European Journal of Research in Dentistry 2020; 4(2): 59–63
DOI: 10.35333/ERD.2020.267

ORIGINAL ARTICLE / ÖZGÜN ARAŞTIRMA

The Effect of Fabrication Technique and Cement Type on the Retention Strength of Implant Supported Crowns

Üretim Tekniği ve Siman Türünün İmplant Destekli Kronların Bağlantı Dayanımı Üzerine Etkisi

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Abstract

Objectives: The purpose of this study was to compare the retention strength of implant-supported frameworks produced by CAD/CAM, direct metal laser sintering, the traditional lost-wax technique by using three different luting cement.

Materials and Methods: Ninety standard titanium abutments screwed to analogs then mounted in acrylic resin. Samples were divided into three main groups according to the manufacturing technique (N=30). Then groups were divided into three subgroups based on the cement type used (n=10). Specimens were subjected to the pull-out test by using a universal testing machine at a 1 mm/min crosshead speed. The highest pull-out strength values were recorded in Newton. Statistical analysis of the data was performed using two-way analysis of variance and post hoc Tukey multiple comparison test at a significance level of 0.05.

Results: The two-way analysis of variance revealed that the fabrication technique and cement type had a significant effect on pull-out strength ($p<0.05$). However, the interaction of fabrication technique and cement type did not significantly affect the pull-out strength of groups ($p>0.05$). The highest pull-out strength was found in the laser sintering group, while the conventional lost-wax technique had the lowest values. Within the subgroups, self-adhesive resin cement had the highest pull-out strength, traditional cement subgroup had the lowest.

Conclusions: Fabrication technique and cement type have a statistically significant effect on the retention of the implant-supported crowns.

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This study was presented at 24th International Scientific Congress Of Turkish Prosthodontics And Implantology Association (TPID 2019, Muğla, Turkey).

Submitted / Gönderilme: 26.11.2018 **Accepted/Kabul:** 14.05.2019

Keywords: CAD/CAM; Implant-supported Crowns; Laser Sintering; Retention Strength.

Öz

Amaç: Bu çalışmanın amacı CAD/CAM, lazer sinterizasyon, ve konvansiyonel döküm yöntemleri ile üretilen metal altyapıların abutmentlara olan bağlantı dayanımını üç farklı siman kullanarak karşılaştırmaktır.

Gereç ve Yöntem: 90 adet abutment analoglara vidalanarak akrilik rezin içerisine gömüldü. Örnekler üretim tekniğine göre üç ana gruba ayrıldı (N=30). Sonrasında gruplar kullanılan siman türüne göre üç alt gruba ayrıldı (n=10). Örneklere üniversal test cihazı ile 1mm/dk hızla çekme testi uygulandı. Universal test cihazında metal alt yapıların dayanaklardan ayrıldığı en büyük kuvvet değerleri Newton biriminde kaydedildi. İstatistiksel analiz 0.05 anlamlılık düzeyinde iki yönlü varyans analizi ve post-hoc tukey çoklu karşılaştırma testi kullanılarak yapıldı.

Bulgular: İki yönlü varyans analizi üretim tekniği ve siman tipinin tutuculuk üzerinde anlamlı bir etkisi olduğunu ortaya koymuştur ($P<0.05$). Bununla birlikte üretim tekniği ve siman tipinin ikisinin etkileşiminin tutuculuk üzerinde istatistiksel olarak anlamlı bir etkisinin olmadığı görülmüştür ($p>0.05$). En yüksek bağlantı dayanımı lazer sinter grubunda bulunurken konvansiyonel kayıp mum tekniği en düşük değeri göstermiştir. Alt gruplardan kendinden adezivli rezin siman en yüksek bağlantı dayanımı değerine sahipken geleneksel siman en düşük değeri göstermiştir.

Sonuç: Üretim tekniği ve siman türü metal altyapıların abutmentlara olan bağlantı dayanımını istatiksel olarak anlamlı düzeyde etkilemiştir.

Anahtar Kelimeler: CAD/CAM; Implant Destekli Kron; Lazer Sinterizasyon; Bağlantı Dayanımı.

