

Original article

Fatigue cyclic loading test of an auro-galvanofforming ceramic bridge

ZHANG Xiang-hao, SUN Feng, WANG Huan and XU Man-qiong

Keywords: dental occlusion; dental prosthesis; cementation

Background In dental clinics, dentition defects are commonly restored with conventional porcelain-fused-to-metal fixed bridges. However, Ni-Cr alloy ceramic fixed bridges are known to have several drawbacks such as marginal coloration of the neck, low casting precision and, most seriously, poor biocompatibility. These problems could be circumvented by using noble metal ceramic bridges; however, one negative issue related to the conventional noble metal ceramic bridges is its high price due to the use of a large amount of gold for pontic. Therefore, an auro-galvanofforming ceramic bridge would be ideal to retain the advantages of a conventional material, yet reduce the amount of noble metal used. This study aimed to investigate whether any destructive changes occur to the auro-galvanofforming ceramic bridge under a fatigue cyclic loading test.

Methods On standard models which the left maxillary first premolar is lost and with the cuspid teeth and the second premolar as the fixed bridge abutment teeth, six maxillary auro-galvanofforming ceramic bridges and six corresponding nichrome ceramic jointed crowns were made as group A, six nichrome ceramic bridges and six corresponding nichrome ceramic jointed crowns were made as group B (control group). And then all specimens were fixed and tested on a fatigue cyclic loading machine; the changes occurring to the surfaces of occlusal contact with large functional area and to the porcelain-metal interfaces of the nichrome primary copings margins were observed through a scanning electron microscope (SEM).

Results In 120 hours' continual observation, none of the specimens had porcelain coating fractures or scraping occurrence and all of the porcelain coatings had been kept intact under sinusoidal cyclic loading with the load range of 120–200 N and frequency of 5 Hz.

Conclusions Auro-galvanofforming ceramic bridges exhibited excellent fatigue strength in the fatigue cyclic loading test and may satisfy the clinical demand in theory, while the practical application shall be evaluated by observations in long-term clinical usage.

Chin Med J 2008;121(19):1896-1899

Metal-porcelain prosthesis, since their birth in the 1950s,¹ have become one of the most commonly used repair methods through unceasing development and improvement, and the porcelain fusing technology is also being perfected in China. In fixed denture prosthesis for defect dentition, non-noble metal-porcelain prosthesis,² because of its low price, was the choice for most patients ten years ago; however, years of clinical observations have identified some problems in it: the liberation and release of nickel ions from the nichrome of non-noble metal may color the gingiva at the margins of the dental prosthetic restoration and even lead to toxic reactions,³⁻⁵ and the nichrome casting shrinkage of the non-noble metal may lead to unfavorable precision of the restoration and cause marginal micro-leakage.^{6,7} The problems may be solved by using noble metal gold alloy porcelain prosthesis, which, however, will consume large amounts of gold and therefore increase the cost, and even worse, fail to perfectly close the margin of the restoration due to the casting shrinkage of the primary copings. So it has become an urgent issue to develop a repair method which may not only have preferable repair effect but also relatively lower cost. As a new crown repair method developed in Europe in recent years,⁸ auro-galvanofforming crown technology adopts an primary coping formed by

electroplating a sedimentation of aurum ions, which is only 0.2 mm thick, and therefore greatly reduces the gold consumption. Meanwhile, the adoption of plating technology has avoided the casting shrinkage of the crown and increased the marginal fitness of the crown restoration.⁹ In addition, it may be used for the manufacture of upper structures of attachment dentures and implants.¹⁰ As a completely new crown repair method applied in the clinic in recent years, auro-galvanofforming ceramic bridges have excellent marginal fitness, steady biocompatibility and outstanding aesthetic properties, as well as the extraordinary physical and mechanical properties of non-noble porcelain bridges. However, whether or not the auro-galvanofforming single crown and the nichrome bridge may be combined perfectly and

Outpatient Dental Center, Peking University School of Stomatology, Beijing 100034, China (Zhang XH, Sun F and Wang H)

Department of Engineering Mechanics, Tsinghua University, Beijing 100084, China (Xu MQ)

Correspondence to: Dr. WANG Huan, Outpatient Dental Center, Peking University School of Stomatology, Beijing 100034, China (Tel: 86-10-58595090. Fax: 86-10-58595002. Email: wanghuan1958@vip.sina.com)

This work was supported by a grant from Beijing Science and Technology Committee Funds (No. Z0005190041491).

whether or not the above two metals may form perfect metal-porcelain integration need to be confirmed by tests.

