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Dimensional Accuracy of Polyether and Poly Vinyl Siloxane Materials for Different Implant Impression Technique

K. Seyedan, H. Sazegara, M. Kalalipour and K. Alavi
Dental School, Shaheed Beheshti University of Medical Sciences, Tehran, Iran

Abstract: Passive fit is one of the most important requirements for successful implant supported prosthesis. Failure to achieve passive fit can result in complications. Present study evaluated dimensional accuracy of polyether and poly vinyl siloxane impression materials, used with different impression techniques in splinted and nonsplinted implants. Ten samples were made for each group. The model was fabricated to obtain 4 implants by the diameter of 4 mm. Forty trays were fabricated with metacrylate composite resin. Four groups of impression materials (poly vinyl siloxane and polyether) and procedures (splinted vs. nonsplinted) were used. Implant abutments were placed on implant analogues after impression techniques were completed and ball tops were also seated on the abutments. Abutment distances were measured by Coordinate Measuring Machine (CMM) machine by an automatic probe measuring the center of ball tops from each other and also a reference point. The records were analyzed by descriptive statistics, one way and 2 way analysis of variances. We did not observe any statistically significant difference between Δx and Δy values of the 2nd and 3rd implants comparing to the 1st implant. In the 4th implant, the difference in length of splinted group was less than nonsplinted group. Within the limitations of the present study, 2 impression materials exhibited no error differences. But, splinted technique produced less error in the 4th implant compared to nonsplinted technique.

Key words: Implant, supported prosthesis, dimensional accuracy, passive fitness, impression

INTRODUCTION

The connection of a fixed partial denture (FPD) to osseintegrated implants produce a unified structure in which the FPD, the implants and the bone act as one unit and any misalignment of the FPD to osseointegrated implants may induce internal stresses in the FPD, the implants and the bone matrix (Branemark *et al*., 1985; Adell, 1983; Zarb and Zarb, 1985; Skalak, 1983; Brunski, 1988). When fabricating superstructure on osseointegrated dental implants, the primary objective is to produce a prosthesis that fits accurately and passively (Branemark *et al*., 1985; Adell, 1983; Zarb and Zarb, 1985). Endosteal implants distribute the physiologic loads onto the surrounding supporting tissues, implants unlike natural teeth cushioned in alveoli by periodontal fibers are somewhat intolerant to movement in their adaptation to the demands of the metal supporting structure (Skalak, 1983; Brunski, 1988; Lemons and Bidez, 1993). Failure to achieve passive fit can result in bone microfractures, zones of marginal ischemia and fibro integration of the implant producing major risks for the implants treatment (Skalak, 1983). Non passive prosthesis also may lead to unsteady restorations, crestal bone loss and implant fracture and mobility (Misch Carl, 2005).

The range of clinically tolerable stress regarding the long-term retention of implant prosthesis is still unclear (Spector *et al*., 1990; Lundqvist and Carlsson, 1983). Accurate impression, fabrication of a model to precisely reproduce implant position and avoiding distortion during model transfer the laboratory are required for passively fitting casts (Wee, 2000).

Several implant impression techniques have been advocated to achieve a definitive final cast with passive fit of prosthesis on implants. Branemark *et al*. (1985) emphasized on the importance of splinting impression copings intraorally before making the impression. This technique is used by some others with modifications (Herbst *et al*., 2000; Roberts *et al*., 1984; Sullivan, 1986; Hobo *et al*., 1991; Jemt, 1996; Kohavi, 1997). Zarb and Zarb (1985) used splinted impression copings with autopolymerized acrylic resin and dental floss to produce more accurate casts, while Assif *et al*. (1999) showed when acrylic resin was used to splint transfer copings in an impression, all casts were more accurate. But, Humphries *et al*. (1990), Hsu *et al*. (1993) and Herbst (2000) did not report any significant difference between splinted and nonsplinted impression technique. Also, splinting is mentioned to reduce implant impression accuracy by Inturregui *et al*. (1993) and Burawi *et al*. (1997).

