Comparative Study of Dimensional Accuracy in Three Dental Implant Impression Techniques: Open Tray, Closed Tray with Impression Coping, and Snap Cap

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ABSTRACT

Aim: Several impression techniques have been proposed to result passive fitness between the prosthesis and osseointegrated implant. The aim of the study was to compare dimensional accuracy of three impression methods: Open tray, closed tray with impression coping, and closed tray with snap cap.

Materials and methods: In this experimental study, a mandibular acrylic model was prepared with a milling machine to place three holes for dental implant analogs (Dio SM) with the dimension of 3.8×10 mm into the intended sites (one in midline and two others on the side at a distance of 10 mm) parallel with each other and perpendicular to the plane. Twenty-seven casts were prepared with impression material of polyvinyl siloxane (PVS) and dental stone type IV and divided into three groups. Implant situations were measured by coordinate measuring machine (CMM) and results were analyzed with Kruskal–Wallis and Mann–Whitney test to perform pairwise comparison among the groups.

Results: The mean ΔR values for open tray, closed tray with impression coping, and closed tray with snap cap were respectively, 0.070 ± 0.088 , 0.173 ± 0.205 , and 0.142 ± 0.044 .

There were statistically significant differences between open tray and closed tray as well as open tray and snap cap methods ($p < 0.05$), but there was no statistically significant difference between closed tray and snap cap method ($p = 0.1$).

Conclusion: Regarding the results, open tray impression technique had the highest dimensional accuracy compared with the other two methods. There were no statically significant differences between closed tray with snap cap and closed tray with impression coping technique.

Clinical significance: Snap cap technique is less time consuming with similar dimensional accuracy in comparison with open tray impression technique.

Keywords: Dental implants, Dental materials, Dental prosthesis, Dimensional accuracy, Impression techniques.

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INTRODUCTION

Providing passive fitness is one of the main goals of biomechanics in implant-supported prostheses and it requires sometimes complex clinical and laboratory processes in order to achieve this goal.¹ Passive fitness term in implant treatments is a prosthetic compatibility, in which there is the possibility of creating a specific fitness and simultaneous bone reconstruction around implant body; however, it is unlikely to achieve a completely passive and error-free fitness.²

Adequate and acceptable clinical fitness is a state in which the amount of the resulting stress is physiologically tolerated and no damage is incurred to dental implant and the bone after insertion. Since no cushioning effect

of periodontal ligaments exists around dental implants, from biomechanics, implant-supported restorations, implant and bone act as a functional unit³ and misfitting at this connection can cause irreversible problems in prosthesis, implants, and the surrounding structure.⁴ It is difficult to access complete passiveness between the interfaces of abutment and implant.

Distortion may occur between X, Y, and Z axes due to the various factors which affect prostheses construction,⁵ such as impression technique, elastic deformation of the impression material (dimensional changes), parallel or nonparallel implants, the depth of inserted implants, the abutment types, wax deformation, metal shrinkage, plaster expansion, die system used, acrylic or porcelain shrinkage, soldering carelessness, investing and casting problems and diversity of manufacturers making components of superstructures, and length of the impression copings. Although undoubtedly some of these factors are not directly controlled by the dentist, if there is any problem, dentist will fail to achieve complete passive fitness.⁵⁻⁸ Considering this issue, the dentist can only minimize misfitting that occurs in the construction process. The first and the most important step in providing passive fitness is to make an accurate impression without any mistakes.

Researchers have proposed different techniques to achieve the required accuracy in impression making and transferring of dental implants position from mouth to the casts. There are mainly two different impression techniques to transfer these impression copings from dental implants to impressions. The transfer technique uses tapered copings and a closed tray to make an impression. The copings are connected to the implants, and an impression is made and removed from the mouth, while the copings are left in the mouth. Subsequently, the copings are removed and connected to the implant analogs, and then the coping-analog assemblies are inserted into the impression before pouring the definitive cast.⁸⁻¹⁰ The clinical indications for using closed tray technique are limited interarch space, tendency to gag, difficult accessibility in the posterior region of the mouth, and angulated implants.⁹

The supporters of this technique claim that it is more reliable, as the connection between analog and impression coping is visible.¹¹ Conversely, the pick-up impression technique uses square copings and an open tray (a tray with an opening), allowing the coronal ends of the impression coping screw to be exposed. Before removing the impression, the copings screws are unscrewed to be removed along with the impression.

Some implant manufacturers have introduced "snap fit" impression technique to transfer the implant position and their three-dimensional orientations to final cast.

