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ORIGINAL RESEARCH

Comparison of Internal Fit between Implant Abutments and Cast Metal Crowns *vs* Laser-sintered Crowns

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ABSTRACT

Aim: A common problem related to cemented single crowns is the internal misfit, which may cause inadequate retention, especially when seated on the implant abutment. The aim of this study was to compare the internal fit of Co-Cr crowns using a traditional lost-wax casting technique from laser-sintered Co-Cr alloy crowns.

Materials and methods: Twelve metallic crowns per each technique were fabricated. The effect of the thickness of cement, originated internal gap was evaluated. Crowns were cemented on the implant abutments with resin cement, and the internal fit of crowns was measured at five areas with an optical microscope. The data were analyzed, and the means were compared with a t-test ($p<0.05$).

Results: The internal gap width measurements for the laser-sintered group (min. 52.19 ± 11.61 µm and max. 140.01 ± 31.84 µm) indicated the presence of a significantly closed internal gap compared to the crowns obtained through the lost wax method (min. 65.50 ± 9.54 µm and max. 313.46 ± 48.12 µm).

Conclusion: The fit of the metal crown likely varies with the fabrication technique. The use of techniques that enable the adjustment of crown parameters, such as the laser sintering technique, maintains the desired fit between casting and implant abutments.

Clinical significance: This study investigated which technique affects the internal fit of cemented implant-supported crowns, comparing the use of lost wax casting and laser-sintered metal dental alloys. The results of this study indicate that the use of laser-sintered crowns can improve for crown accuracy.

Keywords: Accuracy of crown, Internal fit, Dental implant abutment, Implant-supported crown.

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INTRODUCTION

Metal ceramic crowns are one of the successful standard treatment modalities for implant-supported restorations. Single-tooth implant-supported restorations are preferably retained by screws or cementation. Cementation may favor the passiveness of the superstructure. In this way, cement-retained fixed implant prostheses are more advantageous than screw-retained prostheses in many clinical conditions, enhancing the implants' axial load and occlusal stability.[1,2] However, the retentive strength of cemented single crowns can be affected by factors related to the abutment's geometry, height and taper.[3-5] Crown retention is negatively affected, as the volume of an abutment is smaller than that of a natural tooth. It can cause clinical failure during the use of crowns with a single tooth implant attachment. The type of metallic substrates and the geometry of abutments seem to affect the retentive strength.[3,5,6] In addition to these factors, the adaptation of crowns to the abutment is very important in their retention.

Studies on the marginal and internal fit of cemented crowns have mainly investigated the influence of different crown materials, the type of tooth preparation and the finish line. Many studies have compared the marginal and internal fit of metal-ceramic crowns fabricated using various materials under various conditions.[7-16] However, there are very few studies that assess new manufacturing methods and their relationship with the adaptation of crowns between abutments.

Because of fundamental deficiencies in the dental casting technique, a gap of varying width is likely to occur between a casting and the abutment, both internally and at the margin. Obtaining a precise film thickness of dental cement depends on a good marginal seal, and internal fit is one of the most critical prerequisites in determining the long-term clinical success of all-cast restorations.[8,17] The film thickness of dental cement is a significant factor in stress transfer, retentive forces of cemented casting and the prevention of microleakage.[18] If an internal gap on the axial, occlusal and marginal surfaces could be adjusted and minimized via the manufacturing method, the mechanical retention of the crown can be increased.[19] Excessive marginal opening and poor adaptation increase the potential for microleakage and plaque retention, which in turn raises the risk of recurrent caries and periodontal disease and bone loss in natural teeth.

