Original Article

Scanning electron microscope evaluation of marginal discrepancy of gold and base metal implant-supported prostheses with three fabrication methods

Hakimeh Siadat, Ali Mirfazaelian, Marzieh Alikhasi
Department of Prosthodontics, Implant and Dental Research, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran

For correspondence
Dr. Marzieh Alikhasi, Department of Prosthodontics and Dental Research Center, School of Dentistry, Tehran University of Medical Sciences, Ghods St, Enghelab St. Tehran, Iran. E-mail: m_alikhasi@yahoo.com

BACKGROUND: Marginal discrepancies in implant-supported prosthesis are inevitable, despite careful waxing, investing, and casting procedures. The choice of metal also affects these discrepancies. **MATERIALS AND METHODS:** A total of 48 frameworks were fabricated: 16 made with the Burn-out Coping (group 1), 16 made with Impression Coping (group 2) and 16 with conventional wax-up technique (group 3). Each group was divided into two subgroups, based on the metal alloy used. Eight of the specimens in each group were fabricated with noble alloy (Begostar, Bego, Bremen, Germany) (groups 1n, 2n and 3n) and the other eight with base metal alloy (Verabond 2, Albadent, Cordelia, California) (groups 1b, 2b, and 3b). All specimens were waxed on the analogue abutments and cast. After fixing and embedding, the specimens were sectioned and prepared for scanning electron microscope (SEM) evaluation. Frameworks were analyzed for vertical and horizontal discrepancies with ×200 magnifications. Data were analyzed statistically by multivariate analysis and post hoc tests (α=0.05). **RESULTS:** The vertical discrepancy measurements for noble groups (1n, 2n and 3n) were significantly less than those of the base metal alloy groups (1b, 2b and 3b) (P<.001), whereas horizontal discrepancies were significantly greater in noble groups (P<.001). Although the differences in interfacial gaps were not statistically significant in all the three fabrication techniques (P>.05), waxing the frameworks with impression copings significantly increased the horizontal discrepancy at the interfaces (groups 2n and 2b) (P<.001). **CONCLUSIONS:** Vertical discrepancies of the frameworks made with proposed techniques were comparable with each other. Noble alloy frameworks produced more horizontal and less vertical discrepancies..

Key words: Horizontal discrepancy, implant, vertical discrepancy

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INTRODUCTION

A precise fit between the implant and the framework is necessary to ensure a satisfactory long term clinical outcome. Although dental implants are clinically well-accepted, they are not without mechanical and technical complications.[1] A perplexing problem is to fit the prosthesis to the supporting components.[2] Authors cite concerns about the fit of the dental prosthesis, describing a high likelihood for misfit of implant components.[3-8]

Nickel-Chromium (Ni-Cr) alloy has been a popular alloy for metal ceramic restorations. This popularity has been achieved because of its useful properties and low cost.[9] However, technical difficulties, such as the procedure of grinding and polishing with conventional chair side and laboratory instruments, restricted the use of base metal alloys in dental practice. More recently, an improvement in alloy composition and the development of new manufacturing techniques have optimized the use of these alloys.[10]

Several authors have pointed out the advantages of Ni-Cr alloys for metal-ceramic restorations, in comparison with gold alloys.[9,11] The higher mechanical strength of the Ni-Cr alloys is considered by some clinicians to result in superior restorations.[11] The low density and high modulus of elasticity of these alloys enable the fabrication of restorations with greater rigidity per-unit-thickness.[12] This greater rigidity and lower density could be valuable in implant supported prostheses, which are usually lengthy and bulky. There are several studies on the marginal fit of artificial crowns and fixed partial dentures (FPDs) made from base metal alloy-porcelain.[9,11,13,14] However, there have been fewer reports that have demonstrated the marginal discrepancies of implant supported frameworks made of base metal alloys and the resulting behavior of these prostheses in oral environment.

