Dental Research Journal

Original Article

# Comparison of dimensional accuracy of digital models by intraoral scanning method in comparison with molding with alginate

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## ABSTRACT

**Background:** Intraoral scanners (IOS) have been developed to address the drawbacks of traditional impression systems, such as improving patient comfort and expediting the restoration process. The objective of this study was to compare the dimensional accuracy of IOSs with traditional impression systems.

**Materials and Methods:** In this experimental study, a maxillary reference model was utilized for the study. The mesiodistal, occlusogingival, and buccolingual distances between points were measured on the model using a digital caliper and recorded as the control group. The reference model was then scanned once using an IOS device (CEREC AC) to generate a digital model. Reference points were measured and recorded using EXOCAD V.2019 software. Sixteen alginate impressions were cast in separate trays from the reference model, and dental stone IV was poured into them. Reference points were also measured on the casts using a caliper. Finally, the measurements of IOS models, alginate templates, and reference models were compared in terms of size and dimensional differences. Data analysis was performed using the analysis of variance with independent *t*-tests, with a significance level of <0.05. The study utilized a maxillary reference model.

**Results:** The mean differences in mesiodistal dimensions of only the right second premolars ($P = 0.017$), buccolingual dimensions of central incisors ($P = 0.037$), lateral incisors ($P = 0.050$), and right first molar ($P = 0.028$) showed significant differences between IOS and alginate methods compared to the reference model. The dimensions reported in the IOS method were higher (0.71–1.26 mm) than those in the alginate method compared to the reference model.

**Conclusion:** Based on the results of this study and acknowledging its limitations, it can be concluded that the IOS method yielded a greater number of measurements than the reference model when evaluated on a limited number of teeth within the complete maxillary arch. However, the measurements obtained using the alginate method were more closely aligned with those of the reference model. The minimal differences observed between digital impressions and traditional measurement techniques, the IOS method may be regarded as a viable alternative to conventional methods, owing to its numerous advantages.

**Key Words:** Alginate impressions, dental stone, dimensional accuracy, intraoral scanners, measurement techniques, patient comfort

**Received:** 13-Jun-2024
**Revised:** 27-Dec-2024
**Accepted:** 25-Jan-2025
**Published:** 22-May-2025

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**DOI:** 10.4103/drj.drj_255_24



**How to cite this article:** Kazemian M, Kheirati M. Comparison of dimensional accuracy of digital models by intraoral scanning method in comparison with molding with alginate. Dent Res J 2025;22:18.

## INTRODUCTION

The traditional molding technique employed in dentistry presents several challenges, including the difficulty of selecting the appropriate tray size, ensuring adequate isolation, and accurately positioning the molding material around the teeth and adjacent tissues.[1-3] Furthermore, the removal of the mold from the oral cavity can lead to complications such as cracks, bubbles, tears, and inaccurately registered edges around the prepared teeth.[1-4] To address these issues, irreversible hydrocolloids such as alginate are commonly used in traditional molding. While alginate is easy to use and records desirable details, it can shrink and change shape due to water loss if the plaster is not poured within 10 min. Intraoral scanners (IOSs) represent a new generation of molding technique that was developed in the early 1980s to solve the problems associated with traditional molding.[5-7] Various types of IOS are available that can scan dental restorations, surgical guides, and other items with high accuracy. Some of these systems can produce 3D images and allow for the direct fabrication of the desired restoration. This process is known as computer-aided design/computer-aided manufacturing (CAD/CAM) and involves the use of a system to prepare the cut tooth.[6,7]

IOS technology eliminates the need for traditional trays to store molding materials. Instead, optical or light images are taken from within the mouth and sent directly to a computer for viewing or saving, resulting in improved template quality, especially in the cut line areas and chipped teeth.[7-9] The clinician can repeat the template until the desired outcome is achieved, increasing productivity and patient comfort. IOS files can be stored in small spaces, and various software have been developed to use the information and models obtained from IOS. However, IOS technology has drawbacks, such as expensive equipment and relatively long scanning times, which may affect treatment outcomes.[8-12] Therefore, the accuracy of the images produced by IOS is essential to achieve favorable treatment results. Several studies have investigated the accuracy of digital scanning techniques in dental implant and restoration processes. However, the accuracy of these scanners varies depending on the device type and application.[13-21] The presence of reference points is crucial for evaluating the accuracy of digital models produced by IOS. Most studies evaluating the accuracy of digital models use calipers, which increases the risk of carelessness in the evaluation.[13-16] Therefore, the aim of this study is to compare the dimensional accuracy of models produced by the IOS method to traditional molding systems to obtain favorable and quality treatment results. In traditional dentistry, molding techniques were used for registering the three-dimensional structure of dental tissues. However, the volume changes of the material and dental casts could lead to errors in the final result, requiring flawless efforts of dental laboratories.[17-22] To overcome these problems, the use of IOS systems for digital molding began to spread. With the help of CAD/CAM devices, treatment planning has become easier, leading to reduced operating time, storage requirements, and treatment duration. The IOS system consists of a handheld camera, computer, and software, with the standard application being the STL format. This digital format is widely used in many industrial sectors apart from dentistry.[23-37] Many studies have been conducted to investigate the accuracy of digital molding techniques.[38-43] Mennito *et al*.[44] compared the accuracy of seven digital molding systems with conventional techniques, using chiseled and intact teeth as well as palatal tissue of the human maxilla. They found that all digital molding techniques, except Planscan, were able to reproduce the shape of bones and teeth accurately. Ender *et al*.[45] compared the accuracy of complete and partial jaw arch molds obtained through IOS systems with traditional molding techniques. They found that the digital molding method is a suitable alternative for the molding of the maxillary part, but complete jaw molding remains a challenge for IOS systems. The performance of some devices can be efficient in this field. Two studies have compared the accuracy of digital and traditional molding systems. Keul and Güth[46] compared the accuracy of digital and traditional molding systems in arch registration. They found that the iTero-scan and M-SCAN methods showed similar or better results in terms of accuracy compared to other methods. Tomita *et al*.[15] in Japan investigated the accuracy of digital production models obtained through IOS techniques and traditional formats. They found no statistically significant difference between the accuracy of the IOS technique and traditional molding techniques using alginate and PVS. It was also concluded that using IOS directly is more accurate than scanning plaster models obtained from alginate or PVS. The purpose of this study is to compare the dimensional accuracy of digital models obtained through intraoral scanning with traditional molding systems.[36-43] To achieve this, the mesiodistal, buccolingual, and occlusogingival dimensions of the central teeth up to the maxillary right first molar will be measured on the reference cast, as well as using the IOS method and molding with alginate.

