Evaluation and comparison of the marginal adaptation of two different substructure materials

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PURPOSE. In this study, we aimed to evaluate the amount of marginal gap with two different substructure materials using identical margin preparations. **MATERIALS AND METHODS.** Twenty stainless steel models with a chamfer were prepared with a CNC device. Marginal gap measurements of the galvano copings on these stainless steel models and Co-Cr copings obtained by a laser-sintering method were made with a stereomicroscope device before and after the cementation process and surface properties were evaluated by scanning electron microscopy (SEM). A dependent *t*-test was used to compare the mean of the two groups for normally distributed data, and two-way variance analysis was used for more than two data sets. Pearson's correlation analysis was also performed to assess relationships between variables. **RESULTS.** According to the results obtained, the marginal gap in the galvano copings before cementation was measured as, on average, 24.47 ± 5.82 µm before and 35.11 ± 6.52 µm after cementation; in the laser-sintered Co-Cr structure, it was, on average, 60.45 ± 8.87 µm before and 69.33 ± 9.03 µm after cementation. A highly significant difference ($P<.001$) was found in marginal gap measurements of galvano copings and a significant difference ($P<.05$) was found in marginal gap measurements of the laser-sintered Co-Cr copings. According to the SEM examination, surface properties of laser sintered Co-Cr copings showed rougher structure than galvano copings. The galvano copings showed a very smooth surface. **CONCLUSION.** Marginal gaps values of both groups before and after cementation were within the clinically acceptable level. The smallest marginal gaps occurred with the use of galvano copings. ***[J Adv Prosthodont 2015;7:257-63]***

KEY WORDS: Galvano crowns; Marginal adaptation; Laser sintered Co-Cr; Electroformed coping; Biocompatibility

INTRODUCTION

Rehabilitation of tooth loss that may have occurred for various reasons with prosthetic restorations positively affects the quality of the patient's life.[1] In addition to the mechanical properties, marginal compatibility of the prosthetic restorations is expected to be good, to satisfy the patient esthetically and functionally, to be biocompatible with the oral tissues, and to show long term clinical success. Any excess in the marginal gap can give rise to bruises, periodontal problems, and even loss of teeth.[2,3]

Today's dentistry commonly uses materials that can be divided into four groups: metals, ceramics, polymers, and composites.[4] The materials most frequently used in prosthetic restorations are metal alloys, acrylic resin polymers, and ceramics.[5] Dentists use Ni-Cr alloys widely in the substructures of fixed partial dentures due to the material's relatively low cost.[6-8] However, Ni-Cr alloy-ceramic restorations have a number of disadvantages, despite being economical. The major disadvantages are a color mismatch in the cervical area, a lack of good casting clarity, and, most

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importantly, relatively poor biocompatibility.[9,10] In addition, it should be taken into consideration that nickel can cause allergic reactions and beryllium can have toxic effects.[11,12] Because of the disadvantages of Ni-Cr alloy-ceramic restorations, substructure materials that are nickel-free and have better biocompatibility are desirable as alternatives.[13] Co-Cr-containing alloys and gold-containing alloys are two such alternatives.[3,6,14-17]

The Co-Cr alloy composition is typically 53-65% Co (cobalt) and 27-32% Cr (chromium). Mo (molybdenum) content varies between 2 and 6%. This alloy group can be used in fixed partial dentures, although it is more widely used in casting of the main binding of removable partial dentures because they are economical and highly durable.[12] The content of fixed partial Co-Cr substructures obtained with laser sintering typically includes no Ni (nickel) or Be (beryllium), although different proportions are used in this alloy group (Table 1).

In 1961, Rogers described gold layer 'electroforming,' precipitating it on a metal surface.[18,19] Then, Rogers extended these procedures on porcelain crowns, including gold copings.[20,21] Such galvanoceramic restorations, made along with porcelain veneers on galvano copings, have been used as an alternative to other ceramic restorations. These galvanoceramic restorations have some significant advantages, such as high biocompatibility, good marginal adaptation, being esthetically pleasing, and being in compliance with the gingival tissues in the cervical region.[8,15]

In this study, we aimed to measure and compare the surfaces of marginal gaps of copings obtained with two different substructure materials and stainless steel models with a chamfer preparation, before and after cementation.