Corresponding Auhtor: K. Seyedan, Dental School, Shaheed Beheshti University of Medical Sciences, Tehran, Iran

Rigidity to hold the direct impression coping and prevent accidental displacement of the coping and minimal positional distortion between implant analogues as compared with their intraoral implants are 2 important characteristics of impression materials. Consequently, polyether and poly vinyl siloxane materials are preferred to others (Wee, 2000), although, no significant differences was observed between the accuracy of implant restorations fabricated from polyether and poly vinyl siloxane in the study of Barrett *et al*. (1993). Others suggested polyether as to produce more accurate casts (Branemark *et al*., 1985; Adell, 1983; Zarb and Zarb, 1985; Skalak, 1983; Brunski, 1988; Lemons and Bidez, 1993). Vigolo *et al*. (2004) declared poly vinyl siloxane could possibly reduce permanent distortion of impression material.

Mahshid and Ashtiani (2005) reported no significant difference among techniques of splinted and nonsplinted with open and perforated trays. The techniques didn't transfer the location of indicated points of laboratory model to master casts on X, Y, Z axes or spatial position of them precisely. Vigolo *et al*. (2004) reported splinted square copings with autopolymerizing acrylic resin will provide more accuracy. The same researchers showed; splinted square copings with autopolymerizing acrylic resin and sandblasted square copings will provide more accurate results in implant superstructures compared to nonsplinted impression technique (Vigolo *et al*., 2003). Herbst *et al*. (2000) revealed no clinical advantages of splinting impression copings with acrylic resin. Wee (2000) showed more dimensional accuracy for polyether and addition silicones materials. Due to the controversy in the field, this study was designed to evaluat dimensional accuracy of polyether and poly vinyl siloxane materials for splinted and nonsplinted implant impression techniques.

MATERIALS AND METHODS

Forty specimens studied in this experimental study, were assigned randomly in 4 groups. A steel model of 8×8 cm^2 size was fabricated while four 10×3 mm^2 slots were engraved on the model to act as stops and standardize tray position during impression. An 800N weight distributes an even load to all impression copings (Vigolo *et al*., 2004). Four implants (Biohorizon Maestero, USA) 4 mm in diameter cemented on the steel model by cyanoacrylate adhesive numbering from right to left. Impression copings (Impression coping Hexed, Biohorizon Maestro) were connected to implants by coping screws (Fig. 1). Forty similar custom trays fabricated according to the manufacturer's instruction with light polymerizing methacrylate composite resin (Loffelmaterial UV Band/Germany) with 2 mm thickness.

Four reference model implants were covered with 2 layers of base plate wax (Modeling wax, high stability Densply) to produce similar thickness of impression material. The reference model impression was made by Elite-H-Dt (Zhermak, Italy). It fully reproduced the stops, while a similar impression was used for all trays (Fig. 1 and 2).

Four apertures were made on trays against the implant centers of coping screws. All trays were fabricated 24 h prior to implant impression.

Impression techniques included nonsplinted with open tray and polyether, nonsplinted with open tray and poly vinyl siloxane, splinted with open tray and polyether and splinted with open tray and poly vinyl siloxane impression materials.

Group A: Impression trays were coated with polyether adhesive 15 min before each impression and square impression copings were screwed with coping screws to the implants (Fig. 3).

Polyether impression material (Impregum F 3M ESPE) mixed for 45 sec, while small amount of the materials was carefully syringed around the impression copings. The remaining impression material was used to load the impression tray. Impression tray was placed on the

Fig. 1: Model impression

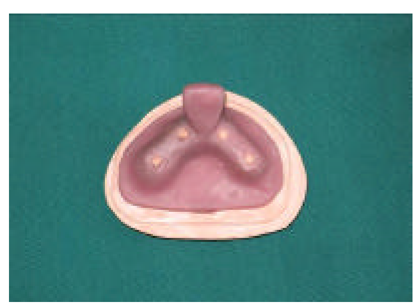


Fig. 2: Impression tray

Fig. 3: Impression tray coated with adhesive

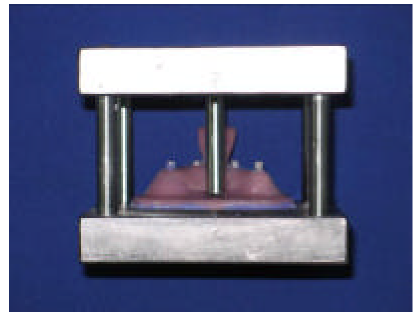


Fig. 4: Impression placed in Model

reference model so that the tray was fully seated on the 4 stops. The 800 N steel sinker was placed on the impressions during setting procedure (setting time was 6 min) (Fig. 4). Then, the coping screws were released so that the impression could be removed. The Analogues were screwed to Impressions (Fig. 5).