"Snap-on" technique is another method in which the impression components are placed on the transmucosal neck of the implants and will be picked up in the impression with no screw-like components.¹²

This technique is easy to perform, saves time, and convenient for both the patient and clinician and allowing the copings to be removed along with the impression. It also has benefits of both direct and indirect techniques and overcomes the problem of coping displacement in the impression materials.¹³ Although many studies have compared closed tray and open tray impression techniques,^{5,8,11,12} there are few studies that compared the accuracy of snap-on impression technique with these two common techniques.¹⁴ The aim of this study was to compare the dimensional accuracy of three impression methods: Open tray, closed tray with impression coping, and closed tray with snap cap. The null hypothesis of the present study was that there is no difference between the dimensional accuracy of these three techniques.

MATERIALS AND METHODS

In this experimental study, a mandibular arch-shaped acrylic model (Frasaco typodont, Greenville, USA)^{12,15} was used. In this model, three holes were inserted for analog implant placement (one in midline and two others on the side at a distance of 10 mm), using the milling machine (K9, Kavo, Berlin, Germany) so that these three holes provided a triangular pattern in a plane. They were parallel with each other and perpendicular to the plane¹ (Fig. 1).

Implant analogs (Dio SM, Busan, South Korea) with dimensions of 3.8 × 10 mm were placed in each of these holes and fixed in place by cyanoacrylate cement (Razi Super Glue, Tehran, Iran). This study compared the dimensional accuracy of 27 casts in three groups of nine casts obtained from open tray impression technique, nine

Fig. 1: Preparation of the model for implant analog placement

Fig. 2: Primary cast

Fig. 3: Preparation of cast to fabricate the special tray

A

B

Figs 4A and B: (A) A special tray for open tray impression. (B) A special tray for closed tray impression

casts from closed tray with impression coping technique, and nine casts of closed tray impression with snap cap. At first, notches were created around the model in order to guide placing the tray and the initial impression was made using putty and wash Speedex (Colten, Alstatten, Switzerland) through a stock tray from the main model. The dental cast was poured with type III dental stone (COECAI, GC, Chicago, USA) and the primary cast was obtained (Fig. 2).

The special tray with self-curing acrylic resin (Megatry, Megadenta, Radeberg, Germany) was fabricated for final impression. For this purpose, open tray impression copings were initially connected on the cast and two layers of base plate wax (Dentsply, New York, USA)¹⁶⁻¹⁸ with a thickness of 1 mm were placed to create the necessary space for impression materials as well as to embed the tissue stops in order to create a uniform thickness of impression material around the copings (Figs 3 and 4).

Then, all the surfaces of the trays were drilled with a round hand-piece drill with a diameter of 1 and 10 mm

spacing. This process was performed for the construction of all 27 trays. Then open tray impression copings were connected on the main acrylic model with a torque of 10 Ncm^{19,20} and the final impression was made for each group using Panasil Monophase additional silicone impression material (Kettenbach, Aarbergen, Germany). Polyvinyl siloxane tray adhesive was used 15 minutes before the impression process (Universal Tray adhesive, Kettenbach, Aarbergen, Germany).¹²

A 1.5 kg metal block was used to apply standard pressure to each tray during polymerization.²¹ After 5 minutes, the impression was detached and the implant analogs were connected to the impression copings. The same steps were repeated in closed tray with impression coping and with snap cap. Abutments (Dio SM two-piece abutment, torx, diameter 4.3 mm, cuff 1 mm) were connected on the main model with 10 Ncm torque in the snap cap impression technique and plastic caps were placed. After impression making, abutments were detached from the main model and were connected to the fixture analog

Fig. 5: Master casts

Fig. 6: Coordinate measuring machine

and were later carefully returned in caps buried in the impression, so that the snapping sound was heard. The definitive dental casts were poured using dental stone type IV (Zhermack, Rovigo, Italy) (Fig. 5).

Since the purpose of this study was to investigate the dimensional differences of abutments and their positional transfer accuracy from the model to the samples, a new variable called “spatial position” was defined for each base. For this purpose, the center of the middle abutment was considered as the point of reference and its central distance to other abutments was measured in three dimensions across the three axes of x, y, and z using CMM (Trimek, Alava, Spain) with a contact accuracy of 0.1 μm (Fig. 6).

The CMM, a three-dimensional measurement method, is considered as one of the most accurate methods for measuring the accuracy of implant position transfer and has been used in the present study and numerous other studies.^{22,23} The CMM is a device to measure the contact accuracy with an accuracy of 0.1 μm with a 1 $\times$ 1.8 m table and a sensitive probe that moves across the entire length and width of the table by two vertical and horizontal arms. All measurements were carried out by an operator who was unaware of the type of impression method. To record the exact center of each abutment and its angle, a cylinder was defined for each of them by defining six points in each abutment and the point of intersection between the central axis of the cylinder and the horizontal plane was considered as a central point and criterion for measuring the distance between the bases.

