



Comparative Evaluation of Accuracy of Three-Dimensional Printed Casts, Digital Casts and Conventional Casts: An In Vitro Study

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ABSTRACT:

Purpose: The purpose of this invitro study was to evaluate the accuracy of the accuracy of three-dimensional (3D) printed cast, digital cast and conventional stone cast.

Material and methods: In this in vitro study, a typodont of maxillary and mandibular arches with full dentate ivory teeth was used as a reference cast. The typodont was digitized using 3D shining intraoral scanner to create digital casts. The digital files were converted into 3D printed physical casts using a prototyping machine that utilizes the stereolithography printing technology and photocurable polymer as printing material. Linear measurements (mesiodistal and occlusocervical) and interarch measurements (intercanine and intermolar) were made for conventional stone casts, digital and prototyped models and were compared with the typodont model. The reference teeth were canines, first molar and first premolars in the maxillary and mandibular arches on the right and left sides. The measurements on printed and conventional casts were done by digital caliper while on digital casts; Geomagic Qualify software was used.

Results: Conventional dental stone casts showed significantly higher error than the other three groups in all linear and interarch measurements. No statistical differences ($p > 0.05$) were seen for the digital casts made using intraoral scanner and digital casts made using desktop scanner.

Conclusion: The linear and interarch measurements made on the three-dimensional printed casts were significantly more accurate followed by digital casts and least by conventional dental stone casts.



INTRODUCTION

Digital technology has revolutionized the field of dentistry. In particular, computer-aided design and manufacturing (CAD/CAM) systems, technology originally introduced by Duret and Termoz in the 1970s, has been widely accepted by the prosthodontic and restorative dentistry field.¹

Accurate impressions and working models are key factors for the execution of dental procedures. Major advancements have been made in recent years in the rehabilitation of partially and completely edentulous patients, the most promising being dental implants. Accuracy of impressions and casts is of great importance for the fabrication of precisely fitting prostheses and consequently for the long-term clinical success of these restorations. The fidelity of the impression with respect to dimensional accuracy is critical as even small discrepancies can result in difficulty while the restoration is fabricated and delivered.²

Fabrication of master cast is a critical step to obtain the definitive restoration or prosthesis. It provides a stable and accurate representation of human dentition and their surrounding structures. Despite their importance, they have several drawbacks, such as the need for a storage area, as the dental records of the patients need to be maintained for a period of 7–10 years, the possibility of wear or fracture of stone, and the difficulty in communication between laboratory and dental professionals. These disadvantages of conventional casts have mainly led to the use of digital models.³

Several studies were done to search for alternatives to conventional stone casts. Production of master model can be done by capturing secondary impression through direct intraoral scanners manufacturing the final restoration without master model fabrication. After capturing digital impression, master cast can be produced by sending the standard tessellation language (STL) file to produce physical model by three-dimensional (3D) printer.⁴

Digital casts allow prosthodontists to perform diagnosis, treatment planning, and fabrication of the final restoration virtually by computer aided appliance manufacturing. They allow digital casts to completely replace conventional casts in case when a physical

representation of the cast is needed for legal purposes or prosthesis design. It is now possible to fabricate physical casts from digital files with the help of rapid prototyping.

Digital casts can be created by direct or indirect scanning of hard and soft tissues by means of intraoral or extraoral scanning methods. The replacement of plaster study models with virtual images has several advantages including ease of access, storage and transfer, and the accuracy of image capture techniques has been reported. However, if the physical restoration of a digital occlusal record is needed, possibly for medico-legal reasons, an accurate method of three-dimensional (3D) reconstruction is required.⁵

Rapid prototyping (RP) systems, such as stereolithography, generate 3D models from a digital file through incremental layering of photo-curable polymers. The dimensional accuracy of physical replicas reproduced using the stereolithography technique has been evaluated by a number of authors.⁶

The advantages of 3D-printed casts include light weight, minimal fracture risk, high abrasion resistance, and the possibility of fabricating multiple replicas at the same time. The oldest and most commonly used 3D printer method is stereolithography (SLA), which includes a photosensitive resin basin, a platform for cast fabrication, and an ultraviolet laser beam to polymerize resin. The SLA technology polymerizes resin casts layer by layer with a laser beam in a water container. The most commonly used material with an SLA printer is polymethylmethacrylate resin (PMMA).⁷

