The Effect of Pattern Materials on the Marginal Gap of Metal Copings Fabricated On Titanium Implant Abutments

Amir Ali Reza Khaledi[1], Mitra Farzin[1], Amir Hassain Fathi[1], Soheil Pardis[2]

[1]Faculty of Dentistry, Prosthodontic Department, Shiraz, Shiraz University of Medical Sciences, Shiraj, Iran

[2]Faculty of Dentistry, Oral and Maxillofacial Pathology Department, Shiraz University of Medical Sciences, Shiraj, Iran

Abstract

Aims: This study was aimed to compare the effect of three different pattern materials on the vertical marginal discrepancy of Nickel-Chromium copings fabricated on titanium implant abutments. Methods: A titanium implant abutment was used to receive 30 Nickel-Chromium copings. The copings were constructed using pattern wax (group 1), acrylic pattern resin (group 2), and light-cured pattern resin (group 3). The marginal gap of the Nickel-Chromium copings was measured at 4 points on the abutment-implant assembly by using a digital microscope. One-way ANOVA and post hoc tests were adopted for statistical analysis (α=0.05). Results: The mean marginal gap values of Nickel-Chromium copings fabricated from pattern wax, acrylic pattern resin, and light-cured pattern resin were 34.00, 31.78 and 25.87 μm, respectively. There was a statistically significant difference between groups 1 and 3 (p=0.02), whilst the difference between groups 2 and 3 and between groups 1 and 2 was not statistically significant (p>0.05). Conclusions: The marginal gaps of the copings, fabricated from tested pattern materials, were within the clinically acceptable range. Nevertheless, light-cure pattern resin had a better vertical marginal fit than acrylic pattern resin and pattern wax.

Key Words: Implant abutment, Marginal gap, Metal coping, Pattern wax, Resin pattern materials

Introduction

A precise fit between the abutment and the framework is indispensible to provide a satisfactory long-term clinical outcome. Although dental implants are clinically well-accepted, they may still manifest some mechanical and technical complications [1]. For instance, fitting the prosthesis to the supporting components is a bewildering problem [1,2] and many researchers concerned the fit of the dental prosthesis, reporting the high likelihood of misfit in dental implant components [3-8].

Marginal fit has been recognized as a reason in failure of cast restorations [2]. The association between the ill-fitting margins and bacterial irritation should also be concerned as an impending clinical problem with implant-supported restorations. Oral micro-organisms penetrate through the gaps present in implant-supported supra-structures and this microbial leakage becomes a definite jeopardy to induce peri-implantitits [9,10]. Beyond these biologic disputes, it has been reported that prosthesis misfit would lead to occlusal imprecision, screw fracture, screw loosening and increasing the possibility of abutment and/or implant fracture [2,7,11]. In fact, marginal misfit transmits high stresses to the alveolar bone and dental implant components [9,12,13].

The use of base metal alloys for the construction of ceramometal restorations became popular, especially in developing countries, after the cost of gold alloys increased considerably in the 1970s [14]. The disadvantages of base metal alloys include higher melting temperatures and difficult handling and finishing in comparison to noble alloys. But these nonprecious metals are superior to gold-based metals in several respects, including low density, hardness, elasticity modulus, and tensile strength. The use of base metal alloys have made possible high-quality treatment for a large number of patients with limited financial means. Currently, the most used base metal alloys for metal-ceramic restorations are nickel-chromium (Ni-Cr) materials [14-16].

Dental casting patterns are conventionally made from inlay casting wax. The acquaintance and simplicity of manipulation with decent replication of details and their reasonable price are some of the main advantages of these materials, although waxes have high coefficient of thermal expansion and a distortion propensity on standing that can be considered as their main disadvantages [17,18]. The distortion of wax depends on time and temperature values; hence, wax patterns should preferably be invested just right after their detachment from the preparation [17-20].

To compensate the adverse characteristics of waxes, alternative materials have been investigated including the chemically cured resins and lately, the light-cured pattern resin materials. The chemically accelerated plastics can be manipulated easily and show acceptable dimensional stability, while patterns fabricated from auto-polymerizing acrylic resins exhibit substantial shrinkage within a day (24 hours) after being made [21-24]. Skillful manipulation and understanding of dimensional changes of wax and acrylic resin may yield an acceptable pattern, whilst sustained storage time before investment would cause distortions that influence the marginal integrity [18-20,22].

