Digital evaluation of the accuracy of impression techniques and materials in angulated implants

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OBJECTIVES
Objectives: The aim of this study was to investigate the accuracy of 2 different impression techniques and 3 different impression materials in models simulating parallel and angulated implants.

METHODS: Three master models simulating partial edentulous mandible with 2 implants at the sites of second premolars (parallel) and second molars with different angulations (parallel, 10⁰ or 20⁰ angulated) were fabricated. Two different impression techniques [splinted direct (D), indirect (I)] and 3 different monophase impression materials [polyether (PE), vinyl polysiloxane (VPS), vinyl polyether silicone (VPES)] were used for each master model and a total of 180 impressions were made (n = 10). Master model and casts were scanned by a modified laser scanner and data were transferred to VRMesh software. Master model and duplicate cast scans were digitally aligned observing the superposition of anatomic markers. Angular and coronal deviations between master and duplicated copings were calculated and data were statistically analyzed.

RESULTS: Mean angular and coronal deviations were in a range of 0.205–0.359⁰ and 22.56-33.33 μm, respectively. Statistical analysis revealed that the angulation of implant affected both coronal and angular deviations of the impression copings (P < 0.05). According to statistical analyses, for parallel implants, the accuracy of impression materials and techniques were ranging as VPS-D = PE-D > VPS-I = PE-I > VPS-D > VPES-I from most accurate to the least. For 10⁰ and 20⁰ angulated implants the most accurate material and technique was VPS-D whereas the least accurate combination was VPES-I (P < 0.05).

CONCLUSION: Angulation, impression technique and material were found to be effective on the accuracy of implant impressions.

CLINICAL SIGNIFICANCE: Clinicians may prefer VPS impression material and splinted direct technique for impressions of both parallel and up to 20⁰ angulated implants.

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1. Introduction

The passive fit of implant-supported prosthesis is critical for long term clinical success. Any misfit between the prosthesis and implant may lead to complications, such as screw loosening, screw fracture, occlusal discrepancies, increased plaque accumulation caused by misfit components and even loss of osseointegration and implant fracture. Impression is one of the most important steps for a passive fit and transfer of the precise position of implant to definitive cast with an accurate impression is essential. Impression technique, type of impression material, splinting or non-splinting impression copings, type of splinting material, number and angulation of implants are the factors that affect the accuracy of impression.

To date, several implant impression techniques have been introduced and evaluated for accuracy. Two basic impression techniques are commonly used in implant dentistry: the indirect (transfer, closed tray) and the direct (pick-up, open tray) technique. In indirect technique, the copings are connected to the implant and after the removal of the impression they are retained on the implants. The copings are then removed from implant, attached to the implant analogues and reinserted in the impression. In direct technique, an open tray that exposes coronal ends of the impression coping screws is used. Screws of the copings are loosened when the impression material is set and impression is removed from the mouth with impression copings retained in the impression. The implant analogues are connected to the copings using the same screw.

The accuracy of direct and indirect techniques were compared in many studies. However the results are still contradictory. In a systematic review, Lee et al. investigated the published researches regarding the accuracy of implant impressions and concluded that there was no difference between direct and indirect techniques if there were 3 or fewer implants.

Accuracy of various implant impression materials were investigated in numerous studies and more accurate impressions were obtained with polyether (PE) and vinyl polysiloxane (VPS) in comparison to condensation silicone, polysulfide, reversible hydrocolloid, irreversible hydrocolloid and plaster. Wetting behaviour is an important physiochemical property of elastomeric impression materials that affects the accuracy of the material. Hydrophilicity provides detailed reproduction of wet oral surfaces and increased wettability with gypsum slurry. Hydrophobic or hydrophilic character of materials can be attributed to their chemical structure. VPS has hydrophobic aliphatic hydrocarbon groups which surround the siloxane bond. However, PE contains functional groups that attract and interact with water molecules, making this material hydrophilic.

