EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 68, 3487:3494, October, 2022

Print ISSN 0070-9484 • Online ISSN 2090-2360

EDJ
EGYPTIAN DENTAL JOURNAL

Fixed Prosthodontics and Dental Materials

Submit Date : 12-06-2022 • Accept Date : 07-08-2022 • Available online: 01-10-2022 • DOI : 10.21608/edj.2022.144412.2147

EVALUATION OF MARGIN AND INTERNAL FIT OF FULL ARCH METAL COPING FABRICATED USING COMPUTER AIDED MILLING, DIRECT LASER SINTERING, AND TRADITIONAL CASTING TECHNIQUE

Ehab A Farghaly[*] *and* Mohammad M Rayyan[**]

ABSTRACT

Objectives: The purpose of this study was to compare the internal and marginal fit of metal cores for metal ceramic crowns fabricated using three different construction techniques.

Materials and methods: Upper full arch Giroform model with missing 4 incisors, first molars, and right second premolar was prepared to receive 5 full arch metal frameworks constructed by each technique; traditional Casting, CAD/CAM milling, and Selective Laser Sintering (SLS). Internal gap of the retainer was performed by replica technique, using light and heavy body addition silicon for marginal and internal gap measurements. Six sections at each tooth were cut to measure the gab distance at the: Margin, Axial, Axio-occlusal angle, and Occlusal area. All measurements were performed using compact stereo microscope under 100 magnification. Data was collected and statistically analysed.

Results: Marginal gap showed statistically significant difference between three tested techniques; it was found to be least for core fabricated with SLS technique, followed by CAD/CAM, and the widest gap was found at cores fabricated with Cast technique . The least internal gap distance was found to be at the axial surface, followed by the axial occlusal line angle, and the widest internal gap distance was found to be at the occlusal surface.

Conclusion: Metal ceramic full arch rehabilitation fabricated with SLS, CAD/CAM, and casting systems exhibited clinical marginal adaptation within an acceptable range.

KEY WORDS: Casting, Selective Laser Sintering, Co-Cr alloy, replica technique

* Lecturer, Fixed Prosthodontics Department, Faculty of Oral and Dental medicine, Nahda University
** Professor of Fixed Prosthodontics, Faculty of Dentistry Saini University Kantara Campus.

INTRODUCTION

Metal ceramics up-to-date considered one of the widely used materials for fixed dental prostheses [1]. It considered a metal framework covered with porcelain material. Marginal and internal fit of metal copings are intentionally required to achieve the most clinically accepted results for long term prognosis of metal ceramic restorations.

A good fit of fixed dental prosthesis specially at the marginal area may reduce risks of gum diseases and secondary caries due to dissolution of luting agent by reducing food accumulation, plaque and bacteria.[2] Therefore, poor marginal fit considered one of the most critical cause of failure of fixed partial dentures. [3]

Improper marginal fit could be accepted when it is indiscernible visually, or undetectable by dental probe. Clinically acceptable marginal gab values considered between 100 and 150 μ [4,5,6]. In addition internal gap distance is also important, as when it is greater than 70μ could reduce the fracture resistance of the crowns.[7]

Metal coping are fabricated traditionally by lost wax technique and casting method. Although, this complex procedure suggested possible problems, in addition to, discomfort for the patients during taking physical impression in the oral cavity.[8] These problems may lead to inaccurate internal and marginal fit due to distortion of impression material through improper handling during impression making steps, distortion of wax pattern, or improper casting metal through complex casting procedures.[9]

Automated systems acquisition in turn improved the development of a various range of metal ceramic crowns fabrication methods, to control the disadvantages of metal casting; CAD/CAM milling systems, involve restoration processing from digital 3D shape produced through computer software, and milled by the aid of milling machine from a solid metal blocks.[10, 11]

Another method for metal coping manufacturing is selective laser sintering (SLS) system which incorporates an additive manufacturing technology to fabricate copings by selectively heating substrate metal powder with a laser beam to build up layers of solidified material, based on software data from the CAD design, [12]

These methods have drawn distinct attention through their ability to prevent distortion and fabrication defects of the traditional casting method.[13] Moreover using operations of an automated systems, through elimination of fabricating procedures including wax pattern, spruing, investing, and casting, which by default lead to less distortion and working time, better internal and marginal accuracy of the restoration. One disadvantage of these methods considered the high cost of the equipment needed in the fabrication processes.[14]

CAD/CAM and SLS improve lab fabrication procedures; however, more researches on these techniques is needed on marginal and internal adaptation of metal cores construction.[15]

This clinical study compares the internal and marginal fit of metal cores for metal ceramic crowns construction using three different techniques: traditional casting, CAD/CAM milling, and selective laser sintering.