Three-dimensionally printed casts have been compared with conventional stone casts, but further studies are needed to compare the accuracy of digital casts, 3D-printed casts, and conventional stone casts. This may answer the question of whether to replace conventional stone casts with 3D-printed casts and digital casts.⁸

Digital casts and rapid prototyped replicas are becoming increasingly popular among prosthodontists as a part of modern trends toward incorporating modern technologies into every day practice. However, clinical technology has to be tested before it can be implemented into clinical practice.⁹

The present study was conducted to evaluate and compare the accuracy of the three-dimensional (3D)



printed casts, digital cast, and conventional stone casts. The null hypothesis was that there is no difference in the accuracy of three-dimensional (3D) printed cast, digital cast and conventional dental stone cast.

METHODOLOGY

The present study was conducted in the Department of Prosthodontics and Crown & Bridge, to compare the accuracy of three-dimensional (3D) printed casts, digital cast, and conventional dental stone casts. Ethical approval was obtained from the Institutional Ethics Committee. Sample size for the present study was 32. They were four groups with eight samples in each group. Group 1: Conventional dental stone casts, Group 2: Digital cast made using desktop scanner, Group 3: Digital cast made using intra oral scanner, Group 4: 3D printed cast made using intra oral scanner. A typodont with full set of maxillary and mandibular teeth was used in this study as the reference cast.

Group 1: Conventional dental stone casts. Maxillary and mandibular impressions were made of typodont using polyvinylsiloxane (putty) impression material. Impressions were poured in Type III gypsum product. Eight conventional dental stone casts (n=8) were obtained. Group 2: Digital cast made using desktop scanner. Conventional dental stone cast was scanned by the desktop scanner. Maxillary and mandibular casts were scanned separately. Maxillary and mandibular arches were scanned by utilizing the "bite registration algorithm." Digital casts (n = 8) were exported in STL file format. Group 3: Digital cast made using intra oral scanner. The typodont was scanned using intraoral scanner. Maxillary and mandibular arches were scanned by utilizing the "bite registration algorithm." Digital casts (n = 8) were exported in STL file format. Group 4: 3D printed cast made using intra oral scanner. The digital casts obtained using intraoral scanner were exported in STL file format. STL file was sent to stereolithographic (SLA) 3D printer and 3D printed casts (n = 8) were made using photopolymer resin as printing material.

Reference, conventional and 3D printed casts were evaluated using digital vernier caliper with sharpened peaks. Anatomical contact points and cusps tips were marked with a fine pencil to improve accuracy. Digital casts were evaluated using 3D Geomagic imaging software; zoom and rotation functions were utilized

when needed to gain better visualization of landmarks. Linear measurements were mesiodistal (MD) for first molar, first premolar and canine and occlusocervical (OC) for first molar, first premolar and canine. Intermolar width (IMW) on maxillary arch and Inter canine width (ICW) on maxillary arch.

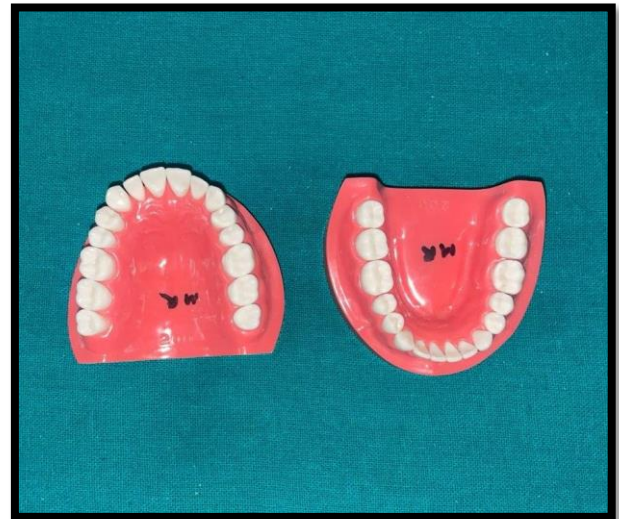


Figure1: Typodont models



Figure2: Digital vernier calliper



Figure3:Scanningconventionalcastswithdesktop scanner(Ceramill map 400)