Group B: In these specimens, impression copings were splinted with autopolymerized acrylic resin (Duralay, GC, USA) (Fig. 6).

Shrinkage of acrylic material mostly occurs at first 24 h with 80% in the first 17 min, the resin splint was performed 24 h before the impression procedure to overcome the shrinkage of acrylic polymerization. The resin splint was cut in 3 points with a standard 0.2mm distance. The pieces were reconnected before the impression by Bead-Brush Technique (Vigolo *et al*., 2004). Adhesive material was applied 15 min before the procedure and impression was made as previously stated in the first group.

Group C: Poly vinyl siloxane impression material (hydrophilic, vinylpolysiloxane, Elite, HD+, regular, Zhermack) was used in the third group. The custom made light cure impression trays were coated with adhesive (Elite, Perlink LCT) left untouched for 15 min. The impression material was mixed with mixing gun (Coltene Whaledent/Swiss) and syringed around the copings. Complete setting time of 5.5 min was repeated according to the manufacturer's instructions. Afterwards, the coping screws were released and impression was removed from the reference model. The steel sinker was on the impression tray (as previous groups) using tray stops for similar positioning of the trays.

Group D: The specimens were splinted like group B and the impression procedure was done like group C, by poly vinyl siloxane impression material. Implant analogues were connected to copings (Biohorizon Maestro, USA). All

Fig. 5: Impression with Implant Analogues screwed into

Fig. 6: Impression copying s splinted with autopolymerized resin acrylic

impressions were poured with dental stone (Shera Maximum, Germany) with 100 mg/20 m/liquid/powder ratio in accordance to the manufacturer's instructions. Dental stone was mixed with Vacuum Mixer (Easy Mix, Bego, Germany) and impressions poured. The casts were retrieved from the impressions after 24 h. All casts were stored at room temperature during this time. All clinical and laboratory procedures were performed by the same operator.

Implant abutments (Abutment for Cement, Hexed, Biohorizon Maestro, USA) were screwed to the analogues (External; Hexed 4 mm, Implant Analogue, Biohorizon, USA) and ball top screws (Biohorizon Maestro, USA) were screwed to them for measurements. Coordinate measuring machine (CMM) (TRIMEK Spark, 12.10.07, Spain) was used to evaluate the positional accuracy of samples (Fig. 7).

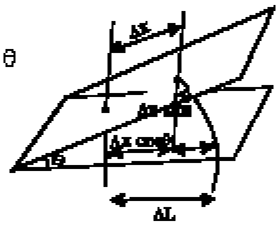
The instrument was capable to move in its confine in the space measuring points dimension by the probe by means of its computerized numerical control system (Fig. 8 and 9).

$\Delta L = \Delta x \cos\theta + \Delta x \sin\theta \times \theta$

$\Delta L = \Delta x (\cos\theta + \sin\theta \times \theta)$

$\sin\theta \approx \theta$ and $\cos\theta \,\Delta\, 1$

$\Delta L = \Delta x (1 + \theta^2)$



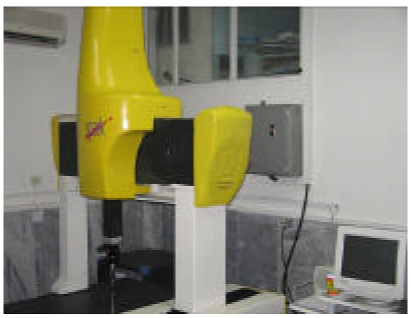


Fig. 7: Coordinate Measuring Machine (CMM)

