The marginal fit of selective laser melting–fabricated metal crowns: An in vitro study

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Statement of problem. The selective laser melting technique is attracting interest in prosthetic dentistry. The marginal fit is a key criterion for fixed restorations.

Purpose. The purpose of the study was to evaluate the marginal fit of cast cobalt-chromium alloy crowns versus the fit of selective laser melting–fabricated crowns.

Material and methods. The marginal gap widths of 36 single crowns (18 selective laser melting–fabricated cobalt-chromium metal crowns and 18 cobalt-chromium cast crowns) were determined with a silicone replica technique. Each crown specimen was cut into 4 sections, and the marginal gap width of each cross section was evaluated by stereomicroscopy (×100). The Student *t* test was used to evaluate whether significant differences occurred in the marginal gap widths between the selective laser melting–fabricated and cast cobalt-chromium metal crowns (α=.05).

Results. The mean marginal gap width of the cast crowns (170.19 μm) was significantly wider than that of the selective laser melting–fabricated crowns (102.86 μm).

Conclusions. Selective laser melting–fabricate cobalt-chromium dental crowns found improved marginal gap widths compared with traditional cast crowns. (J Prosthet Dent 2014;112:1437-1440)

Clinical Implications

In the present in vitro study, selective laser melting–fabricated cobalt-chromium dental crowns exhibited significantly improved marginal gap widths compared with traditional cast crowns. This finding may indicate that selective laser melting crowns are more acceptable.

Selective laser melting (SLM) is a rapid prototyping method for fabricating metal products directly from computer-aided design (CAD) data. Automated fabrication is accomplished layer-by-layer by selectively fusing together metal powders.[1-3] Compared with the traditional casting method, SLM offers several advantages, such as a higher definitive product density, reduced manufacturing time and costs, minimization of human errors, and the prevention of casting defects.[4-7] The SLM technique is attracting interest in prosthetic dentistry.

Because SLM is a relatively new manufacturing technique, it requires extensive evaluation before it can be used to produce prostheses for clinical use. An important consideration is the marginal fit, which is a key criterion for fixed restorations. Once the restoration is placed onto the tooth, the gap between the gingival margin and the tooth preparation serves as a connection to the oral environment. Several clinical trials have emphasized the importance of marginal fit for the clinical success of fixed restorations.[8-12] If the crown and the abutment do not fit well, then problems, such as gingival bleeding or alveolar bone reaction, may occur.

It is not clinically desirable that a crown should have a perfect fit with no marginal gap[13] because there must be space for the luting agent. Clinical evaluation procedures should be comfortable and convenient both to the patient and the dentist. However, if the

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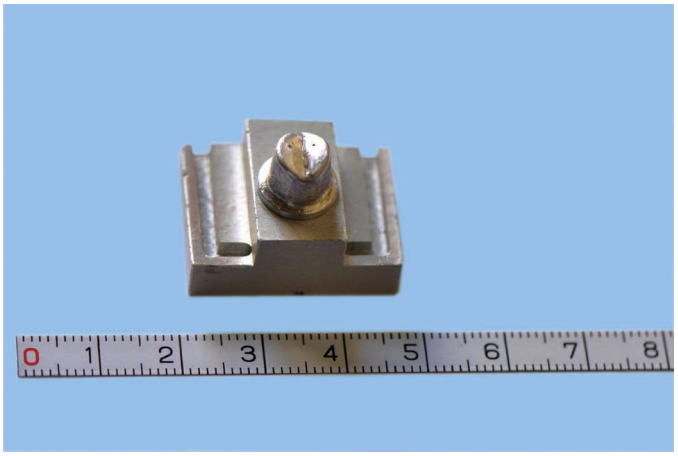
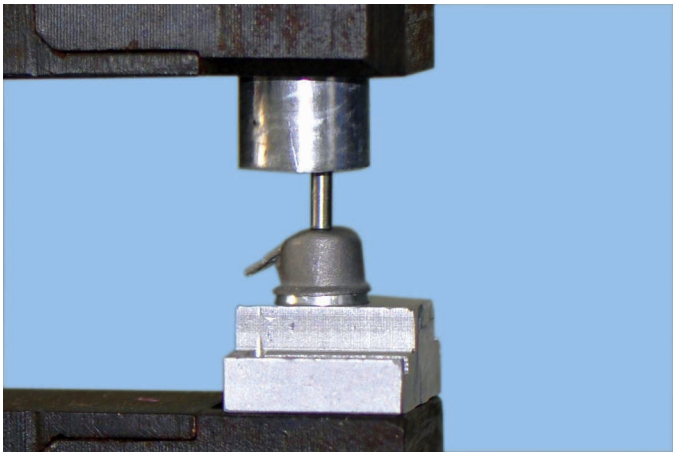


