Deformation of Metal Frameworks with Different Thickness During Cementation

Farklı Kalınlıktaki Metal Alt Yapıların Simantasyon Esnasında Deformasyonu

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ABSTRACT Objective: Deformation of metal framework during cementation of metal-porcelain restoration may contribute to its clinical failure. The purpose of this study was to determine the deformation of metal frameworks with different thickness during cementation. **Material and Methods:** Thirty stainless steel dies were prepared at the computer-assisted lathe. Dies were randomly divided into 3 groups (n= 10). Specimens of 0.2 mm (Group 1), 0.3 mm (Group 2) and 0.4 mm (Group 3) thickness were prepared with self-curing acrylic die material (Pattern Resin LS) using stainless steel indexes. Acrylic specimens were invested and cast with NiCrMo alloy (Remanium CS). Marginal diameters of specimens were measured with Nikon V12 Profile Projector from three different angles. Metal frameworks were cemented with polycarboxylate cement (Poly-F Plus Bondex) using standard forces (300 N). Measurements of marginal diameters were repeated. Differences before and after cementation values were statistically analyzed by Paired-Samples T test. **Results:** Deformations formed at metal frameworks during cementation in Group 1 and Group 2 ($p< 0.05$). Group 3 was not affected by cementation ($p> 0.05$, $p= 0.734$). **Conclusion:** From the results, it may be proposed that NiCrMo alloy frameworks should be prepared at least thicker than 0.3 mm in clinical practice.

Key Words: Dental restorations, cementation, metal ceramic alloys

ÖZET Amaç: Metal-porselen restorasyonların simantasyonu esnasında metal alt yapının deformasyonu restorasyonun klinik başarısını etkileyebilir. Bu çalışmanın amacı, farklı kalınlıktaki metal alt yapıların simantasyon esnasında deformasyonunu belirlemektir. **Gereç ve Yöntemler:** Otuz paslanmaz çelik die bilgisayar kontrollü tornada hazırlandı. Die'lar rastgele 3 gruba ayrıldı (n= 10). 0.2 mm (Grup 1), 0.3 mm (Grup 2) ve 0.4 mm (Grup 3) kalınlıkta örnekler otopolimerizan akrilik rezin die materyali (Pattern Resin LS) ile paslanmaz çelik kalıplar kullanılarak hazırlandı. Akrilik örnekler revetmana alındı ve NiCrMo alaşımı (Remanium CS) ile döküldü. Örneklerin marjinal çapları 3 farklı açıdan Nikon V12 Profile Projector ile ölçüldü. Metal alt yapılar polikarboksilat siman (Poly-F Plus Bondex) ile standart kuvvet kullanılarak (300 N) semente edildi. Marjinal çap ölçümleri tekrarlandı. Simantasyondan önceki ve sonraki değerlerdeki farklılıklar Paired-Samples T testi kullanılarak analiz edildi. **Bulgular:** Grup 1 ve Grup 2'de simantasyon esnasında metal alt yapılarda deformasyonlar oluştu ($p< 0.05$). Grup 3 simantasyondan etkilenmedi ($p> 0.05$, $p= 0.734$). **Sonuç:** Sonuçlara dayalı olarak NiCrMo alaşım alt yapıların klinik pratikte 0.3 mm'den daha ince hazırlanmaması önerilebilir.

Anahtar Kelimeler: Dental restorasyonlar, simantasyon, metal seramik alaşımlar

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Metal-porcelain restorations are currently the most widely used in prosthodontic practice because of mechanical properties of metal framework to fabricate especially long-term fixed partial denture (FPD).[1] Metal-porcelain restorations combine the strength and accuracy of cast metal with the aesthetics of porcelain.[2]

Preparing thick metal framework increases resistance against permanent deformation; however, it is usually impossible to prepare the metal thicker than 0.5 mm, because the metal and porcelain material must be prepared within the limits of normal teeth morphology in this type of restorations. When aesthetic limits are considered, preparing thinner metal framework has advantages.

Successful cementation is as important as fabricating a restoration for the long-term success of restoration. It has been demonstrated by previous studies that crown deformation during cementation is affected by crown thickness, marginal designs, cement type and viscosity, venting, die spacing, and seating forces.[3,4] Hydraulic force of the cementation can induce (or generate) stresses on the metal framework, thus, these stresses may contribute to its clinical failure.