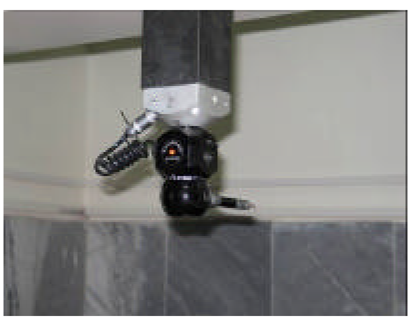


Fig. 8: Probe

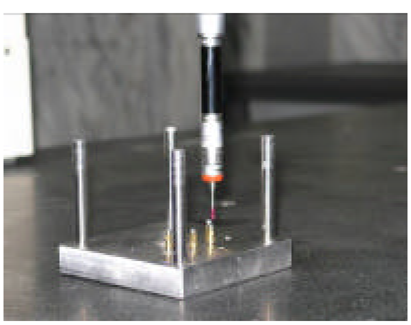


Fig. 9: Measuring over the ball top

As the specimen reference surfaces were not parallel to xy coordinates and vertical to z coordinate, the plane passing through center of the holes possibly would not be parallel to xy sheet. Then, Δx and Δy, the Δelative distance of x and y coordinates of 2 holes centers to each other produces a line according to numeral relationships.

So, the new created coordinates resemble the coordinates of center of the holes in a plane parallel to xy. The center of the holes in the samples was positioned similar to the reference model, so the linear distances between the specimens with their corresponding distances in the reference model was compared. All points were rotated until the line connecting first and 4th points are placed along the x coordinate. The linear distance between the points in the reference model was measured by setting first point of the samples on the same point in the reference model. Solidworks software-(software for making 3 dimensional models) was used to perform the mentioned procedures and determine the final coordinates of the points in order to measure their linear distance from the corresponding points in the reference model (Fig. 13 and 14) A new part was created in the software following a 3 dimensional sketch in that part. Coordinates of the 4 points measured by CMM machine were entered in the sketch, processing them as a 3 dimensional points in the space. Three points were selected randomly producing a plane. The 4th point was projected and limited to the plane. The plane was rotated to get parallel to xy plane. So, coordinates of the 4 points in every sample were measured parallel to xy plane. As the points were rotated in a way that the line passing the points 1 and 4 to the x axis, then a line passed every point and the line between 1 and 4 points superimposed on x axis using Along X command. So, all the points were rotated to place the line crossing 1 and 4 points x axis. The described procedures were repeated for all the samples and reference model. An assembly file was developed in Solidworks software (a program to compare 3-dimensional models with each other) and measurements of the x, y and z coordinates of the reference model and all samples were recorded. The first point of every sample were superimposed to the first point of the reference model using coincident command and the linear distance between the other points were assessed. So, the deviation of the points from the reference model was achieved. An average rate of the width and length was used in the implants and using the formula of

$$\left(\Delta R = \sqrt{(\Delta X)^2 + (\Delta Y)^2}\right)$$

consequent width and length dimensions were calculate. As z coordinate values of the samples were not subjected to final analysis as the records were fixed. To analyze data, we used SPSS10 software (SPSS, Chicago). One-way analysis of variance (ANOVA) was used for statistical analysis after test of variance homogeneity. Tukey's multiple comparisons test was used in the event of homogenous variances and otherwise Games-Howell test was employed. Two-way analysis of variance used to compare the interaction between impression materials and techniques. As type I error (á) was set at 0.05, $p<0.05$ was considered statistically significant.

RESULTS AND DISCUSSION

Δx and Δy values measured as the linear distance between the 2nd, 3rd and 4th implants with the first implant and the consequent distance calculated using Pythagorean theorem ($\Delta R^2=\Delta y^2+\Delta x^2$) (Table 1). The results revealed a significant difference between the length of the 4th implant and only its corresponding distance in all groups ($p<0.002$). Together with the fixed values of Δy, $(\Delta R)^2= (\Delta x)^2$, the ΔR would be equal to Δx.

Games-Howell test showed higher values of linear and consequent distances in poly vinyl siloxane + nonsplinted technique compared to poly vinyl siloxane + splinted technique and polyether + splint technique. But no significant differences were found between results of nonsplinted technique + poly vinyl siloxane and nonsplinted technique + polyether material (Table 2). No significant differences were found in other comparisons. Two-way analysis of variance was used to compare the interaction between impression material and technique. The results showed a significant difference between impression techniques ($p<0.001$) but not in the impression materials ($p>0.736$). Also, the interaction between impression techniques and impression materials was not significant ($p>0.333$).