1 Standardized stainless-steel die.



2 Metal crown coping seated on original master die after application.

marginal discrepancies are too large, then the luting agent will be exposed to the oral environment. Thus, the larger the marginal discrepancy is, the faster the rate of cement dissolution will be.[13] Subsequent failure of the cement seal and bacterial percolation can cause pulpal inflammation and even pulpal necrosis.[14]

Many studies have compared the marginal fit of complete metal, metal ceramic, and/or ceramic crowns that were fabricated either through CAD/computer-aided manufacturing systems or traditional casting machines.[15-19] Studies performed with various materials and techniques reported a wide range of marginal gaps, which ranged from 10 to 500 μm, mean (SD) range, 10 ±50 μm to 500 ±100 μm.[10,20] In a study of single cast crowns, 50% of the marginal gap values exceeded 150 μm.[20] In another report, single metal alloy crowns fabricated by computer-supported laser-melting technology had mean marginal gap widths of 74 to 99 μm.[21] Comparing these studies is difficult because they differ markedly in many aspects of the fabrication process, including impression making, definitive casts, casting, and scanning. Moreover, such differences cannot be avoided because cast crowns are fabricated with an entirely manual procedure. In contrast, human errors can be minimized by fabricating crowns with SLM. A literature review revealed no prior investigation of the marginal fit of SLM-fabricated cobalt-chromium (CoCr) metal crowns. Therefore, in the present study, the marginal fits of SLM-fabricated and conventional cast CoCr metal crowns were compared. The null hypothesis was that the average marginal gap widths would not be significantly different between the SLM-fabricated and cast single crowns.

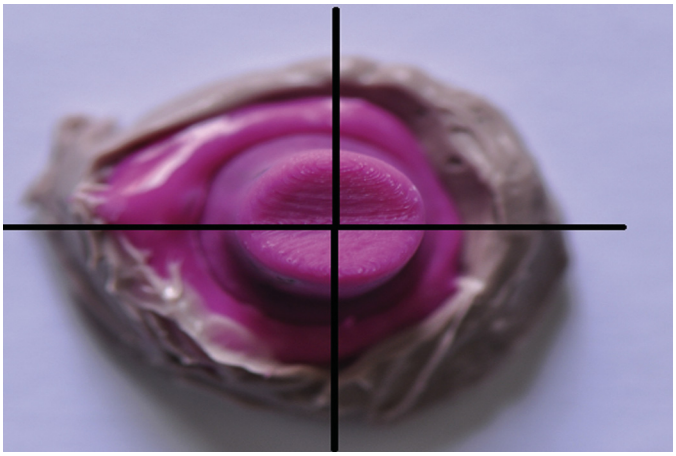
MATERIAL AND METHODS

Thirty-six single crowns were examined in this study (18 SLM-fabricated CoCr metal crowns and 18 CoCr cast crowns). To fabricate the metal crowns, a maxillary premolar crown preparation was simulated by using a stainless-steel die with a height of 6.0 mm (with assuming a 2-mm flat occlusal reduction), a uniform heavy chamfer finish line of 1.0 mm in width, and a total occlusal convergence of 5 degrees (Fig. 1). The die was manually prepared by using tungsten carbide burs (MANI Inc) and trimmed on a survey plate (Combilabor CL-MF 2000; Heraeus). The specimens were prepared from a CoCr alloy (Wirbond C+; Bego Dental) in casting and powder form.