The purpose of this study was to determine the deformation of NiCrMo alloy frameworks with different thicknesses during cementation. The hypothesis for this study was that the NiCrMo alloy frameworks with different thicknesses have different rates of deformation during cementation.

MATERIAL AND METHODS

PREPARATION OF METAL DIES AND INDEXES

Thirty stainless steel dies were prepared with the hexagonal substructure using the computer-assisted lathe (NV 500A/40, Mori Seiki, Yamato, Koriyama, Japan) (Figure 1). Stainless steel dies simulating a molar tooth preparation were used to produce a standard crown specimen shape; the outside diameter of preparation was 9 mm. The die had 6 degrees of axial taper, 1 mm width in shoulder finish line, 1 mm of occlusal reduction and 5.5 mm of occluso-gingival height. Dies were randomly divided into 3 groups (n= 10). Three custom stainless steel indexes for three different framework thicknesses of 0.2 mm, 0.3 mm and 0.4 mm were fabricated by using the computer supported lathe. Group 1, Group 2, and Group 3 metal frameworks with 0.2 mm, 0.3 mm and 0.4 mm thicknesses were produced with these indexes (Figures 2a-d), respectively.

FIGURE 1: Thirty stainless steel dies.

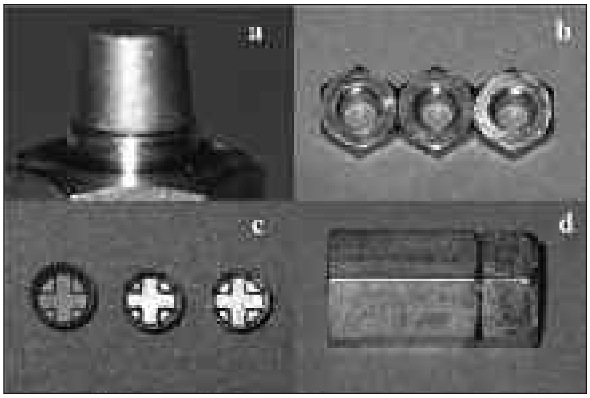

FIGURE 2: a: Placed specimen on own metal die. **b:** Three special stainless steel indexes. **c:** 3 metal frameworks with 0.2 mm, 0.3 mm and 0.4 mm thickness. **d:** Placed index on a metal die.

Metal dies and indexes were used to standardize and to avoid fracture or distortion of the die during testing.

METAL FRAMEWORK PREPARATION

Die spacer (Bredent, Degussa, Germany) was applied on the metal dies. Separating medium was used with a brush on a metal die and index. Self-curing acrylic die material (Pattern Resin LS, GC America Inc, Alsip, IL, USA) was prepared according to the manufacturer's instructions. Acrylic material was injected to the space between index and metal die. The metal die and the metal index were kept in constant pressure with maximal finger force up to the acrylic material set. After the resin had set for 3 min at 23 °C, the pattern was carefully removed from the metal index and the margin and the internal surface were checked. The acrylic specimens and the metal die were numbered and marked to seat on the metal die in the correct position of the prepared specimen. Acrylic patterns with 0.2 mm, 0.3 mm and 0.4 mm thicknesses were invested with a phosphate-bonded investment (Castorit-Super C, Dentaurum, Pforzheim, Germany). Metal frameworks were cast with NiCrMo alloy which consists of 61% Ni, 26% Cr, 11% Mo, 1.5% Si, 1% S, Fe, Se, Al (Remanium CS, Dentaurum, Ispringen, Germany;) using induction melting (Fornax 35 EM, Bego Bremer Goldschlägerei Wihl. Herbst GmbH&Co., Bremen, Germany). The castings were divested and sprues were removed.

Internal casting irregularities were removed with small round diamond stones and finished using a microblaster with 50 µm aluminium oxide (Korox®, Bego, Bremen, Germany). After the specimens were ultrasonically cleaned (Whaledent Biosonic Jr., Whaledent International, New York, USA) for 15 min and rinsed with distilled water, they were dried in air.