To improve the wettability of VPS, manufacturers added extrinsic surfactants and labelled these as hydrophilic VPS materials. Recent studies reported that hydrophilized VPS has similar hydrophilicity to PE. Many studies showed that there was no difference in the accuracy of PE and VPS and both of the materials are recommended for implant impressions. VPS materials contain vinyl polyether silicone (VPS) (EXA’lence, GC America Inc., Alsip, IL, USA), a combination of VPS and PE was introduced a few years ago. According to the manufacturer, VPS has intrinsic hydrophilicity and high dimensional stability. However, the data regarding the accuracy of VPS is very limited. In a recent study, Schaefer et al. evaluated the accuracy and reproducibility of VPS, PE impression materials by a 3-D analysis. They reported that there was no significant difference among the materials in terms of spatial deviation and all of the materials demonstrated high accuracy and reproducibility.

Parallel placement of implants is not always possible due to the anatomical limitations and angulations may occur in implant positions. The effect of angulation of implants on the accuracy of impression has been evaluated in previous studies and researches reported that angulated implants caused less accurate impressions in comparison to parallel implants when there were 5–6 implants. However, the studies that used 2 or 3 implants did not report any difference between angulated and parallel implants in terms of impression accuracy. There is limited data regarding the accuracy of impression materials in case of implant angulation. The results of previous studies investigating the accuracy of impression materials for angulated implants showed inconsistency. Sorrentino et al. found VPS more accurate than PE whereas Akalin et al. obtained more accurate impressions with PE. On the other hand, Reddy et al. reported that there was no significant difference in accuracy of VPS and PE for angulated implants. To the best of authors’ knowledge, the accuracy of VPS impression material with angulated implants has not been investigated.

The aim of the present study was to investigate the accuracy of 2 different impression techniques (splinted direct and indirect) and 3 different impression materials (PE, VPS, VPS) in models simulating parallel and angulated (10°, 20°) implants.

2. Materials and methods

2.1. Fabrication of master models

Three autopolymerizing transparent acrylic resin (Pegasus Plus Repair Acrylic, Davis Schottlander & Davis Ltd., Hertfordshire, England) master models simulating partial edentulous mandible were fabricated. Two implants (T4 3810, NucleOSS, Sanilkar Tibbi Cihazlar Medikal Kimya San Tic Ltd. Sti, Izmir, Turkey) were placed at the sites of the right second premolar (implant 1) and right second molar (implant 2) of each model with different angulations (parallel, 10° and 20° angulated) (Fig. 1).

Model 1: Implant 1 and implant 2 were positioned parallel to each other and long axes of neighbouring teeth; perpendicular to the horizontal plane.

Model 2: Implant 1 was positioned parallel to the long axis of neighbouring tooth and perpendicular to the horizontal plane; implant 2 was placed with 10° mesial angulation with respect to the long axis of implant 1.

Model 3: Implant 1 was positioned parallel to the long axis of neighbouring tooth and perpendicular to the horizontal plane;
implant 2 was placed with 20° mesial angulation with respect to the long axis of implant 1.

2.2 Fabrication of custom trays

Ninety custom trays with 3 mm relief and 2 guide stops on the occlusal surface of neighbouring teeth were made for each impression technique (totally 180 trays) with light polymerizing resin (Plaque Photo, W + P Dental, Hamburg, Germany) and polymerized (Tray Lux, Ampac Dental, Rockdale, Australia). For direct impression technique, a hole was made on the trays to access to the coronal ends of the impression copings.

2.3 Impression procedures

A total of 180 impressions were made with 2 different impression techniques (splinted direct and indirect) and 3 different impression materials (PE, VPS, VPES) from each master model (n = 10).

Indirect technique (I): Impression copings (T4 4040, NucleOSS) were screwed into the implants and tray with impression material was placed on the model. After the impression material set, the tray was removed from the model. The copings were unscrewed from the model and screwed to the implant analogues (T4 4020, NucleOSS) and they were repositioned in the impression.

Splinted direct technique (D): Impression copings were screwed on implants and the copings were splinted with dental floss and autopolymerizing acrylic resin (Pattern Resin LS, GC America Inc., Alsip, IL, USA). Splint was sectioned after 16 min of application and reconnected with an autopolymerizing acrylic resin. Open tray with impression material was placed on the model and a syringe was used to inject the impression material around the exposed surfaces of the impression copings. After the impression material set, the screws of the copings were loosened and the impression was separated from the model. Implant analogues were screwed to the impression copings that fixed in the impression.

