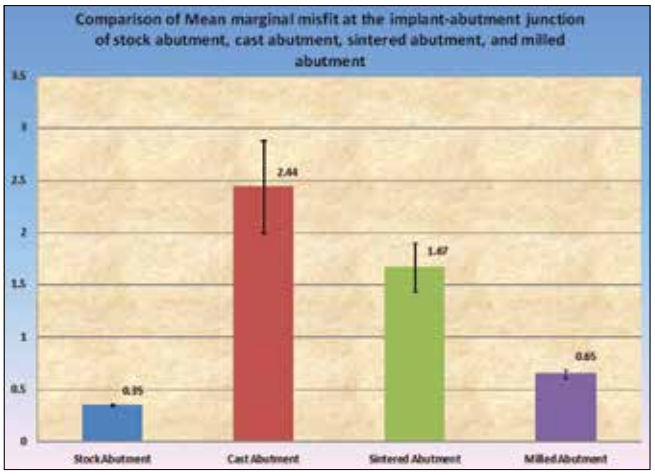


Figure 7: (a) Two-dimensional laser image of scanned milled abutment at the implant-abutment junction. (b) Three-dimensional laser image of scanned milled abutment at the implant-abutment junction. (c) Two-dimensional grayscale scanned image of milled abutment at the implant-abutment junction. (d) Three-dimensional grayscale scanned image of milled abutment at the implant-abutment junction. (e) Two-dimensional colored image showing depth and curvature of the milled abutment at the implant-abutment surface. (f) Three-dimensional colored image showing depth and curvature of the milled abutment at the implant-abutment surface

was best for stock abutments with no measurable gap. A mean marginal gap of 2.5 ± 1.0 μm was found in laser sintered abutments. They stated that the difference in result may be due to the composition of the material, as titanium stock abutments were used in the study and not by the manufacturing process. In the present study also a similar result was obtained with titanium Stock abutments having the least marginal discrepancy. CoCr material was used for fabrication of customized abutments and among that laser sintered abutments had a more mean marginal gap (1.67 ± 0.232 μm) compared to the milled abutment (0.65 ± 0.041 μm).

Reported literature states that laser sintering causes distortion, porosity, and delamination and produces a rough connection between abutment and implant. This creates a microgap and inhibits achieving a passive fit.[19,44-46] The present study with its finding supports that the migrogap created at the implant-abutment connection is not only due to abutment material and type of connection, but it is also due to the different manufacturing process.

In the present study, the CLSM imaging technique was used, as the resolution obtained is best compared to SEM



Graph 1: Comparison of mean marginal misfit at the implant-abutment junction of the stock abutment, cast abutment, sintered abutment, and milled abutment

In CLSM, true 3D images can be obtained by suppressing any signal coming from out-of-focus planes. Atomic force microscopy or scanning tunneling microscope produces the image with scanning by a fine tip over a surface, whereas CLSM does not require a probe to be placed close to the surface.[30] Illumination in CLSM is by a point laser in a 3D diffraction fashion.[28,29,47]

The use of CoCr alloy as an abutment is sparse. This material is used as an abutment would reduce the cost of implant-supported fixed restorations, so this study was done to find a marginal gap at the implant-abutment interface to find its suitability as an abutment with the different manufacturing processes. The findings of the present study also support that the marginal misfit was insignificant ($P = 0.052$) when CoCr milled abutments were compared with titanium stock abutments. The limitations of the study are that its an *in-vitro* study and only CoCr abutments with internal hexagonal implant connection were evaluated. Further *in-vivo* research is needed to be evaluated with different abutment materials to find the clinical relevance.

CONCLUSION

The difference in marginal misfit exists between the titanium stock abutments and customized CoCr abutments. Among the customized abutments, Milled CoCr abutments have the least marginal discrepancy and Cast CoCr abutments have a maximum marginal discrepancy. Milled CoCr abutments can be used as an alternative to titanium stock abutments.

Financial support and sponsorship
Nil.

Conflicts of interest

There are no conflicts of interest.

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Research

Bacterial microleakage in endodontically treated teeth following two methods of postspace preparation at two-time intervals: An *in vitro* study

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Abstract

Aims: The goal of this study was to analyze the bacterial microleakage following two methods (heat vs. rotary) of postspace preparation after two-time intervals (immediate vs. 1 week later).

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

Materials and Methods: Eighty-two single-rooted teeth were decoronated at the cementoenamel junction. Root canals were prepared using rotary files. After root canal obturation, specimens were randomly allocated to 4 experimental groups based on the method of postspace preparation (heat or peeso reamer) and time interval (immediate or 1 week later) ($n = 18$). Group 1: Peeso reamer-immediate, Group 2: Heat-immediate, Group 3: Peeso reamer-1 week later, Group 4: Heat-1 week later. 10 specimens were considered as positive and negative controls ($n = 5$ each). Custom-made dual-chamber devices were used to appraise the bacterial microleakage for 60 days.

Statistical Analysis Used: Data were analyzed with Chi-Square and Log-Rank tests and Cox regression.

Results: All through the experimental period, there was no significant difference ($P = 0.41$) between the studied groups. Groups 2 and 4 had the highest microleakage and the lowest survival rate (55.56% ± 11.71%). Group 1 showed the lowest microleakage and the highest survival rate (77.8% ± 9.80%).

Conclusions: The applied techniques for postspace preparation and the time intervals (neither independently nor simultaneously) showed no significant difference in the field of bacterial leakage.

Keywords: Dental instruments, dental leakage, heat, post and core technique, time

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Submitted: 10-Sep-2021, **Revised:** 06-Mar-2022, **Accepted:** 12-Mar-2022, **Published:** ***

INTRODUCTION

The three-dimensional (3D) seal of the root canals is one of the most important achievements of endodontic treatment, and by disrupting it, the possibility of treatment failure increases. Teeth with this problem often require difficult and complex treatments. According to studies in endodontic treatment, canal contamination is possible in two stages; lack of proper cleansing of the canal and subsequent

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_441_21

How to cite this article: Mostafavi AS, Rasoulzadehsheikh M, Meraji N, Pourhajibagher M. Bacterial microleakage in endodontically treated teeth following two methods of postspace preparation at two-time intervals: An *in vitro* study. J Indian Prosthodont Soc 2022;22:233-9.

remaining infection or coronal leakage after treatment.[1,2] It is noteworthy that coronal leakage after treatment is the most common cause of endodontic treatment failure.[3] Therefore, proper restorative reconstruction will increase the success rate of dental treatment remarkably. After endodontic treatment, the teeth need to return to their function. In most cases, a significant amount of coronal tooth structure is missing and needs to be reconstructed with a postcore and an extra-coronal restoration. A dowel is considered to provide the crown retention that commonly would have been gained from coronal tooth structure. Since endodontic retreatment after postcementation would be so complicated, maintenance of the seal of the filling material which can be jeopardized during postspace preparation is of great importance.[4,5] Therefore, besides successful endodontic treatment, the 3D seal of the root canal system should not be compromised during postspace preparation. Studies have displayed that the accuracy of the remaining filling material depends on several elements such as; the amount of residual Gutta-percha,[6] the type of obturation material,[7] the method of root canal filling,[5] the technique and time of postspace preparation,[8] placement of temporary restoration[9] and the sealer used.[10] Throughout the preparation of the postspace, the remaining gutta-percha can be displaced and ultimately jeopardize the apical seal.[11] As a result, choosing a more appropriate and safer method for preparing the postspace can reduce the likelihood of leakage which consequently may fail. It is demonstrated that the leakage of endodontically treated teeth would be initiated within 7 to 28 days after postspace preparation depending on temporary restoration existence.[9] In addition to the method, the time of postspace preparation is also controversial. It can be done immediately after root canal treatment or sometime after endo treatment. Immediate postspace preparation is definitely less time-consuming, but it would threaten the apical seal due to the incomplete setting of sealer. Impaired apical seal before postcementation has consequences that are difficult to compensate. Therefore, it is necessary to try to prevent the probable leakage until receiving the permanent restoration by scrutinizing the factors in which we can intervene and selecting more appropriate alternatives. There are different techniques to provide postspace such as mechanical (bur/drills), physical (heat instrument), and chemical (solvents). Heated appliances and peeso reamers are among the most common and widely used preparation methods.[12] Failure of endo treatment is due to the penetration of bacteria or their products into the canal and the apical region. In Torabinejad *et al*.'s study, more than 50% of the root canals exposed to *Staphylococcus epidermis* and 50% of the canals exposed to proteus vulgaris were completely infected after 19 and 42 days orderly.[13] In previous studies about microleakage subsequent to postspace preparation, contradictory results have been stated that may be due to the use of different materials and measurement methods.[7,14-17] The goal of this study was to investigate the bacterial microleakage of endodontically treated teeth following two methods (peeso reamer vs. heat plugger) of postspace preparation at different timings (immediately vs. 1 week after endodontic treatment). The null hypothesis was that neither techniques nor timing of postspace preparation would affect the bacterial microleakage of endodontically treated teeth.

MATERIALS AND METHODS

Eighty-two recently extracted single-rooted human teeth were chosen according to the inclusion criteria (at least 15 mm root length, absence of root caries, cracks, curve, and structural imperfections) for the present *in vitro* study. A power analysis was performed based on the results of a previous study by Grecca *et al*.[17] The sample size was calculated as 18 specimens per group for a significance level of $\alpha = 0.05$ and power of 0.80. The selected teeth were extracted due to orthodontic and periodontal reasons, also this project was accepted by the ethical committee of Tehran University of Medical Sciences (the ethical code: IR. TUMS. DENTISTRY. REC.1397.096). The teeth were immersed in 5.25% sodium hypochlorite solution for 24 h and then maintained in normal saline 0.9%. Single-rooted teeth were verified by mesiodistal and buccolingual radiographs. Different types of teeth (central, canines, and premolars) were marked to be divided equally into different groups. The crowns were removed at the cementoenamel junction level by a high-speed fissure bur; the length of all specimens was adjusted using a #10 k-file to 14 mm. The teeth with the same mark were randomly allocated into four groups ($n = 18$). Two groups ($n = 5$) were also considered positive and negative controls.

Root canal treatment

The root length of the specimens was determined by inserting a manual No. 10 k-file (Dentsply, Maillefer, Ballaigues, Switzerland) into the root canal until the tip could be seen from the root tip and reducing it by 1 mm. The desired length was confirmed by digital radiography. Root canal preparation was achieved by using rotary files (SP1 V-Taper, China) up to #40.06 according to the manufacturer's instructions. RC Perp (Master-Dent RC Lube, Dentonics Inc, USA) was used as a lubricant, and smear layer was removed by 17% EDTA (MD-Cleanser™, Meta Biomed Co. Ltd., Cheongju City, Chungbuk, Korea). Rinsing of root canals was done with Sodium

hypochlorite solution (2.5%) followed by saline. Root canal obturation was done by lateral compaction method using gutta-percha (Meta Biomed Co., Ltd., Cheongju City, Chungbuk, Korea) and AH26 sealer (Dentsply DeTrey GmbH, Konstanz, Germany). Finally, the quality of the root canal filling was confirmed by radiography. Specimens in the positive control group (n = 5) were not filled after root canal preparation and the ones in the negative control group (n = 5), were not prepared for the postspace after filling the root canal. As a result, the specimens were divided randomly into four experimental groups (n = 18) according to the method and time of the postspace preparation, and two groups of 5 roots were prepared as control groups. The studied groups are depicted in Table 1. Specimens in groups 2 and 4 were stored at 37°c and 100% humidity for 7 days in the incubator. To avoid leakage through dentinal tubules, root surface of the specimens was covered with two coats of nail polish except in the apical section.

Microbial process

All the specimens were sterilized by gamma radiation (activity: 6450 ci and dose rate: 1.54 G/sec) so that external microbial contamination would not be a source for errors in the results during the microbiological process.[9] To test the bacterial penetration, a modified method similar to Torabinejad *et al*. set-up which was a customized dual-chamber device was used.[13] The upper chamber containing artificial saliva and contaminated with *Enterococcus faecalis* (1.5 × 108 colony forming units/mL of EF ATCC 29212, Iranian Biological Resource Center, Tehran, Iran) was placed on the coronal part of the specimens, and the lower chamber containing the Trypticase Soy Broth (TSB, Merck KGaA, Darmstadt, Germany) was in contact with the apical part of the roots; all the connections between two chambers were sealed so that the only connection between two chambers was through the root canal. It was planned to renew the suspension every 3 days. The assemblies were stored at 37°C and the culture medium (TBS broth) was checked daily over the next 60 days. The sterile yellow TBS medium is amber and transparent, which would become cloudy in case of microorganisms' growth. Therefore, specimens with the opaque chamber (culture medium) were considered positive in terms of microleakage and the day was recorded. The phenol-red reagent was added to the lower chamber for photographic resolution of the specimens and to facilitate their detection. The culture medium in which the bacteria penetrated was acidic due to bacterial metabolism and the reagent changed color to red [Figure 1]. 10 µL of infected TBS broth was then cultured in bile esculin agar plates as a selective and differential medium which is used to identify the *E. faecalis* strain and the plates were incubated at 37°C. After 24 h, the microbial colonies were counted using the Miles *et al*. method.[18] At the end of the test period, microleakage information of the specimens was recorded and statistical analysis was performed.

Statistical analysis

Data pertinent to microbial microleakage were reported as numbers and percentages on different days. Analysis was performed with SPSS software (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY, USA: IBM Corp). Microleakage percentage during 60 days was examined among the groups by Chi-square test. The survival rate without microleakage was tested using the Kaplan–Meier curve and the Log-Rank test. The interaction of time and method of postspace preparation

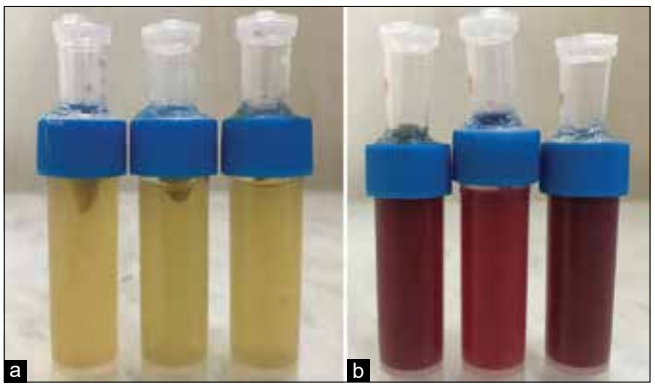

Figure 1: The color of culture medium (a) turned into red (b) in case of bacterial penetration (due to existence of phenol red reagent)

Table 1: The studied groups in this study

Studied groups	Sample size	Method and time of post space preparation
Group 1	18	The post space was prepared using peeso reamers number 1, 2 and 3 immediately after the sealer was set
Group 2	18	The post space was prepared using heat instruments (heat carrier) immediately after the sealer was set
Group 3	18	The post space was prepared using peeso reamers number 1, 2 and 3, 1 week after filling the canal
Group 4	18	The post space was prepared using heat instruments (heat carrier), 1 week after filling the canal
Group 5	5	Root canal was prepared without filling
Group 6	5	Root canal was prepared and filled without post space preparation

In the case of post space preparation, 5 mm Gutta-percha was maintained in the apical region

was examined using Cox regression and hazard ratio (HR) was reported accordingly.

RESULTS

The number of specimens contaminated during daily examinations is presented in Table 2. All the specimens in positive control group became infected during the 1st week but the negative control group did not show any sign of microleakage till the end of the survey. Groups 2 and 4 had the highest microleakage and the lowest survival rate (55.56% ± 11.71%). Group 1 showed the least microleakage and the highest survival rate (77.8% ± 9.80%). There was no significant difference among studied groups in terms of bacterial microleakage ($P = 0.37$) and survival rate ($P = 0.41$) [Figure 2]. Furthermore, according to the Cox regression, two examined factors (time and method of postpreparation) had no significant interaction ($P = 0.71$); besides these two factors had no significant effect on the obtained results (HR = 0.76, 95% confidence interval [CI]: 0.35–1.67, $P = 0.49$ and HR = 0.57, 95% CI: 0.25–1.29, $P = 0.17$, respectively).

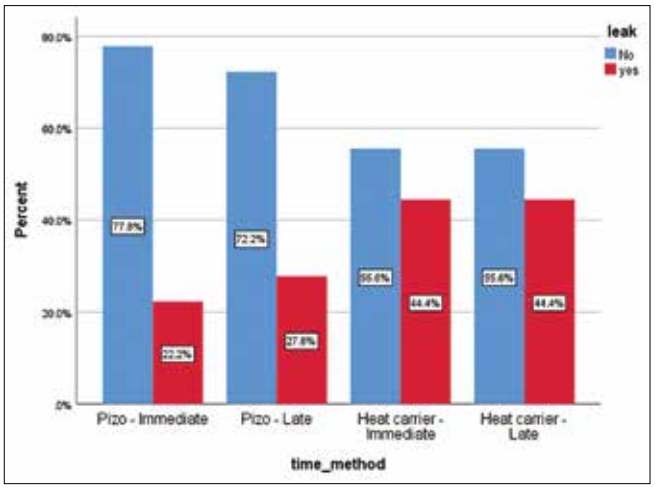

Figure 2: Bacterial leakage and survival rate based on two factors of time and method of post space preparation

Table 2: Number of infected specimens in each group during the determined weeks

Groups	Time								
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Group 1	0	0	0	0	4	4	4	4	4
Group 2	0	0	0	1	8	8	8	8	8
Group 3	0	3	4	5	5	5	5	5	5
Group 4	0	1	1	5	8	8	8	8	8
Group 5	5	5	5	5	5	5	5	5	5
Group 6	0	0	0	0	0	0	0	0	0

DISCUSSION

In this study, two methods of postspace preparation (peeso reamer vs. heat) at two different times (immediately after obturation vs. 1 week later) were investigated in terms of bacterial microleakage. According to insignificant obtained results among the studied groups, the null hypothesis of the research was confirmed. It has been demonstrated that the length of remaining filling material is inversely related to apical leakage after postspace preparation; according to the literature, the appropriate length of 5 mm was considered in the present study. Since most of the pulp and peri-radicular diseases are related to microorganisms, using them for microleakage evaluation is more precise and similar to the oral condition compared to other methods such as fluid filtration,[7,10] dye penetration,[4,5] electrochemical,[8,11] SEM analysis,[19] radioactive tracer assay,[6] micro-computed tomography scans.[20] In addition, saliva seems to be the most suitable carrier for the microorganisms used due to its similarity to clinical conditions and viscosity. In this study, *E. faecalis* ATCC29212 was selected, which is one of the commonly known bacteria in dental infections and is associated with periapical infections. To standardize the root canal preparation, rotary files were used and due to the routine use of lateral compaction technique, the canals were filled with this method in the present study. Root canal sealers are used to fill the remaining gaps between the gutta-percha and root canal walls. In addition, sealer may trap the residual bacteria in dentinal tubules. AH 26 is an epoxy resin-based sealer applied in this research because of its good sealing properties and widespread use. There was no statistically significant difference between the study groups in terms of bacterial microleakage neither in different methods of postspace preparation nor in different timing. There is still no consensus about the superior method of gutta-percha removal regarding apical seal in the literature. Mattison *et al.* showed no significant difference in leakage between hot pluggers and Gates-Gliddens.[11] This finding has been confirmed with other studies[6,17,21,22] and also the current study. On the other hand, according to Haddix *et al.* survey,[23] heat instruments were safer than rotary ones (Gates-Glidden drill and GPX instruments) in terms of the apical seal. Although, heat instruments could be applied without the risk of stripping or perforation; rotary instruments are faster, easier, and commonly used.[8] It has been declared that applying heat instruments would result in gutta-percha expansion and therefore improve the seal. In addition, the resulting frictional heat during the use of heat instruments would lead to plasticized deformation of gutta-percha which diminishes the gap between the filling material and dentinal wall, moreover, hinder excessive pulling of gutta-percha and results in a better seal.[11,23] Haddix *et al.* considered the speed of rotary instruments as

an influential factor in this context.[23] Nonetheless, Balto *et al*. revealed less leakage for peeso reamers compared to hot pluggers.[12] The authors attributed gutta-percha shrinkage to more leakage of heat instruments. It has been suggested that insufficient or inaccurately condensed obturation material, would be displaced during postspace preparation.[24] Therefore, the obturation phase and also condensing of the remaining filling material after preparation of the root canal are of great importance. The existed heterogeneity among studies could be due to different filling techniques, exitances of coronal dressing, follow-up times, and analyzing methods.

In contrary to the nonsignificant results for time of postspace preparation in this study, Padmanabhan *et al*. reported less apical microleakage in immediate postspace preparation groups than delayed ones.[25] The authors argued that in the immediate method, the setting time of sealer is not completed yet while the hot plugger or peeso reamers enter the root canal. Therefore, microfractures do not cause a gap between the sealer/gutta-percha or sealer/dental tissue. Whereas, after the completion of setting time, the entrance of tools into the root canal may cause the gutta-percha to move and break the interfaces.[25] Although the filling technique in the recent study was single cone obturation and the leakage was evaluated using dye penetration. Salim declared similar outcomes with the same method.[26] Methylene blue, like India ink, is not very accurate due to its small molecules, different viscosity, and structural differences with saliva, and its results are questionable. According to Torabinejad *et al*., if a filling material does not allow small molecules (such as the ink molecule) to pass through, it is very likely to prevent the penetration of larger particles like bacteria and their products.[27] Based on this theory, it can be accepted that the nonpassage of dye molecules means the nonpassage of bacteria, but the leakage of dye does not mean the passage of bacteria and its byproducts which shadows the obtained results of dye-based studies. The results of Padmanbhan *et al*. study were in accordance with the observations of Dhaded *et al*. research in which the seal and adaptation of Gutta-percha filling material to the dentinal walls and the interface were examined by SEM analysis.[19] Furthermore, other studies have suggested immediate root canal preparation due to the less following leakage.[7,14,28-31] Abramovitz *et al*. stated no significant difference between immediate postspace preparation with a hot plugger and late removal with rotatory instruments which was in line with the results of the present study.[6] They increased the sensitivity of the assay by using a pressure system, but this question arises that this system does not simulate the intra-oral condition. The result of Madison and Zakariasen study was similar in terms of apical dye leakage with immediate or delayed (48 h later) removal of gutta-percha either with heated pluggers or peeso reamers.[21] In confirmation of recent results, Grecca *et al*. reported that immediate and delayed postspace preparation either with heated plugger or LA Axxess rotary instruments yielded similar outcomes regarding the canal seal.[17] Furthermore, no significant result was addressed in Aydemir *et al*. study in which the leakage analysis performed by electrochemical method and postspace was prepared after 30 days in the delayed group.[8] The same outcome was presented in other studies.[12,16,20,32-39] Although Chen and Chang also came to the same conclusion, the authors suggested postponding the time of postspace preparation until the complete setting of sealer and close to the time of restoration installation.[4] The reason for this precaution is mentioned to sustain the integrity of filling material and apical seal. In contrast to the previous studies, Nagas *et al*. addressed better apical seal by delayed postspace preparation compared to immediate postpreparation.[10] The authors claimed that polymerization of sealers may also be a reason for better sealing of delayed postpreparations. However, a modified fluid transport system was applied to measure the leakage in their study. Chen *et al*. expressed optimal results in case of waiting for the complete reaction and settlement of filling materials before any preparations.[5] In addition, Ibrahim *et al*.'s study was in consistent with the previous studies.[40] Lack of consensus in this context could be due to different methodology, filling material and sealer, filling and removal technique, presence of coronal dressing, leakage analysis, and following time in performed studies.

Despite nonsignificant difference between studied groups in the present study, it is noteworthy that in groups with immediate removal, leakage was seen in no specimens till the 24th day, while in delayed preparation groups, leakage was recorded from the first of the second week. Therefore, it can be concluded that in immediate postspace preparation, apical leakage would occur later and exactly this time is needed to form the postpattern, laboratory process, and postcementation. Based on the obtained results, regardless of the time and technique for postspace preparation, apical leakage occurred in all groups. Therefore, it is of great importance to maintain the coronal seal of the access cavity with an accurate material after endodontic treatment. Furthermore, immediate removal of filling material would have advantages in terms of postponed leakage compared to the delayed method, which needs to be confirmed by further studies. Lack of turbidity in the negative group indicates the importance of accurate filling to prevent leakage through the root

canal. The main determining factor in the success of the root canal treatment was proved to be the quality of the root canal filling in Tronstad *et al*. study rather than the quality of the coronal restoration.[41] However, contamination of all specimens in the positive group during the 1st week indicates the importance of appropriate remaining obturation material and coronal seal. Regarding the obtained findings, the remaining filling material cannot hinder bacterial leakage in root canals exposed to the oral environment, which asserts to expedite the prosthesis delivery. Providing postspace by an endodontist or dentist who has performed the root canal treatment has several benefits; this clinician is more acquainted with the anatomy of root canals and the working length; root canal preparation would be done under the same aseptic condition as endodontic treatment.[42] Besides, it prevents accidents such as ledge, stripping, or perforation. On the other hand, higher postoperative pain has been reported when postspace preparation and postinstallation were performed in the same appointment.[43] However, based on nonsignificant obtained results in the present study, dentists can make the decision about the time and method of postspace preparation based on each individual's situation. One of the limitations of this study was the lack of intra-oral conditions like thermocycling and cyclic loading, furthermore, coronal temporization was not considered which commonly is applied for patients to reduce coronal leakage during treatment sessions. Furthermore, it is recommended to implement this project as an *in vivo* research with follow-up sessions to essay the experimented factors in the clinical situations.

CONCLUSIONS

Based on the statistically nonsignificant results, the practitioner can choose each of the removal techniques (peeso reamer or hot plugger) and time intervals (immediate or 1 week later) based on the patient's condition, ease of work, clinical factors, and time management related to the patient.

Acknowledgement

This research was supported by the grant number 97-02-69-38991 from Tehran University of Medical Sciences.

Number of pages: 13, Number of photographs: 2, Word counts for abstract: 245, Word count for text: 3119, word counts for introduction + discussion: 2110.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Research

Evaluation and comparison of vertical marginal fit of three different types of multiunit screw-retained framework fabricated for an implant-supported prosthesis – An *in vitro* study

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Abstract

Aim: The present study aimed to evaluate on a comparative basis the vertical marginal fit between conventionally casted, direct metal laser sintered (DMLS), and milled computer-aided design/computer-aided manufacturing (CAD-CAM) one-piece metal framework supported by five implants using one-screw test and screw resistance test.

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

Materials and Methods: Five implants were placed parallel to one other in a Styrofoam master model. A total of 30 implant-supported screw-retained superstructures were manufactured using three techniques, i.e., conventionally casted, milled, and sintered. To evaluate the vertical marginal discrepancy, screw resistance test, and one-screw test were used, and measurements were made using a stereomicroscope.

Statistical Analysis Used: The data was analysed using two statistical tests, i.e., ANOVA and the post hoc Bonferroni test.

Results: On evaluating the frameworks using one-screw test, the mean vertical misfit value at the terminal implant for the control group was 292.58 ± 15.46μm, for conventionally casted framework 398.41 ± 21.13 μm, for DMLS 343.44 ± 24.73 μm, and for CAD-CAM was 304.03 ± 14.23 μm, whereas the average misfit values at four implants on applying screw resistance test were 1268.65 ± 84.24 (control), 1774.88 ± 67.70 (casted), 1508.02 ± 62.19 (DMLS), and 1367.29 ± 81.87 (CAD-CAM). The average misfit values on two implants using screw resistance test were 635.02 ± 57.33 for the control group; for conventionally casted, it was 879.75 ± 35.93; for (DMLS) framework, it was 761.51 ± 32.85; and for milled CAD-CAM framework, it was 687.07 ± 42.17 μm.

Conclusion: The mean vertical marginal discrepancy, when compared with control, was least in milled CAD-CAM frameworks, followed by sintered DMLS and conventionally casted frameworks. Hence, according to the present study, CAD/CAM technique is recommended to achieve maximum marginal fit in full mouth screw-retained implant-supported FDPs.

Keywords: Computer-aided design/computer-aided manufacturing, casting, DMLS, implants, screw-retained

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Submitted: 20-Jan-2022, **Revised:** 24-Apr-2022, **Accepted:** 26-Apr-2022, **Published:** ***.

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_28_22

How to cite this article: Singh M, Yadav BK, Phukela SS, Ritwal P, Nagpal A, Saluja P. Evaluation and comparison of vertical marginal fit of three different types of multiunit screw-retained framework fabricated for an implant-supported prosthesis – An *in vitro* study. J Indian Prosthodont Soc 2022;22:240-8.

INTRODUCTION

The marginal gap present at the interface of frameworks and the underlying implant body is critical for a successful long-term osseointegration. Inaccurate implant superstructures can result in various mechanical complications such as abutment or prosthesis screw loosening or breakage of different components in the system. It can also result in biological complications of the surrounding tissue such as loss of osseointegration, swelling, pain, inflammation, and crestal bone loss.[1] A poor marginal seal at the implant framework junction may further propagate compressive, tensile, and shear load, resulting in failure of the restoration or failure of the underlying implants.

An ill-fitted framework can create a marginal gap between the superstructure and the implant or abutment, leading to plaque accumulation and biological complications.[2] In multiunit implant-supported prostheses, achieving marginal fit is more complex and arduous. On the other hand, it is easier to attain passive fit in cement-retained implant prostheses because of 40 μm cement space provided by the die spacer.[3] For overlying implant frameworks, the passive fit is relatively important. Passive frameworks are assumed to transfer less pathological forces on the supporting structures. Establishing a passive fit among the superstructures and implants screw-retained multiunit implant prosthesis will prevent stress transformation from the framework to the implant body and the underlying and surrounding bone. It is achieved with the precise adaptation between the superstructures and the implants, without any marginal gap formation. Although the influence of passive fit on bone response has not yet been demonstrated in experimental Vivo studies, there seems to be a consensus on the importance of passive fit between dental implant components and the superstructure. The osseointegrated implants have no resilience in the bone, and consequently, bony tissues do not adapt to a misfitting framework without generating stress in the bone and the metal framework.[4]

The primary approach for metal framework fabrication was the "lost wax technique." This technique entails many inevitable procedures, armamentariums, and materials that can cause inaccuracies in the final framework. Many methods have been described in the literature to improve implant framework fit, which can be divided into two main categories, first is the refinement of fit through adding certain steps such as the use of cement-retained restorations, sectioning and soldering the framework, horizontal sectioning, and laser welding or vertical welding with use of the CrescoTi Precision TM technique.

The second is eliminating specific fabrication steps by utilizing modern technology such as computer-aided design/computer-aided manufacturing (CAD-CAM). The ability of this technique to improve implant-supported FDP's accuracy is achieved by skipping conventional manufacturing steps, such as the impression of the prepared tooth, wax frameworks, investing, and finally casting in metal alloys. Specific steps such as intraoral or laboratory scanning, designing through advanced software, multiple axis milling, and material processing make the CAD/CAM technique imprecise.[5-7] In a comprehensive review by Abduo *et al*.[7] in 2014, on the vertical marginal fit of CAD/CAM implant superstructures, the authors concluded that the accuracy of CAD/CAM implant superstructure was significantly better than that of the conventionally casted one-piece frameworks and the sectioned and laser-welded frameworks.

Direct metal laser sintering (DMLS), also known as "Three dimensional (3D) printing," is a comparatively recent technology for the fabrication of dental prostheses. DMLS technique utilizes a process in which metal dental frameworks are built using a high-powered laser beam focused onto a bed of the Co-Cr alloy powder and subsequently welding it together into thin solid layers of around 0.020 mm, followed by cooling. In DMLS, it is easier to manufacture complicated angular designs and structures, which are otherwise difficult or impossible in subtractive (machining) technologies. Hence, it is expected that this method is superior to milling. Many studies have suggested that the DMLS technique has a promising future and can be a possible alternative to the conventional casting technique.[8]

Even though the concept of conventional casting, additive (DMLS), and subtractive manufacturing (CAD-CAM) technologies for implant and biomaterial manufacturing is well accepted, there are still limited data available on the comparison of these three techniques in the current scientific literature. Hence, the present study aims to evaluate on a comparative basis the marginal fit and flexural strength between conventionally casted screw-retained, direct metal laser sintered (DMLS) screw-retained and milled CAD-CAM one-piece metal framework supported by five implants using one-screw test and screw resistance test.