This study was designed to seek answers to the above mentioned doubts through fatigue cyclic loading tests.

METHODS

Materials

The auro-galvanoforming machine and pure gold solution (Ahafna, Germany), Galvano-Comp high temperature-resistant adhesive (Servo-Dent, Germany), self-solidification resin and nichrome (Heraeus, Germany), porcelain fusing machine and matching ceramic cement (Ivoclar, Liechtenstein), electro-hydraulic servo fatigue testing machine (Shimadzu, Japan) and scanning electron microscope (SEM) (Shimadzu, Japan).

Methods

Twelve fixed dentures with the left maxillary first premolar loss and with the cuspid teeth and the second premolar as the fixed bridge abutment teeth were made on a maxillary standard model by technicians in the technic room.

Conventional Ni-Cr alloy ceramic fixed bridges

Six conventional Ni-Cr alloy ceramic fixed bridges were used as controls. The procedure of making six auro-galvanoforming ceramic bridges is as follows: Step I: auro-galvanoforming primary copings for left maxillary cuspid and the second premolar were made. Step II: nichrome pontic were made on a standard model having auro-galvanoforming primary copings, with the distances between the nichrome pontic and the auro-galvanoforming primary copings being appr. 1–2 mm for mesiodistal margin and appr. 3–5 mm buccal-palatal side margin. Step III: the nichrome pontic and the auro-galvanoforming primary copings were cemented with high-temperature resistant adhesives for preparation of the auro-galvanoforming pontic, and the auro-galvanoforming ceramic bridge was completed by porcelain fused to the pontic. Step IV: the completed auro-galvanoforming ceramic bridges were fixed within the resin modules with resin cement. Step V: six mandibular nichrome fixed ceramic crowns corresponding to the maxillary restorations were made on a standard model and fixed within the resin modules. The fine grinding of maxillary auro-galvanoforming ceramic bridges was carried out on an articulator to form occlusal contact with a large functional area. Step VI: the maxillary and mandibular modules in occlusal contact were fixed on the electro-hydraulic servo fatigue testing machine and given a vertical press of 2 kg for fixation; the test pieces were fixed horizontally in the SEM sight chamber. The shot of the SEM was aligned at the test pieces to observe the changes on the cervical margins on the buccal and lingual sides of the second premolars. Step VII: cyclic load, with the range of 120–200 N and frequency of 5 Hz, was exerted on the test pieces according to references.¹¹⁻¹³

RESULTS

In 120 hours' continual loading observations from group A, none of the six test specimens' occlusal contact area had porcelain coating fractures or scraping occurrence, and all the porcelain coatings had been kept intact under sinusoidal cyclic loading with the load range of 120–200 N and the frequency at 5 Hz. At the same time, both buccal and lingual cervical margins of nichrome pontic had no porcelain coating fracture or scraping occurrence, and all the porcelain coatings were continuous in the second premolar, whose the bonding layer of the crown's margin had the same integrity with pre-test. And the porcelain coatings of opposing occlusion nichrome fixed ceramic crowns stayed integral (Figures. 1–7).

In group B, none of the six test specimens' occlusal contact area had porcelain coating fractures or scraping occurrence and all the porcelain coatings kept intact under sinusoidal cyclic loading with the load range of 120–200 N and a frequency of 5 Hz.

DISCUSSION

Excellent physical and mechanical properties of auro-galvanoforming ceramic bridges

Nichrome ceramic crown and bridge¹⁴ have been used in the clinic for decades and they meet the clinical requirements. Though having certain defects, the technology, because of its excellent physical and mechanical properties as well as the outstanding metal-porcelain bonding force,^{15,16} is the first choice for full crown repair after pulp treatment in China, and most other developing countries and even some moderately developed countries. The auro-galvanoforming ceramic bridge mentioned in this article has the binding force interfaces all above the nichrome porcelain coating, which means that in reality the function is performed by a nichrome porcelain bridge. Therefore, the laboratorial and clinical experience with the nichrome porcelain bridge is also applicable when extended to auro-galvanoforming bridges, which is confirmed by the test results.