The light-curing materials show better characteristics such as they produce lesser heats in their polymerization, and they exhibit virtuous dimensional stability, higher strength, greater resistance to flow and burn out with absence of residue [23,24]. The light-cured materials depend on an ample light intensity to start their polymerization. This light intensity is substantial at the material surface, but is reduced by absorption and scatter at deeper levels, restricting the depths of cure that can be yielded. A thorough polymerization is imperative for light-cure pattern materials because the presence of unpolymerized or partially-polymerized particles would cause plastic deformation of the pattern when handled, and in turn, would cause impaired fit of the succeeding casting [18,23,24].

Although pattern materials are widely used to fabricate indirect dental restorations, they are subject to distortion that

Corresponding author: Dr. Fathi, Shiraz Dental School, Prosthodontic Department,Shiraz University of Medical Sciences, Shiraz, Iran, Tel: +98 71 3230 5410; E-mail: amiralireza_khaledi@yahoo.com

influence the marginal integrity of these restorations. To the best of authors' knowledge, up to the time of this study, there is no published article to evaluate the accuracy of different pattern materials when used on titanium abutments of dental implants during most real laboratory situations. Therefore, we conducted this study to appraise the marginal fit of Nickel-Chromium copings fabricated from a pattern wax, a pattern acrylic resin material and a light-cured pattern resin on prefabricated titanium abutments of dental implant fixtures.

Methods

One Intra-Lock 5.5 mm solid abutment with anti rotation feature (Intra-Lock International Inc; Boca Raton, FL, USA) was screwed onto an Intra-Lock implant analogue (4×12mm) using a torque of 20 Ncm. To quantify the vertical marginal gap, four points (0o, 90o, 180o, and 270o) [8] were marked on a groove that was prepared 3mm beneath the margin of abutment by using a high-speed hand piece and a diamond bur. Lastly, the abutment-implant assembly was embedded in an acrylic block and a dental surveyor (Ney Dental Surveyor; Dentsply, Ballaigues, Switzerland) was employed to adjust its long axis perpendicular to the horizontal plane. To purge the effect of dissimilarities in impression and stone pouring methods, this assembly was considered as the master die. Based on previous studies a total of 30 Nickel-Chromium (Ni-Cr) Cement-retained copings (4 All; Ivoclar-Vivadent, Germany), 10 made from pattern wax (group 1), 10 made of acrylic pattern resin (group 2), and 10 made from light-cured pattern resin (group 3) were fabricated on the master die.

To standardize the contour and thickness of all copings recruited in 3 groups; a master wax-up with thickness of 1.5 mm was made on another similar abutment-implant model. To lodge the tip of the holding apparatus, a depression was made in the occlusal surface of the wax-up. After casting this wax-up, the resultant coping was cemented on the die and then a silicone index was prepared and cut into two sections. During pattern fabrication, the contour of all patterns in all three groups were constantly maintained and standardized by using this silicon index.

For fabricating patterns from Inlay type B pattern wax (GC Corporation; Japan), an electrically-controlled wax bath was used to melt the wax. The molten wax was applied on the master die and then allowed to cool in room temperature; the margins were redefined.

In group 2, the auto polymerized resin pattern material (GC Corporation; Japan) was distributed in two distinct plastic mixing saucers; one containing the powder (polymer) and one the liquid (monomer). By using brush-on technique, the patterns were then built up incrementally.

In group 3, the low viscosity light-cured pattern resin material (Bredent; America Inc, USA) was incremented and polymerized in the light-curing unit in layers; each layer was cured for 90 seconds.

Finally, the patterns were accurately inspected, using a magnifying lens to confirm proper marginal adaptation. The patterns with any imperfections or deformation were excluded.

Then the copings were cast using the conventional lost-wax method. The Ni-Cr castings were divested and cleaned in an ultrasonic cleaner. The inner surface of the copings were checked for surface irregularities by using magnifying lens and adjusted with a carbide bur. A silicone disclosing medium was used to attain the best potential fit.

All metal copings were individually placed on the master die and fixed on a specific mounting device. A constant vertical load of 10 N [8] was exerted to all specimens to ensure the complete seating of copings on the die.

The relevant images were then taken from all four previously- marked points by a digital microscope (AM413FIT Dino-Lite Pro; Dino-Lite electronic corp., Taipei, Taiwan) that was adjusted for 230X magnification and connected to a personal computer. The captured images were analyzed by image-analysis software (Dino Capture 2.0; AnMo Electronics Corp).