This also causes a decrease in the mechanical retention of the crown.[11,17,20-23] Similarly, misfit between the implant abutment and the crown may lead to inflammation of the peri-implant soft tissue by providing a reservoir for bacterial colonization. This is an undesired clinical situation, as it may result in lysis of the marginal crestal bone.[24,25]

Fixed prosthetic restorations are commonly fabricated in the dental laboratory using the lost-wax technique, which was introduced by Taggart in 1907.[28-30] Initially, gold alloys and noble alloys were selected because of their biocompatibility, satisfactory mechanical properties and ease of processing. However, the use of base metal alloys increased in many countries, as these materials are economic and can be used with alternative techniques. While noble metal casting alloys are generally used to fabricate the metal substructure because of their superior properties, economical base metals, such as Ni-Cr and Co-Cr casting alloys, are often selected when cost is a major consideration.[28,30] However, the casting of base metal alloys is more difficult and more technique-sensitive relative to noble alloys because of the high melting range and oxidation of base metal alloys during casting.[28,29] Misfit problems can occur due to the personal manipulation of waxing and the casting shrinkage of the wax pattern in the lost-wax technique. More recently, technological improvements have enabled the development of different techniques, such as computer-aided design/computer-aided manufacturing (CAD/CAM), electroforming, and the laser sintering technique for the manufacturing of dental crowns. Computer-aided methods are used to standardize the process and to eliminate personal manipulation in order to avoid compatibility problems and improve crown retention.

Laser sintering is a new technology that may re-establish the use of the base metal alloys. A high-power laser can rapidly fuse small particles on the surface of a powder bed of the base metal alloy into a mass that represents the desired three-dimensional object by scanning cross-sections generated from a three-dimensional digital description of the area. This can be performed with a computer-aided design file or with another file created from scanned data. After each cross-section is scanned, the thickness of the powder bed of the base metal alloy is decreased by one layer, and a new layer of base metal alloy is applied on top. This process is repeated until the segment is completed.[31,32]

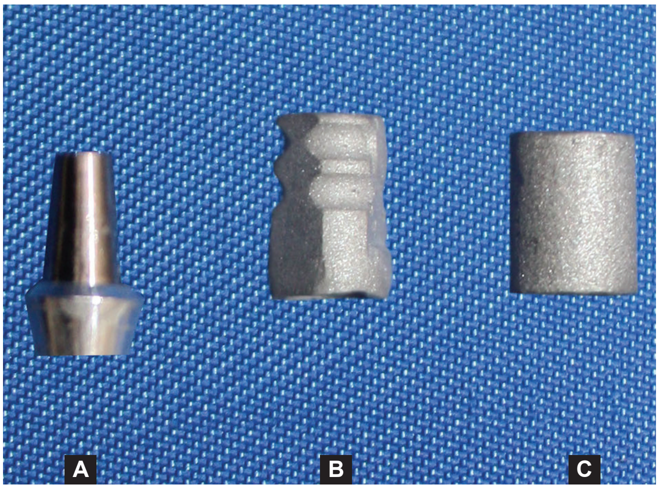
The aim of this study was to evaluate whether the crown manufacturing technique affects internal accuracy of single metallic castings by simulating implant-supported single crowns cemented with resin cements. For this purpose, Co-Cr metal alloy copings were obtained using two different techniques, and the internal fit of the crowns was compared with light microscope measurements.

MATERIALS AND METHODS

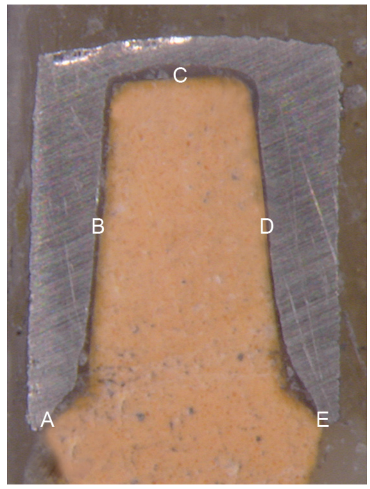
Twelve regular diameter implant analogs (SwissPlus® Implant System OPR Lot:61693796; Zimmer Dental Inc, Carlsbad, USA) were embedded perpendicularly in a cube mold and filled with autopolymerizing acrylic resin (Imicryl SC Lot:10102; Imicryl Dental Materials Inc, Konya, Turkey). Unmodified straight and narrow abutments (SwissPlus® Implant System OPA2 Lot:60962596; Zimmer Dental Inc, Carlsbad, USA) measuring 5.7 mm in height and 4.8 mm at the base and designed superiorly with six round tapering walls and a single flat three tapered wall were placed in the analogs and torqued to 35 Ncm using a torque wrench (Zimmer Dental Inc, Carlsbad, USA). The abutment screw was covered with a cotton pellet, and the access hole was closed with resin filling material (Filtek™ Z250 Lot:8YF, St. Paul, MN, USA) flush with the occlusal surface of each abutment.