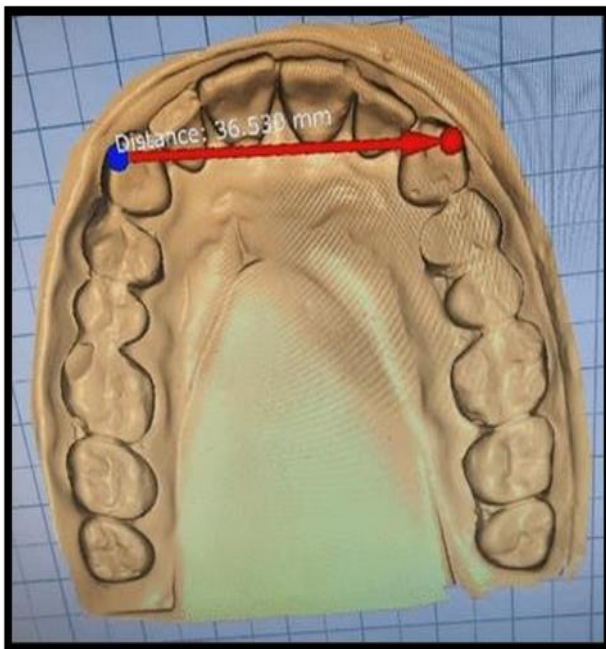


Figure4:Maxillarydigitalcastwithintercanine measurement

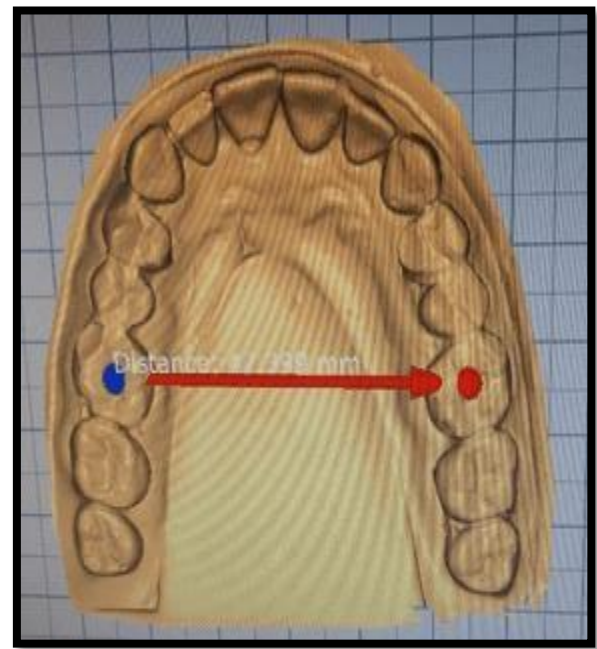


Figure5:Maxillarydigitalcastwithintermolar measurement



Figure6:Scanningtypodontmodelwiththe intraoralscanner

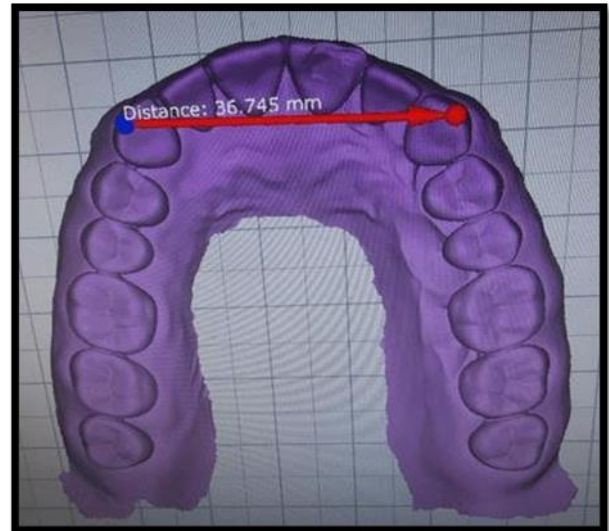


Figure7:Maxillarydigitalcastwithintercaninemeasurement.