MATERIALS AND METHODS

Stainless steel dies, 5 mm long, in the occlusal-gingival direction and 4.1 mm occlusal diameter, were designed according to the shape of a chamfer finishing line. A 1 mm chamfer finishing line was designed to be inclined at 6° to the coronal direction. A drawing for this marginal preparation shape was prepared using computer software (AutoCAD, Autodesk, Munich, Germany). To perform the measurements at the same points on the stainless steel dies, 10 lines were drawn down to the finishing line of all models at 36° intervals (Fig. 1).

According to the drawings, 20 stainless steel dies were produced using a CNC milling device (Victor Vturn II-20, Victor Europe Ltd., Rochdale, UK).

To prepare a cement gap of 24 µm thick on the inner surface of copings being prepared on 10 of the stainless steel die models, a die spacer (Die Spacer Kit; Benzar Dental AG, Zurich, Switzerland) was used, to be 1 mm above the finishing line of the stainless steel die models. The die spacer-applied stainless steel die models were then placed into a specially prepared polyvinyl silicone (Elite P&P, Zhermack, BadiaPolesine (RO), Rovigo, Italy) mold. After removal of the preplaced stainless steel die models, Type 4 plaster (Excalibur, Siladent, Dr. Böhme & Schöps GmbH, Goslar, Germany) was poured into the silicone mold. Following a 1-hour period to allow hardening, the duplicate dies were removed from the mold. Trimming was carried out on the duplicate dies. Attention was paid to trimming to 3 mm below the finishing line. Following trimming, a hole, 0.8 mm in diameter, was drilled 1 mm below the finishing line. A copper wire of 0.8 mm in diameter and 190 mm in length, on average, was placed into the hole drilled in the duplicate dies and was glued in place with cyanoacrylate glue (Power Glu, Magpow, Hunan Magic Power Industrial Co., Ltd., Liuyang, Changsha, Hunan, China).

The ends of the wires were protruded by about 1 mm so as to provide electrical contact between the copper wires and the crown portions of the duplicate dies. Then, the die models were covered with silver lacquer (Gramm Technik GmbH, Ditzingen-Heimerdingen, Stuttgart, Germany) using a brush to carry out the electroforming on the die models; the exposed surfaces of the copper wire were also covered with silver lacquer. We waited 2 hours for the silver lacquer

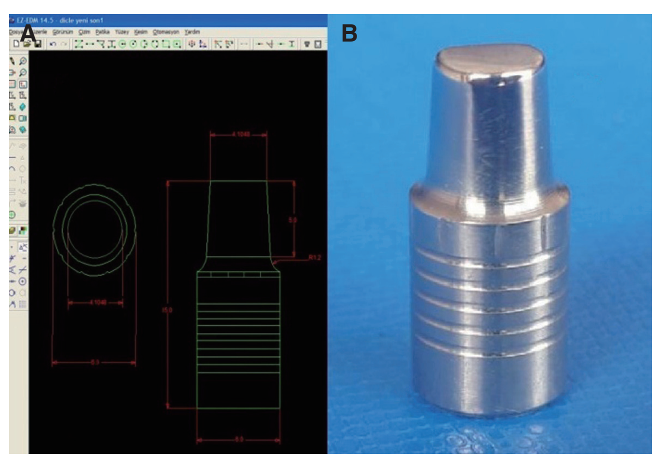

Fig. 1. (A) Drawing of stainless steel die models with computer program, (B) the obtained stainless steel die model.

Table 1. Starbond cos powder (Scheftner GmbH, Germany) alloy composition values

Co	Cr	W	Mo	Si	Other elements: <1%
59%	25%	9.5%	3.5%	1%	C, Fe, Mn, N

to dry. Then, dies were placed in the loading head of device for electroforming and care was taken not to put them closer than 1 cm from each other. The amounts of solution and activator to be used were calculated according to the technical criteria of GAMMAT (Gramm Technik GmbH). Electrolyte solution (ECOLYT SG 100, Gramm Technik GmbH) and activator (Activator SG 100, Gramm Technik GmbH) in amounts to prepare a coping thickness estimated to be 0.2 mm for each die were added to the solution reservoir of the electroforming device. Then, electroforming was performed after the loading head including the dies was placed into the solution. Electroforming was completed after 6 hours of treatment and substructures were removed from the device and cleaned (Fig. 2).