## MATERIALS AND METHODS

The present study used 16 plaster casts of a patient's dental system as a dimensionally stable reference. The study is an experimental and laboratory study and the data collection technique used was laboratory observation with a two-sided test method. The sample size was 16 items in each experimental group. The study compared digital models obtained through the IOS method and traditional molding systems. Research questions will focus on the accuracy and level of agreement between the different methods, as well as the advantages and disadvantages of the IOS method compared to traditional molding systems. The study aims to provide valuable insights into the use of digital models in dentistry.

$$n = \frac{2\sigma^2 \left( Z_{1-\alpha/2} + Z_{1-\beta} \right)^2}{\delta^2}$$

Two methods were used to make the models: one involved scanning a one-time reference cast using CEREC AC® Connect, and the other involved obtaining 16 alginate molds from the reference cast using traditional molding methods. The measurements were taken using a digital caliper and reference points were measured and recorded by a laboratory technician. The measurement reference points in the study included the most central points in dimensional distances mesiodistal, buccolingual, and occlusogingival in the central teeth to the first molar on the right side of the upper jaw. The present study did not involve any human subjects, and the raw data were obtained from the artificial models. Therefore, there were no ethical considerations for this study. The relevant code of ethics was obtained from the ethics committee of the Islamic Azad University, Khorasgan Branch. The data analysis was performed using descriptive indicators such as minimum, maximum, average, standard deviation, and statistical charts at the descriptive level, and analysis of variance with repeated measures and independent *t*-test at the inferential level. The statistical analysis was conducted at a 5% error level using SPSS software version 24, and GraphPad Prism 8 (7825 Fay Ave, Ste 230, La Jolla, CA 92037, US) was used to draw graphs from the software. The current investigation is conducted in a laboratory setting, relying exclusively on artificial models for data collection, thereby eliminating the ethical concerns associated with the study. Nevertheless, the necessary ethical approval has been granted by the Ethics Committee of Islamic Azad University, Khorasgan Branch. Ethics Code: IR.IAU.KHUISF.REC.1399.006.

## RESULTS

The results of the study are organized into two sections: descriptive and inferential analysis.[47-49] The results indicate the distribution of values and average dimensions of the mesiodistal, buccolingual, and occlusogingival measurements of the central right and left first molars of the maxilla, as assessed using both the intraoral scanning (IOS) method and the alginate molding technique.[49-53] The comparison of the average dimensions between the three methods was done using the repeated-measures analysis of variance. A significant difference was observed in the average sizes of U.L.C.I. and U.R.F.M. teeth based on the results of this test. The results of the *post hoc* Bonferroni test indicated that the average size of the U.R.F.M. tooth obtained using the IOS method was significantly greater than that of the reference cast; however, no significant difference was found between the reference cast and the alginate molding method. Moreover, the average sizes recorded for both the IOS methods and the alginate molding method did not demonstrate any significant differences. In the case of the U.L.C.I. tooth, the Bonferroni *post hoc* test results revealed that the average size in the IOS method was significantly larger than that of the reference cast, while no significant difference was noted between the reference cast and the alginate molding method. In addition, the average sizes for the two IOS methods and the alginate molding method showed no significant differences.[54-56] Figure 1 shows the digital inter-point measurement of lingual baculo teeth UL FM. The lingual baculo teeth are located in the upper left side of the maxillary arch, specifically the first molar (UL6) and the second molar (UL7). The inter-point measurement refers to the distance between two specific points on the teeth, which in this case are being measured digitally using an IOS.

Figure 2 shows the measurement between the mesiodistal digital points of the tooth ULCI. ULCI stands for upper left central incisor, which is one of the front teeth in the maxillary arch. Mesiodistal refers to the distance between the mesial (toward the midline) and distal (away from the midline) surfaces of the tooth.

Figure 3 shows the measurement between the mesiodistal digital points of the tooth URFPM. URFPM stands for upper right first premolar, which is located in the upper right side of the maxillary arch, between the canine and the second premolar.

Mesiodistal refers to the distance between the mesial (toward the midline) and distal (away from the midline) surfaces of the tooth. Figure 4 shows the digital occluso-gingival inter-point measurement of teeth ULC.

