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Fabrication Materials and Techniques: Influence on Prosthesis Fit Precision

A precise fit for a prosthesis, however difficult to obtain, is the clinician's goal. Improved fabrication methods and materials have been designed to achieve that outcome. This issue of Report on Prosthodontics reviews the current literature regarding the fit precision of implant frameworks.

Fit Precision of Zirconium Dioxide and Titanium CAD/CAM Frameworks

While a passive fit can decrease the risk of mechanical and biological complications, the methods and materials used to fabricate implant-supported frameworks may lead to inaccuracies in prosthesis fit. Computer-aided design and computer-aided manufacturing (CAD/CAM) technologies have made it possible to mill prostheses from homogenous blocks, eliminating the shortcomings of alloy and cast procedures. Katsoulis et al from the University of Bern, Switzerland, examined methods and materials used to fabricate implant-supported full-arch prostheses to analyze the fit accuracy of laser- and tactile-scanned CAD/CAM zirconium dioxide (ZrO) frameworks, CAD/CAM titanium frameworks and conventional cast alloy frameworks.

After creating a polyester resin maxillary edentulous cast, the researchers positioned 6 implant analogues (4.3-mm diameter). The 2 implants in the central incisor region were angulated by 10° to the sagittal plane, while the remaining implants were parallel and vertically aligned.

Six laser-scanned ZrO frameworks were fabricated using the NobelProcera Scanner to digitize the implant platform and resin framework pattern. Five tactile-scanned ZrO frameworks were fabricated using the Procera Forte Scanner. The laser scanner was also used to fabricate 6 CAD/CAM titanium frameworks.

Inside this issue:
- Fit Precision of Long-span Screw-retained CAD/CAM Prostheses
- Fit of Long- vs Short-span CAD/CAM Prostheses
- Effect of Ceramic Firing on CAD/CAM Titanium Prostheses Fit

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A blinded production laboratory used a CNC milling machine to produce the ZrO frameworks from solid presintered ZrO monoblocks; the titanium frameworks were made using the same procedure. All frameworks were sintered and finished by the same experienced laboratory technician. Five cobalt-chromium wolfram alloy frameworks conventionally cast using a lost-wax technique served as the control.

All measurements were made on the same master model by 1 calibrated investigator. Using the 1-screw test, the vertical gap was measured at all non-screw-retained implants using a calibrated scanning electron microscope with 2000x magnification. The mean misfit per implant was calculated from 3 mesial, 3 buccal and 3 distal measurements. Comparisons of the total mean values of all implants and for values of single implants were made among the groups.

A significant difference in fit precision was found among the 4 groups \((p < .001)\). The mean vertical gap for each of the CAD/CAM groups was significantly smaller than it was for the conventional cast group, with none of the cast frameworks showing misfits \(\leq 50 \mu m\). There was no significant difference between the laser-scanned ZrO and the laser-scanned titanium group. There was no statistically significant difference for overall median values between the ZrO laser- and tactile-scanned frameworks.

However, 50% of the ZrO laser-scanned frameworks showed misfit values of \(\leq 50 \mu m\) only for the shorter spans (3–6 units), unlike the tactile-scanned ZrO group, of which only 1 framework exhibited a gap of \(> 50 \mu m\). In all CAD/CAM groups, there was a trend of increasing values of misfit the farther the examined implant was from the screw-retained implant. The laser-scanned titanium frameworks showed the most consistent results; all gap sizes were \(\leq 50 \mu m\).

The limiting factor for precision of fit may lie in the clinical steps taken prior to the laboratory fabrication of a CAD/CAM framework. The authors concluded that the laser and tactile scanners both showed a high degree of accuracy.


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**Fit Precision of Long-span Screw-retained CAD/CAM Prostheses**

Despite the various materials and techniques available to fabricate implant-supported frameworks, no combination of techniques or materials has led to a standardized method that decreases processing time, is low in cost and has an accurate fit. Cobalt-chromium (Co-Cr) alloys have gained interest for use in computer-aided designed and computer-aided manufactured (CAD/CAM) restorations due to their decreased cost. To compare the precision of fit of 3-unit screw-retained fixed dental prostheses (FPDs) of zirconia and Co-Cr fabricated by CAD/CAM, and conventionally fabricated Co-Cr alloy, de França et al from the State University of Rio Grande do Norte, Brazil, fabricated 16 frameworks as follows:

- CAD/CAM-fabricated zirconia (ZirCAD group; \(n = 4\))
- CAD/CAM-fabricated Co-Cr (CoCrCAD group; \(n = 4\))
- conventionally fabricated Co-Cr with premachined Co-Cr abutments (CoCrUCi group; \(n = 4\))
- conventionally fabricated Co-Cr with castable abutments (CoCrUCi group; \(n = 4\))

Three external hexagon implants (4.1 mm × 9 mm) inserted into an aluminum matrix represented the left mandibular second premolar, first molar and second molar. A polyether impression was made by a splinted direct-transfer coping technique, and a master cast of type IV dental stone was fabricated; 3 Co-Cr abutments were attached to the implant analogues for framework waxing.

Using 3-dimensional laser scanning technology, 4 frameworks were milled from presintered yttrium-stabilized tetragonal zirconia polycrystal blocks, and 4 were milled from Co-Cr blocks; four 3-unit FPDs were waxed with castable abutments, and four 3-unit FPDs were waxed with Co-Cr abutments. An index standardized the wax dimensions. A passive fit of the wax pattern was verified prior to investing and casting.

The vertical gap between framework platform and implant was evaluated using the 1-screw test (passive fit) and after all
retaining screws had been tightened (definitive fit). A scanning electron microscope set at 250× magnification measured the vertical gap. The minimum critical vertical misfit for the definitive fit was set at 10 μm.

Examination of passive fit using the 1-screw test revealed no statistically significant difference among the groups; however, the CAD/CAM frameworks had a more uniform level of fit. The standard deviations were smaller, with less variability between the maximum and minimum values (Table 1). The mean vertical gap in the definitive fit was significantly smaller in the CAD/CAM frameworks than in the conventionally fabricated frameworks (Table 2).

While the vertical misfit in the passive condition was not significantly different between the conventionally fabricated and the CAD/CAM frameworks, the mean vertical gaps of the conventionally fabricated frameworks in the definitive fit were above the 10-μm threshold. Although the results were limited by the small number of frameworks examined, the CAD/CAM-fabricated frameworks exhibited better vertical fit values than did the conventionally fabricated frameworks.


### Table 1. Mean and range of vertical misfit values in passive fit condition for all groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean ± SD (μm)</th>
<th>Range (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZirCAD</td>
<td>107.2 ± 36.0</td>
<td>31.9–163.8</td>
</tr>
<tr>
<td>CoCrCAD</td>
<td>107.5 ± 26.0</td>
<td>65.2–143.0</td>
</tr>
<tr>
<td>CoCrUCci</td>
<td>124.7 ± 74.0</td>
<td>25.0–263.8</td>
</tr>
<tr>
<td>CoCrUCcl</td>
<td>108.8 ± 85.0</td>
<td>25.0–317.8</td>
</tr>
</tbody>
</table>


### Table 2. Mean and range of vertical gap values, and the proportion of vertical misfit values above and below 10 μm in the definitive fit condition

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean ± SD (μm)</th>
<th>Range (μm)</th>
<th>0–10 μm (%)</th>
<th>&gt;10 μm (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZirCAD</td>
<td>5.9 ± 3.6a</td>
<td>0–13.89</td>
<td>83.3</td>
<td>16.7</td>
</tr>
<tr>
<td>CoCrCAD</td>
<td>1.2 ± 2.2b</td>
<td>0–8.33</td>
<td>100.0</td>
<td>0.0</td>
</tr>
<tr>
<td>CoCrUCci</td>
<td>11.8 ± 9.8c</td>
<td>1.39–44.44</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>CoCrUCcl</td>
<td>12.9 ± 11.0d</td>
<td>2.78–55.56</td>
<td>54.2</td>
<td>45.8</td>
</tr>
</tbody>
</table>

p for mean vertical gap values among all groups <.001. a,b,c,d statistically significant difference between specific groups at p < .05 (Kruskal–Wallis test). SD, standard deviation.

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**Fit of Long- vs Short-span CAD/CAM Prostheses**

Computer-aided designed and computer-aided manufactured (CAD/CAM) prostheses are becoming the standard for both long- and short-span implant-supported prostheses. Katsoulis et al from the University of Bern, Switzerland, compared the fit precision of long- and short-span implant-supported screw-retained porcelain-veneered CAD/CAM titanium-fixed dental prostheses (FDPs).