PE (Impregum Penta Soft, 3M ESPE AG, Seefeld, Germany), VPS (Hydorise Maxi Monophase, Zhermack, Badia Polesine, Italy) and VPES (EXA’lence 370 Monophase, GC America Inc., Alsip, IL, USA) impression materials were used for both impression techniques. Before making the impression, custom trays were coated with tray adhesives recommended by the manufacturer. All impression materials used in this study were monophase and prepared straight from the polyester bag using the automated mixing device (Pentamix 2, 3M ESPE, Seefeld, Germany). The mixed impression materials were both syringed around the impression copings and loaded in the custom tray. The custom tray was seated over the guide stops with finger pressure and tray was removed after the material set. All the impressions were taken by a single operator.

All impressions were poured with a type IV dental stone (Hinriplast N, Ernst Hinrichs GmbH, Goslar, Germany) following the manufacturer’s instructions. The stone was left for 1 h and then the casts were gently separated from the impression.

2.4 Measurement procedures

After the impression procedure, impression copings were screwed to the implants on the master models. Master models and duplicate casts were scanned by an optical scanner (Activity 880, Smart Optics Sensortechnik GmbH, Bochum, Germany) within 10 μm accuracy ratio. To avoid glossy surface reflections, a single layer of powder was applied on the surface of master models with handy pushbutton powder brush pen (NextEngine Inc., CA, USA). Master model and duplicate cast scans were aligned observing the superposition of anatomic markers using software (VRMesh Studio, Virtual-Grid Inc., Bellevue City, WA, USA) (Figs. 2 and 3). Two points were located (x-, y-, z-coordinates) on the long axes of each master and duplicate impression copings of implant 2 and the copings were converted into cylinders. The first point was located at the centre of the bottom of impression coping whereas the second point was located at the centre of the top of impression coping (Fig. 4). The linear differences between the centres of the master and duplicate copings for bottom point (coronal deviation) and the angles occurred between the
long axes of master and duplicate copings in x-, y-, z-axes (angular deviation) (Fig. 5) were measured by cartesian multiplication of the analytical coordinates of the points by a single observer.\textsuperscript{47,48}

2.5. Sample size calculation

A minimum significant difference in deviation of 0.05 mm was determined from available literature on accuracy of implant impressions.\textsuperscript{25} The power analysis was conducted based on this minimum significant difference in deviation, using alpha at level 0.05, at 80% power and a \( \alpha \) of 0.048 according to our preliminary study. On the basis of these data, the number of samples required to be enrolled to conduct this study has been calculated as 10.

2.6. Statistical analysis

Shapiro–Wilks test was used to confirm that the data were normally distributed. Data were analyzed by three-way analysis of variance (ANOVA). The considered variables were impression technique (splinted direct, indirect), impression material (PF, VPS, VPES) and implant angulation (parallel, 10°, 20°). Post hoc comparisons were performed using the Bonferroni test when significance was detected. Values of \( P < 0.05 \) were accepted as statistically significant.

3. Results

Mean values and standard deviations of angular and coronal deviations of the copings are shown in Tables 1 and 2, respectively. Mean angular and coronal deviations were in a range of 0.205–0.359° and 22.56–33.33 \( \mu \)m, respectively. Three-way ANOVA revealed that impression technique, impression material and the implant angulation had significant effects on both angular (Table 3) and coronal (Table 4) deviations (\( P < 0.0001 \)).

According to statistical analysis, direct splinted technique showed higher accuracy in comparison to indirect technique for all impression materials and angulations (\( P < 0.05 \)). Angular and coronal deviations increased with the increase in angulation of implants for all impression techniques and materials. For parallel positioned implants, significantly lowest angular and coronal deviations were observed in splinted direct group (\( P < 0.05 \)) and there was no statistically significant difference between PF and VPS (\( P > 0.05 \)). In 10° and 20° angulated implants, significantly low deviations were detected in splinted direct technique with VPS impression material. For all angulations, regardless of the impression

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technique, VPES showed the highest deviations ($P = 0.0001$) (Tables 1 and 2).

4. Discussion

An impression that precisely records the exact 3-dimensional positions of implants is paramount in order to achieve a passively fitting prosthesis. Therefore, in implant dentistry, comparative accuracy of impression techniques and materials becomes an important issue in consideration of passive fit. In the present study, accuracy of 2 different impression techniques and 3 different impression materials were compared and the effect of implant angulation on the accuracy of impression was evaluated. Statistical analysis revealed that impression technique, impression material and implant angulation had a significant effect on the accuracy of impressions. Among the evaluated parameters, for both angular and coronal deviations, impression material was found to be the most significant factor and it was followed by impression technique and implant angulation (Tables 3 and 4).

