Clinical marginal and internal adaptation of single metal-ceramic crowns fabricated by casting, milling, and milling/sintering methods

Hedaiat Moradpoor, DDS, MSc,a Mahsa Samavati, DDS,b Sahar Raissi, DDS, MSc,c Maryam Emami, DDS,d Maliheh Habibkhodaei, DDS,e and Mohammadjavad Shirani, DDS, MSc.f

a Associate professor, Department of Prosthodontics, School of Dentistry, Kermanshah University of Medical Sciences, Kermanshah, Iran

b Dentist, Dental Students’ Research Committee, School of Dentistry, Kermanshah University of Medical Sciences, Kermanshah, Iran

c Assistance professor, Department of Prosthodontics, School of Dentistry, Kermanshah University of Medical Sciences, Kermanshah, Iran

d Dentist, Student Research Committee, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran

e Post graduate student of Prosthodontics, Student Research Committee, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran

f Assistant Professor, Department of Prosthodontics, Faculty of Dentistry, Lorestan University of Medical Sciences, Khorramabad, Iran

Dr. MJ. Shirani http://orcid.org/0000-0002-9122-4178

Assistant Professor, Department of Prosthodontics, Faculty of Dentistry, Lorestan University of Medical Sciences, Khorramabad, Iran

Phone: 0098-935-6039479

E-mail: Javaad.shf@gmail.com, Javaad.sh_f@yahoo.com.

Submitted September 21, 2021; accepted June 5, 2022.

Abstract
**Purpose:** To compare the adaptation of single metal-ceramic crowns (MCCs) fabricated by three different methods: lost-wax metal casting (LMC); milling of hard cobalt-chromium (HCC) blanks; and milling of soft presintered cobalt-chromium (SCC) blanks. **Materials and Methods:** In this double-blinded parallel randomized clinical trial, 60 single MCCs were fabricated using three different methods. The adaptation of copings was evaluated radiographically, visually, and microscopically. Data were compared among the three groups using Kruskal-Wallis test followed by Dunn post hoc test, one-way ANOVA, and paired t test (α = .05). **Results:** Radiographic data showed that the frequency of crowns with no marginal discrepancy was significantly higher in the SCC group than the LMC group. Evaluation of marginal adaptation with an explorer revealed that crowns with excellent marginal adaptation had lower frequency in the LMC group than the HCC and SCC groups. In the silicone replica technique, the recorded data revealed no significant difference. Application of porcelain veneering did not affect the adaptation of copings. **Conclusion:** The SCC and HCC groups showed better clinical outcomes compared to the LMC group. However, all MCCs fabricated by the LMC method, milling of HCC blanks, and milling of SCC blanks had acceptable clinical adaptation. *Int J Prosthodont* 2022. doi: 10.11607/ijp.8024

**Introduction**

Digital dentistry is currently the most popular method for the fabrication of restorations. The use of ceramics for dental restorations is increasing; however, metal-ceramic crowns (MCCs) are still widely used specially in the posterior region. The lost-wax metal casting (LMC) technique is the conventional method for the fabrication of metal framework of MCCs. The time-consuming procedure, some undesirable properties of wax, high technical sensitivity, and risks of casting are
the most common problems of the LMC technique. Thus, computer-aided design/computer-aided manufacturing (CAD/CAM) system was proposed to overcome these limitations.\textsuperscript{3-5}

Because of optimal physical properties, acceptable adaptation with the veneering dental porcelain, and low cost of base-metal alloys, they are widely used for the fabrication of MCCs.\textsuperscript{4,6} Metal frameworks can also be fabricated by milling of hard cobalt-chromium (HCC) and pre-sintered soft cobalt-chromium (SCC) blanks.\textsuperscript{7,8} However, the clinical efficacy of these methods needs to be investigated.

