Evaluation of the Accuracy and Adaptation of BioHPP Removable Partial Denture Frameworks Constructed by Milling vs the Pressing Technique

Tarek Mohamed AL Sayed El Saeedi, BDS, MDS
Yasmine Galaleldin Thabet, BDS, MDS, PhD
Shaimaa Lotfy Mohamed, BDS, MDS, PhD
Marwa Ezzat Sabet, BDS, MDS, PhD
Oral and Maxillofacial Prosthodontics Department, Faculty of Dentistry, Ain Shams University, Cairo, Egypt.

Purpose: To evaluate the accuracy and adaptation of BioHPP removable partial denture frameworks constructed from milling vs the pressing technique. Materials and Methods: This in vitro study was applied on an educational maxillary stone model with bilateral bounded saddles. Two different manufacturing techniques were used, and thus two groups were defined: (1) the pressed group, in which 20 BioHPP frameworks were constructed by milling a castable resin that was pressed into BioHPP using the lost wax technique; and (2) the milled group, in which 20 BioHPP frameworks were constructed directly by milling the BioHPP blanks. The accuracy of the frameworks was evaluated using Geomagic Control X software, and the gap distance was captured using a stereomicroscope. Results: The milled group showed higher values of accuracy than the pressed group in the x, y, and z axes, and according to Student t test, this difference was statistically significant in the x and z axes. Regarding the adaptation of the frameworks, the milled group showed lower adaptation values than the pressed group. Student t test showed that this difference was statistically significant regarding adaptation of the major connector. However, there was no statistically significant difference concerning adaptation of the denture bases between the two groups. Conclusion: Within the limitations of this study, it could be concluded that: (1) the milling technique could be used to fabricate BioHPP RPD frameworks with higher accuracy than the pressing technique; and (2) the pressing technique showed less gap distance (ie, better adaptation) at the area of the major connector. Int J Prosthodont 2022;35:647–652. doi: 10.11607/ijp.7822
as well as constant homogeneity and extremely good polishing properties. In addition, it is rapidly manufactured with reduced material consumption. Additional advantages of this polymer include absence of allergic reactions and metallic taste, low plaque affinity, and good wear resistance.

BioHPP could be used with acrylic denture teeth as an alternative for fabrication of RPD frameworks. Due to its white color and high strength, BioHPP could also be used for the fabrication of metal-free clasps and occlusal rests. The frameworks could be milled out of blanks or vacuum-pressed using either granules or pre-pressed pellets.

The key advantages of milling a restoration from an industrial-grade blank are the durability, homogenous consistency, and reduced porosity of the material. Moreover, the waxing up, investing, and casting of a prosthesis are avoided, thus avoiding steps that are assumed to influence the overall accuracy and adaptation. Although multiple steps of the conventional fabrication protocol are omitted, this CAD/CAM protocol introduces some additional steps in the fabrication process. The CAD/CAM technique includes scanning, digital design, and manufacturing, which may inevitably be causes of inaccuracies. Precise fitting of RPD frameworks is one of the most important requirements for the success of the prosthesis. Improper fit may be destructive to the abutment teeth and might cause discomfort, which could prevent many patients from wearing their prosthesis. Hence, this study was conducted to compare the accuracy and adaptation of RPD frameworks constructed by milling vs pressing BioHPP. The first null hypothesis was that no difference would be found in the accuracy of the RPDs fabricated by the two techniques. The second null hypothesis was that no difference would be found in the adaptation of the RPDs fabricated by the two techniques.

**MATERIALS AND METHODS**

This in vitro study was applied on an educational maxillary stone model with bilateral bounded saddles (Kennedy Class III, modification I). The abutments were the first premolar and the second molar, bilaterally. Preparations for rest seats were made according to conventional design principles, and the midline was drawn extending from the incisive papilla anteriorly to a point measured midway between the hamular notches.