ULC stands for upper left central incisor, which is one of the front teeth in the maxillary arch. Occluso-gingival refers to the distance between the biting surface of the tooth (occlusal surface) and the gum line (gingival margin). Figure 5 shows the cast casts of alginate molds.

The alginate molds were created using traditional impression techniques, which involve taking a physical impression of the patient's teeth using a soft, putty-like material called alginate. The alginate is placed in a tray and inserted into the patient's mouth, where it is allowed to set and harden. Once the alginate has set, it is removed from the mouth and used to create a cast of the patient's teeth. Figure 6 shows the measurement between the buccolingual points of the ULCI tooth in cast plaster of an alginate mold.

ULCI stands for upper left central incisor, which is one of the front teeth in the maxillary arch. Buccolingual refers to the distance between the buccal (outer) and lingual (inner) surfaces of the tooth. Figure 7 shows the distribution of values and average mesiodistal dimensions of the central teeth to the maxillary right first molar on the reference cast.

The maxillary right first molar is located in the upper right side of the maxillary arch, and the central teeth refer to the central incisors. The mesiodistal dimension refers to the distance between the mesial (toward the midline) and distal (away from the midline) surfaces of the teeth. In this study, the mesiodistal dimensions of the central teeth to the maxillary right first molar on the reference cast were measured using a digital caliper. Figure 8 shows the distribution of values and

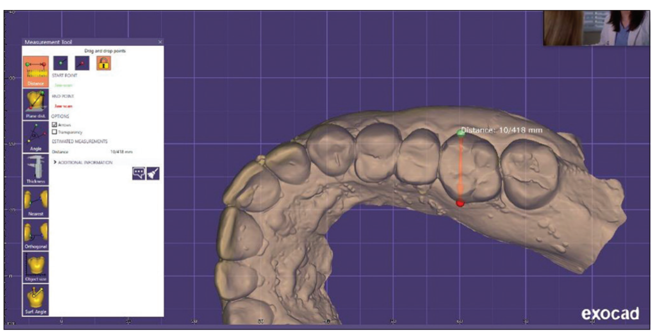


**Figure 1:** Digital inter-point measurement of lingual baculo teeth UL FM.


**Figure 3:** Measuring between the mesiodistal digital points of the tooth URFPM.

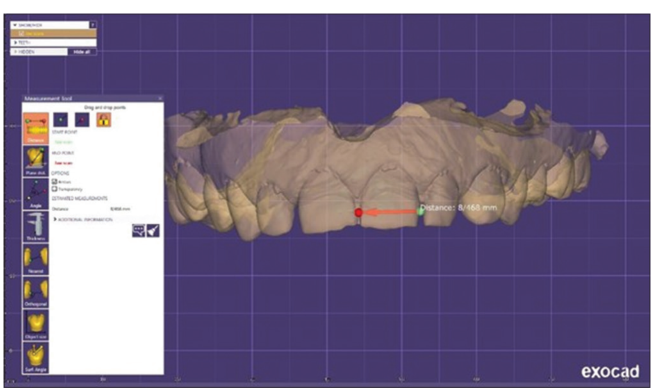


**Figure 2:** Measurement between the mesiodistal digital points of the tooth ULCI.

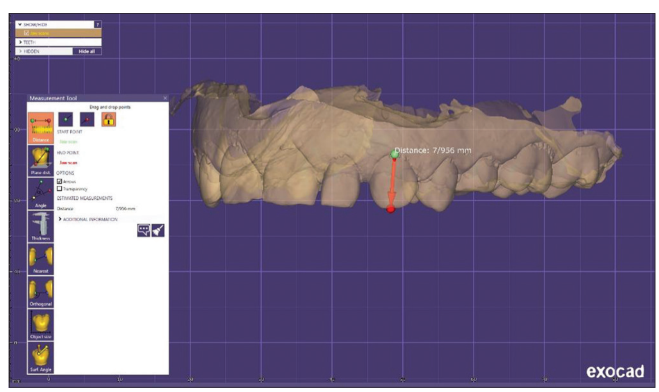


**Figure 4:** Digital occluso-gingival inter-point measurement of teeth ULC.

average buccolingual dimensions of the central teeth to the maxillary right first molar on the reference cast.

The maxillary right first molar is located in the upper right side of the maxillary arch, and the central teeth refer to the central incisors. The buccolingual dimension refers to the distance between the buccal (outer) and lingual (inner) surfaces of the teeth. In this study, the buccolingual dimensions of the central teeth to the maxillary right first molar on the reference cast were measured using a digital caliper. Figure 9 shows the distribution of values and average occlusogingival dimensions of the central teeth to the maxillary right first molar on the reference cast.

The maxillary right first molar is located in the upper right side of the maxillary arch, and the central teeth refer to the central incisors. Figure 10 shows the distribution of values and average mesiodistal dimensions of the central teeth to the first molar on the right side of the maxilla by the IOS method.

The first molar on the right side of the maxilla refers to the upper right first molar, which is located in the upper right side of the maxillary arch, and the central teeth refer to the central incisors. Figure 11 shows the distribution of values and average buccolingual dimensions of the central teeth to the first molar on the right side of the maxilla by the IOS method. The first molar on the right side of the maxilla refers to the upper right first molar, which is located in the upper right side of the maxillary arch, and the central teeth refer to the central incisors.