Cobalt-chromium is among the commonly used base-metal alloys. It has optimal physical properties and acceptable resistance to tarnish and corrosion. Cobalt strengthens the restoration while chromium confers resistance to corrosion.\textsuperscript{9,10} Moreover, copings made of cobalt-chromium have shown superior adaptation at critical regions such as the restoration margins.\textsuperscript{1,11}

One considerable advantage of the milling method compared with the LMC method is the ability to use different alloys. The alloys used for casting should have less than 30% chromium to fulfill the casting requirements. Milling alloys containing more chromium can confer more resistance to tarnish and corrosion.\textsuperscript{6} The fully-sintered hard alloys used for the CAD/CAM systems require more milling time, and are more damaging to the milling machine. Therefore, pre-sintered wax-like alloys were introduced. In addition to decreased time, cost, and milling machine depreciation in use of pre-sintered blanks, these blanks can undergo dry milling, which minimizes the risk of contamination.\textsuperscript{12,13}

Acceptable tooth-restoration adaptation is a fundamental requirement for successful dental restorations. Adaptation of restorations can be evaluated by assessing their marginal and internal fit.\textsuperscript{14,15} To date, some methods such as silicone replica technique,\textsuperscript{3,4,13,16,17} dual-scan technique,\textsuperscript{18}
triple-scan protocol,\textsuperscript{19,20} measurement under a microscope,\textsuperscript{21,22} and micro-computed tomography\textsuperscript{7} have been used for assessment of restoration adaptation. Because of the limitations in clinical conditions, the silicone replica technique is one of the applicable and acceptable methods for use in clinical trials.\textsuperscript{3}

No consensus has been reached about the acceptable clinical value of absolute vertical marginal discrepancy. In this regard, as an ideal clinical goal, the specification 8 of the American Dental Association (ADA) suggests that the absolute vertical marginal discrepancy should range from 25 to 40 µm.\textsuperscript{23} Many studies reported 100 µm as the acceptable clinical threshold,\textsuperscript{18-19} and the range of 80 to 120 µm was assumed acceptable in most previous studies.\textsuperscript{4,17,24,25}

The results of previous studies regarding the adaptation of restorations fabricated by different methods are conflicting. An in-vitro study used micro-computed tomography to compare the copings made by different methods and found the best results for the SCC group followed by the LMC group, and the worst adaptation was reported for the HCC group.\textsuperscript{7} On the other hand, one study reported the weakest adaptation for the SCC group and best adaptation for the HCC, while the LMC group showed intermediate adaptation.\textsuperscript{25} Another study evaluated in vitro marginal fit of copings using the silicone replica technique and reported the same findings for LMC and SCC methods; however, both of these methods showed better results than the HCC method.\textsuperscript{13} Two in vitro studies reported better adaptation for the SCC rather than the LMC method.\textsuperscript{12,26} Another study reported better marginal adaptation for the HCC and SCC compared with the LMC method.\textsuperscript{8}

As stated earlier, some studies preferred CAD/CAM fabricated restorations to MCCs fabricated by the LMC method,\textsuperscript{8,17,21,26,27} while some other studies reported better adaptation for restorations made by the LMC technique.\textsuperscript{20,22} The effect of porcelain firing cycles on the accuracy of metal
frameworks is another matter of discussion, with conflicting results reported by previous studies. Further studies are required on the adaptation of crowns fabricated using pre-sintered SCC blanks. Considering the importance of clinical studies in providing evidence, this in vivo study was designed and carried out to elucidate this topic.

The purpose of this study was to clinically compare the adaptation of single MCCs fabricated by 3 different methods. This study had 2 null hypotheses. The first null hypothesis was that there would be no difference in marginal and internal adaptation of single MCCs fabricated by the LMC, milling of HCC blanks, and milling of SCC blanks. The second null hypothesis was that the porcelain firing cycles would have no significant effect on the marginal and internal adaptation of restorations.

