Electronic survey: An *in-vitro* study on reliability of the technique

Original Article

P. Rohit, Shilpa Shetty, Babu Satish

ABSTRACT

Aim: The main purpose of this study is to determine the dimensional accuracy of digital models as compared to that of study models and the reliability of electronic surveying. The study aims to measure and compare distances between selected landmarks on study models and digital models, angles of cervical convergence and undercut depth at predetermined points on the abutment teeth. **Material and Methods:** The study used partially edentulous study models of each of Kennedy's class I, II and III classifications. All the three models were scanned using multislice helical computerized tomography (CT) scan and digitized on the computer. The physical model and digitized models were surveyed and measured using various parameters and study designs. Measurements were conducted directly on study models and computer models using Altair Hyper mesh network version 7.0. The differences between the two seta of measurement were statistically analyzed using a suitable method. (t- test). **Results:** The differences between measurement of distance on study models and digital models were found to be within the precision of 0.17mm, 0.08,o for the angle of cervical convergence and precision of 0.04mm for undercut depth of the abutment teeth. All these measurements were statistically slightly significant and well within the range of intraoperator variations. **Conclusion:** This study shows that dental cast can be scanned with the help of an accurate and sophisticated scanner and the scanned data can be transferred to the computer and used for the purpose of digital or electronic surveying.

KEY WORDS: Computer aided design, dental cast, electronic surveying, study model, three dimension

DOI: 10.4103/0972-4052.55250

INTRODUCTION

Computer aided design and manufacturing technique have shown some promising applications in the fabrication of crown,[6,14] inlays and maxillofacial and oral surgery,[16,18,24] the field of removable prosthodontics has not embraced this technology so far.[2] If electronic surveying programs can be developed, digitized surveying of a three-dimensional (3D) scanned dental cast may be almost instantaneous. Due to remarkable development in medical CT in recent years, 3D computer graphic presentation using a Voxel model has become possible. Also, 3D image reconstructions canbe completed in a matter of minutes, which is a strong advantage.[11,14,15]

The purpose of this study was to verify the dimensional accuracy of the digitized 3D dental cast and reliability of surveying the same, which may eventually enable the prosthodontic procedures to be carried out digitally.

METHODOLOGY

Partially edentulous study models of each of Kennedy's class I, II and III classifications were obtained from Frasaco partially edentulous rubber moulds using type III dental stone.

These casts were scanned using a Siemens Somatom sensation 16 and a multislice CT scan with slice thickness of 0.75 mm. Image acquisition was carried out with 120kV of X-ray tube voltage and 80 mA tube current. The scanned 3D computer data was obtained in DICOM format. The data points obtained from the scan were aligned and combined using CAD software (Mimics) to provide single coherent data set of the entire object. The resultant data points were used to generate a 3D surface model using Mimics software.

Department of Prosthodontics, V S Dental College and Hospital, Bangalore, India

Address for correspondence: Dr. Dr. P. Rohit, #20/2, Sougandika Nilaya. 8th main, M.C.Binny layout, Vijayanagar, Bangalore – 560 040, India.
E-mail: silverrohi@yahoo.co.in

Graphic pre processing software Altair Hyper mesh version 7.0 was used in a workstation computer with hard ware Pentium processor with a speed of 2.1 GHz and 512 MB RAM for creating hyper mesh models. This computer model provided similar geometry of study models.

The following three criteria were selected for the purpose of determining the dimensional accuracy and reliability of electronic surveying:

1. Measurement of distance between predetermined points on the surface of the models
2. Determination of angles of cervical convergence of the abutment teeth
3. Determination of under cut depth of the abutment teeth

Measurement of Distance Between Specific Points

On the study models and digital models, following specific points were located for measuring the dimensions.