Twelve metallic crowns per casting technique were fabricated. Crowns were also fabricated using the conventional lost-wax casting technique and the laser-sintering method. Conventional cast crowns (CCCs) were cast from a Co-Cr alloy (Microlit isi Lot:2009005019; Schütz Dental GmbH, Rosbach, Germany) using induction casting furnaces (INF 2010; Mikrotek Dental, Ankara, Turkey). Plastic molding caps that were prefabricated for abutments were used to standardize the sample waxing and to eliminate the size differences that may arise from personal manipulation. (SwissPlus® Implant System OPC Lot:61645969; Zimmer Dental Inc, Carlsbad, USA) Plastic caps were invested, burned out, and cast with Co-Cr alloy. On the other hand, laser-sintered Co-Cr alloy (EOS Cobalt Chrome SP2 Lot:H270901; EOS GmbH, München, Germany) crowns (LSC) were prepared using the EOS M270 Dental system (EOS GmbH, München, Germany) (Figs 1A to C). Later, another one of the plastic caps was cemented on the metal abutment before manufacturing the crown in order to obtain a predefined cement gap. A cemented sleeve was embedded in autopolymerizing acrylic resin (Imicryl SC Lot:10102; Imicryl Dental Materials Inc, Konya, Turkey) and sectioned longitudinally in the labio-lingual direction using an electronically controlled diamond saw (Microcut precision cutter; Metkon, Bursa, Turkey). The obtained value was considered to be the reference value for the assignment of the cementation gap in the laser-sintering method. According to this value, the cement gap was determined to be 0.02 mm to ensure the maximum level of compliance between the abutment and crown. The compositions of the alloys are listed in Table 1.

After crown manufacturing, to evaluate the gap dimension between the copings and the abutments, an index was prepared from the abutment using the putty wash technique



Figs 1A to C: (A) Implant abutment, used for stone replicas, (B) Co-Cr crown using a traditional lost-wax casting technique, (C) Laser-sintered Co-Cr alloy crown



Figs 2A to E: Standardized areas which were measured of internal gaps width: (A) Labial margin, (B) Labial axial surface, (C) Incisal edge, (D) Lingual axial surface, (E) Lingual margin

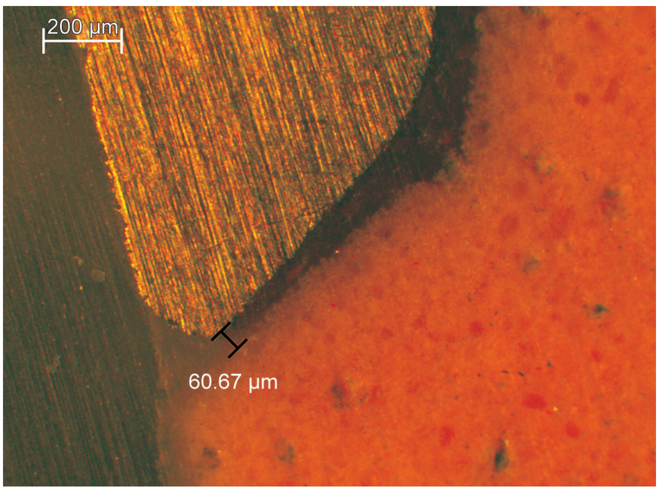


Fig. 3: Internal gap on the labial margin (×40)