MATERIALS AND METHODS

Model construction

Upper full arch Giroform model (Amann Girrbach AG Herrschaftswiesen 16842 Koblach, Austria) with missing 4 incisors, first molars, and right second premolar was prepared (Figure 1). Abutment preparation was performed on the remaining teeth from the right second molars to the left second molar with circumferential 1 mm chamfer finish line, 1.5 mm occlusal reduction, with 6 degrees axial inclination, putty index was used to standardized the amount of reduction. Roundation of all internal line angles was done by end of the preparation. Reduction was performed by a single, experienced hand operator.

Fig. (1) Abutment preparation on the Giroform model

The full arch model was scanned using extra oral laser scanner (D-700, 3shape A/S, Copenhagen, Denmark). Full arch fused copings were designed with 0.5 mm-thickness including 30 μ for cement film thickness and pontics filling the areas of missed teeth, following the manufacturer's directions, and standard template library (STL) files that were used to construct 15 full arch frameworks by three different techniques using CAD software (3shape Dental Designer, 3shape A/S, Copenhagen, Denmark); 5 constructed by casting technique, 5 CAD/CAM and milling technique, and 5 using selective laser sintering technique.

Framework fabrication

5 full arch frameworks were fabricated for casting technique, data from the STL file was sent to the CAM machine (3Shape A/S, Copenhagen K, Denmark) for construction of castable resin pattern which were invested in a phosphate-bonded investment with metal ring, and casted with the Co-Cr-based metal alloy. Casting was done by centrifugal machine using heat induction. Separating disc was used to cut the sprues after casting, coping thickness was checked using a calliper, margin and casting beads were examined using magnified glass. No internal adjustment was applied except elimination of casting nodules using rotary instrument.

5 full arch frameworks were fabricated for CAD/CAM milling technique, the same data from the STL file was sent to the CAM machine for milling from a Co-Cr alloy blanks, which was milled to the framework outline and thickness as created by the computer software.

For selective laser sintering technique 5 full arch frameworks were fabricated. This technology depend on fusing Co-Cr alloy powder into a solid coping by melting it locally through directed laser beam using a direct metal laser sintering machine (EOSINT M270; EOS GmbH, Krailling, Germany) and building up the full arch coping additively layer by layer, from the same virtual coping design of the CAD software program. Coping was built with a sintered powder layer thickness of 20 μm from the incisal or occlusal surface to the margin at 1500^{o} C in an inert gas environment, then it was cooled down to the room temperature in the furnace. No treatments were performed for the CAD/CAM milled and laser sintered copings after fabrication.

Internal gap replica model

Internal gap of the retainer was performed using replica technique; retainers of the full arch frameworks from each group were filled with pink addition silicon light body impression material, and seated on the prepared teeth in the Giroform model. Finger pressure was applied on each framework at the edentulous posterior area first, then at the right and left retainers until complete seating. After setting framework was carefully removed with the pink light body attached into it which represent the gap distance between the retainer and the abutment. Orange addition silicon light body was injected over the pink one inside the retainers for support, and inverted on a heavy body base previously prepared to hold the silicon abutments in place (Figure 2).

After setting the framework and the two light body layers with the putty base was separated. Each silicon abutment was sectioned buccolingually first into three equal parts, and mesiodistally into two equal parts using a surgical blade.

Internal gap measurement

For marginal and internal gap measurements, six sections at each tooth were cut as follows; Mesio Buccal, Middle Buccal, Disto Buccal, Mesio Lingual, Middle Lingual, Disto Lingual. Each section contains four landmarks; Marginal Gap (P1), Axial wall (P2), Axio-occlusal angle (P3) which is the intersection between the occlusal plane (OP) and axial plane (AP), Occlusal area (P4), measuring the thickness of the pink layer of the light body representing the marginal discrepancy (Figure 3).