Point A: mid point between the incisors
Point B: midpoint at the posterior boundary of the cast
Point C: anterior mid point on the base of the cast
Point D: posterior mid point on the base of the cast
Point E: located at 15mm from the top most point on the posterior base on the left side of the cast
Point F: located at 15 mm from the top most point on the posterior base on the right side of the cast
Point G: located at the buccal cusp tip of
14 of Kennedy' class I
44 of Kennedy's class II and class III
Point H: located at the buccal cusp tip of the
24 of Kennedy's class I
34 of Kennedy's class II and class III.

These points were carefully chosen to accurately locate them on both study models and digital models. The distance between these points were measured both on the study and digital models, five times each, by the same operator to avoid the intraoperator error.

Measurement I: distance between Point A and Point B
Measurement II: point C and Point D
Measurement III: point E and Point F
Measurement IV: point G and Point H

A Vernier Caliper was used to measure the distance between the above-mentioned points on the study model. Measurements between the points on the digital model were read and recorded by the computer.

Measurement of Angle of Cervical Convergence

As it was not feasible to measure the precise angle of cervical convergence on the study models, photographic images of the study models with the analyzing rod placed against the proximal surfaces of the abutment teeth were obtained. The procured images were transferred to the computer and angles were measured. On the hyper mesh digital model a node was located at the most convex point on the proximal surface of the abutment teeth (premolars and molars). A tangent was drawn to this particular node. Angle of cervical convergence was measured between this node and the tangent.

Measurement of Undercut Depth

For the purpose of standardizing and comparing the undercut depth in the study models as well as digital models, photographic images of the study models with analyzing rods placed against the proximal, buccal and lingual surfaces of the abutment teeth were obtained. A point, 2 mm apically, was located on the analyzing rod from the contact point of the analyzing rod with the tooth surfaces. Distance in mm was measured between these points to the tooth surface to determine the undercut depth. On the hyper mesh digital model, a node was located at the most convex point on the proximal, buccal and lingual surfaces of the abutment teeth (premolars and molars). A tangent was drawn to this particular node. A point, 2mm apically, was located on the tangent from the contact point of the tangent with the tooth surfaces.

All the measurements were repeated five times each to eliminate intra operator errors. All the values are recorded and analyzed with a suitable statistical method.

RESULTS

The results show the,

- measurement of the distances AB(I), CD(II), EF(III) and GH(IV) in Kennedy's Class I , class II and class III in both the study models and digital models.
  {in class I Measurement I, the mean distance measured is 61.14 mm in study model and 61.04 mm in digital model with a mean difference of 0.10 mm and standard deviation of 0.0089. P less than 0.001}.
- measurement of angles of cervical convergence.
  {In class I – first pre molar: the mean degree of angle of convergence is 4.01 degree on study model and 4.09 degree on digital model with mean difference is angle measured of 0.08 degrees and SD is equal to 0.008. p less than 0.001}
- measurement of under cut depth on the proximal surface.
  {in class I – first pre molar, the mean distance of under cut depth measured is 0.81mm on the study model and 0.61 mm on the digital model with a mean difference of 0.2 mm and SD is equal to.0.0008 .p less than 0.001.}
- measurement of under cut depth on the buccal/ lingual surface

{In class I – first pre molar , the mean distance of under cut depth measured is 0.120 mm on the study model and 0.101mm on the digital model with a mean difference of 0.090 mm and SD = .0.0012. p less than 0.001.}

DISCUSSION

Computer aided design and computer aided machining techniques have been successfully introduced in the field of fixed partial denture[6] and maxillofacial technology[11,14,16] over a number of years. The development and evaluation of these advances continue. Advantages of such system have been well documented, and may well eventually become the "next generation" method of fabrication.[1] Electronic surveying of scanned cast enables a pattern for a metal framework to be fabricated on computer screen according to the principles of RPD.[1] Various methods were used for imaging dental hard structure such as holography, Moiré topography, Ppotostereometry, laser scanner etc. For electronic surveying, the digitized 3D image should be an accurate/reliable reproduction of the dental cast. If not, the clinical results will be affected.[11,14,16,17]