Ten stainless steel die models were prepared by a modeling process after being scanned with a D700 Scanner (3Shape, Copenhagen, Denmark), maintaining the diameter of the model at 1:1 proportion.

By sprinkling powder in the ReaLizer SLM 100 (ReaLizer GmbH, Borchen, Germany) device and melting the powder by means of laser beams for the first layer, the model was formed step by step (Fig. 3).

Measurements were performed at 10 reference points on the stainless steel die model. Before measurements, bonding with single path temporary cement was performed to prevent possible movement of copings during the measurements. While doing this, we paid attention to using minimal amounts of cement so as not to overflow onto finishing lines. Images of marginal compatibility on the finishing lines of the model were gathered with a stereomicroscope (Leica DMLM). Marginal gap measurements in the images were obtained using the ImageJ software (Fig. 4).

Fig. 2. (A) Adjustment of the device for Electroforming process, (B) Placement of dies into the loading head of device and (C) Galvano copings obtained after electroforming.

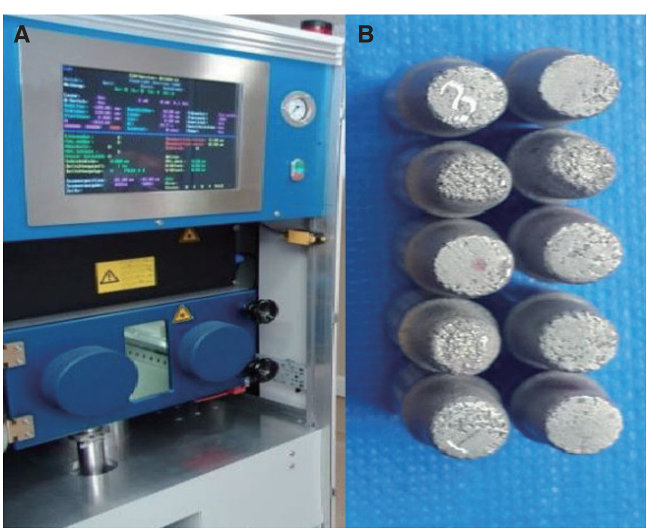

Fig. 3. (A) The devicefor laser sintered copings and (B) The obtained laser sintered Co-Cr copings.

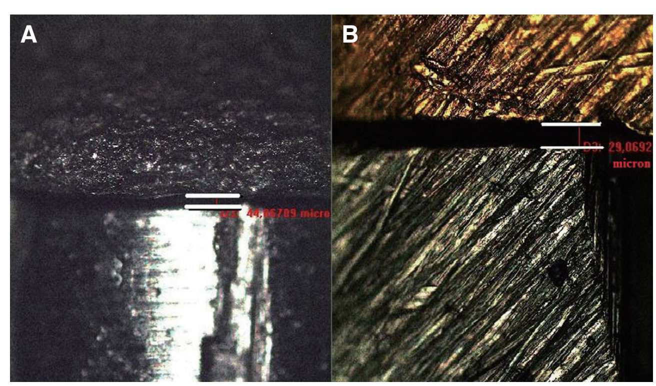

Fig. 4. Measurement of marginal gap amounts of (A) Co-Cr and (B) Galvano copings on the preobtained stereomicroscope image with image analysis program.

Measurements were made of the vertical gap from right and left of the notch on the stainless steel die models to the coping limits. After conducting measurements and before the permanent cementation, the copings were bonded under 100 N pressure with glass ionomer cement (Meron, Voco GmbH, Cuxhaven, Germany) for 5 minutes. The cementation process for the copings was performed by placing them in a dynamic force application device (Algol Instrument Co., Hsin-Chuang, Taipei, Taiwan). Marginal gaps were remeasured after the cementation process.

For the qualitative characterization, all specimens were subjected to scanning electron microscopy (QUANTA 400F Field Emission, FEI Company, Hillsboro, OR, USA) after cementation. The surfaces were examined at a magnification of 7X–5000X at 20 keV. Surface properties of all specimens after cementation, was characterized.

