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Original research

Dimensional accuracy of vinyl polyether and polyvinyl siloxane impression materials in direct implant impression technique for multiple dental implants

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Purpose

The present study compared the dimensional accuracy of vinyl polyether silicone (VPES) and polyvinyl siloxane (PVS) impression materials used for non-splinted (NS) and splinted (S) direct open-tray impression techniques for multiple implants inserted in simulated edentulous mandibles.

Materials and Methods

A mandibular stainless steel model with eight internal connections for implant analogs was fabricated to simulate a clinical scenario. The acrylic resin splinted and non-splinted direct impressions were obtained for both VPES and PVS materials. Seventy-two cast samples were divided into four groups based on the impression techniques and materials used. The dimensional accuracies of the casts were measured in three different axes using a computerized coordinate measuring machine (CMM), and were statistically compared.

Results

The differences in the distortion values between the VPES and PVS impression materials were not statistically significant. Similarly, the differences between the splinted and non-splinted groups among the VPES and PVS materials were not statistically significant.

Conclusion

The casts fabricated from VPS or PVS impression materials provide similar dimensional accuracy regardless of the implant splinting method.

Keywords: *Dental implants, Direct impressions, Polyvinyl siloxane, Vinyl polyether silicone, Dimensional accuracy*

Introduction

Implant-supported prostheses have become an essential treatment modality (1,2). The passive fit of the implant–supported superstructure is an important factor that determines the treatment success (3). The mismatch between osseous implants and their superstructures induces stresses in prostheses, implants, and peri-implant structures (4,5). Fit precision depends on many factors, among which the impression and an accurate master cast are vital components (6). The factors that influence the cast accuracy are the characteristics of the impression material, technique, type of tray, die material, implant angulation, and fit tolerance between the implant components and transfer copings (7-12). In the case of multiple implants, the quality of the final impression and transfer of the exact positions of the implants to the model are of utmost importance (13).

Various impression techniques have been considered for obtaining accurate master casts (14,15). Open and closed tray techniques are the most

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commonly used protocols. Previous studies have demonstrated that the open-tray technique is more accurate than the closed-tray method (16,17). Herbst *et al.* (18) observed no difference between splinted and non-splinted impression copings. Assuncao *et al*. (19) inferred that splinting impression copings with acrylic resin provided favourable results in angled implants. Papaspyridakos *et al.* (20) reported that the splinted technique produced master casts that were more accurate than the ones produced using the non-splinted method, for one-piece implant-supported fixed dental prostheses in edentulous jaws. Inconsistent findings have been reported in various studies regarding splinted or non-splinted impression copings (21,22).

Different materials have been considered for making implant impressions. Polyether (PE) and polyvinyl siloxane (PVS) have been selected as materials of choice (15,16,23). Studies have justified the use of PE as an impression material for multiunit implant-retained restorations in completely edentulous situations, because it has the property of low strain during compression, with the most advantageous Shore A hardness value (24,25). Further, the PVS impression material aids in easy removal of the set impression owing to its suitable modulus of elasticity; thus, it has been suggested as a preferred material for the direct implant impression technique (13). The advantages and limitations of these materials have led to the development of new-generation vinyl PE silicone (VPES) impression materials that combine the benefits of the PE and PVS materials. These novel materials are hydrophilic and combine the most desired properties of both materials (11,26). Limited research and evidence are available in the literature to recognize the dimensional accuracy of these novel materials over PVS in situations of multiple-implant impression making.

The present study aimed to evaluate and compare the dimensional accuracy of the VPES and PVS impression materials in direct tray splinted and non-splinted approaches to multiple-implant impressions. The null hypothesis tested is that no difference would be detected between the dimensional accuracies of the two impression materials and the splinted and non-splinted techniques.