All measurements were performed using compact stereo microscope (Olympus SZ61, Olympus corporation, Tokyo, Japan) under 100 magnification (Figure 4). A digital camera is connected to the microscope (Olympus LC30, Olympus corporation, Tokyo, Japan) through which the images were acquired, measurements were performed using imaging software (Olympus Stream Image Analysis Software 2.4.3).

Data were analyzed using Statistical package for Social Science (SPSS) version 22.0., Quantitative data were expressed as mean± standard deviation (SD). Qualitative data were expressed as frequency and percentage. One-way analysis of variance (ANOVA) is used to test the difference between the means of several subgroups of a variable (multiple testing). Post-hoc test (the Tukey-Kramer test) is used for pairwise comparison of subgroups, when the ANOVA test is positive

RESULTS

Table 1 shows comparison of mean gap difference between groups at the margin, axial, angle, and occlusal areas. Marginal area showed statistically significant difference between core frameworks

Fig. (2): Prepared abutment with the internal gap prepared with two different colors of addition silicon impression materials ready for sectioning

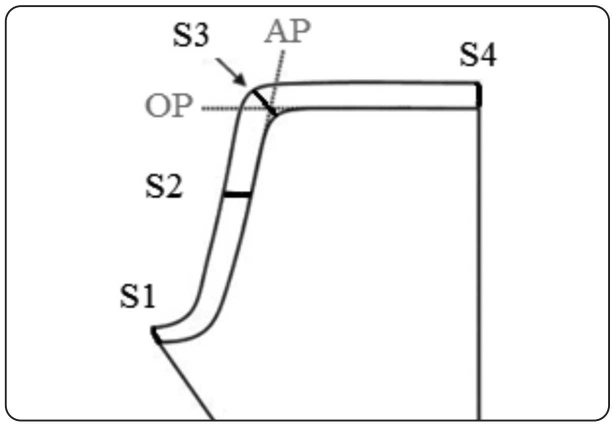

Fig. (3): Areas of measurements S1. Marginal gap, S2. Middle of Axial wall, S3. Axio-occlusal angle, and S4. Occlusal area, OP. Occlusal plane, AP. Axial plane.

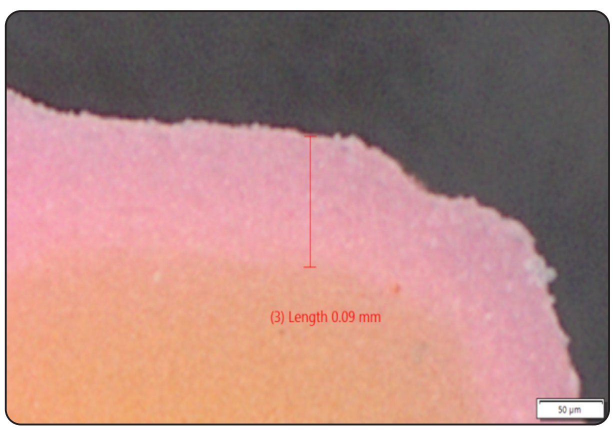

Fig. (4): Measurement of the gap distance (Pink silicone) thickness by Stereo Microscope fabricated by all three tested groups (122.14± 22.66, 100.24± 20.54, 79.76± 10.82) (P<0.05).

Axial area showed statistically significant difference between core frameworks fabricated by CAD/CAM (88.21± 27.85), SLS (85.12± 19.59) groups and CAST group (109.29± 26.68) (P<0.05), no significant difference was found between CAD/CAM and SLS groups.

While angle and occlusal areas showed statistically significant difference between core frameworks fabricated by CAD/CAM (152.40±39.02, 194.29± 39.29) , CAST (154.26± 30.27, 207.52± 46.54) groups and SLS group (117.86± 38.84, 149.17± 49.20) (P<0.05), no significant difference was found between CAD/CAM and CAST groups.