The IBM SPSS software (ver. 15.0 for Windows) was used for statistical evaluations (SPSS Inc., Chicago, IL, USA). A dependent *t*-test was used to compare the mean of the two groups for normally distributed data, and two-way variance analysis was used for more than two data sets. Pearson's correlation analysis was also performed to assess relationships between variables. Hypotheses were bidirectional and P values that are lesser than ≤.05 were considered statistically significant.

RESULTS

The mean Co-Cr coping measurement values obtained with the laser sintering method and galvano copings before and after the cementation process are presented in Table 2.

Galvano copings had the lowest gap measurement values before cementation (24.47 ± 5.82 µm). A highly significant difference ($P<.001$) was found in marginal gap measurements of galvano copings before and after cementation. A significant difference ($P<.05$) was found in marginal gap measurements of the laser-sintered Co-Cr copings before and after cementation. The marginal gap measurement values of the galvano copings and laser-sintered Co-Cr copings differed significantly ($P<.001$).

We examined the surface properties of the galvano copings by SEM. Smooth images were obtained (Fig. 5A).

In contrast, when we examined the surface properties of the laser-sintered Co-Cr copings with SEM, a comparatively rougher surface was observed (Fig. 5B).

DISCUSSION

Materials used in prosthetic restorations are typically metal alloys produced in the dental laboratory and are used in crown-bridge restorations, and in making removable partial and complete prostheses with acrylic resin polymers and ceramics.[22] Ni-Cr-based non-precious metal alloys have been used widely in dentistry due to their relatively low cost and high mechanical resistance. However, nickel, used in Ni-Cr alloys, can have allergic effects and beryllium, used in some alloys, can be a carcinogen under some circumstances. Research has shown that nickel used in dental alloys can cause allergies in patients and beryllium has toxic effects on

Table 2. Average marginal gap values of two substructure material before and after cementation

	Mean ± SD	Result
Galvano before cementation	24.47 ± 5.82 µm	$P<.001$***
Galvano after cementation	35.11 ± 6.52 µm	
Laser before cementation	60.45 ± 8.87 µm	$P<.05$*
Laser after cementation	69.33 ± 9.03 µm	

***indicateshighly significant differences ($P<.001$).
*indicates significant differences ($P<.05$).

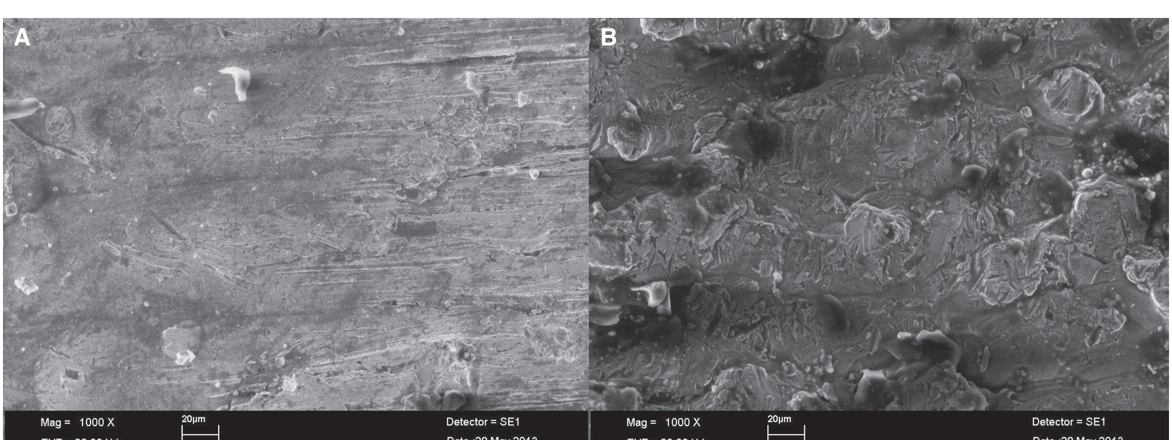

Fig. 5. ×1000 images of (A) Galvano coping surface and (B) Laser sintered Co-Cr coping surface.

dental technicians when exposed orally and through dermal contact. For this reason, the continued and frequent use of Ni-containing alloys in the substructure of prosthetic restorations has been questioned.[7,9,23]

Because of the potential for allergic and toxic effects associated with nickel alloys, the dentist needs alternatives for patients.[24] Cobalt alloys and gold alloys are used as alternatives.[6,14,25] In this study, laser-sintered Co-Cr copings and galvano copings were assessed as alternatives to the 'traditional' methods.