METHODOLOGY

Three manufacturing techniques for the fabrication of screw-retained implant prosthesis, i.e., conventional casting, CAD-CAM, and DMLS, were compared in the present study. A total of 30 frameworks were fabricated,

10 each from 3 techniques. The study was approved by the Institutional Review Board (SGTU/FDS/MDS/24/1/547).

A Styrofoam edentulous mandibular model was used as a master model. Five conical hex regular platform implants (4 mm × 10 mm, super line, Dentium implants, Buk-su, Daegu, Korea) were inserted in the model [Figure 1]. A surveyor was used to place the implants parallel to one another and perpendicular to the horizontal crestal plane. Implants were placed supra crestal and marked as 1, 2, 3, 4, and 5 from right to left. Two posterior implants, i.e., 1 and 5 were placed in the mandibular first molar region. Two implants, i.e., 2 and 4, were placed in 1st premolar region on both sides, and one implant, i.e., 3 was placed in the midline. Osteotomy was drilled in 1, 2, 3, 4, and 5 regions in Styrofoam up to 4.0 mm drill conventionally using Dentium Implant kit. 4 mm × 10 mm implants (Dentium Dental Implants, Korea) were placed in the drilled site on the master model. A tiny dot was engraved on the facial edge of all five implants using a laser (20W, Fiber Laser) which will act as a common reference point to help measure the marginal discrepancy under a stereomicroscope.

Five abutments with Ti bases (conical hex, UCLA Abutment; Dentium) were attached to implants on the master model and were splinted with pattern resin and ligature wires. After setting, the framework was resectioned and splinted again with pattern resin to compensate for the polymerization shrinkage. The framework formed on the master model will act as the standard control framework to be compared with the framework created from the three different techniques.

A special tray with double spacer and 3 stoppers was fabricated over the master model; holes were made in the special tray for open tray impression coping corresponding to implant positions. Five direct transfer copings (4 mm hex, open tray; Dentium) were used to make the impression. The open tray impression copings were splinted with ligature wire and red auto polymerized pattern resin. Splinting was done to stabilize the open tray transfer copings and prevent displacement while making the impression. Impression was made using polyether impression material (Impregum F; 3M ESPE) with medium body consistency. The special tray which was used to take the impression was coated with tray adhesive (Polyether Adhesive; 3M ESPE), and the material was manipulated in a pentamix auto mixer. Then, some material was loaded into the syringe and transferred to the abutment implant areas, and the rest was put on the custom tray to make the final impression. Following the setting of the impression, the screws of the transfer copings were loosened, and the model was separated from the impression. Implant analogs were attached to the open tray transfer copings [Figure 2], and Type IV die stone was mixed and poured into the impression to obtain a working cast.

Five UCLA abutments with Ti base (4 mm, conical hex, Dentium) were secured to the implant analogs for wax-up of the superstructure. The wax framework, along with the working cast, was dispatched to a milling center (Dentcare Kerala). The framework was initially scanned using a 3D laser scanner (3Shape E 3). After obtaining the images following the scanning, the framework was designed using 3D software [Figure 3]. In this way, a CAD file of the framework was obtained, following which milling was done to manufacture the frameworks from Co-Cr metal blocks using a high-speed five-axis machine (3Shape Dental System 2012). Ten frameworks were milled in a similar fashion using the same machine with the same settings to minimize the bias in the manufacturing process.

DMLS sintered frameworks were manufactured using an AM250 laser melting machine (Reni Shaw plc.) using

Figure 1: Implants placed in model

Figure 2: Polyether impression with analogues

ASTM75 Co-Cr powder. During the sintering process, the powdered metal without binder and flux was sintered by scanning with a high-power laser beam at 20 or 40 μm per layer. Following the sintering of the first layer, the recoater arm of the machine swept over a new layer of powder and thus forming a fresh layer to be sintered on the already built layer. Ten frameworks were sintered in a similar fashion simultaneously [Figure 4].

UCLA abutments were secured to implant analogs on the master model and tightened with hex for conventional casted frameworks. Wax patterns were fabricated using blue inlay wax (BEGO USA). The wax pattern dimensions were standardized using an index obtained from the CAD/CAM milled and sintered frameworks. Before fabricating wax patterns, UCLA abutments were attached to each other with pattern resin. An electrically controlled wax bath was used to melt the wax and applied to the UCLA abutments and pattern resin. The wax patterns, along with UCLAs, were removed carefully from the cast so as to minimize distortion and were sprued. Before investing, a surface tension reducing agent (Silikon- and Wach Entspanner, DFS) was carefully applied to the patterns, and then the investment was done using a phosphate bonded investment (Vesto-Fix, DFS, and Germany). The wax patterns were then casted in Co-Cr alloy and finished. The castings were examined for gross defects before placing them on the master Styrofoam model. The finished frameworks were then tried on the master model [Figure 5].

Evaluation of vertical marginal fit

The vertical marginal fit between the superstructure and implant was assessed using a stereomicroscope [Figure 6] by employing one-screw test and screw resistance test. Laser dots were marked on the framework at the base of each abutment of all the frameworks and the other on the implant. The same trained investigator measured the distance between the two points to give the readings for the vertical misfit between the frameworks in micrometers using pictures obtained from a million instructions per second (MIPS) mounted on a stereomicroscope.

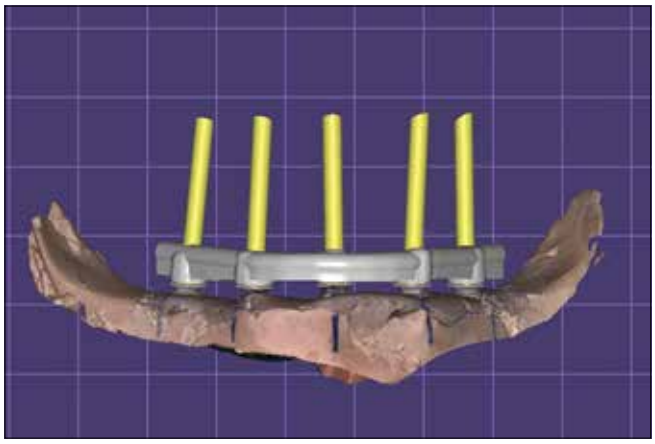

Figure 3: Computer-aided design designing for the framework

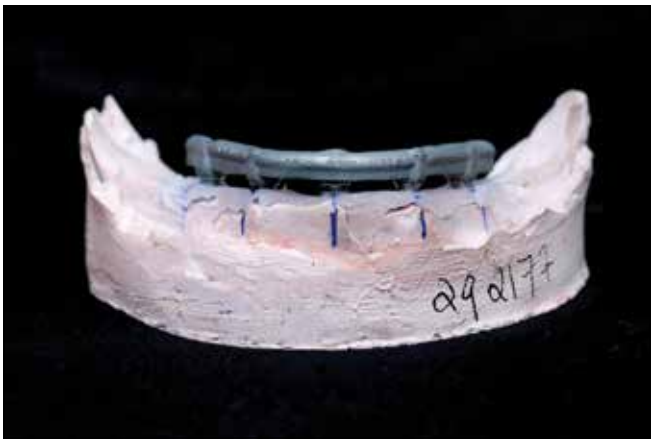

Figure 4: Framework on master cast

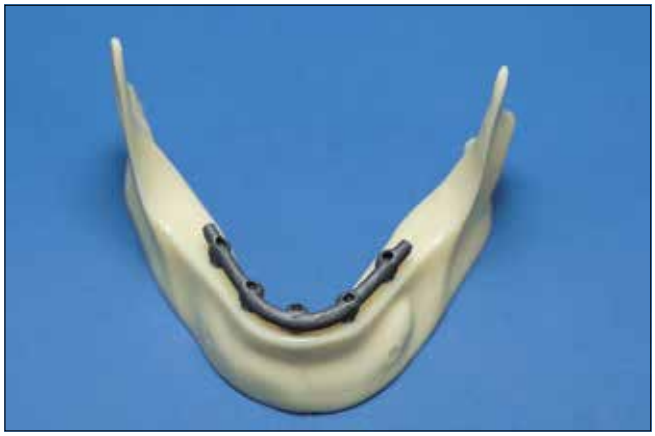

Figure 5: Framework on master model

Figure 6: Framework under stereomicroscope

The model and the framework were placed on the microscope's stage horizontally and stabilized using the stage clips. Stage clips helped in maintaining a continuous seating force between the framework and the model during the microscopic measurement. The stereomicroscope was focused at ×100 magnification, and the image obtained from the MIPS mounted on the stereomicroscope was captured in the computer attached to it. The image analysis software was then calibrated to a microns scale, and the image obtained was analyzed for the vertical misfit by calibrating the distance from the laser engraving on a framework to the engraving on the implant.

One-screw test

One-screw test was implemented to quantitatively evaluate the discrepancy measurement. In one-screw test, screw that corresponds to implant number 5 and 3 was first tightened by hand. After this, screw of implant number 5 was tightened to 15 N cm torque, and the screw at implant number 3 was removed. The vertical marginal fit was measured at implant number 1 at the interface of the implant and the abutment superstructure using a stereomicroscope.

Screw resistance test

The assessment of the marginal fit between the framework and implants was also performed using screw resistance test. The screw resistance test is done in two parts; in the first part, the screw corresponding to implant number 3 was tightened with a torque of 15 N cm, and the readings of vertical misfit were measured on implants number 1, 2, 4, and 5 using a stereomicroscope. In the second step, the screw corresponding to implants number 2, 3, and 4 was tightened with a torque of 15 N cm, and the vertical marginal fit was simultaneously measured at implants number 1 and 5 using a stereomicroscope.

A master chart with all the readings was prepared, and the data were analyzed using two statistical tests, i.e., ANOVA and the *post hoc* Bonferroni test. The software used for the statistical analysis was SPSS (the statistical package for the social sciences) version 21.0 and Epi-info version 3.0 SPSS Inc., IBM Corp., Armonk (N.Y., USA).

RESULTS

This *in vitro* study compared the fit accuracy of full arch screw retained frameworks fabricated from three different techniques. Marginal fit was measured by employing one screw test and screw resistance test using stereomicroscope.

Evaluation of the marginal fit using one screw test

On evaluating the frameworks using one-screw test, the mean vertical misfit value at the terminal implant for the control group was 292.58 ± 15.46μm, for conventionally casted framework 398.41 ± 21.13μm, for DMLS 343.44 ± 24.73 μm, and for CAD-CAM it was 304.03 ± 14.23 μm.

Evaluation of the marginal fit using screw resistance test

The average misfit values at four implants on applying screw resistance test were 1268.65 ± 84.24 (control), 1774.88 ± 67.70 (casted), 1508.02 ± 62.19 (DMLS), and 1367.29 ± 81.87 for CAD-CAM respectively. Whereas, the average misfit values on two implants using screw resistance test were 635.02 ± 57.33 for the control group; for conventionally casted, it was 879.75± 35.93; for (DMLS) framework, it was 761.51 ± 32.85; and for milled CAD-CAM framework, it was 687.07 ± 42.17 μm.

DISCUSSION

The present *in vitro* research compared the marginal fit and accuracy of full arch screw retained frameworks fabricated from three different manufacturing systems using the same material, i.e., CAD/CAM milling or subtractive manufacturing system, DMLS sintering or additive technique, and conventional casting. The hypothesis was rejected that the vertical marginal fit of a multiunit screw-retained prosthesis would not be influenced by fabrication technique. The frameworks fabricated using CAD/CAM technique depicted the best marginal fit. The conventionally casted frameworks had the highest mean marginal discrepancy with higher variability of results. The results are in accordance with Gema Arroyo-Cruz,[9] who stated that the CAD-CAM technique has been extensively used in the designing and manufacturing of implant prosthesis and is believed to produce high-quality restorations with very few inaccuracies. Furthermore, CAD/CAM simplifies the process, eliminates various steps such as investment, burnout, casting, finishing, and polishing, and reduces the time required for manufacturing implant restorations.[10-13]

Brånemark[14] was the first person who stated that the misfit of the implant framework should be not more than 10 μm. Whereas Zeroas *et al*.[15] concluded that a 30 μm discrepancy at the implant-abutment junction would be admissible if it does not exceed 10% of the perimeter. Recently, Jemt and Book[4] in their research stated that a vertical misfit of around 150 μm would also be acceptable. However, with the existing techniques and materials available for manufacturing implant frameworks, a certain degree of inaccuracy and vertical misfit is inescapable, as demonstrated by various *in vitro* investigations in the past and comparable to those presented in this study.[16-18] Therefore, the vertical marginal misfit values obtained in

the present study may reasonably represent the situation clinically.

Begoña Ormaechea *et al*.[19] proposed the 1-screw test for long span/full arch implant superstructures, and it states that the vertical marginal discrepancies tend to be more magnified at the opposite terminal abutment in long-span frameworks. The mean vertical misfit value at the terminal implant for the control group was 292.58 ± 15.46 μm, for the conventionally casted framework was 398.41 ± 21.13 μm, direct metal laser sintered (DMLS) screw-retained framework was 343.44 ± 24.73 μm, and milled CAD-CAM one-piece framework was 304.03 ± 14.23 μm when observed under a stereomicroscope [Table 1].

The mean marginal difference when the control group was compared with the CAD-CAM framework was 11.45 μm which was statistically nonsignificant. In contrast, the mean marginal discrepancy was statistically significant when the control group was compared with the DMLS framework (50.86 μm), and marginal discrepancy further increased when compared with conventionally casted frameworks, i.e., 105.82 μ [Tables 2 and 3]. The present study results agree with the studies conducted by Klineberg and Murray,[20] Helldén and Dérand,[21] and Lencioni *et al*.,[22]

Table 1: Descriptive statistics of the different groups according to one-screw test

One-screw test	*n*	Mean±SD
Control	10	292.58 (15.46)
Conventional	10	398.41 (21.13)
DMLS	10	343.44 (24.73)
CAD/CAM	10	304.03 (14.23)

SD: Standard deviation, DMLS: Direct metal laser sintered, CAD: Computer-aided design, CAM: Computer-aided manufacturing

Table 2: Comparison of one-screw test within the group using ANOVA test

One-screw test	ANOVA				
	Sum of squares	df	Mean square	*F*	*P*
Between groups	68494.66	3	22831.56	60.912	0.001**
Within groups	13493.79	36	374.827		
Total	81988.45	39			

**Significant at 0.01 level

who compared Au and Ti FDP frameworks fabricated by CAD CAM and conventional methods and found similar results. These results obtained were probably because CAD/CAM technique is very accurate and reproduce the same results repeatedly as it eliminates almost all the errors related to conventional casting procedure such as investing, dewaxing, casting, finishing, and polishing.[22-24]

Buzayan and Yunus[25] reported that the fabrication method is an essential criterion influencing the marginal fit, probably because each manufacturing technique produces different surface roughness. The authors noted that CAD-CAM milled restorations had a superior marginal fit and better contact with the implant body than casted restorations, eliminating the micro gaps between implant components.

The fit and passivity of CAD-CAM fabricated prosthesis might be influenced by the scanning procedure, which is used to transfer the position of implants. This procedure is of two types, i.e., direct and indirect. The direct technique is scanning directly inside the mouth, and the indirect means the cast is scanned in the laboratory with labotatory scanners. In the present study, the indirect technique was performed because the indirect method has been reported to provide more precise values when compared with the direct technique.[26] Ortorp and Jemt[27] reported that CAD-CAM frameworks fabricated from direct technique had increased vertical misfit values at the interface than for conventionally manufactured frameworks. Although the literature quoted above suggests that the indirect scanning technique may provide the desired accuracy of CAD-CAM implant superstructures, still more research is required to compare the two methods.

The screw resistance test was introduced by Jemt and Book[4] in 1991. The test was based on his clinical experience, and the clinically acceptable level of marginal misfit was set at 150 μm. A 5-year clinical study demonstrated the absence of mechanical fatigue fractures in fixed prostheses provided to a group of edentulous

Table 3: *Post hoc* analysis for one-screw test by using the Bonferroni test

One-screw test					95% CI	
Group I	Group J	Mean difference (I–J)	SE	Significance	Lower bound	Upper bound
Control	Conventional	−105.82	8.66	0.001**	−123.38	−88.26
Control	DMLS	−50.86	8.66	0.001**	−68.42	−33.30
Control	CAD	−11.45	8.66	0.194 (NS)	−29.01	6.11
DMLS	Conventional	−54.97	8.66	0.001**	−72.52	−37.41
DMLS	CAD	39.41	8.66	0.001**	21.85	56.97
CAD	Conventional	−94.38	8.66	0.001**	−111.94	−76.82
CAD	DMLS	−39.41	8.66	0.001**	−56.97	−21.85

**Significant at the 0.01 level. SE: Standard error, CI: Confidence interval, DMLS: Direct metal laser sintered, CAD: Computer-aided design, NS: Not significance

patients, and the authors recommended that the screw resistance test was clinically adequate for fit assessment. Therefore, a screw resistance test was used to assess the marginal fit in the present study.

The screw resistance test has two parts – in the first part, only the screw in the middle corresponding to implant number 3 was torqued, and marginal discrepancy at the remaining 4 implants was measured under a stereomicroscope. The mean vertical marginal discrepancy value for the control group was 1268.65 ± 84.24 μm, the non-hexed screw-retained conventionally casted framework was 1774.88 ± 67.70 μm, the DMLS framework was 1508.02 ± 62.19 μm, and milled CAD-CAM framework was 1367.29 ± 81.87 μm. On comparing the four groups statistically, the mean vertical marginal discrepancy value in CAD-CAM milled framework (98.64 μm) was found to be nonsignificant on compared with the control group, whereas it was statistically significant when the control was compared with the other two frameworks, i.e., conventionally casted (506.23 μm) and DMLS (239.37 μm) [Tables 4-6].

Table 4: Descriptive statistics of the different groups according to screw resistance test part 1 (μm) (i.e., screw secured on implant number 3)

Screw resistance test	*n*	Mean±SD
Control	10	1268.65±84.24
Conventional	10	1774.88±67.70
DMLS	10	1508.02±62.19
CAD	10	1367.29±81.87

DMLS: Direct metal laser sintered, CAD: Computer-aided design, SD: Standard deviation

Table 5: Comparison of marginal fit at 4 implants (1, 2, 4 and 5) using screw resistance test part 1 (μm) (i.e., screw secured on implant number 3) within the group using ANOVA test

Screw resistance test	ANOVA				
	Sum of squares	df	Mean square	*F*	*P*
Between groups	1451109	3	483703	86.958	0.001**
Within groups	200249.5	36	5562.486		
Total	1651358	39			

**Significant at 0.01 level

Further, in the screw resistance test, the screws correspond to implants number 2, 3, and 4 were torqued, and the vertical misfit of the frameworks at implants number 1 and 5 was measured using a stereomicroscope. The mean vertical misfit value for the control group was 635.02 ± 57.33 μm, screw-retained conventionally casted framework was 879.75 ± 35.93 μm, DMLS framework was 761.51 ± 32.85 μm, and Ti-milled CAD-CAM one-piece framework was 687.07 ± 42.17 μm. The mean values of vertical misfit of conventionally casted, DMLS, and CAD-CAM were statistically significant compared to the control group. This study concluded that the CAD-CAM framework showed a statistically insignificant difference with control and a better marginal fit than DMLS and conventionally casted frameworks [Tables 7-9].

The milled and sintered frameworks were associated with lower marginal discrepancy values when compared with conventionally casted frameworks. Both CAD/CAM and DMLS are advanced CAM systems for implant-supported restorations; one is an additive manufacturing (sintering), and another is subtractive (milling). The fit produced in the CAD-CAM technique can also be influenced by factors related to the accuracy of the units, such as the software version used, calibration of the machine, condition of the tools, and the overall working condition of the milling or additive unit. In the present study, the machines used to mill and sinter Co-Cr were high-speed five-axis with simultaneous motion. The recommended pressure and temperature conditions were used according to the manufacturer's instructions. However, since both the machines were different, differences in the precision of the fit achieved in CAD-CAM and DMLS may have occurred in the present study. However, the results of the present study were in contradiction with the research of Ortorp and Jemt.[27] and Jemt and Book[4] who reported a superior marginal fit for sintered structures, whereas the investigations done by Patterson[8] and Buzayan and Yunus[25] did not reported any statistically significant differences in the marginal accuracies in the framework

Table 6: *Post hoc* analysis for screw resistance test part 1 using Bonferroni test

Screw resistance test (μm) (i.e., screw secured on implant number 3)					95% CI	
Group I	Group J	Mean difference (I–J)	SE	Significance	Lower bound	Upper bound
Control	Conventional	−506.23	33.35	0.001**	−573.873	−438.583
Control	DMLS	−239.37	33.35	0.001**	−307.016	−171.725
Control	CAD	−98.64	33.35	0.005*	−166.282	−30.9916
DMLS	Conventional	−266.86	33.35	0.001**	−334.503	−199.212
DMLS	CAD	140.73	33.35	0.001**	73.0881	208.3787
CAD	Conventional	−407.59	33.35	0.001**	−475.236	−339.946
CAD	DMLS	−140.73	33.35	0.001**	−208.379	−73.0881

*Significant at 0.05 level, **Significant at 0.01 level. SE: Standard error, CI: Confidence interval, DMLS: Direct metal laser sintered, CAD: Computer-aided design

made by the three methods which are being compared in the present study.

Vertical marginal fit of milled superstructures was better than that of sintered and conventionally casted ones. This result of the present study indicates a promising future for CAD-CAM manufactured implant-supported prosthesis as the materials used are more homogenous, and during the manufacturing phase, the physical and mechanical properties of the materials are less affected when compared to conventional casting.[28] As the CAD-CAM technology is getting more advanced and developing at a fast pace, it will become even more accurate and precise in the near future. Furthermore, with increased usage, it might become more cost-effective and flexible, as, presently, the cost is a potential limitation of this computerized technique.

While it is difficult to determine if the selected parameters in the present study are clinically relevant or reflect vital information to predict the clinical problem, every clinician should aim to maximize the passivity of the fit of the prostheses. Nonetheless, technology that delivers high precision and decreases variability should be obligatory for implant-supported restorations.

In screw-retained implant prostheses, higher preload forces are indicated compared to other prosthesis types resulting in higher stress and tension generation within the peri-implant tissues and the adjacent bone. Furthermore, newer materials introduced for the fabrication of implant superstructures such as Co-Cr, Titanium, and zirconia are less yielding than previously used gold alloys, which might introduce even higher stress levels.[29] Thus, to reduce the stress produced by these modern restorative materials, achieving passivity in the frameworks becomes even more essential for implant-supported prosthesis success and longevity.

A stereomicroscope was used to assess the marginal fit in the current study. Examination of the interface of abutment/superstructure and implant fixture with stereomicroscope is a justifiable method as it allows for direct measurement of any discrepancies on photomicrographs by using the provided scale. Stereomicroscope produces high contrast images with low magnification, with a minimum amount of flare and geometrical distortion. It uses a fiber-optic light source to illuminate the small specimens, making it ideal when dealing with thick or opaque samples.

The results obtained in the present study were statistically significant. However, a possible limitation of the study may be related to the number of samples included and the number of assessment points in each framework. Evaluation points could not be increased due to technical and practical difficulties with a measurement under the stereomicroscope. The sample size and the number of points for measuring marginal discrepancy in the present study were similar to the previous studies on the fit and micro gap in implant restorations.[30-33] The current *in vitro* study results can be correlated with the clinical trials, which would provide meaningful results and help assess crestal bone loss, peri-implant soft tissue health, screw loosening, screw fracture, and framework fracture. This would help

Table 7: Descriptive statistics of different groups according to screw resistance test part 2 (i.e., screw secured on implant number 2, 3, and 4)

Screw resistance test	*n*	Mean±SD
Control	10	635.02±57.33
Conventional	10	879.75±35.93
DMLS	10	761.51±32.85
CAD	10	687.07±42.17

DMLS: Direct metal laser sintered, CAD: Computer-aided design, SD: Standard deviation

Table 8: Comparison of marginal fit on 2 implants (1 and 5) screw resistance test part 2 (i.e., screw secured on implant number 2, 3, and 4) within the group using ANOVA test

Screw resistance test	ANOVA				
	Sum of squares	df	Mean square	*F*	*P*
Between groups	338132.2	3	112710.7	60.633	0.001**
Within groups	66920.24	36	1858.896		
Total	405052.4	39			

**Significant at 0.01 level

Table 9: *Post hoc* analysis for screw resistance test part 2 using Bonferroni test

Screw resistance test (i.e., screw secured on implants number 2,3 and 4)					95% CI	
Group I	Group J	Mean difference (I–J)	SE	Significance	Lower bound	Upper bound
Control	Conventional	−244.73	19.28	0.001**	−283.838	−205.628
Control	DMLS	−126.50	19.28	0.001**	−165.6	−87.3906
Control	CAD	−52.05	19.28	0.011*	−91.1563	−12.9467
DMLS	Conventional	−118.24	19.28	0.001**	−157.342	−79.1328
DMLS	CAD	74.44	19.28	0.001**	35.3391	113.5487
CAD	Conventional	−192.68	19.28	0.001**	−231.786	−153.577
CAD	DMLS	−74.44	19.28	0.001**	−113.549	−35.3391

*Significant at 0.05 level, **Significant at 0.01 level. DMLS: Direct metal laser sintered, CAD: Computer-aided design, CI: Confidence interval, SE: Standard error

in increasing the longevity of full-arch screw-retained implant-supported restorations.

CONCLUSION

Within the scope of this *in vitro* study, it can be concluded that frameworks manufactured by CAD/CAM technique had better vertical fit values when compared with conventionally casted or DMLS fabricated frameworks. Compared with control, the mean vertical marginal discrepancy was least in milled CAD-CAM frameworks followed by sintered DMLS and conventionally casted frameworks when tested using one screw and a screw resistance test. Hence, according to the present study, CAD/CAM technique is recommended to achieve maximum marginal fit accuracy in full mouth screw-retained implant-supported FDPs.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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Research

A comparative study to evaluate surface electromyographic correlations of mandibular implant-supported overdentures to conventional complete dentures in edentulous patients: An *in vivo* study

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Abstract

Aim: The aim of this study was to compare the function and coordination of masticatory muscles for patients with two implant-supported mandibular overdenture (ISOD) with that of conventional complete dentures (CCD) using surface electromyography (sEMG). The objectives were to assess the muscle activity (efficiency) and clinical outcome after the transition of CCD patients to ISOD.

Setting and Design: This was a crossover study.

Materials and Methods: This clinical trial was conducted in the department of prosthodontics. A total of 15 patients (nine males and six females) were assessed using sEMG. In each patient, a total of four surfaces were examined above the following muscles – right and left masseter and right and left temporalis muscles. The electromyography readings were recorded to assess muscle activity during Clenching, cotton roll clenching, and chewing. The readings were recorded first for CCD and then for ISOD (after installing attachments).

Statistical Analysis Used: Data analysis was done using independent *t*-test and one-way ANOVA.

Results: Mean muscular activity of masseter during clenching, cotton roll clenching, and chewing for patients with ISOD (44.3 ± 11.2 μV, 41.1 ± 13.4 μV, and 45.2 ± 17.5 μV) was higher than CCD (26.0 ± 11.3 μV, 22.6 ± 9.7 μV, and 24.2 ± 9.5 μV). The mean muscular activity of temporalis during clenching, cotton roll clenching, and chewing was also higher with ISOD (47.9 ± 11.2 μV, 45.6 ± 11.9 μV, and 51.0 ± 14.4 μV) than CCD (31.0 ± 12.2 μV, 29.7 ± 15.3 μV and 31.9 ± 14.2 μV). No statistically significant result was found between masseter and temporalis muscle activity on both sides ($P < 0.05$), indicating symmetrical activity on both the sides.

Conclusion: Two-ISODs prove to be a better and efficient treatment modality in rehabilitating edentulous patients as it enhances retention and also increases masticatory muscle activity and chewing efficiency.

Keywords: Electromyography, implant-supported overdenture, masseter muscle, masticatory muscle activity, temporalis muscle

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Submitted: 14-Jul-2021, **Revised:** 02-May-2022, **Accepted:** 02-May-2022, **Published:** ***.

Access this article online	
Quick Response Code:	**Website:** www.j-ips.org
	DOI: 10.4103/jips.jips_368_21

How to cite this article: Garg Y, Nagrath R, Lahori M. A comparative study to evaluate surface electromyographic correlations of mandibular implant-supported overdentures to conventional complete dentures in edentulous patients: An *in vivo* study. J Indian Prosthodont Soc 2022;22:249-55.

INTRODUCTION

Mastication is a complicated process that receives input from voluntary and automatic motor pathways. In dentulous subjects, this process is well coordinated, but in edentulous subjects, masticatory process gets affected as there are resorption of bone and muscular hypotonicity, which, in turn, reduces various functions of the stomatognathic system.[1] Edentulous patients often complain of unstable lower dentures, leading to diffidence, inefficacious chewing, and in general disappointment with the prosthesis. Such patients when rehabilitated with mandibular implant-retained overdentures show improved masticatory function and overall satisfaction.[2]

Many techniques exist for studying the stomatognathic mechanism; the electromyographic readings are one of the most comprehensible and valuable means as it directly records muscle activity.[3] Hardyck in the 1960s clinical used surface electromyography (sEMG) to treat specific disorders.[4] Robert E. Moyers is known as a pioneer for using electromyography (EMG) in dentistry. He used it to verify the neuropsychological analysis of the factors linked to prosthetic rehabilitation procedures.[5] A study done by Dakhilalian *et al*., Tiwari *et al*., and van der Bilt *et al*. showed that masticatory function and coordination improves in edentulous patients rehabilitated with two-implant-supported overdenture.[6-9] de Liz Pocztaruk *et al*. found out that patients with overdenture with ball or bar–clip attachment showed enhanced masticatory performance and satisfaction, but the result was not equivalent to those found for dentate subjects.[2] In a study done by Soni *et al*., it was observed that all-on-four treatment shows the highest biting force and chewing efficiency, followed by implant-supported overdenture and complete denture.[10] Bersani *et al*. found that during rest maintenance position, the patients with mandibular implant-supported prosthesis in accordance with the Branemark protocol and removable maxillary complete dentures showed increased electromyographic activity than the dentulous patients.[11]

In consideration to the currently available studies, it has been observed that the comparison between conventional complete denture (CCD) and implant-supported mandibular overdenture (ISOD) has mostly been recorded on different patients. The previous studies have made use of calibrated EMG device which require manual interpretation of reading, leading to human error. This study uses a digital EMG apparatus to obtain precise values of muscle activity which has never been used in the past. The present study aimed to compare the function and coordination of masticatory muscles of the same patients when rehabilitated with conventional and two-ISODs using surface electromyograms. The objectives were to assess the muscle efficiency and clinical success after the transition of CCD patients to ISOD. The null hypothesis stated that the masticatory muscle activity increases when the transition is made from CCD to ISOD.

MATERIALS AND METHODS

This crossover trial was conducted in the department of prosthodontics. A total of 15 patients (both male and female) were selected as per the inclusion and exclusion criteria [Schematic Chart 1 and Figure 1]. The study was accepted by the institutional ethical committee.

Placement of dental implants

These patients were referred for cone-bean computed tomography and routine blood investigation. A dose of prophylactic antibiotic was administered orally an hour before surgery as per the guidelines of Centers for Disease Control and Prevention. Lignocaine 2% with 1:100,000 adrenalin (Septodont, India) was infiltrated locally. A crestal incision was made on the mandibular ridge followed by raising a full-thickness mucoperiosteal flap. Two implants (3.5 mmD × 10 mmL, Touareg™-S Spiral Implant, double-lead threads, ADIN Dental Implant System Ltd.) of selected diameter were placed in B and D regions following a standard protocol. Cover screws were placed over implants and flaps were closed with interrupted sutures. Patients were asked to come after 2 weeks for sutures removal and postoperative checkup.