The prepared model was duplicated to produce 40 identical stone models made from scannable dental stone (Fujirock EP, OptiXscan, GC Europe). The models were divided into two groups, and two different manufacturing techniques were used. In the pressed group, 20 BioHPP frameworks were constructed by milling a castable resin, which was pressed into BioHPP using the lost-wax technique. In the milled group, 20 BioHPP frameworks were constructed directly by milling the BioHPP blanks.

The D850 desktop scanner (3Shape) was used to scan the original model. Digital surveying of the scanned model was performed, followed by digital design according to the design principles of RPDs using 3Shape design software (3Shape Dental System). The denture bases and the major connector were drawn by placing points and connecting them together until the proper form was reached. Aker’s clasp assembly was designed by applying the occlusal rest and adapting it to the rest seat preparation. The retentive and reciprocal arms were designed on three abutments, where the right first premolar was excluded. The design was finalized using the sculpt tool.

A notch was made on the anterior and posterior sides of the major connector corresponding to the midline previously drawn on the cast, and a notch was made on the buccal surface of the denture base on each side. An STL file of the design was created by the software and was used to construct the partial denture frameworks using the two different manufacturing techniques (Fig 1).

**Construction of the Frameworks**

In the pressed group, 20-mm blanks of castable resin (Vipi Block) were milled using a five-axis milling machine (K5 five-axis dry milling machine, vhf) to produce the RPD frameworks. The pattern was removed from the milled blank and then sprued and invested with a special phosphate-bonded investment material (Brevest for 2 press, Bredent). The ring was preheated for elimination of the castable resin, then the BioHPP (BioHPP granules, Bredent) was heated and pressed using the pressing machine (for 2 press, Bredent).

In the milled group, the same STL file of the design was used to directly mill the frameworks from...
the BioHPP blanks (BioHPP blank, Bredent). The five-axis milling machine with 20-mm blanks was used to fabricate the frameworks (Fig 2). After completion of the milling process, the blanks were removed from the machine, and the partial denture frameworks were retrieved.

**Evaluation of the Accuracy of the Frameworks**

After finishing and polishing, the frameworks were seated on the casts (Figs 3 and 4). Then, each framework was scanned using the 3Shape desktop scanner. The STL file of each framework was superimposed with the initial STL file of the design by using surface-matching software (Geomagic Control X, 3D Systems). The initial design was selected as the reference data, and the STL file of each framework was imported separately and selected as the measured data. Alignment between the reference and the measured data was performed, and then measurement of the surface deviations between the two data was done at three axes: $x$, $y$, and $z$ (Fig 5). The measurements were recorded and tabulated for proper statistical analysis.

**Evaluation of the Adaptation of the Frameworks**

All of the partial denture frameworks were seated on their respective casts and fixed inside the precision saw (IsoMet 4000, Buehler). First, each cast was split in an anteroposterior direction in a straight line connecting the two notches previously made on the major connector using a 0.6-mm disc (Fig 6). Then the stereomicroscope (MA100, Nikon) was used to capture the gap distance between the split major connector and the cast, and the gap was analyzed and measured using image analysis software (OmniMet Image Analysis Software, Buehler) at multiple points (300 µm from each other, starting from the anterior end of the major connector), and an average value was calculated (Fig 7).

The split framework with its respective cast was fixed again inside the IsoMet saw to be split in a mediolateral direction in a straight line guided by the previously made
notches on the denture bases. The stereomicroscope and image analysis software were used to measure the gap distance between the denture base and the cast at multiple points.

The data were all collected, and statistical analysis was performed with SPSS version 20 software for Windows (IBM). Data were presented as mean and SD values. Statistical analysis of the resultant data was performed using Student t test. The significance level was set at $P \leq .05$.

**RESULTS**

As shown in Table 1, the milled group had higher accuracy values than the pressed group in the $x$, $y$, and $z$ axes, and according to Student $t$ test, this difference was statistically significant in the $x$ and $z$ axes. Regarding adaptation of the frameworks, the pressed group had higher adaptation values than the milled group (Table 2). Student $t$ test showed that this difference was statistically significant regarding adaptation of the major connector. However, there was no statistically significant difference in the adaptation of the denture bases between the two groups.