Introduction

Implant-abutment connection and retention type (cemented or screw retained) are critical factors for the long-term success of ISFP (Implant supported fixed prosthesis)(1). Despite the disadvantages of cement-retained restorations such as peri-implantitis, peri-implant mucositis, and difficulties in removing for future maintenance, cemented restorations are still commonly used in clinical practice due to less mechanical complication, easy production, esthetics, and lower costs(2,3).

Metal-ceramic restorations have been widely used for the implant-supported prosthesis and revealed sufficient long period clinical performance. With the development of CAD/CAM (Computer aided design/computer aided manufacturing) technologies, CAD/CAM and direct metal laser sintering (DMLS) fabricated restorations have gain popularity as an alternative treatment option to conventional ones (lost-wax technique)(4,5). The problems encountered in the lost-wax technique have been eliminated by CAD/CAM techniques(6). Virtual structure work as a model for reconstruction of the restoration from a solid Co-Cr (Cobalt-Chromium) blank in CAD/CAM applications.

A metal additive manufacturing technology (DMLS) uses a high temperature laser beamed to selective metal powder. The beamed area was fused and the metal framework was finished according to CAD data(7,8).

Previous studies revealed that fabrication techniques and frameworks materials have an effect on the retention of the restorations (9,10). Loss of retention is one of the most common complication for the implant-supported fixed restorations(11). Additionally, the retention of restorations depends on type of cement, axio-occlusal angle, composition of crown material and texture, abutment height and firstly frictional retention(3). In clinical practice, cement-retained restorations should exhibit easy retrievability and adequate retention strength to avoid decementation(1). Zinc phosphate, zinc polycarboxylate, glass-ionomer, and self-cure resin cements have been commonly selected for the permanent cementation of ISFP(12). For semi-permanent fixation which provides proper retention, new low strength resin cement with low solubility are being developed.

Regardless of the abutment shape and the other factors, the cement type notably determines the success of the implant-supported restorations. However, there are few studies in the literature investigating the effect of different metal framework fabrication techniques on cement retention of implant-supported prosthesis. So, the effect of the cement type and fabrication technique of frameworks on the retention of the implant-supported restorations is unclear. Therefore, the purpose of this *in vitro* study was to evaluate the effect of cement types and fabrication techniques of framework on the retention strength of the ISFP. The first null hypothesis of the study was that the fabrication technique has no effect on the retention strength of implant-supported prosthesis. The second null hypothesis of the study was that the cement type has no effect on the retention strength of implant-supported prosthesis.

Materials and Methods

Ninety titanium standard abutments with the diameter of 4.3 mm and the gingival height of 2 mm were screwed to implant analogs (T6, Nucleoss, İzmir, Turkey) and torqued to 30 Ncm by an implant wrench. The standard polyurethane mold and 90° angled plate were used to achieve stable and standard positioning of the samples on the universal testing machine (The Testometric Company Ltd., Rochdale, İngiltere) and a silicone guide was prepared to mount the implant analogs in the acrylic resin with leaving 1 mm neck of the implant analogs outside to simulate the clinical conditions. Then, the polyurethane mold was isolated by petrolatum jelly and embedded with auto-polymerizing acrylic resin (Imicryl, Konya, Türkiye) and the implant analogs, screwed to abutments, were mounted in the acrylic resin with the help of silicone guide. After preparation of the 90 samples, they were divided into 3 groups (N=30) according to fabrication techniques (Lost-wax, DMSL, and CAD/CAM). Then groups divided into 3 subgroups (n=10) according to cement type used. The groups are summarized in Table 1.

Table 1: Fabrication techniques and cement types used in the study among the groups.

Group	n	Fabrication Technique	Cement type
Group Laser-Pan	n=10	Laser sintering	Composite resin (Panavia F 2.0; Kuraray, New York, USA)
Group Laser-Multi	n=10	Laser sintering	Composite resin (Multilink Implant, IvoclarVivadent, Schaan/Liechtenstein)
Group Laser-Poly	n=10	Laser sintering	Polycarboxylate (Durelon™, 3M ESPE, USA)
Group Mill-Pan	n=10	CAD/CAM	Composite resin (Panavia F 2.0; Kuraray, New York, USA)
Group Mill-Multi	n=10	CAD/CAM	Composite resin (Multilink Implant, IvoclarVivadent, Schaan/Liechtenstein)
Group Mill-Poly	n=10	CAD/CAM	Polycarboxylate (Durelon™, 3M ESPE, USA)
Group Cast-Pan	n=10	Lost-wax Technique	Composite resin (Panavia F 2.0; Kuraray, New York, USA)
Group Cast-Multi	n=10	Lost-wax Technique	Composite resin (Multilink Implant, IvoclarVivadent, Schaan/Liechtenstein)
Group Cast-Poly	n=10	Lost-wax Technique	Polycarboxylate (Durelon™, 3M ESPE, USA)