Fabrication of conventional complete denture

Upper and lower complete denture was fabricated using a standard protocol. Bilaterally balanced occlusion was given using semi-anatomic acrylic resin teeth. Dentures were evaluated for retention, stability, support, esthetics, centric relation, and occlusion. Patients were recalled after 1 week for postinsertion checkup. After 3 months of denture

Schematic Chart 1: Inclusion and exclusion criteria for subjects

Inclusion criteria	Exclusion criteria
Age 45 years and above	Poor oral hygiene
Total edentulism in mandible for atleast 3 months	Presence of some systemic condition, parafunctional habit, and muscle tenderness
Absence of local inflammation, temporomandibular disorder, muscle dystrophy	Temporomandibular disorders, including clicking, crepitus, limited mouth opening, deviation
Residual bone volume of at least 3.5 mm in diameter and 10 mm in length	Severe intermaxillary skeletal discrepancy
No history of radiotherapy	Heavy smokers

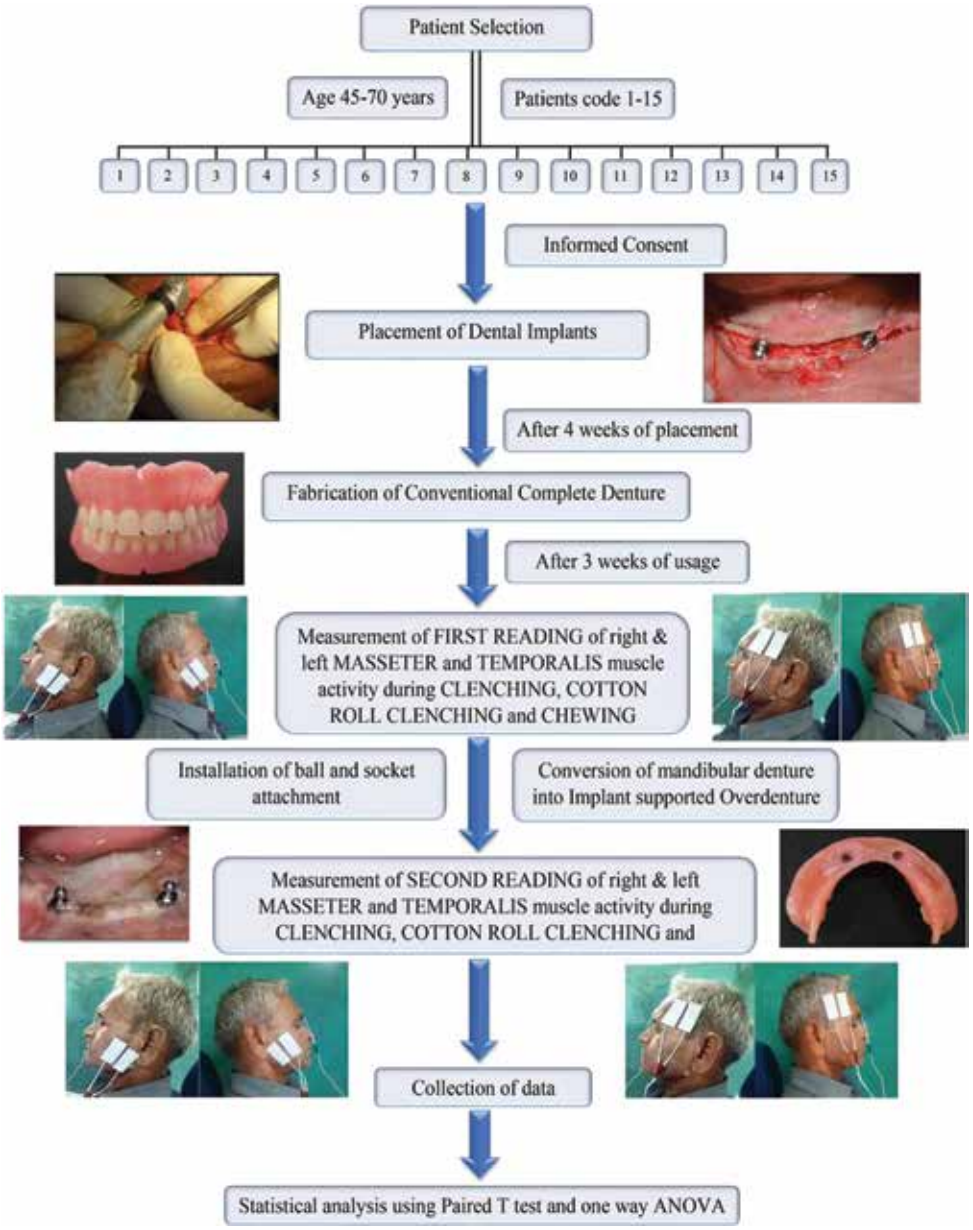


Figure 1: Schematic presentation of methodology

insertion, masticatory muscles (masseter and temporalis) of patients were assessed using sEMG (NeuroTrac Simplex, Verity Medical Ltd., Co., Wexford, Ireland).

Electromyography recording and measurement

In each patient, a total of four surfaces above the following muscles were examined – right and left masseter and right and left temporalis muscles. Pregelled and self-adhesive electrodes of size 23 mm × 50 mm with three surface leads (two recording electrodes and one reference electrode placed on glabella) were used. During this process, patients were made to sit on a chair looking straight at a distant object with a head unsupported. The number of trials in EMG machine was set to one.

Electrodes placement

- For temporalis muscle, the electrodes were placed by palpating the muscle contraction above a line joining the outer canthus of the eye to the upper ear [Figure 2]
- For masseter, the angle of the mandible was palpated and electrodes were placed anterosuperiorly over the muscle [Figure 3].

Recording procedure

The area of electrode placement was cleaned with alcohol in order to accomplish superior conductivity. Readings were taken for three actions such as during clenching (maximum intercuspation), during cotton roll clenching (maximum bite force), and during chewing peanuts for CCD. For

recording muscle activity during clenching, patients were asked to relax for 10 s, followed by 10 s of clenching and 10 s of rest. For cotton roll clenching and chewing, patients were asked to rest for 10 s, followed by 10 s of continuous unilateral cotton roll clenching/chewing and 10 s of rest. Implant placement and EMG recordings for all the patients were recorded by the same operator. EMG readings were obtained in microvolt (μV) digitally.

Installation of ball and socket attachment

For second-stage surgery, these patients were recalled after 3 months of implant installation. The region from canine-to-canine was reopened following the same protocols of surgery and healing caps were installed. After 2 weeks, healing caps were removed and ball attachments (ADIN Dental Implant System Ltd.) were installed and tightened to 35–40 N/cm. On the intaglio surface of mandibular denture, metal housings (RS2675SS, stainless steel ball cap, ADIN Dental Implant System Ltd.) and nylon caps (RS2660, plastic ball cap white, 0.35GPa Young' modulus, ADIN Dental Implant System Ltd) were installed using standard technique.

Readings for implant-supported overdenture were then recorded as per the predetermined protocol.

Statistical analysis

Statistical analysis was done using IBM SPSS statistical software 21.0 statistical software. Shapiro–Wilk test was accustomed to ensure that all variables followed statistical distribution. Bivariate analyses were performed using independent *t*-test and one-way ANOVA.

RESULTS

Masticatory muscle activity

The mean values of masseter muscle for patients with ISOD during clenching were 44.3 ± 11.2 μV, during cotton roll clenching were 41.1 ± 13.4 μV, and during chewing were 45.2 ± 17.5 μV, whereas for patients with CCD, the mean values during clenching were 26.0 ± 11.3 μV, during cotton roll clenching were 22.6 ± 9.7 μV, and during chewing were 24.2 ± 9.5 μV. The mean values of temporalis muscle for patients with ISOD during clenching were 47.9 ± 11.2 μV, during cotton roll clenching were 45.6 ± 11.9 μV, and during chewing were 51.0 ± 14.4 μV, whereas for patients with CCD, mean values during clenching were 31.0 ± 12.2 μV, during cotton roll clenching were 29.7 ± 15.3 μV, and during chewing were 31.9 ± 14.2 μV. Thus, from these values, it infers that the activity of masseter and temporalis muscle for patients rehabilitated with ISOD is significantly higher ($P = 0.00$) than with CCD during all three actions [Table 1].

Muscle harmony

No statistically significant result was seen in right and left masseter and temporalis muscle activity, indicating symmetry on both the sides [Graphs 1 and 2].

Gender

With CCD, the mean activity of temporalis muscle was significantly higher in males than females during cotton roll clenching ($P = 0.02$) and chewing ($P = 0.01$), although no significant difference was observed between genders for masseter muscle during all three actions [Table 2].

With ISOD, the mean activity of temporalis muscle was significantly higher in males than in females during chewing ($P = 0.01$) though there was no statistically significant difference during clenching and cotton roll clenching. No significant difference was observed among male and female for masseter muscle during all three actions [Table 3].

Figure 2: Electrode placement for recording temporalis muscle activity

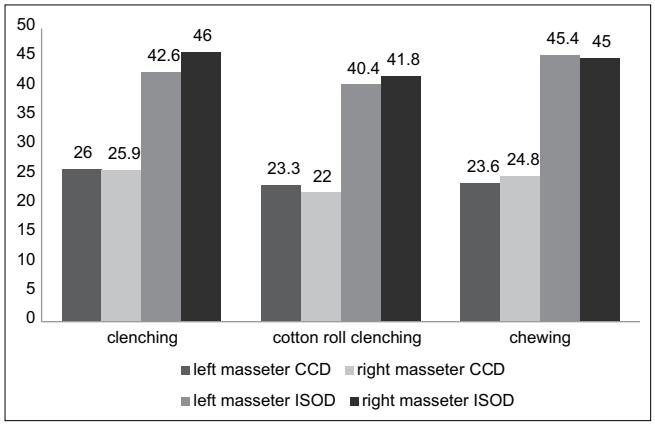
Figure 3: Electrode placement for recording masseter muscle activity

DISCUSSION

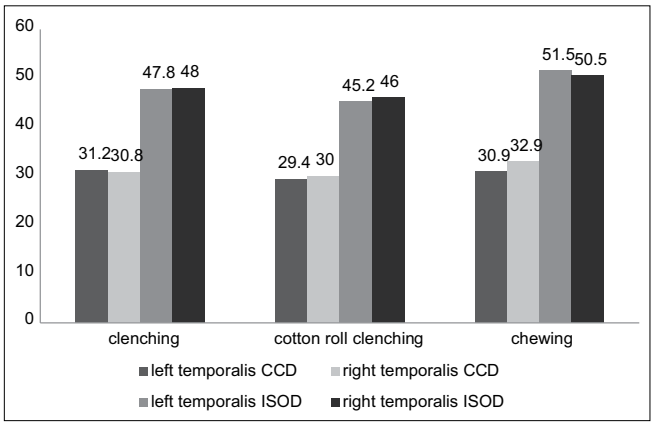
In this study, the null hypothesis that there is a difference in masticatory muscle activity between ISOD and CCD was accepted. The crossover study design used in this study reduces patient variability as comparison of denture was done on the same patient.

In this study, both muscle groups exhibited increased muscle activity in patients with ISODs. This result is congruous with the results of van der Bilt *et al*. where the mean wave range (MWR) of both masseter and temporalis muscle during mastication with recently constructed CRCDs was significantly reduced as compared to ISODs. Their study also showed that maximum bite is 60–200 times more for ISOD as compared to CCD patients.[8] Dakhilalian *et al*. in their study also reported decreased MWR of the masseter and temporalis muscles while clenching after removing the attachments.[6] Increase in muscular activity as well as bite force can be attributed to greater retention and stability of the ISODs in relation to CCDs.[6,13-15] According to Misch, removable denture exhibits less efficiency in comparison to fixed dentures.[16] This fact was verified in this study as ISOD group showed higher muscle efficiency.

van der Bilt *et al*. proclaimed that during maximum bite force, the temporalis presents significantly reduced activity with CCD compared to masseter muscle. The muscle activity was comparable for patients with ISOD.[8] In this research, when subjects clenched and chewed with an implant-supported denture, temporalis muscle activity was significantly pronounced compared to the masseter muscle. This recommends that the temporalis muscle is active to a greater extent as opposed to the masseter



Graph 1: Comparison of left and right masseter muscle in CCD and ISOD patients. CCD: Conventional complete denture, ISOD: Implant-supported overdenture



Graph 2: Comparison of left and right temporalis muscle in CCD and ISOD patients. CCD: Conventional complete denture, ISOD: Implant-supported overdenture

Table 1: Mean comparison of the masseter and temporalis muscle activity among implant-supported overdenture and conventional complete denture group

	n	Mean±SD	SE	95% CI for mean		Minimum	Maximum	Mean difference	*P*	Inference
				Lower bound	Upper bound					
Masseter (clenching)										
CCD	15	26.00±11.30	2.91	−21.54	−15.12	14.50	62.00	−18.33	0.001	ISOD >CCD
ISOD	15	44.33±11.29	2.91			31.00	78.00			
Masseter (cotton roll clenching)										
CCD	15	22.67±9.78	2.52	−23.96	−13.03	8.45	35.00	−18.49	0.001	
ISOD	15	41.16±13.42	3.46			14.50	75.50			
Masseter (chewing)										
CCD	15	24.23±9.51	2.45	−26.52	−15.40	12.25	49.00	−20.96	0.001	
ISOD	15	45.20±17.50	4.52			28.00	92.00			
Temporalis (clenching)										
CCD	15	31.06±12.20	3.15	−20.01	−13.65	13.00	47.00	−16.83	0.001	
ISOD	15	47.90±11.26	2.90			31.50	69.00			
Temporalis (cotton roll clenching)										
CCD	15	29.75±15.35	3.96	−18.56	−13.12	6.90	55.00	−15.84	0.001	
ISOD	15	45.60±13.95	3.60			27.00	71.00			
Temporalis (chewing)										
CCD	15	31.93±14.26	3.68	−22.03	−16.16	11.50	56.00	−19.10	0.001	
ISOD	15	51.03±14.48	3.73			31.50	77.00			

SD: Standard deviation, SE: Standard error, CI: Confidence interval, CCD: Conventional complete denture, ISOD: Implant-supported overdenture

Table 2: Gender-wise comparison of masseter and temporalis muscle activity in patients with conventional complete denture

Variables	Mean±SD		*F*	*P*	Inference
	Male	Female			
Masseter (clenching)	24.38±5.15	28.41±17.43	0.438	0.519	Male >female
Masseter (cotton roll clenching)	24.18±10.35	20.39±9.28	0.524	0.482	
Masseter (chewing)	24.83±6.30	23.33±13.72	0.084	0.777	
Temporalis (clenching)	33.94±10.48	26.75±14.28	1.276	0.279	
Temporalis (cotton roll clenching)	36.72±13.27	19.30±12.65	6.429	0.025	
Temporalis (chewing)	39.11±12.64	21.16±9.07	8.916	0.011	

SD: Standard deviation

Table 3: Gender-wise comparison of masseter and temporalis muscle activity in patients with implant-supported overdenture

Variables	Mean±SD		*F*	*P*	Inference
	Male	Female			
Masseter (clenching)	41.88±8.08	48.00±15.01	1.058	0.322	Male >female
Masseter (cotton roll clenching)	39.27±11.98	44.00±16.08	0.427	0.525	
Masseter (chewing)	42.83±15.37	48.75±21.33	0.393	0.541	
Temporalis (clenching)	50.61±11.77	43.83±10.02	1.334	0.269	
Temporalis (cotton roll clenching)	51.00±14.01	37.50±9.89	4.120	0.063	
Temporalis (chewing)	58.00±14.37	40.58±6.18	7.698	0.016	

SD: Standard deviation

muscle when ISOD is employed. It implies patients using ISODs had conspicuous excursive movements. The result of the present study, however, is congruous to the research done by Soni *et al*. where masseter muscle exhibited larger electromyographic activity compared to other muscle group.[10]

In this study, EMG values masseter and temporalis muscle on both sides reported no comparable differences pre- and postattachment installation demonstrating a balance in muscle activity on both sides. This result is analogous to Bersani *et al*. and Ferrario *et al*. study, where the wave range of masticatory muscles on both sides did not show appreciable differences when rehabilitated with ISODs.[11,12] Contrary to this study, Dakhilalian *et al*. in their study reported significant differences in masseter muscle activity while chewing ($P = 0.03$), indicating asymmetrical activity with CCD. They also stated that the temporalis muscles showed asymmetrical activity with ISOD.[6]

Temporalis muscle activity with ISOD observed in the study during cotton roll clenching and with CCD was appreciably high in males ($P < 0.05$). This suggests that the force of contraction of temporalis muscle is reduced when attachments are removed, but the contraction rate of muscle increases. During chewing with ISODs, temporalis muscle shows statistically significant results ($P = 0.01$) between men and women, indicating that temporalis is more active in men as compared to females during mastication.

In this study, digital sEMG device was used which gives precise value of muscle activity in microvolts. Digital device reduces operator error and data are also easy to interpret. In the past, digital EMG has never been used. In previous studies, either needle electrodes were used or the electrodes were replaced by superficial electrodes wherein the device was calibrated. Therefore, the error margin was higher compared to the present study.

Also, in this study, the same dentures were used for ISOD and CCD electromyographic evaluation. The vertical dimension at rest and vertical dimension at occlusion were therefore sustained throughout the period of research to ensure a similar direction of forces and muscle action.

This research surmises that advocating implant-supported overdentures with two implants in the lower canine region proves to be a beneficial treatment modality to enhance masticatory efficiency for completely edentulous patients. The results of the present study brace the advantages of implant therapy, and patients can be acquainted about the enhancement of oral function with ISOD. Thus, rehabilitating with mandibular implant-supported overdenture will improve masticatory muscle efficiency and chewing efficiency in completely edentulous patients.

Limitations of the study

1. Ball attachment was used in this study. Future studies should be done using different attachment systems such as locators
2. This study included a limited number of subjects. Future studies should include more subjects for more reliable conclusions
3. Future studies should compare muscle efficiency between ISOD and implant-supported fixed prosthesis.

CONCLUSIONS

In accordance with the finding of this *in vivo* study, the conclusions drawn were that the overall masticatory efficiency enhances in patients with implant-supported overdenture compared to a conventional denture. For both implant-supported overdenture and CCD, temporalis was found to be more active in males than females during chewing and cotton roll clenching. Coordinated and

symmetrical muscle activity on both sides was observed in the masseter and temporal muscle with CCD and ISOD both during clenching and chewing.

Clinical significance

Rehabilitation with two implants in the mandible remarkably enhances oral function by enhancing overall masticatory efficiency and bite force giving a better quality of life to edentulous patients.

Ethical policy and institutional review board statement

Ethical approval for this study was provided by the Institutional Ethical Committee of K.D. Dental College and Hospital, Mathura (Ref. KDDC/EC/9956A/2021) on December 21, 2018.

Patient declaration of consent statement

The authors certify that appropriate consent was obtained from all the patients included in the study in which they approve to use their photograph and clinical information in the journal. Patients understood that appropriate measures will be taken to conceal their identity and their names will not be published, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Research

Comparative evaluation of efficacy of three different denture cleansing methods in reducing *Candida albicans* count in removable partial denture wearers: A randomized controlled trial

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Abstract

Aims: The study aims to find out the best possible method of cleaning the removable partial denture (RPD) by evaluating the *Candida* count limiting ability in RPD users using three different cleaning methods.

Settings and Design: The present study is randomized controlled trial. Three groups were formed with 20 participants in each. The groups were Group 1 RPD cleansing done using sterile saline and denture brush (negative control group), Group 2 RPD cleansing done using soap and denture brush and Group 3 RPD cleansing done using denture cleansing tablet and denture brush.

Materials and Methods: A baseline data and 15 days' postinsertion data of *Candida* count was recorded using swab collection, from the RPDs given. The swab was collected, cultured, and incubated using standard methods. Once *Candida* was identified using Sabouraud's dextrose agar, *Candida albicans* was further confirmed using germ tube test and cornmeal agar.

Statistical Analysis Used: The analysis was done using SPSS software (IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp.). Paired *t*-test, was used to compare the number of colonies pre and postintervention. The difference between the groups was analyzed using one-way analysis of variance (ANOVA) and Tukey's *post hoc* analysis.

Results: The comparison of baseline data and postintervention data within each group using paired *t* test demonstrated statistically significant values; $P = 0.046$ and 0.000 in Group 2 and 3 respectively. The difference between the Candida colonies in three different groups after the intervention (15 Days) was analyzed using analysis of variance and found to be statistically significant with $P = 0.004$. Tukey's *post hoc* analysis was used to analyze the difference between the groups. It was concurred that there was a statistically significant difference between all three groups, but the difference in the mean was highest between the Group 1 and 3 (1210.99).

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Submitted: 17-Dec-2021, **Revised:** 16-May-2022, **Accepted:** 19-May-2022, **Published:** ***.

Access this article online	
Quick Response Code:	**Website:** www.j-ips.org
	DOI: 10.4103/jips.jips_553_21

How to cite this article: Rajendran A, George R, Mathew N, Ranjith M, Nazar NA. Comparative evaluation of efficacy of three different denture cleansing methods in reducing *Candida albicans* count in removable partial denture wearers: A randomized controlled trial. J Indian Prosthodont Soc 2022;22:256-61.

Conclusion: Within the limitations of the study, it is concluded that the use of denture cleansers and brush on a daily basis would actively reduce the number of C. albicans colony formation in RPD and thereby improve the overall health of denture wearer.

Keywords: *Candida* associated denture stomatitis, *Candida* colony, denture cleansers, denture cleansing methods, removable partial denture

INTRODUCTION

Removable partial denture (RPD) is one of the most common treatment options which patient would select for the replacement of one or more missing tooth/teeth. The RPD is most commonly made with Polymethylmethacrylate (PMMA) type resin material.[1] Proper maintenance of denture is essential to avoid the accumulation of biofilm and plaque on the denture surface. Various factors that result in these accumulations are improperly polished RPDs, denture porosity, salivary constitution of the patient, dietary constituents, inadequate maintenance due to poor dexterity or reluctance in cleaning, abrasion due to use of brushes, duration of denture wearing, inappropriate patient education and unsuitable materials for cleaning.[2-4]

Background and objectives

Poor oral hygiene, resulting in biofilm accumulation on RPDs can increase the incidence of tissue inflammation, *Candida*-associated denture stomatitis and caries on abutment teeth and some important systemic infections.[5,6] Hence, proper maintenance and cleaning of RPD are inevitable for the best outcome.

Although cleaning of RPDs is commonly done by brushing, the dexterity limitations and complexities in RPD design, can impair complete biofilm removal.[7] The American College of Prosthodontists recommended soaking of dentures in an effective, nonabrasive denture cleansing solution and daily brushing to reduce the levels of potentially harmful biofilm.[8]

Routine use of denture cleansers by RPD wearers could improve biofilm control and effectively limit *Candida* levels.[9] Some clinical studies were reported toward the effectiveness of denture cleansers in controlling the *Candida* biofilm in complete denture wearers.[10,11] *In vitro* studies that provided evidence regarding its effect on physical and mechanical properties of resin teeth, acrylic, and metallic framework were also published.[12-15] While most of the studies were concentrated toward complete denture, only very few studies have been published regarding denture cleansing habits and the effect on *Candida* species in RPD users.[16-18] Some studies had shown that there were differences in the quantity of *Candida* biofilm in complete denture wearers as compared to RPD wearers.[19,20] Hence, the effect of different denture cleansing methods, and its effect in controlling *Candida* biofilm in RPD patients should be studied separately.

The present study is a randomized controlled trial (RCT) that aims to evaluate the effectiveness of common denture cleansing methods followed by the patients in reducing the *Candida* counts in RPD wearers.

MATERIALS AND METHODS

Trial design

Randomized parallel-arm controlled trial.

Participants

Participants were selected based on satisfaction of inclusion criteria.

Inclusion criteria

1. Subjects with good oral and systemic health conditions irrespective of age and sex
2. Subjects who were fresh denture wearer because baseline data is collected on the day of insertion
3. Subjects who were willing to continuously use the RPD and to follow the instructions.

Exclusion criteria

1. Subjects whose consent to participate was not obtained
2. Subjects who underwent antimicrobial therapy in the past 3 months
3. Subjects who reported with denture stomatitis or any other oral inflammatory conditions.

The study was conducted in the department of Prosthodontics at a dental college in South India. It was approved by the Institutional Ethics Committee with reference number-KIDS/IEC/05-2014/11 and was conducted according to the instructions from the institutional ethical committee and with the Helsinky declaration of 1975 as revised in 2000. The study was conducted from April to June 2014.

The sample size was derived to be 20 in each group. Since the study design consisted of three groups, one negative control group and two study groups, a total of

60 participants with twenty subjects in each group were planned. The participants were selected from those subjects who were rehabilitated with RPDs in the department of prosthodontics. Sixty participants, who satisfied all the inclusion criteria, were selected after examining 84 new RPD wearers. The selected participants signed the informed consent. Study subjects were randomly selected and allocated using lottery method of randomization. There were no dropouts among the participants.

- Group 1: Subjects who cleaned their RPD using sterile water and denture cleaning brush. This group acted as a negative control group
- Group 2: Subjects who cleaned their RPD using soap and denture cleaning brush
- Group 3: Subjects who cleaned their RPD using denture cleansing tablet and denture cleaning brush.

Group allocation was double-blinded. Normal saline (Albert David Ltd, Kolkata), Lifebuoy bath soap (Hindustan Unilever Limited, Mumbai), Fittydent Denture Cleansing Tablets (Dr. Reddy's Laboratories Ltd., Hyderabad), and Clinsodent denture cleansing brush (ICPA Health products Ltd, Mumbai) were used in the study. All the participants were provided with the materials for cleaning the denture, based on the study group they were involved. Oral hygiene measures were done for all the participants before starting with the impression procedures.

Sample collection: Baseline data (first denture biofilm) was collected on the day of insertion of RPD. 1 h postinsertion, RPDs were removed, debris and saliva were removed by gentle washing with sterile distilled water and then a sterile swab was rubbed onto the whole denture-both inner and outer surfaces in the following sequence-clasps, teeth and acrylic denture base.

The swab was immediately placed in a polypropylene tube containing 3 mL of sterile saline solution (0.9% Sodium Chloride) and then sonicated at 7 Watts for 30 seconds. The resulting suspension containing biofilm was diluted 10-fold and then it was inoculated by the spread plate technique in Sabouraud's Dextrose Agar (SDA) culture media with 10% Chloramphenicol (Himedia, India). The plates were incubated for 48 h at 37°C in aerobic condition and the number of colony-forming units was quantified using a stereomicroscope.

Candida was preliminarily identified by the characteristic creamy convex yeast colonies on SDA. Gram staining of the smear revealed Gram-positive budding cells. Germ tube test and cornmeal agar formed germ tube and chlamydospores, respectively, which further confirmed *Candida albicans*.

Once swab collection was completed, the dentures were given back to the respective patients for use. They were instructed to rinse the RPD once in plain water before the cleaning procedure. The cleaning was done once a day, after their routine nocturnal brushing using the method they were asked to follow. The brushing time of RPD was kept as 3 min for all. No additional hygiene instructions were provided to avoid any bias.

The participants in Group 1 were asked to brush the denture using sterile water and brush provided. The participants in Group 2 used soap before they brush the denture. Those participants who were included in Group 3 were instructed to dissolve one denture cleansing tablet in 200 ml warm water and soak the denture for 10 min in it followed by brushing. A reminder message for following the instructions was sent every night to subject's registered mobile number at 9:00 pm and a printed checklist was also given to tick mark on a daily basis after performing the cleaning of denture in instructed manner.

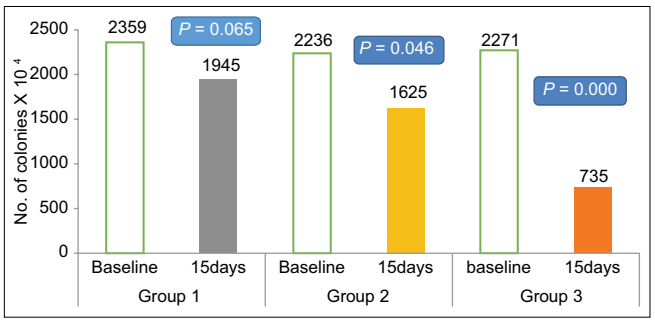
Fifteen days' postinsertion, the study subjects turned back for the posttreatment sample collection. Checklists were evaluated for confirming that the subjects followed the instructions properly. Patients were given instruction to wear the RPD at least 1 h before the sample collection. The same procedures were followed as done for the baseline sample collection. The dentures were given back to the participants after sample collection.

Statistical methods

The analysis was done using SPSS software (IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp.). Paired *t*-test, was used to compare the number of colonies pre and postintervention. The difference between the groups was analyzed using one-way analysis of variance (ANOVA) and Tukey's *post hoc* analysis.

RESULTS

A final sample consisted of 20 subjects in each group. Group 1 comprised of 12 males and 8 females with



Graph 1: Distribution of *Candida albicans* colonies in three different groups

a mean age of 45 ± 8.6 years; Group 2 comprised of 13 males and 7 females with mean age of 47 ± 5.6 years: Group 3 comprised of 11 males and 9 females with mean age of 42 ± 5.88 years. Graph 1 shows the distribution of *C. albicans* counts. The figure also shows the *P* values of paired *t*-test, which was used to compare the number of colonies pre and postintervention. It was seen that there was a statistically significant difference in the mean colony in Group 2 and 3 with $P = 0.046$ and 0.000 respectively.

Table 1 shows the difference between the *Candida* counts in three different groups after the intervention (15 days). The difference between the groups was analyzed using one-way ANOVA. It was seen that there was a statistically significant difference within the groups. Tukey's *post hoc* analysis was used to analyze the difference between the groups. It was concurred that there was a statistically significant difference between all the three groups, but, the difference in the mean was highest between the Group 1 and 3 (1210.99). A subset of alpha scores showed that the highest scores were of Group 1 and lowest of Group 3 [Table 2].

DISCUSSION

The efficacy of different methods of cleaning the RPD is not well documented. The present study evaluated the efficacy of three commonly used methods of cleaning the denture. Micro-porosities in dentures made from PMMA can cause easy adherence and colonization of *Candida*. Since *C. albicans* is the main causative organism of denture stomatitis, the count of *C. albicans* colony was used to assess the effectiveness of various denture cleansing methods.[10]

The RPD is less studied when compared to complete denture regarding the effectiveness of cleansing agents.

Table 1: Difference between the *Candida* colonies in three different groups after the intervention (15 days)

ANOVA	Degree of freedom	*F*	*P*
Between the groups	2	198.258	0.004
Tukey's *post hoc* analysis			
Group	**Mean difference**	***T***	***P***
Group 1-Group 2	320.33	5.154	0.045
Group 2-Group 3	890.65	11.856	0.013
Group 3-Group 1	1210.99	24.891	0.001

Table 2: Distribution of the subsets

Groups	*n*[a]	Subset for alpha=0.05		
		1	2	3
3	20	735.13		
2	20		1625.33	
1	20			1945.47

[a]Uses harmonic mean sample size=20.000. Means for groups in homogeneous subsets are displayed

Hence, RPD was studied in the present RCT. It is demonstrated in some studies that the *Candida* biofilm formed is less in RPD as compared to complete denture. This was because of the reduced surface area of PMMA and the highly polished surface of metallic framework in RPD that reduces the colonization of *Candida* species.[19,20] The present study involve RPDs fabricated with PMMA without any metal framework.

Comparisons between different types of cleaning agents are available in literature. One study suggested that there were no significant differences in the efficiency of plaque removal of denture using toothpaste, liquid handwashing soap, and two different chemical-soak denture cleansers.[11] Another study revealed that removal of coffee stains was least effective while turmeric stains were easily removed by both sodium perborate and sodium hypochlorite-based denture cleansers.[12]

The reduction of *Candida* biofilm is always considered important. Hence, few studies were done to improve the antimicrobial property by incorporation of different types of materials into tissue conditioners. Some authors have suggested that few materials such as *Azadirachta indica*, *Melaleuca alternifolia* oil, and *Cocos nucifera* oil reduced the *Candida* colony formation if incorporated into the tissue conditioners.[21,22]

Many studies which evaluated the change in physical and mechanical properties of denture while using denture cleansers were reported and found that the color stability was in the clinically acceptable range.[12] Other factors such as hardness, flexural strength, and surface roughness are seriously affected.[13-15]

Within the group, the present study shows that the *Candida* count was reduced to a statistically significant level when 15 days cleaning protocol was followed as compared to the baseline value in groups 2 and 3 ($P = 0.046$ and 0.000 respectively). The Group 1 was added as a negative control group which showed no statistically significant improvement in *Candida* control as compared to baseline. This proves that both soap and brush technique and denture cleanser and brush technique are effective in controlling *Candida* species in RPD.

