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Accuracy of Polyvinyl Siloxane Impression Material with Different Inter Implant Angulation

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Abstract: ***The suitability of a recommended material for implant impressions and the effects of implant angulation on the accuracy of the working cast remain debatable. Thus, evaluating the effect of impression materials with different implant angulations on the accuracy of impression is important (Cehreli et al., 2006).Four block shaped acrylic master models were fabricated with two implant analogs in each: the first was placed at 0° angulation (reference implant) while the second was at 0°, 5°, 10°, and 15° respectively. Sixty-four impressions were taken, 16 impressions for each of the four master casts, eight of them made using Aquasil impression material and the other eight impressions with Virtual impression material. IBM SPSS v.22 (SPSS Inc, Chicago) was demonstrated. according to the results material elasticity and inter-implant angulation had a combined effect on the accuracy of the implant impression (p =0.03). The inter-implant angulations were significantly associated with the impression accuracy (p= 0.027) regardless of the elasticity of the material. Post-hoc analysis using Tamhane's procedure showed a significant difference between angulation pairs of 0 º- 10 º and 0 º- 15º. The study demonstrated that the interaction between PVS impression materials of different elasticity (Virtual and Aquasil medium body) and the inter implant angulation of the analogs placed divergently produced a significant adverse effect on the impression accuracy. Regardless of material elasticity, the angulation of the implant analogs also adversely affects the impression accuracy.***

Keywords: Dental Implants; inter-implant angulation; elasticity, Vinyl Polysiloxane; Dimensional Measurement Accuracy

1. Introduction

An accurate impression is important for dental implants because prosthesis should be fabricated such that it does not confer any stress to the inserted implant when completely seated [(1)]. Oral rehabilitation of partially and completely edentulous patients with dental implants is currently routine procedure, and clinical studies have proven the longitudinal effectiveness of this treatment modality [(2)]. As endosseous implants are functionally ankylosed with direct contact to the bone, they lack the inherent mobility of the periodontal ligament [(2)]. Hence, they cannot accommodate distortions or misfit at the implant-abutment interface.Screw loosening and/or fracture, implant fractures, and prosthetic-component strain and fracture have been related to prosthesis misfit. It is still unclear what degree of prosthesis misfit will lead to biologic or technical complications. [(3)].

At present, the most popular impression material in dental implant preparation is polyvinyl siloxane (PVS) because of its good handling characteristics, physical properties, and dimensional stability [(4)]. Addition silicones with higher modulus of elasticity are advantageous over earlier condensation silicones because they have less dimensional change and higher elastic recovery [(5)]. Previous studies have proposed that set impression can be easily removed when addition silicone materials used because of their more favorable modulus of elasticity [(6)]. High-level stress has been speculated to occur between the impression copings and impression materials when the impressions with their copings are removed from the internally connected implants [(7)].

Most studies on dental implant impressions have evaluated the improvement of impression accuracy using parallel implants with 0° angulation, while several studies have investigated the effect of nonparallel implants with angulations of different degrees on the final precision of the impression [(8)]. The increasing divergence or convergence of implants had been reported to have detrimental effects on impression accuracy [(8,9)], whereas some other studies reported no angulation effect on the accuracy [(10)].

2. Literature Survey

In general, the accuracy of any implant cast depends on some basic factors which include the technique of implant impression, the type of impression material and, the angulation of the implant. A definitive clinical goal ought to be to fabricate prosthesis that seats passively onto the implants. Several questions have been raised, such as whether the difference in the elasticity of two PVS impression materials (i.e., Virtual and Aquasil medium bodies) affects the impression accuracy of the dental implant; whether the angulated dental implant affects the accuracy of the implant impression; and whether the interaction between material and angulation significantly affects the implant impression [(11)].Various studies have determined that impressions made with angulated implants are less accurate than those made with parallel implants (Assuncão et al., 2004; Sorrentino, et al., 2010; Assif et al., 1999; Carr, 1997). Moreover, implant angulation significantly affected impression accuracy when implants with internal connections were used (Sorrentino et al., 2010).