In most of the studies, direct technique was reported to be more precise and predictable in comparison to indirect technique using repositioning copings. However, the studies evaluating non-splinted direct and indirect techniques demonstrated none of the two procedures to be superior. Splinting of impression copings has been suggested as an important factor for increasing the precision of the impressions. Therefore in the present study, accuracies of splinted direct and indirect techniques were compared. In splinted direct technique, autopolymerizing acrylic resin was used and to reduce the effects of polymerizing shrinkage it was separated and reconnected after 17 min of application. According to the results of this study, regardless of the impression material, splinted direct technique had a greater accuracy than indirect technique for both parallel and angulated implants.

Angulated implants are common clinical situation due to the anatomic and aesthetic limitations. It has been reported that the increased angulation of the implants tended to increase the distortion of the impression material and decrease the impression accuracy since higher strength is needed for the removal of the impression. In the present study, angular and coronal deviation of the both 10° and 20° angulated copings were significantly higher than the parallel copings. Contradictory, in previous studies, angulation was not found to be effective on the accuracy of impressions for 3 or fewer nonparallel implants with up to 15° of angulation. However, in these studies master models were block shaped and had flat impression surfaces which may not simulate the deformation of the impression material upon removal. In this study, partial mandible models with an anatomical shape and neighbouring teeth were used to better simulate the clinical conditions. On the other hand, the methodology for the assessment of the impression accuracy showed differences among the studies. In aforementioned studies, the positional changes of the analogues were evaluated by measuring inter-implant distances either with coordinate measuring machine or measuring microscope, or evaluating the stress in the metal framework with strain gauges. In this study, a digital method was used for the evaluation of deviations which may provide more precise results.

PEs and VPESs have been suggested as the materials of choice for implant impressions due to the superior chemical and physical properties. For direct impression technique, impression material should show sufficient rigidity to hold the coping in its position and prevent any displacement during the removal of the impression.
Table 1 – Mean and standard deviation (SD) values of angular deviations of the copings. Same capital letters in the same column and same lower cases in the same row show no statistically significance according to 3-way ANOVA.

<table>
<thead>
<tr>
<th>Material–technique</th>
<th>0° Mean</th>
<th>SD</th>
<th>Sig.</th>
<th>10° Mean</th>
<th>SD</th>
<th>Sig.</th>
<th>20° Mean</th>
<th>SD</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE-I</td>
<td>0.235</td>
<td>0.005</td>
<td>B,a</td>
<td>0.245</td>
<td>0.005</td>
<td>F,G,b</td>
<td>0.292</td>
<td>0.003</td>
<td>L,c</td>
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<td>PE-D</td>
<td>0.204</td>
<td>0.007</td>
<td>A,d</td>
<td>0.233</td>
<td>0.007</td>
<td>F,e</td>
<td>0.252</td>
<td>0.006</td>
<td>K,f</td>
</tr>
<tr>
<td>VPS-I</td>
<td>0.229</td>
<td>0.005</td>
<td>B,g</td>
<td>0.247</td>
<td>0.006</td>
<td>G,H,h</td>
<td>0.254</td>
<td>0.004</td>
<td>K,i</td>
</tr>
<tr>
<td>VPS-D</td>
<td>0.205</td>
<td>0.009</td>
<td>A,j</td>
<td>0.216</td>
<td>0.016</td>
<td>E,k</td>
<td>0.227</td>
<td>0.018</td>
<td>J,l</td>
</tr>
<tr>
<td>VPES-I</td>
<td>0.266</td>
<td>0.007</td>
<td>D,m</td>
<td>0.276</td>
<td>0.008</td>
<td>I,n</td>
<td>0.359</td>
<td>0.046</td>
<td>M,o</td>
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<tr>
<td>VPES-D</td>
<td>0.250</td>
<td>0.006</td>
<td>C,p</td>
<td>0.259</td>
<td>0.005</td>
<td>H,r</td>
<td>0.305</td>
<td>0.005</td>
<td>L,s</td>
</tr>
</tbody>
</table>

Table 2 – Mean and standard deviation (SD) values of coronal deviations of the copings. Same capital letters in the same column and same lower cases in the same row show no statistically significance according to 3-way ANOVA.