Gold copings, obtained by electroforming, have some significant advantages compared with metal-ceramic restorations, such as being more biocompatible, having more compatible marginal limits, and requiring less preparation of the teeth.[3,26] Weisthaupt *et al*. examined the effects of galvano-ceramic and metal-ceramic restorations on periodontal tissues and as a result of clinical and periodontal examinations after 24 months, they reported that galvano-ceramic restorations were more compatible with periodontal tissues and elicited a less-intense inflammatory response.[16] In a study by Sönmez, when comparing the marginal gaps of copings obtained by conventional casting methods and copings obtained by an electroplating system, one of the stainless steel die models having a chamfer preparation with gold copings was reported to form much smaller marginal gaps (23.1 ± 3.70 µm) than Ni-Cr copings (65.2 ± 12.30 µm).[27] In the study by Buso *et al*. of the marginal adaptation of copings with chamfer and rounded-shoulder preparation before and after ceramics, there was no statistically significant difference between the two groups. Marginal gap values of copings with a chamfer preparation (22.582/29.774 µm) and copings with a rounded-shoulder preparation (23.020/26.779 µm) were reported to increase after the porcelain application process.[17] In our study, the marginal gap values of galvano copings with a chamfer preparation before cementation were consistent these values.

In many studies laser sintered Co-Cr substructures achieved the best marginal fit. For example, Oyagüe *et al*.[28] reported that laser sintered Co-Cr substructures showed better marginal fit than vacuum cast Co-Cr and vacuum cast Pd-Au. And in the study by Örtop *et al*.,[29] comparing marginal and internal adaptation of Co-Cr substructures produced with four different techniques having a chamfer preparation, the 'best' adaptation was reported to be in substructures obtained with a laser-sintered method, of 84 µm, in measurements made with sectioning after cementation. In our study, the marginal gap values of laser-sintered Co-Cr copings with a chamfer preparation were lower than these previously reported values.

Various values of marginal gaps are deemed clinically acceptable. Some researchers consider a marginal fit between 50 and 100 µm to be valid.[30-32] In our study, the marginal gaps of the galvano and laser-sintered Co-Cr copings with a chamfer preparation were below the clinically accepted 100 µm.

Many factors can affect marginal fit. These include preparation shape and size, finishing line forms, the viscosity of the cement used, moisture and temperature in ambient conditions, physicochemical interactions, the design of the copings and the type of crown.[33,34] Buso *et al*.[35] considered that several factors were responsible for the change in the marginal gaps, such as applied laboratory steps, marginal termination method, the measuring materials and methods used, the applied cement type, and the pressure applied during cementation.

According to the SEM images of the experimental groups are outlined in Fig. 5, the laser sintered Co-Cr copings showed rougher surface structure than galvano copings. Similarly, in the study by Oyagüe *et al*.,[28] SEM images of laser sintered Co-Cr substructures exhibited a characteristic rippled surface with undulated margins.

Studies conducted to evaluate marginal gaps have not used a standard number of measurement points. However, several researchers have carried out measurements on reference points determined at regular intervals around the models.[29,36,37] Thus, in our study, we performed measurements at 10 predetermined reference points on stainless steel die models. Crown cementation has not been standardized in marginal fit measurement studies; however, measurements have been carried out before and after cementation of crowns.[38-41] In our study, in total, 20 measurements were performed: 10 on each model before and after cementation, based on the reference points marked on the models.

The obtained results could prove useful for clinicians in the field of prosthodontics. Further laboratory experiments must be performed to test the change of marginal gap value after porcelain build up and the behaviour of conventional and dual-cure resin cements under thermocycling and loading conditions.

CONCLUSION

The smallest marginal gaps occurred with use of galvano copings. In addition to this result, marginal gaps values of both groups before and after cementation were within the clinically acceptable level. Also, when we examined the surface properties of Co-Cr copings obtained with a laser sintering method using SEM, a considerably rougher structure was observed. The galvano copings were determined by SEM to have a very smooth surface.