The marginal fit was assessed by determining the length of a perpendicular line drawn between the most cervical edge of the framework and the most outer edge of the finishing line of the abutment.

The mean values of four measurements of each coping were assumed as the marginal discrepancy of each specimen. Means and standard deviations were calculated from 40 replications (10 copings × 4 locations) of each category. One-way ANOVA and post hoc tests were adopted to compare the marginal gaps of the study groups. The level of statistical significance was set at 5%. All statistical analyses were performed in SPSS version 21 (IBM SPSS Statistics; IBM Corp, New York, USA).

Results

Table 1. The minimum, maximum, means and standard deviation (SD) of vertical marginal gaps of Nickle-chromium copings (μm) depending on pattern material.

Groups	Minimum	Maximum	Mean	SD
Group 1 (pattern wax)	28.12	41.2	34	4.42
Group 2 (acrylic pattern resin)	20.37	51.15	31.78	8.09
Group 3 (light-cured pattern resin)	12.3	37.45	25.87	7.29

Table 2. One-way ANOVA analysis of mean vertical marginal gap differences between copings depending on pattern materials.

Mean of the gap	Sum of squares	dF	Mean of square	Ratio	P-value
Between groups	353.646	2	176.823	4.006	0.03
Within groups	1191.678	27	44.136		
Total	1545.325	29			

The minimum, maximum, mean and standard deviations for the marginal gap of the specimens in three experimental groups are summarized in *Table 1*. One-way ANOVA analysis revealed there were significant differences between mean values of three study groups (p=0.03) (*Table 2*).

Group 1 represented the greatest mean values for marginal gap (34.00 µm) whilst group 3 showed the least mean values for the marginal gap of the copings (25.87 µm).

Post hoc tests revealed there was a statistically significant difference between groups 1 and 3 mean values. Group 2 had copings with lower marginal gap (31.78 µm) compared to group 1 (34,00 µm), but not statistically significant. The differences between group 2 and 3 was also not statistically significant (*Table 3*).

***Table 3.** Multiple comparison of vertical marginal gap (µm) of copings fabricated from three different pattern materials, using post hoc tests.*

Groups comparisons	Mean difference	SD	P-value
Pattern wax Vs acrylic pattern resin	2.22	2.97	0.73
Pattern wax Vs light-cured resin	8.13	2.97	0.02*
Acrylic pattern resin Vs light-cured pattern resin	5.91	2.97	0.13

*SD= Standard Deviation, significant difference P<0.05

Discussion

There are some studies on the marginal fit of artificial crowns and fixed partial dentures (FPDs) made from base metal alloy-porcelain [25,26]. However, it seems that no report exists to demonstrate the marginal discrepancies of base metal copings resulting from different pattern materials when used on titanium implant abutments. Therefore, it is crucial to recognize the behavior of pattern materials on titanium abutments.

In current study, a single titanium abutment was employed to standardize the preparation and hinder any abutment wear that could happen during the manufacturing and measuring course. Moreover, all the measurements were accomplished on this distinct abutment and the specimens were not cemented in order to prevent the possible discrepancies that could occur because of the type of the luting agent, viscosity and seating forces during cementation. Several approaches have been made to assess the marginal fit of framework in different studies [27-31]. From all these surveys, two most common non-destructive methods are direct microscopic view and replica technique with which the evaluation of marginal discrepancy of restorations at different stages of fabrication is possible [30,31]. In present study, direct microscopic view was employed to assess the marginal gap. In this method, contrasting the replica technique, marginal gap could be quantified in several points. Besides, in direct microscopic view, using intermediate media such as impression materials is not required; these materials restrict the measurement of the marginal fit in replica technique [30-33]. Conversely, in the direct microscopic assessment, the horizontal marginal gap could not be evaluated. The retention of cement in the margin is typically subjective to the vertical marginal discrepancy, while horizontal marginal discrepancy has a major role in, hygiene (plaque control) and maintenance of the restorations [30].

A holding device was used in this study to normalize the seating of the specimens on the die during measurements. The device had the necessary requirements for a standard holding device that was firstly proposed by Ushiwata and de Moraes [33]. To normalize the seating of the frameworks on the abutment, the occlusal surface lodged to the tip of the holding device. With a conical tip, this device help orient the specimens only in one individual plane during measurements while it provides the possibility of rotational movements of the restorations and therefore, measurements around the margins were conceivable [27].

