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EFFECT OF IMPRESSION MATERIALS AND TECHNIQUES ON IMPRESSIONS ACCURACY FOR ANGULATED IMPLANTS

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ABSTRACT

Purpose: Reproducing the intraoral relationship of implants through impression procedures is the first step in achieving an accurate, passively fitting prosthesis. This study was designed to evaluate the effect of three different impression materials, polyether (PE, Impregum™Soft), additional silicone (PVS, Enthus) and vinyl siloxanether (VSXE, EXA'lence), on the accuracy of impressions in nonparallel implants.

Material and Methods: An epoxy resin completely edentulous mandibular model with three implants (OsseoLink USA LLC. 4 mm ×9 mm, internal connection type) with different angles (0 and 15 degrees) was used as reference model. Sixty stone casts were made from the reference model using three impression materials; polyether (PE, Impregum™Soft) Group 1, additional silicone (PVS, Enthus) Group 2 and vinyl siloxanether (VSXE, EXA'lence) Group 3 with two impression techniques indirect and direct technique. The inter-implant distances were measured for casts using a coordinate measuring machine and the deviations compared to the reference models were calculated. Data were collected, tabulated and statistically analyzed using one-way ANOVA followed by Tukey's Post-hoc test to detect significance between groups (P=0.05).

Results: Tukey's Post-hoc test in the indirect technique showed non-significant differences (p>0.05) between VSXE and PVS for $\Delta r1$ and $\Delta r2$ while showed significant differences (p> 0.05) between VSXE and PE also between PVS and PE for $\Delta r1$ and $\Delta r2$, while Tukey's Post-hoc test in the direct technique showed significant differences (p<0.05) between VSXE and PVS, between VSXE and PE and between PVS and PE groups for $\Delta r1$ and $\Delta r2$.

Conclusion: Within the limitations of this study, for nonparallel implant conditions, the distortion values of casts produced by VSXE was significantly lower than casts produced by PVS, which was significantly lower than casts produced by PE in direct impression technique, while VSXE and PVS produced casts with more accuracy compared to casts produced by PE group in the indirect impression technique.

KEYWORDS: Dental implant, Impression material, Impression technique.

This study was conducted at faculty of dentistry, Tanta University, Egypt after the approval of the Ethics committee of the faculty.

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INTRODUCTION

In dental implant prosthesis, fabrication of passively fitting prosthesis will lead to the long-term success of the restorations[1]. Reproducing the intraoral relationship of implants through impression procedures is the first step in achieving an accurate, passively fitting prosthesis. The critical aspect is to record the 3-dimensional orientation of the implant as it is present intraorally, other than reproducing fine surface detail for successful implant prosthodontics treatment[2,3].

Magnified dissipation of stresses, due to a lack of passivity has been proposed to be associated with mechanical failure of the restorative components, and of the implants themselves, due to peri-implant bone loss[4].

Literature shows that the accuracy of the implant cast depends on many factors; the type of impression material, implant impression technique, the implant angulation, the die material accuracy, and the master cast[2].

There are two main techniques for dental implants impression, the direct (open tray) and indirect (closed tray) impression technique. The open tray technique allows for the impression coping remaining in the impression. This reduces the effect of the implant angulation, the deformation of the impression material upon recovery from the mouth, and removes the concern for replacing the coping back into its respective space in the impression. Disadvantages of this technique are that there are more parts to control when fastening, there may be some rotational movement of the impression coping when securing the implant analog, and blind attachment of the implant analog to the impression coping may result in a misfit of components[5].

There may be clinical situations which indicate the use of the closed tray technique, such as when the patient has limited interarch space, a tendency to gag, or if it is too difficult to access an implant in the posterior region of the mouth. The closed tray technique uses a single-piece impression coping that remains attached intraorally to the implant once the impression is removed from the mouth[6]. The coping is then removed from the implant, attached to the implant analog, and carefully repositioned with the correct orientation back into the impression[5]. Supporters of the closed tray technique suggest that it is more reliable as visual fastening of the analog to the coping is more accurate. There is concern that inaccuracies with recovery and subsequent deformation may be encountered with nonparallel implants. Impression copings must also be repositioned exactly into their respective positions in the impression, otherwise, misfits will occur[5].

A lack of parallelism among the implants, and that between the implants and the teeth is a common finding in clinic, which is due to anatomical limitations or the esthetic considerations. While unfavorable angulation can be corrected with the restoration, the lack of parallelism in implants and the presence of undercuts create an undesirable path of placement that may distort the impression material upon removal and may produce an inaccurate master cast, especially when multiple implants are used[7].

