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Research Article

Dimensional Accuracy of Splinted Open Tray Implant Impression Technique: Comparison of Four Splinting Materials

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Abstract

Introduction: Dimensional accuracy of impressions for the fabrication of implant-supported prosthetic restorations has been a concern for clinicians. The material used for splinting of implants in the open tray technique can affect the passive fit between the abutments.

Aim of Works: This study sought to assess the dimensional accuracy of splinted open tray implant impression technique with four commonly used splinting materials.

Methods: In this *in vitro*, experimental study, four internal hex implants with 4mm diameter and 11.5mm length were placed in a mandibular model. Two implants were placed parallel in the right and left quadrants with 10 mm distance from the midline. The third implant was placed with 15° and the fourth with 25° angle with 10 mm distance from each other and fixed with cyanoacrylate glue. Open tray copings were splinted using Duralay (Reliance), Pattern Resin, Duralay (Ariadent) and Futar D. Special trays were fabricated for each group and impressions were taken using Monopren addition silicon. Impressions were poured with type IV dental stone. Three linear distances including the distance between the most anterior and most posterior analog (A1), distance between the internal margin of anterior analogs in the right and left quadrants (A2) and distance between the external margins of the posterior analogs in the right and left quadrants (A3) were measured on the reference model and on the final cast with eight repetitions using a coordinate measuring machine (CMM). Dimensional changes were assessed by ANOVA and post hoc Tukey's test.

Results: The maximum dimensional change was 0.7% in A1 ($P = 0.6$), 0.5% in A2 ($P = 0.2$) and 0.8% in A3 ($P = 0.8$). Dimensional accuracy of impressions was not significantly different among the four materials ($P > 0.05$).

Conclusion: The four splinting materials used in this study for the open tray impression technique were not significantly different in terms of the accuracy of impressions. Pattern Resin showed slightly superior accuracy.

Keywords: *Analog; Dental Implants; Dental Impression Technique; Dimensional Measurement Accuracy; Splinting Materials*

Abbreviation

CMM: Coordinate Measuring Machine

Introduction

Dimensional accuracy of impressions for the fabrication of implant-retained prosthetic restorations has always been a concern for clinicians [1]. Dimensional changes of impression materials are mainly related to their shrinkage as the result of polymerization reactions and production of volatile byproducts, excess pressure during impression taking, the selected impression technique and type of impression material used [1].

In implant dentistry, an accurate impression of implant is necessary to achieve passive fit [2,3]. Passive fit refers to a state of prosthetic adaptation in which, implant body has adequate fit for adaptation while allowing bone remodeling. Optimal passive fit has reported to be 10μ [1,2]. Fabrication of a superstructure with passive fit is a prerequisite for a successful implant-retained prosthetic restoration. To achieve this goal, an accurate impression with minimal dimensional changes is necessarily required to obtain passive fit [2]. Precise transfer of implant position is much more important than reconstruction of details of prosthetic surfaces [4]. Not achieving passive fit leads to adverse biological and mechanical complications. The generated stress impairs the process of osseointegration. Moreover, destructive forces are applied to the superstructure and implant and result in eventual fracture of restoration, failure of implant, peri-implant bone loss, peri-implant ischemia, scar tissue formation and infection. All these complications can lead to treatment failure [5].

There are several methods to achieve passive fit; however, no consensus has been reached on one single protocol [5]. It has been reported that increasing the accuracy of the cast by promoting the impression technique is one way to improve passive fit [6]. Advances in impression techniques and improved design of impression trays have also been evaluated as possible factors to improve passive fit [7,8]. Several methods are available for multiple implants impression such as splinted or non-splinted open-tray impression [9], data in a systematic review showed that in 10 studies no difference between these methods but in 7 studies there were better results in splinted techniques [10]. Some investigators suggest that better results will achieve with splinting copings then sectioning the acrylic resin then join the acrylic resin again with painting resin in the section area because of this method will decrease polymerization shrinkage [11], but other studies show that it is better that to just join impression coping together [12]. The material used for splinting of implants in the open tray technique can affect the passive fit between the superstructure and the abutment. Cerqueira., *et al.* [13], in 2012 stated that type of acrylic resin and method of splinting affected the micro-strain applied on implants.