Many studies examined the effects of various factors on the accuracy of implant impressions. Among all the impression materials available, the rigidity of PVS provides the optimal resistance against coping displacement in the impression. Given its favorable properties, PVS has been recommended as an impression material for clinical use and thus selected as the material for this study. One issue that has not been discussed yet in the literature is the comparison of two medium body PVS impression materials of different elasticity with regards to the distortion of resultant implant casts. The elasticity of PVS impression material provides high impression accuracy at different angulations. However, the comparison of the different elasticity of PVS with different angulations using closed-tray impression technique has not been reported.

3. Problem Definition

To compare the impression accuracy of dental implants analogs placed at different angulations taken using PVS (medium body) impression materials of different elasticity.

4. Materials and Methods

Four block shaped acrylic master models (length: 3 cm, width: 2 cm, height: 2 cm) were fabricated. They were prepared at the dental laboratory of Advanced Medical and Dental Institute, Universiti Sains Malaysia.

Two holes with a depth of 9 mm were drilled at 100 mm (1 cm) intervals in each acrylic model using a 5-axis milling machine (DeckelMahoGmbh, Germany). The first hole was prepared at 0° angulation while the second hole was prepared at 0°, 5°, 10° and 15° angulation for each block. In this study, implant analogs were used as a substitute for implant fixtures as used in actual clinical setting. The analogs (analog for RN synOcta L 12 mm, stainless steel, Straumann, Switzerland) were inserted into the first hole of each block at 0° angulation to serve as the reference line, and another analog placed in the second hole at an angulation of 0°, 5°, 10°, and 15° in each block (Figure 1).

Figure 1: Acrylic master models with implant analogs at different angulations; block a: 0° & 0°, block b: 0° & 5°, block c: 0° & 10°, block d: 0° & 15°.

The analogs were secured with auto-polymerizing acrylic resin with the tops of the analogs positioned 1 mm above the model.

A special tray was fabricated for taking the implant impression. To provide mechanical retention for the impression material, two-mm diameter holes were drilled into the tray at 10 mm intervals. Stops were incorporated in the tray to standardize tray positioning during impression taking.

The impressions were taken using closed-tray (indirect) technique in this study. Firstly, RN Impression Caps (H 8 mm, Straumann, Switzerland) and RN synOcta Positioning Cylinders (H 12 mm, Straumann, Switzerland,) were placed over the fixture head of the analogs.

Two brands of PVS dental impression materials were selected: Virtual medium body, (Manufacturer: IvoclarVivadent, USA, and Aquasil medium body, (Manufacturer: Dentsply, USA Figure 2), they were managed according to the manufacturers' recommendations.

Figure 2: Virtual medium body and Aquasil medium body impression materials.

The impression material was loaded around the dental analog and on the special tray. The tray was then placed on the master casts until fully seated. Any excess material was immediately wiped off to verify the complete setting of each tray. A standard 3 kg weight cylinder was placed over the trays during the setting of the material. The PVS impression material was allowed to set for 4 min as recommended by the manufacturer. Any remaining excess material was trimmed using dental LeBron standard wax carver.

For each master model, the impression procedure was repeated eight times with each of brand of the impression materials. Therefore, a total of 16 impressions procedures were conducted for each individual master model, giving a total of 64 impressions. New impression caps and position cylinders were used for each impression. (Figure 3)

Figure 3: The total 64 study casts

Closed-tray impression copings remained on the master casts upon removal of the tray after the impression material had polymerized. These copings were removed one at a time from the master casts and attached to an implant analog. The implant analog was inserted into the impression by firmly pushing it into place to full depth. After 15 minutes, the impressions were poured under constant vibration with high-strength low-expansion die-hard stone of 100g powder: 20ml water ratio. After the stone has set an hour later, study casts were separated from the impressions and then trimmed and labeled to prepare for the measurements procedure. The procedures were performed by the same operator.

Measurement procedure of the distance between the analogs on the master model and on the study model was measured using a measuring profile projector machine (Racks Vision DC3000, Taiwan; Figure 4.