Setting of the load

Many scholars have carried out extensive research^{11,12} to determine the human occlusal forces of different tooth positions in different situations, and in most research the occlusal forces of healthy and complete natural dentures are generally divided into the ranges of 150–200, 350–400 and 500–600 N from incisor teeth to premolars to molars. With the increase of dentition defect areas, the occlusal forces of fixed dentures decrease dramatically to about 30%–40% of those of complete natural dentures.^{17,18} Therefore, it is reasonable to set the load within the range of 120–200 N in the test.

Bio-safety of auro-galvanoforming ceramic bridges

Needless to say, the nichrome porcelain crown and bridge also have shortcomings. The metallic nickel ions may be

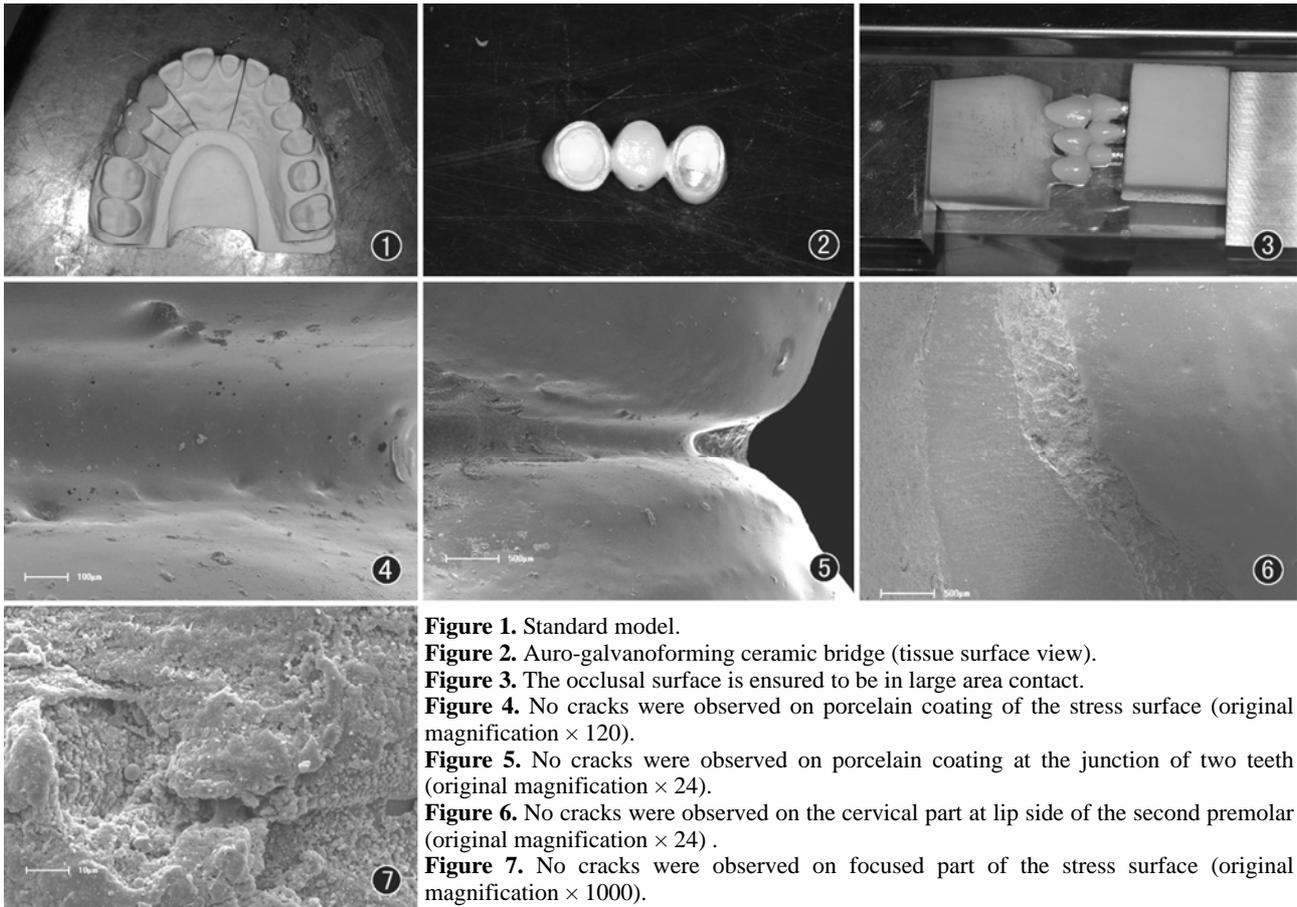


Figure 1. Standard model.

Figure 2. Auro-galvanofarming ceramic bridge (tissue surface view).

Figure 3. The occlusal surface is ensured to be in large area contact.

Figure 4. No cracks were observed on porcelain coating of the stress surface (original magnification $\times 120$).

Figure 5. No cracks were observed on porcelain coating at the junction of two teeth (original magnification $\times 24$).

Figure 6. No cracks were observed on the cervical part at lip side of the second premolar (original magnification $\times 24$).

Figure 7. No cracks were observed on focused part of the stress surface (original magnification $\times 1000$).

released in large amounts in the oral acid environment. The separated nickel ions may adhere to the gingiva and form gray lines on the gingival margins and thus destroy the aesthetics. In addition, the biotoxicity may cause an allergic reaction^{4,5} of the gingiva and do harm to health. While adopting the excellent physical and mechanical properties, as well as the outstanding metal-porcelain binding force of nichrome, the auro-galvanofarming bridge envelops tightly the nichrome with a porcelain coating so that the nichrome has no opportunity to be exposed to the oral acid environment, which, as is suggested by our test, has a nickel separation rate close to zero. It is the auro-galvanofarming primary copings with 99.99% gold purity and excellent biological stability that is in contact with the abutment and the gingival cervical fluid, and thereby the harmful results caused by nickel ion separation are completely avoided.

Marginal fitness and aesthetic property of auro-galvanofarming bridges