This study, therefore, was undertaken to determine the dimensional accuracy of digital models as compared to conventional study models. Study models and digital models of Kennedy's class I, class II and class III partially edentulous situations were used. The main reason behind using Kennedy's classification is that, it permits immediate visualization of partially edentulous arch. It also permits a logical approach to the problem of design and makes possible the application of sound principle of partial denture design.[3,4,9,10] The triangular faceted models termed as stereo lithography or STL files are commonly used in transferring CAD model to rapid prototyping technologies.[23]

A multislice helical CT scan with 0.75mm collimation width was used to produce these images later which are converted to digital models by the use of Mimic software. A collimator regulates the tomographic slice thickness and can be varied to produce different slice thicknesses typically from 1mm to 10-15mm. DICOM format. (Digital imaging and communication in medicine) is supported by CT scanner to transfer the scanned images.[11]

For the purpose of determining the dimensional accuracy and the reliability of electronic surveying the following three criteria were used:

- measurement of the distance between pre determined points on the surface of the models
- determination of angle of cervical convergence of the abutment teeth
- determination of under cut depth of the abutment teeth

Measurement of distance was done by locating specific points, which were carefully chosen as they could be repeated both on the study models and the digital models The size of the angle of cervical convergence determines the amount of retention. To be retentive the teeth must have angle of cervical convergence cervical to the height of contour.[3,4] As it was not feasible to measure the precise angle of cervical convergence and undercut depth on the study models, photographic images of the study models with the analyzing rod placed against the proximal surfaces of abutment teeth were obtained and transferred. The angle of cervical convergence and the depth of undercut were also measured on the hyper mesh digital model. These values were recorded and analyzed with a suitable statistical method.

Some minor differences in measurement of the distance between predetermined points on both study model and digital model were seen. The difference in the measurement of the distance ranged from 0.01 mm to 0.17 mm with a mean of 0.104 mm and standard deviation (SD) = 0.011. But these differences were statistically significant (p less than 0.05). When the angles of cervical convergence were measured on the proximal surface of the abutment teeth, it was found that, there was a difference of 0.07^0 to 0.09^0 with a mean difference of 0.078^0 and SD is equal to 0.0047. The p value was significant.(p less than 0.05). The under cut depths were measured on the proximal surfaces as well as buccal and lingual surfaces of the respective abutment teeth. The differences in measurement of under cut depth varied from 0.03 mm to 0.21 mm with a mean of 0.09mm and SD of 0.0059. Statistically, these differences were significant.

The differences between the manual measurements and measurements made on the 3D image were slightly statistically significant and were, in fact, well within the range of intra operator variation. When the measurements are made on 3D digital image operators variation plays a role because the operator has to click on the points to be measured.

Limitation

There are difficulties in measuring the undercut depth in mesiobuccal and distobuccal line angles because of the superimposition of adjacent tooth structure and also; the junction of the tooth surface and the gingival tissue is not delineated on the digital model. These limitations can, however, be overcome with further research in software programs.

CONCLUSION

From this study we can conclude that the dental cast can be scanned with the help of an accurate and sophisticated scanner such as multislice helical CT scan and the digital model used for the purpose of diagnosis, treatment planning and storage for future use. The dimensional accuracy of the digital models when compared to the study models was statistically significant; and measurement can be made to a precision of 0.17mm.Therefore, digital/ electronic surveying is a reliable method which can be accomplished by locating the height of contour, guide planes and undercut depth measurements as the digital model can be viewed from various angles and positions.

Information of the cast can be utilized more effectively if the 3D shapes of the cast are digitized for medico legal purposes as the consumer protection act (1987) states that it is necessary to retain all patient records for not less than 11 years.[5] Compared with hand-made set-up models, the computed diagnostic cast has advantages such as high speed processing and quantitative evaluation on the amount of 3D movement of the individual tooth relative to the craniofacial plane.[21]

Future developments may enable the computer to automatically determine a suggested path of insertion and with further research unwanted undercut could be eliminated and useful undercuts identified. At another stage, components of removable partial denture could be stored in a computer library and "dragged and dropped" in place on a scanned and surveyed cast from icons appearing on the screen. This would allow virtual patterning to be carried out much faster than by using current techniques.[1]