Materials and methods

Model design

The study was approved by the Institutional Review Board (SRMDC/IRB/2015/MDS/NO:202). A standard mandibular stainless-steel reference model was milled to simulate the clinical scenario of the direct implant impression technique (26). A completely edentulous, die stone cast of the mandible was selected and three-dimensional (3D) scanning was performed using CAD CAM. A reference model was fabricated using CAD CAM with the grade 404 stainless steel material (Siva Shakthi Engineering Works, India). Eight sites with dimensions of 3.5 mm × 10 mm (Adin Dental Implant Systems Ltd, India) were selected at the lateral incisor, canine, second premolar, and molar regions on either side of the arch. A three-axis vertical milling machine (Denford VMC 1300, Denford Ltd., UK) was used to ensure parallelism among the implants. They were sequentially described by letters A to H from the left-most posterior to the right distal implant site. The tray thickness, spacer, positioning, and impression were performed as described previously (27). 2-mm-wide and 1-mm-deep grooves were made in three different places for effective positioning, stabilization of the tray during impression procedures and to obtain uniform thickness of impression materials. The two posterior grooves were placed between implants A and H, and the anterior groove was placed between implants D and E.

Impression taking

Two impression materials, VPES (Figure 2) (EXA'lence 370 regular set; GC, USA) (Product no: 137805, Lot no: 1510051, 1602081) and PVS (GC Flexceed, GC Dental, USA) (Lot no:1610191), were evaluated for their dimensional accuracy using both the splinted and non-splinted techniques. Eight square-shaped internal connection hexagonal transfer copings were used (Adin Dental Implant Systems Ltd, India) (Figure 1). Each transfer coping was internally secured into the analogue and tightened with a torque wrench calibrated to 10 Ncm. The copings were connected by dental floss (Oral B Company, Chennai, India) and wrapped around to act as a scaffold. A pattern resin with thickness of 2–3 mm (GC pattern resin, GC Ltd, India) (Lot no: 1608092) was applied around the impression copings and to the scaffoldings of the dental floss before making the impression, using an incremental application technique with a brush. The splint was cut using 0.17-mm-thick diamond discs (Acurata Manhardt Dental, Chennai, India). The bars were approximately 2–3 mm in diameter; they were sectioned into a length of approximately 5 mm and joined using the bead-brushing method after 24 h with the auto-polymerizing acrylic resin (27-30). Impressions were made immediately after the material was set. Seventy-two samples were analyzed, with 18 samples in each group, listed as follows. Group VPES (S): Direct splinted technique with VPES. Group VPES (NS): Direct non-splinted technique with VPES. Group PVS (S): Direct splinted technique with PVS. Group PVS (NS): Direct non-splinted technique with PVS.

A mandibular edentulous, perforated metal stock tray was used to make impressions. Eight perforations were created in the tray with a round bur (width, 2 mm) at the site of the implants, to provide access for the guide pins of the impression copings. The stock trays were coated with a tray adhesive (Universal VPS adhesive, GC India) and allowed to dry for 15 min before making impressions. Both the VPES and PVS impressions were made using a single-step double-mix putty wash impression technique, following the manufacturer's instructions. Impression of the reference stainless steel model was made, and the tray was fully seated on the three location marks of the model and maintained in position throughout the setting time. The stock tray was seated over the guide stops, and a circular piece of steel weighing 1 kg was placed on the impression tray to standardize the seating load. After the material was set, the tray was removed. One operator made all impressions to reduce inter-operator variability. Retrieved impressions were examined and repeated if any inaccuracies were found such as air voids or material residues between the analogue-impression coping interfaces, and if any separation from the tray was detected. Implant analogs were screwed to the impression copings (Figure 2), and type-

4 gypsum casts (Ultra Rock die stone, Shruti products, Upleta, India) (Batch no: 170603) were made (Figure 3) (29,30).