TABLE (1): Comparison of mean gap difference between tested groups (unit: µm,) at the margin, axial, angle, and occlusal areas, numbers between brackets show the significant difference between groups (P<0.05)

Area	n	Mean	SD	Cross statistics
Margin				
CAST (1)	42	122.14	22.66	(2)(3)
CADCAM (2)	42	100.24	20.54	(1)(3)
SLS (3)	42	79.76	10.82	(1)(2)
Axial				
CAST (1)	42	109.29	26.68	(2)(3)
CADCAM (2)	42	88.21	27.85	(1)
SLS (3)	42	85.12	19.58	(1)
Angle				
CAST (1)	42	154.26	30.27	(3)
CADCAM (2)	42	152.40	39.02	(3)
SLS (3)	42	117.86	38.84	(1)(2)
Occlusal				
CAST (1)	42	207.52	46.54	(3)
CADCAM (2)	42	194.29	39.29	(3)
SLS (3)	42	149.17	49.20	(1)(2)

The mean internal and marginal discrepancy of various tested groups is shown in Figure 5. Values indicate that the marginal gap was least for core fabricated with SLS technique followed by CAD/CAM and the widest gap was found in the core fabricated with Cast technique. The least internal gap distance was found to be at the axial surface, followed by the axial occlusal line angle, and the widest internal gap distance was found to be at the occlusal surface.

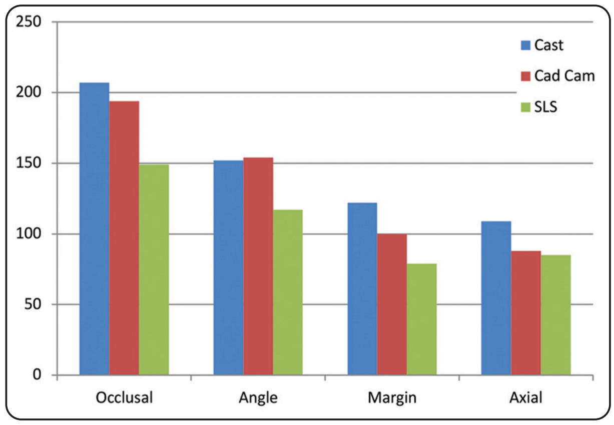

Fig. (5): Mean internal and marginal discrepancy between various tested groups

DISCUSSION

Dental field has changed dramatically during the last 6 decades. Many of these materials and technology advancements have been beneficial, and with each change comes new opportunities which allow more possibilities to enhance quality of dental outcome. Introduction of digital systems in dental restorations is one of them.

The present study attempts to evaluate marginal gap distance and internal fit of metal coping fabricated using computer aided milling, direct laser sintering, and traditional casting technique.

Due to anatomical variations of the teeth to be restored with metal ceramic restorations, as well as changes in preparation and impression processes, in-vivo evaluation could not be totally standardised. In-vitro studies are still reliable for assessing the performance of dental restorations, including marginal and internal fit of metal ceramic restorations, which considered the core of dental restoration durability [16, 17].

Replica technique was used in this study to measure gab distance of the cores fabricated with the three different techniques, previous studies demonstrated replica technique as accurate and reliable method for measuring marginal gab distance and internal film thickness.[18, 19] Laurent et al [20] stated that, gab distance can be actually measured at any position using appropriate silicon replica technique.

Previous studies evaluated different finish lines effect on marginal fit for metal ceramic restorations, it was found that chamfer finish line showed high and predictable marginal fit [21, 22] . Therefor in this study chamfer finish line was chosen for the margin design.

Mclean et al [23] stated that 120 µm marginal gab considered accepted, other studies ranged from 100-150 µm [24] . In the meantime 200–300 µm concluded to be accepted marginal misfit. [25] . Mean marginal gab in our study was found to be (122.14 ± 22.66), (100.24 ± 20.45), and (79.76 ± 10.82) for the tested Cast, CAD/CAM, and SLS respectively, which found to be within the accepted range of gab distance.

Different fabrication techniques indicate no marginal gap difference. However, significant differences were found between the Cast and the other two techniques at marginal, and axial areas (table 1). These variation could be due to distortion tend to appear at these areas while the wax modeling stage or during milling of castable resin. Thus, the marginal and axial gap values can be affected by technique of construction.