The manufacture technology of an auro-galvanofarming ceramic crown is based on the electrodepositing of aurum ions on the dies, therefore it compensates for the poor crown marginal fitness caused by high-temperature casting shrinkage in metal casting technology.¹⁹ Many researchers^{20,21} have also confirmed that a gap of only 15–20 μm is left between an auro-galvanofarming single crown and bridge restoration margin and the preparative abutment, far less than the gap of 70–100 μm of the casting restoration margin. These publications also

pointed out the outstanding aesthetic property of auro-galvanofarming restoration and suggested that the auro-galvanofarming restoration has incomparable advantages in saturation and lucency of porcelain coating over casting-primary-copings-porcelain-restorations. Certainly, this superiority benefits from the influence of the warm color given by the 99.99% gold of the auro-galvanofarming primary copings on the porcelain coating. Besides, the auro-galvanofarming primary copings is only 0.2 mm thick, which not only reduces the abutment preparation quantity, but also guarantees the thickness of the porcelain without compromise of the restoration shape, which ensures a favorable aesthetic property.

Indications of auro-galvanofarming ceramic bridges

The preparation quantity of auro-galvanofarming ceramic bridges should be equal to or larger than that of casting alloy ceramic bridges, with only 0.4–0.5 mm more at the truss than in common practice. Auro-galvanofarming ceramic bridges are not suitable for patients of dental defects with compact occlusion, and should be applied to vital dental bridges with caution. It is suggested to use on pulpless abutments.

Application scope of auro-galvanofarming ceramic bridges

With pleasant color and high fitness, the auro-galvanofarming crown has been widely used in clinics.^{22,23} However, because the auro-galvanofarming primary copings is very thin and the shape of the

preparation cannot be changed, the auro-galvanoforming crown has strict demands for the preparation that the thickness of the veneering porcelain of the ceramic crown should be controlled during preparation. In the molar area or when the abutment shape is irregular, the uneven thickness or partial high thickness of the veneering porcelain will increase the risks of brisment or fraction of the restoration, and thus auro-galvanoforming crown restoration is not satisfactory. Besides high fitness, reliable bio-safety and low cost (significant especially in multi-pontic restorations), the auro-galvanoforming ceramic bridge, because the truss is positioned at the incisal margin of the inferior tooth and the occlusal facing of posterior tooth and thus is conducive for the control of the thickness of the veneering porcelain with the form of the truss, has a guaranteed thickness of the veneering porcelain and can be applied for restorations in different areas and on abutments of different shapes.

