Original Article

Evaluation of the accuracy of digital and conventional implant-level impression techniques for maxillofacial prosthesis

Mohammad Taghi Baghani[1], Ammar Neshati[1], Mehdi Sadafi[1], Shireen Shidfar[2]

[1]Department of Prosthodontics, Faculty of Dentistry, Aja University of Medical Sciences, Tehran, Iran, [2]Dental Research Center, Research Institute of Dental Sciences, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Abstract

Objectives: This study aims to evaluate the accuracy of digital impression making based on trueness and precision measurements of dental implants placed in maxillofacial lesions to produce Maxillofacial prosthesis substructures. **Methods:** Two intra-oral scanners (Trios 3 and CS 3700) and one Desktop scanner (open technology) were examined in this study. A Model of a patient with a lesion in the ear region was created as a reference. The reference model was scanned by each scanner 10 times. Standard Tessellation Language files were provided from each scanner and were examined in terms of Trueness and Precision aspects. **Results:** In Distance 1, in the one-way analysis of variance test, there was a significant difference between the three scanners. The Trios group has less deviation than the Open Technology group ($P = 0.015$) compared with the CareStream (CS) group that showed more deviation ($P < 0.000$). There is a statistically significant difference in distance 2 among scanners. The Trios group showed more deviation as compared with the Open Technology group ($P < 0.000$). While this deviation is not statistically significant compared with the CS group ($P = 0.0907$). Open Technology Group compared with the CS group also has less deviation in distance 2, which has been statistically significant ($P < 0.000$). The preparation of a precise model of maxillofacial lesions is still difficult for some Intraoral scanners. **Conclusion:** There were significant statistical differences in Trueness and Precision among scanners. Used scanners can be applied as an alternative to conventional impression methods.

Keywords: CAD/CAM, digital scan, intraoral scanners, maxillofacial prosthesis

Introduction

Surgical techniques are routinely used to repair maxillofacial lesions. However, achieving the natural appearance and structure of the face is now beyond the capabilities and possibilities of surgical reconstruction techniques (due to the delicate properties of the tissue in this area).[1] Maxillofacial prostheses improve the quality of life of patients suffering from congenital or acquired lesions by restoring function, preserving anatomical structures after surgical treatment, and improving their appearance.[2]

An artificial ear prosthesis can be attached to the lesion site with glue and adhesive materials or with implants attached to the bone. Ear prostheses are typically made of elastic silicones that can be customized to closely resemble the patient's skin and the patient's natural ear.[3,4] However, many surgeons and technicians consider prostheses to be one of the most difficult maxillofacial treatments due to the complexity of the ear surfaces and a large number of undercuts, ridges, and edges present in the ear because the reconstruction of these features plays a major role in the natural appearance of the prosthesis.[5,6] Traditional prosthetic

Address for correspondence: Dr. Ammar Neshati, Department of Prosthodontics, Faculty of Dentistry, Aja University of Medical Sciences, Tehran, Iran.
E-mail: Ammar.Neshati@yahoo.com

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techniques have had a significant impact on treatment during this period, but some fundamental problems with these techniques remain.[7] Traditional techniques have a complex process and have several stages. These therapeutic options may face distortion and changes in the soft tissue of the face, time-consuming conditions, patient discomfort during the molding process, and the need for long-term cooperation of the patient during treatment.[7,8]

Recent advances in digital imaging have made it possible to measure and construct three-dimensional (3D) anatomical models without physical contact with the patient's facial area.[9] Using computer-aided design and computer-aided manufacturing (CAD/CAM) have introduced new ways and approaches to making and designing facial prostheses.[10] In the past, the information received from Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) techniques were used to make digital files from the lesion site and the healthy ear site.[11] In this technique, the file of the healthy site is placed on the lesion site as a mirror. They gave data and superimposed, which helped to shape the phone prosthesis as naturally as possible.[11] Recently, 3D optical scanners have been developed that can be used as an alternative to MRI and CT techniques with harmful effects on the human body.[12,13]

A possible advantage of digital impressions would be the intervention potential prior to the osseointegration. In this regard, a digital impression could arrest the intraoral condition at the osseointegration initial phases depriving of implant abutment component stressing. Another digital implant impressions advantage is the patients' comfort level and acceptance of treatment. Furthermore, dental practitioners have more satisfaction after the digital implant impressions owing to their high accuracy, quality, and easiness. These features will guarantee the implant quality and will increase the oral health levels of the families in the community.