Abutments are usually supplied with prefabricated burn-out copings that snap onto the abutment analogues. These copings are manufactured to provide a defined cement gap between the crowns and the abutments, thereby eliminating the need for die spacer. This built-in cement space measures approximately 20μm, which is consistent with ADA specification # 96 for ideal cement thickness.[15] The presence of this uniform cement space also decreases the need for casting adjustments. Branemark suggests that components should have no more than 10μm misfit.[16] However, many manufactured components do not practically provide these levels of accuracy and it is unlikely that these levels of accuracy are consistently achieved.[17,18] Consequently, misfit of prostheses is a clinical reality, but the amount of misfit that can be tolerated without adverse mechanical[3] or biological[4,19] complications is yet to be determined. Takahashi found a mean value of 46.8μ marginal discrepancy in gold frameworks.[7]

On the other hand, technicians may not be used to prefabricated components which require additional cost. Also, recasting the framework requires additional components and thus additional cost. Therefore, technicians often use the conventional method for waxing. The conventional method is characterized by simplicity and low cost. Considering financial burden, some technicians also utilize used impression copings taken out of the impressions.

The purpose of this study was to compare the marginal discrepancies of metal frameworks cast from gold and Nickel-Chromium alloys. This study also evaluated the gap and overhang of metal copings fabricated using different methods. The marginal fit was measured by means of scanning electron microscope (SEM). The comparison was made between the conventional wax-up and using two prefabricated components.

MATERIALS AND METHODS

Forty-eight solid analogue abutments, 4 mm in height (ITI; Straumann AG, Waldenburg, Switzerland) were used and randomly divided in three groups. A total of 48 copings, 16 made with the burn-out copings (ITI; Straumann AG, Waldenburg, Switzerland) (Group 1), 16 made of reused impression copings (ITI; Straumann AG, Waldenburg, Switzerland) (Group 2) and 16 with conventional wax-up technique (Group 3) were fabricated on the analogues [Table 1].

A burn-out coping was seated on an analogue abutment and waxed to the thickness of 0.7 mm in all areas. This dimension was evaluated using a digital caliper (Mitutoyo America Corp, Aurora, Ill), which was 0.001 mm accurate. This pattern was cast and used as a model. Custom mold was made with polyvinyl siloxane impression material (Rapid; Coltene AG, Altstatten, Switzerland) on this model, to preserve the individual dimensions. This impression was later used as a custom mold for the castings in all the groups [Figure 1].

Table 1: Description of study groups

Group	Method	Number
1	Burn-out coping	8
2	Impression coping	8
3	Wax-up	8
Total		24

In group 1, burn-out copings were seated on the analogue abutments and preheated liquid wax (Pico Sculpting wax, Renfert GmbH, Hilzingen, Germany) was inserted into polyvinyl siloxane matrix, and seated directly on the analogue abutments along the long-axis. After cooling of the wax, excess wax and the matrix were removed. In Group 2, impression copings were seated on the analogue abutments and cut 1 mm coronal to the finish lines and the same waxing procedure was performed. In group 3, only the custom mold was used to perform wax-up and no prefabricated component was used.

Each group was divided into two subgroups consisting of eight specimens, based on the alloy used for casting (n = noble and b = base metal). Plastic components are characterized by the fact that they swell up when they are burned out. For that reason, according to the manufacturer's guideline, a wax layer of at least 0.3 mm was used in the marginal region of plastic component (groups 1, 2). The copings were cast using the conventional lost-wax technique.[20-22] Eight patterns were invested and cast with noble alloy (Begostar, Bego, Bremen, Germany) and eight with base metal alloy (Verabond 2, Albadent, Cordelia, Calif). All the castings were fabricated in the same laboratory. The castings and their corresponding analogue abutments were numbered for the purposes of identification, during the procedures.

The castings were divested and cleaned in an ultrasonic cleaner. The inner surfaces of the copings were inspected for surface irregularities under a stereomicroscope (Meiji Techno, Model BM 38834, Tokyo, Japan) at ×10 magnification and adjusted with a carbide bur (# 169L-009, Brasseler Inc, Savannah, GA) [Figure 2]. After casting, which is available in most implant systems and is provided by a tiny lip on the margin of the copings, was removed with a reamer (ITI; Straumann AG, Waldenburg, Switzerland) before seating the casting on the abutment. This was also done under a stereomicroscope (Meiji Techno, Model BM 38834). Silicone disclosing medium (Fit Checker, GC Corporation, Tokyo, Japan) was used to achieve the best possible fit. A thin uniform film of disclosing medium inside the castings imply in completing adjustments. The castings were seated on the analogues and embedded in self-polymerizing acrylic resin blocks (Repair Material, Dentsply International, Milford, DE.).