Numerous data have been published regarding the clinically acceptable marginal gap of crown in the current literature. The study of Christensen et al. [34] identified the range of 34-119 µm as an acceptable value for subgingival marginal gap, and also 2-15µm for supragingival marginal gap. However, Maclean and Von Franunhofer [35] studied more than 1000 restorations in a 5- year study and reported 120µm as the maximum value for a clinically- acceptable marginal gap.

In current study, the mean marginal gap of copings fabricated from pattern wax, acrylic pattern resin, and light-cured pattern resin was 34.00, 31.78 and 25.87 µm respectively. Regarding the values reported by aforementioned studies, the amount of marginal gap yielded in this study, for all the three groups were within the clinically acceptable range.

The study of Sushma et al. [36] ,with promise to the notions of pattern fabrication, showed that the inlay pattern wax - if invested instantly- can be considered as an acceptable material for fabrication of a casting with minimal marginal discrepancy; reminding that this pattern material is cost-effective and less technique-dependent.

In agreement with the results of Rajagopal et al. [24] study, we experienced that the light-cured pattern resin was the most dimensionally stable material, followed by the auto-polymerized resin, and inlay wax respectively.

Inlay waxes benefits from appropriate characteristics such as easy manipulation, predictable coefficient of thermal expansion, and absence of residue on burnout. However, due to their thermoplastic properties, thermal changes and release of internal stresses may cause distortion and increasing temperature accelerates this process [17,19]. This is an important issue which must be deliberated in any technique that accompanies delayed investment or includes heating the wax pattern prior to investing procedure or complete setting of the investment. A low-storage temperature is therefore recommended to minimize distortion and moreover, to obtain an ideal result, the patterns should be invested instantly after being removed from the preparation [17-20].

Resins can be employed as an alternative pattern material for casting. The working time of these resins is reduced and the rotary instruments can be used with these materials without the risk of pattern distortion [18,21,22]. Benefiting from better dimensional stability and easy manipulation, auto-polymerized pattern materials are prevalent for their use in clinical direct pattern fabrication; though they can never replace wax as an indirect pattern material. This is largely due to their polymerization shrinkage as their major disadvantage.

Mojon et al. [22] assessed the standard mixture of two self-cure resins and observed that the polymerization contraction after 24 hours in Duralay resin and Palavit G was 7.9% ± 1.4% and 6.5% ± 0.5%, respectively.

Moon et al. [37] suggested that FPD units prepared for soldering and indexed with acrylic resin material must be invested very soon; relatively within 1 hour.

McDonnel et al. [21] studied the effect of this delay on the accuracy of two common acrylic resins (Duralay and GC pattern resin) which were utilized to assemble an implant framework for soldering. The results of their search point out that both resin-indexed implant assemblies were accurate for 15 minutes after polymerization but not at following test intervals. Previous studies have indicated that the polymerization shrinkage of auto polymerized resin was much greater when used with the bulk technique [21-24], the reason that the auto polymerized resin pattern was fabricated with the incremental technique in the present study.

On the other hand, light-curing materials are broadly used in dentistry and have superiority over chemically-activated materials in numerous clinical and laboratory situations. They endure many advantages such as faster and complete curing; lesser porosity since their mixing is usually not required; nearly prompt finishing time; suitable working time for intricate procedures; and cost-effectiveness. Literature states that the advantages of these light-curing resins are low polymerization shrinkage and adequate dimensional stability [18,23,24]. The light beam is very intense on the surface area of the material specimen, but it is attenuated by interaction of light and material (absorption and scattering) in deeper layers, which limits the depth of curing [23,24]. The main imperative restrictive factors can be stated as the intensity of the incident light, the exposure time, the color of the material and also the nature, shape, and the volume of fillers used in these materials. In addition to the innate shortcomings of these materials, the initial cost of the equipments manufactured for these light-cure resins sorts it as the second choice compared to inlay wax [36,38].

A survey conducted by Danesh et al. [38] on different polymerization characteristics of the light-curing and auto-polymerized pattern resins revealed that the volumetric shrinkage of the light-curing resins are comparable to the auto-polymerized pattern resin; an outcome that might be interrelated with the results obtained by the present study.

As a limitation of the current study, the accurateness of the pattern materials was not assessed on storage off the die in different time intervals. Moreover, this study only measured the vertical marginal gap and did not scrutinize the horizontal discrepancy. To measure the internal gap, cementation and sectioning of the specimens is inevitable, therefore, internal gap was not measured in this study. Also future research should implement the use of CAD/CAM system to fabricate pattern materials to ensure consistency.