In the lost-wax technique, prefabricated casting caps were used to standardize the internal fit of frameworks. Prefabricated casting caps were waxed and sprued. Then the casting caps were invested and casted with Ni-Cr alloy (Meto A, Meto Dent, Turkey). After the casting process, frameworks were sandblasted at a 3 cm distance under 2 atm pressure using 250 um Al2O3 particles. The intaglio surfaces of the frameworks were evaluated for the marginal fit and complete seating. All samples were ultrasonically cleaned in distilled water for 8 minutes, then steam-cleaned for 15 seconds.

The models were scanned and frameworks were designed using a software (Sirona InLab, Dentsply Sirona, Germany). Then thirty frameworks were produced with a laser sintering system (EOSINT M270, EOS, Germany), which is an additive manufacturing technique by using the alloy powder (EOS Cobalt Chrome SP2, EOS, Germany) with the layer thickness of 20 µm. After the sintering process, specimens were sandblasted with 50 µm Al2O3 particles at 2 atm pressure for 15 seconds at a distance of 8 cm. The intaglio surfaces of the frameworks were evaluated for the marginal fit and complete seating. All specimens were ultrasonically cleaned in distilled water for 8 minutes, then steam-cleaned for 15 seconds.

The models were scanned (7 Series, Dental Wings, Canada) and then frameworks were designed using a software. Then the frameworks were milled from cobalt chrome metal blocks (CopraBond K, Whitepeaks) using 5-axis CAD/CAM milling unit (DS MagnumH60, Mesa Company, Italy). After the milling process, the intaglio surfaces of the frameworks were evaluated for the marginal fit and complete seating. All specimens were ultrasonically cleaned in distilled water for 8 minutes, then steam-cleaned for 15 seconds.

Three different types of cement were used in this study: Polycarboxylate cement (Durelon™, 3M ESPE, USA); resin composite cement (Panavia F 2.0; Kuraray, Japan); resin composite cement (Multilink Implant; Ivoclar, England) (Table 1). Before cementation, screw holes were filled fully with polytetrafluoroethylene tape. The frameworks were completely surrounded with the luting cement and were placed on the abutment by applying light finger pressure and excess cement was removed from the margin and in all groups, cementation was completed according to manufacturer's instructions by the same clinician(13,14). Thus, 9 test groups that were produced by different fabrication techniques (lost-wax, direct metal laser sintering, and CAD/CAM) and cemented by 3 different types of cement, were obtained to assess endurance of retention strength between metal framework and abutment. Before pull-out testing, samples were held on for 24 hours and then placed in distilled water for at least 24 hours. The pull-out test was performed by a universal testing device at a 1 mm/min crosshead speed. The loads at failure were recorded in Newton and mean values for each group were calculated. The statistical analyzes were conducted using a software (SPSS 19, SPSS, IBM, USA). The normality of the data was assessed by the Kolmogorov-Smirnov test. The statistical analysis was performed using Two-way ANOVA (Analysis of variance) and multiple comparison tests with Bonferroni correction (a=0.05) at a significance level of 0.05. The methodology of this study was reviewed by an independent statistician.

RESULTS

According to the statistical analysis conducted, fabrication technique and cement type have a significant effect on the retention strength ($p<0.05$), and interaction between these factors was not found to be significant ($p>0.05$). (Table 2) The highest retention strength was determined in Laser Groups and differences between Cast Groups and Mill Groups were not significant ($p<0.05$). The highest retention value was observed in Pan Group, Multi Group, and Poly Group, respectively. ($p<0.05$) The highest pull-out value was found in Group Laser-Pan on the other hand, the lowest pull-out value was found in Group Mill-Poly. (Table 2)

Table 2. Retention strength (Mean± Std.) of the groups, different superscript letters, uppercase in columns, and lowercase in lines, indicate significant differences ($p<0.05$).