Figure 1: Cast frame fabricated as a model for other specimens (Left). Silicone index as a mold for preparing specimens (Right)

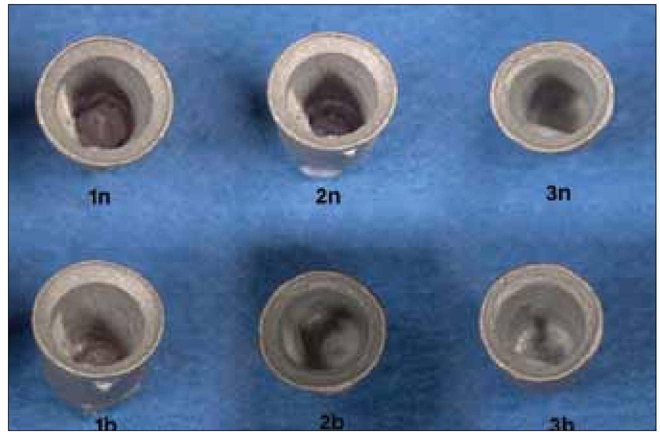

Figure 2: Metal copings fabricated using three different techniques (1: waxing using burn-out, 2: waxing on the impression coping, and 3: conventional waxing) and two types of alloy (n: gold alloy, b: base metal alloy)

Figure 3: Specimen embedded in acrylic resin (Left). Longitudinal section of the specimen (Right)

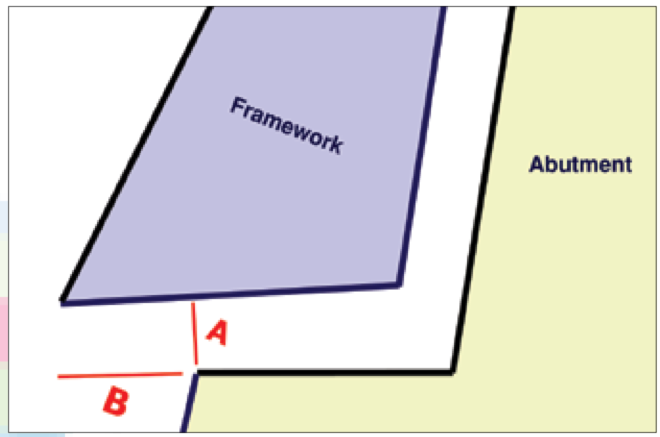

Figure 4: Schematic measurement of vertical (A) and horizontal (B) discrepancy after sectioning resin block longitudinally through the center

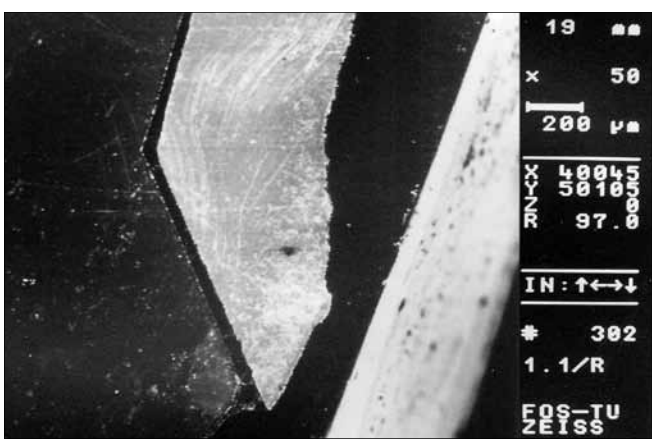

Figure 5: The SEM views of burn-out coping in gold casting group (group 1n)

All specimens were sectioned longitudinally through the center of an acrylic resin block, using a low speed saw (Isomet; Buehler, Lake Bluff, Ill.) [Figure 3]. The section surface of the specimens were polished with a polishing machine (Ecomed 3 Grinder and Polisher; Buehler, Ltd) for 15 seconds and cleaned in distilled water with an ultrasonic cleaner (Whaledent Biosonic; Colte`ne Whaledent Inc, New York, N.Y.) for 10 minutes. The vertical (gap) and horizontal (overhang) discrepancies in the margin areas were measured, as shown in [Figure 4], between the analogue abutments and castings in the SEM views.[23]

For SEM observation, all specimens were mounted on aluminum stubs and sputter coated with Au-Pd and observed using a field emission scanning electron microscope (JSM-6340F, JEOL, Tokyo, Japan). The overall views of the areas coronal and apical to the margins were obtained at ×200 magnification [Figures 5-10]. The measurements were made at two predetermined reference locations at right and left sides of the analogue abutments.