Among the impression materials so far used for implant impression, polyether and additional silicone (A-silicon) are mostly suggested [2, 8-11]. Many published studies have validated usage of polyether as an impression material for multiunit implant-retained restorations in completely edentulous situations for its properties of low strain during compression with an optimum Shore A hardness[12-14]. In contrast, use of addition silicone as an impression material permits easy removal once the impression is set due to its more favorable modulus of elasticity and therefore has also been recommended as a preferred material for implant impressions using direct technique[15-18]. Henceforth, it could be concluded that polyether and addition silicone are the most commonly recommended materials of choice for multi-implant impressions.

Advances in elastomeric chemistries have given origin to a new generation of impression material that is a combination of polyvinylsiloxane and polyether material called vinylsiloxanether, which has been made available commercially. It combines some of the most desired properties of both into one material. This has been claimed by the manufacturer to possess acceptable mechanical and flow properties, besides its unique wetting characteristics. Moreover, the accuracy of impressions is improved by its enhanced hydrophilicity resulting in improved flow with recording of finer details of impression[19,20]. However, there is an insufficient scientific evidence to prove its clinical efficiency as an impression material for multiunit implant impressions.

The aim of the present study was to evaluate the effect of three different impression materials; polyether (PE, Impregum™Soft), additional silicone (PVS, Enthus) and vinyl siloxanether (VSXE, EXA'lence), and impression techniques (indirect and direct) on the accuracy of impressions in nonparallel implants.

MATERIALS AND METHOD

Fabrication of master model:

An epoxy resin (Ramses medical products factory, Alex, Egypt) completely edentulous mandibular model representing a clinical situation was used as reference cast.

The cast had received three implants (OsseoLink USA LLC. 4mm × 9mm, internal connection type); implant at the midline perpendicular to the horizontal plane of the cast and two implants at the premolar regions angulated at 15 degree to a line drawn perpendicular to the occlusal plane in the following manner :

The master cast was held in a vertical milling machine (Milling &Drilling machine, RF-Sakkary, Taiwan), and holes matching the depth, diameter and angulation of the implants were prepared. A protractor was used to align the cutting bur in the proper angulation by tilting the milling machine table **(Figure 1)**.

Fig. (1) The drill at the premolar region is 15° to a line drawn perpendicular to the occlusal plane.

Custom tray fabrication:

Preparation of stone duplicate:

After the impression copings were connected to the master model, the space for impression material was created with two sheets of baseplate wax (Cavex setup waxes, Haarlem, Holland) around the copings and over the ridge area and stoppers (2x4mm) were made on the molar regions to standardize the tray position and impression material thickness at 3 mm.

An impression was taken from the model, using condensation silicone (Zetaplus, Zhermack SpA, Italy). Impressions were boxed and poured with type IV dental stone (elite® stone, Zhermack GmbH Deutschland) in a vacuum device. The stone was set for 30 minutes and the impression was separated. The stone cast was used to fabricate all the custom trays.

Preparation of the master custom tray

Separating medium was painted on the stone duplicate before making the master custom tray. Self-cured acrylic resin (Acrostone cold cure special tray material, Cairo, Egypt) was mixed following the manufacturer's instructions and when reached the dough stage, the mix was pressed between two glass slabs to give 2 to 3 mm thick layer, then it was adapted over the stone duplicate.

The tray was left for 24 hours to allow for polymerization shrinkage, and then it was removed from the model, trimmed and smoothened. Then replaced on the master model and verified for clearance of 2-3 mm between it and the model.

Preparation of the custom trays:

A two-part mold was fabricated using the master custom tray and type IV dental stone in a dental flask to make 60 identical custom trays of a 2-mm self cured acrylic resin (Acrostone cold cure special tray material, Cairo, Egypt). The trays were trimmed, perforated for added retention of the impression material and these trays were divided into:-

- Thirty closed trays for the indirect technique.
- Thirty trays with a window cut over the implant for the direct technique to allow access to the long coping screws

The trays were stored at the room temperature for 24 h before impression taking.

Impression Procedure:

In this study, there were six experimental groups (due to the three impression materials evaluated using two impression techniques). A sample size of 10 was used in the experimental groups.

