Evaluation of Accuracy of Casts of Multiple Internal Connection Implant Prosthesis Obtained From Different Impression Materials and Techniques: An In Vitro Study

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Movement of impression copings inside the impression material using a direct (open tray) impression technique during clinical and laboratory phases may cause inaccuracy in transferring the 3-dimensional spatial orientation of implants intraorally to the cast. Consequently, the prosthesis may require corrective procedures. This in vitro study evaluated the accuracy of 3 different impression techniques using polyether and vinyl polysiloxane (VPS) impression material to obtain a precise cast for multiple internal connection implants. A reference acrylic resin model with 4 internal connection implants was fabricated. Impressions of the reference model were made using 3 different techniques and 2 different impression materials. The study consisted of 24 specimens divided into 6 groups of 4 each. Impressions were poured with ADA type IV stone (Kalrock, Kalabhai Karson Pvt Ltd, Mumbai, India). All casts were evaluated for the positional accuracy (mm) of the implant replica heads using a profile projector. These measurements were compared to the measurements calculated on the reference resin model, which served as a control. Data were analyzed with 2-way analysis of variance (ANOVA) followed by Bonferroni multiple comparison procedures to evaluate group means. The results revealed significant difference for anterior implant distance between the 2 impression materials ($P < .01$) and also among the 3 different techniques ($P < .05$). The lowest mean variation was found with the polyether impression material and the splinted technique. For posterior implants, the results suggested no significant difference between the 2 impression materials ($P \geq .05$). Although results were not statistically significant, the polyether impression material showed the lowest mean variation as compared to the VPS impression material. However, there was a significant difference among the 3 different techniques ($P < .05$). Among the 3 different techniques, the lowest mean variation between 2 posterior implants was found in the splinted technique. Casts obtained from impression techniques using square impression copings splinted together with autopolymerizing acrylic resin prior to the impression procedure were more accurate than casts obtained from impressions with nonmodified implant impression copings and with airborne particle–abraded, adhesive-coated copings. Casts obtained from polyether impression material were more accurate than casts obtained from vinyl polysiloxane impression material.

Key Words: dental implants, implant impression techniques, pick-up impression technique, transfer impression technique

INTRODUCTION

Impression techniques and materials used in dentistry have come a long way since the early times, when it was just an attempt to record the tissues without the knowledge and appreciation of the anatomy and physiology

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of the tissues being recorded, to the more scientific and well-documented making of biologic impressions followed today. Impression materials have been used in the production of accurate replicas of teeth and surrounding oral tissues since Philip Pfaff reported making the first dental impression in 1756.\(^1\)

Computer-assisted design and computer-assisted manufacture are technologic advancements used in dentistry today. These technologies have been developed to fabricate a complete arch substructure for a fixed, screw-retained, implant-supported prosthesis. However, because of certain technical aspects and the cost factor, computer-assisted design and manufacture has yet to gain popularity. Therefore, the various conventional impression techniques used for master cast fabrication play a key role in the fabrication of prosthesis even today.\(^2\)

Dental implants have been proven successful in the treatment of edentulism. Osseointegrated implants were used for rehabilitation of edentulous patients with the principle objective of replacing conventional complete dentures with an implant-supported prosthesis.\(^3\),\(^4\) In implant prosthodontics, a successful result can be achieved only when passively fitting prostheses are fabricated.\(^5\) Although there is some evidence that prosthesis misfit may not affect osseointegration, there is evidence that prosthesis misfit is likely to increase the incidence of mechanical component loosening or fracture. The causes of component failure and loosening are multifactorial, but it must be assumed that prosthesis misfit plays an important role in complications such as occlusal and abutment screw loosening and fracture in implant restorations.\(^6\)–\(^9\) Because of these, prosthesis misfit has to be minimized.