**DISCUSSION**

Despite the evolution in treatment options available for partially edentulous patients, RPDs continue to be the treatment of choice for some patients. An in vitro study was conducted to reduce the variables that may affect the treatments results in which notches were made both on the major connector and the denture base to standardize the area where the frameworks were split for measuring the adaptation.

In the present study, milling was used to fabricate the castable resin and the BioHPP frameworks, as it reduces the fabrication flaws in the dental prostheses by relying more on the higher-quality control of the material processing by the manufacturer. Milling eliminates waxing, investing, and casting to improve the overall accuracy of the prosthesis.

A previous study reported that wax was affected by exposure. When wax patterns are left unrestrained, they tend to distort as the temperature and time of storage increase. Residual or internal stresses released by action of the time and temperature may result in dimensional changes, which lead to inaccuracies of the final prosthesis. These drawbacks were overcome in the study by milling the castable PMMA.

Accuracy of measurement is described as trueness or precision. Trueness is defined as the closeness of agreement between the arithmetic mean of many test results and the true or accepted reference value, while precision refers to the closeness of agreement between the test results. In this study, trueness was evaluated using a surface-matching software.

Geomagic Control X software was used to measure the accuracy of the frameworks using surface-matching and best-fit algorithms. The frameworks were superimposed with the initial design to allow digital measurements to be recorded, as these measurements are more accurate than traditional physical measurements. Accurate measurement and quick analysis of the manufactured parts and assemblies were performed. On the other hand, according to the Glossary of Prosthodontic Terms, “adaptation” is defined as the degree of fit between a prosthesis and supporting structures. In this study, the mean gap distance (ie, adaptation) between the framework and the support structure was measured using image analysis of representative cross sections using the stereomicroscope. Hence, “accuracy” refers to the overall deviation of a prosthesis, while “adaptation” refers to the closeness of agreement between the test results.

![Fig 6](image6.png) The split framework on its cast immediately after using the IsoMet saw.

![Fig 7](image7.png) The gap distance (adaptation) between the denture base and the cast under a stereomicroscope (x30).
refers to the deviation of the fitting surface only. The results obtained from the present study showed that the milled BioHPP frameworks had higher accuracy but less adaptation than the pressed ones and that the difference was statistically significant. Thus, both the first and the second null hypotheses were rejected.

These results are similar to a previous study stating that the indirect technique showed more pressure areas at the major connector than the direct technique, while the direct technique revealed superior overall trueness compared to the indirect technique. The study also concluded that both techniques revealed an acceptable clinical fit (~0.09 to 0.11 mm) and trueness (17.36 to 71.68 μm).27 According to other studies, a gap distance from 50 to 311 μm was defined as clinically acceptable.28,29 Thus, the values of accuracy and gap distance (adaptation) measured at the major connectors in both groups in the present study are within an acceptable range. However, higher values of gap distances were found at the areas of the denture bases because the minimum amount of automatic relief permitted by the software in these areas is 400 μm.

These findings could be attributed to expansion of the thermopressed frameworks causing compression in some areas of the final frameworks, resulting in a tight fit. These results coincide with a previous study showing that the dimensional accuracy of the BioHPP varied depending on the mold temperature and specimen depth. An expansion of approximately 33% from the original dimension of 0.8 mm and of approximately 32% in the case of the 1-mm depth of the thermopressed specimen was noted at 200°C.30

Studies reported that the accuracy of fit of the milled BioHPP frameworks was better than the conventional pressed ones. This finding was attributed to the different processing chains. The pressing process includes a more difficult sequence, with a higher number of potential sources for error.11,27 It was assumed that the finishing and polishing of the polished surface of the frameworks led to loss of the stippling in the pressed technique, while it was preserved in the milling technique, as this study demonstrated that RPDs fabricated using the direct CAD/CAM technique showed the lowest distortion and highest precision. These findings were explained by the high-quality surface finish achieved by milling, which facilitates the polishing procedure.31

To date, only a few studies have evaluated the different qualities of digital RPDs. Thus, further research is recommended regarding the use of recent fabrication techniques and materials.