Polyether (PE) (Impregum™ Soft, 3M Deutchland GmbH, Neuss- Germany) Group 1, addition silicon (PVS) (Enthus Impression Material, Dharma Research, USA) Group 2 and vinyl siloxanether (VSXE) (EXA'lence, GC EuropeNV, Leuven, Belgium) Group 3 impression materials, all with medium consistency, were selected for this study.

The impression protocol was standardized as follows:

1. A 1.5 kg metal block exerted a standardized pressure on each tray during the polymerization to force the excess material to flow out and to maintain constant pressure throughout the working time.
2. The impression copings were secured with flat head screw on the implant analogues using dedicated torque wrench calibrated at 10 Ncm.
3. The custom trays were filled with regular body impression material mixed using an impression gun. The same material was also syringed around the impression copings on the epoxy resin cast.

In the Indirect technique, the impression copings remained on the definitive cast after the impression material had polymerized when the tray was removed. These impression copings were removed and attached to an implant analog. The combined impression coping analog unit was inserted into the impression by firmly pushing it into place to full depth till hearing the audible click and slightly rotating clockwise to feel for the anti-rotational resistance.

In the direct technique, the guide pins were loosened with a hex driver and removed, the tray was separated from the definitive cast, and the impression copings remained locked in the impression. The guide pins were placed back into the open tray impression copings from the top, while an implant analog was connected to the hex on the bottom, and the guide pins were tightened with the driver.

The impressions were stored at room temperature for at least two hours before pouring the casts[8].

Cast Production Procedure:

All the impressions were poured with type IV dental stone (elite® stone, Zhermack GmbH Deutschland) using a single prefabricated mold made with laboratory silicone (Ramses medical products factory, Alex, Egypt) to obtain standardization of the resulting casts and the amount of dental stone used.

After the stone had been allowed to set for 1 hour, the casts were separated from the impressions, trimmed, and the three healing abutments were tightened to their respective implant analogues for each cast before the measuring procedures. All casts were labeled and stored at room temperature for a minimum of 24 h prior to measurements.

Measurement Procedure:

A coordinate measuring machine (CMM) (Mitutoyo CRYSTA-Apex S544, Japan) (Egypt-Japan University of Science and Technology, Egypt) was used to evaluate the positional accuracy of the samples. The accuracy of the CMM according to the manufacturer was 0.0001mm **(Figure 2).** The implant abutments are donated as seen in **(Figure 3).**

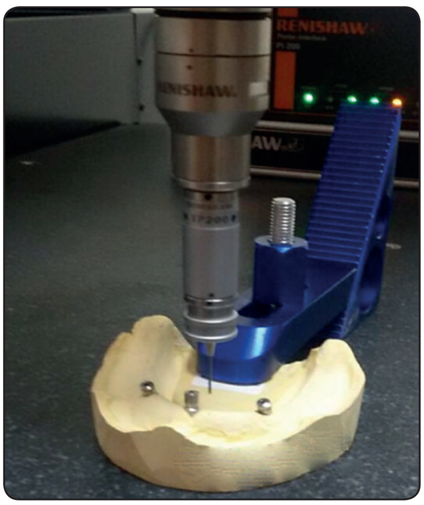

Fig. (2) Measurement of stone cast.

The center of abutment 1 is considered as the reference point for all measurements. The planar surface from this point was regarded as XY. Two imaginary XZ lines were considered between the centers of the analogue 1, 2 and 1, 3. The XZ planes were perpendicular to XY plane. Therefore, the center of analogue 1 was laid on the origin (0, 0, 0). For each analogue in the master models as well as the definitive casts, CMM measured the coordinates (X, Y and Z) of each analogue with respect to the determined reference axis **(Figure 4).**

The center of each implant abutments was located using a CMM probe with a diameter of 1 mm by touching eight points on the circumference of the outer diameter of the implant abutments.

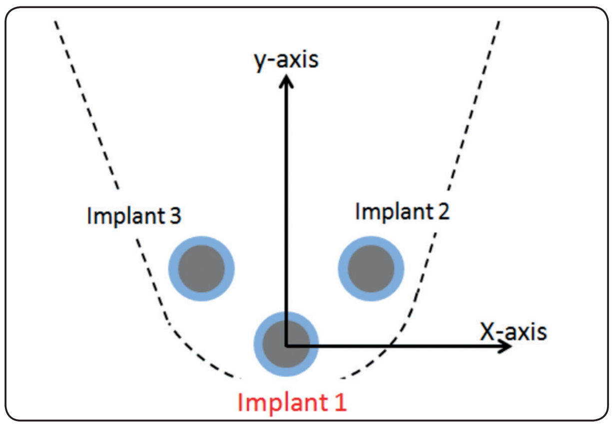

Fig. (3) Implant donations.