<table>
<thead>
<tr>
<th>Material–technique</th>
<th>0° Mean</th>
<th>SD</th>
<th>Sig.</th>
<th>10° Mean</th>
<th>SD</th>
<th>Sig.</th>
<th>20° Mean</th>
<th>SD</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE-I</td>
<td>26.33</td>
<td>1.11</td>
<td>B,a</td>
<td>27.34</td>
<td>1.13</td>
<td>F,b</td>
<td>28.83</td>
<td>1.39</td>
<td>I,c</td>
</tr>
<tr>
<td>PE-D</td>
<td>22.56</td>
<td>0.67</td>
<td>A,d</td>
<td>25.66</td>
<td>1.83</td>
<td>E,F,f</td>
<td>28.53</td>
<td>1.62</td>
<td>I,g</td>
</tr>
<tr>
<td>VPS-I</td>
<td>25.88</td>
<td>1.36</td>
<td>B,h</td>
<td>27.19</td>
<td>1.65</td>
<td>F,i</td>
<td>28.69</td>
<td>1.34</td>
<td>I,j</td>
</tr>
<tr>
<td>VPS-D</td>
<td>22.74</td>
<td>1.74</td>
<td>A,k</td>
<td>23.54</td>
<td>0.68</td>
<td>E,I</td>
<td>25.18</td>
<td>1.43</td>
<td>H,m</td>
</tr>
<tr>
<td>VPES-I</td>
<td>30.24</td>
<td>1.17</td>
<td>D,n</td>
<td>31.86</td>
<td>1.75</td>
<td>G,o</td>
<td>33.33</td>
<td>1.71</td>
<td>J,p</td>
</tr>
<tr>
<td>VPES-D</td>
<td>28.28</td>
<td>1.44</td>
<td>C,r</td>
<td>29.67</td>
<td>1.29</td>
<td>F,s</td>
<td>31.74</td>
<td>1.81</td>
<td>J,t</td>
</tr>
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Table 3 – Results of 3-way ANOVA for angular deviations.

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III sum of squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Sig.</th>
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</thead>
<tbody>
<tr>
<td>Corrected model</td>
<td>0.251*</td>
<td>17</td>
<td>0.015</td>
<td>85.755</td>
<td>0.000</td>
</tr>
<tr>
<td>Intercept</td>
<td>11.455</td>
<td>1</td>
<td>11.455</td>
<td>66,432.772</td>
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<tr>
<td>Technique</td>
<td>0.038</td>
<td>1</td>
<td>0.038</td>
<td>221.664</td>
<td>0.000</td>
</tr>
<tr>
<td>Material</td>
<td>0.108</td>
<td>2</td>
<td>0.054</td>
<td>311.851</td>
<td>0.000</td>
</tr>
<tr>
<td>Angulation</td>
<td>0.073</td>
<td>2</td>
<td>0.036</td>
<td>210.741</td>
<td>0.000</td>
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<tr>
<td>Technique × material</td>
<td>0.000</td>
<td>2</td>
<td>0.000</td>
<td>0.996</td>
<td>0.372</td>
</tr>
<tr>
<td>Technique × angulation</td>
<td>0.005</td>
<td>2</td>
<td>0.003</td>
<td>15.861</td>
<td>0.000</td>
</tr>
<tr>
<td>Material × angulation</td>
<td>0.024</td>
<td>4</td>
<td>0.006</td>
<td>35.077</td>
<td>0.000</td>
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<tr>
<td>Technique × material × angulation</td>
<td>0.003</td>
<td>4</td>
<td>0.001</td>
<td>4.239</td>
<td>0.003</td>
</tr>
<tr>
<td>Error</td>
<td>0.028</td>
<td>162</td>
<td>0.000</td>
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</tr>
<tr>
<td>Total</td>
<td>11.735</td>
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<tr>
<td>Corrected total</td>
<td>0.279</td>
<td>179</td>
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</table>

* R² = 0.900 (adjusted R² = 0.889).

Table 4 – Results of 3-way ANOVA for coronal deviations.