The comparison between the groups reveals that both Group 2 and 3 shows statistically significant difference ($P = 0.045$ and 0.001 respectively) when compared to Group 1. This suggests that both soap and brush technique and denture cleanser and brush technique are more

effective than saline and brush technique in controlling *Candida* species in RPD.

There is statistically significant difference ($P = 0.013$) while comparing Group 2 and 3 which shows that soap and brush technique is less effective when compared to denture cleanser and brush technique. The effectiveness of peroxide-effervescent denture cleansers is attributed to its immediate decomposition to Hydrogen Peroxide followed by release of nascent oxygen when dipped in water, which in turn cleanses the surface of denture by the effervescent action.[23]

Few studies reported the influence of denture cleansers on mechanical and physical properties such as flexural strength and adaptation of denture base. The use of medium power microwave heating method and Sodium hypochlorite solution (5.25% for 5 min) for denture disinfection showed better disinfection and dimensional stability as compared to Chlorhexidine gluconate (for 5 h) and effervescent tablets.[24] Another study stated that thyme essential oil showed better flexural strength along with good cleansing activity as compared to denture cleansing tablets.[25] Hence, judicious use of denture cleansers is important.

The patient education is also a key factor in good denture hygiene care. The patients need to be educated well by the dentist regarding the requirement of cleaning the denture on daily basis using an effective plaque control method. However, few studies analyzed that, the knowledge of dental practitioners themselves regarding the effectiveness of various denture cleansing methods and materials is compromised.[4,26] One systematic review stated that the poor patient education is attributed to the poor guidance from the professional bodies and at the same time professional bodies are not able to guide because of a lack of research publications on effective methods of cleaning the denture.[27]

The study used the methods which are commonly recommended by the dentists. Hence, this study is clinically relevant and can be generalized. Although denture cleanser and brush method was the most effective cleaning method against *C. albicans* colony formation, none of the methods was able to completely remove it.

This study is limited to the use of only one type of denture cleansing tablet. More studies need to be done to evaluate the most effective denture cleanser in removing *Candida* colonies.

CONCLUSION

The effect of antiplaque agents is unquestionable in reducing *Candidal* growth.[28] Within the limitations of the study, it is concluded that the use of denture cleansers and brush on a daily basis would actively reduce the number of *C. albicans* colony formation and thereby improve the overall health of denture wearer.

Financial support and sponsorship

The study received a grant from Indian Council of Medical Research (ICMR), department of Health Research, Ministry of Health and Family Welfare, Government of India as a part of Short Term Studentship in 2014 with reference no. 2014-03365.

Conflicts of interest

There are no conflicts of interest.

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Research

Effect of physical and psychological status on oral health quality of life of geriatric patients undergoing complete denture treatment

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Abstract

Aim: The present study was conducted to evaluate differences in Oral Health-Related Quality of Life (OHRQoL) in denture wearers based on psychological classification and patient satisfaction.

Settings and Design: A prospective study.

Materials and Methods: 284 patients, aged 30 years and above who fulfilled the eligibility criteria were recruited. Participants answered the OHIP – EDENT questionnaire at the time of denture insertion and 6 months later. Psychological categorization was based on MM House classification. Patient satisfaction was graded from totally satisfied to not very satisfied.

Statistical Analysis Used: SPSS 23 version was used for analyzing descriptive and inferential statistics. ANOVA was used to find significant differences for OHRQoL based on psychological classification and patient satisfaction. Before and after intervention analysis was assessed using student '*t*' test.

Results: Philosophical and exacting patients had better adaptation to dentures than the hysterical and indifferent class of denture wearers. Totally satisfied and very satisfied patients with dentures had lesser mean scores as against the other categories which was significant in all domains suggesting better. Overall, OHIP – EDENT score decreased from 20.253 ± 12.466 to 17.168 ± 14.143, which were significant at $P = 0.043$, thus showing an improvement after a 6 month follow up.

Conclusions: Psychological attitude of denture wearers must be considered by the prosthetic specialist for effective adaptation and acceptance by the edentulous patient.

Keywords: dentures, edentulousness, patient satisfaction, quality of life

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Submitted: 01-Apr-2022, **Revised:** 16-May-2022, **Accepted:** 29-May-2022, **Published:** ****

INTRODUCTION

Oral health as defined by Dolan is "a comfortable and functional dentition that allows individuals to continue their desired social role.[1] Edentulism impacts an individual's work capacity and concentration in their daily routine. Literature studies documenting demographic trends depict an increase

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_162_22

How to cite this article: Dhaded S, Kumar SM, Kaur M, Subhasini, Hegde P. Effect of physical and psychological status on oral health quality of life of geriatric patients undergoing complete denture treatment. J Indian Prosthodont Soc 2022;22:262-7.

in the number of elderly patients with a subsequent increase in the frequency of edentulousness.[2,3] This extent of growth calls for meticulous oral care to be taken among the elderly to maintain optimal health and acceptable standard of life. The current era offers a multitude of treatment choices for the replacement of missing teeth. Despite this, complete denture therapy has remained the mainstay treatment for edentulism and is the preferred choice in many countries owing to its cost-effectiveness, esthetic appeal, and easy maintenance." Often the success of a complete denture was based solely on the dentist's clinical judgment and evaluation of characteristics such as retention, stability, esthetics, and occlusion. However, these quantifications do not consider about patient's satisfaction or their perception about oral health-related quality of life (QoL).[4-6]

The ultimate goal of prosthetic treatment is to reinforce the patient's well-being. However, the criteria adopted in clinical practice do not consider the patient's requirement or attitude, which is the deciding drive for patient satisfaction or QoL.[7]

In recent years, QoL has evolved to be a conceptual patient outcome measure for health-care intervention. It includes multidimensional factors such as physical health, psychological state and well-being, social functioning, economic situation, relationships, and environment. It is a dynamic interaction of the individual with his/her social settings which shapes the individual. The concept is the interaction of different oral conditions, social and contextual factors, as well as the rest of the body.[8,9]

Sociodemographic factors, psychological framework, and oral health-related QoL (OHRQoL) are significant factors linked with patients' satisfaction in determining denture adaptation and acceptance, consequently materializing into "success" or "failure of dentures. It hence becomes important for a dentist to understand the interplay of these factors. Literature correlating OHRQoL in denture wearers to psychological status or sociodemographic variables are limited in this part of the country.

A thorough understanding of these factors helps to evaluate patient satisfaction which is significant for denture acceptance. The existing data does not evaluate OHIP– EDENT, but mostly OHIP 14. Based on the knowledge obtained, oral health promotion and care programs can be planned to enhance general and oral health status.

Hence, the present study was conducted to test the hypothesis –"There is no effect of psychological factors or patient satisfaction on OHRQoL in edentulous patients undergoing denture treatment." The objective of the study was to find the effect of psychological framework and patient satisfaction on OHRQoL as measured by the OHIP– EDENT questionnaire.

MATERIALS AND METHODS

A prospective cohort study was designed to evaluate OHRQoL among patients seeking complete dentures intervention based on physical and psychological status in a representative population of Belgaum, North Karnataka. Every subject was assessed two times; first at baseline which is immediately after consenting to be a part of the study and 6 months forming the second evaluation time.

Permission to conduct the study was obtained from the Institutional Ethical Committee of Jaipur Dental College. Informed consent of all participants was obtained. Patients requiring complete dentures aged 30 and above with good mental and physical health were included. Patients presenting with any systemic illness or any disease affecting their QoL and undergoing therapy for psychological conditions or having problems with communication were excluded. A single examiner conducted the study and assessed the psychological attitude of all patients, thus overcoming the element of variability.

Considering a 43% impact of complete dentures on OHRQoL as per the article of Nareudee Limpuangthip *et al*.,[10] the sample size was calculated to be as 284 based on the below formula, wherein n is the sample size, Z is the statistic corresponding to the level of confidence, P is expected prevalence, and d is precision.

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

A convenient consecutive sampling technique was employed till 284 samples were collected. This technique minimized volunteerism and other related selection biases by consecutively recruiting each accessible patient who met the eligibility criteria.

Sociodemographic information of age and gender were collected in a carefully designed pro forma. The psychological status of the patients was categorized employing the MM House classification into four kinds: philosophical, exacting, hysterical, and indifferent. OHRQOL was measured using the OHIP-EDENT[11] at the time of denture insertion and 6 months later. OHIP–EDENT utilizes a 19 variable questionnaire divided into seven domains, namely functional disability, physical pain, psychological discomfort, physical disability,

psychological disability, social disability, and handicap. It is specifically developed for edentulous subjects, addressing questions of masticatory capability, eating pleasure, comfort level, assurance while wearing prosthesis, and problems in relationships because of denture wearing. Questions regarding denture satisfaction (posttreatment) following the placement of the new complete dentures were recorded.

Data were analyzed using the Statistical Package for the Social Sciences version 23.0 (IBM; Chicago, Illinois, USA). One-way analysis of variance (test) was run to find the significant difference of OHRQoL with patient satisfaction and psychological classification. Paired *t*-test assessed differences between baseline and 6 months OHRQoL scores. $P < 0.05$ was considered to be statistically significant.

RESULTS

The present study was done on 284 denture wearers who were completely edentulous patients. Table 1 shows the demographic data of the study population. A clear female predilection was noted with 70.6% of denture wearers being females. Of the 284 individuals examined, 58.8% were of the philosophical type, followed by exacting, hysterical, and indifferent.

Table 2 demonstrates OHIP–EDENT scores against the psychological status of patients. In the physical pain domain, painful aching was found to be higher in the hysterical patients with a mean of 2.053 ± 0.000 and lowest in the philosophical patients with a mean of 0.160 ± 0.370 which was highly significant. The hysterical category of patients worried more with a mean of 4.046 ± 0.024 while philosophical patients worried lesser with a mean of 0.820 ± 0.690 which was statistically significant at $P < 0.001$. Exacting patients exhibited had a higher mean score of 2.5 29 ± 0.514, followed by hysterical, indifferent, and philosophical which was statistically significant at $P < 0.001$. Philosophical type of denture wearers had better scores for the functional domain variables of food catching and dentures not fixing as well at $P < 0.0001$. In the physical disability domain, the hysterical group of patients had higher scores for avoiding eating and unable to eat, while the indifferent class of denture wearers was interrupted during meal time. Social disability domain scores and handicap scores were lesser in the philosophical and exacting patients compared to the other two divisions. Overall, when OHRQoL was compared with the psychological status of patients, philosophical and exacting patients had better adaptation to dentures than the hysterical and indifferent class of denture wearers.

Table 1: Demographic data of the study population

Variables	*n* (%)
Age (years)	
<65	33 (38.8)
>65	52 (61.2)
Gender	
Male	25 (29.4)
Female	60 (70.6)
Psychological classification	
Philosophical	50 (58.8)
Exacting	17 (20.0)
Hysterical	9 (10.6)
Indifferent	9 (10.6)
Patient satisfaction	
Totally satisfied	26 (30.6)
Very satisfied	33 (38.8)
Reasonably satisfied	17 (20.0)
Not very satisfied	9 (10.6)

Table 3 shows OHIP–EDENT scored against patient satisfaction. Totally satisfied and very satisfied patients with dentures had lesser mean scores as against the other categories which was significant in all domains.

When domain scores were compared between two evaluation periods, i.e., baseline and after 6 months, a significant difference was noted in functional limitation with mean scores decreasing from 3.084 ± 1.383 to 2.870 ± 2.613 at $P < 0.001$. Although the scores of physical pain did decrease, it was not significant. Psychological discomfort significantly improved at $P = 0.038$. Psychological disability and handicap did not demonstrate any remarkable change between 6 months. The social disability domain significantly improved with mean values reduced to 2.164 ± 2.219 at the end of 6 months from 3.613 ± 2.002 at the baseline as seen in Table 4.

Overall, the adaptability of the study population to dentures was significantly better in domains of functional limitation, psychological discomfort, and social disability. Correlation analysis was assessed for the various variables against which OHRQoL was evaluated, as shown in Table 5. Psychological status and state of denture satisfaction were found to be significantly correlated with OHRQoL, suggesting a definite influence of these factors on oral health and its QoL.

DISCUSSION

Various elements work together to ensure a patient's contentment while adopting a complete denture prosthesis. The ultimate concern for an operating dentist has been effective mastication, good aesthetics, comfortable speech, and patient wearing comfort. A psychological evaluation as

Table 2: Oral health-related quality of life with psychological status[23]

Domains	Variables	Mean±SD				Total	Mann–Whitney U-test	*P**
		Philosophical	Exacting	Hysterical	Indifferent			
Functional limitation	Difficulty in chewing	0.320±0.471	2.529±0.514	2.000±0.000	1.223±1.189	1.223±1.189	185.125	<0.001**
	Food catching	0.160±0.370	1.000±0.000	1.000±0.000	1.000±0.000	0.505±0.502	58.368	<0.001**
	Dentures not fitting	0.340±0.478	1.529±0.514	3.000±0.000	3.239±0.000	1.412±1.156	169.195	<0.001**
Physical pain	Painful aching	0.160±0.370	0.529±0.515	2.053±0.000	2.000±0.000	0.623±0.816	110.899	<0.001**
	Uncomfortable to eat	0.500±0.505	0.470±0.515	2.000±0.000	3.000±0.000	0.917±0.966	99.525	<0.001**
	Sore spots	0.500±0.505	1.058±1.028	2.000±0.000	3.0000±0.000	1.035±1.017	52.689	<0.001**
	Uncomfortable dentures	0.3400±0.478	2.058±1.028	3.843±0.242	0.103±0.291	1.352±1.445	141.779	<0.001**
Psychological discomfort	Worried	0.820±0.690	2.058±1.028	4.046±0.024	2.884±0.025	1.635±1.307	69.221	<0.001**
	Self conscious	1.406±0.973	1.470±0.514	1.011±0.042	0.026±0.264	0.867±1.192	1.620	0.191 (NS)
Physical disability	Avoid eating	0.680±0.471	0.941±1.028	2.967±0.036	2.786±0.023	1.223±1.095	70.779	<0.001**
	Unable to eat	0.980±0.588	0.529±0.514	2.018±0.003	3.021±0.007	1.211±0.887	57.236	<0.001**
	Interrupts meals	0.000±0.000	0.000±0.000	0.000±0.000	2.003±0.103	0.211±0.671	-	<0.001**
Psychological disability	Upset	0.000±0.000	1.058±1.028	2.007±0.000	2.010±0.000	0.635±0.936	90.450	<0.001**
	Has been embarrassed	0.010±0.001	1.529±0.514	2.010±0.012	0.000±0.000	0.517±0.825	337.800	<0.001**
Social disability	Avoids going out	0.160±0.370	0.000±0.000	2.010±0.018	2.000±0.006	0.517±0.825	202.916	<0.001**
	Less tolerant of others	0.340±0.478	0.000±0.000	0.000±0.000	2.017±0.052	0.411±0.667	65.859	<0.001**
	Irritable with others	0.860±0.700	0.470±0.514	3.002±0.001	3.019±0.130	1.235±1.098	69.794	<0.001**
Handicap	Unable to enjoy company	0.6600±0.478	0.470±0.515	2.010±0.004	3.043±0.008	1.011±9.19	97.250	<0.001**
	Life unsatisfying	1.180±1.100	1.470±0.514	3.000±0.004	3.017±0.063	1.623±1.133	18.818	<0.001**

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

Table 3: Oral health-related quality of life with patient satisfaction

Domains	Variables	Mean±SD					Mann Whitney U-test	*P**
		Totally satisfied	Very satisfied	Reasonably satisfied	Not very satisfied	Total		
Functional limitation	Difficulty in chewing	1.038±1.455	0.484±0.507	2.529±0.514	2.000±0.019	1.223±1.189	21.997	<0.001**
	Food catching	0.346±0.485	0.242±0.435	1.000±0.000	1.000±0.000	0.505±0.502	21.025	<0.001**
	Dentures not fitting	1.038±0.823	0.242±0.435	2.058±1.028	3.000±0.003	1.141±1.156	48.876	<0.001**
Physical pain	Painful aching	0.3462±0.485	0.242±0.435	1.058±1.028	2.000±0.007	0.623±0.816	25.299	<0.001**
	Uncomfortable to eat	0.3077±0.470	0.515±0.507	2.058±1.028	2.000±0.000	0.917±0.966	41.922	<0.001**
	Sore spots	0.692±0.970	0.757±0.435	1.588±1.543	2.000±0.179	1.017±0.110	7.646	<0.001**
	Uncomfortable dentures	1.038±1.455	0.515±0.507	2.588±1.543	3.000±0.178	1.352±1.445	20.685	<0.001**
Psychological discomfort	Worried	1.346±1.294	1.000±7.071	2.058±1.028	4.000±0.029	1.636±1.307	24.850	<0.001**
	Self conscious	1.615±0.941	1.212±0.857	1.470±0.514	1.000±0.368	1.364±0.799	2.054	0.113
Physical disability	Avoid eating	0.346±0.485	0.757±0.435	2.529±0.514	3.000±0.962	1.223±1.095	141.124	<0.001**
	Unable to eat	1.000±0.072	0.969±0.728	1.558±1.543	2.000±0.000	1.211±0.887	5.441	<0.001**
	Interrupts meals	0.000±0.000	0.000±0.000	1.0588±1.028	0.000±0.000	0.211±0.619	24.300	<0.001**
Psychological disability	Upset	0.692±0.970	0.000±0.000	1.0588±1.028	2.000±0.000	0.635±0.936	22.154	<0.001**
	Has been embarrassed	0.692±0.970	0.000±0.000	0.470±0.514	2.000±0.853	0.517±0.825	28.629	<0.001**
Social disability	Avoids going out	0.000±0.000	0.242±0.435	1.058±1.028	2.000±0.722	0.625±0.285	40.170	<0.001**
	Less tolerant of others	0.001±0.578	0.515±0.507	1.058±1.028	0.572±0.330	0.4118±0.677	14.371	<0.001**
	Irritable with others	0.653±0.485	0.787±0.857	2.058±1.028	3.000±0.022	1.235±1.098	32.018	<0.001**
Handicap	Unable to enjoy company	0.3077±0.470	0.757±0.435	2.058±1.028	2.000±0.012	1.011±0.919	40.157	<0.001**
	Life unsatisfying	0.653±0.485	1.545±1.148	2.529±0.514	3.024±0.013	1.623±1.133	28.729	<0.001**

**Highly significant, *Significant. SD: Standard deviation

Table 4: Comparative analysis of baseline versus 6 months evaluation for each domain

Domain	Mean±SD		Paired *t*-test	*P*
	Mean scores (baseline)	Mean scores (6 months)		
Functional limitation	3.084±1.383	2.870±2.613	8.359	<0.001**
Physical pain	4.053±2.070	3.858±3.842	4.822	0.064 (NS)
Psychological discomfort	3.934±2.291	3.000±1.371	1.893	0.038*
Psychological disability	2.934±2.835	2.641±2.213	11.110	0.117 (NS)
Social disability	3.613±2.002	2.164±2.219	5.885	<0.001**
Handicap	2.635±1.8850	2.420±1.898	3.243	0.962 (NS)

**Highly significant, *Significant. NS: Nothing Significant, SD: Standard deviation, OHIP: Oral health impact profile

related to satisfaction could be used to better comprehend patient–dentist relationships and treatment outcomes.[12] Self-reported assessments may be more significant than clinical measures, and they have been the most important determinants of happiness in this situation.[13]

The OHIP-EDENT employed in the current study is a validated questionnaire and is specific for edentulous patients. This version is used in several studies to verify the impact of oral rehabilitation on QoL parameters in patients requiring new complete dentures and to facilitate the comparison of data.[14]

Table 5: Correlation of oral health impact profile-EDENT with factors

OHIP-EDENT	Correlation coefficient	*P*
Age	0.149	0.173 (NS)
Gender	0.832	0.028*
Psychological classification	0.896	<0.001**
Denture satisfaction	0.660	<0.001**

**Highly significant, *Significant. NS: Nothing significant, OHIP: Oral health impact profile

A finding worth mentioning is that the dissatisfaction for lower dentures was higher when a new denture was delivered, probably due to problems of stability. However with time, this improved suggesting better adaptation of dentures overcoming functional restrictions. This is supported by the study of Forgie *et al*.[15]

OHRQOL was influenced by denture satisfaction. All domains of OHRQOL were found to have significant associations with denture satisfaction. These findings matched those of Yoshida *et al*.,[16] who found that patients who were happy with their prosthesis were indeed happy with their life quality. Although no effort was made in this study to quantify separately for maxillary and mandibular denture satisfaction, Berg[17] discovered that 1 year after implantation, patients still had increased pain from the mandibular denture.

OHRQoL was assessed as per patient satisfaction and psychological mindset. The present study showed a comparative evaluation of OHIP–EDENT before and after intervention, as shown in Table 4. A higher mean suggests a poorer QoL. The functional limitation score at baseline was 3.784 ± 1.383 which decreased to 2.870 ± 2.613, which was statistically significant at $P < 0.001$. Similarly, psychological discomfort also reduced from 3.934 ± 2.291 to 3.000 ± 1.371 in 6 months duration, statistically significant at $P = 0.038$. An improvement was also noted for the social disability score from 3.613 ± 2.002 to 2.164 ± 2.219 which was highly statistically significant. The domains of physical pain, psychological disability, and handicap on the other hand did not exhibit any significant changes. Overall, OHIP–EDENT score decreased from 20.253 ± 12.466 to 17.168 ± 14.143, which were statistically significant at $P = 0.043$. These findings are consistent with the study of Srdjan Dusan Postic *et al*.[18] wherein OHRQoL improved significantly from 35.367 to 32.709, significant at 0.027.

An evaluation of the mental attitude of the patients in the study of Julia *et al*.[20] revealed that the majority of the patients were of philosophical in attitude, with only a few exhibiting an aggressive attitude. No patient displayed a hysterical or indifferent attitude toward treatment. Our study also reported a greater segment of the patient in the philosophical category, consequently determining patient satisfaction. Literature shows a definite relationship of psychological factors affecting denture satisfaction. Al Quran *et al*.[21] observed a significant association of neuroticism with denture satisfaction in their study. Similar findings were noted in the study of Winkler.[20]

The current research is well designed to showcase the performance report of the best methodology, as per the principles of evidence-based practice. Yet certain considerations like behavioral and personality traits of patients cannot be standardized which in turn can destine denture acceptance. The subjective dilemma of the individual in reporting a disability or discomfort in eliciting OHRQoL also can be a possible limitation. The study design does not determine the causal relation of OHRQoL with either patient satisfaction or psychological categorization. Further studies employing larger multicentric options are needed to understand this relationship.

As rightly stated by Jamieson "Fitting the personality of the elderly patient is often more challenging than fitting the denture to the mouth." It is critical for the dentist to recognise the patient's personality and mental attitude to facilitate treatment. The attitude of the dentist and effective communication are essential factors in the patient's attitude during treatment and acceptance of dentures.

CONCLUSION

The present study reports a significant improvement in OHRQoL in complete dentures, 6 months after delivery when measured by OHIP–EDENT in all its domains. This finding is consistent with the findings of several other studies that examined the OHRQoL of completely edentulous patients before and after treatment. The patients' QoL was also found to be higher at 6 months than at baseline. This disparity in mean scores could be explained by the patients' continued adaptation to their new prostheses. It also upholds that patient satisfaction and the psychological status of the individual can influence OHRQoL.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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Research

Retention force of Molloplast-B with ball attachment in implant-supported overdentures: An *in vitro* study

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Abstract

Aim: The purpose of this study is to evaluate the retention effectiveness of Molloplast B as a female attachment compared to O rings' in implant supported overdentures.

Settings and Design: This systematic review and meta-analysis was evaluated using the Preferred Reporting Items for Systematic Review and Meta-Analysis guidelines.

Materials and Methods: Sixteen female part models were divided into two groups: eight female parts made with O ring (Group A) and eight female parts made with Molloplast B (Group B). All of the models were soaked in artificial saliva for 24 h, then, their retention force was measured in Newton using a Universal mechanical testing machine, initially, after 500, after 1000, and after 1500 of loading and dislodging cycles.

Statistical Analysis Used: The statistical analysis was conducted by using one way ANOVA test and Bonferroni test. SPSS Software (SPSS, Version 27, IBM Co., Chicago, IL, USA).

Results: After 1500 loading and dislodging cycles, Group B has the highest mean retention force (4.09), followed by Group A, which has a mean retention force of 3.73.

Conclusion: Molloplast B with a 2.7 mm diameter ball attachment lost the least amount of retention force after 1500 loading and dislodging cycles.

Keywords: Attachment, implant, Molloplast-B, O-ring, overdenture, retention

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Submitted: 25-Jan-2022, **Revised:** 18-Apr-2022, **Accepted:** 29-May-2022, **Published:** ***

INTRODUCTION

Edentulism is a common problem that develops as individuals get older and it has serious consequences for their general health.[1] Complete dentures are one of the most common treatment options for edentulous patients because they are simple and affordable.[2] In edentulous patients, resorption of the alveolar ridge, particularly in the mandible, results in a loss of retention, stability, and patient's comfort.[3] Implant-supported overdentures have a number of advantages over regular dentures, including increased retention and stability, improved mastication efficiency, and improved quality of life.[4,5] Implant-supported overdentures use a variety of attachment devices, including ball, bar, magnet, telescopic, and locators.[6] A ball attachment is a stud attachment

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_43_22

How to cite this article: Salloum A, Alassafeen A, Kassis J. Retention force of Molloplast-B with ball attachment in implant-supported overdentures: An *in vitro* study. J Indian Prosthodont Soc 2022;22:268-71.

that consists of a ball abutment that is attached to the implant and a female portion that is a silicone loop inside a metal cap housing.[7,8] Ball attachments improve force transfer to the implant's body and improve overdenture stability.[9] The ball attachment requires about 12 mm of occlusal space, which affects esthetics when there is not enough; in addition, the metal cap housing of the ball attachment is a weak point of the overdenture and may cause repeated fractures; and subsequently, the attachment will lose much of its retention after 6–12 months of use.[10] Soft liners are used with dentures to distribute functional forces on the denture bearing area due to their viscoelastic properties. They are classified as permanent or semi-permanent and are further divided into silicone elastomers and plasticized acrylics, both of which can be heat cured or self cured.[11] Molloplast-B (DETAX, Germany) is a permanent heat-cured silicone soft liner with a long-lasting viscoelastic property.[12] In a Shernoff technical report in 1984, it was used as a female part with grooves on surviving roots and a conventional overdenture to promote retention.[13] Another technical remark found that employing heat-curing soft liner materials as a female connector with implant-supported overdentures produced good outcomes for 1–6 years.[14] Silicone soft liners (including Molloplast-B) outperformed acrylic soft liners in a research of retention force of numerous soft lining materials when used as a female connector with bar connector.[15] Ball abutment retention force was acceptable with different types of self-curing acrylic and silicone soft liners when employing a ball with a diameter of 2.5 mm or greater.[16,17] The retention force of Molloplast-B with ball abutment had never been studied before.

The purpose of this study is to determine the retention force of Molloplast-B as a female connector with ball abutment as a male connector after a series of loading and dislodging cycles as a cost-effective method that requires less vertical occlusal space than metal cap housing after a number of loading and dislodging cycles.

MATERIALS AND METHODS

Using models, in which one male connector (ball abutment with a diameter of 2.7 mm) and sixteen female connectors divided into two groups:

1. Group A: Eight Molloplast-B attachments
2. Group B (A control group): Eight O-ring attachments.

A male connector was inserted into a stone model [Figure 1], after which a spacer (6 mm in diameter and 5 mm in height) was made from flexible temporary light-curing material (ReLight tempo, TehnoDent company, Russia),

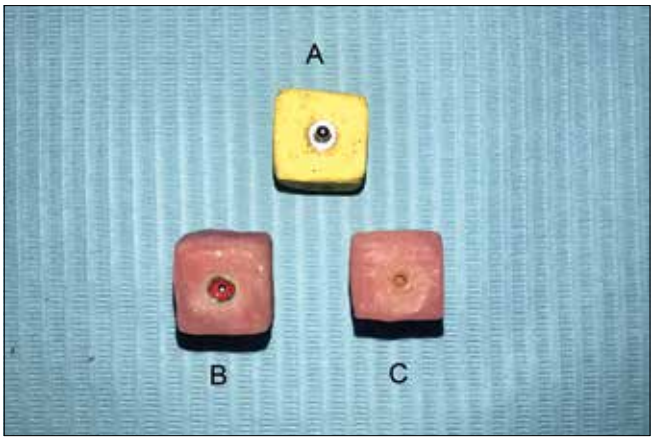

Figure 1: (A) Male connector, (B) O-ring female connector, (C) Molloplast-B connector

which was injected around the male connector inside the wax cylinder and light-cured for 20 s, and after that, the wax cylinder was removed, leaving a space for Molloplast-B to be inserted into the acrylic base during the processing procedure. The lost wax technique was used to create a wax model that resembled an experimental base before being turned into heat-cured acrylic. The wax model, a stone model with the male connector, and a flexible temporary light-curing spacer were all placed within the processing flask. After melting the wax and isolating both parts of the flask, a heat-curing acrylic (Vertex Regular, Vertex Dental B. V., the Netherlands) was used to fill the melted wax gap, simulating the experimental basis. After removing the flexible temporary light-curing material, the flask was pressurized with hydraulic pressure for 15 min before being opened to place Molloplast-B. The entire processing method was carried out in accordance with the manufacturer's instructions.

The O-Ring attachment was connected to the experimental base in the same way as the flexible temporary light-curing material, but instead of using flexible temporary light-curing material, the O-Ring attachment was connected directly to the male connector [Figure 2], and the heat curing acrylic processing procedure was used to measure the retention force. The experimental bases and stone model were soaked in artificial saliva for 24 h then the stone model was fixed to the experimental base, and the initial retention force was measured with a universal testing machine (Testometric Co, UK). Retention force was measured at the beginning, after 500, after 1000, and after 1500 loading and dislodging cycles.

Statistical analysis

The retention forces were calculated using score values and the results were analyzed using one way ANOVA test and Bonferroni test. SPSS Software (SPSS, Version 27, IBM

Co., Chicago, IL, USA) was used to perform the statistical analyses of the data. Numerical variables were described with a mean (± standard deviation). A statistical significance level of $P < 0.05$ was used.

RESULTS

Molloplast-B attachment had a retention force of (4.64 ± 0.2 N) initially. After 500 cycles, the testing machine reported (4.6 ± 0.2 N), then (4.38 ± 0.2 N) after 1000 cycles, and finally (4.09 ± 0.3 N) after 1500 cycles. In terms of O-Ring attachment, the retention force was initially (4.94 ± 0.3 N), then (4.86 ± 0.3 N) after 500 cycles, then (4.43 ± 0.3 N) after 1000 cycles, and finally (3.73 ± 0.2 N) after 1500 cycles [Table 1].

According to the one-way ANOVA test, there were significant differences between Molloplast-B attachment and O-Ring attachment regarding retention force in stages (initially, after 500 cycles, after 1000 cycles, and after 1500 cycles) ($P < 0.001$), which means that at the 95% confidence level, there is statistical significance in the mean retention forces between both groups according to the studied stages, [Table 2] however, when results were analyzed employing Bonferroni test for multiple comparisons, the test showed no statistically significant differences between both groups at the stage (after 1000 cycles) [Table 3].