Evaluating internal fit in this study; highest internal gap at the axial, angle, and occlusal was found in Cast technique (109.28, 154.26, 207.52 µm) followed by the CAD/CAM (88.21, 152.40, 194.28 µm), while the lowest values were found in SLS technique (85.11, 117.85, 149.16 µm). This result is consistent with other studies as SLS was found to be the least marginal gap distance and best fit. Oyague et al [26], measured the internal fit and marginal gap using conventional lost wax technique and Direct laser metal sintering technique, and was (50.1 and 30.5 µm) respectively. Also replica method was used by Quante et al [27] to evaluate gap values between laser melting technology and laser sintering Co-Cr single crowns which was (250 and 36 µm) respectively, which were similar to our findings.

Ortorp et al [28], also found that the least gab distance was found with the metal laser sintering followed by conventional casting technique, values were found to be below 100 µm which considered accepted, however this study was performed in three unite bridge while the present study performed in full arch bridge which needs more space in performing common path of insertion.

Findings of this study, however, disagree with previous study by Park et al [29] who stated that Casting technique produced the narrowest gap in all coping areas, whereas axial and incisal proved narrower in CAD/CAM than in laser sintering. Although coping in their study was performed on maxillary canine, in addition to the die spacer and wax pattern was applied manually on single die. In the mean while the present study applied on full arch copings with much more line angles to insure common path of insertion. However their findings were agreed with our study where the gap distance generally tended to increase from the marginal area towards the axial surface, with the widest gap at occlusal or incisal area.

Occlusal gap was found to be the highest value in our study, which was in convenient with other studies [27, 30], especially in the cast technique due to occlusal reduction of burnout copings. Moreover, it is also due to more of the prepared abutment teeth at occlusal surface area to perform even teeth height and common path of insertion with multiple teeth angels.

CONCLUSION

Within the limitations of this in vivo study, it was concluded that:

1. Metal ceramic full arch rehabilitation fabricated with SLS, CAD/CAM, and casting systems exhibited clinical marginal adaptation within an acceptable range.
2. Mean marginal gap values of the three tested groups was significantly higher for Cast, CAD/CAM, and SLS respectively.
3. The least overall gab was found in SLS group, followed by CAD/CAM and finally the cast method
4. The occlusal region was found to have the highest gab distance in all groups.

REFERENCES

1. Petteno D, Schierano G, Bassi F, Bresciano ME, Carossa S. Comparison of marginal fit of 3 different metal–ceramic systems: an in vitro study. International Journal of Prosthodontics 2000;5:405–8.
2. White SN, Sorensen JA, Kang SK, Caputo AA. Microleakage of a new crown and fixed partial denture luting agent. Journal of Prosthetic Dentistry 1992;67:156–61.
3. Foster LV. Failed conventional bridge work from general dental practice: clinical aspects and treatment needs of 142 cases. British Dental Journal 1990;168:199–201.
4. Kokubo Y, Ohkubo C, Tsumita M, Miyashita A, Vult von Steyern P, Fukushima S. Clinical marginal and internal gaps of Procera AllCeram crowns. Journal of Oral Rehabilitation 2005;32(July (7)):526–30.
5. Beuer F, Aggstaller H, Richter J, Edelhoff D, Gernet W. Influence of preparation angle on marginal and internal fit of CAD/CAM-fabricated zirconia crown copings. Quintessence International 2009;40(March (3)):243–50.
6. Annu Eliza James, B. Umamaheswari, and C. B. Shanthana Lakshmi. Comparative Evaluation of Marginal Accuracy of Metal Copings Fabricated using Direct Metal Laser Sintering, Computer-Aided Milling, Ringless Casting, and Traditional Casting Techniques: An In vitro Study. Contemp Clin Dent. 2018 Jul-Sep; 9(3): 421–426.
7. Tuntiprawon M, Wilson PR. The effect of cement thickness on the fracture strength of all-ceramic crowns. Australian Dental Journal 1995;40(February (1)):17–21.
8. Zuskova L, Mortadi NAA, Williams RJ, Alzoubi KH, Khabour OF. Comparison of Overall Fit of Milled and Laser-Sintered CAD/CAM Crown Copings. Int J Dent. 2019 Jul 7;2019:7310175.
9. Jong-Kyoung Park, Wan-Sun Lee, Hae-Young Kim, Woong-Chul Kim, Ji-Hwan Kim J Adv Prosthodont. 2015 Apr; 7(2): 122–128
10. Hamza TA, Ezzat HA, El-Hossary MM, Katamish HA, Shokry TE, Rosenstiel SF. Accuracy of ceramic restorations made with two CAD/CAM systems. J Prosthet Dent 2013;109:83-7.
11. AndreiotelliM, Kamposiora P, Papavasiliou G. Digital data management for CAD/CAM technology. An update of current systems. Eur J Prosthodont Restor Dent 2013; 21:9-15.
12. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y. A review of dental CAD/CAM: current status and future perspectives from 20 years of experience. Dent Mater J 2009;28: 44-56.
13. Kim M, Kim J, Mai HN, et al. Comparative clinical study of the marginal discrepancy of fixed dental prosthesis fabricated by the milling-sintering method using a presintered alloy. J Adv Prosthodont. 2019;11(5):280-285.
14. Ullattuthodi S, Cherian KP, Anandkumar R, Nambiar MS. Marginal and internal fit of cobalt-chromium copings fabricated using the conventional and the direct metal laser sintering techniques: A comparative in vitro study. J Indian Prosthodont Soc. 2017;17(4):373-380.
15. Ece Tamac, Suna Toksavul, Muhittin Toman. Clinical marginal and internal adaptation of CAD/CAM milling, laser sintering, and cast metal ceramic crowns. J Prosthet Dent 2014;112:909-913.
16. Contrepois M, Soenen A, Bartala M, Laviole O. Marginal adaptation of ceramic crowns: a systematic review. J Prosthet Dent 2013;110:447-54.