A single polyester resin master cast of an edentulous maxilla with 6 implant analogues was used for the evaluation. Implants were placed in FDI positions 15, 13, 11, 21, 23 and 25; those in sites 11 and 21 were angulated by 10° in the sagittal plane. Two groups of FDPs were fabricated: Group A consisted of six 10-unit FDPs (FDI #15–25); group B consisted of six 5-unit FDPs (FDI #21–25).

Each step of fabricating the FDPs was performed separately, including the laser scanning, CAD/CAM and veneering processes. One trained technician consecutively fabricated all 12 FDPs. The frameworks were milled from a homogenous block of grade 5 titanium. The same technique and ceramic material were used for all veneering.

One investigator performed all measurements using the 1-screw test and a scanning electron microscope (at up to 2000× magnification). Each prosthesis was aligned on the master cast using screws in positions 21 and 25. After hand-tightening, the screw in position 25 was tightened to 30 Ncm, and the screw in position 21 was removed. The vertical distance between the implant shoulder and the FDP platform on the mesial, buccal and distal surfaces was measured 3× on all unretracted interfaces, and the mean of those measurements was recorded as the misfit.

The CAD/CAM-fabricated frameworks were highly accurate, with misfit values <40 μm for all vertical microgaps measured: from 2 μm to 81 μm for the long-span FDPs and from 4 μm to 24 μm for the short-span FDPs.
Significant differences in vertical misfit between implants were observed in the long-span FDPs. The anterior implants in group A (13, 11 and 21 of all FDPs) showed higher values than did the most distant implant (15). Five of the 6 FDPs in group B had increased vertical gap values for the most distant implant (21) compared with the closest implant (23).

The comparison between long- and short-span FDPs revealed a statistically significant difference at implant 21 and an insignificant difference at implant 23. All short-span FDPs demonstrated smaller values at both positions 21 and 23 than did long-span FDPs.

Although there was a statistical difference between the long- and short-span FDPs at implant 21, the fabrication of 2 short-span FDPs instead of 1 long-span FDP would only minimally increase the accuracy. Thus, treatment strategies should depend on other factors.


Effect of Ceramic Firing on CAD/CAM Titanium Prostheses Fit

Porcelain firing of the veneering process could theoretically lead to distortion of the framework and imprecise prosthesis fit. Katsoulis et al from the University of Bern, Switzerland, compared the fit precision before and after veneering procedures of full-arch, implant-supported, screw-retained, computer-aided designed and computer-aided manufactured (CAD/CAM) titanium-fixed dental prostheses (FDPs).

A single polyester resin master cast of an edentulous maxilla with six 4.8-mm diameter implants was used for the evaluation. Implants were placed in FDI positions 15, 13, 11, 21, 23 and 25; implants in sites 11 and 21 were angulated by 10° in the sagittal plane. Digitization of the implants in the master model was performed separately for each framework with a CARES Scan CS2. A solid homogenous block of grade 4 titanium was milled using a computer numerical control milling machine. The same veneering porcelain was then applied to all frameworks following manufacturer’s instructions.

Fit accuracy was measured by the same operator using the 1-screw test and a scanning electron microscope (at 2500x magnification) both before and after veneering. Each prosthesis was aligned on the master cast using screws in positions 15 and 25. After hand-tightening, the screw in implant 25 was tightened to 30 Ncm, while the screw in implant 15 was removed. The vertical distance between the implant shoulder and the FDP platform was measured 3x on the mesial, buccal and distal surfaces of all unrestrained interfaces. The mean of those measurements was recorded as the misfit.

All vertical microgaps were <90 μm. Three unveneered and 4 veneered FDPs showed a high fit precision (≤50 μm) at all implant positions. There was no statistically significant difference between the total mean vertical misfit in unveneered and veneered frameworks. Comparisons within groups showed a significant difference between implants before and after veneering. There was a steady trend of increasing values from the implant closest (23) to the screw-retained implant to that of the implant farthest (15) from it.

The results suggested a high precision of fit for CAD/CAM titanium FDPs before and after porcelain firing. All frameworks showed a clinically acceptable misfit before and after porcelain firing. The porcelain firing had no impact on the frameworks’ precision of fit.


In the Next Issue:

- Influence of prosthesis-retentive mechanism on complications
- A systematic review of the performance of screw- vs cement-retained prostheses
- Survival and complication rates of cement- vs screw-retained prostheses

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