Table 1: Comparison of maximum retention force in different stages

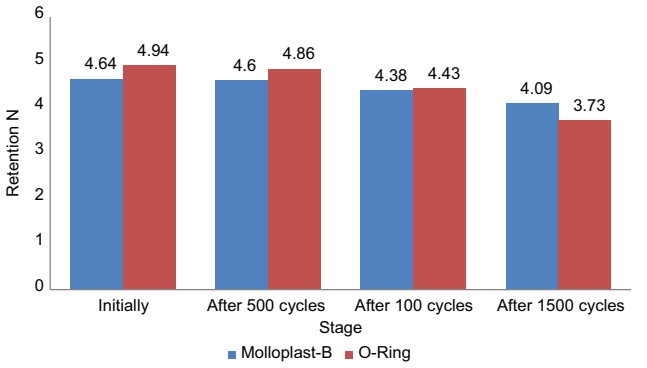

Table 2: The results of the one-way ANOVA test to study the significance of differences in the average retention force, in Newton's, among the two groups of the retention method studied in the research sample, according to the stage studied

Stage studied	F value	Significance level
Initially	450.583	0.000
After 500 Cycles	492.486	0.000
After 1000 Cycles	534.286	0.000
After 1500 Cycles	537.560	0.000

DISCUSSION

Ball attachment is one of the most popular attachment techniques for implant-supported overdentures, and the majority of ball attachments rely on the O-Ring connector for optimal retention.[18] Although the O-Ring is a good attachment system, it has several flaws, such as diminishing its holding force with time (6–12 months).[19] While O-Ring attachments rely on the silicon ring's viscoelastic properties to obtain retention with ball attachment,[20] Molloplast-B, which has viscoelastic features as well, can also be used with ball attachment, especially because Molloplast-B keeps its viscoelastic capabilities for a long time.[21]

The testing sample consisted of sixteen female connectors separated into two groups: (Group A) eight Molloplast-B attachments, (Group B) as a control group, with another eight O-ring attachments, and one male connector (A ball attachment) with a diameter of 2.7 mm. All of the connectors were submerged in artificial saliva for 24 h, and the maximum retention force was recorded in four

Figure 2: O-ring connector in place after processing the experimental base (Male connector)

Table 3: The results of binary comparison using the Bonferroni test to study the significance of the binary differences in the average retention force (in Newton's) among the two groups (A and B)

Studied stage	Retention technique used (I)	Retention technique used (J)	Difference between means (I-J)	Standard error of the difference	Significance level
Initially	Group A	Group B	-0.30	0.09	0.022
After 500 cycles	Group A	Group B	-0.26	0.09	0.037
After 1000 cycles	Group A	Group B	-0.05	0.08	1.000
After 1500 cycles	Group A	Group B	0.36	0.07	0.000

phases using a universal testing machine (initially, after 500 cycles, after 1000 cycles, and after 1500 cycles). There were no significant variations in Molloplast-B attachment retention force after 500 cycles, which can be explained by Molloplast-B long-lasting's viscoelastic properties and high wear resistance after a significant number of dislodging cycles.[15] After 1000 cycles, however, there was no significant difference between Molloplast-B and O-Ring attachments, indicating that Molloplast-B and O-Ring attachments are both durable over time.[22] After 1500 cycles, however, a significant difference was observed between Molloplast-B and O-Ring attachments, owing to the former's higher wear resistance after dislodging cycles.[23] compared to the latter's loss of retention with additional dislodging cycles.[19] As a result of its wear resistance, long-lasting viscoelastic properties, cost-effectiveness, and esthetic properties in cases of lack of vertical space for overdenture, Molloplast-B could be a good female connector with ball attachment in implant-supported overdentures, in addition to having an easy way to gain retention in implant-supported overdentures without interrupting teeth arrangement.

CONCLUSION

Under the experimental conditions of this study:

1. Regardless of whether the female connection is Molloplast-B or O-Ring, there is a continuous loss of retention with ball attachments throughout dislodging cycles under the experimental conditions of this research
2. During dislodging cycles, retention loss with the Molloplast-B female connector is lower than with the O-Ring female connector
3. When used with a 2.7-mm diameter ball attachment, the Molloplast-B female connector may survive for a longer time.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Research

Influence of zirconia/glass veneer thickness and implant abutment material on the final shade of implant restorations

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Abstract

Aim: The aim of this study was to investigate the combined effect of ceramic material, ceramic thickness, and implant abutment background to the final color of restorations.

Settings and Design: This was a comparative *in vitro* study.

Materials and Methods: Three different types of monolithic and porcelain-veneered zirconia disc-shaped specimens (Prettau Anterior, VITA YZ ST, and VITA YZ HT) were prepared in A3 shade with two different thicknesses (1 mm and 1.5 mm) ($n = 10$). Each zirconia material was made of 4-mm thickness as a control specimen of each monolithic zirconia type, and 4-mm thick veneering ceramic (VITA VM9 Base Dentine) was made as a control for veneered zirconia groups. Three simulated implant abutments were fabricated from titanium, white-shaded and yellow-shaded zirconia. The zirconia specimens were placed on different abutment backgrounds, and the color difference (ΔE) between experimental and control specimens was measured.

Statistical Analysis Used: The three-way ANOVA and the Scheffé test were used for data analysis ($\alpha = 0.05$).

Results: The mean ΔE values between two thicknesses were significantly different in every background for all zirconia materials. The ΔE values of zirconia specimens on yellow zirconia were lower than those of other abutments. The clinically acceptable ΔE value ($\Delta E < 3$) was found in some monolithic zirconia specimens on white-shaded and yellow-shaded abutments, while the ΔE value is approximately 3 or less in all 1.5-mm thick porcelain-veneered zirconia groups.

Conclusions: Different zirconia materials on implant abutments affected the final color of restorations. To achieve satisfactory color, the minimum thickness of zirconia restorations should be at least 1.5 mm on yellow zirconia abutment.

Keywords: Ceramics, implant abutment, zirconia

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Submitted: 10-Apr-2022, **Revised:** 21-May-2022, **Accepted:** 23-May-2022, **Published:** ***

Access this article online	
Quick Response Code:	**Website:** www.j-ips.org
	DOI: 10.4103/jips.jips_179_22

How to cite this article: Woo M, Anunmana C, Eiampongpaiboon T. Influence of zirconia/glass veneer thickness and implant abutment material on the final shade of implant restorations. J Indian Prosthodont Soc 2022;22:272-8.

INTRODUCTION

Dental ceramics have been widely used as cosmetic restorations since the color of ceramics is similar to the color of natural teeth. The restorations in fixed dental prostheses were developed from metal-ceramic to all-ceramic restorations, which provide tooth-like color and translucency superior to metal-ceramic restorations. In addition, CAD-CAM technology can provide accuracy and time-saving process to fabricate ceramic restorations.[1] To achieve a more esthetic outcome of the restorations, one of the critical factors is the translucency of the restorations.[2] The translucency of the material allows the light to transmit through the object that mimics the natural appearance of the teeth; accordingly, ceramic materials have been developed and continuously researched for better clinical outcomes.

Various types of dental ceramics have been used for ceramic restorations including zirconia, which has high fracture toughness to resist fracture of the restorations from the occlusal force. Thus, zirconia is currently a widespread treatment option as a restorative material in the posterior teeth.[3] Because zirconia is a highly crystalline ceramic material, which the average grain size is initially < 1 μm, the translucency of zirconia is lower than that of other dental glass ceramics.[4] In addition, other factors such as particle size, porosity of structure, thickness of restorations, and other components also influence the translucency of zirconia. These factors can cause the scattering of light from the material.[5]

To overcome the opacity of early zirconia material, the more translucent veneering ceramic is originally applied to the zirconia framework where it can replicate the tooth-like color of the restorations.[6] However, chipping or fracture of the veneering layer is the main complication when bilayered zirconia restoration is used. Therefore, the monolithic zirconia was developed and introduced to avoid chipping or delamination of veneering glass, and it also provides better optical properties than metal-ceramic material with sufficient mechanical properties under occlusal loading.[5,7] Furthermore, the translucency of zirconia can be improved with different methods such as modified grain size, increased cubic phase, or reduced impurities in its structure to enhance tooth-colored restorations.[3,7,8]

The final color of ceramic restorations was affected by many factors including the thickness of zirconia and glass veneer, type of zirconia, and color of the underlying background.[9-11] In dental implants, titanium abutment is mainly used in prosthetic parts as it shows biocompatibility to oral tissue with excellent mechanical properties.[12] However, the metal color of titanium abutment may alter the color of the ceramic restorations that may compromise the esthetic outcome.[13] Therefore, zirconia abutment was introduced as an alternative material in the esthetic zone where it can reduce dark metal color at the gingival margin from the titanium abutment.[12,14]

To evaluate the color shade, a spectrophotometer is used to measure the reflected light from the object and calculate in CIE L*a*b* color space with high accuracy.[15,16] This system identifies the color into lightness (L*) that shows the values from 0 for black to 100 for white, red-green (a*), and blue-yellow (b*). Positive a* values are defined as red, while negative a* values are defined as green. Furthermore, positive b* and negative b* values are defined as yellow and blue, respectively.[17]

From previous studies, the effects of monolithic zirconia thickness on the masking ability to background color were observed. The results showed that the thickness of zirconia influenced the final color of the restorations.[9,18] In addition, the color of background substrates affected the outcome of the final shade.[19,20] Moreover, different zirconia materials and thicknesses in zirconia-based restorations also affected the final color of restorations.[6,21] However, the optical effect of translucent zirconia with or without glass veneer on a different background was limited. Therefore, the aim of this present study was to investigate the combined effect of ceramic material, ceramic thickness, and implant abutment background to the final color of restorations. The null hypothesis was that zirconia restoration and implant abutment material had no influence on the final outcome of the implant restorations.

MATERIALS AND METHODS

Three different so-called translucent zirconia materials (Prettau Anterior, VITA YZ ST, and VITA YZ HT) and three different abutment materials (titanium and IPS e.max ZirCAD white shade and yellow shade) were investigated in this study [Table 1]. Ten specimens in 12-mm diameter with two different thicknesses (1 mm and 1.5 mm) were tested in each zirconia material [Table 2]. The sample size was estimated from the results of the previous study,[6] with a significant level (α) at 0.05 and power of the test at 80%.

For the monolithic zirconia groups, a total of 60 specimens of 1-mm and 1.5-mm thick were made (n = 10) [Table 2]. The Prettau Anterior specimens were immersed in A3

Table 1: Materials used in this study

Material	Manufacturer	Composition	Shade
Prettau Anterior	Zirkonzahn GmbH, Gais, Italy	8%-12% Y_2O_3, <1% Al_2O_3, 0.02% SiO_2, 0.01% Fe_2O_3	A3
VITA YZ ST	VITA Zahnfabrik, Bad Säckingen, Germany	6%-8% Y_2O_3, 1-3% HfO_2, 0%-1% Al_2O_3, 0%-1% Pigments	A3
VITA YZ HT	VITA Zahnfabrik, Bad Säckingen, Germany	4%-6% Y_2O_3, 1%-3% HfO_2, 0%-1% Al_2O_3, 0%-1% Pigments	A3
VITA VM9 Base Dentine	VITA Zahnfabrik, Bad Säckingen, Germany	60%-64% SiO_2, 13%-15% Al_2O_3, 4%-6% Na_2O, 7%-10% K_2O, 1%-2% CaO, 0%-1% ZrO_2, 3%-5% B_2O_3	A3
Titanium grade V	Miracle metals, Thailand	90% Ti, 6% Al, 4% V	-
IPS e.max ZirCAD	Ivoclar Vivadent AG, Schaan, Liechtenstein	4.5%-6% Y_2O_3, ≤5% HfO_2, ≤1% Al_2O_3, ≤1% Other oxides for coloring	White (MO 0)
IPS e.max ZirCAD	Ivoclar Vivadent AG, Schaan, Liechtenstein	4.5%-6% Y_2O_3, ≤5% HfO_2, ≤1% Al_2O_3, ≤1% Other oxides for coloring	Yellow (MO 2)

Table 2: Zirconia specimens in this study

Material	Zirconia thickness (mm)	Veneer thickness (mm)	Total thickness (mm)	Symbol
Monolithic zirconia groups				
Prettau anterior	1	-	1	PRTA
	1.5	-	1.5	
VITA YZ ST	1	-	1	Vita ST
	1.5	-	1.5	
VITA YZ HT	1	-	1	Vita HT
	1.5	-	1.5	
Porcelain-veneered zirconia groups				
Prettau anterior	0.5	0.5	1	P-PRTA
	0.5	1	1.5	
VITA YZ ST	0.5	0.5	1	P-Vita ST
	0.5	1	1.5	
VITA YZ HT	0.5	0.5	1	P-Vita HT
	0.5	1	1.5	

shade coloring liquid for 1 s (Colour Liquid for Prettau Anterior Aquarell A3 shade; Zirkonzahn GmbH, Germany) and subsequently removed to be dried for 20 min under drying lamp (Zirkonlampe 250; Zirkonzahn GmbH, Germany) before sintering in furnace at a temperature of 1450°C (Zirkonofen 600; Zirkonzahn GmbH, Germany) following the manufacturer's instruction. The VITA YZ ST and VITA YZ HT zirconia specimens were fired according to the recommended temperatures (VITA YZ ST at 1530°C and VITA YZ HT at 1450°C) in a sintering furnace (inFire HTC speed; Sirona, NC, USA).

After the sintering process, all specimens were polished with 600, 800, 1000, and 1200 grit silicon carbide paper under water coolant (Phoenix Beta; Buehler, Leeds, UK). The final thickness of all specimens was verified by a digital micrometer (Digimatic Micrometer; Mitutoyo, Japan) at five different points on the surface of each sample.

For porcelain-veneered zirconia groups, sixty specimens of 0.5-mm thick zirconia made from three different materials were prepared [Table 2]. Each material was divided into two groups for layering with compatible A3 shade veneering ceramic (VITA VM9 Base Dentine; VITA Zahnfabrik) to derive the final thickness of 1 mm and 1.5 mm (n = 10). The specimens were layered using a plastic mold on which the size was considered the shrinkage of the ceramic after the firing process. All veneered ceramics were fired in a furnace (VITA V60 i-Line; VITA Zahnfabrik, Germany) according to the manufacturer's guideline and subsequently ground with 600–1200 grit silicon carbide paper on the polishing machine (Phoenix Beta; Buehler, Leeds, UK). The final thickness of each sample was verified with a digital micrometer.

For the control specimens, three types of translucent zirconia with A3 shade (Prettau Anterior, VITA YZ ST, and VITA YZ HT) were made in 4-mm thickness as a control sample of each monolithic zirconia type. For the control samples of veneered zirconia groups, veneering ceramic (VITA VM9 Base Dentine A3 shade) was made in 4-mm thickness using a plastic mold. All control specimens were sintered and polished with the silicon carbide paper from 600 to 1200 grit under water coolant, and then, the final thickness was verified using a digital micrometer.

Three different types of simulated implant abutments were prepared as 2-mm thick plates from titanium grade V (Ti), IPS e.max ZirCAD MO 0 white shade (ZirW), and IPS e.max ZirCAD MO 2 yellow shade (ZirY). To fabricate the titanium background, titanium blank was designed and sectioned with lathe machine (SJ-430 × 1000; Ecoca, Taiwan) to the specified thickness. For zirconia backgrounds, zirconium dioxide blocks were cut with a low-speed cutting machine (IsoMet; Buhler, IL, USA). Subsequently, the zirconia backgrounds were fired in sintering furnace and adjusted to the desired thickness. A digital micrometer was used to verify the thickness of specimens at five different points on the surface. All backgrounds and zirconia specimens were cleaned in an ultrasonic bath (Quantrex 210H; L&R Manufacturing Co., NJ, USA) using distilled water for 10 min and dried before color measurement.

Color parameters were conducted by a spectrophotometer (Ultrascan Pro; Hunterlab, VA, USA) with a wavelength range of 360–780 nm and standard illuminant D65/10°.

The spectrophotometer was calibrated before the color analysis according to the instruction of the device. Each tested specimen was placed over the different backgrounds, and clear glycerin was dropped between two materials to improve optical contact. The tip of the spectrophotometer was placed at the center of the sample. Color measurement of all specimens was repeated three times and recorded in the CIE L*a*b* system, which demonstrates in L*, a*, and b* data in three-dimensional color space. The color difference between control and tested specimens was calculated in ΔE using the equation $\Delta E = ((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)^{1/2}$.

The data analysis was performed using statistical software (IBM SPSS Statistics version 22.0; Armonk, NY, IBM Corp). The findings of the Kolmogorov–Smirnov test and Levene's test showed that the data from this study were normally distributed ($P > 0.05$), and variances were homogeneous ($P > 0.05$). The three-way ANOVA ($\alpha = 0.05$) was performed to evaluate the ΔE among the groups considering the factors of ceramic material, ceramic thickness, and abutment type. For the multiple comparisons, the Scheffé test was used to analyze the data ($\alpha = 0.05$).

RESULTS

In monolithic zirconia groups, the results indicated that zirconia material, ceramic thickness, and abutment background significantly affected the ΔE ($P < 0.05$). The means and standard deviations of ΔE values with the Scheffé multiple comparisons are shown in Table 3. A monolithic zirconia specimen on titanium abutment showed more grayish shade, and a specimen on a white-shaded background presented brighter color than the control specimen. However, the color of zirconia restoration over yellow-shaded abutment was more similar to the control than the others [Figure 1].

The mean ΔE within the clinical acceptable value (ΔE <3)[22] was found in all monolithic zirconia specimens on ZirY abutment and in 1.5-mm thick of PRTA and VITA ST on ZirW abutment [Table 3]. However, the ΔE value of 1-mm thick PRTA specimens on ZirY was greater than 3, where it was considered clinically noticeable.

The multiple comparisons indicated that ΔE value of 1-mm thick PRTA on Ti background was significantly higher than those of the other specimens. When ceramic thickness was compared, the ΔE values between 1- and 1.5-mm thick specimens were significantly different in each abutment background for all zirconia materials. Significant differences were also found between Ti and ZirY backgrounds in each zirconia thickness of three materials. The same outcomes were similar between ZirW and ZirY abutments except for 1.5-mm thick PRTA ($P > 0.05$). There were significant differences between Ti and ZirW abutments with 1.5-mm thick specimens in all monolithic zirconia materials ($P < 0.05$) except for VITA HT.

For porcelain-veneered zirconia groups, the results of three-way ANOVA revealed that materials, ceramic thickness and abutment material significantly influenced the ΔE values ($P < 0.05$) [Table 4]. The color of porcelain-veneered zirconia specimens was also affected by the color of the underlying abutments. A zirconia specimen on yellow-shaded abutment displayed the most similarity of color to the control [Figure 2].

The mean ΔE values of the ceramics with 1.5-mm thickness were clinically acceptable where the ΔE values were approximately 3 or less. The results of multiple comparisons for veneered zirconia groups showed that 1-mm thick P-PRTA specimens on Ti background and 1-mm thick P-VITA ST and P-VITA HT on ZirW background had greater ΔE values than those of the other specimens. The ΔE values between 1- and 1.5-mm thick ceramic specimens were significantly different in every background for all zirconia materials ($P < 0.05$). When the abutment backgrounds were considered, the ΔE values of ZirY groups were lower than those of Ti and ZirW groups in all thicknesses [Table 4].

Table 3: Means±standard deviations of ΔE values and multiple comparisons for monolithic zirconia groups

Materials	Thickness (mm)	Background		
		Ti	ZirW	ZirY
PRTA	1	6.94±0.59^{h}	5.71±0.73^{g}	3.27±0.49^{cde}
	1.5	5.72±0.44^{g}	1.84±0.28^{ab}	1.74±0.20^{ab}
VITA ST	1	5.57±0.27^{g}	5.17±0.32^{fg}	2.55±0.22^{cd}
	1.5	4.66±0.23^{f}	2.30±0.33^{bc}	1.22±0.66^{a}
VITA HT	1	5.44±0.24^{g}	5.17±0.24^{fg}	2.63±0.31^{cd}
	1.5	3.74±0.24^{e}	3.14±0.28^{de}	1.31±0.37^{a}

The same superscripts indicate no significant difference between groups ($P>0.05$)

Table 4: Means±standard deviations of ΔE values and multiple comparisons for porcelain-veneered zirconia groups

Material	Thickness (mm)	Background		
		Ti	ZirW	ZirY
P-PRTA	1	5.90±0.49^{g}	5.09±0.46^{fg}	3.16±0.37^{de}
	1.5	2.31±0.32^{bc}	2.28±0.25^{b}	1.32±0.67^{ab}
P-VITA ST	1	4.88±0.64^{fg}	5.94±0.27^{g}	3.72±0.45^{e}
	1.5	3.02±0.14^{d}	1.29±0.28^{a}	1.01±0.23^{a}
P-VITA HT	1	4.51±0.24^{f}	5.59±0.31^{g}	3.67±0.35^{e}
	1.5	2.96±0.30^{cde}	1.97±0.20^{b}	1.18±0.28^{a}

The same superscripts indicate no significant difference between groups ($P>0.05$)

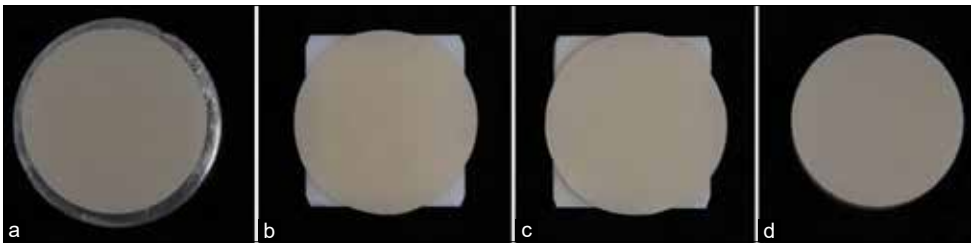

Figure 1: Monolithic zirconia specimen on (a) titanium grade V, (b) IPS e.max ZirCAD MO 0 white shade, (c) IPS e.max ZirCAD MO 2 yellow shade abutment, and (d) control specimen

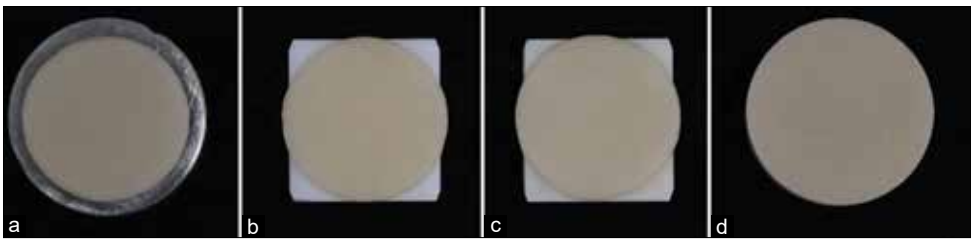

Figure 2: Porcelain-veneered zirconia specimen on (a) titanium grade V, (b) IPS e.max ZirCAD MO 0 white shade, (c) IPS e.max ZirCAD MO 2 yellow shade abutment, and (d) control specimen

DISCUSSION

Based on the results of this *in vitro* study, the null hypothesis was rejected because zirconia material, ceramic thickness, and types of abutment background affected the color difference.

The optical effect of ceramic restorations has been evaluated in previous studies.[6,9,18-21] Nevertheless, there was no consensus on the optical effect of translucent zirconia on different implant abutments. In this study, two different thicknesses of three zirconia materials for monolithic and porcelain-veneered zirconia restorations were investigated. The findings showed that the thickness of zirconia significantly influenced the overall color of restorations. The 1-mm thick ceramics in both monolithic and bilayered zirconia were inadequate to mask the color of the underlying abutments. However, when the thickness was increased to 1.5 mm, such masking effect was also practically increased that the influence of the underlying materials diminished, since the dental ceramic allows some degree of light passing through the material and the translucency is related to its thickness.[3,18]

Implant abutment materials influenced the final color differently as they had different color properties.[19] In this study, $\Delta E = 3$ was assumed as an acceptability threshold of the human eyes to describe the color difference.[22] The results showed that all zirconia restorations with a thickness of 1.5 mm over yellow-shaded zirconia background presented superior color matching with acceptable esthetic color ($\Delta E < 3$). Nonetheless, titanium background provided greater color difference. These could be reasoned that yellow-shaded abutment had similar color to the control specimens. The yellow-shaded background showed less color difference than that of titanium and white zirconia backgrounds, regardless of monolithic or bilayered zirconia. In a similar study, it was found that the minimum coping thickness and minimum veneer thickness should be 0.6 mm and 1.2 mm, respectively, to achieve the expected color of the implant restoration.[6] In addition, when $\Delta E < 3$ was considered clinically perceptibility threshold, the result of this study was in agreement with another study that when the thickness of veneered zirconia was 1.5 mm, it could completely mask all the abutment backgrounds including gold, base metal alloy, and resin composite.[21]

As zirconia is a semi-translucent material, it permits more light transmission and has less light absorption than metal abutment. When ceramic material was restored on zirconia abutment, it showed more preferable outcome than metal abutment. Likewise previous *in vivo* study, it suggested that zirconia abutment should be employed in the area of high esthetic demand rather than titanium abutment.[23]

The previous study reported that the reduction of monolithic zirconia from 2 to 1 mm resulted in perceptible color differences ($\Delta E > 3.7$).[18] This was comparable to the findings of this study that the thickness of zirconia altered the final color of restorations. However, it was reported that the minimum thickness of monolithic zirconia should not be < 0.9 mm to reach acceptable color when restorations were placed on A4 shade background.[9] Furthermore, it was shown that monolithic zirconia of

1.8 mm was inadequate to cover metal and discolored tooth shade substrates while porcelain-veneered zirconia restoration with 0.8-mm zirconia core and 1-mm veneering ceramic provided adequate thickness for masking only in discolored tooth shade backgrounds.[20] In addition, the results from another study presented that zirconia coping thickness and veneering ceramic thickness should be more than 0.6 mm and 1.2 mm, respectively, to cover the titanium background and A3 shade zirconia abutment.[6] The conflict of minimum ceramic thickness from this present study could be attributed to different zirconia materials and methods designed in this test.

Because zirconia is mainly composed of crystalline contents in its structure, light scattering is occurred through the materials and resulted in high opacity. To improve the optical properties of zirconia, translucent zirconia has been developed to enhance its esthetic appearance. Thus, zirconia brands with different levels of translucency may cover substrate color differently. In this study, the Prettau Anterior zirconia was reported by the manufacturer that it is composed of 8%–12% mol yttria with more than 50% cubic phase zirconia, which is higher in content than that of VITA YZ ST and VITA YZ HT zirconia. Therefore, the increased volume of isotropic structures resulted in reduced light scattering at the grain boundaries.[7,8] The results of this study showed that 1-mm thick Prettau Anterior specimens on titanium abutment had higher ΔE than those of the other specimens. These could be caused by the higher translucency of Prettau Anterior zirconia that allowed more light transmission. Therefore, the background effect was more distinct than the other zirconia materials in this study.

Although highly translucent zirconia was developed for better clinical outcomes, the shade and translucency of the restoration are frequently dissimilar to the adjacent teeth because of the highly crystalline nature of zirconia. Accordingly, glass veneer is frequently applied to the anatomical design zirconia framework to imitate natural-like tooth color.[6,24] In general, the zirconia framework with veneering porcelain could be made only on the labial or buccal surface to achieve adequate esthetic results, while stronger zirconia was designed on the lingual or occlusal surface to resist fracture of restorations from mastication.[25] Nevertheless, research should be taken on the bonding quality between zirconia and glass veneer to avoid the chipping and delamination problem between two different ceramic materials.[26]

This study found that the appropriate thickness for porcelain-veneered zirconia groups to achieve color matching was 1.5 mm, which was in agreement with the results by Oh and Kim, who reported most of the 1.5-mm thick zirconia-based restorations could cover base metal alloy, tooth-colored shade, and gold alloy abutment with a clinically acceptable color difference ($\Delta E < 2.6$). Even though 1-mm thick ceramic could be enough to cover metal abutment, it may be because of the different microstructure of zirconia used in the study. In addition, the previous study used a colorimeter to measure the color of specimens that may cause edge loss effect where some reflected light cannot completely turn back through the small window of the device. This effect may reduce the accuracy of color measurement.[27] Furthermore, a portable spectrophotometer may not be precise in color determination as the position of equipment could affect the color assessment.[28]

In bilayered zirconia, glass veneering ceramic which has high translucency was applied on a zirconia framework.[29] However, the bilayered ceramic with 1.5-mm thickness had a higher ability to cover the background than the monolithic zirconia with equal thickness although the veneer layer is intrinsically more translucent than the zirconia. These could be explained by the different refractive index between glass veneering ceramic and zirconia core, and also the interface effect, which increased light scattering and reflection at the interface between two layers, and therefore, these improved masking ability.[30] This would be beneficial when the bilayered zirconia is employed over the underlying titanium or discolored substrates according to this ability and the greater translucency from the glass property.

The control specimens used in this study were the 4-mm thick ceramic plates of monolithic zirconia or glass veneer for the reason that these ceramic plates represented the expected shade of the final restorations. However, due to the opaque white color of zirconia, the color of zirconia may not match with the commercial shade guides that are usually based on the Vita shade system. Therefore, a custom shade guide for zirconia may be required for color matching in clinical situations.

This *in vitro* study evaluated the effect of ceramic thickness on implant abutment using only one shade color of restorations without using luting cement. The result may differ if the lighter or darker shade of restorations and luting cement were used. There should be further study to include the other factors as they could influence the overall color of restorations.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn.

1. The different translucent zirconia materials on implant abutments affected the final color of restorations
2. The yellow-shaded zirconia implant abutment provided the most appropriate color for monolithic zirconia and porcelain-veneered zirconia restorations
3. The minimum thickness of monolithic translucent zirconia and zirconia-based restorations on yellow abutment should be at least 1.5 mm to achieve satisfactory outcome.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Research

Accuracy between intraoral and extraoral scanning: Three-dimensional deviation and effect of distance between implants from two scanning methods

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Abstract

Aim: Evaluate the accuracy between the intraoral and extraoral scanning regarding the three dimensional (3D) deviation and distances between the implants, through 2 scanning methods.

Settings and Design: An *in vitro* study.

Materials and Methods: An edentulous mandibular model was used to install four implants and abutments, recommending 6 distances between the implants. Scans were performed using an intraoral (SI) and extraoral (SE) scanner for each studied group: Scanning with the scan bodies (SB) and device (SD) ($n = 10$). The files were imported into a surface evaluation program to assess 3D deviations and measure distances between implants.

Statistical Analysis: Precision was assessed as the difference between files (Kruskal–Wallis test), while trueness was assessed from the difference between scans, applying the Wilcoxon and Mann–Whitney test.

Results: As for the 3D deviations, SI showed accuracy, for the faces and positions of the implants in relation to the SE, in both scanning methods ($P < 0.05$). Regarding the capture of distances between implants, the SD scan obtained better trueness than the SB group ($P < 0.05$).

Conclusion: We concluded that the type and scanning methods used did not influence the 3D deviations, while for distances, scanning with the device had better trueness.

Keywords: Dental implant, dimensional measurement accuracy, edentulous, protheses supported-implant, three-dimensional

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Submitted: 01-Mar-2022, **Revised:** 14-May-2022, **Accepted:** 19-May-2022, **Published:** ***.

INTRODUCTION

The introduction of technological innovations in dentistry provided the possibility of obtaining the topography of the oral cavity with greater speed, comfort and patient satisfaction, in view of the elimination of inconvenient steps of the conventional method.[1] Computer-aided design (CAD) and computer-aided manufacturing, together with intraoral scanners, have been used with predictability for the manufacture of monolithic restorations,[2] removable partial dentures,[3,4] unitary,[5-7] and fixed partials on implants.

Access this article online	
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	DOI: 10.4103/jips.jips_108_22

How to cite this article: Pereira AL, Segundo HV, Júnior LC, Germano AR, Carreiro AD. Accuracy between intraoral and extraoral scanning: Three-dimensional deviation and effect of distance between implants from two scanning methods. J Indian Prosthodont Soc 2022;22:279-87.