Recent studies have shown that surface 3D scanning of dental tissue with these scanners has high accuracy and repeatability to record the complex morphology of the tooth.[14,15] They mainly have a simpler treatment plan, improved interaction with laboratories, reduced overall treatment time, and reduced storage space for each treatment compared with traditional methods.[16]

Considering the advantages mentioned for intraoral scanners, this study aimed to assess the accuracy in the form of Trueness and Precision in scans taken from reconstructed lesions of the ear by dental implants and intraoral and extraoral scanners available in the Iranian market.

Materials and Methods

Study design

The present study was aimed to assess the accuracy of digital impression making based on trueness and precision measurements of dental implants placed in maxillofacial lesions to produce maxillofacial prosthesis substructures. This study was performed as an *in vitro* intervention survey on a patient with an ear lesion referred to the prosthesis department of the Faculty of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Samples

The statistical population in this study consisted of three groups, each with 10 replications. Therefore, the statistical population consisted of 30 samples. The sample size was determined.

Considering the α value equal to 0.05, power equal to 80%, and the standard deviation of the marginal mismatch values in the four groups of 8 microns and 40-micron variance, the number of samples required for each group was estimated as 10 samples (30 samples in total).

$n = (Z\alpha/2 + Z\beta)\ 2 * 2*\sigma 2/d2$

Study procedure

A patient with a defect of the maxillofacial region was scanned with a three-dimensional scanner (Sense2, UDP, USA) from the patient's lesion and the Surface Tessellation Language (STL) file was removed from this scan. The STL file was entered into Exocad software to design a UTS number (for the possibility of performing measurement steps) inside the designed model and an acrylic model reference was prepared by a 3D printer (Formlab 2, USA).

According to the conventional techniques in maxillofacial prostheses, two endosteal implants (Straumann, Basel, Switzerland) were placed inside the outer wall of the temporal bone. After preparing the reference model by oral scanners [Carestream (CS) 3700, Trios3 3 shape], they were scanned on the implants after closing the scan bodies on the implants. Each scanner scanned the model 10 times using the manufacturer's proposed protocol. To measure the accuracy of the conventional molding technique using impression coupling produced by the implant manufacturer with augmented silicone (Panasil, Ketenbach, California, USA), conventional molding was done. Then, the molds were cast with a scannable type 4 plaster and by an extra oral scanner (Open Technology) that was scanned 10 times. The reference model was scanned by an industrial 3D scanner with an accuracy of 0.2 microns (GOM Atos scanner).The cloud point model was prepared from this scanner. The STL file was extracted from all scanners and inserted into GOM3D (USA) software, and their differences were checked by software algorithms. The differences were calculated as the difference in linear distance between two fixed points from the location of the implants. Due to the differences with the scan of the original Trueness model and according to the differences between the diverse scans of each Precision scanner, each of the scanners was examined, which indicates the accuracy of each scanner according to the ISO standard.

Data analysis

SPSS software (version 22) was used for data analysis. Descriptive statistics were used to describe the data. Kolmogorov-Smirnov

Table 1: Descriptive data deviation scans compared with the reference file at a distance of Descriptive

Groups	*n*	Mean	Std. deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
TR	10	0.164700	0.0141057	0.154609	0.174791	0.1466	0.1869
OT	9	0.181211	0.0073475	0.175563	0.186859	0.1704	0.1917
CS	10	0.096310	0.0310635	0.074089	0.118531	0.0510	0.1516

test was used to determine the data distribution. One-way analysis of variance (ANOVA) and *Post hoc* Games-Howell tests were used to compare the variables. The significance level was considered $P < 0.05$.

Results

Normality assessment of data

In this study, STL scan files were generated using TRIOS 3 (TR) and CS 3700 intraoral scanners and open technology (OT) extraoral scanners. A total of 10 scans were performed in each group. A total of 30 scans were taken by the mentioned methods. After evaluation of data extracted from tests using the Kolmogorov–Smirnov test, one of the samples in the Open technology extraoral scanning group was excluded from the study due to a large distance from the normal distribution, and the total number of scans in this group reached 9 and the total number of scans performed reached 29.

Table 1 shows the descriptive data deviation scans compared with the reference file at a distance of 1. There is a significant difference between the 3 scanners examined. Levene test to examine the homogeneity of variances in the distance showed a statistically significant difference between the variances (F [2:28] 46.894, $P < 0.000$).

Table 2 shows the comparison of the significant difference between the deviation of distance number 1 from the actual distance between the scanners studied.

Due to the inequality of variances, the Games–Howell method was used to compare two by two scanners with each other, which showed that the Trios group had less deviation than the Open technology group ($P = 0.015$), while the CS group had a higher deviation ($P < 0.000$), and the Open technology group has shown more deviation in the distance of 1 than CS ($P < 0.000$) [Table 2].