After recording the coordinates of the center of each implant in X, Y, and Z dimensions of each group, the distance difference within each of the abutments relative to the reference was calculated. None of the coordinate axes was removed in these calculations. So, there was no need to independently calculate each coordinate axis that requires the elimination of information in this axis

and the distance difference between the centers of the implants in the prepared samples compared with the analog, compared with the main model, was used as a criterion to evaluate the accuracy of implant position transfer from model to the casts. The difference between coordinate values of X, Y, and Z of samples in each group, compared with the basis vectors, was determined and results of distances were calculated in three axes. To carry out statistical analyses, a nonparametric test, Kruskal–Wallis, was used respectively. Also, Mann–Whitney test was used to perform pairwise comparison among the groups; Statistical Package for the Social Sciences version 16 was used for data analysis.

RESULTS

In order to calculate reconstruction accuracy of various impression methods compared with the original model, the following formula was used: $\Delta R = \sqrt{\Delta x^2 + \Delta y^2}$ where Δx is equal to the distance difference between the right analog and the central analog in the impression samples and the main sample, Δy is equal to the distance difference between the left analog and the central analog in the impression samples and the main sample. The ΔR values for each group are separately shown in Table 1.

Table 1: ΔR values for three impression techniques

Snap tray	Open tray	Closed tray
0.180	0.074	0.069
0.124	0.298	0.450
0.103	0.047	0.088
0.182	0.038	0.118
0.101	0.067	0.066
0.122	0.029	0.070
0.106	0.041	0.603
0.227	0.029	0.055
0.132	0.006	0.035

Table 2: Descriptive statistics of the three methods

Method	n	Maximum	Minimum	Standard deviation	Median	Mean
Close	9	0.603	0.035	0.205	0.070	0.173
Open	9	0.298	0.006	0.088	0.041	0.070
Snap cap	9	0.227	0.101	0.044	0.124	0.142

The mean values for ΔR in the closed tray impression coping group, open tray group and closed tray snap cap were 0.173 ± 0.205 , 0.070 ± 0.088 , and 0.142 ± 0.044 respectively (Table 2).

According to the results, open tray group had the lowest mean ΔR value, indicating that this method reconstructs the main sample more accurately. Kolmogorov–Smirnov test was used in order to assess the normality of the data. This test rejected the null hypothesis of normality ($2p = 0.04$); therefore, according to the rejection of the null hypothesis of normality and impossibility of using one-way analysis of variance; its nonparametric equivalent Kruskal–Wallis was used to compare the dimensional accuracy of the three groups. The analysis result showed that there was statistically significant difference between the study groups ($p = 0.008$) (Table 3).

Mann–Whitney test was used to perform pairwise comparison among the groups. This test showed that there was a statistically significant difference between open tray and closed tray as well as open tray and snap cap ($p < 0.05$), but no statistically significant difference was observed between closed tray and snap cap ($p = 0.1$) (Table 4).

DISCUSSION

Different methods have been used to achieve passive fitness in the implant-supported prostheses and the following factors have crucial importance in the development of this fitness: making an accurate impression, absence of impression distortion to the time of laboratory transferring and fabrication of a suitable model for an accurate reconstruction of implant positions in the mouth.^{7,14} The results of this study showed that the null hypothesis was rejected.

Open tray impression technique had higher dimensional accuracy compared with the other techniques. Although numerical values between the two groups of closed tray with impression coping and closed tray with snap cap were different, this difference was not statistically significant. There is no doubt that the results of the present study are limited to a particular implant system (Dio SM) and positioning of implants (parallel to each other and perpendicular to the horizontal plane), and may have limited generalizability in evaluating larger number of implants, other implant systems, or in cases of positions with more angles.

Table 3: Kruskal–Wallis test for comparison of values in three groups

Chi-square	9.75
Degree of freedom	2
p-value	0.008*

*Statistically different

Table 4: Comparison test of value for each two groups by Mann–Whitney test

Groups	Z	p-value	Result
Open and snap tray	-1.9	0.047	S
Closed and snap tray	1.72	0.1	NS
Open and closed tray	2.78	0.005	S

S: Significant; NS: Not significant

The results of many of the relevant studies were similar to our study. For example, Kim et al¹⁸ in a systematic study concluded that the direct method has more accurate results than the indirect technique. Also, in their systematic studies, Baig²⁴ and Papaspyridakos et al²⁵ concluded that open tray technique is better than closed tray technique, especially in case of larger number of implants²⁴ and in edentulous patients.²⁵ Balamurgan and Manimaran¹⁴ examined the impression accuracy of direct transfer open tray and direct transfer snap-on impression coping closed tray techniques and showed that casts which were obtained by the open tray technique were more accurate. Bambini et al,²⁶ Daoudi et al,^{27,28} Carr,¹¹ and Spector et al²⁹ stated that closed tray technique is less predictable compared with the open tray technique. Patil et al⁵ in a comparative analysis showed that the open tray impression technique with a special tray have shown the most accurate results among all the techniques.