17. Naumann M, Ernst J, Reich S, Weißhaupt P, Beuer F.Galvano- vs.metal-ceramic crowns: up to 5-year results of a randomized split-mouth study. Clin Oral Invest 2011;15:657-60.

18. Rahme HY, Tehini GE, Adib SM, Ardo AS, Rifai KT. In vitro evaluation of the "replica technique" in the measurement of the fit of Procera crowns. J Contemp Dent Pract. 2008;9(2):25-32.

19. Cardoso KB, Bergamo ETP, Cruz VM, Ramalho IS, Lino LFO, Bonfante EA. Three-dimensional misfit between Ti-Base abutments and implants evaluated by replica technique. J Appl Oral Sci. 2020;28:e20200343.

20. Laurent M, Scheer P, Dejou J, Laborde G. Clinical evaluation of the marginal fit of cast crowns – Validation of the silicone replica method. J Oral Rehabil 2008;35:116-22.

21. Bottino MA, Valandro LF, Buso L, Ozcan M. The influence of cervical finish line, internal relief, and cement type on the cervical adaptation of metal crowns. Quintessence Int 2007;38:425-32.

22. Shiratsuchi H, Komine F, Kakehashi Y, Matsumura H. Influence of finish line design on marginal adaptation of electroformed metal-ceramic crowns. J Prosthet Dent 2006;95:237-42.

23. McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. Br Dent J 1971;131:107-11.

24. Coli P, Karlsson S. Fit of a new pressure-sintered zirconium dioxide coping. Int J Prosthodont 2004;17:59-64.

25. Stappert CF, Denner N, Gerds T, Strub JR. Marginal adaptation of different types of all-ceramic partial coverage restorations after exposure to an artificial mouth. Br Dent J 2005;199:779-83.

26. 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.

27. Quante K, Ludwig K, Kern M. Marginal and internal fit of metal-ceramic crowns fabricated with a new laser melting technology. Dent Mater 2008;24:1311-5.

28. 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.

29. Park JK, Lee WS, Kim HY, Kim WC, Kim JH. Accuracy evaluation of metal copings fabricated by computer-aided milling and direct metal laser sintering systems. J Adv Prosthodont. 2015;7(2):122-128

30. Kahramanoglu E, Kulak-Özkan Y. The effect of different restorative and abutment materials on marginal and internal adaptation of three-unit cantilever implant-supported fixed partial dentures: An in vitro study. J Prosthodont 2013;22:608-17.