**Materials and methods**

In this double-blind parallel randomized clinical trial, 60 single MCCs were fabricated from October 2018 to January 2019. All clinical procedures and also the silicone replica technique were performed by one prosthodontist (H.M) who was blinded to the method of fabrication of metal copings. Two blinded trained and calibrated operator (H.M and S.R) assessed clinical and radiographic adaptation variables (Kappa> 0.815 and Intraclass Correlation Coefficient> 0.987). Any disagreements were resolved by discussion.

Minimum sample size was calculated to be 18 in each group according to a previous study by Tamac et al, assuming the standard deviation for marginal discrepancy to be 24.15 for the HCC group and 21.03 for the LMC group, \( \alpha = 0.05 \), 90% power, and \( d=32 \). In order to account for possible dropouts, 20 participants were included in each group.
Ethical approval was granted by the Regional Ethics Committee of Kermanshah University of Medical Sciences (#IR.KUMS.REC.1396.531). Also, this trial was registered in the Iranian Registry of Clinical Trials (#IRCT20160213026538N3).

Our study population comprised of patients requiring single MCCs for their non-vital maxillary or mandibular first molars and met the following criteria: Individuals without systemic or mental disorders, healthy periapical (lack of any radiographic lesion and giving normal response to percussion and palpation tests) and periodontal tissue (plaque index < 20%, no bleeding on probing, and lack of considerable mobility), no need for periodontal surgery, lack of signs or symptoms of bruxism/clenching or temporomandibular disorders, sufficient gingivo-occlusal height to provide acceptable retention and resistance, and providing written informed consent prior to participation in the study. The participants who were not eligible or were unwilling to participate in the study were excluded.

A total of 60 eligible participants including 24 males and 36 females with age range from 27 to 71 years old (mean age ± standard deviation: 50.33 ± 12.50) were assigned to 3 groups using random block assignment. Twenty blocks were selected from all 6 possible triplex blocks of study groups, and the participants were randomly assigned to one of the LMC, HCC, or SCC groups. The prosthodontist prepared all teeth with a round-end taper diamond bur for axial reduction and a shoulder diamond bur for occlusal reduction. A 1-mm heavy chamfer as the buccal finish line at 0.5-mm subgingival and 0.5-mm chamfer at the lingual and proximal finish lines were prepared. Functional cusps were reduced by 2 mm, and other occlusal surfaces were reduced by 1.5 mm. For all of the participants, the 2-step putty-wash impressions were made using polyvinyl siloxane (Panasil; Kettenbach GmbH) after double-cord technique, and were poured with type IV dental stone (Siladent Dr. Böhme & Schöps GmbH). All laboratory procedures were done by one
instructed technician. The dies were scanned using Amann Girrbach Ceramill Map 400 scanner. Then, the coping patterns were designed with 0.5 mm thickness with 60 µm relief space using the Exocad software (exocad DentalCad 2015). The final design was transferred to the milling machine (Ceramill Motion 2-Amann Girrbach) in STL file.

The LMC group included MCCs with copings made by milling of the CAD/CAM wax (Ceramill Wax White; Amann Girrbach) and conventional casting of cobalt-chromium alloy (Magnum Simplex; Mesa). The margins of the milled wax copings were reflowed on the respective dies, and the marginal adaptation of the wax patterns was checked at ×10 magnification.

The copings for the HCC group were made by milling of the HCC blanks (Magnum Splendidum; Mesa). To prepare the copings for the SCC group, pre-sintered SCC blanks (Ceramill Sintron; Amann Girrbach) were milled and sintered using a sintering furnace (Ceramill Argotherm 2; Amann Girrbach) in argon gas atmosphere at 1300°C according to the manufacturer’s instructions.

Then, the fabricated copings were clinically evaluated.