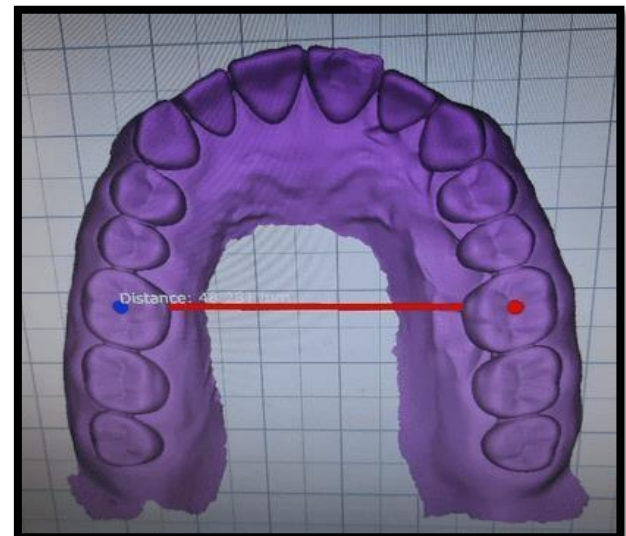
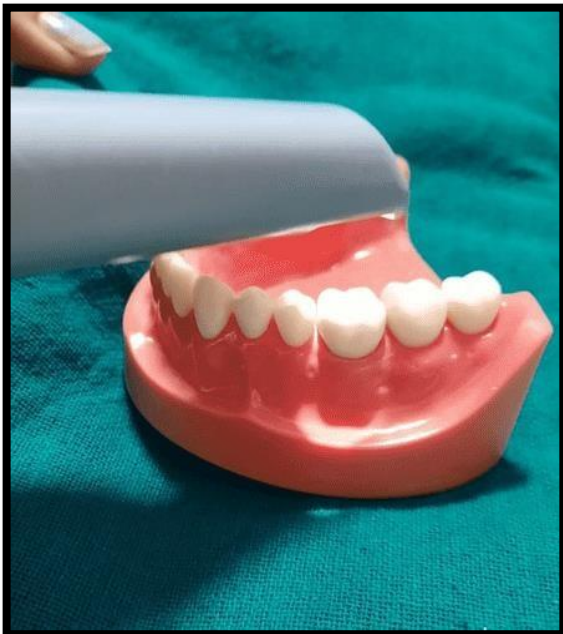


Figure8:Maxillarydigitalcastwithintermolarmeasurement.

RESULTS

Conventional dental stone casts showed significantly higher error than the other three groups in all linear and interarch measurements. No statistical differences ($p>0.05$) were seen for the digital casts made using intraoral scanner and digital casts made using desktop scanner.

**Table1: Intergroup comparison of intercanine width of maxillary among all groups**

Group	Groups	Mean Difference	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Group1	Group2	-.4887*	.0448	.000	-.616	-.362
	Group3	-.9147*	.0448	.000	-1.042	-.788
	Group4	-.4381*	.0448	.000	-.565	-.311
Group2	Group1	.4887*	.0448	.000	.362	.616
	Group3	-.4260*	.0448	.000	-.553	-.299
	Group4	.0506	.0448	1.000	-.077	.178
Group3	Group1	.9147*	.0448	.000	.788	1.042
	Group2	.4260*	.0448	.000	.299	.553
	Group4	.4766*	.0448	.000	.349	.604
Group4	Group1	.4381*	.0448	.000	.311	.565
	Group2	-.0506	.0448	1.000	-.178	.077
	Group3	-.4766*	.0448	.000	-.604	-.349

Table2: Intergroup comparison of intermolar width (IMW) of maxillary among all groups

Group	Groups	Mean Difference	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Group1	Group2	-5.6094*	1.3179	.001	-9.351	-1.868
	Group3	-6.5904*	1.3179	.000	-10.332	-2.849
	Group4	-6.1620*	1.3179	.000	-9.903	-2.421
Group2	Group1	5.6094*	1.3179	.001	1.868	9.351
	Group3	-.9810	1.3179	1.000	-4.722	2.760
	Group4	-.5526	1.3179	1.000	-4.294	3.189
Group3	Group1	6.5904*	1.3179	.000	2.849	10.332
	Group2	.9810	1.3179	1.000	-2.760	4.722
	Group4	.4284	1.3179	1.000	-3.313	4.170
Group4	Group1	6.1620*	1.3179	.000	2.421	9.903



	Group2	.5526	1.3179	1.000	-3.189	4.294
	Group3	-.4284	1.3179	1.000	-4.170	3.313

DISCUSSION

Dental stone cast is a cornerstone in prosthodontic diagnosis and treatment planning with long and proven history, but its associated drawbacks gave rise to digital alternatives. However, the digital cast has to be accurate to replace the stone cast and physical replication should be possible if needed.