A computer software program (Optimas Version 5.22; Media Cybernetics, Silver Spring, Md) was used to visually aid in quantifying the vertical space and overhang between the analogue abutments and castings

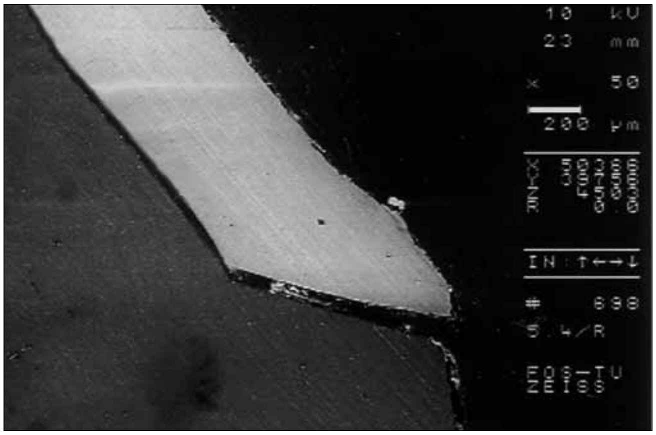

Figure 6: The SEM views of burn-out coping in base metal casting group (group 1b)

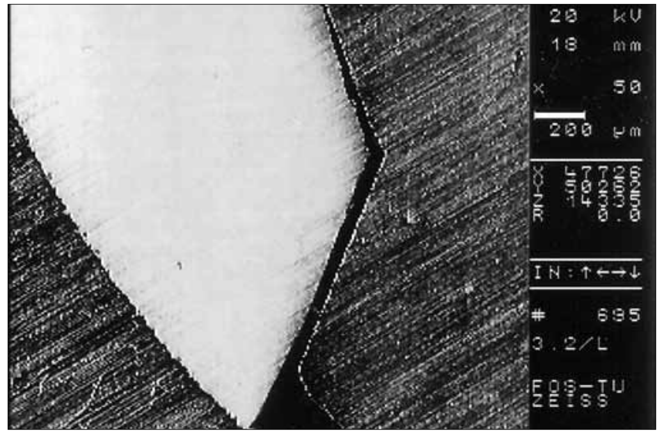

Figure 7: The SEM views of impression coping in gold casting group (group 2n)

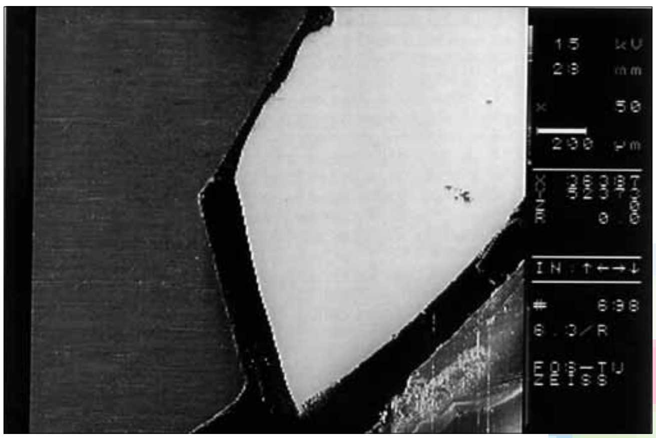

Figure 8: The SEM views of impression coping in base metal casting group (group 2b)