Dimensional stability measurements

The dimensional stability of the impression materials was evaluated for the linear and rotational distortions observed in the casts. A computerized coordinate measuring machine (CMM OL-3020, Opus Precision Instruments, India) with a mechanical probe (diameter, 0.5 mm; resolution, 0.0001 mm) was used for measuring the relative linear distortion in the X, Y, and Z coordinates of the centers of the implant platforms. The 3D or rotational distortion (r) was calculated from the linear displacements using the following formula:

$$r = \sqrt{x2 + y2 + z2}$$

Linear distortion was evaluated from the left-most posterior implant (implant A). The centroid of the implant A head was used as a reference from which measurements were made. Linear distortions were defined as absolute differences between the reference model values and the definitive cast in the X, Y, and Z directions, and are denoted as ΔX, ΔY, and ΔZ.

The reference planes were defined to measure the sample coordinates (ΔX, ΔY, and ΔZ).

The center of the implant positioned on the model was scanned using a machine. The Z plane was outlined on the anterior – posterior surface of the implant. The X-plane was expressed as a line transiting through two implant centers perpendicular to the Z plane. Perpendicular to these X and Z planes was the Y plane. The impression analogues were fastened on the implants, and the implants were circularly scanned around the center to establish the X, Y, and Z axes. The distances in the three axes were measured as AB, AC, AD, AE, AF, AG, and AH (between the implants) (Figure 4). A single operator that was blinded to the experimental setup recorded all measurements three times to avoid intra-operator-related errors, and the mean of the values was recorded. The differences in the values for all axes were tabulated and statistically analyzed.

Statistical analysis

The data was analyzed with SPPS 17.0 (SPSS Inc. Released 2008. SPSS Statistics for Windows, Version 17.0. Chicago, IL, USA) software. Based on the distribution characteristics of the data, the one-way analysis of variance (ANOVA) test was used for multiple comparisons among study groups.

Results

The mean differences, standard deviation, and statistical data of the various axes and groups are summarized in Table 1. The results suggest no statistically significant relationship pertaining to the axes, materials, and techniques. The 3D displacement (Table 1) suggests no statistically significant relationship between the techniques and materials. The ANOVA test results comparing the splinted and non-splinted groups of the VPES and PVS are listed in Table 2 and Table 3. The results suggest no statistically significant differences (f (1.27) = 3.490, p = 0.33).