Each specimen was placed on its own metal die and located on the Nikon V12 Profile Projector (Nikon Corporation, Tokyo, Japan). Marginal diameters of specimens were measured with Profile Projector from three different axes by rotating dies and were recorded (Figure 3). The specimens were viewed under ×10 magnification with a profile projector. Each measurement was repeated 3 times with 1 µm sensitivity between the reference points, and then its average was calculated. The examiner did not have any knowledge regarding which treatments the casts had received before making measurements.

CEMENTATION

Metal frameworks were cemented with polycarboxylate cement (Poly-F Plus Bondex, Dentsply Detrey GmbH, Konstanz, Germany) onto their own dies by the same operator. Cement was prepared according to the manufacturer's instruction and was placed uniformly on the entire inner surface of each metal framework. The metal framework was seated on the metal die in the correct position with minimal finger force to prevent the metal framework tilting. Metal frameworks were subjected to 300 N of force using hydraulic press (Hydrofix, BEGO Bremer Goldschlägerei Wilh, Herbst Gmbh and Corp., Bremen, Germany).

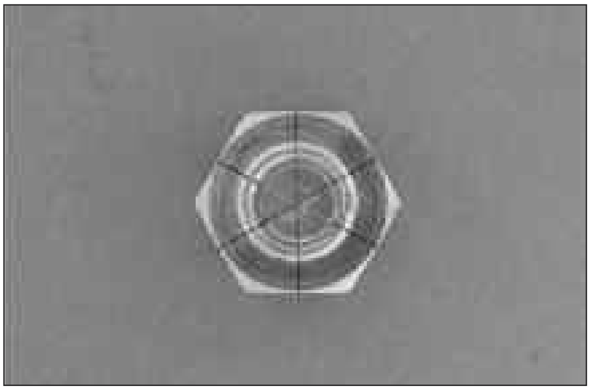

FIGURE 3: Three axes made measurement.

Measurements of marginal diameters were repeated and recorded. The differences between values before and after cementation were compared at three different axes to determine the deformation quantity.

STATISTICAL ANALYSIS

Differences between pre- and post-cementation values were statistically analyzed with Paired-Samples T test using SPSS 11.0 (*SPSS Inc.*, *Chicago*, Illinois, USA) Differences were considered significant at $p< 0.05$.

RESULTS

The means and standard deviations of marginal diameters for the groups were presented in Table 1. There are significant differences between marginal diameter values of pre- and post-cementation for all groups when Table 1 is examined. Nevertheless, it is important if the present difference is statistically significant.

The deformations occurred at metal frameworks during cementation in Group 1 and Group 2 ($p< 0.05$, $p= 0.009$ and $p= 0.005$, respectively), whereas cementation did not affect Group 3 ($p> 0.05$, $p= 0.734$). The mean value of the marginal diameters increased in Group 3; whereas it decreased in

TABLE 1: Marginal diameters for the groups (Mean ± Standard deviation).

Groups	Metal thickness (mm)	n	Before cementation (μm)	After cementation (μm)
1	0.2	10	7577.98 ± 44.41	7566.44 ± 48.14
2	0.3	10	7743.56 ± 39.70	7732.79 ± 59.28
3	0.4	10	8076.31 ± 40.62	8107.24 ± 299.50

Group 1 and Group 2 after cementation, respectively.

Examination of the photographs clearly revealed patterns of deformation in occlusal, axial and neck regions of metal framework (Figure 4). There was increase as well as decrease in the marginal diameters after cementation. As cement came out of one region, marginal diameter increased with the hydraulic pressure, whereas it decreased in another region (Figure 5).

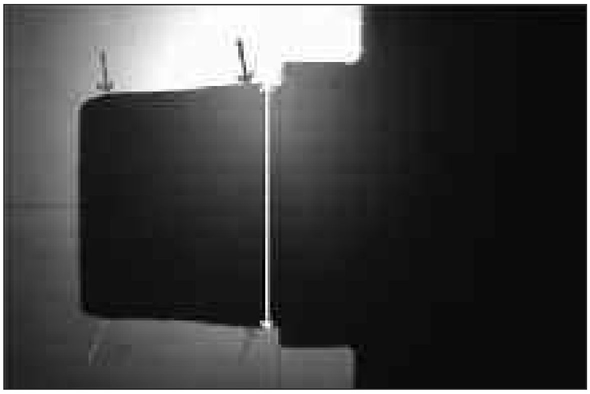

FIGURE 4: Red arrows: Deformations in occlusal, axial and neck regions. White arrow: Measurement of marginal diameter.