REFERENCES

1. Delong R, Heinzen M, Hodges JS, Ko CC, Douglas WH. Accuracy of the system for creating three dimensional dental arches. J Dent Res 2003;82:438-42.
2. William RJ, Bibb R and Rafik T. A technique for fabricating pattern for removable Partial denture frameworks using digitized casts and electronic surveying. J Prosthet Dent 2004;91:85-8.
3. Mc Cracken's. Removable Partial Prosthodontics. 11th ed. Mc Givney, Carr AB, Brown DT, editors. Mosby-year book, Inc.
4. Stewart KL, Rudd KD, Kuebeker W. Clinical removable Partial Prosthodontics. 3rd ed. U.S.A: Medico dental media Inc.
5. Bell A, Ayoub AF, Siebert P. Assessment of accuracy of three dimension imaging system for achieving dental study models. J Orthodont 2003;30:219-23.
6. Rudolph H, Quass S, Luthardt RG. Matching point clouds: Limits and possibilities. Int J Comput Dent 2002;5:155-64.
7. Beaumont AJ Jr. Microcomputer aided removable denture design-the next evolution. J Prosthet Dent 1989;62:551-6.
8. Nokubi T, Ono T, Morimitsu T, Ikebe K, Yasui S, Kita S, *et al.* Clinical application of newly developed surveying system for designing and fabricating removable partial denture. J Osaka Univ Dent Sch 1992;32:104-17.
9. Maeda Y, Minora M, Tsutsumi S, Okado M, Nokubi T. A CAD-CAM system from Removable partial denture part-I; Fabrication of complete denture. Int J Prosthodont 1994;7:17-21.
10. Spiral computerized tomography with three-dimensional reconstruction in the study of maxillofacial pathologies. /Acta Otolaryngeal Ital 1995;15:443-8.
11. Kuroda T, Nobuyoshi M, Reiji T, Koji I. Three- Dimensional dental cast analyzing systems. Am J Ortho Dentofac Orthop 1996;110:365-9.
12. Lindquist TJ, Clancy JM, Jhonson LA, Wiebelt FJ. Effectiveness of Computer- aided removable partial denture design. J Prosthodont 1997;6:122-7.
13. Willer J, Rossbach A, Webber HP. Computer- assisted milling of dental restoration using a new CAD-CAM data acquisition system. J Prosthet Dent 1998;80:346-53.
14. Pfeiffer J. Dental CAD-CAM technology, the optical impression (II) Int J Compute Dent 1999;2:65-72.
15. Motohoshi N, Kuroda T. A 3D computer aided design system applied to diagnosis and treatment planning in orthodontics and orthognathic surgery. Euro J Orthodont 1999;21:263-74.
16. Nan X, Fan Y, Li R, Wu Z. Clinical application of three dimensional spiral CT in the complex maxillofacial fracture. Hua Xi Kou Qiang Yi Xue Za Zhi 2001;19:372-4.
17. Braskey ME, Pesun IJ, Lowder PD, Delong R, Hodges JS, Laser digitization of cast to determine the effect of tray selection and cast formation technique on accuracy. J Prosthet Dent 2002;87:204-9.
18. Sykes LM, Parrott AM, Owen CP, Snaddon DR. Application of rapid prototyping technology in maxillofacial prosthetics. Int J Prosthodont 2004;17:454-9.
19. Ciocca L, Scotty R. CAD-CAM generated ear cast by means of Laser scanner and rapid prototyping machine J Prosthet Dent 2004;92:591-5.
20. Williams RJ, Bibb R, Eggbeer D, Collis J.Use of CAD/CAM technology to fabricate a Removable Partial denture Framework. J Prosthet Dent 2006;96:96-9.
21. Persson A, Andersson M, Oden A, Sandborgh-Englund G. A three – dimensional evaluation of a laser scanner and a touch probe scanner. J Prosthet Dent 2006;95:194-200.

Source of Support: Nil, Conflict of Interest: None declared.