The buccolingual dimension refers to the distance between the buccal (outer) and lingual (inner) surfaces of the teeth. In this study, the buccolingual dimensions of the central teeth to the upper right first molar on the right side of the maxilla were measured using an IOS. Figure 12 shows the distribution of values and average occlusogingival dimensions of the

**Figure 5:** Cast casts of alginate molds.


**Figure 6:** Measurement between the buccolingual points of the ULCI tooth in the cast plaster of alginate mold.

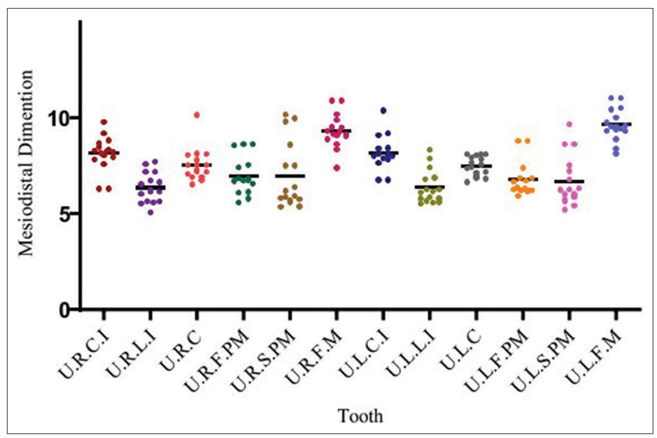


**Figure 7:** Distribution of values and average mesiodistal dimensions of the central teeth to the maxillary right first molar on the reference cast.

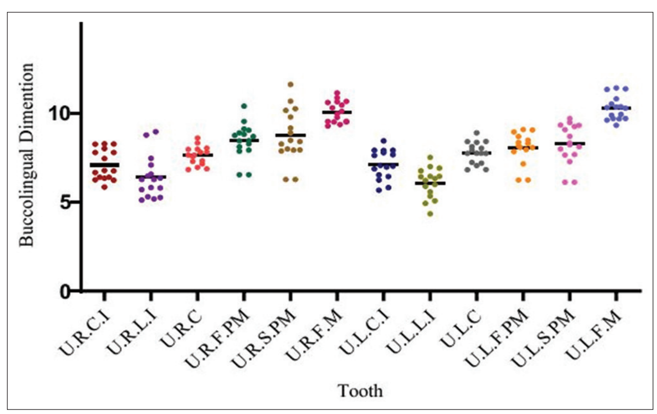


**Figure 8:** Distribution of values and average buccolingual dimensions of central teeth to maxillary right first molar on the reference cast.

central teeth to the first molar on the right side of the maxilla by the IOS method.

The occlusogingival dimension refers to the distance between the biting surface of the tooth (occlusal surface) and the gum line (gingival margin). In this study, the occlusogingival dimensions of the central teeth to the upper right first molar on the right side of the maxilla were measured using an IOS. Both Figures 11 and 12 demonstrate the range of dimensions for each tooth and the average dimension indicated by the red line. The central incisors (CI) have the smallest dimensions, followed by the lateral incisors (LI) and the canines (C), with the upper right first molar (UR6) having the largest dimensions.

## DISCUSSION

The use of IOSs for digital measurement provides a reliable and efficient method for obtaining the accurate measurements of dental structures, which can improve the precision and efficiency of dental treatments. Figure 13 shows the distribution of values and average mesiodistal dimensions of the central teeth to the maxillary right first molar by molding with alginate.

The maxillary right first molar is located in the upper right side of the maxillary arch, and the central teeth refer to the central incisors. The mesiodistal dimension refers to the distance between the mesial (toward the midline) and distal (away from the midline) surfaces of the teeth. The results of the study showed that, in general, there were statistically significant differences in the sizes of the central teeth to the first molars between the IOS and alginate methods compared to the reference cast. However, the differences were small, ranging from 0.71 to 1.26 mm, and only a few teeth showed significant differences in the mesiodistal and buccolingual dimensions. The alginate method provided slightly more accurate templates in this study. Other studies have also compared the accuracy

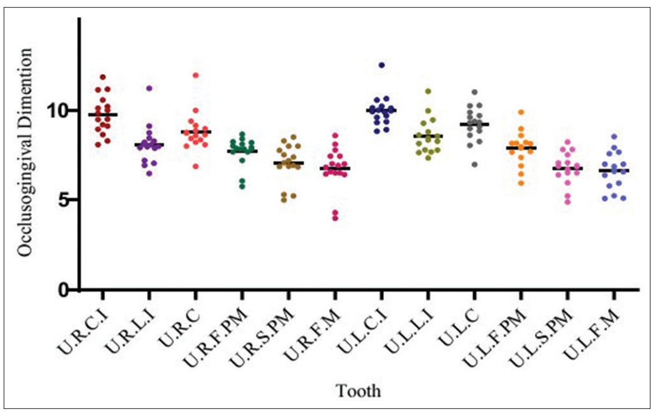


**Figure 9:** Distribution of values and average occlusogingival dimensions of the central teeth to the maxillary right first molar on the reference cast.