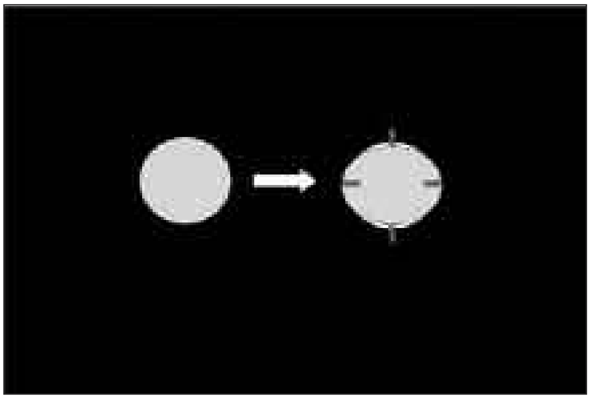

FIGURE 5: The circular form before cementation became elliptical after cementation.

DISCUSSION

Although the metal coping is an important part of the metal-porcelain restoration, it is unfortunately one that is often overlooked. Its design may have an important effect on the success or failure of the restoration. The metal framework must allow the porcelain to remain in compression by supporting the incisal region, the occlusal table, and the marginal ridges.[2] Porcelain should be kept at a minimum thickness that is still compatible with good esthetics. Relatively thin porcelain of uniform thickness supported by rigid metal is the strongest.[2]

Because of its good physical characteristics such as its high yield strength, elongation limit and ductile yield, NiCrMo alloy is frequently used as metal alloy in metal-porcelain restorations. NiCr alloys have the highest elastic modulus of all dental alloys, which reduce flexibility to a significant degree. The high tensile strength permits use of thinner metal sections than noble metal alloys.[5] In this study, we preferred using NiCrMo alloy at clinical practice due to these advantages.

Prior studies of viscosity and film thickness have shown that cement flow is important.[6,7] A polycarboxylate cement was shown to have a lower viscosity than zinc phosphate cement.[6,8] Film thickness is a physical property of material that influences the sizes of cement spaces between castings and teeth. In addition to film thickness, viscosity and geometric configuration are known to affect cement space size by limiting cement flow and preventing or enhancing close approximation of particular surfaces.[6,8-12] After cementation, an acceptable margin is not over-extended, under-extended, too thick, or open.[2]

Die relief not only provides space for a cement layer between casting and tooth, but also facilitates the escape of excess cement despite its viscosity or film thickness. Most conventional complete crowns rarely seat completely because of hydraulic pressures.[6,13,14] Venting of the crowns partly reduced this problem.[12] However, we did not prepare vent because most dentists do not seal vents with direct restorations.[15]

The 300 N seating force created the best marginal seating, with the average being less than 10 μm.[16] The maximum biting force generated by the masticatory muscles varies from 200 to 600 N.[17] This suggests that the loading technique to achieve maximum crown seating in the clinical environment can proceed as follows: seat the crown in place with finger force, and then ask the patient to occlusion in centric occlusion with maximum force.[16] We also used hydraulic press for constant 300 N pressure after seating crowns in place with finger force.

Mumford has stated that, for adequate strength and rigidity, a noble metal coping should be at least 0.3 to 0.5 mm thick.[18] A base metal alloy with a higher yield strength and elevated melting temperature may be as thin as 0.2 mm.[19] However, in the present study, deformations occurred at metal frameworks during cementation in 0.2 and 0.3 mm groups, whereas cementation did not affect 0.4 mm group and thus, the research hypothesis was accepted.

The profile projector consisted of a screen with horizontal and vertical reference lines and was equipped with a light source to project a magnified image of the object onto the screen in the form of a shadow (original magnification x10). The profile projector allowed measurement of linear distances with an accuracy of 2 μm.[20] Conventional measurement techniques often require surface contact with the object being measured; this could potentially damage the specimen. The advantage of our method is its being a method that requires no contact. Rotating of dies prepared with the hexagonal substructure provided measuring between the same points before and after cementation.