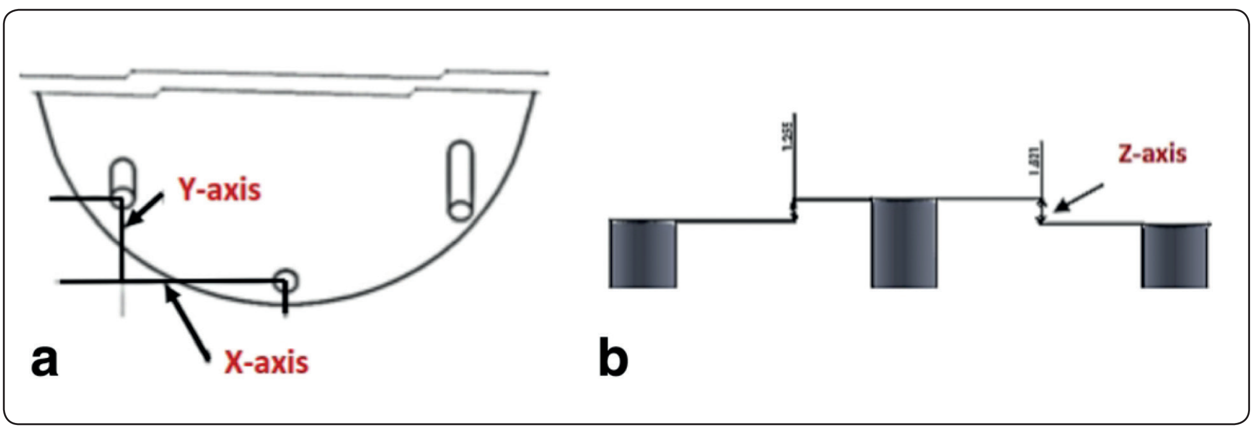

Fig. (4) a) Inter-implant distances in X- and Y-axes. b) Inter-implant distance in Z axis

Four points on the upper surface of each implant abutment were measured to form a plane used to calculate the vertical distances between implant abutments 1 and 2 and 1 and 3 in the z-axis.

Three measurements were recorded for inter implant distances in x, y, and z axis, and then the mean values were calculated. Six inter implant distances were measured for the reference models and for each of the 60 casts.

The distances (in micrometers) between the implant analog centers with the reference point were calculated according to the following formula [21]:

The distance from the reference point (r) =

$$\sqrt{x^2+y^2+z^2}.$$

The absolute error (Δ r) of impression for each pair of implant analogs was computed as the Euclidean distance between the analogs in the duplicated cast with the distance in the master cast regardless of its direction:

$$\text{Absolute error } (\Delta r) = \sqrt{x_{m+}^2 y_{m+}^2 z_m^2} - \sqrt{x_{d+}^2 y_{d+}^2 z_d^2}$$

Where m = master; d = duplicated.

The mean average values obtained from the casts were compared with the standard values acquired from the reference model and the differences were calculated. A spreadsheet (Excel 2016, Microsoft) was customized and employed to accomplish this task.

Each model has two Euclidean distances and named Δ r1 (absolute error between implant abutments 1 and 2) and Δr2 (absolute error between implant abutments 1 and 3).

Statistical analysis:

Data analysis was performed for each group and descriptive statistics including mean and standard deviation were calculated and reported for each Euclidean distance. Data were statistically analyzed using one-way ANOVA followed by Tukey's Post-hoc test to detect significance between groups (P=0.05).

RESULTS

The mean descriptive values of distortion for the three impression materials with both techniques were obtained and provided in **Table (1).**

TABLE (1) Descriptive mean analysis of test impression materials (μm).

		Mean ± SD	
		Δr1	**Δr2**
Indirect technique	**VSXE**	41.48±9.1	44.71±8.4
	PVS	45.13±9	48.94±10
	PE	57.07±6.27	59.66±8.7
Direct technique	**VSXE**	38.11±3.18	37.08±3.77
	PVS	44.31±5.35	45.12±2.76
	PE	55.88±5.29	55.89±7.79

In the indirect technique: One-way ANOVA between the three impression materials revealed statistically significant differences in deformation (Δ r1 or Δ r2) between VSXE, PVS and PE (F= **9.676, 6.775** P-value= **0.000, 0.004** for Δr1 and Δr2 respectively) as shown in **table (2).**

TABLE (2) Comparison of test impression materials with indirect technique (*Significance: P < 0.05).