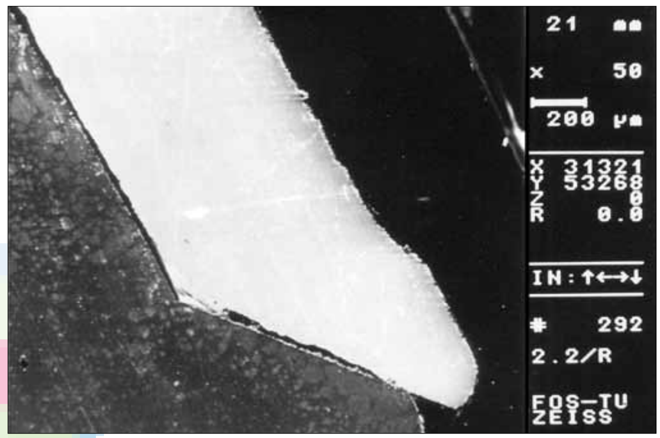

Figure 9: The SEM views of conventional wax-up in gold casting group (group 3n)

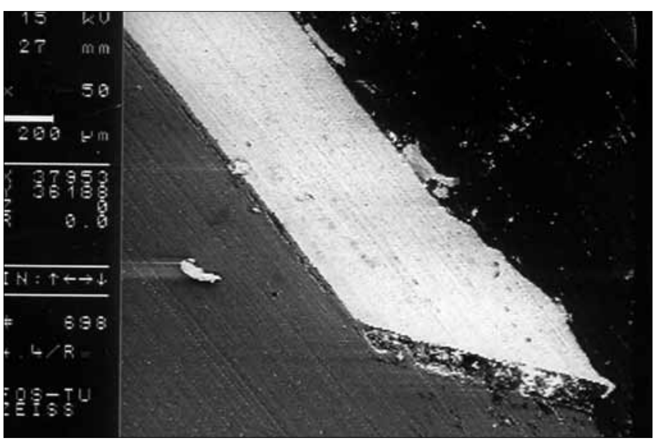

Figure 10: The SEM views of conventional wax-up in base metal casting group (group 3b)

at the mating surfaces. The software program allowed calibration of measurements based on the amount of magnification being used. Once the magnification values were entered, the program calculated the value of the distance traversed by the cursor. All the measurements were made by the same investigator. The values were entered into a spreadsheet for statistical analysis. The values were analyzed using a multivariate test. A *post hoc* (Bonferroni) test was used to evaluate the overhang in the groups. A significance level of α=.05 was used for all comparisons. All statistical analyses were performed at %95 confidence level.

RESULTS

Statistical analysis was performed using the SPSS program (SPSS Inc., Chicago, IL,). In an attempt to summarize the gap and overhang values across the two reference points, the average of these measurements was used. The mean values and standard deviations (SD) for each technique are presented in Tables 2 and 3. The multivariate test was used to compare vertical discrepancies between the casting groups. Although the multivariate test showed that there was no significant difference between the gap values in the three groups (P = .092), the subgroups had significant differences (P<.001).

The multivariate and *post hoc* tests (Bonferroni) were

Table 2: Mean ± SD of analogue abutment/gold frame marginal discrepancies (μm)

	Specimen groups		
	Burn-out coping (group 1) (Mean ± SD)	Impression coping (group 2) (Mean ± SD)	Direct wax-up (group 3) (Mean ± SD)
Gap left	57.55 ± 16.37	65.98 ± 17.92	49.28 ± 18.05
Gap right	49.94 ± 8.83	61.24 ± 15.74	51.06 ± 17.18
Total gap	53.74 ± 11.0	63.6 ± 13.2	50.1 ± 17.3
Overhang left	132.62 ± 25.59	308.33 ± 60.49	139.20 ± 37.72
Overhang right	115.69 ± 15.38	252.77 ± 74.83	136.87 ± 33.61
Total overhang	124.1 ± 10.2	280.5 ± 47.5	138.0 ± 31.4

Table 3: Mean ± SD of analogue abutment/base metal frame marginal discrepancies (μm)