The accuracy of 2 polyether and poly vinyl siloxane impression materials was evaluated in the present study. To prevent problems of resin polymerization shrinkage and also to save clinical chair time, the specimens were connected to each other 24 h prior to impression procedure and reconnected again after sectioning by a disk (Vigolo *et al*., 2004). A similar steel sinker was placed on the implants forcing the released stress to be equal after impression procedure throughout the study. As any deviation from the position of the implants would be misleading, so relative distances were considered to determine the positions of implants not absolute distances. Then, any deviation of 2 implants in the same side was achieved with no change in the distance. For this purpose, the implant distances were measured in 3 dimensions of length, width and height with a reference point by Solidworks software. As a result, errors in points positioning were assessed in spite of absolute distances of the implants. The study revealed no difference between the casts made of polyether and poly vinyl siloxane. The position of the 2nd and 3rd implants was similar to the first implant in all 4 groups. But, little errors were observed in the 4th implant using splint impression technique especially in the casts made of poly vinyl siloxane.

The results of the present study suggest that when impression copings are splinted with acrylic resin, more accurate definitive casts can be obtained. As the position of the 4th implants has been increased from 2nd and 3rd implants, the error may be increased consequently.

Mahshid and Ashtiani (2005) found no significant differences between 4 techniques of open tray + splinted, perforated tray + nonsplinted, perforated tray + splinted and open tray + splinted. Their results are similar to the present study. In their study, an exact reproduction of implant position was never accomplished in the x, y and z coordinates and also spatial orientation of the points.

Table 1: Mean (micrometer) and standard deviation of linear, width and consequent distances according to impression materials and techniques

	Linear distance		Width distance		Consequent distance	
	Mean	SD	Mean	SD	Mean	SD
Polyether + splinted	176.962	149.14	158.342	124.446	248.159	189.037
Polyether + nonsplinted	199.036	77.25	164.797	49.484	274.212	84.762
Poly vinyl siloxane + splinted	190.39	132.595	145.656	114.3	246.581	169.908
Poly vinyl siloxane + nonsplinted	183.321	54.746	98.755	30.756	221.679	64.978

Table 2: Result of Games-Howell test for paired comparisons when a significant differences were found between groups

			P value
Implant linear distance/consequent distance of implant 4	Polyether + splinted	Polyether + nonsplinted	0.289
		Poly vinyl siloxane + splinted	0.943
		Poly vinyl siloxane + nonsplinted	0.002
	Polyether + nonsplinted	Poly vinyl siloxane + splinted	0.195
		Poly vinyl siloxane + nonsplinted	0.852
	Polyvinyl siloxane + splinted	Poly vinyl siloxane + nonsplinted	0.004

The results of the present study were similar to some studies (Wee, 2000; Hsu *et al*., 1993; Herbst *et al*., 2000) and contradict others (Inturegui *et al*., 1993; Buwari *et al*., 1997; Humphries *et al*., 1990). The similarity of 2 impression techniques maybe due to decreased mass of the resin during connecting impression copings to prevent polymerization shrinkage or selecting suitable impression material to keep copings stable (Herbst *et al*., 2000).

Operator skill is also important to transfer the position of impression copings to implant analogue. This factor may justify the controversy about superiority of splinted and nonsplinted techniques. Little role is considered for satisfactory properties of the impression materials or acrylic resin.

Higher standard deviations and range of errors were observed in all groups. Also, some cases showed noticeable errors in the linear and width dimensions. Although, it was tried to control all interventional variables in the present study, but these variables surely will make great influence under clinical conditions. So, some instructions are needed to decrease the error rate. It seems that splinting the copings will prevent their movement in impression materials during impression procedure and connecting implant analogue to them.

The present study was carried on casts with 4 implants, so it is clear that if the number of implants changes the results also would change. Although, it was clearly visible that the error in the 4th implant was persisted among all study groups, but further studies are necessary to evaluate the errors absolutely or in comparison with other technique together with implant numbers.

Likewise all experimental studies, the results of present study were achieved under the described conditions in static environment while spatial dimensions are dynamic in body and therefore the complications of implant restorations may not be easily tolerated. Regarding different impression techniques and their pros and cons it is note worthy to consider the operator skills and clinical experience and its impact upon accuracy and precision of dental implant impression procedures.

CONCLUSION

The study revealed no significant differences between the 2nd and 3rd implants in all groups either on accuracy of the impression materials (polyether or poly vinyl siloxane) or impression techniques (splinted or nonsplinted). Splinted technique produced less error in the 4th implant.

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