Scan's deviations compared with reference in distance No 2

Table 3 shows the descriptive data deviation scans compared with the reference file at a distance of 2. Examination of the means in the ANOVA test showed that there was a significant difference between the 3 scanners. Levene test to examine the homogeneity of variances in the distance showed a statistically significant difference between the variances (F [2:28] 39.194, $P < 0.000$).

Due to the inequality of variance, the Games–Howell method was used to compare two scanners, which showed that the Trios group has significantly more deviation than the Open technology group ($P < 0.000$), while this deviation is not significant compared with the CS group ($P = 0.0907$). The Open technology group also has a lesser deviation than the CS group ($P < 0.000$) [Table 4].

Table 2: Comparison of the significant difference between the deviation of distance number 1 from the actual distance between the scanners studied

	(I) Scanner	(J) Scanner	Mean difference (I-J)	Std. error	Sig.
Games-Howell	TR	OT	-0.0165111	0.0050888	0.015
		CS	0.0683900	0.0107885	0.000
	OT	CS	0.0849011	0.0101239	0.000

Table 5 shows the precision descriptive data comparison scans at a distance of 1. There is a significant difference between the three scanners examined. Levene test to examine the homogeneity of variances in the distance showed a statistically significant difference between the variances (F [2:28] 39.194, $P < 0.000$).

Due to the inequality of variances, the games-Howell method was used to compare two-by-two scanners, which showed that the Trios group had a significantly higher deviation than the Open technology group ($P < 0.000$), while compared with the CS group, this deviation is not significant ($P = 0.0907$). The Open technology group also showed less deviation than CS in distance 2, which is statistically significant ($P < 0.000$) [Table 6].

Discussion

Digital workflow has been used more and more in maxillofacial prostheses in recent years. However, compared with the great advances and popularity recorded by CAD and CAM technologies in other dental specialties, such as fixed and removable dentures, cosmetics, dental implantology, and orthodontics, its progress in maxillofacial prosthetics has been limited to date.[17] Several technical notes, case reports, and even case studies have been published in recent years, but scarce literature is available to provide a reliable protocol for the use of CAD and CAM technology in the rehabilitation of patients with jaw defects.[18] Advances in the construction of these devices have only been made in recent years by Elbashti *et al.* (2016),[19] Park *et al.* (2017),[20] Rodney and Chicchon (2017).[21] and Ye *et al.* (2017)[22] occurred with promising results.

The present survey was done to appraise the accuracy of digital impression making based on trueness and precision

Table 3: Descriptive data deviation scans compared with the reference file at a distance of 2

Groups	*n*	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
TR	10	0.062960	0.0136472	0.053197	0.072723	0.0421	0.0836
OT	9	0.010544	0.0050644	0.006652	0.014437	0.0040	0.0218
CS	10	0.059770	0.0195861	0.045759	0.073781	0.0291	0.0951

Table 4: Comparison of the significant difference between the deviation of distance number 2 from the actual distance between the scanners studied

	(I) Scanner	(J) Scanner	Mean difference (I-J)	Std. Error	Sig.
Games-Howell	TR	OT	0.0524156	0.0046341	0.000
		CS	0.0031900	0.0075489	0.907
	OT	CS	-0.0492256	0.0064196	0.000

measurements of dental implants placed in maxillofacial lesions to produce maxillofacial prosthesis substructures. Findings showed that at distance 1, the Trios group had lesser deviation than the Open technology group ($P = 0.015$), while the CS group had more deviation ($P < 0.000$). Additionally, open technology group had more deviation than the CS group ($P < 0.000$). At distance 2, Trios had significantly more deviation than the Open technology group ($P < 0.000$), while compared with the CS group, this deviation was not significant ($P = 0.0907$). The Open technology group had a lesser deviation than the CS group, which was statistically significant ($P < 0.000$). Thus, rendering the type of surgical operations, examined methods can use as an alternative to conventional techniques.

Scarce surveys have been conducted in this field. Studies show that intraoral scanners were more accurate than conventional molding with polyvinyl siloxane[23,24] or indirect digitization of molds[25] in the cases of one extracted tooth scanning. However, at distances larger than one tooth, their distortion was higher than other groups, although they were clinically acceptable.[26] In the case of whole-jaw molding, some studies have shown that there is no significant difference between indirect and direct digitization,[26] while others have argued that indirect digitization is more accurate.[27] In the majority of *in vitro* studies, such as the Ender *et al*. (2015)[27] and Patzelt *et al*. (2014)[28] investigations, intraoral scanners were more accurate only in the molding of single teeth, and in the case of larger molds, such as full-jaw molds, conventional techniques were more acceptable. Similarly, a study conducted by Dds *et al*. (2015)[29] showed that intraoral scans could be clinically less effective for molding teeth at intervals of less than half of the jaw. Regarding the methods used to measure accuracy, some studies compare the final restoration fit and others compare the Surface Tessellation Language (STL) data.[24]