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III sum of squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Sig.</th>
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</thead>
<tbody>
<tr>
<td>Corrected model</td>
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<td>17</td>
<td>91.900</td>
<td>39.759</td>
<td>0.000</td>
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<tr>
<td>Intercept</td>
<td>133,380.178</td>
<td>1</td>
<td>133,380.178</td>
<td>57,703.952</td>
<td>0.000</td>
</tr>
<tr>
<td>Technique</td>
<td>278.656</td>
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<td>278.656</td>
<td>120.554</td>
<td>0.000</td>
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<tr>
<td>Material</td>
<td>1010.211</td>
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<td>505.105</td>
<td>218.523</td>
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<tr>
<td>Angulation</td>
<td>172.624</td>
<td>2</td>
<td>86.312</td>
<td>37.341</td>
<td>0.000</td>
</tr>
<tr>
<td>Technique × material</td>
<td>19.233</td>
<td>2</td>
<td>9.617</td>
<td>4.160</td>
<td>0.017</td>
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<tr>
<td>Technique × angulation</td>
<td>8.768</td>
<td>2</td>
<td>4.381</td>
<td>1.895</td>
<td>0.154</td>
</tr>
<tr>
<td>Material × angulation</td>
<td>57.458</td>
<td>4</td>
<td>14.365</td>
<td>6.215</td>
<td>0.000</td>
</tr>
<tr>
<td>Technique × material × angulation</td>
<td>15.358</td>
<td>4</td>
<td>3.839</td>
<td>1.661</td>
<td>0.162</td>
</tr>
<tr>
<td>Error</td>
<td>374.456</td>
<td>162</td>
<td>2.311</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>135,356.937</td>
<td>180</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Corrected total</td>
<td>1936.759</td>
<td>179</td>
<td></td>
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</tbody>
</table>

* R² = 0.807 (adjusted R² = 0.786).

use of PE is recommended for fully edentulous and multi-implant cases.\textsuperscript{41} On the other hand, elastic recovery is a significant factor in determining the accuracy of an impression material.\textsuperscript{53} The use of a more elastic material may reduce the permanent distortion caused by the stress between copings and the implant impression material.\textsuperscript{19} Thus, VPS could be considered as a feasible option especially when nonparallel implants are present.\textsuperscript{41} In the present study, accuracies of 3 monophase elastomeric impression materials with medium-consistency were assessed. Regardless of the impression technique, no significant difference was detected between the accuracies of PE and VPS for parallel implants, whereas VPS provided statistically the most accurate impressions for 10° and 20° angulated implants. This may be explained by the higher elastic recovery of VPS in comparison to PE. The highest angular and coronal deviations of the copings were detected in the casts obtained with VPS. VPES is a relatively new material and there is limited data regarding the accuracy and rigidity of this material. Further studies are needed for evaluation of its chemical and physical properties.

According to the results of the present study, the best combination of impression material and technique for angulated implants were VPS and splinted direct technique. Although significant differences were detected among the accuracies of the materials and techniques tested in this study, the mean deviations were in a range of 22.56-33.33 μm. Assuncao et al.\textsuperscript{25} stated that in a good impression, a discrepancy of 50 μm may be found in any axis. The discrepancies are not only caused by the accuracy of impression techniques and materials but also by the machining tolerances between implant and the impression coping, and abutments. Ma\textsuperscript{40} reported machining tolerances between implant components ranging from 22 to 100 μm. When interpreting the results of the studies regarding the accuracy of implant impressions, machining tolerance should also be considered.\textsuperscript{5}

This in vitro study has several limitations. The hardness, structure and wettability of acrylic resin surface of the master models are different from oral tissues. Also 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. Another possible limitation of the study was that the axial rotation of the implant components caused by the impression technique and material were not detected. Furthermore, the results are limited to two internal connection implants and may not be relevant with higher number of implants and different connection geometries. Further studies testing more implants, different angulations and connection geometry are needed to evaluate the accuracy of implant impressions.

5. Conclusions

Within the limitations of this study, the following conclusions can be drawn:

1. Angulation, impression technique and impression material were found to be effective on the accuracy of implant impressions.

2. For parallel implants, more accurate impressions were obtained with splinted direct technique and there was no significant difference between PE and VPS. However VPES showed higher deviations.

3. In the presence of angulated implants the most accurate impression material was VPS and the most accurate technique was splinted direct technique.

Conflict of interest

The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article. This study was self-funded by the authors.

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