Figure 1. *Impression coping attached to the reference model.*

Figure 2. *Direct Impression with attached lab analogues.*

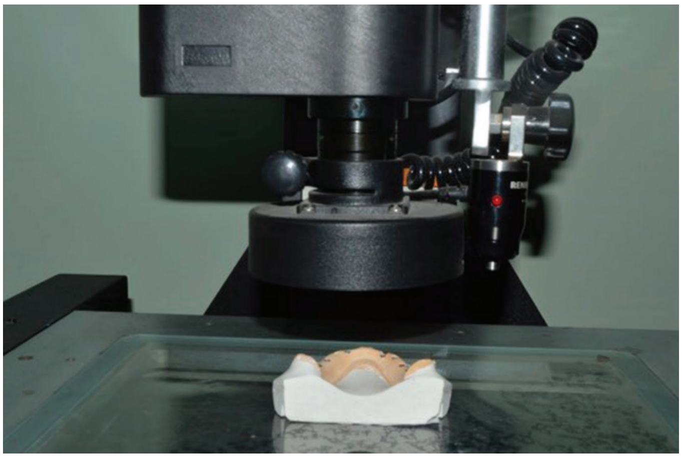

Figure 3. *Cast obtained from impression.*

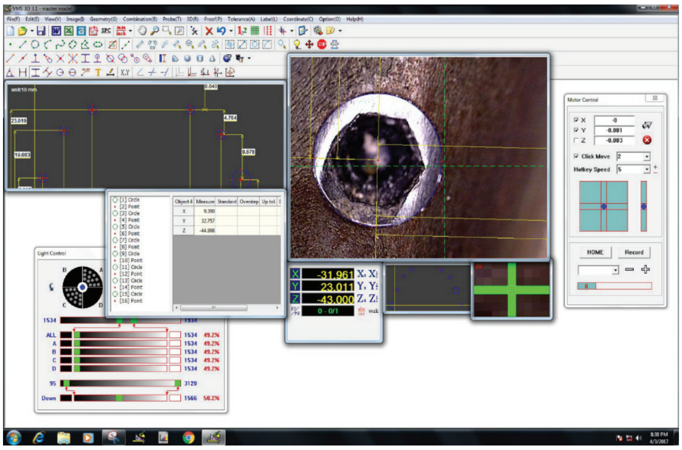

Figure 4. *Recorded measurements through the software of CMM.*

Table 1. *Mean, standard deviation, p and F values of the splinted and non-splinted impression materials in mm.*

Axis		VPES (S)	VPES (NS)	PVS (S)	PVS (NS)	P value	F value
X axis	Mean	0.11	0.18	0.15	0.16	0.29	1.32
	SD	0.08	0.07	0.05	0.07		
Y axis	Mean	0.10	0.13	0.10	0.11	0.10	2.30
	SD	0.02	0.08	0.07	0.07		
Z axis	Mean	0.08	0.11	0.09	0.10	0.18	1.76
	SD	0.04	0.05	0.04	0.05		
3 D	Mean	0.16	0.27	0.22	0.30	0.09	2.45
	SD	0.08	0.08	0.08	0.17		

Table 2. *ANOVA (Single factor) : Summary statistics between groups*.

Groups	Count	Sum	Average	Variance
VPES (S)	4	0.37542857	0.09385714	0.0015738
VPES (NS)	4	0.66457143	0.16614286	0.00781488
PVS (S)	4	0.53985714	0.13496429	0.00514211
PVS (NS)	4	0.708	0.177	0.00300307

Table 3. *ANOVA analysis.*

Source of Variation	SS	df	MS	F	P value	F crit
Between Groups	0.01668474	3	0.00556158	1.27	0.33	3.490
Within Groups	0.05260161	12	0.00438347			
Total	0.06928635	15				

Discussion

The results were statistically insignificant and failed to reject the null hypothesis about the relationship between materials and techniques. A marginal numerical advantage was observed for VPES over PVS. Siadat *et al.* (12,13) observed a smaller discrepancy for VPES and suggested it as a material of choice for direct and indirect impression techniques Higher tensile strength and better flow properties of VPES can make it more advantageous and preferred to other impression materials. Baig *et al.* (11) determined that the accuracy of the VPES impression material was comparable with that of PE for multi-implant abutment level. Kurtulmus *et al.* (17) and Vojdani *et al.* (32) compared the VPS, VPES, and PE impression materials' accuracy in angulated implants, and found no significant differences among the compared impression materials. The accuracy was marginally higher for PVS, owing to elastic recovery. This study determined that VPES exhibited less distortion compared with PVS impression materials. The differences observed can be attributed to the higher number of implants considered in the present study, and the superiority can be related to the elastic properties of the considered materials.

Only a few studies evaluated situations with more than six implants and the impact of distortion for scenarios with many implants. This study determined the influence of eight implants, different impression materials, and techniques. The higher number of implants engages the elastic recovery properties of the materials owing to the increase in linear and rotational forces. Unlike earlier studies, the results of this study can be impacted by the higher number of implants and the properties of the used impression materials.

The majority of the existing studies used reference models made of acrylic or simulated materials (11,28). These materials can affect the studies' outcomes, owing to their dimensional changes. This limitation was reduced in this study by using metallic reference models.

The present study found no statistically significant difference between the splinted and non-splinted impression techniques (f (1.27) = 3.490, p = 0.33). This is consistent with the findings reported by the majority of existing studies. Al-Quran *et al.,* Papaspyridakos *et al.,* Naconecy *et al.,* Ongul *et al.*, Hariharan *et al.,* and Kim *et al*. showed that the splinted technique is better than the non-splinted implant impression technique (7,20,21,33-35). The variability in the observations reported in a few literature studies can be owing to different study designs, implant systems, different splinting materials, inaccurate repositioning of impression copings, different implant angulations, and expansion of stone materials.