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, rather than reproduce fine surface details for successful implant prosthodontic treatment.\(^10\)–\(^12\) The development of impression techniques to accurately record implant position has become more complicated and challenging. Several impression techniques have been suggested to obtain a master cast that will ensure passive fit of a prosthesis on implants.\(^13\),\(^14\)

To date, many authors have investigated factors affecting the accuracy of implant impressions, such as the necessity of splinted impression copings, surface treatment of impression copings, direct or indirect impression techniques, and use of different impression materials. However, the results are not always consistent, and limited literature is available to compare the accuracy of impression techniques as well as materials. Therefore, the present in vitro study was carried out to evaluate the effect of surface treatment of square impression copings (nonmodified square impression copings, impression copings airborne particle–abraded and adhesive-coated, and by splinting those impression copings with autopolymerizing acrylic resin) on accuracy of open tray impression technique by using 2 impression materials.

**Materials and Methods**

An acrylic resin model (Figure 1) of a maxillary edentulous arch with 4 internal connection 4.2-mm diameter implant analogs (LifeCare Devices Pvt Ltd, Mumbai, India) was fabricated. These 4 implant analogs in the acrylic resin model were sequentially numbered as 1, 2, 3, 4 from left to right. The 4 implant analogs in the resin model were covered with 2 layers of modelling wax (Hindustan Dental Products, Hyderabad, India) to allow a consistent thickness of impression material, and an irreversible hydrocolloid impression was made to obtain a single cast on which all custom trays were fabricated. Twenty-four identical 2-mm–thick custom impression trays were made with autopolymerizing polymethyl methacrylate resin (DPI-RR Cold Cure, DPI, Mumbai, India), according to the manufacturer’s instructions. Tissue stops were incorporated between each implant to standardize tray positioning during impression making. The study consisted of 24 specimens divided into 6 groups of 4 each. The groups were categorized as follows:

- **Group 1**: nonmodified square impression copings (NM group) with polyether impression material.
- **Group 2**: square impression copings splinted together with autopolymerizing acrylic resin (R group) with polyether impression material.
- **Group 3**: square impression copings airborne-particle abraded and coated with the impression
adhesive (M group) with polyether impression material.

- Group 4: nonmodified square impression copings (NM group) with putty wash vinyl polysiloxane (VPS) impression material.
- Group 5: square impression copings splinted together with autopolymerizing acrylic resin (R group) with putty wash VPS impression material.
- Group 6: square impression copings airborne-particle abraded and coated with the impression adhesive (M group) with putty wash VPS impression material.

For groups 1 to 3, 12 medium-consistency polyether impressions (Impregum Penta, 3M ESPE, Seefeld, Germany) were made according to the manufacturer’s directions. Impression trays were coated with tray adhesive (Impregum, 3M ESPE) 1 hour before each impression was made. The impression material was mixed using glass slab and spatula, and part of the material was meticulously syringed around the impression copings to ensure complete coverage of the copings. The remaining impression material was used to load the impression tray. The impression trays were fully seated over the resin model with finger pressure, and the position was maintained throughout the polymerization time.

In the first group, impression copings as supplied by the manufacturer were used (non-modified square impression copings, NM group)
Polyether was used as an impression material. Each impression tray was seated, and the material was allowed to polymerize. The guide pins were released so that the transfer copings remained in the impression when the impression was removed.

In the second group (R group), impression copings were splinted with acrylic resin (DPI-RR Cold Cure, DPI) (Figure 3). The acrylic resin splint was fabricated 1 day prior to the impression procedure and divided into 4 separate pieces with a handpiece diamond disk, and a 0.2-mm standardized gap space was left between the single pieces. The pieces were reconnected just before the impression procedure with an incremental application technique to minimize polymerization shrinkage of the resin. The impression procedure was accomplished as previously described.

In the third group, impression copings were airborne-particle abraded and coated with adhesive (Impregum, 3M ESPE) (modified square impression copings, M group) (Figure 4), and the impression procedure was accomplished as previously described.