Comparing between the groups with **indirect technique**				F	P-value
	Group1 PE	**Group 2 PVS**	**Group 3 VSXE**		
	Mean±SD	**Mean±SD**	**Mean±SD**		
Δr1	57.07±6.27	45.13±9	41.48±9.1	**9.676**	**0.000***
Δr2	59.66±8.7	48.94±10	44.71±8.4	**6.775**	**0.004***

Tukey's Post-hoc test in the indirect technique showed non-significant differences (p>0.05) between VSXE and PVS for Δr1 and Δr2 while showed significant differences (p0.05 <) between VSXE and PE also between PVS and PE for Δr1 and Δr2 as shown in **table (3).**

TABLE (3) Comparison of test impression materials with indirect technique with Tukey's Post-hoc test.

Indirect technique		***Tukey's Post hoc***	
Comparing between materials		***P value***	
		Δ r1	**Δ r2**
PE	**PVS**	0.009*	0.042*
PE	**VSXE**	0.001*	0.004*
PVS	**VSXE**	0.592	0.576

****Significance: P < 0.05***

In the direct technique: One-way ANOVA between the three impression materials revealed statistically significant differences in deformation (Δ r1 or Δ r2) between VSXE, PVS and PE (F= **36.538, 32.360** P-value= **<0.001** for Δ r1 and Δ r2 respectively) as shown in **table (4).**

TABLE (4) Comparison of test impression materials with direct technique.

Comparing between the groups with **direct technique**				F	P-value
	Group 1 PE	**Group 2 PVS**	**Group 3 VSXE**		
	Mean±SD	**Mean±SD**	**Mean±SD**		
Δr1	55.88±5.29	44.31±5.35	38.11±3.18	**36.538**	**<0.001***
Δr2	55.89±7.79	45.12±2.76	37.08±3.77	**32.360**	**<0.001***

****Significance: P < 0.05.***

Tukey's Post-hoc test in the direct technique showed significant differences (p<0.05) between VSXE and PVS, between VSXE and PE and between PVS and PE groups for Δ r1 andΔ r2 as shown in **table (5).**

TABLE (5) Comparison of test impression materials with direct technique with Tukey's Post-hoc test .

Direct technique		***Tukey's Post hoc***	
Comparing between materials		***P value***	
		Δ r1	**Δ r2**
PE	**PVS**	<0.001*	<0.001*
PE	**VSXE**	<0.001*	<0.001*
PVS	**VSXE**	0.018*	0.005*

****Significance: P < 0.05***

DISCUSSION

Accurate impression registration in implant dentistry is important to accurately relate an analog of the implant or implant abutment to the other structures in the dental arch[19].

The relation between implant angulation and impression materials and techniques can be established that as with increase in angulation, the amount of forces of deformation increases which require an impression material which can withstand these forces that affect the accuracy of master cast[21] and also requires an impression technique that allows precise inter-implant relationship[22].

The goal of this study was to evaluate two well- recognized impression techniques using three impression materials and compare their accuracy with the requirements of passive fit for non-parallel implants as Stimmelmayr et al[23] found that if multiple implants are parallel to each other, there will be no horizontal shift in the transfer; while if the implants are positioned angled, the rotational misfit leads to a horizontal discrepancy.

Also, it is reported that angular positional transfer deformation increases with an increase in an implant's buccal/lingual inclination with respect to horizontal crestal plane. As implant angulations increase, distortion in the experimental cast increases. This can be explained with increased material deformation upon impression removal. Especially in multiple implant cases, an increase in implant angulation increases the area of friction and the amount of stresses generated in an impression decreasing impression accuracy [24].

The model selected in this study had three implants; implant at the midline perpendicular to the horizontal plane of the cast and two implants at the premolar regions angulated at 15 degree to a line drawn perpendicular to the occlusal plane. This was a simulation to a common clinical situation that may necessitate placement of angulated implants in lower premolar region as the submandibular fossa mandates implant placement with increasing angulation as it progresses distally [20]. Furthermore, unlike most of previous studies, the implants in this study were also tilted to the mesial side, which better represents clinical conditions[25].