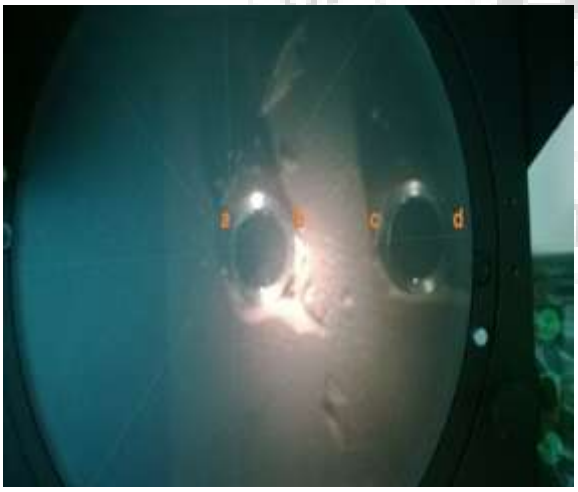

Figure 4: Study cast distance measurement using profile projector

This profile projector was set to measure the distance between the analogs from the center of the first analog (reference point) to the center of the second analog (the angulated analog). The normality of the data distribution was checked using Kolmogorov-Smirnov test. The impression accuracy was determined by comparing the difference in linear measurement relative to the master casts in µm. Two-way (ANOVA) was used to compare the combined effect of impression materials and the inter implant angulation on the mean difference (µm) in linear measurement relative to master casts. Independent *t* test was used to compare the distance in linear measurement between the two materials regardless the inter-implant angulations. One-way statistical analysis of variance (ANOVA) and the Tamhane post hoc test were used to compare the effect of inter-implant angulations on the linear measurement. The data were analyzed with IBM SPSS v.22 (SPSS Inc, Chicago) with the level of statistical significance (p) set at<0.05.

5. Results & Discussion

A significant interaction existed between the two PVS materials and angulation of the analogs (p = 0.03, Table 1). This suggested that material elasticity and inter-implant angulation had a combined effect on the accuracy of the implant impression.

Table 1: Two-way ANOVA comparing the effect of impression materials and the inter implant angulation on the mean difference (µm) in linear measurement relative to master cast of the implants

Material	*n*	*Adj. mean (95% CI)*	*Adj. mean diff. (95% CI)* [b]	*F stat.*[a]	*P Value*[c]
Virtual	32	- 0.005 (- 0.020, 0.010)	- 0.012 (- 0.034, 0.009)	1.314 (1,56)	0. 03
Aquasil	32	- 0.017 (- 0.032, - 0.002)			

[a] Adjusted mean while the effect of Virtual and Aquasil were controlled
[b] Bonferroni adjustment for 95% confidence interval for difference
[c] Two- way ANOVA

On the other hand, the inter-implant angulations were significantly associated with the impression accuracy (p= 0.027) regardless of the elasticity of the material (Table 2). Post-hoc analysis using Tamhane's procedure showed a significant difference between angulation pairs of 0 º- 10 º and 0 º- 15 º.

Table 2: One-way ANOVA comparing the effect of inter implant angulation on the mean difference (µm) in linear measurement relative to master cast of the implants regardless of the elasticity of the impression material.

Inter implant angulation	*Mean (SD) (µm) Virtual*	*Mean (SD) (µm) Aquasil*
0º	- 0.012 (0.0215)	0.026 (0.0461)
5 º	- 0.002 (0.0254)	0.018 (0.0273)
10 º	0.001 (0.0416)	- 0.074 (0.0865)
15 º	- 0.008 (0.0324)	-0.034 (0.0164)

Mean difference(SD) (µm)	*F Statistic (df)*	*P Value*[a]
(0.0386)	3.273	0.027
0.008 (0.0274)		
- 0.036 (0.0761)		
- 0.021 (0.0283)		

[a] One-Way ANOVA test

In modern dentistry, the dental prosthesis is an important and well-accepted tool in maintaining quality oral care. As previously mentioned, only when fitting prostheses are fabricated can dental implant process be successfully accomplished. In particular, prosthesis should essentially be fabricated on a definitive cast which provides accurate positioning of dental implants, thus eliminating discrepancies in fit [(11)].