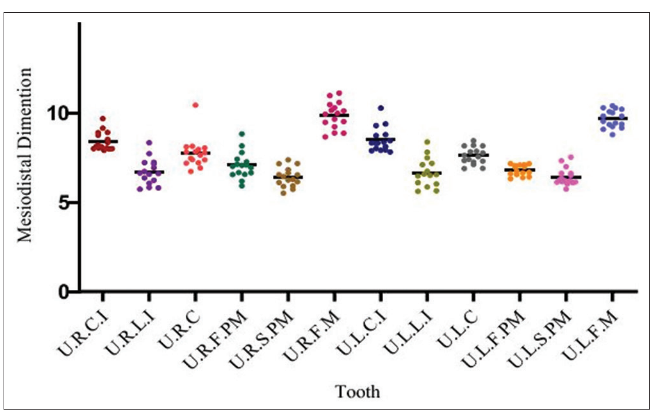


**Figure 10:** Distribution of values and average mesiodistal dimensions of the central teeth to the first molar on the right side of the maxilla by method intraoral scanner.

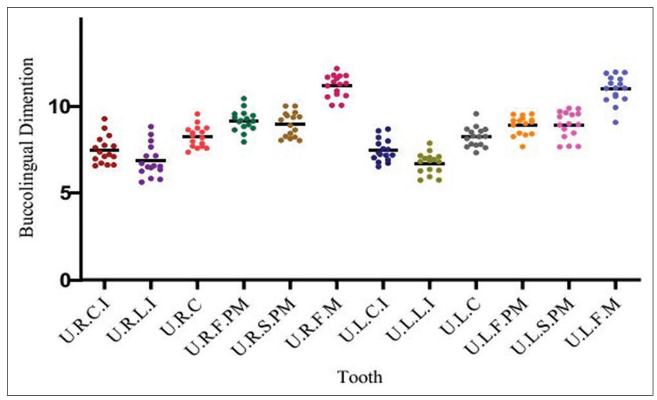


**Figure 11:** Distribution of values and average buccolingual dimensions of the central teeth to the first molar on the right side of the maxilla by method intraoral scanner.

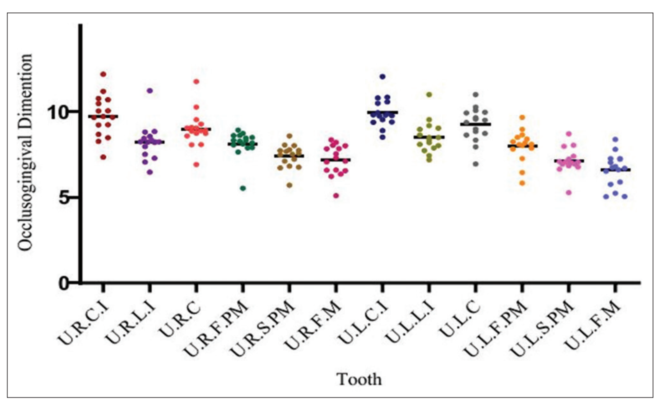


**Figure 12:** Distribution of values and average occlusogingival dimensions of the central teeth to the first molar on the right side of the maxilla by method intraoral scanner.

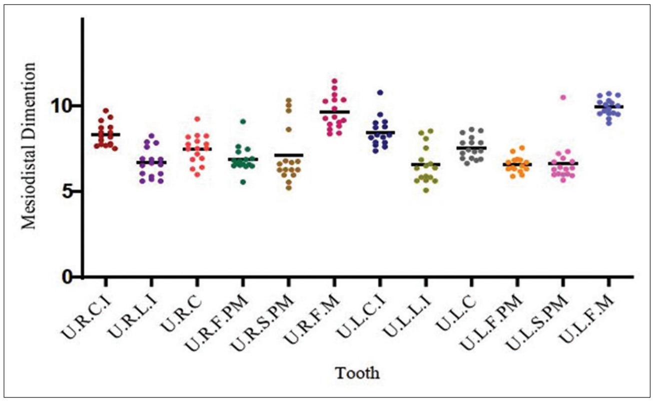


**Figure 13:** Distribution of the values and average mesiodistal dimensions of the central teeth to the maxillary right first molar by molding with alginate.

of IOS and traditional molding techniques and found that IOS can be a viable alternative to traditional molding, particularly when reconstructing up to 10 dental units. The digital molding techniques offer advantages over traditional methods, including increased patient comfort, the ability to repeat the format as needed, and the possibility of implementing different treatment plans in the virtual form. Ender *et al*.,[45] it was found that IOS systems have limitations in accurately capturing the complete dental arch, but they can be a suitable alternative to traditional methods for partial arches. Imburgia *et al*.[50] also concluded in a similar study that IOS performs better in partial arch models with implant analogs. A review of studies conducted over a 10-year period found that IOS systems generally perform poorly in long-span restorations and in recording the depth of the edges of the prepared lathe.[57-60] However, IOS is accurate in recording the details for short-length prosthetic restorations for natural teeth and implants and can be used in designing smiles, mobile prostheses, and obturators. In the current study, the IOS system showed greater differences compared to the reference cast in three teeth in the buccolingual dimensions and one tooth in the mesiodistal dimensions out of the 12 teeth examined. However, it should be noted that user error in measuring between points, calibration, and brand type of the scanner can also affect the accuracy of the measurements.

The present laboratory examination only evaluated arches with teeth in the upper jaw outside the oral cavity, and up to six teeth from the midline will be comparable. Evaluation in other conditions, such as edentulous arches, may have different outcomes due to having more levels of tissues not connected to teeth. In addition, the effects of the oral cavity's environmental conditions were not evaluated in the present investigation.[61-65] When choosing between digital and traditional molding methods, factors such as patient comfort, duration and cost of the molding process should be considered. While obtaining an alginate mold takes less time than the IOS technique, the laboratory work for plastering and casting may take a similar amount of time. However, in any case, the amount of time spent on the patient in the digital technique will be less.[66-70] Recent research emphasizes significant developments in materials science, concentrating on novel approaches to improve the properties of scaffolds for biomedical applications.