Differently, the digitization of total edentulous arches and the position of multiple implants is a limiting factor for intraoral scanners, which is due to the presence of homogeneous areas, associated with edentulous arches,[8] and also the large extensions of space between the implants.[9,10] As a result, the inaccuracy of the virtual images is linked to errors of distance[11,12] and angulation of the implants.[13]

Therefore, the alternative would be to digitize the plaster model, obtained by conventional molding, using an extraoral scanner (laboratory) for then projection of the prosthesis. Previous studies comparing the accuracy between different intraoral and extraoral scanners were carried out from the perspective of total edentulous arches,[1,8,12] total dentate,[14-17] and multiple implants between teeth.[18] For total edentulous arches rehabilitated with multiple implants, the evaluations consisted of investigating the accuracy of intraoral scanners based on the conventional molding[9,11,19-21] or coordinate measuring machine[13,22] and even by a totally conventional workflow for making the final prosthesis.[23]

Software programs for the analysis of three-dimensional (3D) deviations have been used to determine the displacement of implants and identify the error in transferring their positions to the virtual environment.[19,20] However, none of the previous studies evaluated the displacement of implants by face and position, but rather, considering the position of the implants in the complete model.

The evaluation of both variables is fundamental for a better predictability of making a framework with passive adjustment, once quantifying how much the 3D discrepancy of the virtual image can imply in the materialization of the final prosthetic work.[24] In this sense, there is still a need to studies that evaluate the 3D deviation considering the implant, as well as the effect of different linear distances in capturing the virtual transfer of the position of multiple implants, based on the comparison between intraoral and extraoral scanning and scanning methods.

Therefore, it is proposed to carry out this *in vitro* study with the objective of evaluating the accuracy (precision and trueness) between the intraoral and extraoral scanning, regarding the 3D deviation and distances between the implants, through two scanning methods. The null hypothesis consisted in showing that there is no difference between the intraoral and extraoral scans, either with the digitizing bodies or the device, regarding the 3D deviations and distances between the implants.

MATERIALS AND METHODS

A rigid polyurethane total edentulous mandibular model with gingival simulation (Edentulous mandible with gum; Nacional Bones) [Figure 1] was used as the master model for this study. Prior to the preparation of this model, the position of the implants was coded according to their distribution in the arch, being: (1) right posterior, (2) right anterior, (3) left anterior, and (4) left posterior. Afterward, with the aid of a digital caliper (150 Mn Mtx; Mtx) and permanent pen for marking surfaces, six distances were linearly determined, (D1: 1–2; 16 mm), (D2: 1–3; 23.5 mm), (D3: 1–4; 40.2 mm), (D4: 2–3; 9.0 mm), (D5: 2–4; 26.2 mm), (D6: 3–4; 22 mm), which determined the location of the four implants in the regions of the right lateral incisor, right mandibular first premolar and their respective contralateral positions.[25]

Implants with external hexagon connection (H. E.4.1 mm × 3.75 mm) (Neodent; Straumann) and Conical Mini Abutments (Neodent; Straumman) were selected for this study. With the aid of a 4.1 mm trephine drill (Neodent; Straumman) adapted to the implant engine (Neodent; Straumann) an adaptation of direct access to the bone was performed, followed by drills: Spear, for milling and initial access, which provided space for the others: Ø2.0, Ø2/3, and Ø3.0 (sequence recommended by the manufacturer), with a final torque of 45Ncm. Afterward, the Mini Conical Abutments (Neodent; Straumman) with a gingival height of 1 mm, angle of 0° and diameter Ø4.1 mm, with torque of 32Ncm were installed.

With the master model prepared, it was submitted to four scanning steps: (1) extraoral scanning with the scan bodies (SE-SB), (2) intraoral scanning with the SB (SI-SB) [Figure 2], (3) extraoral scanning with the device attached to the scan bodies (SE-SD) and (4) intraoral scanning with the device attached to the scan bodies (SI-SD) [Figure 3]. The intraoral scans performed with the device coupled to the digitization bodies have three parts: Pin with ball-shaped

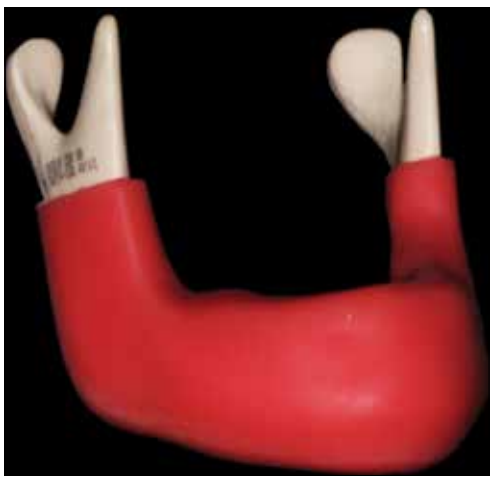

Figure 1: Totally edentulous mandibular master model

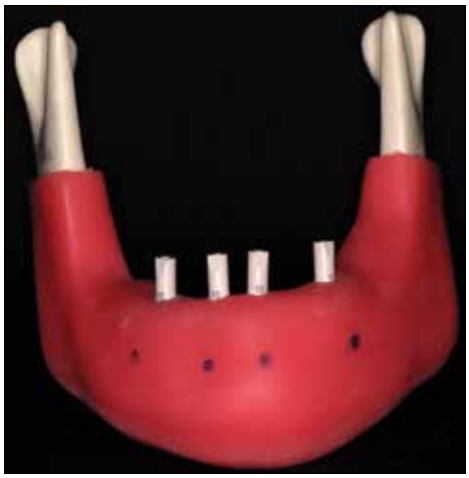

Figure 2: Master model with scan bodies (SB). SB: Scan bodies

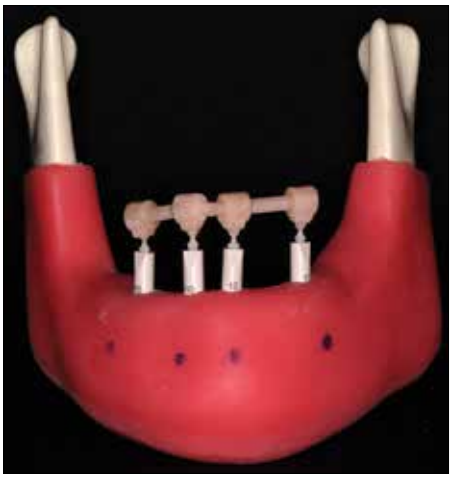

Figure 3: Master model with the device attached to the scan bodies (SD). SD: Scan device

fixation, fixation support, and cylindrical union bar,[24] which was assembled during the digitization act.

For each group mentioned above, 10 scans were performed, all obtained by a single operator, whose intraoral (SI) scans were performed by an intraoral scanner (TRIOS; 3Shape A/S) and the extraoral (SE), a bench scanner (S600 ARTI Scan; Zirkonzahn). For this, four marking points along the model were made, following the position of the implants, buccal and lingual, to facilitate the recognition of the region to be digitized by the scanner. The master model was fixed on the mobile table of the bench scanner (S600 ARTI Scan; Zirkonzahn) and the set (table/model) on a flat surface, using the following scanning technique: Occlusal face of the right end of the arch, continuing to the left contralateral area, extending to the buccal face, and finally to the lingual face.[24]

After the digitization step, the scans were stored in standard tessellation language (STL) format in the digital library of the scanner software program used and renamed (study group name; 1–10), following the order in which the scanning. The STL files were submitted to the two dependent variables of this study: 3D deviation and distance between the implants, which were evaluated using an inspection software program (GOM Inspect; GOM GmbH).

In the analysis of the 3D deviations, the discrepancy between the extraoral and intraoral scans was evaluated. For this, the files corresponding to the extraoral scan (SE) were imported into the software in the "Body CAD" format and the files of the intraoral scan (SI) in "Mesh," i.e., SE-SB with SI-SB, as well as, SE-SD with SI-SD. Afterward, using the three-point alignment and best fit methodology, the two files were superimposed, using the entry of the screws from the scanning bodies as a coincident point between the files. Then, a comparison analysis of the superimposed surfaces was performed with a maximum distance of 0.200 mm[26] between the files. With the projection of the 3D comparison map, deviation labels were projected on the faces (mesial, distal, buccal, and lingual) of each implant to extract the discrepancy values between the files. For this variable, 40 faces were measured per group, totaling 160 for the 4 groups [Figure 4].

As for the analysis of the distances between the implants, the six predefined distances were measured before the installation of the implants for the four groups (SE-SB, SE-SD, SI-SB, and SI-SD). For this, the model obtained by the extraoral scan of each intraoral scan was used as a digital table, given its absence in the software used, to standardize the insertion axis of the files for evaluation. Therefore, as reported for the analysis of 3D deviations, the files were superimposed, and then the cylinders were projected for each digitizing body, forming a vertical central line inside each cylinder, this point being used to draw the lines of measurement between implants. Therefore, assuming that the model has four implants and each group contains 10 STL files, then 6 distances were measured, totaling 60 per group and 240 for the four groups [Figure 5].

All analyzes were performed by a single operator (H. V. M. S.) and reviewed by a second evaluator (A. F. P. C.), three times for each face and measured distance, in the 10 STL files of each group. From that, an average was obtained and the analyzes of this study were carried out from it. The Intraclass Correlation Coefficient was applied to both variables, showing "good" value power for 3D deviations (0.731) and "excellent" value power for the distance between implants (SE-SB: 1.000; SE-SD: 1.000; SI-SB: 1.000; SI-SD: 1.000).[27]

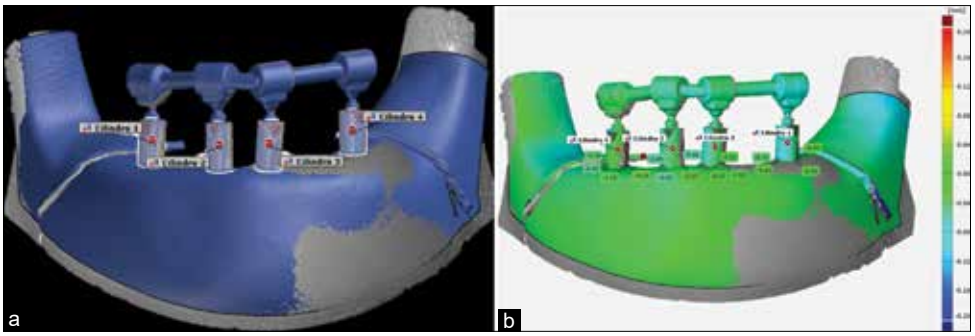

Figure 4: (a) Projection of two virtual cylinders for three-dimensional capture of the position of two implants. (b) Analysis of the three-dimensional deviation between the extraoral and intraoral scans per face

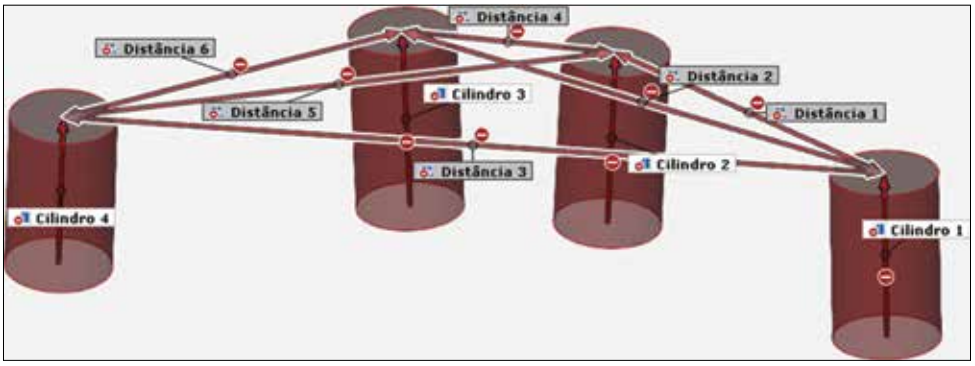

Figure 5: Evaluation of the distances between the implants

Data were tabulated and analyzed using statistical software (IBM SPSS Statistics, v22.0; IBM Corp, Chicago, EUA). Initially, the Kolmogorov–Smirnov test was performed to estimate the normality of the data, which did not show normal distribution. Descriptive analysis was based on the median ($\overline{x}$) and quartile 25 (Q25) and 75 (Q75). In assessing precision for the two dependent variables of this study, the difference between the chronological sequence of the STL files was considered, regardless of face, position, and distance between the implants. For this, we used the nonparametric Kruskal–Wallis test with Dunn's posttest. As for trueness, for the two dependent variables of this study, the difference between intraoral and extraoral scanning was evaluated, considering the faces, position, and distance between the implants. For this, the nonparametric Wilcoxon test was used to compare the intraoral with the extraoral of the same scanning method and the Mann–Whitney test to compare the four scans. In carrying out all tests, a significance level of 5% was adopted.

RESULTS

3D deviations are shown for precision [Figures 6 and 7] and trueness [Tables 1 and 2]. For the precision of 3D deviations, when comparing the scan sequence (STL1-10 files), no statistically significant differences were identified between extraoral and intraoral scanning for both scanning methods. When comparing the order in which the STL files were obtained between the types of scans and scans, differences were also not found (STL^1: $P = 0.379$; STL^2: $P = 0.605$; STL^3: $P = 0.438$; STL^4: $P = 0.052$; STL^5: $P = 0.256$; STL^6: $P = 0.535$; STL^7: $P = 0.301$; STL^8: $P = 0.641$; STL^9: $P = 0.717$; STL^{10}: $P = 0.301$). The faces, with the exception of the buccal face [Table 1] and the position of the implants [Table 2], did not influence the trueness of the 3D deviations.

The distances between the implants are shown for precision [Figure 8] and trueness [Table 3]. As for precision, an analysis was performed considering each measured distance and STL file. For each distance, it was observed that when comparing the scans for each type of scan, statistically differences were found in the distances: D1 when comparing SE ($P = 0.009$) and SI ($P = 0.092$) scans, D2 for SI ($P = 0.017$), D3 for SE ($P = 0.013$), D4 for SI ($P = 0.005$), D5 for SE ($P = 0.092$) and SI ($P = 0.028$), and D6 for SE ($P = 0.037$) and SI ($P = 0.005$). In the other evaluations, no significant difference was observed (D2: SE-SD × SE-SB/$P = 0.333$; D3: SI-SD × SI-SB/$P = 0.203$; D4: SE-SD × SE-SB/$P = 0.285$).

In the evaluation between the sequence of scans (STL1 10 files), there was no difference in precision [Figure 8]. Table 3 shows the intraoral scanning with the device

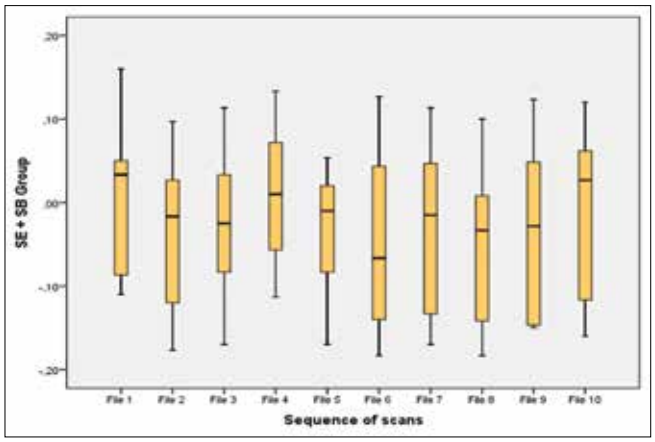

Figure 6: Precision of three-dimensional deviations between SE and SI only with the SB ($P = 0.449$). SE: Scanning extraoral, SI: Scanning intraoral, SB: Scan bodies

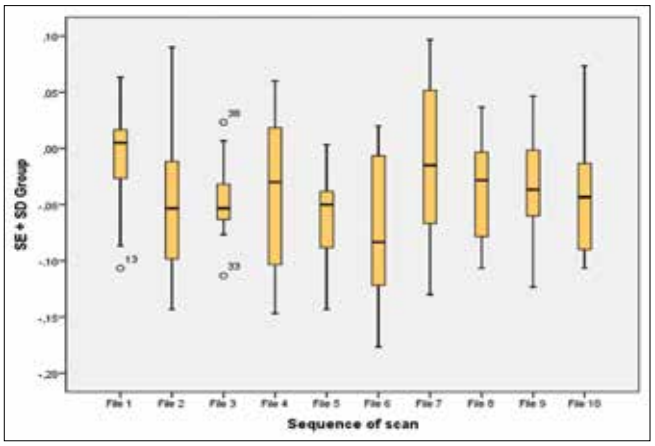

Figure 7: Precision of three-dimensional deviations between SE and SI with the device coupled to the scan bodies (SD) ($P = 0.081$). SE: Scanning extraoral, SI: Scanning intraoral, SD: Scan device

Table 1: Trueness values by implant faces between groups (extraoral and intraoral scanning with the device attached to the scanning bodies and extraoral and intraoral scanning with scan bodies only)

Faces	SE + SD		SE + SB		
	Med	$Q^{25/75}$	Med	$Q^{25/75}$	*P*
Mesial	−0.04	−0.10/−0.01	−0.03	−0.11/0.03	0.914
Distal	−0.03	−0.06/+0.01	−0.06	−0.11/0.04	0.481
Vestibular	+0.01	−0.09/0.06	−0.07	−0.12/−0.02	0.001*
Lingual	−0.01	−0.05/+0.01	−0.01	−0.09/0.04	0.856

Med: median; $Q^{25/75}$: Quartile $^{25/75}$; $P<0,05$; SB: Scan bodies, SD: Scan device; SE + SD: Extraoral and intraoral scanning with the device attached to the scanning bodies; SE + SB: Extraoral and intraoral scanning with scan bodies only. SE: Scan extraoral. *$^{P}<0.05$

Table 2: Trueness values per implant between groups (extraoral and intraoral scanning with scan bodies only e extraoral and intraoral scanning with the device attached to the scanning bodies)

Implante	SE + SD		SE + SB		*P*
	Med	$Q^{25/75}$	Med	$Q^{25/75}$	
1	−0.03	−0.07/+0.01	−0.02	−0.11/+0.05	0.872
2	−0.05	−0.08/+0.04	−0.01	−0.11/+0.04	0.545
3	−0.04	−0.06/+0.04	+0.01	−0.09/+0.05	0.192
4	−0.04	−0.10/−0.08	−0.02	−0.11/+0.03	0.420

Med: median; $Q^{25/75}$: Quartile $^{25/75}$; $P<0,05$; 1: Right posterior implant, 2: Right anterior implant, 3: Left anterior implant, 4: Left posterior implant, SE + SD: Extraoral and intraoral scanning with the device attached to the scanning bodies, SE + SB: Extraoral and intraoral scanning with scan bodies only

coupled to the scan bodies (SD) obtained greater trueness for the six distances compared to scanning only with the SB.

DISCUSSION

The null hypothesis that there is no difference between intraoral and extraoral scans, either with SB or device, was accepted for the variable 3D deviations and denied for the distances between implants. For 3D deviations, the intraoral and extraoral scans showed precision and truness within an acceptable range for clinical use, in both scanning methods. The distances between the implants and the scanning method no influenced the scanning precision. The intraoral scanning with the device coupled to the SB trueness captured interimplant distances of 9.0–22 mm and 23.5–40.2 mm in a crossed arc, while the scanning with only the SB, interimplant distances of 9 mm and 23.5–26.2 mm in crossed arch, when compared to extraoral scanning.

Most intraoral scanners project a leisure beam onto the object's geometric surface and capture the reflected light through a charge-coupled device. Afterward, the scanner system will calculate the position of the points, for the union of several triangles and formation of the final image. Some factors can influence the quality of this image, such as: Mouth arch curvature, where large curvatures will promote highly dense meshes, while flatter regions have lower mesh density,[28] the scan time, as the greater the area and complexity, the longer the scanning time, leading to lower accuracy, especially when associated with operators with little experience[15] and the surface to be scanned.

In this last aspect, the greatest difficulty in capturing total edentulous arches is due to the lack of reference along the ridge,[10] due to the physiological process of bone resorption triggered by edentulism. In addition, although the presence of multiple implants configures reference points for the intraoral scanner, the loss of follow-up in the recognition of the region between the implants influences the quality of the mesh,[9] especially in view of the large extensions of space.[11] With this, proposals for improving the capture accuracy of such arches have been addressed, all of which promote the union of the scanning bodies and filling the spaces between the implants.[23,29-32] These findings justify

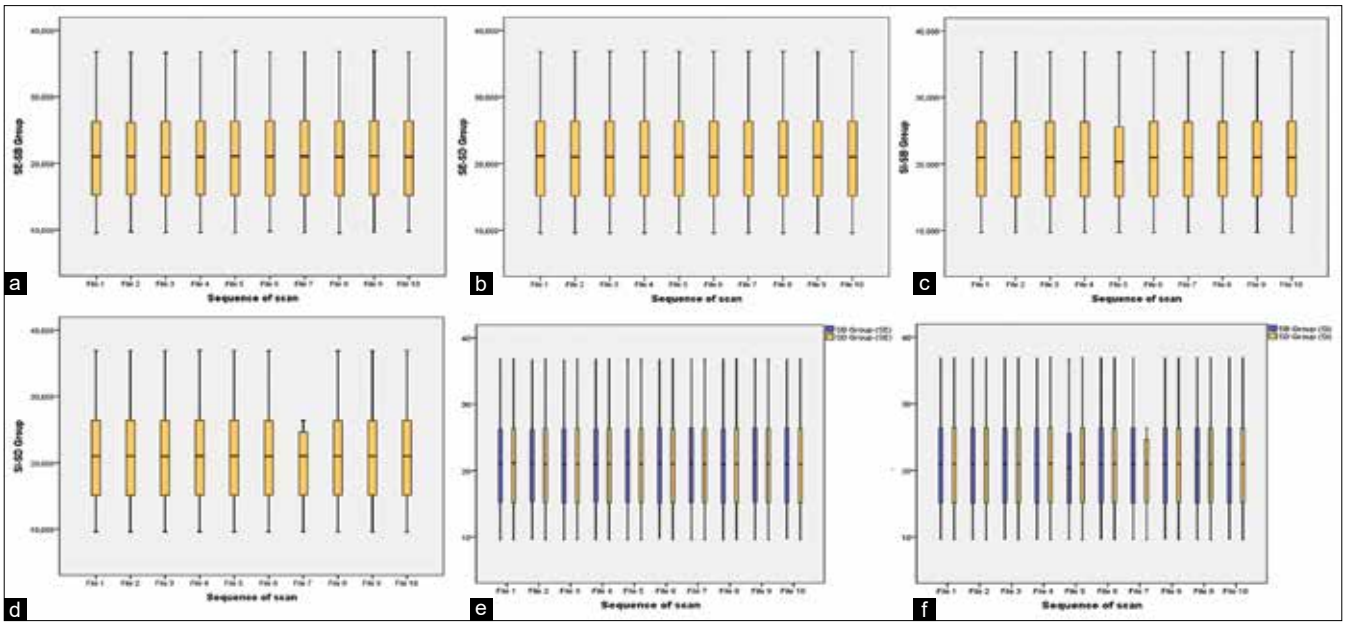

Figure 8: Analysis of precision between the sequence of scans regarding distances between implants. (a) Extraoral scanning with scan bodies only (P = 1.000). (b) Extraoral scanning with the device attached to the scanning bodies (P = 1.000). (c) Intraoral scanning with scan bodies only (P = 1.000). (d) Intraoral scanning with the device attached to the scanning bodies (P = 1.000). (e) Extraoral scans between SB and SD groups (P = 0.414). (f) Intraoral scans between the SB and SD groups (P = 0.113). SB: Scan bodies. SD: Scan device

Table 3: Trueness values comparing intraoral and extraoral scanning

Distances	*n*	SD				*P*	SB				*P*
		SE		SI			SE		SI		
		Med	$Q^{25/75}$	Med	$Q^{25/75}$		Med	$Q^{25/75}$	Med	$Q^{25/75}$	
D1	10	15.13	15.13/15.14	15.13	15.09/15.14	0.241	15.19	15.14/15.22	15.10	15.09/15.11	0.005*
D2	10	23.83	23.82/23.84	23.83	23.82/23.84	0.646	23.90	23.83/23.93	23.86	23.84/23.87	0.169
D3	10	36.83	36.82/36.83	36.89	36.87/36.91	0.074	36.74	36.71/36.79	36.85	36.83/36.88	0.009*
D4	10	9.57	9.56/9.58	9.57	9.56/9.59	0.878	9.59	9.53/9.71	9.66	9.65/9.66	0.203
D5	10	26.33	26.33/26.34	26.35	26.33/26.37	0.114	26.28	26.26/26.38	26.32	26.30/26.34	0.919
D6	10	18.17	18.16/18.17	18.18	18.16/18.18	0.759	18.10	18.05/18.21	18.01	18.00/18.03	0.028*
All	60	21.0	15.13/26.34	21.0	15.13/26.35	0.122	20.99	15.19/26.29	20.94	15.10/26.32	0.457

D1: Right posterior implant - right anterior implant (16 mm), D2: Right posterior implant - left anterior implant (23.5 mm), D3: Right posterior implant - left posterior implant (40.2 mm), D4: Right anterior implant - left anterior implant (9.0 mm), D5: Right anterior implant - left posterior implant (26.2 mm), D6: Left anterior implant - left posterior implant (22 mm), SD: Scanning with the device attached to the scan bodies, SB: Scanning with scan bodies only, SE: Extraoral scanning, SI: Intraoral scanning. *$P<0.05$

the inclusion, in the present study, of a new scanning alternative to improve the position capture accuracy of multiple implants in total edentulous arches.

In the comparative evaluation between intraoral and extraoral scanning, considering the two scanning methods, we observed that scanning with the device coupled to the digitization bodies captured the recommended distances with greater accuracy compared to the scanning with only the SB. Therefore, previous studies[9,13] also showed that scans of total edentulous arches rehabilitated with multiple implants, using only SB, lead to large errors in distance and angulation, making these images inaccurate for planning passive framework.

When joining the SB, references are provided for the intraoral scanner between one implant and another, making the process faster and consequently improving the mesh quality. This is how Cappare *et al*.[23] and Carneiro Pereira *et al*.[24] showed from clinical studies, in which they used a splinting device or a joining device to obtain images with better accuracy. Tan *et al*.[11] stated that by decreasing the inter-implant distances, linear distortions regarding the position of the implants can be reduced. In this sense, we showed, as in previous studies, that inter-implant distances from 9.0 mm to 22 mm were accurately captured when the intraoral scan was obtained with the device coupled to the SB, justified by the reduced distances associated with the union device.

Braian and Wennerberg,[12] corroborate the findings of this study by showing that a range of 19 μm to 23 μm for inter-implant distances and 23 μm to 94 μm for crossed arch are the minimum and maximum possible limits to

perform an intraoral and get accurate images. However, we disagree about the scanning method, since the authors have found such results for scanning only with the scanning bodies, which was discussed previously about the difficulty of performing such a procedure without any object of edge modulation.

The findings of the present study show a proportional effect of the error in capturing cross-arc distances as inter-implant distances are increased, which justifies the fact that scanning only with the SB presented difficulty in capturing inter-implant distances >9 mm and 26.2 mm in crossed arc. The error also increases due to the increased extension of the area to be scanned, generating a greater number of images, requiring more seams to form the final image, as explained above. Thus, these values can be compared to data from the study by Braian and Wennerberg.[12]

As for the comparison between intraoral and extraoral scanning, we showed that the type of scan influenced the precision and trueness of the images obtained by each scanning method. Therefore, the virtual images obtained with the intraoral scan from the device were able to be trueness reproduced by the extraoral scan, for all tested inter-implant and cross-arc distances. Thus, we agree with Ribeiro *et al*.,[20] who showed no difference between intraoral and extraoral scanning in total edentulous arches rehabilitated with multiple implants. On the other hand, we disagree with previous studies that stated that there is a superiority of intraoral scanning over the conventional one,[21,22] once dealing with *in vitro* studies and that no alternative to solve the limitations of intraoral scanners was presented or discussed.

The assessment for 3D deviations was performed to quantitatively identify the discrepancy between the intraoral and extraoral scanning for the two types of scans. For this analysis, the STL files were superimposed at a maximum distance of 0.200 mm, this being the minimum possible provided by the software, as well as using Papaspyridakos *et al*.[26] From this determination, the direction of the 3D deviation was indicated by positive numbers or negatives of the average displacement, illustrated by a 3D color map. Therefore, the present study showed precision regarding the 3D deviations of the intraoral scans with their respective reference (extraoral) scans, pointing to a reproducibility of the methods in a continuous sequence of ten scans.

However, when assessing trueness, the mean 3D distortion was consistently negative for all faces, with the exception of the buccal face of the SE + SD group, and all implant positions, except for the left anterior implant SE + SB. The signal does not interfere in the interpretation of the data when the same value differs from each other by the signal, being symmetrical in relation to the origin (zero). In this context, a statistically significant difference was found in the vestibular face between the two groups, where SE + SD obtained a distortion (+0.01) closer to the origin than SE + SB of (−0.07), not being considered clinically relevant. This punctual and minimal result may have been triggered by the method used (overlay). This introduces an inaccuracy due to the compensation of positive and negative deviations between the values, which can generate a reduced or increased estimate of the actual deviation of the reference model, being necessary to calculate the root mean square to eliminate this inaccuracy, which does not was possible due to the absence of this tool in the software used in this study.

Although the lack of studies comparing the 3D deviations of two intraoral scanning methods from the extraoral scanning is scarce and makes this discussion difficult, the results of the present study are in agreement with previous *in vitro* and clinical studies that also evaluated the 3D deviations between the conventional and digital method in mandibular arches with multiple implants. These showed similarity in terms of accuracy between the intraoral and reference scanning,[19,33] considering 200 μm as the clinically acceptable limit for digitizing implants in total edentulous arches.[34,35] All values presented by this study are below this one limit, indicating clinical irrelevance, even not using the same measurement unit.

The *in vitro* findings of this study allow the clinician to have greater predictability of the final prosthetic work, by noting that the positions of the implants present clinically irrelevant deviations and showing that the biggest problem in the search for passive framework is concentrated in the distances between the implants. From the results found, we observed that if the virtual images obtained by the SB group were used to design a metallic framework, it would present large vertical and horizontal marginal mismatches, which could be minimized if the images provided by intraoral scanning of the SD group were used since there was no difference with extraoral scanning.[24]

Therefore, this *in vitro* study compares in an innovative way two scanning and scanning methods, through the 3D deviations and distances between the implants, seeking to quantify the 3D discrepancy between the scans and the possible distances to be accurately captured. In addition, it shows that the use of a joining device allows

obtaining more accurate 3D images, which can enable the construction of framework with a better fit. Future studies should be conducted to evaluate different quantities of implants, connections, intraoral scanners, angulations, and new alternative techniques to improve the accuracy of the images obtained by intraoral scans of total edentulous arches.

CONCLUSION

Based on the results of this *in vitro* study, the following conclusions were drawn:

1. The intraoral scanning, only with the SB and with the device coupled to the SB, showed precision and trueness, in relation to the extraoral scanning for 3D deviations
2. The scanning method did not influence the precision of capturing the distances between the implants in the intraoral and extraoral scanning, resulting in greater distance errors in the SB group
3. The intraoral scanning with the device attached to the SB accurately captured interimplant distances from 9 mm to 22 mm and 23.5 mm to 40.2 mm in a crossed arc while scanning with only the SB, interimplant distances 9 mm and 23.5–26.2 mm in crossed arch, when compared to extraoral scanning.

Acknowledgments

CAPES - Coordination for the Improvement of Higher Education Personnel (N°88887.531281/2020-00).

Conflicts of interest

There are no conflicts of interest.

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Research

Effectiveness of denture cleansers on flexible denture base resins in the removal of stains colored by food colorant solution: An *in vitro* study

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Abstract

Aim: The aim of the study was to compare the efficiency of three denture cleansers (Valclean, Polident and Clinsodent) in removal of turmeric stains from flexible denture base resins.

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

Materials and Methods: A total of 45 specimens of flexible denture base resins were fabricated and subjected to baseline colour measurements using spectrophotometer. Specimens were stained with turmeric and colour measurements of stained specimens were made. All the stained specimens were divided into three groups ($n = 15$) for removal of stains with three denture cleansers: Valclean, Polident, Clinsodent and colour measurements of cleansed specimens were made. The colour measurements (ΔE) values obtained were collected and statistical analysis was done.