There were studies, among the previous researches, in which the results were inconsistent with the results of the present study. Stimmelmayer et al³⁰ in their clinical study, and Prithviraj et al⁹ and Lee et al,³¹ in their systematic studies, stated that pick-up technique is more accurate than the transfer technique in case of four implants or more. Prithviraj and Lee reported that when there are three implants or fewer, most of studies have not shown any differences between pick-up and transfer techniques. The results of these studies are somewhat different from the present study, in which three fixture analog was used. This difference could be due to the use of different implementation methods, different implant systems used, and different impression materials. Siadat et al³² compared the impression accuracy of open and closed tray impression techniques in the treatment protocol of All-on-4 for Noble Biocare implants and concluded that less displacement is seen when the open tray technique is used. Although they reported that abutment-level impression with open tray technique is more accurate,

implant-level impression was more accurate when closed tray technique was used. Since our study evaluated open tray and closed tray techniques just at the implant-level impression, it is not comparable to the above study from this aspect. Balouch et al³³ who compared the dimensional accuracy of closed tray and open tray impression techniques in 15° angled implants concluded that closed tray technique has less dimensional changes compared with the open tray technique; therefore, the closed tray technique is more accurate. The difference between the results of the present study and the above study could be due to use of different type of impression material (poly-ether in Balouch's study and PVS in the current study) as well as different angles of implants. Angled implants can cause much more stress in the impression material when the tray is going to be removed from the model or the mouth which can lead to permanent deformation in these materials.

Kempler³⁴ examined the effect of impression techniques, connection type, and positioning angle of the implant on the impression accuracy. Based on their results, there was no difference in terms of impression accuracy, using open and closed tray techniques except that closed tray technique was more accurate compared with the open tray technique in terms of horizontal plane values. The different results between the above study and the current study may be due to different methods of implementation, different implant systems, components, number of implants, implant angles, and different impression materials. Walker et al³⁵ examined the accuracy of casts with implants as a function of impression techniques and viscosity of impression materials. Impressions were made in this study, using closed tray or snap-on plastic impression caps in the implant and abutment levels respectively. Their results indicated that the casts fabricated from the indirect metal impression copings were more accurate than those that were made by plastic impression caps and this result was inconsistent with the results of the present study, which may be due to the difference implant systems, different types and consistency of the materials and the type of plastic caps. Ebadian et al³⁶ demonstrated that although less distortion rate was observed in the open tray technique, there was no significant difference between the closed tray and open tray impression techniques. The differences between the present study and the above study can be attributed to differences in the implant systems and the types of impression copings used in closed technique (closed impression copings with ball top screw). Papaspyridakos et al²⁵ did not find substantial difference between the open tray and closed tray techniques in partially edentulous patients. Mpikos et al,³⁷ Conrad et al,³⁸ Herbst et al,³⁹ and Carr⁴⁰ also did not report significant differences between

closed tray and open tray techniques, while Tsagkalidis et al¹³ who examined the accuracy of three impression techniques of nonsplinted, splinted, and indirect snap fit with the open and closed tray in angled implants concluded that splinted impression technique has higher accuracy than other techniques, and indirect snap fit technique has the lowest accuracy among all studied techniques when the implant angle is between 0° and 25°. A reasonable explanation for this could be that the plastic caps are completely covered by the impression material, made the visual control difficult when the implant analogs were placed again. Furthermore, such impression inaccuracy can be due to failure of full placement of closed tray transfer inside the snap fit impression cylinder or adversely due to the too much placement-induced pressure leading to the deformation in the impression material.

In contrast to this study, Nakhaei et al¹² who examined the dimensional accuracy of various impression techniques for Biohorizons and Strumann implants concluded that snap-on impression technique has higher dimensional accuracy than the transfer coping technique; but its accuracy is similar to the open tray technique. In a study on ITI implants, Akça and Çehreli⁴¹ also concluded that the snap-on technique dimensional accuracy is similar to direct impression technique. In addition, Çehreli and Akça⁴² also acknowledged in a study that use of snap-on technique in Strumann implants results in an acceptable superstructures, regardless of the types of the impression materials. Different implants systems, different forms of snap caps, and impression copings and Strumann system equipped with a piece called positioning cylinder which leads to more accurate reimplantation of the impression copings, and finally, different consistency of the impression material used in these studies are among the causes that can be cited for the inconsistency between the results of these studies and the present study.

CONCLUSION

Based on the results of this study, open tray impression technique had the highest dimensional accuracy than other two techniques. Also closed tray with snap cap technique was more accurate than closed tray with impression coping technique, but this difference was not statistically significant.

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