The use of intraoral scanners in creating a successful direct template of maxillofacial lesions has not yet been reported. The main reason for this may be due to problems in connecting images taken from intraoral scanners to each other due to the lack of clear landmarks on the extra-oral soft tissues compared with small and clear signs in the morphology of the tooth during intraoral scanning. Properly connecting the resulting images requires the preparation of multiple scanned images with overlapping fields to create a three-dimensional data set. Landmarks that are not identified in out-of-mouth scans lead to faulty processing and summary of errors for the entire data set.[30] Another limitation of digital technology is the distance between the implants. The accuracy of intraoral scanners decreases as the distance between air scans and impression couplings increases.[31] In keeping with this, the use of digital techniques in the treatment of maxillofacial patients may enable the physician to make and deliver ear prostheses more accurately than conventional methods. It can also be used in geographical areas where local specialists may not have the ability to shape the ear with traditional methods. This approach can replace the sculpting and shaping skills needed to make a maxillofacial prosthesis by taking accurate images of the soft tissue of a healthy ear and copying them.[30]

Recent studies have shown improvements in the accuracy and precision of intraoral scanners and their potential use as an alternative to conventional dental molds.[32-35] However, the use of intraoral scanners has not been reported to create a successful direct template for jaw and face defects. The main reason for this may be due to problems in connecting images taken from intraoral scanners to each other due to the lack of specific landmarks on extraoral soft tissues compared with small and clear landmarks in the morphology of teeth during intraoral scanning.

Digital implant-level impression techniques have several advantages for clinicians. This technique results in more efficient impressions than conventional methods. Conventional impressions need higher levels of preparation and working with time-consuming procedures. The digital technique has lower difficulty even for dental students in the second year of education. Additionally, a higher satisfaction rate of patients operated using the digital implant impression was reported in previous surveys. Additionally, the digital impression can be positively used for the impressions for implant restoration based on efficiency and participants' perception.[36,37]

The present study was a baseline study to begin further research into the use of intraoral scanners. The main limitation of this research is it's *in vitro* analysis.

Key Learning Points

- In this survey, the accuracy and precision of digital and conventional implant-level impression techniques for

Table 5: Precision descriptive data Comparison scans at a distance of 1							
	n	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
TR	9	0.012311	0.0083268	0.005911	0.018712	0.0004	0.0217
OT	8	0.011750	0.0066425	0.006197	0.017303	0.0004	0.0213
CS	9	0.026267	0.0175802	0.012753	0.039780	0.0017	0.0549

Table 6: Comparison of significant differences in Precision distance number 1 between the studied scanners				
(I) Scanner	(J) Scanner	Mean Difference (I-J)	Std. Error	Sig.
TR	OT	0.0005611	0.0036358	0.987
	CS	-0.0139556	0.0064842	0.123
OT	CS	-0.0145167	0.0063131	0.100

maxillofacial prosthesis were examined with each other. For this purpose, STL scan files were generated using TRIOS 3 (TR) and CS 3700 (CS) intraoral scanners and open technology (OT) extraoral scanners.

- Findings showed that there is a significant difference between the 3 scanners examined. Variances showed a statistically significant difference between the variances (F [2:28] 46.894, $P < 0.000$). Groups scanned with Trios group had less deviation than the Open technology group ($P = 0.015$), while compared with CS group had a higher deviation ($P < 0.000$) and the Open technology group has shown more deviation in the distance of 1 than CS ($P < 0.000$).
- Significant differences were obtained between the 3 scanners according to ANOVA test. The Trios group has significantly more deviation than the Open technology group ($P < 0.000$), while this deviation is not significant compared with the CS group ($P = 0.0907$). The Open technology group also has a lesser deviation than the CS group ($P < 0.000$).
- Compared with conventional techniques, digital implant-level impression methods have higher accuracy and quality. Additionally, patient and dentist's satisfaction are higher after operation using digital implant-level impression techniques.
- The main key take-home message from this manuscript is that using digital implant-level impression cause better approaches with easier operation.

Conclusion

As shown applied techniques can effectively address the full frame picture of the maxillofacial part to design a better approach for further surgical operation. The preparation of a precise model of maxillofacial lesions is still difficult for some Intraoral scanners. There were significant statistical differences in Trueness and Precision among scanners. Used scanners can be used as an alternative to conventional impression methods.

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Conflicts of interest

There are no conflicts of interest.

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