Considering the gap of information in this regard and lack of a comprehensive study to compare commonly used splinting materials in terms of dimensional accuracy of the impressions, this study aimed to assess the dimensional accuracy of implant impressions taken with splinted open tray technique by use of four commonly used splinting materials. The null hypothesis was that the four splinting materials would not be significantly different in terms of the dimensional accuracy of the implant impression taken with splinted open tray technique.

Materials and Methods

In this *in vitro*, experimental study, a stainless steel model of the mandible measuring 8 cm in diameter and 3 cm in height with four holes for placement of internal hex implants was used (Figure 1). Considering $\alpha = 0.05$, $\beta = 0.2$ and 80% power of study, sample size was calculated to be eight test samples and one control (a total of 33).

Figure 1: *Stainless steel edentulous model with prepared implant sites.*

Four internal hex implants (SIC Invent AG, Basel, Switzerland) with 4mm diameter and 11.5 mm length were placed in the model in such a way that two implants were placed parallel at the two sides of the midline with 10 mm distance from the midline (20 mm distance from each other). The third implant was placed with 15° (distal) angle and 10 mm distance from the parallel implant and the fourth implant was placed with 25° (distal) angle and 10 mm distance from the implant in the other quadrant [8]. The implants were fixed into their respective holes using cyanoacrylate glue (Razi, Tehran, Iran). Open tray copings were placed on the implants.

The following distances were measured on the model:

- A1: The distance between the most anterior and most posterior analog.
- A2: The distance between the internal margins of anterior analogs in the right and left quadrants.
- A3: The distance between the external margins of the posterior analogs in the right and left quadrants (Figure 2).

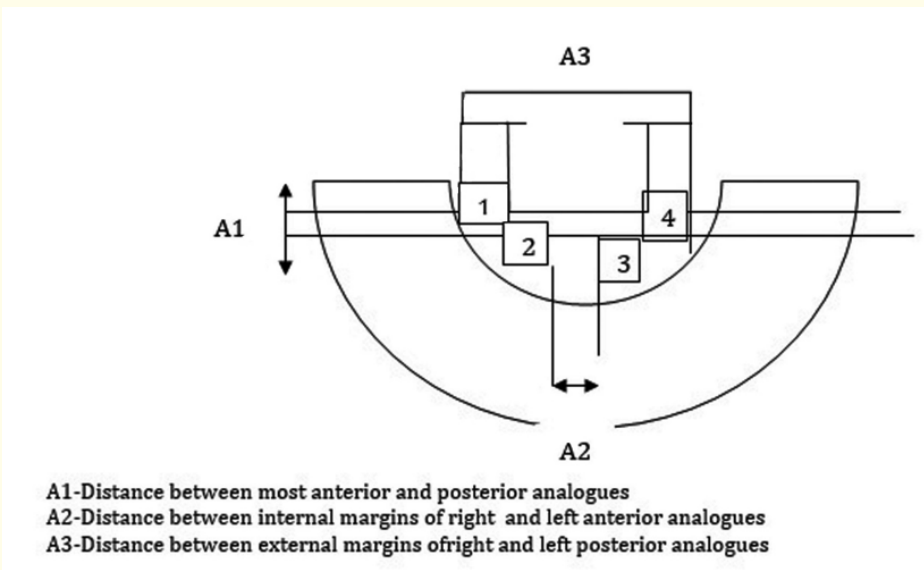

Figure 2: *Schematic view of the measured distances on the model.*

Open tray copings were splinted with the four splinting materials. material namely the Pattern Resin (GC America, Chicago, IL, USA), Duralay (Reliance, Dental Manufacturing Co., Alsip, IL, USA), Duralay (Ariadent, Tehran, Iran) and Futar D addition silicon bite registration material (Kettenbach GmbH and Co. KG, Eschenburg, Germany). A special tray was fabricated for each speciement. An impression was taken using Monopren (Panasil, Kettenbach GmbH and Co. KG, Eschenburg, Germany) addition silicon impression material with 10 psi pressure at 23°C. Ten minutes was allowed for the impression material to set as recommended by the manufacturer. The impressions were poured with type IV dental stone (Fuji Rock, GC America, Chicago, IL, USA) 30 minutes later and were allowed 60 minutes to set. The distances were measured again on the master casts using a CMM (Mitutoyo, Nakagawa, Japan) in millimeters. Impression copings were joint together with splinting materials then section with 0.5 mm thickness using low-speed hand piece with double-side diamond disc were performed between copings. After 24 hours to parts were join together again using these materials. After 17 minutes impressions were made [14]. To prevent shrinkage in the splinted complex, the distances between the implants were sectioned by a disc and reattached with a small amount of acrylic resin. The excess impression material was removed from the tray window in order for the pins to appear. The guiding pins were then loosened by a hex driver and extracted. The tray was separated from the master cast and the impression copings remained in the impression. Implant analogs were attached to the inferior segment. The impressions were assessed and in case of errors, they were repeated. Vel-Mix type IV dental stone (Kerr, Orange, CA, USA), mixed by a vacuum mixer, was used to fabricate the master cast. After setting, the casts were trimmed and coded. The aforementioned distances were measured on the cast using the CMM. The data were analyzed using ANOVA and post hoc Tukey's test.