CONCLUSIONS

Within the limitations of this study, it could be concluded that:

- The milling technique could be used to fabricate BioHPP RPD frameworks with higher accuracy than the pressing technique.
- The pressing technique showed less gap distance (i.e., better adaptation) at the area of the major connector.

REFERENCES


Table 1  Mean, SD, and P Values for the Comparison of Accuracy Between Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean (SD), mm</th>
<th>P value</th>
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<tbody>
<tr>
<td>x axis</td>
<td>Pressed 0.034 (0.0049)</td>
<td>.0001</td>
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<tr>
<td></td>
<td>Milled 0.0275 (0.003)</td>
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</tr>
<tr>
<td>y axis</td>
<td>Pressed 0.040 (0.005)</td>
<td>.1301</td>
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<tr>
<td></td>
<td>Milled 0.038 (0.005)</td>
<td></td>
</tr>
<tr>
<td>z axis</td>
<td>Pressed 0.028 (0.004)</td>
<td>.0223</td>
</tr>
<tr>
<td></td>
<td>Milled 0.0025 (0.0035)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Pressed 0.0344 (0.007)</td>
<td>.0019</td>
</tr>
<tr>
<td></td>
<td>Milled 0.030 (0.007)</td>
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Student t test.

Table 2  Mean, SD, and P Values for the Comparison of Adaptation at the Major Connector and Denture Base Between Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean (SD), μm</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major connector</td>
<td>Pressed 64.97 (11.27)</td>
<td>.0006</td>
</tr>
<tr>
<td></td>
<td>Milled 76.55 (8.086)</td>
<td></td>
</tr>
<tr>
<td>Denture base</td>
<td>Pressed 450.9 (77.75)</td>
<td>.4174</td>
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<tr>
<td></td>
<td>Milled 466.54 (34.58)</td>
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Anterior Implant Restorations with a Convex Emergence Profile Increase the Frequency of Recession: 12-month Results of a Randomized Controlled Clinical Trial

The purpose of this study was to test whether the emergence profile (convex or concave) of implant-supported crowns influences the mucosal margin stability up to 12 months after placement of the final restoration. A total of 47 patients with a single implant in the anterior region were randomly allocated to one of three groups: (1) convex (n = 15), where patients were provided with an implant provisional and an implant-supported crown both with a convex profile; (2) concave (n = 16), where patients were provided with an implant provisional and an implant-supported crown both with a concave profile; and (3) control (n = 16), where patients received no implant provisional and an implant-supported crown both with a concave profile. Pink esthetic scores amounted to 5.9 in the convex group, 6.2 in the concave group, and 5.4 in the control group, with a convex profile was significantly associated with the presence of recessions (odds ratio: 12.6, 95% CI: 1.82–88.48, P = .01) compared to the concave profile. Pink esthetic scores amounted to 5.9 in the convex group, 6.2 in the concave group, and 5.4 in the control group. Regression models revealed that the presence of recession, multivariable logistic regressions were performed, and linear models using generalized estimation equations were conducted for the different outcomes. A total of 44 patients were available at 12 months postloading. The frequency of mucosal recession amounted to 64.3% in the convex group, 14.3% in the concave group, and 31.4% in the control group. Regression models revealed that a convex profile was significantly associated with the presence of recessions (odds ratio: 12.6, 95% CI: 1.82–88.48, P = .01) compared to the concave profile. Pink esthetic scores amounted to 5.9 in the convex group, 6.2 in the concave group, and 5.4 in the control group, with no significant differences between the groups (P = .735). The convex and concave groups increased the number of appointments and costs compared to the control group. This study concluded that use of implant-supported provisionals with a concave emergence profile results in greater stability of the mucosal margin compared to a convex profile for up to 12 months of loading. This is accompanied, however, by increased time and costs compared to the absence of a provisional and may not necessarily enhance the esthetic outcomes.


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