Conclusions

Considering the limitations of this study, there was no significant difference in mean marginal gap of copings fabricated from pattern wax and acrylic pattern resin and also between mean values of those copings fabricated from acrylic pattern and light-cured pattern resins. However, mean marginal gap of copings fabricated from pattern wax was significantly greater than the copings fabricated from light-cured pattern resin. The marginal gaps of copings fabricated from tested pattern materials were within the clinically acceptable range.

Acknowledgements

The authors thank the Vice-Chancellery of Shiraz University of Medical Sciences for supporting this research (Grant # 1723).

Conflict of Interest

The authors of this manuscript certify that they have no financial or other competing interest concerning this article.

References

1. Siadat H, Alikhasi M, Mirfazaelian A, Zade MM. Scanning electron microscope evaluation of vertical and horizontal discrepancy in cast copings for single-tooth implant-supported prostheses. *Implant Dentistry.* 2008; **17:** 299-308.

2. Sahin S, Cehreli MC. The significance of passive framework fit in implant prosthodontics: current status. *Implant Dentistry.* 2001; **10:** 85-92.

3. Kallus T, Bessing C. Loose gold screws frequently occur in full-arch fixed prostheses supported by osseointegrated implants after 5 years. *International Journal of Oral and Maxillofacial Implants.* 1994; **9:** 169-178.

4. Carr AB, Gerard DA, Larsen PE. The response of bone in primates around unloaded dental implants supporting prostheses with different levels of fit. *Journal of Prosthetic Dentistry.* 1996; **76:** 500-509.

5. Lee A, Okayasu K, Wang HL. Screw- versus cement-retained implant restorations: current concepts. *Implant Dentistry.* 2010; **19:** 8-15.

6. Jemt T, Lie A. Accuracy of implant-supported prostheses in the edentulous jaw: analysis of precision of fit between cast gold-alloy frameworks and master casts by means of a three-dimensional photogrammetric technique. *Clinical Oral Implants Research.* 1995; **6:** 172-180.

7. Takahashi T, Gunne J. Fit of implant frameworks: an in vitro comparison between two fabrication techniques. *Journal of Prosthetic Dentistry.* 2003; **89:** 256-260.

8. Keith SE, Miller BH, Woody RD, Higginbottom FL. Marginal discrepancy of screw-retained and cemented metal-ceramic crowns on implants abutments. *International Journal of Oral and Maxillofacial Implants.* 1999; **14:** 369-378.

9. Brägger U, Karoussis I, Persson R, Pjetursson B, Salvi G, et al. Technical and biological complications/failures with single crowns and fixed partial dentures on implants: a 10-year prospective cohort study. *Clinical Oral Implants Research.* 2005; **16:** 326-334.

10. Weber HP, Kim DM, Ng MW, Hwang JW, Fiorellini JP. Peri-implant soft-tissue health surrounding cement- and screw-retained implant restorations: a multi-center, 3-year prospective study. *Clinical Oral Implants Research.* 2006; **17:** 375-379.

11. Wee AG, Aquilino SA, Schneider RL. Strategies to achieve fit in implant prosthodontics: a review of the literature. *International Journal of Prosthodontics.* 1999; **12:** 167-178.

12. Jemt T, Rubenstein JE, Carlsson L, Lang BR. Measuring fit at the implant prosthodontic interface. *Journal of Prosthestic Dentistry.* 1996; **75:** 314-325.

13. Sutherland JK, Loney RW, Syed S. Marginal discrepancy of all-ceramic crowns cemented on implant abutments. *Journal of Prosthodontics*. 1995; **4:** 173-177.

14. Salazar MS, Pereira SM, Ccahuana VV, Passos S, Vanderlei A, et al. Shear bond strength between metal alloys and a ceramic system, submitted to different thermocycling immersion times. *Acta odontológica latinoamericana.* 2007;**20:** 97-102.

15. do Prado RA, Panzeri H, Fernandes Neto AJ, Neves FD, Silva MR. Shear bond strength of dental porcelains to nickel-chromium alloys. *Brazilian Dental Journal.*2005;**16:** 202-206.

16. Fernandes Neto AJ, Panzeri H,Neves FD, Prado RM, Mendonca G. Bond strength of three dental porcelains to Ni-Cr and Co-Cr-Ti alloys. *Brazilian Dental Journal.* 2006;**17:** 24-28.

17. Bonilla W, Masood SH, Iovenitti P. An Investigation of Wax Patterns for Accuracy Improvement in Investment Cast Parts. *International Journal of Advanced Manufacturing Technology.* 2001; **18:** 348-356.