Results

Three distances were measured for each splinting material with eight repetitions. Thus, a total of 96 measurements were made. Table 1 shows the dimensional changes in the designated distances for the four types of splinting materials. As seen in table 1, in A1, the greatest distance was measured in Futar D group (19.12 ± 0.04 mm) while the smallest distance was measured in Ariadent group (18.81 ± 0.04 mm); according to ANOVA, this difference was not statistically significant (P = 0.6). Maximum difference with the actual value (measured on the model) was 0.7% (0.12 mm). In A2, the greatest distance was measured in Futar D group with a mean value of 7.03 mm and the smallest distance was measured in Ariadent group with a mean value of 7.03 mm; according to ANOVA, this difference was not statistically significant (P = 0.2). Maximum difference with the actual value was 1.3% (0.096 mm). In A3, the greatest distance was measured in GC America and Ariadent groups (mean value of 34.61 mm) and the smallest distance was measured in Ariadent group (34.6 mm); according to ANOVA, this difference was not statistically significant (P = 0.8). Maximum difference with the actual value was 0.8% (0.26 mm).

P Value	Dimensional change	Distance	Splinting material
P = 0.6	18/15 ± 0/02	A1	Duraley (Reliance)
P = 0.2	7/15 ± 0/11	A2	
P = 0.8	34/6 ± 0/09	A3	
P = 0.6	18/81 ± 0/04	A1	Ariadent (Duraley)
P = 0.2	7/21 ± 0/03	A2	
P = 0.8	34/61 ± 0/03	A3	
P = 0.6	18/91 ± 0/01	A1	Pattern Resin (GC America)
P = 0.2	7/03 ± 0/03	A2	
P = 0.4	34/61 ± 0/03	A3	
P = 0.6	19/12 ± 0/04	A1	FuturD (Ketenbuch)
P = 0.2	7/42 ± 0/03	A2	
P = 0.8	34/41 ± 0/03	A3	
According to ANOVA, the differences were not significant			Test result

Table 1: *Dimensional changes in the designated distances for the four types of splinting materials.*

Discussion

This study assessed the dimensional accuracy of implant direct impressions by the open tray technique using four splinting materials namely Duralay (Reliance), Pattern Resin (GC America), Duralay (Ariadent) and Futar D (Kettenbach). Success of direct impression techniques with splinting of impression copings depends on accurate registration of implant position [15]. Splinting with acrylic resin has also been reported [15]. Thus, we also assessed splinting with the use of a bite registration addition silicon material (Futar D). Our results showed that the four splinting materials were not significantly different in terms of the accuracy of impressions, and the distances measured on the final cast had insignificant differences with those measured on the model. A1 distance was the largest in Futar D and the smallest in Ariadent group, but this difference was not significant. Maximum change was 0.7% compared to the actual value. A2 distance was the largest in Futar D and the smallest in Pattern Resin group, but this difference was not significant. Maximum change was 1.3% compared to the actual value. A3 distance was the largest in Pattern Resin and Duralay (Ariadent) and the smallest in Duralay (Reliance) group, but this difference was not significant either. Maximum change was 0.8% compared to the actual value. The greater dimensional changes in the impressions taken by use of bite registration addition silicon material for splinting was probably due to the lower rigidity of this material; although this difference did not reach statistical significance. Despite some differences in the methodology and measuring devices, our findings were in line with those of a previous study [16].

Several techniques have been suggested in the literature for splinting of the impression copings including splinting with acrylic resin and dental floss, use of prefabricated acrylic resin bars, use of stainless steel bars and orthodontic wires [17]. Splinting is done to stabilize the impression copings and prevent their movement. However, some other considerations in addition to methods to stabilize impression copings must be taken into account such as working time, patient satisfaction, affordability, accuracy of impression material and accuracy of impression tray.