In the present study, the accuracy of three-dimensional (3D) printed casts, digital casts, and conventional dental stone casts were compared. Numerous studies have been performed on the accuracy of three-dimensional (3D) printed casts, digital casts, and conventional dental stone casts, but data regarding their comparison is lacking.

The conventional casts, three-dimensional printed casts were measured using the digital vernier caliper and the digital casts were measured using 3D geomagic imaging software. The 3D geomagic imaging software, allowed for a streamlined process scanning and analyzing the digital casts accurately. The linear measurements were made mesiodistally for the canine, first premolar and first molar and interarch measurements for the intermolar and intercanine width.

In mesiodistal measurements, the accuracy of the three-dimensional printed casts ($p < 0.0001$). was significantly higher than the accuracy of the other three groups for the canine, first premolar and first molar. The high accuracy of the three-dimensional printed casts may be attributed to the minimal shrinkage caused by resin polymerization for printing the casts, magnification tools of the software and less operator errors in measurements. Fleming et al³⁵ in their study found the similar results wherein they compared the digital scanned models versus conventional plaster models and reported that three dimensional printed casts were more accurate than conventional casts.

Similarly, in the occlusocervical measurements, the accuracy of the three-dimensional printed casts was significantly higher than the accuracy of the other three groups for the canine, first premolar and first molar. The same findings were reported by the study done by Kim

et al³⁶ where the comparison was made between the 3D printed casts, digital casts and conventional casts. In intermolar width measurement, the accuracy of the digital casts made using intraoral scanner was found to be more followed by the digital casts made using desktop scanner, three dimensional printed casts and conventional casts. The least accuracy of the conventional casts was due to the difficulty in positioning digital callipers correctly due to bulkier calliper ends.

Interarch measurements, for the intercanine width measurements, the accuracy of the three-dimensional printed casts was found to be more followed by digital casts made using intraoral scanner, digital casts made using desktop scanner and conventional casts.

The accuracy of the digital casts was less than the three-dimensional printed casts. It might be due to overestimation of digital measurements and the distortion of arch happens while scanning of dental casts. But this error is still within the acceptable clinical range which comes in agreement with the study done by Keating et al.³⁷ Polyvinylsiloxane impression material used in the present study to prepare conventional stone casts undergoes dimensional changes due to difference in temperature between oral cavity and room temperature. This difference was not modeled; thus, the conventional cast accuracy might have been over estimated.

The results of the current study showed that the 3D-printed casts produced from intraoral scanners had higher accuracy than the digital casts made using intraoral scanner and both exhibited greater accuracy than the digital casts made using desktop scanner and conventional casts.

Thus, prototyped casts are valid alternative to digital and stone casts with clinically acceptable accuracy in terms of diagnosis, treatment planning, and fabrication of prosthetic restorations or appliances. Although digital casts showed a positive bias in comparison to printed and conventional casts, the errors of digital casts are within acceptable clinical range as seen in a recent



study done by Hazeveld et. al³⁸, wherein he had made linear measurements on plaster and its replica models, and had found the highest measurement difference of 0.25 mm which was clinically acceptable. Similar to other study of Wiltshire et al³⁹ who also found a linear measurement difference of 0.20 mm that was clinically acceptable.

Thus, the null hypothesis that no differences would be found between the accuracy of the three dimensional-printed casts and conventional stone casts was partly supported; however, the part of the hypothesis about the accuracy of three dimensional -printed casts and digital casts was rejected because there were statistically significant differences.

Zieberman et al⁴⁰ compared the conventional stone casts and the digital casts and reported that the measurements made directly on the conventional casts with the digital caliper was more accurate and repeatable which is in inconsistent with the present study.

Redlich et al³¹ compared the conventional casts and digital casts where the ortho CAD scanner was used and linear measurements were done, it was reported that the 3mm discrepancy exist between the digital calliper and digital measurement similar to the present study.

In the present study, it was observed that the measurements obtained from all the four methods varied, either decreased or increased from the reference value, but these variations were clinically negligible and all the methods were clinically acceptable. The variations in the stone models could be due to the expansion of the gypsum material and the environmental conditions, whereas the accuracy of the intraoral scan could have been influenced by the intraoral conditions, such as limited scan space and production of saliva.