All copings underwent airborne particle abrasion with 50 µm aluminum oxide particles and were then seated on the teeth with no need for internal adjustment. Before cementation, the marginal adaptation of copings was evaluated radiographically (bitewing radiography), visually (assessing the discrepancy by a dental explorer), and microscopically (silicone replica technique). Internal adaptation was also evaluated using the silicone replica technique. Each coping was secured on the related tooth using fit checker (Fit checker advanced; GC). Then, parallel bitewing radiographs (xgenus; de Gotzen) were obtained from all copings by the same operator. The prosthodontists blinded to the specimens observed the radiographs while they were encountered by light-proof black mask. Marginal discrepancies were evaluated using a 3-point scale where score 0 indicated “no marginal discrepancy (definitely can be determined that coping is following with external
tooth surface right beneath the finish line without any gap), score 1 indicated “inability to detect the discrepancy (there is no obvious gap but it cannot be determined that coping is following with external tooth surface right beneath the finish line or not)”, and score 2 indicated “obvious discrepancy (there is gap)”.31

Also, these 2 instructed and calibrated prosthodontists evaluated the marginal adaptation of all MCCs using a dental explorer. The California Dental Association rating criteria32 were used for examination by the dental explorer and data collection. Based on these criteria, marginal adaptation was classified as follows:

Alpha: excellent marginal adaptation (3)

Bravo: acceptable marginal adaptation (2)

Charlie: unacceptable marginal adaptation (1)

Delta: the crown must be exchanged (0)

Since it was a clinical study, the silicone replica technique was also used to evaluate marginal and internal adaptations. The silicone replica technique was used twice for each crown: before and after the application of porcelain veneering. For the silicone replica technique, the X-light silicone (Panasil) was injected into the coping and the coping was pressed on the tooth by finger pressure to set completely. After removing from tooth, regular-body silicone (Soft Heavy-Panasil) was injected to support the initial wash, embed the regular-body in to a heavy-body silicone material, and then the whole silicone was removed. The silicone replica was sectioned buccolingually and mesiodistally.13,16-17 The thickness of each section was measured at 3 points using a stereo-microscope (Optika SZM-2; Optika) with x315 magnification. These 3 points included (a) the
absolute distance between the coping margin and the corresponding point on the finish line, (b) the horizontal distance between the axial wall of the coping and tooth at the mid-occlusogingival area, and (c) the vertical distance between the occlusal wall of the coping and the tooth at the mid-cuspal slope.3 Totally, the adaptation of each coping was measured at 12 points. Finally, all copings were veneered by one technician with feldspathic porcelain (GC MC Porcelain). The digital caliper (Guilin Guanglu Measuring Instrument Co) was used for evaluating and standardizing the porcelain layers thicknesses. The porcelain firing cycles were adjusted according to the manufacturer’s instruction. After the application of the veneering porcelain, the silicone replica measurements were made again.

The Kruskal-Wallis test followed by the Dunn post-hoc test were applied to compare the data obtained by bitewing radiography and dental explorer among the 3 fabrication methods. The level of significance was assumed based on Bonferroni Correction to maintain an overall type I error at 0.05. The Kolmogorov-Smirnov test was used to investigate the normality of the silicone replica data. Considering the normal data distribution, paired t-test was applied to compare the marginal, axial, and occlusal adaptation before and after porcelain veneering. The silicone replica data were compared among the 3 fabrication methods using one-way ANOVA. All data analyses were performed using SPSS version 24 at 0.05 level of significance.

**Results**

Seventy-six participants required restoration for their first molars were examined. In this study, 60 single MCCs were fabricated for the maxillary (34 crowns) and mandibular (26 crowns) first molars. All of the participants entered the study, fulfilled the investigation steps. There were no
significant differences \((p > 0.05)\) between studied groups in terms of age, gender, jaw (maxilla/mandible), and side (right/left).

The adaptation of crowns was evaluated and compared before and after porcelain veneering using 3 evaluation methods including bitewing radiography, assessment by a dental explorer, and the silicone replica technique. Thirty-four crowns were fabricated for the mandibular and 26 for the maxillary first molars.

As shown in Table 1, assessment by bitewing radiography revealed a significant difference among the 3 fabrication methods. In pairwise comparisons, the frequency of crowns with no marginal discrepancy was significantly higher in the SCC group than the LMC group.