For the open tray technique, the guide pins were loosened with a hex driver (EZ Hi-Tec, LifeCare Devices) and removed, the tray was separated from the definitive cast, and the impression copings along with the guide pin remained locked in the impression. The implant analog was connected to the hex at the bottom of the impression coping, and the guide pins were tightened with the hex driver.

In the fourth, fifth, and sixth groups VPS impression material was used. The procedure for these 3 techniques was the same as for the first 3 techniques. The custom trays were painted with VPS adhesive (VPS Tray Adhesive, 3M ESPE, St Paul, Minn) and allowed to dry for 15 minutes. The custom trays were filled with heavy body VPS impression material, while the regular body VPS material (Imprint II Garant, 3M ESPE) was syringed around the impression copings on the definitive cast. The custom trays were seated on the definitive cast, and any excess material from the open tray windows was removed with a finger swipe to expose the guide pins.

An ADA type IV die stone (Kalrock, Kalabhai Karson Pvt Ltd, Mumbai, India) was used in accordance with the manufacturer’s instructions. The casts were retrieved from the impressions after 24 hours. All of the casts were stored at room temperature for a minimum of 24 hours before measurements were made. All clinical and laboratory procedures were performed by the same operator. A single examiner, blinded to the nature of the impression technique used, examined all definitive casts to evaluate the positional accuracy of the implant replica heads using a profile projector.

A profile projector is an optical instrument that can be used for measuring. The projector magnifies the profile of the specimen and displays this on the built-in projection screen. All of the casts were secured to a universal movable surveyor table (Ney, Hartford, Conn), and the 3-dimensional position was adjusted so that the horizontal reference plane of the profile projector coincided with the plane connecting the highest points located at the periphery of the 2 implants. This device, composed of a screen with horizontal and vertical reference lines, had a movable table to allow positioning on the screen, the object being studied. It had a light source that projected a magnified image of the object onto the screen in the form of a shadow (original magnification ×10) so that the sharp edges of the projected, silhouetted form of the abutments became the reference points of measurement.

The following measurements were evaluated on the reference acrylic resin model and the definitive cast replicas: (1) posterior measurement, the distance between the external sharp edges of the projected, silhouetted form of the most distal left and right implants (1 and 4); and (2) anterior measurements, the distance between the external sharp edges of the projected, silhouetted form of the most mesial left and right implants (2 and 3). No 3-dimensional positional changes of the casts on the surveyor table were required when calculating these distances. Other measurements were not performed to avoid introducing additional sources of measurement error and to ensure better data reproducibility. Data were analyzed with 2-way analysis of variance (ANOVA) followed by Bonferroni multiple comparison procedures to evaluate group means.

**Results**

The results of the present study reveal that the polyether impression material showed lowest mean
variation as compared to the VPS impression material on average, for both anterior and posterior distances, with statistical significance apparent in only the anterior analysis. However, there was a significant difference between the 3 different techniques for both anterior and posterior distances ($P < .05$). Among the 3 different techniques, lowest mean variation between 2 implants was found in the splinted technique. Next lowest mean variation was found in the airborne particle–abraded technique, and highest mean variation was found in the nonmodified technique (Tables 1 through 6) (Figures 8 through 10).

Results of ANOVA for anterior and posterior implant distance means are shown in Tables 2 and 5. To find out among which pair of techniques a significant difference existed, we carried out multiple comparisons testing using the Bonferroni method. The results for the anterior analysis are shown in Table 3, while those from the posterior analysis are shown in Table 6.

### DISCUSSION

Accuracy of the impression affects the accuracy of the cast, and accurate impression is essential to fabricate prosthesis with a good fit. An inaccurate impression may result in prosthesis misfit, which may lead to mechanical and/or biological complications. Screw loosening, screw fracture, implant fracture, and occlusal inaccuracy have been reported as mechanical complications arising from prosthesis misfit.\(^3\)\(^5\) Biologically, marginal discrepancy from misfit may cause unfavorable soft and/or hard tissue reactions due to increased plaque accumulation. Even though obtaining absolute passive fit is practically impossible,\(^6\)\(^9\) minimizing the misfit to prevent possible complications is generally an accepted goal of implant procedures in prosthodontics.