Statistical Analysis Used: One-way ANOVA (Analysis of Variance), Tukey's post hoc test.

Results: One way ANOVA test revealed that the mean colour difference of three groups were statistically different with P value < 0.001. A further Tukey post hoc test revealed that the Valclean group had lesser mean scores than Polident and Clinsodent group.

Conclusion: It was concluded that Valclean showed statistically significant greater stain removal efficiency than Polident followed by Clinsodent.

Keywords: Denture cleansers, flexible denture base resins, turmeric stains

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Submitted: 04-Oct-2021, **Accepted:** 23-Nov-2021, **Published:** ***.

INTRODUCTION

Removable partial dentures fabricated using polyamide-based denture base materials are proved to be good alternative to rigid denture base materials used.[1] They provide reasonable esthetics and comfort with additional advantage of utilizing tooth and tissue undercuts without the use of metal clasps. Regardless of any material used for prosthesis fabrication, the dentures tend to stain by our food habits, and to a great extent, the amount of staining depends upon the level of finishing and polishing of the dentures. Polyamide-based

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_480_21

How to cite this article: Richa G, Reddy KM, Shastry YM, Aditya SV, Babu PJ. Effectiveness of denture cleansers on flexible denture base resins in the removal of stains colored by food colorant solution: An *in vitro* study. J Indian Prosthodont Soc 2022;22:288-93.

denture base materials are difficult to finish and polish unlike rigid materials, which make them susceptible to stain by Indian foods containing spices and ingredients.[2] Home maintenance of the prosthesis fabricated from polyamide-based materials is thus of utmost importance to maintain odorless and stain-free prosthesis without damaging the inherent properties of dentures needed for longevity of the prosthesis.

There are numerous studies carried out to assess the efficiency of denture cleansers on poly methyl methacrylate, but there was not much of literature available on polyamide-based material on the efficiency of denture cleansers in the removal of stains.[3,4] The present study was designed and carried out to assess the effectiveness of three commonly used denture cleansers having different pH (Valclean-acidic, Clinsodent-alkaline, and Polident-neutral) on Bre.flex 2nd Edition flexible denture base resins in the removal of turmeric stains to observe the color changes using the spectrophotometer.

With the knowledge gathered from the literature, it was hypothesized that all three denture cleansers: Valclean, Polident, and Clinsodent will be equally effective in the removal of turmeric stains from Bre.flex 2nd Edition flexible denture base resins.[5-7]

MATERIALS AND METHODS

Fabrication of specimens

A total of 45 specimens were fabricated of Bre. flex 2nd Edition flexible denture resin by the injection molding technique using Thermopress 400 machine [Bredent, GmbH, Figure 1]. After finishing and polishing of the specimens, initial color measurements [category a – unstained, Figure 2] were made using UV-VIS spectrophotometer [Labindia, UV 3092, Figure 3].

Application of stains to the specimens

Staining of the specimens was done by immersing them in the turmeric solution prepared by dissolving 3 g of turmeric powder in 100 ml of distilled water for 7 days to simulate weekly exposure time with beverages or food in the oral cavity (2 h × 7 days = 14 h). Second color measurements of stained specimens [category – b, Figure 4] were made using UV-VIS spectrophotometer [Labindia, UV 3092, Figure 3].

Removal of stains using denture cleanser

All the stained specimens were randomly divided into three groups containing 15 specimens each (n = 15) for the removal of stains using three different denture cleansers [Figure 5].

- Group 1 − Valclean (acidic denture cleanser)
- Group 2 − Polident (neutral denture cleanser)
- Group 3 − Clinsodent (basic denture cleanser).

Denture cleansing solution was prepared by dissolving one tablet of denture cleanser or one teaspoon of denture cleanser powder in 150 ml of warm water (45°C). All the specimens in Groups 1, 2, and 3 were immersed in their respective denture cleansing solution [Figure 6] for 10 days to simulate the denture cleansing action of 1 month (8 h/day for 30 days = 240 h). Third color measurements of

Figure 1: Thermopress 400 machine

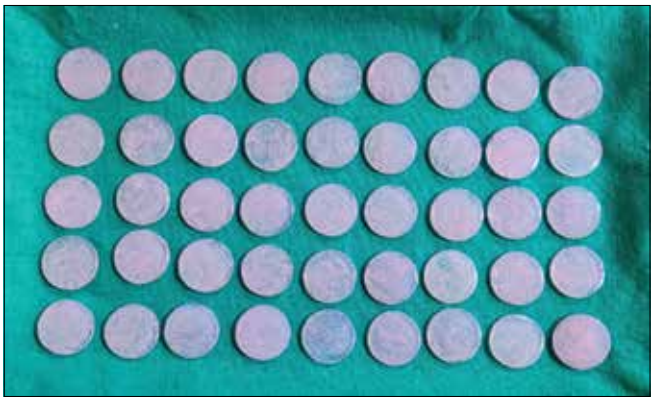


Figure 2: Specimens fabricated using Bre.flex 2nd Edition flexible denture base material

Figure 3: UV-VIS spectrophotometer

cleansed specimens (category – c) were made using UV-VIS spectrophotometer [Labindia, UV 3092, Figure 3] after 10 days.

Color analysis

For evaluating color difference, the spectrophotometric readings were converted to International Commission on Illumination system (CIELAB). This system was based on three parameters for defining color: L, a, and b, they represented lightness, red-green component, and yellow-blue component of color, respectively. The color change (ΔE) of each specimen was calculated using the following equation:

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$

Where ΔE was color change, +a represented red and −a represented green, while yellow corresponded to +b and blue to −b. ΔL, Δa, and Δb represented the color differences measured in L, a, and b values before and after immersion of specimens.

The color measurements (ΔE) values of three groups: Group 1 − Valclean, Group 2 − Polident, Group 3 − Clinsodent and three within group categories: Category a-unstained, Category b-stained and Category c-cleansed were collected.

RESULTS

All the color measurement values obtained were tabulated and subjected to the statistical analysis using SPSS (Statistical package for social sciences, IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0, Armonk, NY: IBM Corp.). One-way ANOVA test with Tukey's *post hoc* was performed to analyze mean color difference among three groups (Valclean, Polident and Clinsodent) and three within group categories (Unstained, Stained and Cleansed) of specimens [Tables 1-3 and Graph 1]. The confidence intervals were set to 95%, as $P < 0.05$ was considered statistically significant. The results revealed that Group 1 (Valclean) showed statistically significant lesser mean scores when compared to Group 2 (Polident) followed by Group 3 (Clinsodent) [Table 4 and Graph 2].

DISCUSSION

Staining of the denture by the food we consume could be a major cosmetic concern for denture wearers.[8,9] Stains, which accumulate on their denture surface may lead to propagation of denture stomatitis.[10] Turmeric − a major food ingredient used by the Indian population is a common staining agent.[11,12] For maintaining the prosthesis in healthy state, there is a need for denture cleanser to effectively remove stains from the prosthesis.[13,14] Therefore, this study was conducted to compare and evaluate the efficiency of immersion type denture cleansers in removal of turmeric stains from Bre.flex 2nd Edition denture base resin.

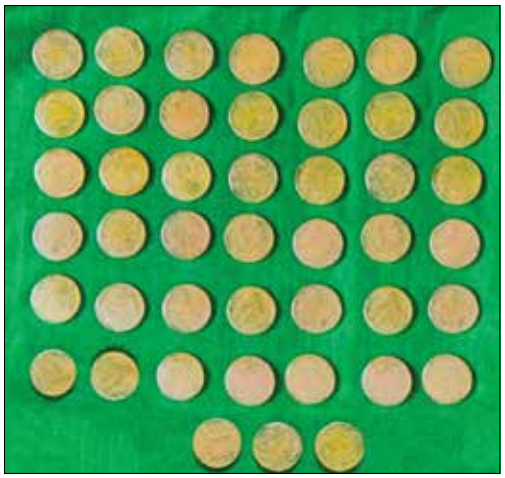


Figure 4: Stained specimens

Figure 5: Denture cleansers

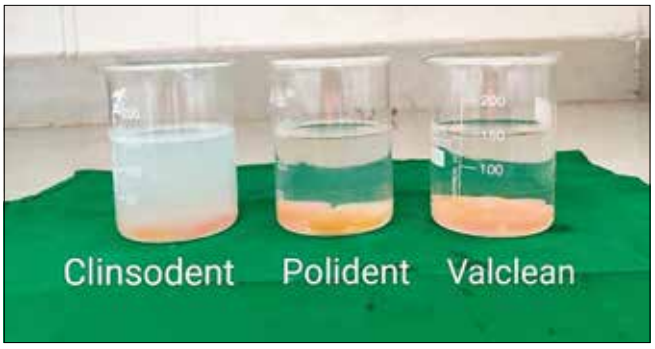


Figure 6: Specimens immersed in denture cleansers

Um and Ruyter[15] mentioned in their study that staining with turmeric is more because the colorant of turmeric is polar. Moreover, whenever the colorant is more polar, it stains more as denture base resins are hydrophilic attracting more water-soluble dyes on the surface. Moreover, the pH of turmeric solution was acidic (pH:

Table 1: Mean and standard deviations of Group 1 (Valclean)

	Mean±SD			*P* One-way ANOVA	Tukey's *post hoc* test
	Category-a (unstained)	Category-b (stained)	Category-c (cleansed)		
Group 1 (valclean)	2.92±0.37	5.27±0.22	3.14±0.13	<0.001	2> (1=3)

SD: Standard deviation

Table 2: Mean and standard deviations of Group 2 (Polident)

	Mean±SD			*P* One-way ANOVA	Tukey's *post hoc* test
	Category-a (unstained)	Category-b (stained)	Category-c (cleansed)		
Group 2 (Polident)	2.84±0.23	5.52±0.26	3.82±0.16	<0.001	2>3>1

SD: Standard deviation

Table 3: Mean and standard deviations of Group 3 (Clinsodent)

	Mean±SD			*P* One-way ANOVA	Tukey's *post hoc* test
	Category-a (unstained)	Category-b (stained)	Category-c (cleansed)		
Group 3 (Clinsodent)	2.96±0.26	5.53±0.27	4.17±0.17	<0.001	2>3>1

SD: Standard deviation

Table 4: Mean, standard deviation of cleansed samples of three Groups (Valclean, Polident and Clinsodent)

Groups	Mean±SD	One-way ANOVA	Tukey's *post hoc* test
Group 1: Valclean	3.14±0.13	*P*<0.001	3>2>1
Group 2: Polident	3.82±0.16		
Group 3: Clinsodent	4.17±0.17		

SD: Standard deviation

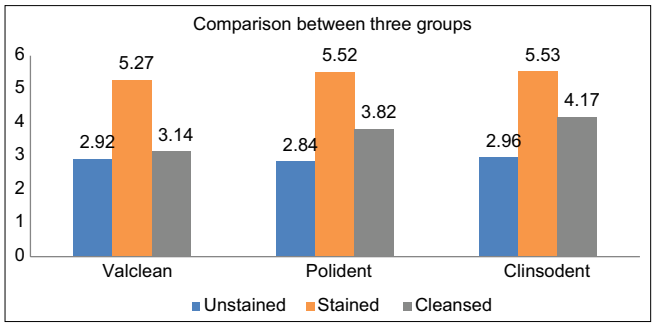
5.5). This indicated the influence of the acidic nature of turmeric on the samples, possibly by eroding the polished surface layer leading to more stain uptake. This finding was similar to the study conducted by Gispin and Caputo.[16]

Dentures can be cleaned mechanically, chemically, or combination of these methods. Although the most widely used method of denture cleansing seems to be the usage of soap and brush, but with increasing age, a large number of geriatric patients (who form the majority of denture wearers) have a loss of manual dexterity and are physically challenged, hence being unable to accomplish mechanical denture cleansing effectively.[17] Therefore, the usage of immersion type of cleansers helps them to keep the dentures clean and devoid of any deposits. Jagger and Harrison,[18] Peracini *et al*.,[19] and Hoad-Reddick *et al*.[20] also reported similar findings.

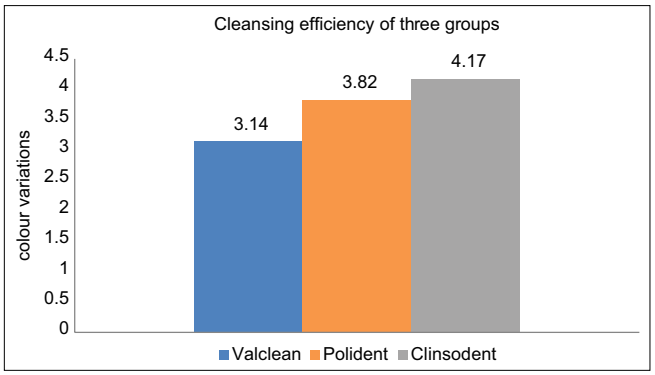
Surface roughness test (Ra) – Arithmetical mean roughness test was done in the present study to assess the effect of acidic (Valclean), alkaline (Clinsodent), and neutral (Polident) denture cleansers on the surface of Bre.flex 2nd Edition flexible denture base resins before and after the removal of turmeric stains. For unstained samples, the Ra value was 0.149 microns, Valclean had 0.399 microns, Polident had 0.222 microns, Clinsodent had 0.150 microns indicating with Valclean (acidic denture cleanser) the surface of the specimens fabricated using Bre.flex 2nd edition flexible denture base resins roughens.

Srinivasan and Gulabani[21] stated that the normal surface roughness value acceptable for dental prosthesis is ≤0.2 microns. Sharma *et al*.[22] reported that the surface roughness of samples was increased after immersion in sodium hypochlorite solution, which is in conformity to the present study. The reason could be explained by a mechanism that by the diffusion of hydrogen ions (H^+) from an aqueous solution into the denture surface and loss of alkali ions (OH^-) from the denture surface into an aqueous solution to maintain electrical neutrality.[23,24]

In the present study, the results demonstrated that the mean value of category - a (unstained) samples of Group 1 (Valclean-pH: 4.5) was 2.92 ± 0.37. The mean of category - b (stained) samples was 5.27 ± 0.22. The mean of category - c (cleansed) samples with valclean was 3.14 ± 0.13. The mean scores of category c (cleansed) samples with Valclean was significantly lesser than other two groups indicating more stain removal efficiency of Valclean. The probable cause for the efficient cleansing action of Valclean could be attributed to ingredients present in it. Valclean contains sodium hypochlorite, as an active ingredient. When dissolved in water, it decomposes releasing hypochlorous acid and due to bleaching action of chloride ions, it removes stains. Furthermore, Acidic pH of denture cleansers indicates presence of more H^+ ions than OH^- ions in the solution. Therefore, hydrolysis is greater in the specimens immersed in acidic denture cleanser leading to greater amount of stain removal.[25] This could also probably contribute to more stain removal efficiency of Valclean compared to Polident and Clinsodent.



Graph 1: Unstained, stained, and cleansed values of three groups (Valclean, Polident, and Clinsodent)



Graph 2: Cleansing efficiency between three groups (Valclean, Polident and Clinsodent)

Mathai *et al*.[26] compared the efficacy of Valclean and Clinsodent in removing tea, coffee, turmeric, and paan stains from heat-cured clear acrylic resins. He concluded that denture cleansers containing sodium hypochlorite had the highest ability for removing stains from the denture surface with a bleaching effect, which are in conformity to the present study. Jagger *et al*.[27] also found that denture cleansers containing sodium hypochlorite had the highest ability for removing stains and irregularities and porosities present on the denture surface played a major role in reducing denture cleansing action and hence increased stain and plaque retention.

In contrast, Makhija *et al*.[11] concluded that denture cleansers containing sodium perborate along with sodium bicarbonate (Clinsodent) showed greater efficiency in the removal of tea and turmeric stains from heat-cured acrylic resins. The reason for variations in mean scores of the above-mentioned study could be because of the different type of material used by them (heat cured acrylic resins) when compared to the present study (flexible denture base resins).

The mean value of category - a (unstained) samples of Group 2 (Polident - pH:7) to be 2.84 ± 0.23. The mean of category - b (stained) samples was 5.52 ± 0.26. The mean of category - c (cleansed) samples with polident was 3.82 ± 0.16. The probable cause for the outcome of the results could be because of lesser cleansing action of ingredients present in it. Polident contain sodium perborate as an active ingredient. Sodium perborate when dissolved in water decomposes releasing peroxides which in turn decomposes releasing oxygen and due to bleaching effect of oxygen, it mechanically removes the stains from the dentures. Furthermore, neutral pH of polident indicate there are equal number of H^+ ions than OH^- ions in the solution indicating lesser degree of hydrolysis.

Shah *et al*.[5] showed that the color changes of Valplast flexible denture base resins with polident were comparatively lesser to other denture cleansers used in the study indicating lesser cleansing action. However, in above-mentioned study, they did not stain the specimens before immersing them in denture cleanser as of the present study.

For Group 3 (Clinsodent - pH:11), the mean value of category - a (unstained) samples were 2.96 ± 0.26. The mean of category - b (stained) samples was 5.53 ± 0.27. The mean of category - c (cleansed) samples was 4.17 ± 0.17. The mean scores of category c (cleansed) samples with clinsodent were significantly greater than other two groups indicating lesser stain removal efficiency of clinsodent. The cause for obtaining the results could be lesser bleaching action of ingredients present in it. Clinsodent is sodium perborate-based denture cleanser and due to bleaching action of oxygen, it removes the stains from the dentures and alkaline pH of clinsodent indicate there are more OH^- ions than H^+ ions in the denture cleanser solution indicating lesser degree of stain removal of the specimens immersed in clinsodent.

Mathai *et al*.[26] also reported lesser efficiency of clinsodent in removing tea, coffee, turmeric, and Paan stains from heat-cured clear acrylic resins, which is in conformity to the present study.

Limitations of the study

The present *in vitro* study had some limitations:

- Storage media did not include saliva due to infection control considerations and hence did not simulate the oral environment entirely
- The specimens were flat and did not resemble a prosthesis from an anatomical perspective
- Turmeric stain was taken and scrutinized separately; this is not possible in the patient's dentures as there is a multifactorial influence in staining of dentures
- Micro porosities present in specimens could have

an effect on absorption of the stains. Although all specimens were finely polished and visually checked for porosity before testing
- The effect of each cleansing agent on surface finish of specimens was not evaluated completely, this may need further study.

CONCLUSION

Within limitations of the study, the following conclusions were drawn:
- The hypothesis of the present study that all three denture cleansers: Valclean, Polident and Clinsodent will be equally effective in the removal of turmeric stains from Bre.flex 2nd Edition flexible denture base resins was rejected
- Group 1 (Valclean) showed greater stain removal efficiency when compared to Group 2 (Polident) followed by Group 3 (Clinsodent).

Clinsodent and Polident can safely be used as denture cleanser for polyamide-based denture resins. Valclean should be used with caution.

Future scope of the study

The present *in vitro* study can be further extended into a clinical study to prove the efficacy of denture cleansers and also the efficiency of the denture cleansers used in this study can be further analyzed for colour variations after prolonged immersion in denture cleansers. Further, the effect of each denture cleanser can also be assessed on the surface finish of the flexible denture base resins.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Case Report

Rehabilitation of a mid-facial defect using maxillary obturator with a maxillary expansion device and orbital prosthesis

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Abstract

Midfacial defects are defined as congenital or acquired defects in the horizontal plane at the middle third of the face and communicate with intraoral maxillary defects. These defects lead to speaking difficulty, difficulty in saliva control and deglutition, mastication, and esthetics. Prosthetic rehabilitation of such defects with maxillofacial prosthesis is a challenging task. Maxillary defects with bilateral undercuts present are common. This case report explains to achieve retention by engaging the bilateral undercuts with the desired path of insertion and obtaining adequate retention of these prostheses. This clinical case report presents prosthetic rehabilitation of a mid-facial defect involving one orbit and the premaxilla region with the help of silicone orbital prostheses and magnets along with an expansion device. This dramatically improved the patient's speech, mastication, deglutition, esthetics, and self-confidence.

Keywords: Maxillary expansion screw, maxillary obturator, orbital prostheses, rehabilitation

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Submitted: 01-Dec-2021, **Revised:** 11-May-2022, **Accepted:** 12-May-2022, **Published:** ***

INTRODUCTION

Middle face defects are either congenital or acquired in the horizontal plane at the middle third of the face and communicate with intraoral maxillary defects. Acquired midfacial defects not only affect patients' speech, deglutition, and mastication but also alter the quality of life and well-being.[1-4] Based on the location of the defect, they are broadly divided into the midline and lateral midline defects. Midline defects include complete or partial nose or upper lip defects in communication with an intraoral maxillary defect. Lateral midfacial defects are complete or partial defects of cheek and orbital contents with an intraoral maxillary defect.[5]

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_527_21

Surgical reconstruction alone rarely rehabilitates such large midfacial defects. A well-fitting, removable maxillofacial prosthesis gives successful results in such cases of prosthodontic rehabilitation to restore function and esthetics.[6] This removable obturator prosthesis restores the lost intraoral and extraoral structures and acts as a barrier between the oral and nasal cavities. Maxillary complete denture along with a modified obturator restores oral functions and esthetics in patients with palatal defects.[7]

This clinical case report explains in detail the prosthodontic rehabilitation of a midfacial defect and restored esthetics and improving the quality of life.

How to cite this article: Parameswari BD, Konwar AK, Hariharan A. Rehabilitation of a mid-facial defect using maxillary obturator with a maxillary expansion device and orbital prosthesis. J Indian Prosthodont Soc 2022;22:294-9.

CASE REPORT

A 57-year-old male reported to the clinical department of maxillofacial prosthodontics for replacement of his missing facial and intraoral structures. Intraoral examination presented a postsurgical defect due to rhino-orbital mucormycosis in the premaxilla region in continuation with the nasal cavity and an orbital defect following enucleation of his left eye [Figure 1]. The defect margins were normal and healthy. The maxillary defect was under the classification of Aramany's Class VI type of maxillectomy defect (anterior resection). The patient had a completely edentulous maxillary arch with hypermobile tissue in the anterior region [Figure 2].

Due to his financial constraints, the option of rehabilitation with an implant-retained prosthesis was opted out. The treatment plan included rehabilitation of the orbital defect with Silicone eye prosthesis, an esthetic flexible material, with a modified two-piece obturator, which closed the intraoral defect and thus separated the oral cavity from the nasal cavity and facilitated swallowing and phonetics. The obturator prosthesis was fabricated in two pieces. The first piece engaged the bilateral undercut of the defect, consisting of an acrylic plate sectioned at the middle and unified using expansion screws. The second piece was the acrylic complete denture. Two pieces were retained together with the help of opposite poles of magnets.

Figure 1: Orbital defect

Figure 3: Primary impression of the maxillary defect

TREATMENT PROCEDURE

The primary impression of the palate along with the defect was recorded with an impression compound (DPI, Pinnacle,) [Figure 3] and the mandibular impression was made with irreversible hydrocolloid (Zhermack, India). The defect was recorded to its permissible extent. Primary casts were made with dental plaster and the special impression tray was fabricated by relieving the anterior flabby tissue region. Border molding was done with a green stick impression compound (DPI, Mumbai, India.). The palatal defect was recorded with a green stick impression compound to record permissible depth, extent, and all possible undercuts of the defect followed by a secondary impression using light body polyvinyl siloxane material (Dentsply Aquasil Impression material) [Figure 4]. The final cast was made with dental

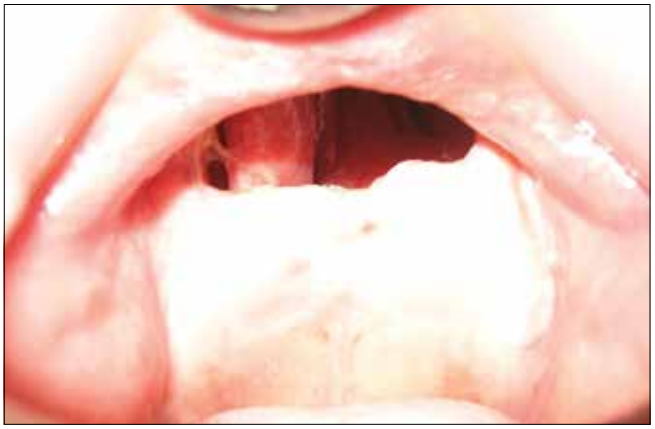

Figure 2: Intra -oral maxillary defect

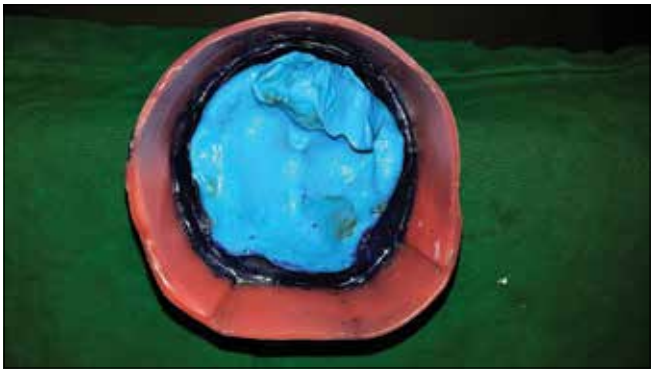

Figure 4: Secondary impression of the maxillary defect

stone (Type III gypsum) and an acrylic record base was fabricated.

Acrylic plates with additional palatal extensions into the lateral undercut were fabricated on the master cast sectioned at the center and unified by a maxillary expansion screw (Dentaurum Hyrex Expansion Screw) with a keyhole and a separate key for activation. Due to inadequate usable undercuts, this maxillary expansion device was used, to ensure maximum retention by engaging the laterally extended acrylic plates and locking onto the palatal undercuts on activation of the device. The activation of this device is done by engaging the key onto the keyhole and making 45° turns upward till the palatal extensions of the device were engaged adequately onto the undercuts [Figure 5a-c]. Two pairs of 5 mm × 1.5 mm diameter cobalt samarium magnets (Milestone, India) were attached on each side of the expanding acrylic plate using autopolymerizing resin (DPI). After positioning the acrylic plates intraorally and the activated maxillary expansion screw, a pickup impression was made with the prefabricated acrylic denture base [Figure 6a and b] onto which a cast was cast poured, and used for new denture base fabrication [Figure 7]. Zinc oxide eugenol (DPI) paste was painted onto each magnet of the screw assembly as an indicating material for proper positioning of opposite poles of another two pairs of magnets and was fixed on the tissue surface of the new maxillary denture base. Jaw relation, wax trial, and final denture processing on the denture base were carried out conventionally. The maxillary denture was then inserted and properly positioned and the denture was attracted by the opposite pole of magnets toward the inner expansion plate [Figure 8].

Orbital prostheses fabrication

An orbital defect impression was made using an irreversible hydrocolloid. Boxing wax was used to outline the margins onto which the impression material was poured after greasing the area with petroleum jelly. A moist gauze pack was kept in the defect to avoid the flow of impression material into the undesired region according to the required impression. Fast-setting dental plaster (about 0.25-inches thick) was used as a base for the impression material to provide support and to avoid tearing and distortion of the impression during removal [Figure 9]. The impression was then boxed and poured with dental stone to get the working cast.

Wax-up was done using modeling wax and a ready-made stock eye shell button matching the patient's previous photograph and right side-eye in color, shape, and size. The patient was called for try-in and an evaluation of the fit of the eye wax pattern, pupil orientation, size, and amount of scleral visibility, when compared to the contralateral eye was done using the paper iris disk technique when the patient was directly looking at a point at eye level at 6 feet away [Figure 10]. Once the mock trial was done on the patient, the final surface contour and skin texture of the wax pattern were carved on the working cast, and wrinkles and lines were obtained by dabbing a wet gauze piece into softened wax [Figure 11]. Investment, flasking, and dewaxing of the pattern were done conventionally. After dewaxing, color matching was done in natural light to achieve the desired color using medical-grade silicone (Technovent Ltd., UK) mixed with the intrinsic colors and was packed following the manufacturer's instructions. It was allowed to set for 24 h under room temperature. The flash from the final prosthesis was trimmed off using a sharp blade. External characterization was done guided by the patient's skin color [Figure 12]. The patient was instructed to use an adhesive (Daro Hydro Bond adhesive) for better retention of the orbital prosthesis. The patient was then trained properly on how to wear the prosthesis by engaging in the available undercuts [Figure 13] and was instructed to maintain proper hygiene of both the prostheses.

DISCUSSION

Acquired defect of the maxilla results in communication between the oral and nasal cavity causing difficulty

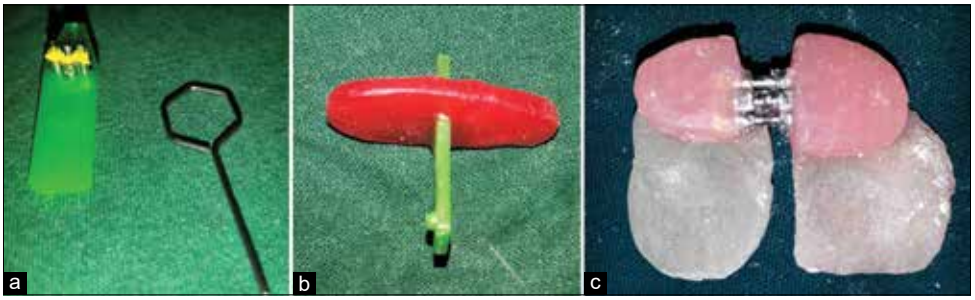

Figure 5: (a) Expansion device, (b) wax up of expansion device, (c) acrylised expansion device with the prosthesis

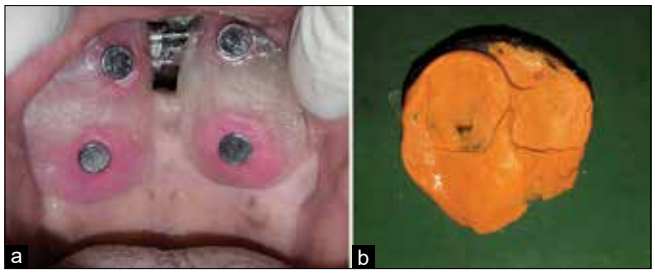

Figure 6: (a) Intraoral positioning of first part of prosthesis, (b) pickup impression – to fabricate second part of prosthesis

Figure 8: Maxillary obturator insertion

Figure 10: Orientation of the orbit – try in

in swallowing, speech, nasal leak, and an unpleasant appearance. Rehabilitation of such defects can either be done by surgical correction or by prosthesis or by using a combination of both methods.[5] Prosthetic rehabilitation of maxillofacial defects has several advantages over surgical reconstruction such as:

(1) It is inexpensive, (2) It facilitates regular clinical examination, (3) Maintenance of oral hygiene, (4) Acceptable esthetic results.