Assessment of marginal adaptation by dental explorer revealed a significant difference among the 3 coping fabrication methods (Table 2). The LMC group had lower adaptation median than the HCC and SCC groups. No significant difference was found in pairwise comparisons between the HCC and SCC groups.

The occlusal fit, axial fit, and marginal fit of all restorations were assessed using the silicone replica technique and compared within each group before and after porcelain veneering and between the 3 fabrication methods. The recorded data revealed no significant difference in any of the comparisons (Tables 3-5).

**Discussion**

In this clinical trial, 60 MCCs were fabricated for first molars using 3 methods namely the LMC, milling of HCC blanks, and milling of SCC blanks, and their adaptation was compared. This study
had 2 null hypotheses. The first null hypothesis was that there would be no differences in marginal or internal adaptation of single MCCs fabricated by the LMC, milling of HCC and milling of pre-sintered SCC blanks, which was partially rejected. The second null hypothesis was that the porcelain firing cycles would not affect the marginal and internal adaptation of restorations, which was approved.

It was approved in previous studies that up to 100 µm marginal discrepancy is clinically acceptable cut-point and this discrepancy do not influence the long-term success of restorations. In the present study, all the evaluated MCCs showed less than 100 µm (73-82 µm) marginal discrepancy. There were not significant differences between the groups and it was found acceptable clinical marginal adaptation for all restorations. Although the silicone replica technique revealed no difference between the groups, “inability to detect the discrepancy” was more common in LMC compared with the SCC group in use of bitewing radiography. Also, comparison of data obtained by examination with a dental explorer revealed that HCC and SCC restorations had higher frequency of “excellent marginal adaptation” compared with the LMC restorations. These findings showed weaker clinical outcomes for LMC compared with HCC and SCC restorations. However, it should be noted that neither the radiographic nor the explorer examinations found unacceptable copings. It seems that investment and casting steps cause higher roughness and irregularities on the external surface and peri-marginal contours of final copings but do not decrease the adaptation of copings.

Also, it should be noted that although no significant difference was found in adaptation of the 3 groups, larger standard deviation values were found in LMC compared with the two CAD/CAM groups. This finding may suggest the possible risk of deterioration of adaptation in investment, burn-out, and casting steps.
The evidence comparing digital and conventional fabrication methods is conflicting. The results of this study regarding absence of significant differences between the groups in assessment by the silicone replica technique were not in agreement with some previous studies. This difference can be due to the use of CAD/CAM for preparation of the wax pattern in the LMC method in this study; whereas, most previous studies performed manual wax-up for preparation of the wax pattern.

Three previous studies used CAD/CAM-made wax patterns for the LMC group, which was similar to our study, and reported larger marginal discrepancies for the LMC group. This disagreement may result from absence of marginal re-melting of the wax before investment in previous studies. This idea should be considered for future studies. Another reason for this disagreement can be related to CAD/CAM system. Scanners use different technologies for image acquisition. Also, many companies have introduced different millings with 3-5 axis. Different precision and accuracy of these devices can affect the restorations adaptation. Another possible reason for the difference between our findings and those of previous studies may arise from the adopted evaluation methods. In this study, the silicone replica technique was used because of its acceptable clinical applicability. Although this method has some inherent problems such as difficulty in reading the finish lines and margins, tearing of the wash layer during crown removal, and sectioning problems, it can be used as a non-invasive and reliable method. Also in this study, the marginal fit was evaluated using radiography and dental explorer as the clinical evaluation methods.

One major strength of this study was its clinical design. Most relevant previous studies had an in vitro design. The results of in vitro studies cannot be accurately generalized to the clinical
setting. However, the findings of this study were in agreement with studies that reported acceptable outcomes for each 3 coping fabrication method.\textsuperscript{12,13,26}

A previous clinical study \textsuperscript{3} found results similar to our findings. That study showed that the HCC and LMC groups had no significant difference in marginal adaptation measured by using the silicone replica technique compared with the LMC group. In each 3 group of present study, larger occlusal discrepancies were observed when the crowns were completely seated on the teeth that was in line with previous study.\textsuperscript{3} Based on this finding, avoiding to use of spacer over the occlusal surface seems to be helpful to provide sufficient occlusal space for the porcelain veneering. This idea should be evaluated in future studies.