The ideal objective is difficult to fully realize clinically because of the potential for distortion of the master cast, which is caused by a combination of dimensional errors in the process of transfer of the replicas, and also because the framework adaptation may change when the retaining screws are tightened. The tolerable discrepancy of a framework over several implants is not known, but because discrepancies of less than 30 µm in the fit of an implant-retained framework on multiple abutments cannot be detected clinically by experienced operators,\(^15\) this figure could serve as a criterion between acceptable and unacceptable frameworks.

Traditionally, there are 2 implant impression techniques, namely direct and indirect techniques, available for transferring the impression copings from the implant to the impression. Various in vitro studies have assessed the effect of these 2 impression techniques on the accuracy of master casts. Studies conducted by Del’Acqua et al,\(^16\) Carr,\(^17\) Phillips et al,\(^18\) and Assuncao et al\(^19\) reveal that impressions obtained with the direct technique (open tray) were more accurate than the indirect technique (closed tray). Many authors have further investigated factors affecting the accuracy of direct implant impression techniques, such as the necessity of splinting impression copings, surface treatment of impression copings, and use of different impression materials. However, the results were not always consistent, and limited literature is available to compare the accuracy of impression techniques as well as materials. The present study evaluated the effect of various surface treatments of square impression copings on the accuracy of direct impression technique by using polyvinylsiloxane and polyether impression materials.

In the present study, the positional accuracy of the implant replica heads was measured using a profile projector. The profile projector allowed measurement of linear distances with an accuracy
Most measuring devices used to assess implant impression accuracy, including calipers, strain gauges, and measuring microscopes, are less accurate than the profile projector.20

The results of the present study revealed that for anterior implant distance there was a significant difference between the 2 impression materials ($P < .01$) and also among the 3 different techniques ($P < .05$). The lowest mean variation was found in the polyether impression material and with the splinted technique. Higher mean variation between the 2 anterior implants was recorded in VPS material with the nonmodified technique followed by the air-borne particle–abraded technique. For posterior implants, the results suggested that there was no significant difference between the 2 impression materials ($P \geq .05$). Although results were not statistically significant, the polyether impression material showed the lowest mean variation as compared to the VPS impression material. However, there was a significant difference among the 3 different techniques ($P < .05$). Among the 3 different techniques, the lowest mean variation between 2 posterior implants was found in the splinted technique. The next lowest mean variation was found in the air-borne-particle–abraded technique, and the highest mean variation was found in the nonmodified technique.

The above findings are comparable with the studies conducted by Vigolo et al,21 Cabral and Guedes,22 Assif et al,23 and Naconecy et al.24 The reason for greater accuracy with the splinted

![Figure 5](image1.png)
![Figure 6](image2.png)
![Figure 7](image3.png)
![Figure 8](image4.png)
![Figure 9](image5.png)
![Figure 10](image6.png)

**FIGURES 5–10.** Figure 5. Mean anterior distance variation in the 2 impression materials. Figure 6. Mean anterior distance variation in the different techniques. Figure 7. Combination effect of different materials and different techniques on anterior implant distance. Figure 8. Mean posterior distance variation in the 2 impression materials. Figure 9. Mean posterior distance variation in the different techniques. Figure 10. Combination effect of different materials and techniques on posterior distance.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sum of Squares (SS)</th>
<th>Mean SS</th>
<th>$F$</th>
<th>$P$ Value</th>
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</thead>
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<tr>
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<td>0.0070</td>
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<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>0.0273</td>
<td>–</td>
<td>–</td>
<td>–</td>
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</table>

*Denotes significance.