## CONCLUSION

In the present study, we compared the dimensional accuracy of digital and traditional molding methods using the CEREC AC system and alginate material, respectively, in the context of a complete arch of the upper jaw. The results indicate that there were statistically significant differences in the sizes of a small number of teeth between the IOS and alginate methods compared to the reference cast, with the alginate method providing slightly more accurate results. However, the IOS method is generally considered reliable for most measurements. One limitation of this study is the lack of access to different brands of IOS devices, which could have affected the quality of the study output. It is recommended to conduct more studies in clinical conditions, including investigating the presence of saliva and the limitations of the oral cavity, the use of different brands of IOS systems, and the comparison of partial and complete dental arches of the jaws to better understand the factors affecting the accuracy of the molds' output.

### Acknowledgment
The authors would like to acknowledge the support and resources provided by the Department of Operative Dentistry, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran. Their assistance and facilities have greatly contributed to the successful completion of this research.

### Financial support and sponsorship
Nil.

### Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

## REFERENCES


1. Gabor AG, Zaharia C, Stan AT, Gavrilovici AM, Negruțiu ML, Sinescu C. Digital dentistry – Digital impression and CAD/CAM system applications. J Interdiscip Med 2017;2:54-7.
2. Donovan TE, Chee WW. A review of contemporary impression materials and techniques. Dent Clin North Am 2004;48:vi-vii, 445-70.
3. Punj A, Bompolaki D, Garaicoa J. Dental impression materials and techniques. Dent Clin North Am 2017;61:779-96.
4. Rajaei A, Kazemian M, Khandan A. Investigation of mechanical stability of lithium disilicate ceramic reinforced with titanium nanoparticles. Nanomed Res J 2022;7:350-9.
5. Samimi P, Kazemian M, Shirban F, Alaei S, Khoroushi M. Bond strength of composite resin to white mineral trioxide aggregate: Effect of different surface treatments. J Conserv Dent 2018;21:350-3.
6. Raji Z, Hosseini M, Kazemian M. Micro-shear bond strength of composite to deep dentin by using mild and ultra-mild universal adhesives. Dent Res J 2022;19:44.
7. Hosseini M, Raji Z, Kazemian M. Microshear bond strength of composite to superficial dentin by use of universal adhesives with different pH values in self-etch and etch and rinse modes. Dent Res J (Isfahan) 2023;20:5.
8. Zadeh Dadashi M, Kazemian M, Malekipour Esfahani M. Color match of porcelain veneer light-cure resin cements with their respective try-in pastes: Chemical stability. Nanochemistry Res 2023;8:205-14.
9. Hosseini Fadabobeh SP, Kazemian M, Malekipour Esfahani MR. Investigating on Surface roughness of nanohybrid and micro-hybrid composite resins following the use of a simplified polishing system. J Simul Anal Nov Technol Mech Eng 2023;15:61-71.
10. Bahrami S, Azarbayejani S, Kazemian M. Comparative evaluation of shear bond strength and debonding properties of GC ortho connect composite and transbond XT composite. Australas Orthod J 2023;39:35-41.
11. Moghadas BK, Ghanbari N, Nasri P. Advancements in nanoparticle biosensors: Applications, properties, and considerations for improving performance and detection capabilities. Sci Hypotheses 2024;1:53-71.
12. Chochlidakis KM, Papaspyridakos P, Geminiani A, Chen CJ, Feng IJ, Ercoli C. Digital versus conventional impressions for fixed prosthodontics: A systematic review and meta-analysis. J Prosthet Dent 2016;116:184-90.e12.
13. Nedelcu R, Olsson P, Nyström I, Rydén J, Thor A. Accuracy and precision of 3 intraoral scanners and accuracy of conventional impressions: A novel *in vivo* analysis method. J Dent 2018;69:110-8.
14. Fleming PS, Marinho V, Johal A. Orthodontic measurements on digital study models compared with plaster models: A systematic review. Orthod Craniofac Res 2011;14:1-16.
15. Tomita Y, Uechi J, Konno M, Sasamoto S, Iijima M, Mizoguchi I. Accuracy of digital models generated by conventional impression/plaster-model methods and intraoral scanning. Dent Mater J 2018;37:628-33.
16. Ward G. Impression materials and impression taking: An historical survey. Br Dent J 1961;110:118-9.
17. Rubel BS. Impression materials: A comparative review of impression materials most commonly used in restorative dentistry. Dent Clin North Am 2007;51:629-42, vi.
18. Hamalian TA, Nasr E, Chidiac JJ. Impression materials in fixed prosthodontics: Influence of choice on clinical procedure. J Prosthodont 2011;20:153-60.
19. Combe E, Burke FT, Douglas WH. Dental Biomaterials. New York, NY: Springer; 1999.
20. Phillips RW. Physical properties and manipulation of reversible and irreversible hydrocolloid. J Am Dent Assoc 1955;51:566-72.
21. Amalan A, Ginjupalli K, Upadhya N. Evaluation of properties of irreversible hydrocolloid impression materials mixed with disinfectant liquids. Dent Res J (Isfahan) 2013;10:65-73.
22. Lepe X, Johnson GH, Berg JC. Surface characteristics of polyether and addition silicone impression materials after long-term disinfection. J Prosthet Dent 1995;74:181-6.
23. Nayyar A, Tomlins CD, Fairhurst CW, Okabe T. Comparison of some properties of polyether and polysulfide materials. J Prosthet Dent 1979;42:163-7.
24. Rathee S, Eswaran B, Eswaran M, Prabhu R, Geetha K, Krishna G, *et al*. A comparison of dimensional accuracy of addition silicone of different consistencies with two different spacer designs – *In-vitro* study. J Clin Diagn Res 2014;8:C38-41.
25. Parviz A, Rahpeyma A, Hejazi M. Comparative analysis of dimensional accuracy of two types of silicone impression materials: Optosil and Elite-HD. J Dent Mater Tech 2017;6:1-6.
26. Pandey, P., Mantri, S., Bhasin, A., and Deogade, S. C. (2019). Mechanical properties of a new vinyl polyether silicone in comparison to vinyl polysiloxane and polyether elastomeric impression materials. Contemporary clinical dentistry, 10(2), 203-207.
27. Stanford JW, Paffenbarger GC, Sweeney WT. A revision of American dental association specification no. 3 for dental impression compound. J Am Dent Assoc 1955;51:56-64.
28. Chandak AH, Deshmukh SP, Radke UM, Banerjee RS, Mowade TK, Rathi A. An *in vitro* study to evaluate and compare the flow property of different commercially available zinc oxide eugenol impression materials. Contemp Clin Dent 2018;9:S137-41.
29. Firtell DN, Koumjian JH. Mandibular complete denture impressions with fluid wax or polysulfide rubber: A comparative study. J Prosthet Dent 1992;67:801-4.
30. Chen LC, Xu ZQ. Innovative 3D dental measurement for tooth model restoration. Key Engineering Materials; Switzerland: 2005;295:145-50. Available from: https://www.scientific.net/KEM.295-296.145. [Last accessed on 2005 Oct 15].
31. Hong-Seok P, Chintal S. Development of high speed and high accuracy 3D dental intra oral scanner. Procedia Eng 2015;100:1174-81.
32. Alikhasi M, Alsharbaty MH, Moharrami M. Digital implant impression technique accuracy: A systematic review. Implant Dent 2017;26:929-35.
33. Duret F. Toward a new symbolism in the fabrication of prosthetic design. Cah Prothese 1985;13:65-71.
34. Baheti M, Soni U, Gharat N, Mahagaonkar P, Khokhani R, Dash S. Intra-oral scanners: A new eye in dentistry. Austin J Orthop Rheumatol 2015;2:1023.