Evidence shows that the marginal fit is the most important factor in long-term clinical success of MCCs. Marginal discrepancies cause periodontal disease, cement solubility, microleakage, plaque retention, and recurrent caries.\textsuperscript{14,15} Aside from the important role of marginal fit in success of restorations, the importance of internal adaption should be emphasized for seating of crowns without compromising their retention and resistance.\textsuperscript{14,20}

In this study, chamfer finish line was prepared for all teeth. A previous study reported higher marginal discrepancy and more distortion for porcelain firing with shoulder margins compared with chamfer.\textsuperscript{30} In this regard, our results suggested the chamfer margin for MCCs.

In this study, the porcelain veneering did not affect the adaptation of copings. Some studies reported significant effects on the adaptation of copings after porcelain firing.\textsuperscript{27-30} Our results in this respect were not in agreement with the abovementioned studies; however, our findings were in line with the results of some other studies, who reported no significant effect.\textsuperscript{5,8} It seems that alloy selection is an important factor in this respect. The selected alloy should be compatible with
the porcelain. If so, porcelain firing would not affect the adaptation of MCCs. Furthermore, in the current study, porcelain was applied in standardized thickness over all crowns. The lack of uniformity in porcelain thickness may cause coping deformation. This hypothesis should be tested in future studies.

One limitation of this study was that the contour and roughness of copings were not evaluated under a microscope. As mentioned earlier, deteriorated contour is a possible reason for weaker outcomes in LMC group. The non-uniform marginal contour would provide plaque accumulation and gingival inflammation. Another limitation was lack of periodontal evaluation. Hence, studies evaluating the long-term clinical outcomes should be considered to find the best restoration.

Within the limitations of the present in vivo study, the following results can be drawn:

1. The best outcomes were found for SCC group.
2. The LMC group showed weaker clinical outcomes compared with SCC and HCC groups.
3. All MCCs fabricated by the LMC method, milling of HCC blanks, and milling of SCC blanks had acceptable clinical adaptation.
4. The porcelain veneering procedure did not affect the adaptation of copings.

Acknowledgments:

The financial support was provided by the Kermanshah University of Medical Sciences. Ethical approval was granted by the Regional Ethics Committee of Kermanshah University of Medical Sciences (#IR.KUMS.REC.1396.531). Also, this trial was registered in the Iranian Registry of Clinical Trials (#IRCT20160213026538N3). We greatly appreciate Mr. Mokhtar Azizpour, our dental technician for helping us in restoration fabrication.
Declarations of interest: none.

References


Tables

<table>
<thead>
<tr>
<th>Table 1. Comparison of marginal fit by bitewing radiography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fit with Bitewing radiography</td>
</tr>
<tr>
<td>Score 0</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Lost wax technique</td>
</tr>
<tr>
<td>Count</td>
</tr>
<tr>
<td>Row N %</td>
</tr>
<tr>
<td>Median (Min-Max)</td>
</tr>
<tr>
<td>Hard cobalt-chromium</td>
</tr>
<tr>
<td>Count</td>
</tr>
<tr>
<td>Row N %</td>
</tr>
<tr>
<td>Median (Min-Max)</td>
</tr>
<tr>
<td>Soft cobalt-chromium</td>
</tr>
<tr>
<td>Count</td>
</tr>
<tr>
<td>Row N %</td>
</tr>
<tr>
<td>Median (Min-Max)</td>
</tr>
<tr>
<td>P-value†                                         0.049</td>
</tr>
</tbody>
</table>

0: No marginal discrepancy; 1: represents inability to distinguish the discrepancy; 2: obvious discrepancy

†Kruskal-Wallis test followed by Dunn’s multiple comparisons

Medians with the same superscript letters are not significantly different (P>0.05)
Table 2. Comparing marginal fit by a dental explorer