$df$ indicates degrees of freedom.
### Table 3

Multiple comparisons test using Bonferroni method for anterior implant distance variation†

<table>
<thead>
<tr>
<th>(I) Technique</th>
<th>(J) Technique</th>
<th>Mean Difference (I−J)</th>
<th>SE</th>
<th>Sig</th>
<th>95% CI Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airborne particle–abraded</td>
<td>Nonmodified</td>
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<td>.012641</td>
<td>1.000</td>
<td>−.03261</td>
<td>.03411</td>
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<tr>
<td></td>
<td>Splinted</td>
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<td>.012641</td>
<td>.024</td>
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<tr>
<td>Nonmodified</td>
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<td>.012641</td>
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<td>.03261</td>
</tr>
<tr>
<td></td>
<td>Splinted</td>
<td>.03688*</td>
<td>.012641</td>
<td>.028</td>
<td>.300351</td>
<td>.07024</td>
</tr>
<tr>
<td>Splinted</td>
<td>Airborne particle–abraded</td>
<td>−.03763*</td>
<td>.012641</td>
<td>.028</td>
<td>−.07099</td>
<td>−.00426</td>
</tr>
<tr>
<td></td>
<td>Nonmodified</td>
<td>−.03688*</td>
<td>.012641</td>
<td>.024</td>
<td>−.07024</td>
<td>−.00351</td>
</tr>
</tbody>
</table>

†Dependent variable: anterior Bonferroni. Based on observed means.
*The mean difference is significant at the .05 level.

### Table 4

Descriptive statistics among different factors and their levels in posterior implants

<table>
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<tr>
<th>Factor</th>
<th>Level</th>
<th>Mean, mm</th>
<th>SD</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
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<tbody>
<tr>
<td>Material</td>
<td>Polyether</td>
<td>0.087</td>
<td>0.044</td>
<td>0.085</td>
<td>0.005</td>
<td>0.157</td>
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<tr>
<td></td>
<td>Vinyl polysiloxane</td>
<td>0.125</td>
<td>0.073</td>
<td>0.121</td>
<td>−0.007</td>
<td>0.276</td>
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<td>Technique</td>
<td>Airborne particle–abraded</td>
<td>0.123</td>
<td>0.023</td>
<td>0.117</td>
<td>0.096</td>
<td>0.174</td>
</tr>
<tr>
<td></td>
<td>Nonmodified</td>
<td>0.144</td>
<td>0.073</td>
<td>0.148</td>
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<td>0.276</td>
</tr>
<tr>
<td></td>
<td>Splinted</td>
<td>0.050</td>
<td>0.034</td>
<td>0.061</td>
<td>−0.007</td>
<td>0.098</td>
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</table>

### Table 5

Analysis of variance for posterior implant distance means

<table>
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<tr>
<th>Source</th>
<th>df†</th>
<th>Sum of Squares (SS)</th>
<th>Mean SS</th>
<th>F</th>
<th>P Value</th>
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<td>Material × technique</td>
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<tr>
<td>Error</td>
<td>18</td>
<td>0.0356</td>
<td>0.0020</td>
<td>–</td>
<td>–</td>
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<tr>
<td>Total</td>
<td>23</td>
<td>0.0883</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

*Denotes significance.
†df indicates degrees of freedom.

### Table 6

Multiple comparisons test using Bonferroni method for posterior implant distance variation†

<table>
<thead>
<tr>
<th>(I) Technique</th>
<th>(J) Technique</th>
<th>Mean Difference (I−J)</th>
<th>SE</th>
<th>Sig</th>
<th>95% CI Lower Bound</th>
<th>Upper Bound</th>
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</thead>
<tbody>
<tr>
<td>Airborne particle–abraded</td>
<td>Nonmodified</td>
<td>−.02088</td>
<td>.022222</td>
<td>1.000</td>
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</tr>
<tr>
<td></td>
<td>Splinted</td>
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<td>.13</td>
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†Dependent variable: posterior Bonferroni. Based on observed means.
*The mean difference is significant at the .05 level.
technique is that the splinting may provide stabilization of transfer copings under the torque from analog tightening and reduce rotational freedom within a resilient impression material. Some authors\textsuperscript{21–24} have suggested the importance of avoiding movement of impression copings inside the impression material throughout the procedures associated with fabrication of the definitive cast. Unscrewing the guide pins from the impression copings when the tray is removed or screwing the matching implant replicas in the impression may cause minor movement and thus influence cast accuracy.