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REFERENCES

1. Shillingburg HT, Hobo S, Whitsett LD, Brackett SE. Fundamentals of fixed prosthodontics. 3rd ed. Chicago: Quintessence Pub. Co.; 1997. p. 290.
2. Jacobs MS, Windeler AS. An investigation of dental luting cement solubility as a function of the marginal gap. J Prosthet Dent 1991;65:436-42.
3. Yang JH, Song TJ, Han JS, Lee JB, Lee SH. Marginal fit of the aurogalvano crown system made using the electroforming technique. J Korean Acad Prosthodont 2004;42:679-84.
4. Rudolf R, Anzel I, Dragoslav S. Dental materials - Challenge and usage of the latest inventions. Metalurgija - J Metal 2008; 14:135-42.
5. Comlekoglu ME, Dundar M, Gungor MA, Aladag A, Artunc C. Dişhekimliğinde Alerji: Döküm Alaşımları, Polimerler ve Seramikler, [Allergy in Dentistry: Casting Alloys, Polymers and Ceramics]. EÜ Dişhek Fak Derg 2008;29:81-92.
6. Zhang XH, Sun F. Clinical follow-up of ceramic bridges with auro-galvanoforming primary coping and Ni-Cr pontic for restoration of dentition defects. Chin Med J (Engl) 2009;122: 3007-10.
7. Setcos JC, Babaei-Mahani A, Silvio LD, Mjör IA, Wilson NH. The safety of nickel containing dental alloys. Dent Mater 2006;22:1163-8.
8. Wataha JC, Lockwood PE, Messer RL, Lewis JB, Mettenburg DJ. Brushing-induced surface roughness of nickel-, palladium-, and gold-based dental casting alloys. J Prosthet Dent 2008;99:455-60.
9. Wataha JC. Biocompatibility of dental casting alloys: a review. J Prosthet Dent 2000;83:223-34.
10. Rubo JH, Pegoraro LF, Marolato F, Rubo MH. The effect of tin-electroplating on the bond of four dental alloys to resin cement: an in vitro study. J Prosthet Dent 1998;80:27-31.
11. Covington JS, McBride MA, Slagle WF, Disney AL. Quantization of nickel and beryllium leakage from base metal casting alloys. J Prosthet Dent 1985;54:127-36.
12. O'brien WJ. Dental materials and their selection. 3rd ed. Quintessence Pub. Co. Inc.; 2002. p. 309.
13. Naumann M, Ernst J, Reich S, Weißhaupt P, Beuer F. Galvano- vs. metal-ceramic crowns: up to 5-year results of a randomised split-mouth study. Clin Oral Investig 2011;15:657-60.
14. Eroglu Z, Gurbulak AG. Investigation of fracture strength of galvano ceramic, metal ceramic three unit bridges. J Health Sci 2011;20:92-8.
15. Vence BS. Electroforming technology for galvanoceramic restorations. J Prosthet Dent 1997;77:444-9.
16. Weishaupt P, Bernimoulin JP, Lange KP, Rothe S, Naumann M, Hägewald S. Clinical and inflammatory effects of galvano-ceramic and metal-ceramic crowns on periodontal tissues. J Oral Rehabil 2007;34:941-7.
17. Buso L, Hilgert E, Neisser MP, Bottino MA. Marginal fit of electroformed copings before and after the coction of the porcelain. Braz J Oral Sci 2004;3:409-13.
18. Stewart RM. Electroforming as an alternative to full ceramic restorations and cast substructures. Trends Tech Contemp Dent Lab 1994;11:42-7.
19. Vrijhoef MM, Spanauf HJ, Renggli HH, Wismann H, Somers GA. Electroforming as an alternative to casting: a preliminary report. Restorative Dent 1985;1:143, 145-6.
20. Rogers OW. The electroformed gold matrix inlay technique. Aust Dent J 1970;15:316-23.
21. Rogers OW. The dental application of electroformed pure gold. III. An investigation into an alternative ceramic bonding system for base metal alloys. Aust Dent J 1980;25:205-8.
22. Hauk V. Structural and residual stress analysis by nondestructive methods: Evaluation-Application-Assessment. Elsevier; 1997. p. 53-72.
23. Moneret-Vautrin DA, Burnel D, Sainte-Laudy J, Beaudouin E, Croizier A. Allergy to nickel in dental alloys. Eur Ann Allergy Clin Immunol 2004;36:311-2.
24. Senkutvan RS, Jacob S, Charles A, Vadgaonkar V, Jatol-Tekade S, Gangurde P. Evaluation of nickel ion release from various orthodontic arch wires: An in vitro study. J Int Soc Prev Community Dent 2014;4:12-6.
25. Wataha JC, Messer RL. Casting alloys. Dent Clin North Am 2004;48:499-512.
26. Kokubo Y, Tsumita M, Ohkubo C, Sakurai S, Fukushima S. Clinical evaluation of porcelain fused to electroformed gold copings: Preliminary results after 30-43 months. Prosthodont Res Pract 2007;6:50-6.
27. Sönmez A. Galvano Kronlarda Marjinal Adaptasyonun ve Porselen Bağlantısının İn-vitro İncelenmesi ve Ni-Cr Alaşımlarla Karşılaştırılması, [In-vitro evaluation of marginal adaptation and porcelain bonding of galvano crowns and comparison with Ni-Cr alloys]. Başkent Üniversitesi Sağlık Bilimleri Enstitüsü PhD Thesis 2008; p. 15-22.
28. Oyagüe RC, Sánchez-Turrión A, López-Lozano JF, Suárez-García MJ. Vertical discrepancy and microleakage of laser-sintered and vacuum-cast implant-supported structures luted with different cement types. J Dent 2012;40:123-30.
29. Örtorp A, Jönsson D, Mouhsen A, Vult von Steyern P. The fit of cobalt-chromium three-unit fixed dental prostheses fabricated with four different techniques: a comparative in vitro study. Dent Mater 2011;27:356-63.
30. Andersson M, Carlsson L, Persson M, Bergman B. Accuracy of machine milling and spark erosion with a CAD/CAM system. J Prosthet Dent 1996;76:187-93.
31. Bindl A, Mörmann WH. Fit of all-ceramic posterior fixed partial denture frameworks in vitro. Int J Periodontics Restorative Dent 2007;27:567-75.
32. Att W, Komine F, Gerds T, Strub JR. Marginal adaptation of three different zirconium dioxide three-unit fixed dental prostheses. J Prosthet Dent 2009;101:239-47.
33. Albert FE. Marginal Adaptation and Microleakace of Procem Allceram Copings- an in vitro study. University of Toronto PhD Thesis 2001. p. 20-2.
34. Wu JC, Lai LC, Sheets CG, Earthman J, Newcomb R. A comparison of the marginal adaptation of cathode-arc vapor-deposited titanium and cast base metal copings. J Prosthet Dent 2011;105:403-9.
35. Buso L, Neisser MP, Bottino MA. Evaluation of the marginal fit of electroformed copings in function of the cervical prep-