In this study, impressions were made at implant level because it allows for the selection of the most proper abutments and is helpful in situations where angulation of the abutments is difficult to be determined intraorally[10,26].

Three elastomeric impression materials have been used for implant impressions including addition silicon (PVS), polyether (PE) and vinyl siloxanether (VSXE) impression materials. PE and PVS have frequently been used for this in vitro studies on implant impressions[10,27]. Very few studies are available demonstrating the efficacy of VSXE [21, 28-30].

In the present study, the experimental protocol was meticulously standardized. This included use of custom trays with a uniform thickness of impression material, repeatable impression techniques, prefabricated mold for working cast production and a reliable measurement technique. The purpose of this standardization was to allow a careful evaluation of different impression techniques and impression materials while isolating other related variables, particularly those associated with laboratory procedures.

Studies comparing the accuracy of implant impression techniques with methods such as micrometers, Vernier calipers, strain gauges, or measuring microscopes could merely carry out two-dimensional measurements. However, when the measurements are 2 dimensional only, relevant information is lost. Therefore, coordinate measuring machine (CMM) was used as the measuring device in this study because it made three-dimensional evaluation of any distortion possible[11,31-33].

Results of this study showed that in the direct impression technique, the distortion values of casts produced by VSXE was significantly lower than casts produced by PVS, which was significantly lower than casts produced by PE.

Sorrentino et al[10] recommended the use of a rigid impression material as PE for fully edentulous and multiimplant cases for direct impression technique as the impression material should show sufficient rigidity to hold the coping in its position and prevent any displacement during the removal of the impression.

On the other hand, Papaspyridakos et al[34] and Vigolo et al[35] found that the elastic recovery is a significant factor in determining the accuracy of an impression material and the use of a more elastic material may reduce the permanent distortion caused by the stress between copings and the implant impression material. Thus, VSXE showed the least distortion followed by PVS in this case of nonparallel implants and this was in agreement with Alam-Eldein and Elshenawy[21] and with Shankar et al [30].

This might be explained by the fact that VSXE is more rigid than regular body PVS, thus preventing movement of the impression copings inside the impression material[31]. Integrating the qualities of PE and PVS into a newer material VSXE has demonstrated good mechanical and flow properties along with excellent wetting characteristics in the unset as well as set conditions. One of the other reasons for improved accuracy of VSXE is the enhancement of the hydrophilicity which may influence the accuracy of impressions and can result in improved flow and finer detail of impressions made on moist dentinal surfaces and in the area of the gingival sulcus[28,29]. The composition of this new material is intended to incorporate the natural hydrophilicity of conventional PE materials along with the desirable properties of additional silicone materials such as elastic recovery and tear resistance.

In this study, with the indirect impression technique, VSXE and PVS produced casts with more accuracy compared to casts produced by PE group; this may be explained by the presence of angulations between adjacent implants can increase the amount of dislodgement, the removal forces and the consequent impression distortion. Moreover, the large contact area between an impression coping and an implant is in internal-connection implants that result in increased dislodgement of impression material when removing the impression tray from the mouth[26].

VSXE having optimized elastomeric properties showing dimensionally accurate recovery and easy removal from the mouth showed the least distortion[36]. PVS exhibits accuracy (showing minimal distortion), which made them comparable to VSXE in the indirect technique.

Very few studies have been available in literature citing the accuracy of VSXE. The results of the present study positively supplement the existing studies[21, 28,37].

This in vitro study has some limitations. All impressions were taken under ideal conditions without the presence of soft tissues, blood, saliva and sulcular fluid, which may affect the accuracy of the impressions. In addition, the results are limited to three internal connection implants and may not be relevant with higher number of implants and different connection geometries.

CONCLUSIONS

Within the limitations of the study, it can be concluded that:

1. In the direct impression technique for nonparallel implant conditions, the distortion values of casts produced by VSXE was significantly lower than casts produced by PVS, which was significantly lower than casts produced by PE.
2. With the indirect impression technique for nonparallel implant conditions, VSXE and PVS produced casts with more accuracy compared to casts produced by PE group.
3. The relation between the angulation and impression material can be established that as with increase in angulation, the amount of forces of deformation increases which require an impression material which can withstand these forces that affect the accuracy of master cast.
4. Further clinical studies testing more implants, different angulations and connection geometry are needed to evaluate the accuracy of implant impressions.

Conflict of interest:

The Authors declare that they have no conflict of interest, have full control of all primary data.

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