18. Cahi E, Rosen M, Becker PJ. A comparison of the dimensional stability of three inlay pattern materials. *Journal of the Dental Association of South Africa.* 1996; **51:** 337-342.

19. Sabau AS, Viswanathan S. Material properties for predicting wax pattern dimensions in investment casting. *Materials Science and Engineering.* 2003; **362:** 125-134.

20. Yarlagadda PKDV, Hock TS. Statistical analysis on accuracy of wax patterns used in investment casting process. *Journal of Materials Processing Technology.* 2003; **138:** 75-81.

21. McDonnell T, Houston F, Byrne D, Gorman C, Claffey N. The effect of time lapse on the accuracy of two acrylic resins used to assemble an implant framework for soldering. *Journal of Prosthestic Dentistry.* 2004; **91:** 538-540.

22. Mojon P, Oberholzer JP, Meyer JM, Belser UC. Polymerization shrinkage of index and pattern acrylic resins. *Journal of Prosthestic Dentistry.* 1990; **64:** 684-688.

23. Iglesias A, Powers JM, Pierpont HP. Accuracy of wax, auto polymerized, and light-polymerized resin pattern materials. *Journal of Prosthodontics.* 1996; **5:** 201-205.

24. Rajagopal P, Chitre V, Aras MA. A comparison of the accuracy of patterns processed from an inlay casting wax, an auto-polymerized resin and a light-cured resin pattern material. *Indian Journal of Dental Research.* 2012; **23:** 152-156.

25. Presswood RG, Skjonsby HS, Hopkins G, Presswood TL, Pendleton M. A base metal alloy for ceramo-metal restorations. *Journal of Prosthestic Dentistry.* 1980; **44:** 624-629.

26. Boeckler AF, Stadler A, Setz JM. The significance of marginal gap and overextension measurement in the evaluation of the fit of complete crowns. *The Journal of Contemporary Dental Practice.* 2005; **6:** 26-37.

27. Balkaya MC, Cinar A, Pamuk S. Influence of firing cycles on the margin distortion of 3 all-ceramic crown systems. *Journal of Prosthestic Dentistry.* 2005; **93:** 346-355.

28. Luthardt RG, Bornemann G, Lemelson S, Walter MH, Hüls A. An innovative method for evaluation of the 3-D internal fit of CAD/CAM crowns fabricated after direct optical versus indirect laser scan digitizing. *International Journal of Prosthodontics.* 2004; **17:** 680-685.

29. Pelekanos S, Koumanou M, Koutayas SO, Zinelis S, Eliades G. Micro-CT evaluation of the marginal fit of different In-Ceram alumina copings. *European Journal of Esthetic Dentistry.* 2009; **4:** 278-292.

30. Sorensen JA. A standardized method for determination of crown margin fidelity. Journal of Prosthestic Dentistry. 1990; **64:** 18-24.

31. Contrepois M, Soenen A, Bartala M, Laviole O. Marginal adaptation of ceramic crowns: a systematic review. *Journal of Prosthestic Dentistry*. 2013; **110:** 447-454.e10.

32. Alghazzawi TF, Liu PR, Essig ME. The effect of different fabrication steps on the marginal adaptation of two types of glass-infiltrated ceramic crown copings fabricated by CAD/CAM technology. *Journal of Prosthodontics.* 2012; **21:** 167-172.

33. Ushiwata O, de Moraes JV. Method for marginal measurements of restorations: accessory device for toolmakers microscope. *Journal of Prosthestic Dentistry.* 2000; **83:** 362-366.

34. Christensen GJ. Marginal fit of gold inlay castings. *Journal of Prosthestic Dentistry.* 1966; **16:** 297-305.

35. McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. British Dental Journal. 1971; **131:** 107-111.

36. Sushma R, Farias A, Soni R. Vertical marginal discrepancies of metal castings obtained using different pattern materials: A scanning electron microscope study. Original Research. *Journal of the International Clinical Dental Research Organization.* 2014 ; **6:** 98-102.

37. Moon PC, Eshleman JR, Douglas HB, Garrett SG. Comparison of accuracy of soldering indices for fixed prostheses. *Journal of Prosthestic Dentistry.* 1978; **40:** 35-38.

38. Danesh G, Lippold C, Mischke KL, et al. Polymerization characteristics of light- and auto-curing resins for individual splints. *Dental Materials.* 2006; **22:** 426-433.