	Resin cement (Pan)	Resin cement (Multi)	Traditional (Poly)
Laser Sintering	535,74±86,13^{Aa}	463,36±56,92^{Ab}	266,77±101,22^{Ac}
CAD/CAM	461,76±82,04^{Ba}	326,37±66,17^{Bb}	223,76±56,20^{Bc}
Lost-wax	493,27±53,72^{Ba}	321±17,44^{Bb}	239,7 ±85,15^{Bc}

Discussion

This study evaluated the retention strength of ISFP which were fabricated with three different techniques by using three different cement materials. Based on the finding of this study, it was found that the laser sintering technique was associated with higher retention value when compared to other techniques, but no significant difference was found between lost-wax and CAD/CAM techniques. Therefore, the first null hypothesis of the study that the fabrication technique has no effect on the retention strength of implant-supported prosthesis was rejected. Besides, significantly different retention strengths among the cement types were observed. Thus, the second null hypothesis of the study that cement type has no effect on the retention strength of ISFP was also rejected.

The production of implant-supported prostheses requires many clinical and laboratory procedures that must be completed within precision. In this study, Laser Group showed significantly higher retention values than other groups. Parallel to our study, Örtorp *et al* compared the marginal and internal accuracy of fixed partial dentures using four fabrication techniques and found that the laser sinter group showed better marginal and internal accuracy than other fabrication techniques(15). Thus, higher retention values in the laser sintering group could be attributed to the better internal fit. On the other hand, Tamac *et al* reported that metal-ceramic crowns fabricated with CAD/CAM, DMLS, and lost-wax techniques exhibited similar marginal and axial accuracy, whereas higher dimensional values were observed for the DMLS system crowns(7).

Permanent cements are commonly used for the cementation of implant-supported prosthesis and previous studies reported that permanent cements were used more frequently than temporary cements in clinical practice(4,16). It is recommended to use resin cement, glass-ionomer cement, and zinc phosphate cements for crown restorations at the posterior region as they provide better retention(17). Based on the results of this study, composite resin cement (Pan Groups) had the highest retention value; followed by composite resin cement (Multi Groups) and conventional cement (Poly Groups). The composite resin cement containing MDP (10-methacryloyloxydecyl dihydrogen phosphate), showed the highest retention value. The phosphate monomer in resin cements may be the occasion of stability of the connection interface. The phosphate ester group in MDP directly bounds to metal oxides at the surface. According to the result of the study, the retention values of each cement group of frameworks produced by the DMSL technique were found different. Pan Groups showed the highest retention value and Poly Groups showed the lowest. Clayton *et al* assessed retention resistance of CeraOne gold cylinder to CeraOne base by using 5 distinct cements (zinc phosphate, glass ionomer cement, zinc oxide eugenol, hybrid glass-ionomer cement, and composite resin) and found that zinc phosphate cement has higher retention values when compared to composite resin cement(16). However, using zinc phosphate cement in clinical practice may lead to difficulty in removal of restorations(16,18). In the current study, composite resin cement had the highest retention value. The differences between cement retention strength may be due to the use of computer-assisted design and prefabricated casting plastics in the production of metal frameworks.

Although the design of the implant body closely resembles a natural tooth, the screw hole is one of the most important differences between the two bases. Cotton, gutta-percha, polyvinyl siloxane, auto-polymerizing acrylic resin, composite, polytetrafluorethylene, and temporary filling materials can be used to fill the screw hole either partially or completely(7,11). It has been emphasized that closure of the screw access route of implant bases affects retention strength and closure technique is also important. Also, there is no consensus regarding the complete or partial filling of the screw access route or material to be used for filling(11). Thus further *in-vitro* and *in-vivo* studies should be investigated.

Conclusions

According to the result of the study, it can be summarized that,

- Retention value was found to be highest in the laser sintering group.
- The highest retention value was observed in the resin cement group.
- Resin-based cements produced for implant-supported restorations show higher retention characteristics than conventional cements.

Acknowledgments

This study was supported by the Coordinatorship of Scientific Research Projects of Hatay Mustafa Kemal University with the project number of 18.U.003. The authors also thank to Professor Cem ÇUHADAR as an independent reviewer, for the review of methodology and statistical analyses carried out.

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