<table>
<thead>
<tr>
<th></th>
<th>Delta (0)</th>
<th>Charlie (1)</th>
<th>Bravo (2)</th>
<th>Alpha (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lost wax technique</strong></td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Row N %</td>
<td>.0%</td>
<td>.0%</td>
<td>55.0%</td>
<td>45.0%</td>
</tr>
<tr>
<td>Median (Min-Max)</td>
<td></td>
<td></td>
<td>2(2-3)</td>
<td></td>
</tr>
<tr>
<td><strong>Hard cobalt-chromium</strong></td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Row N %</td>
<td>.0%</td>
<td>.0%</td>
<td>15.0%</td>
<td>85.0%</td>
</tr>
<tr>
<td>Median (Min-Max)</td>
<td></td>
<td></td>
<td>3(2-3)</td>
<td></td>
</tr>
<tr>
<td><strong>Soft cobalt-chromium</strong></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Row N %</td>
<td>.0%</td>
<td>.0%</td>
<td>5.0%</td>
<td>95.0%</td>
</tr>
<tr>
<td>Median (Min-Max)</td>
<td></td>
<td></td>
<td>3(2-3)</td>
<td></td>
</tr>
</tbody>
</table>

P-value: \underline{0.001}

Alpha: excellent marginal adaptation; Bravo: acceptable marginal adaptation; Charlie: unacceptable marginal adaptation; Delta: the crown must be exchanged

Kruskal-Wallis test followed by Dunn’s multiple comparisons.

Medians with the same superscript letters are not significantly different (P>0.05)
**Table 3.** Comparing occlusal fit by the silicone replica technique

<table>
<thead>
<tr>
<th></th>
<th>Before porcelain veneering</th>
<th>After porcelain veneering</th>
<th>P-value&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Lost wax technique</td>
<td>293.14</td>
<td>105.74</td>
<td>284.80</td>
</tr>
<tr>
<td>Hard cobalt-chromium</td>
<td>248.05</td>
<td>59.27</td>
<td>240.54</td>
</tr>
<tr>
<td>Soft cobalt-chromium</td>
<td>298.59</td>
<td>92.31</td>
<td>288.23</td>
</tr>
<tr>
<td>P-value&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.146</td>
<td>0.135</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Paired t-test; <sup>b</sup> ANOVA
Table 4. Comparing axial fit by the silicone replica technique

<table>
<thead>
<tr>
<th></th>
<th>Before porcelain firing</th>
<th>After porcelain firing</th>
<th>P-value$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Lost wax technique</td>
<td>118.25</td>
<td>41.09</td>
<td>116.18</td>
</tr>
<tr>
<td>Hard cobalt-chromium</td>
<td>121.40</td>
<td>25.16</td>
<td>119.65</td>
</tr>
<tr>
<td>Soft cobalt-chromium</td>
<td>117.29</td>
<td>24.26</td>
<td>113.88</td>
</tr>
</tbody>
</table>

P-value$^b$: 0.909 0.848

$^a$ Paired t-test; $^b$ ANOVA
### Table 5. Comparing marginal fit by the silicone replica technique

<table>
<thead>
<tr>
<th>Material</th>
<th>Before porcelain firing</th>
<th>After porcelain firing</th>
<th>P-value&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Lost wax technique</td>
<td>73.45</td>
<td>23.40</td>
<td>73.75</td>
</tr>
<tr>
<td>Hard cobalt-chromium</td>
<td>78.97</td>
<td>23.00</td>
<td>81.57</td>
</tr>
<tr>
<td>Soft cobalt-chromium</td>
<td>77.61</td>
<td>14.28</td>
<td>77.96</td>
</tr>
<tr>
<td></td>
<td>0.680</td>
<td></td>
<td>0.503</td>
</tr>
</tbody>
</table>

<sup>a</sup> Paired t-test; <sup>b</sup> ANOVA