Figure 7: Magnets position in the second part of prosthesis

Figure 9: Orbital impression

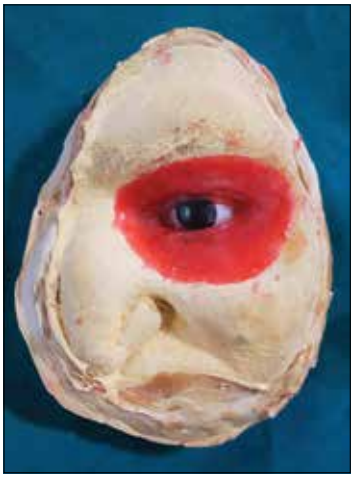

Figure 11: Wax up of prosthesis

However, retaining a maxillofacial prosthesis is a challenging task, due to the constant downward gravitational pull. Many methods of improving the retention of the maxillofacial prosthesis were carried out by Jean Nadeau in 1955, Boucher and Heupel in 1966,

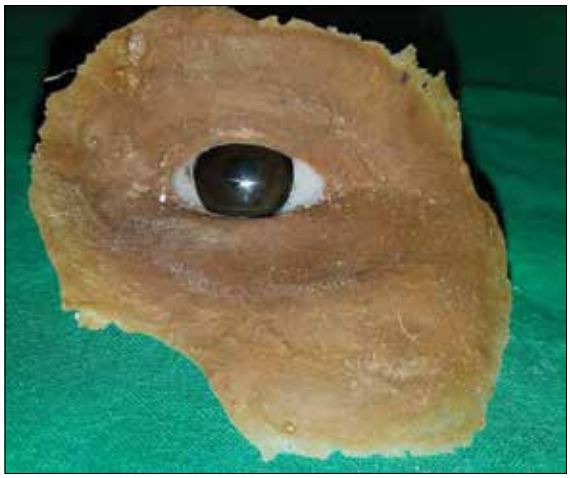

Figure 12: Processed orbital prosthesis

Figure 13: Final prosthesis – post insertion

Javid in 1971, and Federick using magnets.[8] Magnets of smaller dimensions are made using rare earth alloy Sm–Co (Samarium–cobalt) and Nd–Fe–B (Neodymium–Iron–Boron).[9] The reduction of tarnish and corrosion of magnets is achieved by using nickel, gold, and titanium coating of these magnets.[10] The major challenge, in this case, was less retentive prosthesis, as the defect was in the premaxilla region and is completely edentulous with inadequate ridge support. In this case, the only reliable undercut is the bilateral lateral undercut. A single path of insertion is not possible to engage bilateral undercuts. Hence, an acrylic plate is inserted inside the defect with inactivated expansion screws. After the acrylic, the plate is positioned, by activating the expansion screws, both sections of the acrylic plate move and engage bilateral undercut, and retention is achieved.

Magnets were used to keep both the plate and the denture in place thus facilitating retention and easy placement and removal. The orbital prostheses fabricated with medical-grade silicone and pigments improved postoperative esthetics by filling the orbital volume and adhesive facilitated further retention. Though implant-retained prosthesis is the best treatment option, due to economic constraints and inadequate available bone density, magnet retained prosthesis was done as the possible treatment option for this patient.

CONCLUSION

The difficulty that a prosthodontist has to deal with while treating patients with maxillofacial defects is the multiple undercuts, with different paths of insertion. This novel method of engaging the lateral undercuts using expansion screws opens a new arena to engage bilateral undercuts, thus reducing the bulk of the prosthesis as it decreases the vertical extension of the prosthesis inside the defect. Satisfactory functional and aesthetic results for a patient with a maxillofacial defect can be achieved with proper planning and adequate retention is obtained using magnets and other selected retentive aids.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the journal. The patient understand that name and initials will not be published and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Case Report

Bridging form and function: A bilateral auricular prosthesis

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Abstract

Unfortunate loss or absence of an ear has a far-reaching impact on an individual psyche. Auricular defects are seen commonly due to trauma, congenital abnormalities, and malignancies which result in disfigurment of the pinna. Rehabilitation of an auricular defect with a custom-made auricular prosthesis improves social acceptance and self-confidence in an individual. Auricular defects present reconstructive challenges, especially if they are bilateral. Surgical reconstruction provides effective results for defects; however, for some patients, surgical intervention is contraindicated. This case report describes an innovative technique to rehabilitate patients with auricular defects with mixed hearing loss and bilateral microtia using a multidisciplinary approach. The patient was provided with a functional auricular prosthesis. The prime purpose of the treatment rendered was to restore the lost auricular structure to the patient's satisfaction comfortably and cost-effectively. An early rehabilitation promotes physical as well as psychological healing of the patient.

Keywords: Auricular prosthesis, bone-anchored hearing aid, microtia

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Submitted: 14-Dec-2021, **Revised:** 17-Apr-2022, **Accepted:** 18-Apr-2022, **Published:** ***

INTRODUCTION

It is the God-given right of every human being to appear human. Few areas of prosthodontics offer more challenges to the technical skills or higher satisfaction for the rehabilitation of function and esthetics in the patient with widespread anatomic defects and deformities of the maxillofacial region. Although there have been remarkable advances in the surgical management of oral and facial defects, satisfactory repair by plastic surgery alone is mostly a compromise. Hence, the demand for maxillofacial prostheses for the rehabilitation of such patients has intensified in the recent years.

In today's image-conscious society, quality of life is severely compromised by physical defects, especially involving the orofacial region. Auricular defects range from minor deformities to complete anotia, due to congenital or acquired reasons.[1] Prosthetic reconstruction has evolved into becoming an established alternative to techniques using autogenous tissues. Requirements of an ideal prosthesis are esthetics, retention, stability, correct alignment and positioning, biocompatibility, and longevity.[2]

CASE REPORT

A 5-year-old daughter of a serving soldier was referred to the department of prosthodontics from the department of ENT with a chief complaint of deformed ears on both sides since birth. Medical history elicited reduced hearing and delayed speech since birth. The parents

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Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_546_21

How to cite this article: Srivastava A, Hazra R, Kumar D. Bridging form and function: A bilateral auricular prosthesis. J Indian Prosthodont Soc 2022;22:300-4.

had a nonconsanguineous marriage and neither her twin brother presented with similar complaints. On general examination, the patient was moderately built and nourished, and she was well oriented to time, place, and person. The face was bilaterally symmetrical and her complexion was fair. Investigative neurosensory tests and tuning-fork tests were conducted to screen for conductive hearing loss; brain-evoked response auditory was carried out to identify hearing impairment in the child, and it evaluates the auditory nerve response to different sounds. High-resolution computed tomography was carried out to check the suitability for surgical intervention if required. All the investigative tests suggested a bilateral conductive hearing loss.

Based on the observations and investigations, a diagnosis of bilateral congenital microtia with grade two microtia with respect to the right ear and grade three with respect to the left ear with aural atresia was made [Figure 1]. We along with the department of ENT formulated a five-phase treatment plan where phase one included patient education and motivation, phase two included fabrication of a silicon prothesis, phase three included provision of removable bone-anchored hearing aid (BAHA), phase four included the incorporation of this BAHA within the prosthesis, and phase five were the follow-up and maintenance phase. A dual-mode of retention was planned to utilize the redundant tissue as well as the hairband.

Figure 1: Local examination

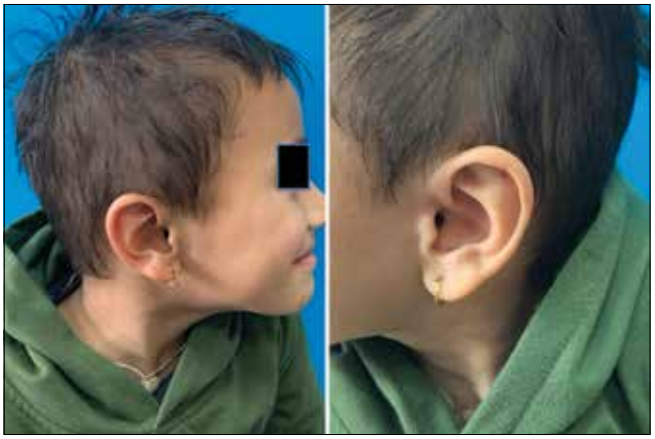

Figure 2: Donor selection

Clinical and treatment report

The patients' twin brother was selected for the donor impression [Figure 2], considering the same age and average facial measurements. Petroleum jelly was coated on the hair and tissue adjacent to the ear and a cotton plug was placed into the ear canal. The irreversible hydrocolloid (Zelgan 2002; Dentsply, Delhi) impression of both donor and patient was made by utilizing modified impression trays consisting of a plastic bowl and cup [Figure 3]. The impressions were poured in Type IV die stone *(Kalabhai Karson, Mumbai)*. A wax pattern was fabricated from the donor impression. The prepared wax pattern was then adapted to the respective defect sites on the patient's cast. Orientation lines were marked on the patient's face and the wax pattern was tried on for the verification of fit, angulation, dimension, and esthetics [Figure 4]. Silicone shade matching was carried out using the trial and error method. The wax pattern was flasked using the three-stage pour technique. The first pour was for the base layer. After the separating medium was applied, the second pour was done on the concave surface of the ears. The counter pour, i.e., the third pour, was done after the separating medium was applied. After every pour, orientation grooves were

Figure 3: Impressions

made to enable re-positioning of all the components. Once the entire assembly was set, dewaxing was done. It was ensured that there was no residue of wax or it would interfere with the vulcanization of silicone rubber. A hollow plastic sleeve was incorporated into the mold before packing, behind the helix using cyanoacrylate for the attachment of the headband [Figure 5]. Incremental packing of the heat vulcanized silicone (Technovent Pvt. Ltd) was done for the prevention of incorporation of voids. This was followed by clamping to remove the flash.

This was then processed at 100° centigrade temperature for 1 h as per the manufacturer's instructions. The silicone prosthesis was retrieved and thoroughly cleaned using acetone [Figure 6], followed by trimming, adjustment by rubber trimmers, and impartment of fine detailing by extrinsic staining.

The hairband was adjusted according to the patient's head circumference till a uniform close fit was achieved and inserted into the plastic sleeve attachment of the prosthesis [Figure 7]. The assembly was then tried on. The BAHA Softband was developed by the Entific Company. It comprises an elastic band with a plastic snap connector as coupling mechanism for a standard BAHA. The snap connector disc is pressed against the skin of the head at a bony location, such as the mastoid or the forehead. Conventionally, this assembly comes attached with a soft elastic head band as supplied by the company, but the processor assembly can be detached as in our case from the elastic band and placed at a specific location from where bone conduction can take place. The BAHA sound processor assembly was attached to the prosthesis metallic headband by crimping it with universal pliers in between its loops at the location suggested by the ENT department [Figure 8]. The evaluations were performed with verbal speech and language tests, by the ENT specialist with only this assembly in place.

Once it was approved, the BAHA incorporated hairband was attached to the patients' soft headband using cyanoacrylate resin segmentally for concealing the BAHA as well as the hairband [Figure 9]. The patient was shown the preoperative and postoperative comparison photographs [Figure 10]. Posttreatment instructions were given to the parents for the maintenance of the prosthesis.

The patient was recalled for review visits at 3 days, 1 week, 3 weeks, and 2 months. The prosthesis assembly was well maintained by the patient, the parents informed that the patient was progressively getting better adapted to the prosthesis, and the response to voiced commands significantly improved apart from the aesthetics.

At the 2-month visit, the button cell of the BAHA processor was replaced by gently stripping the soft head band from the metal hair band substructure. The parents brought a new variety of headband, which they wanted to get replaced. The batteries and headband were replaced and prosthesis was returned to the patient.

DISCUSSION

Auricular defects may occur due to hereditary or developmental causes. The congenital defects may arise due

Figure 4: Wax try in

Figure 6: Retrieved prosthesis

Figure 5: Flasking

Figure 7: Prosthesis try in

Figure 8: Hairband adjustment and BAHA incorporation. BAHA: Bone-anchored hearing aid

Figure 9: Final prosthesis

Figure 10: Preoperative versus postoperative

to anomalies of the 1st and 2nd branchial arches which result in anotia or microtia. In microtia, the external auditory canal is absent and the presence of a small remnant of deformed cartilage, whereas the absence of the whole ear is called anotia. Treacher Collins syndrome and Goldenhar's syndrome are the most common syndromes associated with the same. Among others, bilateral absence of the ear is seen in <10% of all cases.

The classification of Weerda combines the suggestions of various authors and provides an overview based on the increasing levels of deformity and the necessary surgical intervention.[3]

In Grade I malformations, most structures of the normal auricle are present. The examples include prominent ears, macrotia, cryptotia, cleft ear, moderate cup ear deformities, earlobe deformities, and other minor auricular deformities. Grade II includes severe cup ear deformities and the mini ear (concha type microtia). Some of the ear structures are extant but, for a complete reconstruction, additional skin and/or cartilage are needed. In Grade III, none of the normal structures are present. This group includes unilateral or bilateral rudimentary auricle and anotia. In particular, Grade III dysplasia is often associated with the changes in the external auditory canal including aural atresia, malformations of the middle ear, and sometimes even dysplasia of the petrous bone with facial anomalies and the facial nerve being affected on the ipsilateral side. In such cases, additional skin and cartilage or other materials are required for total reconstruction.

In very young children with bilateral congenital aural atresia, surgical intervention is not an option and bone-conduction hearing aids have proved to be the only effective treatment. Conventional bone conduction hearing aids are not popular because there are several major drawbacks. The BAHA is known to be more comfortable to wear and it is highly efficient in audiological terms. To offer them the advantage of bone-conduction hearing without the disadvantages of conventional bone-conduction hearing aids, the BAHA Softband was developed.[4]

Extensive surgical procedures may sacrifice a large part of anatomic retentive features which compromises retention of the maxillofacial prosthesis.[5]

Various means of retention can be categorized into:

- Anatomical anchorage - by utilizing tissue undercuts/concavities
- Mechanical anchorage - by external devices such as eyeglasses, headbands or straps, stud clips, snap buttons, magnets
- Chemical anchorage - with adhesives
- Surgical anchorage - with implants.

Our algorithm for treating the congenital auricular deformity was to provide for the hearing ability first and to manage the esthetics as well. After that, we discussed with the parents, the different methods for rehabilitation. Prosthetic restoration of maxillofacial defects has always been limited by the unavailability of adequate materials. Although there is a spectacular improvement in material sciences and technologies, the quest for the ideal material that resembles or duplicates human skin is still on.

Deformities of the external ear can affect psychosocial well-being and hearing. The current gold-standard reconstructive treatment is autologous costal cartilage grafting despite the vast morbidity profile. Tissue engineering using stem cells and 3D printing can create patient-specific reconstructed auricles with superior cosmetic outcomes and reduced morbidity.[6] However, surgery is not always the solution keeping a multifactorial outlook for the treatment and weighing the merits and demerits. The progress made in the development of the silicones as well as percutaneous titanium implants allow for rehabilitation of patients with microtia with an inconspicuous camouflage that most patients desire. Auricular prostheses may be used as a rescue procedure in failed auricular reconstruction or as a definitive treatment option.[7]

Digital technology improves the clinical outcome of maxillofacial prostheses by increasing fabrication accuracy, reducing treatment time, and facilitating a replacement prostheses in the future. A facial scanner can be used to acquire overall facial data. However, an intraoral scanner is more suitable for recording detailed surface data. In addition, the combined use of a facial and intraoral scanner can produce a prosthesis with accurately reproduced skin texture. One of the drawbacks is the inability of the digital scan to record functional movements which can lead to instability of the facial prosthesis and poor adaptation to the bed tissue during function. Rapid manufacturing has not been routinely used because of the unavailability of printable silicone material.[8]

Maxillofacial prosthetist as a member of the Anaplastology team can rehabilitate the disfigurement with more durable and life-like prosthesis using the latest research, advancements, materials, and techniques in our field to create confidence and a sense of well-being to our patients. Advancement in technology has a profound impact on the maxillofacial restoration of form and function.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the legal guardian has given his consent for images and other clinical information to be reported in the journal. The guardian understands that names and initials will not be published and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Case Report

Prosthetic management of partial anodontia with microdontia from 11 to 20 years of age - 10 years of follow up

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Abstract

Treatment of pediatric patients with partial anodontia is a challenge requiring interdisciplinary approach. Growth period, reduced vertical dimension, microdontia, and unacceptable esthetics present difficulties at various stages of prosthetic rehabilitation. Congenital absence of teeth impairs the nutritional status of the growing child and causes a psychological setback. This article describes the prosthetic management of a patient suffering from partial anodontia done over a period of 10 years. Considering the age and psychological and financial requirements of the patient, removable and fixed prostheses were fabricated at different phases of the treatment. The ultimate aim was restoration of function, improvement of esthetics, and overall psychological upliftment of the patient which was achieved by maxillary metal ceramic bridge and mandibular implant retained hybrid prosthesis.

Keywords: Hybrid prosthesis, microdontia, partial anodontia

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Submitted: 21-Feb-2022, **Revised:** 27-Apr-2022, **Accepted:** 28-Apr-2022, **Published:** ***

INTRODUCTION

Anodontia or congenital failure of odontogenesis can present itself in many forms, ranging from a single missing tooth to total anodontia.[1] Partial anodontia, the congenital absence of one or more teeth, can affect both deciduous and permanent dentition.[2] The overall incidence ranges from 1.6% to 9.6%.[3] It is generally identified in younger age group of children and may or may not be associated with ectodermal dysplasia.

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Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_94_22

Prosthetic rehabilitation of children presents unique and special challenges to the dental profession due to reduced vertical dimension (VD), leading to temporomandibular disorders, growth period, microdontia, multiple missing teeth, and psychological problems arising from unacceptable esthetics.[4,5]

However, an early diagnosis of the problem and a team approach will help in better planning of treatment and achieve the ultimate goal of a functionally rehabilitated patient.[6]

How to cite this article: Kalavathy N, Anantharaj A, Anantharaj N, Mundhra H, Kanrar B. Prosthetic management of partial anodontia with microdontia from 11 to 20 years of age - 10 years of follow up. J Indian Soc Periodontol 2022;22:305-9.

CASE REPORT

An 11-year-old male patient presented with the chief complaint of multiple missing teeth. Intraoral examination revealed multiple retained deciduous teeth, erupting permanent maxillary central incisors, generalized microdontia, and loss of VD of occlusion. The patient did not exhibit any other characteristic of ectodermal dysplasia and did not present any remarkable medical or family history. Clinical and radiographic examination confirmed a diagnosis of partial anodontia. The case has a long treatment span which was divided into four phases. The sequence of different phases of the treatment is illustrated in Figure 1.

Opinion was obtained periodically from an experienced pedodontist, an oral surgeon, and an orthodontist, and a soft cap splint was given to re-establish the VD at 11 years of age. Niswonger's method was used to check freeway space at rest and in occlusion. VD was increased incrementally by 2 mm at one stage making sure that there was a freeway space of 5 mm and Silverman's closest speaking space of 2 mm. This was done periodically as and when the transitional dentures were fabricated as the patient was in growing age. The overall increase in VD was approximately 6 mm for this patient. Thus, the initial phase was fabrication of overdenture for maxilla taking support from the underlying partially edentulous

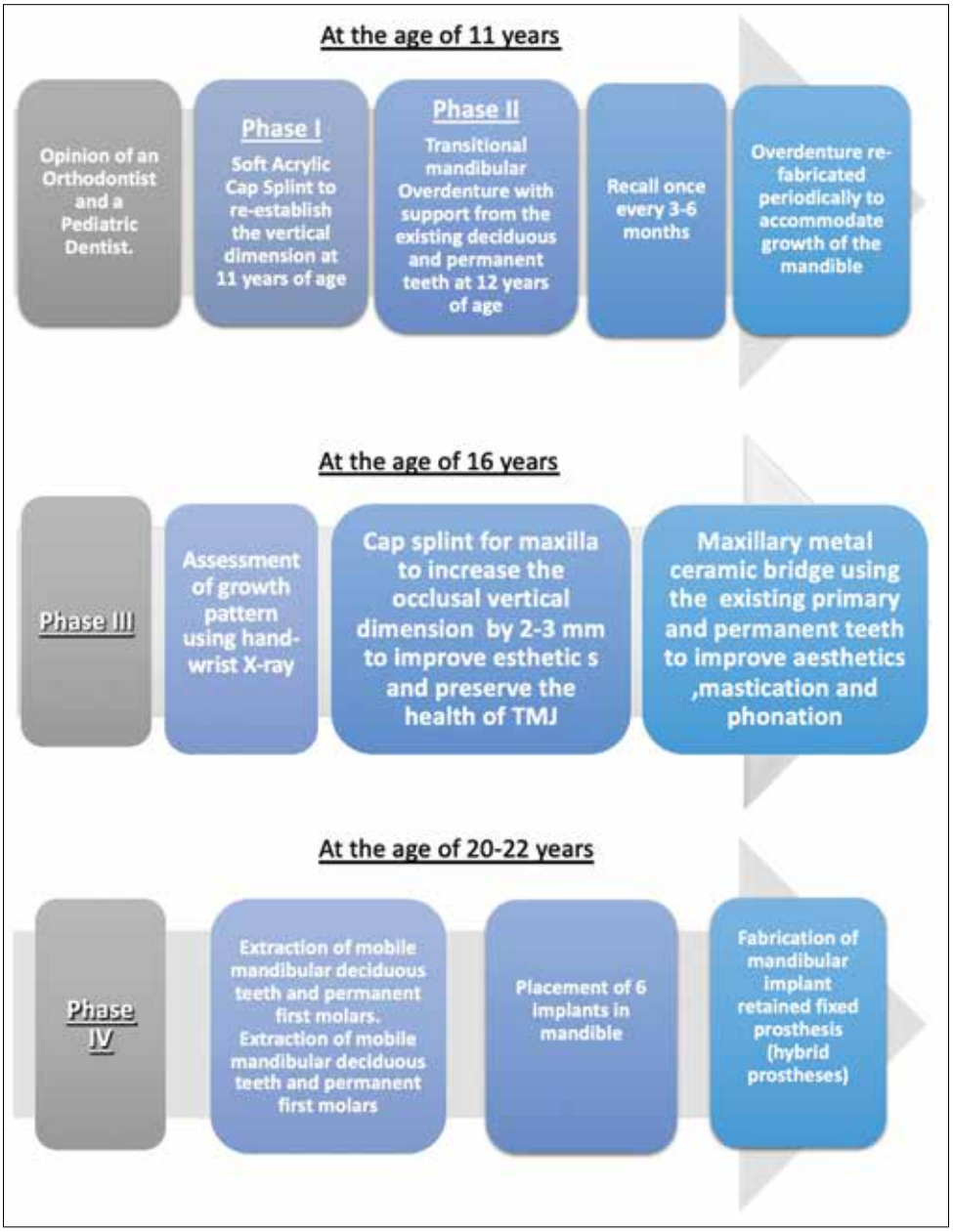

Figure 1: Sequence of treatment plan at various phases

arch and microdontic teeth. During phase I, the patient was given a soft splint for mandible, thus improving the VD periodically. In phase II of treatment planning, transitional maxillary and mandibular heat-cured acrylic overdentures were fabricated for the patient at the age of 11 at the increased VD to improve esthetics, and periodic recall was done every 3–6 months. The overdentures were refabricated as and when required till the age of 16 to accommodate the growth of the jaws and increase in facial height.

At 16 years of age, multiple retained deciduous teeth and generalized microdontia were observed on intraoral examination [Figure 2]. Only eight permanent teeth were present namely 13, 11, 21, 23, 36, 37, 46, and 47. Investigations including diagnostic casts, orthopantomograph, and intaoral periapical radiograph showed two impacted permanent teeth, and hand wrist radiograph revealed completion of sagittal skeletal growth. Thus, phase III of treatment included fabrication of metal ceramic bridge using the existing deciduous and permanent teeth for maxillary arch at the established vertical dimension as the esthetics with the removable maxillary overdenture was satisfactory. Preparation of the teeth was kept minimal due to microdontia and large pulp chamber. Hence, a modified tooth preparation was carried out. This was followed by final impression, provisional prosthesis, permanent metal ceramic bridge fabrication, and cementation using type I glass ionomer cement (GIC). Maxillary restoration improved the esthetics, mastication, and phonation. Permanent restoration of the mandibular arch was deferred till the age of 20 due to certain financial and personal problems.

At the age of 20, the patient presented with multiple mobile mandibular deciduous teeth and knife edge ridge clinically and D1 type of mandibular bone radiographically. Extraction of the mobile deciduous teeth and permanent first molars followed by rehabilitation with an implant supported fixed prosthesis was planned at this stage.

Existing overdenture of the patient was used to fabricate surgical stent. Six implants were decided to be placed in the mandible; four in the interforaminal region and two in the molar region on either side. Six endosseous threaded implants (Nobel Biocare) of suitable dimensions were selected. Two implants each of narrow platform, regular platform, and wide platform variety were used. Surgical placement was carried out under local anesthesia. Bed preparation was done by shaping the mandibular knife edged ridge. Osteotomy of the planned implant sites was done, and implants were placed. Necessary postsurgical medications were prescribed.

After the healing period of 4 months,[7] second-stage surgery was carried out and healing caps were placed [Figure 3].

After healing, custom tray was fabricated and final impression was made by open tray technique using polyether monophase impression material and impression copings. Master casts were prepared using implant analogues and soft tissue replica to duplicate the contours of the soft tissues. Resin pattern with universal castable long abutment was fabricated which was then tried and adjusted in the patient's mouth [Figure 4]. Pick up impression of the resin pattern was made using putty.

The pattern was then casted with cobalt chrome alloy and the metal framework tried in patient's mouth. Passivity of fit was evaluated, and a diagnostic orthopantomograph was made to ensure that no marginal gap existed between the framework and the implants.[8] Centric relation was recorded using interocclusal record material. Individual copings were fabricated on the existing framework, and trial

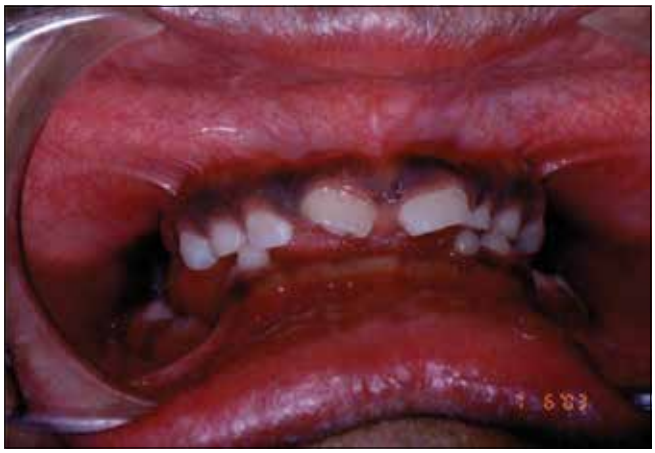

Figure 2: Intraoral photograph of the frontal view

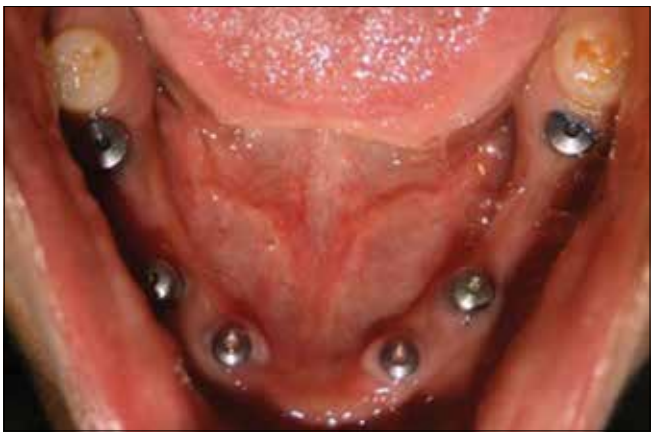

Figure 3: Six implants placed in mandible at 20 years of age

of the same was done intraorally. Porcelain build up on the copings and gingival porcelain build up on the framework were done and tried.[9]

The fit of the cobalt chrome framework and the individual crowns on the framework was verified clinically, and centric occlusion was also established opposing the existing maxillary metal ceramic bridge. The VD was rechecked to make sure that there was sufficient freeway space as well as closest speaking space within the physiologic limit and satisfactory esthetics.

After glazing of the restoration, the cobalt chrome framework was seated on the existing implants intraorally and torqued to 35 N.[10] Individual crowns were also cemented using type I GIC [Figure 5].

Thus, a hybrid implant retained prosthesis was fabricated for mandible while a metal ceramic fixed bridge was designed on the retained primary and permanent teeth for the maxilla. A mutually protected occlusal scheme was incorporated in the prostheses.

The patient was recalled after 24, 48, and 72 h for recall checkup. Oral hygiene maintenance instructions were given along with directions for use of floss and waterpik.[11] The patient was quite satisfied with respect to esthetics as well as function.

DISCUSSION

Clinical features of partial anodontia in young patients pose special challenges to a clinician. Different stages of the treatment provided at various ages - starting from childhood to adulthood requires multidisciplinary approach with meticulous planning and patient cooperation.

Figure 4: Resin pattern with UCLA abutments tried intraorally

Total extraction of the existing teeth followed by fabrication of conventional complete denture was not advised in this case considering the age of the patient and the need of reducing the residual alveolar ridge resorption and the psychological trauma that he and his family might undergo due to the extraction. Orthodontic correction and extrusion of impacted teeth was not possible because of the microdontia. Hence, overdentures were fabricated for both the arches in the first phase of the treatment which were refabricated as per requirement.

Dental implants have expanded the scope of prosthetic rehabilitation of severely debilitated dentition. Fixed metal ceramic maxillary bridge and hybrid implant-retained mandibular prosthesis was fabricated for the above-mentioned patient.

Titanium alloy framework could have been used instead of a cobalt chrome framework for the hybrid implant prosthesis to reduce the total load on the mandibular implants as weight of cobalt chrome alloy would be more than titanium alloy of same size.[12] However, it could not be done due to financial constraints. Moreover, ceramic occlusal table was given to provide superior esthetic results. Retained maxillary deciduous teeth were used as abutments for maxillary bridge. The presence of permanent tooth germ stimulates root resorption of the deciduous teeth. However, even in case of anodontia, the primary teeth may eventually fall.[13] In such a situation, implant retained fixed prosthesis for maxillary arch can be planned depending upon the quality and quantity of available bone. Patient motivation and education play a pivotal role in management of such scenarios.

Due to this oral condition at a young age, the patient initially presented with signs of psychological trauma, low self-esteem, and impaired nutritional status. Fixed

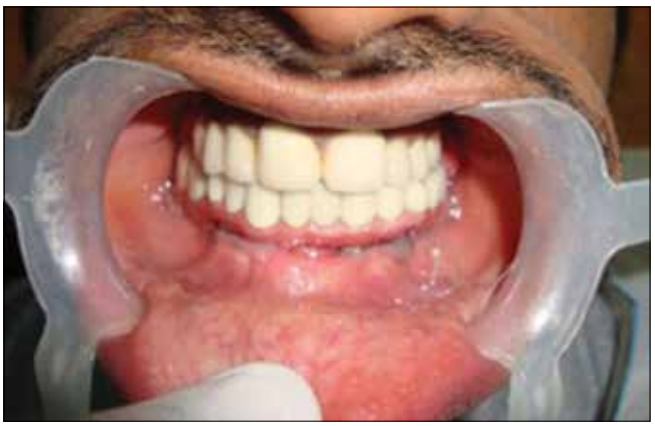

Figure 5: Final placement of mandibular prosthesis against maxillary bridge

prosthesis was highly satisfactory in every aspect and boosted the confidence of the patient and his family members.

The drawback of this prosthetic management was the unfavorable crown-to-root and crown-to-implant ratio. The possible consequences of this line of treatment were explained to the patient. However, 15 years of follow-up of the maxillary prosthesis and 5 years of follow-up of mandibular prosthesis have not shown any signs of failure.

CONCLUSION

Rehabilitation of the partial anodontia patient with the fixed prosthesis provided satisfactory results in terms of esthetics and function.

Acknowledgement

The authors would like to acknowledge the contribution of Dr. Girish Rao, Oral Surgeon, for the surgical phase of the treatment and Dr. Prafulla Thumathi, Prosthodontist, for laboratory support.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the journal. The patient understands that his name and initials will not be published and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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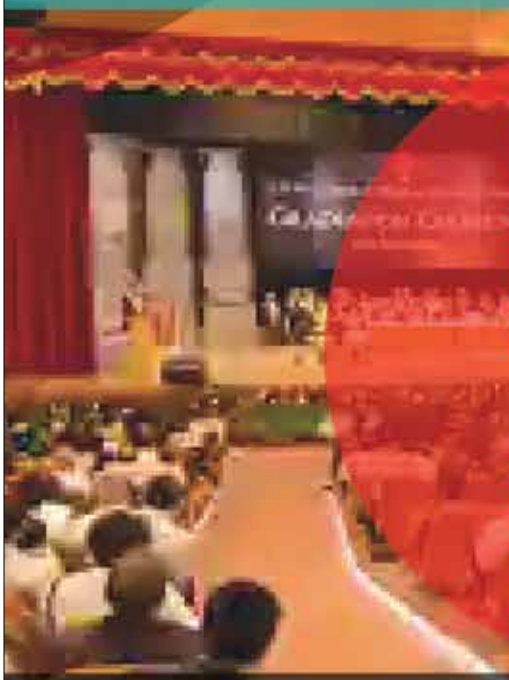

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