	Specimen groups		
	Burn-out coping (group 1) (Mean ± SD)	Impression coping (group 2) (Mean ± SD)	Direct wax-up (group 3) (Mean ± SD)
Gap left	134.55 ± 28.98	153.95 ± 30.76	130.25 ± 36.77
Gap right	177.74 ± 58.22	121.69 ± 29.09	129.16 ± 55.37
Total gap	154.1 ± 33.8	137.8 ± 11.4	129.7 ± 42.8
Overhang left	85.81 ± 20.23	220.83 ± 37.76	106.67 ± 29.21
Overhang right	94.30 ± 10.41	193.05 ± 40.69	79.46 ± 28.67
Total Overhang	90.0 ± 12.5	206.9 ± 27.33	93.0 ± 25.4

used to compare horizontal discrepancies between the casting groups. The horizontal discrepancy significantly increased ($P<0.001$) in the impression coping group (Groups 2n and 2b). Comparison of overhang between burn-out coping (groups 3n and 3b) and wax-up groups (1n and 1b) did not present significant differences ($p>0.05$).

DISCUSSION

The terminology used to describe the marginal fit of dental restorations is not uniform throughout literature. This study measured the vertical marginal discrepancy, which was described by Holmes *et al.*, as the "vertical marginal misfit measured parallel to the path of draw of the casting".[23] Since absolute marginal discrepancy is the result of many combinations between horizontal and vertical discrepancies in 3D (three dimensional space), horizontal discrepancy was also measured in this study. Other investigators have also used this terminology to report marginal misfit easily and accurately.[2,8]

In Keith's study, cast gold copings exhibited a marginal discrepancy of 32.1± 32.5 μm. In this study, discrepancy was calculated by subtracting the height of shoulder bevel from the quantities measured using two predetermined reference points. In the Keith's study, horizontal and vertical discrepancies were not measured separately and it seemed that overall discrepancy was considered.[8]

In this *in vitro* study, the influence of cement thickness on the marginal discrepancy was not investigated. The experiment was designed such that only the imperfections (i.e., gap and overhang) caused by casting have been evaluated. Therefore, other possible sources of imperfections or errors such as those caused by impression technique, dimensional accuracy of impression materials and fabricating the master cast have not played any role in these controlled experiments. One could assume greater magnitudes of distortion if impressioning and veneer application had been introduced into fabrication.

Metzler and Chandler found that the best marginal closure was obtained on gold castings *in vivo* by slightly over waxing the margin and then finishing those accessible margins intraorally.[5] In this study, the averages of the gaps in the three techniques, burn-out coping, impression coping and conventional wax-up, were 53.7, 63.6 and 50.1 μm in gold alloy specimens and 154.1, 137.8 and 129.7 μm in nickel chrome alloy specimens, respectively. It seems that conventional wax-up results performed by technicians are usually more bulky, as compared to the results when using prefabricated components. In this study, although slightly better marginal closure was found in conventional wax-up group, as compared to two other groups, confirming Metzler's study,[5] it was not significantly different. This former observation was in agreement with Jemt's study.[6]

Although plastic components are fairly durable materials, they can be readily abraded by imprudent use and repeating removal. Dental technicians should be careful when handling plastic components during the fabrication of crowns so that they do not increase clinical marginal discrepancy. This could be a possible explanation of increased discrepancies in group 2.

Jemt and Lie evaluated precise fit between the abutment and the framework under stereomicroscope.[6] They have reported that the gap distance between the gold alloy casting framework and the implant abutment was 42 to 74 µm.[6] Takahashi and Gunne reported that mean of gap value between frameworks fabricated by cast gold-alloy and implant abutments was 46.8 µm (SD=8.8).[7] This mean value was lower than that reported by Jemt and Lie.[6] In Takahashi's study, marginal discrepancy was measured using a thin film of light-body material between the framework and implant abutment.[7] Although using disclosing medium is a traditional method of evaluating framework fit, it is not an accurate method for measuring marginal discrepancy.

The results of this study showed that gold alloy frameworks had significantly less vertical discrepancy than nickel chrome alloy specimens (*P*<.001), comparable with Boeckler's study, which measured the gap values of tooth supported crowns under light microscope with a magnification level of 560. He calculated the average marginal gap of base metal and gold alloy specimens, 72.6±18.6 and 35.3±10.7, respectively, with statistically significant differences.[14]

This study showed greater horizontal discrepancies in gold alloy castings (*P*<.001). One possible reason was that lower density of base metal resulted in less perfect castings. Greater overhang was found in group 2 (2n and 2b) and this value was significantly higher than the other groups (*P*<.001).

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