(Zetaplus putty Lot:107678 and Oranwash® L Lot:73281, Zhermack clinical, Badia Polesine, Italy). Duplicates of the master die were prepared from type IV high-strength dental stone (Thixodur; Eisenbacher Dentalwaren ED GmbH, Wörth am Main, Germany). Each silicone index was used only one for the preparation of each stone die. Crowns were cemented on their dedicated dies using dual-polymerizing adhesive resin cement (Panavia™ F 2.0 Light Paste A Lot:00430A, Paste B Lot:00077A; Kuraray Medical Inc, Okayama, Japan) had preset with a high-power LED curing light (Celalux, VOCO GmbH, Cuxhaven, Germany). The manufacturer's instructions were considered during all cementation procedures. The excess cement was removed, and an oxygen-blocking agent (Oxyguard II Lot:00620B; Kuraray Medical Inc, Okayama, Japan) was placed on the crown and the surface of the abutment joint. Cemented crowns were embedded in autopolymerizing acrylic resin and sectioned longitudinally in the labio-lingual direction using the same electronically controlled diamond saw. Sectioned specimens were polished using 500- and 1200-grit Al_2O_3 abrasive paper in order to remove the adhered metal particles in the region of the cement. After obtaining photographs of each area with an optical microscope (Leica DM 4000B; Leica Microsysteme Vertrieb GmbH, Wetzlar, Germany), the internal gap width was measured at 5 standardized areas: the labial margin, labial axial surface, incisal edge, lingual axial surface and lingual margin (Figs 2A to E). The internal gap width was measured with the aid of computer software (Leica Application Suite 2.8.1; Leica Microsystems CMS GmbH, Heerbrugg, Switzerland) using a µm scale for each image. The mean of the measurements for each specimen was considered to represent the internal gap width, and all of measurements were gathered by the same operator. The results for the two groups (n = 12) were also compared using the t-test at a significance level of $p < 0.05$ using the same statistical software (SPSS 15.0 for Windows; SPSS Inc, Chicago, III).

RESULTS

Table 2 displays the descriptive statistics of the internal gap width measurements for the cast Co-Cr and laser-sintered Co-Cr groups. The measurements shown that the lowest gap values are obtained at labial margins (52.19 ± 11.61 µm for the LSC group and 65.50 ± 9.54 µm for the CCC group) and the highest gap values are obtained incisal edge areas (140.01 ± 31.84 µm for the LSC group and 313.46 ± 48.12 µm for the CCC group) for both techniques. Significantly lower mean internal gap widths were observed for the LSC group compared to the CCC group ($p < 0.05$) for all of the measurement locations (Fig. 3).

DISCUSSION

The purpose of current study was to compare the internal fit of single implant supported crowns produced using the laser sintering of a Co-Cr alloy with crowns made using conventionally cast Co-Cr alloy. Various techniques are

Table 1: Alloy compositions provided by the manufacturers (wt%)

Alloy	*Co*	*Cr*	*Mo*	*Si*	*W*	*Fe*	*Mn*
Co-Cr (Microlit isi)	61.1	27.8	–	1.7	8.5	0.5	0.3
Laser-sintered Co-Cr (EOS SP2)	61.8-65.8	23.7-25.7	4.6-5.6	0.8-1.2	4.9-5.9	<0.5	<0.1

Table 2: Descriptive statistics for the fit (μm) of each test group (p < 0.05)

Test group (n = 12)	*CCC*	*LSC*	*p-value*
Labial margin (Mean ± SD)	65.50 ± 9.54	52.19 ± 11.61	0.006
Labial axial surface (Mean ± SD)	126.41 ± 29.78	73.87 ± 9.83	0.001
Incisal edge (Mean ± SD)	313.46 ± 48.12	140.01 ± 31.84	0.001
Lingual axial surface (Mean ± SD)	124.73 ± 30.25	69.2425 ± 9.27	0.001
Lingual margin (Mean ± SD)	69.96 ± 9.61	56.96 ± 13.06	0.011