In this study, a pattern resin was used as the splinting material. The splint was made prior to the impression making, to reduce polymerization shrinkage. The splint was sectioned and reconnected to the impression copings. The retentive design of the impression coping was an internal hexagonal connection that produced less vertical displacement. Machine intolerance was reduced by using novel analogues and impression copings. Significant evidence exists in literature suggesting that the PVS material is ideal for the direct impression technique, owing to its good rigidity and ability to prevent rotation of implant components. The VPES material is also an ideal impression material. It is hydrophilic and has properties comparable to those of the PVS material. The deviations found in the present study were within statistically acceptable limits, similar to the observations reported by Ebadian *et al.* (36). Extreme caution and standard recommendations were adhered to when making implant impressions using materials and techniques. The present study had some limitations. The present study used a stock impression tray. Additional studies using other techniques, different impression trays, and addressing a variety of realistic and clinically relevant scenarios are still required.

Conclusion

Irrespective of the technique and material, the linear and rotational distortion values were within the acceptable range. Therefore, it can be concluded that the casts fabricated from VPS or PVS impression materials provide similar dimensional accuracy regardless of the implant splinting method.

Türkçe Özet: *Vinil polieter ve polivinil siloksan ölçü materyallerinin çoklu implantlar için direk implant ölçü tekniğinde boyutsal doğruluğu. Amaç: Bu çalışma, simule edilmiş dişsiz alt çenelere yerleştirilen birden fazla implant için kullanılan splintlenmiş (S) ve splintlenmemiş (NS) direk açık ölçü tekniğinde polieter (VPES) ve polivinil siloksan (PVS) ölçü materyallerinin boyutsal doğruluğunu karşılaştırmıştır. Gereç ve Yöntem: Klinik durumu simule etmek için paslanmaz çelikten implant analogları için sekiz in-*

ternal bağlantıya sahip paslanmaz çelik bir alt çene modeli üretilmiştir. Akrilik reçine ile splintlenmiş vey splintlenmemiş direk ölçüler VPES ve PVS materyalleri kullanılarak alınmıştır. Yetmiş-iki örnek kullanılan ölçü tekniği ve materyallerine göre dört gruba ayrılmıştır. Modellerin boyutsal doğruluğu üç farklı eksende bilgisayarlı koordinat ölçüm makinesi (CMM) kullanılarak ölçülmüş ve istatistiksel olarak karşılaştırılmıştır. Bulgular: VPES ve PVS ölçü maddelerinin distorsiyon değerleri arasında anlamlı bir farklılık bulunmamıştır. Benzer şekilde, splintlenmiş ve splintlenmemiş gruplarda da VPES ve PVS ölçü maddelerinin distorsiyon değerleri arasında anlamlı bir farklılık bulunmamıştır. Sonuç: VPES ve PVS ölçü maddelerinden elde edilen modeller implant splintlenme metodu gözetmeksizin benzer doğruluk göstermektedir. Anahtar Kelimeler: dental implantlar; direk ölçü; polieter, polivinil siloksan, boyutsal doğruluk

Ethics Committee Approval: The study was approved by the institutional review board (SRMDC/IRB/2015/MDS/NO:202).

Informed Consent: Not required.

Peer-review: Externally peer-reviewed.

Author contributions: RR and NGC participated in generating the data fort he study. RR, NGC and KVA participated in gathering the data fort he study. RR, NGC and BM participated in the analysis of the data. RR and NGC wrote the majority of the original draft of the paper. RR, NGC, KVA and BM participated in writing the paper. RR, NGC and KVA have had access to all of the raw data of the study. All authors have reviewed the pertinent raw data on which the results and conclusions of this study are based. All authors have approved the final version of this paper. All authors guarantee that all individuals who meet the Journal's authorship criteria are included as authors of this paper. All authors participated in designing the study.

Conflict of Interest: The authors had no conflict of interest to declare.

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