In contrast to the above observations, studies conducted by Phillips et al\textsuperscript{18} and Inturregui et al\textsuperscript{25} found that the nonsplinted technique is more accurate than the splinted technique. Some authors\textsuperscript{18,25} have quoted the possible problems with the splinted technique, such as the polymerization shrinkage of the acrylic resin and the rigid fixation of the impression transfer copings, which may have altered the setting expansion of the improved dental stone and, therefore, may have distorted the interabutment relationship from that of the master cast. Some researchers like Del’Acqua et al,\textsuperscript{16} and Kim et al\textsuperscript{26} found that there is no difference between the splinted and nonsplinted techniques using a low-flexibility impression material (polyether).

Connecting the impression copings with acrylic resin is a time-consuming procedure. To avoid problems related to resin polymerization contraction and to save chairside time, the resin scaffold may be prepared in advance, and the final connection may be performed just before the impression procedure by resplinting a narrow gap space between the implants with a minimum amount of material to reduce the effects of polymerization shrinkage.

Casts produced from polyether impression material were more accurate than those produced from VPS impression material. These results are comparable to those of Wee,\textsuperscript{11} who studied the torque resistance of impression materials and reported that polyether material showed the greatest torque values and high initial tear resistance, which may be favorable for the manipulation of a pick-up impression. The rigidity of polyether provides resistance to the accidental movement of the impression coping in the implant impression. Therefore, it provides sufficient rigidity to reduce rotation of the square transfer copings during analog fastening and cast fabrication. Results of this study\textsuperscript{11} support the use of polyether for completely edentulous multi-implant impressions.

In contrast to the present study, the study conducted by Lee et al\textsuperscript{27} reported that VPS impression material was more accurate than polyether impression material. In their study, implants were placed deep subgingivally. The deeper an implant is placed subgingivally, the greater is the portion of the impression coping positioned subgingivally, resulting in less area of the impression coping being covered by impression material. The impressions thus obtained are not as accurate as those in which the impression copings are more fully embedded within the impression material.

A few studies conducted by Barrett et al,\textsuperscript{10} Assuncao et al,\textsuperscript{19} and Liou et al\textsuperscript{28} reported no significant difference in cast accuracy between these 2 impression materials.

It should be noted that discrepancies were evaluated in a horizontal plane between paired implants. Under clinical conditions and in multiple implant restorations, these differences may be greater if the discrepancies are present in other spatial planes and if they occur in opposite dimensions. Thus, such discrepancies may clinically result in a nonprecise fit of the metal supporting structure and potentiate the need for soldering procedures. The limitation of this study is that only horizontal movements of the impression copings were detected. More research in this area should be performed to evaluate eventual 3-dimensional movements of pick-up impression copings inside the impression material.

**Conclusions**

Within the limitations of this in vitro study, it can be concluded that measured impression distances were almost overestimating as the distance in the impression was subtracted from the actual distance of the model.

1. Casts obtained from impression techniques using square impression copings splinted together with autopolymerizing acrylic resin prior to the impression procedure were more accurate than casts obtained from impressions with nonmodi-
fied implant impression copings and with airborne particle–abraded, adhesive-coated copings.

2. Casts obtained from polyether impression material were more accurate than casts obtained from vinyl polysiloxane impression material.

3. Combination of polyether impression material and impression copings splinted together with autopolymerizing acrylic resin produced more accurate casts compared with other groups.

4. Casts obtained from impression techniques using square impression copings and airborne particle–abraded and adhesive-coated copings were more accurate than impressions with nonmodified implant impression copings.

ABBREVIATIONS

VPS: vinyl polysiloxane

REFERENCES