used for the evaluation of the internal fit between dental crowns and abutments. The measurement of the weight of light-body silicone is one of these techniques. Kokubo et al[33] recently used a light-body silicone in place of luting cement to determine the relative marginal gaps for ceramic crowns. McLean and von Frauhofer[26] previously used a light-body silicone to evaluate cement film thickness. The use of light-body silicone for the evaluation of the internal fit of the crowns is a convenient method, because a relative measurement of cement mass is acquired for the three-dimensional volume of the region of the luting cement. Another common technique to determine the width of the internal fit is to measure the gap under an electron or light microscope after obtaining a sectional sample from cemented crowns.[9,13,22,28] The manufacturing parameters were standardized in all samples with the assistance of software in the laser-sintering technique, but this standardization could not be established in the lost-wax technique. Considering this disadvantage in the preparation of lost-wax samples, plastic caps provided by the abutment manufacturer were used in our study in order to overcome individual differences in manipulation. All castings followed the same procedure.

The manufacturer also claimed that the crown fabricated from this laser-sintering system develops electrochemical characteristics. With this system, there is no need to make impressions of the prepared teeth or the abutment, and the processed restorations are purported by the manufacturer to be free of the porosity found in cast prostheses. However, studies on laser-sintered crowns are quite limited. Örtorp et al[13] compared the four techniques and demonstrated that direct laser metal sintering samples exhibited the best crown fit. They also found that the occlusal surface in all tested groups was the region that presented the greatest misfit (123-282 μm). On the other hand, Quante et al[14] evaluated the marginal and internal fit of single crowns fabricated in two different dental alloys using the laser melting technique. This study showed that the use of different alloys did not produce a difference in crown fit, and the mean marginal discrepancies ranged from 74 to 99 μm for both the alloys. The internal gaps were also reported to range from 250 to 350 μm. In the present study, the greatest gap was observed on the occlusal surfaces (313.46 ± 48.12 μm), and the highest mean marginal discrepancy was measured as 69.96 ± 9.61 μm, which is consistent with the values reported in previous studies.

Acceptable marginal discrepancies and crown internal gap widths have been reported for crown restorations.[21,26,27] McLean and Von Fraunhofer[26] evaluated more than 1000 crowns after a 5-year period and concluded that a marginal opening of ≤ 120 μm was still clinically and scientifically acceptable. Bindl and Mörmann[22] investigated both the marginal gap and internal gap width of different all-ceramic CAD/CAM crown copings on chamber preparations and reported results that varied from 17 μm to 43 μm for marginal gap width and from 81 μm to 136 μm for internal gap width.

Internal fit is not a unique factor that determines the clinical success of the implant-supported crowns. Tara et al[32] placed sixty restorations that were fabricated using laser-sintered technology in 39 patients and cemented them with glass-ionomer cement. Follow-ups were performed annually. During a mean observation period of 47 months, one restoration was regarded as a dropout, one crown failed, and one debonded. According to the authors, the results suggest that the clinical outcome of these restorations is promising. However, there is insufficient clinical data on metal crowns that are fabricated by this technique. Moreover, there is still a need for the future evaluation of other mechanical and biological features of laser-sintered crowns, including long-term clinical studies for clinical routine usage.[14,28]

CONCLUSION

Within the limitations of this *in vitro* study, the following conclusions were drawn:

This study indicated that the utilization of different types of metal copings affects the internal accuracy. That is, the means of the specimens from the LSC group were lower in tests compared to those of the CCC group.

The fabrication technique is likely responsible for observed differences in the fit of the metal crown. Techniques that enable the adjustment of crown casting parameters, such as the laser-sintering technique, help to maintain the desired fit between the casting and implant abutments. Thus, the new laser-sintering technique for Co-Cr alloys appears to be promising for prosthetic applications.

Clinical Significances

This *in vitro* study investigated which techniques affects the retentive strength of cemented implant-supported crowns via crown accuracy, comparing the use of lost wax casting and laser-sintered metal dental alloys.

The results of this study indicate that the use of laser-sintered crowns was evaluated to be acceptable for clinical application about implant-supported restoration accuracy.

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