Kasparova et al²⁹ reported comparable accuracy between conventional stone casts and 3D-printed casts manufactured by SLA 3D printer of scanned conventional stone casts which is in contrast with the present study wherein the 3D printed casts were made after scanning the typodont model with the intraoral scanner. Santoro et al³⁹ compared the accuracy of the plaster models and the digital casts made using different scanner the ortho CAD and it was reported that the

accuracy of the digital casts is more then the plaster models.

The present study is in accordance with Fleming et al.³⁵, Kim et al.³⁶, Santora et al.³⁹, who compared the accuracy of conventional casts, digital casts and three-dimensional casts and reached to a similar conclusion that the accuracy of three-dimensional printed cast was more then the digital casts and conventional casts.

Limitations of the present study are that the accuracy can be variable with different types of intraoral scanner, desktop scanners and 3D printers. It is an in vitro study using a dental typodont cast. It does not simulate conditions in the oral cavity such as saliva, bleeding, limited mouth openings, and difficulty in vision. Further clinical studies with the large sample size should be conducted to provide stronger evidence and further validation of results.

CONCLUSION

Within the limitation of the study, the following conclusions drawn were:

1. The linear measurements made on the three-dimensional printed casts were significantly more accurate ($p < 0.05$) followed by digital casts and least by conventional dental stone casts. No statistical differences ($p > 0.05$) were seen for the digital casts made using intraoral scanner and digital casts made using desktop scanner.
2. The interarch measurements made on the three-dimensional printed casts were more accurate ($p < 0.05$) followed by digital casts and least by conventional dental stone casts. No statistical differences ($p > 0.05$) were seen for the digital casts made using intraoral scanner and digital casts made using desktop scanner.

Conflict of Interest: There are no conflicts of interest.

References

1. Aly P, Mohsen C. Comparison of the accuracy of three-dimensional printed casts, digital, and conventional casts: an in vitro study. *J Prosthodont* 2020;14(02):189-93.
2. Saleh WK, Ariffin E, Sherriff M, Bister D. Accuracy and reproducibility of linear measurements of resin, plaster, digital and printed study-models. *J Orthod* 2015;42(4):301-6.