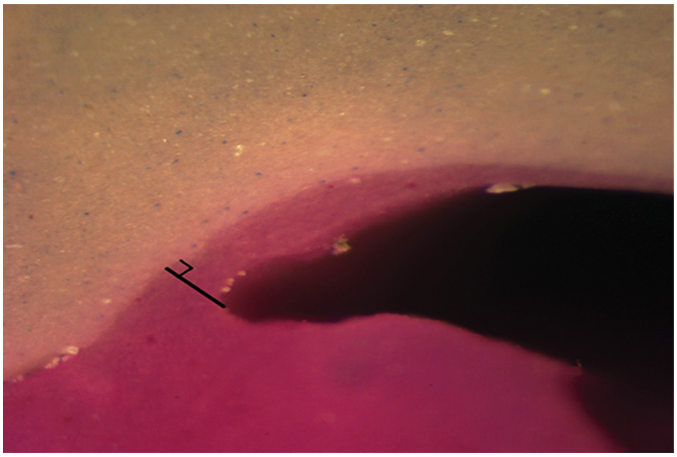
The die was scanned with a dental system scanner (D700; 3Shape), and a 3-dimensional computer cast was created. SLM restorations were fabricated with an SLM system (Bego Medifacturing System; Bego Medical) based on the 3-dimensional computer cast. SLM specimens were fabricated layer-by-layer with a machine that was equipped with an ytterbium fiber laser. The laser produced a beam with a wavelength range of 1060 to 1100 nm, and a maximum power of 200 W. The laser speed was less than 7000 mm/s, and the laser-beam diameter was approximately 0.1 mm.

Wax patterns for investment casting were prepared. The crowns were cast in a standard broken-arm centrifugal casting machine (T.I.M. 500 plus; Dentalfarm), in accordance with the manufacturer's instructions. Briefly, the wax pattern was made on a gypsum die duplicated from the metal die by using a polyvinyl siloxane impression material (Empress II; 3M ESPE) and invested in a casting investment material (Whip Mix Corp). During heating, the wax was eliminated while the casting investment materials solidified. The originally wax-filled cavity was filled with the heated metal solution. The metal solution solidified, and a metal crown was formed.

To determine the marginal fit, each crown was filled with light-body polyvinyl siloxane impression material (Empress II; 3M ESPE), placed onto the abutment tooth of the master cast, and loaded with a torque of 50 N in the apical direction (Fig. 2). The thin polyvinyl siloxane layer represented the gap width between the inner surface of the crown (including the crown margin) and the surface of the die. After the light-body impression material had set, the crown was removed from the



3 Silicone replica with mesiodistal and buccolingual sectioning directions.



4 Photograph, showing marginal gap (×100).

master cast, with the thin impression material layer remaining on the crown. The film was stabilized with a contrasting heavy-body polyvinyl siloxane. Materials were used in accordance with manufacturers' instructions. The premolar replica was sectioned into 4 parts by 2 cuts each in the mesiodistal and buccolingual directions (Fig. 3). Measurements in each of these 2 directions were made for every part, which totaled 8 measurements.

The thickness of the light-body polyvinyl siloxane was measured with a microscope (Stemi 2000C; Carl Zeiss) at ×100 magnification. Cross sections were adjusted horizontally on the modeling clay, with the microscope plate maintained at a parallel orientation to achieve a vertical observation angle. The distance (in μm) was determined with a digital measuring device (SPOT version 4.6; Carl Zeiss), which was calibrated at regular intervals. At each cross section, the marginal gap was measured. The width was measured as the perpendicular distance from the internal surface at the margin of the restoration to the preparation[12] (Fig. 4). The marginal fit of each crown was determined as the average of all 8 measurements.