The present study measured the accuracy of implant impression in-vitro with two PVS impression materials of different elasticity through closed-tray technique and by placing implant analogs at various angulations.

A study was made by Mpikos et al. [(12)] showed that the impression technique, implant angulation, and their interactions significantly affect the accuracy of impressions made of either external- or internal-connection implants. On the contrary, Reddy and colleagues [(13)] reported that the combined interaction of the implant impression material and implant angulation has no effect on the accuracy of duplicate casts, but affects that of definitive casts.

Faria et al. [(14)] reported that different impression materials and techniques affect the stone cast accuracy. In general, dimensional changes in an implant impression occur due to the constriction in the impression material initiated by the polymerization reaction with the formation of volatile materials and by-products, pressure applied during impression and conventional impression techniques. Producing a precise implant mold is therefore a crucial measure in making an accurate impression [(15)].

Parallel to our study, PVS impression material has been reported as the most recommended material for multiple implant restorations because of its' favorable properties [(16)]. It is considerably rigid and provides the best resistance to displacement, although its rigidity has some clinical limitations. In particular, PVS is difficult to be used when undercuts exist or when a great degree of divergence arises between implants. In this case, PVS may not always be the first choice for impression material in such clinical situations [(17)].

The effects of different dental implant angulations on the accuracy of the implant impression were investigated in our study. The differences between the master and duplicate casts were measured in micrometers (µm) and degrees were in relation to the reference analog at 0°. As shown in our results, the measurement of 0° to 10° and 0° to 15° angulation pairs were significantly different. Our results supported the research hypothesis and proved that the angulated analogs have a detrimental effect on the accuracy of implant impression. These findings are in agreement with the results of studies that have determined that impressions made with angulated implants are less accurate than those made with parallel implants [(9,18,19,20,21)]. Moreover, implant angulation significantly affected impression accuracy when implants with internal connections were used [(22)].

Clinically, any divergence or convergence of the dental implants may be even greater than 8° or 10°. On the whole however, most studies agreed that any increase in divergence or convergence of the implants has a crucial destructive effect on impression accuracy, including those that had used experimental casts either with four or five implants which have concluded less accuracy with angulated implants impressions compared with those of non-angulated ones [(9,22,23,24,)].

Akalin et al. [(25)] evaluated the effect of implant angulation, impression material, and difference in width of the arch curvature on transfer models. Statistical evaluations indicated that angular model measurements incurred the greatest deformation values ($p< 0.05$). The models with implants placed parallel to each other exhibited greater accuracy than the model with implants angled to each other, a finding which supported our results.

At current, there are no standard guidelines on the maximum allowable discrepancies or distortions for implant impressions, with discrepancy of up to 136 µm had been reported [(26)]. Therefore, we only draw our conclusions based on the results of the comparative groups in our study. It is important to note that no research has studied the combined effects of PVS impression materials of different elasticity with various implant angulations in determining the impression accuracy before, and thus we are not able to compare our results directly with other studies. The difference in some of the results of other studies compared to ours were most likely attributable to the differences in the implant systems tested, the designs of each study, the implant components, the number of implants used, the degree of the angulation of the implants tested, and the type of impression material used.

6. Conclusion

In conclusion, the study demonstrated that the interaction between PVS impression materials of different elasticity (Virtual and Aquasil medium body) and the angulation of the analogs placed divergently produced a significant adverse effect on the impression accuracy. The material elasticity alone did not appear to significantly affect the impression accuracy. Regardless of material elasticity, the angulation of the implant analogs also adversely affects the impression accuracy.

7. Future Scope

This is an in-vitro study which limits the extrapolation to the clinical setting. Factors such as the intra-oral moisture and humidity, tray removal from the patient's mouth, different impression manipulation techniques and reduced operator's visibility, etc. may produce different results from what were found in this study. Addressing the issues highlighted above is proposed for future studies, as well as investigating the effects of multiple implants with various depths and types of impression copings on the impression accuracy.

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