3. Murugesan A, Sivakumar A. Comparison of accuracy of mesiodistal tooth measurements made in conventional study models and digital models obtained from intraoral scan and desktop scan of study models. *J Orthod* 2020;47(2):149-55.
4. Keating AP, Knox J, Bibb R, Zhurov AI. A comparison of plaster, digital and reconstructed study model accuracy. *J Orthod* 2008;35(3):191-201.
5. Brown GB, Currier GF, Kadioglu O, Kierl JP. Accuracy of 3-dimensional printed dental models reconstructed from digital intraoral impressions. *J Orthod* 2018;154(5):733-9.
6. Ellakany P, Al-Harbi F, El Tantawi M, Mohsen C. Evaluation of the accuracy of digital and 3Dprinted casts compared with conventional stone casts. *J Prosthodont* 2022;127(3):438-44.
7. Alshawaf B, Weber HP, Finkelman M, El Rafie K, Kudara Y, Papaspyridakos P. Accuracy of printed casts generated from digital implant impressions versus stone casts from conventional implant impressions: A comparative in vitro study. *J Clin Exp Dent* 2018;29(8):835-42.
8. Czajkowska M, Walejewska E, Zadrożny Ł, Wiczorek M, Świączkowski W, Wagner L, Mijiritsky E, Markowski J. Comparison of dental stone models and their 3D printed acrylic replicas for the accuracy and mechanical properties. *J Clin Exp Dent* 2016;13(18):4066.
9. Alshawaf B. Comparative in Vitro Study on the Accuracy of Stone Casts from Conventional Implant Impressions versus Printed Casts Generated from Digital Implant. *Am J Orthod Dentofacial Orthop* 2018;145(1):178-15.
10. Etemad-Shahidi Y, Qallandar OB, Evenden J, Alifui-Segbaya F, Ahmed KE. Accuracy of 3-dimensionally printed full-arch dental models: a systematic review. *J Clin Exp Dent*.2020;954(10):3357.
11. Samra AP, Pomini M, Granville F, Zavolski A, de Oliveira FB, Dias AH. Three-dimensional printed models versus conventional stone models: an accuracy analysis. *J Clin Exp Dent* 2020;19:209-34
12. Bohner L, Hanisch M, De Luca Canto G, Mukai E, Sesma N, Neto PT. Accuracy of casts fabricated by digital and conventional implant impressions. *J Prosthet Dent* 2019;45(2):94-9.
13. Hazeveld A, Slater JJ, Ren Y. Accuracy and reproducibility of dental replica models reconstructed by different rapid prototyping techniques. *Am J Orthod Dentofacial Orthop* 2014;145(1):108-15.
14. Alvi S. Comparison of the accuracy between 3D printed and milled dental models by a digital inspection software. *J Orthod* 2018;39(3):151-9.
15. Park ME, Shin SY. Three-dimensional comparative study on the accuracy and reproducibility of dental casts fabricated by 3D printers. *J Prosthet Dent* 2018;119(5):861-8
16. Camardella LT, Breuning H, de Vasconcellos Vilella O. Accuracy and reproducibility of measurements on plaster models and digital models created using an intraoral scanner. *J Orthod* 2012;39(3):151-9.
17. Alcan T, Ceylanoglu C, Baysal B. The relationship between digital model accuracy and time dependent deformation of alginate impressions. *Am J Orthod Dentofacial Orthop* 2009 ;79(1):306.
18. Abizadeh N, Moles DR, O'Neill J, Noar JH. Digital versus plaster study models: how accurate and reproducible are they? *J Orthod* 2012;39(3):151-9.
19. Zilberman O, Huggare J, Parikakis KA. Evaluation of the validity of tooth size and arch width measurements using conventional and three-dimensional virtual orthodontic models. *Am J Orthod Dentofacial Orthop* 2003;73(3):301-6.
20. White AJ, Fallis DW, Vandewalle KS. Analysis of intra-arch and interarch measurements from digital models with 2 impression materials and a modeling process based on cone-beam computed tomography. *Am J Orthod Dentofacial Orthop* 2010;137(4):345-61.



21. Cho SH, Schaefer O, Thompson GA, Guentsch A. Comparison of accuracy and reproducibility of casts made by digital and conventional methods. *J Prosthet Dent* 2015;113(4):310-5.
22. Naidu D, Freer T, Validity, reliability, and reproducibility of the IOC intraoral scanner: a comparison of tooth widths and Bolton ratios. *Am J Orthod Dentofacial Orthop* 2013;144(2):304-4
23. Keating AP, Knox J, Bibb R, Zhurov AI. A comparison of plaster, digital and reconstructed study model accuracy. *J Orthod* 2008;35(3):191-201
24. Sousa MVS, Vasconcelos EC, Janson G, Garib D, Pinzan A. Accuracy and reproducibility of 3-dimensional digital model measurements. *Am J Orthod Dentofacial Orthop* 2012;142(2):269-273
25. Saleh WK, Ariffin E, Sherriff M, Bister D. Accuracy and reproducibility of linear measurements of resin, plaster, digital and printed study-models. *J Orthod* 2015;42(4):301-306
26. Hazeveld A, Huddleston Slater JJR, Ren Y. Accuracy and reproducibility of dental replica models reconstructed by different rapid prototyping techniques. *Am J Orthod Dentofacial Orthop* 2014;145(1):108-115
27. Bell A, Ayoub AF and Siebert P. Assessment of the accuracy of a three-dimensional imaging system for archiving dental study models. *J Orthod* 2003; 30(5): 219-223.
28. Keating AP, Knox J, Bibb R and Zhurov AI. A comparison of plaster, digital and reconstructed study model accuracy. *J Orthod* 2008; 35(4): 191-201.
29. Santoro M, Galkin S, Teredesai M, Nicolay OF and Cangialosi TJ. Comparison of measurements made on digital and plaster models. *Am J Orthod Dentofacial Orthop*. 2003; 124: 101–105.
30. Hazeveld A, Huddleston Slater JJ and Ren Y. Accuracy and reproducibility of dental replicamodels reconstructed by different rapid prototyping techniques. *Am J Orthod Dentofacial Orthop* 2014; 145: 108–115.