The experimental results were subjected to statistical analysis with software (SAS 8.0; SAS Institute). The normality of the marginal gap data distribution of each group was tested, and the results indicated homogeneity of variance ($P>.05$). The Student t test was used to assess the significance of differences in the performances of the 2 materials ($\alpha=.05$).

RESULTS

The mean (standard deviation) of the marginal gap width for the SLM-fabricated crown group was 102.86 ±40.54 μm (95% confidence interval [CI], 54.55-185.94 μm). The corresponding values for the cast crown group were 170.19 ±66.17 μm (95% CI, 96.17-337.63 μm). The marginal gap widths differed significantly between the 2 groups ($P>.05$ by the Anderson–Darling test; $P<.05$ by the Student t test) (Table I).

DISCUSSION

This study compared the marginal fits of SLM-fabricated and cast CoCr metal crowns. The mean marginal gap width of the cast crown group (170.19 μm [95% CI, 96.17-337.63 μm]) was significantly wider than that of the SLM-fabricated crown group (102.86 μm [95% CI, 54.55-185.94 μm]). Therefore, the null hypothesis of the study was rejected. In the present study, restorations fabricated by CAD/computer-aided manufacturing SLM and the traditional lost-wax technique were both fabricated with a gypsum die on which polyvinyl siloxane impression material was applied. For traditional cast restorations, the suitability of the marginal fit can be compromised by shrinkage of the impression material or gypsum, deformation of the wax pattern, and variations in the thickness of the applied adhesion agent. In contrast, the automated method of the SLM approach prevents such errors, which allows the prosthetic crown to be delivered directly to the mouth without the need for impression or creating a gypsum cast. Therefore, SLM-fabricated restoration may be more accurate and suitable for clinical use. Furthermore, CAD technology allows greater design flexibility: specifications can be input during the design process to customize the fit of the crowns and to meet many different exigencies.

Table I. Descriptive statistics of marginal gap width for SLM and cast single crowns

Source	Mean (SD)	Median	Minimum	Maximum	95% CI
SLM	102.86 ±40.54	97.70	54.55	185.94	54.55-185.84
Cast	170.19 ±66.17	136.27	96.17	337.63	96.17-337.63

SLM, selective laser melting; SD, standard deviation; CI, confidence interval.

A study such as this one can be limited by sources of variability in the manufacturing and quality control processes; however, all attempts were made to ensure replicability. Theoretically, using different technicians with different working principles to perform intraoral scanning could lead to variations in precision. To avoid this problem, only 1 person who had been professionally trained examined all 36 crowns. The SLM crowns were manufactured automatically with an SLM system based on CAD data. The automatic fabrication process controlled the fit of the SLM crowns, thereby preventing errors due to casting shrinkage and human errors.

The significant difference in marginal gap widths between the 2 groups indicates that SLM technology leads to a superior marginal fit compared with the traditional casting approach. Most prosthodontists and patients find the lost-wax casting technology for fabricating restorations acceptable, and cast crowns have shown good long-term performance. However, the mean marginal gap width of the SLM-fabricated crowns manufactured in the present study was significantly better compared with that of the cast crowns. Therefore, SLM may be considered suitable for clinical applications to improve restoration performance.

CONCLUSIONS

According to the results of this laboratory study, compared with traditional cast crowns, the SLM-fabricated CoCr dental crowns had significantly smaller marginal discrepancies. Within the limitations of this study, the mean marginal fit of SLM-fabricated CoCr crowns seems to meet the requirements for clinical dental applications. More studies are needed to verify the suitability of this technology, and future in vivo studies that deliver the cast into the mouth with a detector are planned.

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