35. Zimmermann M, Mehl A, Mörmann WH, Reich S. Intraoral scanning systems – A current overview. Int J Comput Dent 2015;18:101-29.
36. Alghazzawi TF. Advancements in CAD/CAM technology: Options for practical implementation. J Prosthodont Res 2016;60:72-84.
37. Logozzo S, Zanetti EM, Franceschini G, Kilpelä A, Mäkynen A. Recent advances in dental optics–Part I: 3D intraoral scanners for restorative dentistry. Opt Lasers Eng 2014;54:203-21.
38. Laborie, M., Naveau, A., and Menard, A. (2024). CAD-CAM resin-ceramic material wear: A systematic review. *The Journal of Prosthetic Dentistry*, *131*(5), 812-818.
39. Skramstad MJ. Welcome to cerec primescan AC. Int J Comput Dent 2019;22:69-78.
40. Chiu A, Chen YW, Hayashi J, Sadr A. Accuracy of CAD/CAM digital impressions with different intraoral scanner parameters. Sensors (Basel) 2020;20:1157.
41. Runkel C, Güth JF, Erdelt K, Keul C. Digital impressions in dentistry-accuracy of impression digitalisation by desktop scanners. Clin Oral Investig 2020;24:1249-57.
42. Michelinakis, G., Apostolakis, D., Tsagarakis, A., Kourakis, G., and Pavlakis, E. (2020). A comparison of accuracy of 3 intraoral scanners: A single-blinded *in vitro* study. *The Journal of prosthetic dentistry*, *124*(5), 581-588.
43. Mangano FG, Admakin O, Bonacina M, Lerner H, Rutkunas V, Mangano C. Trueness of 12 intraoral scanners in the full-arch implant impression: A comparative *in vitro* study. BMC Oral Health 2020;20:263.
44. Mennito AS, Evans ZP, Nash J, Bocklet C, Lauer Kelly A, Bacro T, *et al.* Evaluation of the trueness and precision of complete arch digital impressions on a human maxilla using seven different intraoral digital impression systems and a laboratory scanner. J Esthet Restor Dent 2019;31:369-77.
45. Ender A, Zimmermann M, Mehl A. Accuracy of complete- and partial-arch impressions of actual intraoral scanning systems *in vitro*. Int J Comput Dent 2019;22:11-9.
46. Keul C, Güth JF. Accuracy of full-arch digital impressions: An *in vitro* and *in vivo* comparison. Clin Oral Investig 2020;24:735-45.
47. Medina-Sotomayor P, Pascual-Moscardó A, Camps I. Accuracy of four digital scanners according to scanning strategy in complete-arch impressions. PLoS One 2018;13:e0202916.
48. Ribeiro P, Herrero-Climent M, Díaz-Castro C, Ríos-Santos JV, Padrós R, Mur JG, *et al.* Accuracy of implant casts generated with conventional and digital impressions – An *in vitro* study. Int J Environ Res Public Health 2018;15:1599.
49. Malik J, Rodriguez J, Weisbloom M, Petridis H. Comparison of accuracy between a conventional and two digital intraoral impression techniques. Int J Prosthodont 2018;31:107-13.
50. Imburgia M, Logozzo S, Hauschild U, Veronesi G, Mangano C, Mangano FG. Accuracy of four intraoral scanners in oral implantology: A comparative *in vitro* study. BMC Oral Health 2017;17:92.
51. Ender A, Mehl A. *In-vitro* evaluation of the accuracy of conventional and digital methods of obtaining full-arch dental impressions. Quintessence Int 2015;46:9-17.
52. Lee SJ, Betensky RA, Gianneschi GE, Gallucci GO. Accuracy of digital versus conventional implant impressions. Clin Oral Implants Res 2015;26:715-9.
53. Chow SC, Shao J, Wang H, Lokhnygina Y. Sample Size Calculations in Clinical Research. Taylorfrancis: CRC Press; 2017.
54. Mangano F, Gandolfi A, Luongo G, Logozzo S. Intraoral scanners in dentistry: A review of the current literature. BMC Oral Health 2017;17:149.