aration. Cienc Odontol Bras 2004;7:14-20.
36. Polansky R, Heschl A, Arnetzl G, Haas M, Wegscheider W. Comparision of the marginal fit of different all-ceramic and metal-ceramic crown system: an in vitro study. J Stomat Occl Med 2010;3:106-10.
37. Yeo IS, Yang JH, Lee JB. In vitro marginal fit of three all-ceramic crown systems. J Prosthet Dent 2003;90:459-64.
38. Gonzalo E, Suárez MJ, Serrano B, Lozano JF. A comparison of the marginal vertical discrepancies of zirconium and metal ceramic posterior fixed dental prostheses before and after cementation. J Prosthet Dent 2009;102:378-84.
39. Cho L, Choi J, Yi YJ, Park CJ. Effect of finish line variants on marginal accuracy and fracture strength of ceramic optimized polymer/fiber-reinforced composite crowns. J Prosthet Dent 2004;91:554-60.
40. Quintas AF, Oliveira F, Bottino MA. Vertical marginal discrepancy of ceramic copings with different ceramic materials, finish lines, and luting agents: an in vitro evaluation. J Prosthet Dent 2004;92:250-7.
41. Ehrenberg D, Weiner GI, Weiner S. Long-term effects of storage and thermal cycling on the marginal adaptation of provisional resin crowns: a pilot study. J Prosthet Dent 2006;95:230-6.