Hariharan., *et al.* [18], compared the accuracy of casts obtained by non-splinted and splinted direct impression techniques and reported that impressions taken by splinting of impression copings yielded superior results compared to non-splinted techniques. They added that splinting of impression copings with acrylic resin yielded accurate impressions and bite registration addition silicone-splinted technique yielded the least accurate results. Their results were in agreement with our findings. Papaspyridakos., *et al*. [19], compared splinted and non-splinted impression techniques in terms of the accuracy of fit of restorations. They performed splinting with the use of acrylic resin and reported that splinting with acrylic resin had sufficient accuracy (95% confidence interval), which was in accordance with our results.

It should be noted that several factors might affect the results of studies such as the impression materials used, impression technique, type of gypsum, type of tray and the maxillary or mandibular arch [20].

Accurate transfer of the spatial position of implants in the dental arch to the master cast is the first and most important step in achieving passive fit in implant-supported prosthetic restorations. To achieve this goal, several impression techniques and materials for splinting of impression copings were proposed. Some previous studies did not find a significant difference between splinted and non-splinted impression techniques [21] while some others believe that splinting confers stability to impression copings against the torque from analog tightening and decrease their freedom of rotation in a resilient impression material [22]. For this reason, studies focused on the most suitable materials for splinting of impression copings.

Dumbrigue., *et al*. [23] and Naconecy., *et al.* [10], introduced a technique for splinting of impression copings with prefabricated resin barsand carbon-steel bars, which enabled rigid attachment of impression copings by minimizing the polymerization shrinkage. Assif., *et al*. [17], introduced plaster for splinting of impression copings, since it was easy to use, fast setting, accurate and rigid; however, its use at the site of undercuts was extremely difficult.

Some concerns exist regarding the use of bite registration silicon material for splinting of impression copings mainly due to short working time and low flowability. However, these materials have excellent volumetric stability. In our study, Futar D showed greater dimensional changes than other materials, but not significantly.

Accuracy of impressions is assessed via several techniques. Some studies evaluated the fit of frameworks fabricated on the casts by use of a strain gage and assessed and compared the fit of frameworks on the master cast [5]. Some others evaluated the accuracy of impressions by measuring the distances between implants on the master cast compared to the actual values on the reference model [24]. In the current study, we adopted the latter technique to assess the accuracy of impressions and tried to eliminate the confounding factors as much as possible by selecting an appropriate impression material and an appropriate impression technique. Composite resins and light-cure acrylic resins were recently introduced for splinting of impression copings, which need further evaluation in future studies [25].

Buzayan., *et al*. [26], in an *in vitro* study in 2013 assessed the accuracy of splinted and non-splinted implant direct impression techniques by use of different splinting materials. They compared the distances on the master cast with those on the original model and found no significant difference in splinting materials in terms of linear and three-dimensional measurements, which was in accordance with our results. In contrast, Filho., *et al*. [27], in 2009 compared different splinting techniques for impression copings of angulated implants and showed significant differences among them. Assif., *et al*. [28], in 1999 compared the accuracy of implant impressions taken with the use of three splinting materials *in vitro* and showed that splinting technique with auto-polymerizing acrylic resin or impression plaster (as a splinting material) was significantly more accurate than use of dual cure acrylic resin. Plaster is the material of choice for use in completely edentulous patients because it is easy to use, fast and affordable. Controversy in the results of studies may be due to variable sample sizes and use of different measuring devices and techniques.

Large sample size was strength of the current study. Also, impression taking was standard in our study and small standard deviation values obtained confirmed the accuracy of our findings. Moreover, we had eight repetitions in each group while this value was four in previous studies. The main limitation of the current study was its *in vitro* design. Thus, generalizability of the results to the clinical setting must be done with caution. Future clinical studies are required to assess the accuracy of our findings in the clinical setting. Only one type of implant (SIC) was used in this study. Thus, similar future studies on different types of implants are required. Last but not least, further studies on implant impression techniques other than the open tray technique may yield interesting results.

Conclusion

Within the limitations of this *in vitro* study, the results showed that the four splinting materials used in this study for the open tray impression technique were not significantly different in terms of the accuracy of impressions. Pattern Resin by GC America showed slightly superior accuracy.

Conflict of Interest

Authors declare no conflict of interest.

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