55. Flügge TV, Schlager S, Nelson K, Nahles S, Metzger MC. Precision of intraoral digital dental impressions with iTero and extraoral digitization with the iTero and a model scanner. Am J Orthod Dentofacial Orthop 2013;144:471-8.
56. Aragón ML, Pontes LF, Bichara LM, Flores-Mir C, Normando D. Validity and reliability of intraoral scanners compared to conventional gypsum models measurements: A systematic review. Eur J Orthod 2016;38:429-34.
57. Morovvati MR, Angili SN, Saber-Samandari S, Nejad MG, Toghraie D, Khandan A. Global criterion optimization method for improving the porosity of porous scaffolds containing magnetic nanoparticles: Fabrication and finite element analysis. Mater Sci Eng B 2023;292:116414.
58. Foroutan S, Hashemian M, Khosravi M, Nejad MG, Asefnejad A, Saber-Samandari S, *et al.* A porous sodium alginate-CaSiO 3 polymer reinforced with graphene nanosheet: Fabrication and optimality analysis. Fibers Polym 2021;22:540-9.
59. Salmani MM, Hashemian M, Yekta HJ, Nejad MG, Saber-Samandari S, Khandan A. Synergic effects of magnetic nanoparticles on hyperthermia-based therapy and controlled drug delivery for bone substitute application. J Supercond Nov Magn 2020;33:2809-20.
60. Khandan A, Khosravi M, Roustazadeh D, Aghadavoudi F. Impact of alumina and carbon nanotubes on mechanical properties of a composite: Molecular dynamic (MD) simulation. Iran J Chemist Chem Eng 2024;43:2866-7.
61. Attaeyan A, Shahgholi M, Khandan A. Fabrication and characterization of novel 3D porous Titanium-6Al-4V scaffold for orthopedic application using selective laser melting technique. Iran J Chem Chem Eng Res Artic 2024;43:66-82.
62. Khademi A, Khandan A, Iranmanesh P, Heydari M. Development of a 3D bioprinted alginate-gelatin hydrogel scaffold loaded with calcium phosphates for dental pulp tissue regeneration. Iran J Chem Chem Eng (IJCCE) 2025;44:1-16.
63. Boulaiche K, Boudeghdeg K, Abdelmalek R, Alioui H, Mammeri O. Reuse of sanitary ceramic waste in the production of vitreous china bodies. Iran J Chem Chem Eng Res Artic 2023;42:1889-99.
64. Agbo SC, Ekpunobi EU, Onu CC, Oriaku EC. Mineralogical and physicochemical characterization of Enugu iva-pottery silica-rich deposit for ceramics applications. Iran J Chem Chem Eng Res Artic 2023;42:100-10.
65. Roy J, Maitra S. Non-isothermal dehydration kinetics of diphasic mullite precursor gel. Iran J Chem Chem Eng 2019;8:91-100.
66. Boulaiche K, Boudeghdegh K, Roula A, Alioui H. Potential use of Algerian metallurgical slag in the manufacture of sanitary ceramic bodies and its effect on the physical-mechanical and structural properties. Iran J Chem Chem Eng Res Artic 2023;42:461-71.

67. Babaei M, Rezaei S, Saghafi Khadem S, Shirinbak I, Basir Shabestari S. The role of salivary C-reactive protein in systemic and oral disorders: A systematic review. Med J Islam Repub Iran 2022;36:138.
68. Nazemi Salman B, Basir Shabestari S, Shaboyi Jam M, Alizadeh Tari S, Shirinbak I. Periodontal parameters and oral hygiene in diabetic and nondiabetic adolescents in Zanjan. Med J Islam Repub Iran 2020;34:12.
69. Almasi S, Karbalaei Sabbagh M, Barzi D, Tahooni A, Atyabi H, Basir Shabestari S. Relationship between clinical and laboratory findings of rheumatoid arthritis patients with their oral status and disease activity. Caspian J Intern Med 2021;12:22-8.
70. Ardakani MP, Nabavizadeh A, Iranmanesh F, Hosseini J, Nakhaei M. Relationship of angulation of maxillary impacted canines with maxillary lateral incisor root resorption. Pesquisa Brasileira em Odontopediatria e Clínica Integrada. 2021 May 14;21:e0164.