The results might be different if ceramic is applied over the metal framework. However, the effect of ceramic was ignored in this study.

CONCLUSION

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

1. There is the risk of fracture in the porcelain for the metal-porcelain restorations during cementation and the residual strain occurring on metal framework may cause fracture.

2. Occurrence of both increases and decreases in the marginal diameter at the same time shows existence of shear stress.

3. Preparing the metal frame works thicker than 0.3 mm in clinical practice will be advantageous at preventing deformations.

REFERENCES

1. Lüthy H, Filser F, Loeffel O, Schumacher M, Gauckler LJ, Hammerle CH. Strength and reliability of four-unit all-ceramic posterior bridges. Dent Mater 2005;21(10):930-7.
2. Shillingburg HT. Metal-ceramic restorations. In: Lori A, ed. Bateman.,Fundamentals of Fixed Prosthodontics. 3rd ed. Carol Stream, IL: Quintessence Publishing Co,Inc; 1997. p.455.
3. Wang CJ, Millstein PL, Nathanson D. Effects of cement, cement space, marginal design, seating aid materials, and seating force on crown cementation. J Prosthet Dent 1992;67(6):786-90.
4. Wilson PR, Goodkind RJ, Delong R, Sakaguchi R. Deformation of crowns during cementation. J Prosthet Dent 1990;64(5):601-9.
5. O'Brien WJ. Alloys for porcelain-fused-to-metal retorations. Dental Materials and Their Selection. 2nd ed. Carol Stream, IL: Quintessence Publishing Co,Inc; 1997. p.231.
6. Watts DC, Combe EC, Greener EH. The rheological properties of polyelectrolyte cements II. Glass ionomers. J Oral Rehabil 1981;8(1):61-7.
7. White SN, Yu Z, Kipnis V. Effect of seating force on film thickness of new adhesive luting agents. J Prosthet Dent 1992;68(3):476-81.
8. Vermilyea S, Powers JM, Craig RG. Rotational viscometry of a zinc phosphate and a zinc polyacrylate cement. J Dent Res 1977;56(7):762-7.
9. Jorgensen KD. Factors affecting the film thickness of zinc phosphate cements. Acta Odontol Scand 1960;18(4):491-501.
10. White SN, Kipnis V. Effect of adhesive luting agents on the marginal seating of cast restorations. J Prosthet Dent 1993;69(1):28-31.
11. Kyrios DM, Duke ES, Windeler AS. Glass-ionomer cement film thickness and working time. J Prosthet Dent 1989;62(5):533-6.
12. Strutz JM, White SN, Yu Z, Kane CL. Luting cement-metal surface physicochemical interactions on film thickness. J Prosthet Dent 1994;72(2):128-32.

13. Omura I, Yamauchi J, Harada A, Wada T. Adhesive and mechanical properties of a new dental adhesive. J Dent Res 1984;63(Sp Iss):223. Abst. No. 561.
14. Smith DC. A new dental cement. Br Dent J 1968;124(9):381-4.
15. Dimashkieh MR, al-Shammery AR. Sleeve design for a fixed partial denture. J Prosthet Dent 1993;69(1):8-11.
16. Piemjai M. Effect of seating force, margin design, and cement on marginal seal and retention of complete metal crowns. Int J Prosthodont 2001;14(5):412-6.
17. Miyaura K, Matsuka Y, Morita M, Yamashita A, Watanabe T. Comparison of biting forces in different age and sex groups: a study of biting efficiency with mobile and non-mobile teeth. J Oral Rehabil 1999;26(3):223-7.
18. Mumford G. The porcelain fused to metal restoration. Dent Clin North Am 1965;23:241-9.
19. Weiss PA. New design parameters: utilizing the properties of nickel-chromium superalloys. Dent Clin North Am 1977;21(4):769-85.
20. Vigolo P, Fonzi F, Majzoub Z, Cordioli G. An evaluation of impression techniques for multiple internal connection implant prostheses. J Prosthet Dent 2004;92(5):470-6.