Our test was well controlled for laboratory conditions in both groups. There were no significant differences between groups A and B. From the results of fatigue cyclic loading tests, we may conclude that auro-galvanoforming ceramic bridges satisfy the clinical requirement. While, as a repair method for fixed prosthesis according to the needs of clinical treatment of dental defects, it should be evaluated by long-term observations in clinic usage.

REFERENCES

- Colman HL. Advances in application of porcelain-fused-to-metal restorations. *CDA J* 1975; 3: 60-62.
- Warpeha WS Jr, Goodkind RJ. Design and technique variables affecting fracture resistance of metal-ceramic restorations. *J Prosthet Dent* 1976; 35: 291-298.
- Wataha JC. Biocompatibility of dental casting alloys: a review. *J Prosthet Dent* 2000; 83: 223-234.
- Bearden LJ, Cooke FW. Inhibition of cultured fibroblasts by cobalt and nickel. *J Biomed Mater Res* 1980; 14: 289-309.
- Jacobsen N. Epithelial-like cells in culture derived from human gingiva: response to nickel. *Scand J Dent Res* 1977; 85: 567-574.
- Yesil ZD. Microleakage of four core materials under complete cast crown. *NY State Dent J* 2007; 73: 32-38.
- Kosaka S, Kajihara H, Kurashige H, Tanaka T. Effect of resin coating as a means of preventing marginal leakage beneath full cast crowns. *Dent Mater J* 2005; 24: 117-122.
- Setz J, Dieh J, Weber H. Margin of cemented galvano-ceramic crowns. *Quintessenz* 1989; 40: 1439-1445.
- Kokubo Y, Tsumita M, Ohkubo C, Vult von Steyern P, Murata T, Fukuhsima S. Clinical marginal gap of porcelain fused to electro-formed gold coping crowns. *Eur J Prosthodont Restor Dent* 2006; 14: 85-89.
- Emeklint C, Odman P, Ortengren U, Rasmusson L. Tolerance test of five different types of crowns on single-tooth implants. *Int J Prosthodont* 1998; 11: 233-239.
- Powers JM, Craig RG. *Restorative dental materials*, 11th Edition. Missouri: Mosby, Inc; 2002: 68-69.
- Koolstra JH, van Eijden TM. Application and validation of a three-dimensional mathematical model of the human masticatory system *in vivo*. *J Biomech* 1992; 25: 175-187.
- Kumagai H, Suzuki T, Hamada T, Sondang P, Fujitani M, Nikawa H. Occlusal force distribution on the dental arch during various levels of clenching. *J Oral Rehabil* 1999; 26: 932-935.
- Oh W, Götzen N, Anusavice KJ. Influence of connector design on fracture probability of ceramic fixed-partial dentures. *J Dent Res* 2002; 81: 623-627.
- Tjan AH, Li T, Logan GI, Baum L. Marginal accuracy of complete crowns made from alternative casting alloys. *J Prosthet Dent* 1991; 66: 157-164.
- Aykol H, Toparli M, Dalkiz M. A calculation of stress distribution in metal-porcelain crowns by using three-dimensional finite element method. *J Oral Rehabil* 2002; 29: 381-386.
- Gibbs CH, Mahan PE, Lundeen HC, Brehnan K, Walsh EK, Sinkewicz SL, et al. Occlusal forces during chewing-influences of biting strength and food consistency. *J Prosthet Dent* 1981; 46: 561-567.
- Kheradmandan S, Koutayas SO, Bernhard M, Strub JR. Fracture strength of four different types of anterior 3-unit bridges after thermo-mechanical fatigue in the dual-axis chewing simulator. *J Oral Rehabil* 2001; 28: 361-369.
- Sun F, Qian DS, Wei KL. The application of auro-galvanoforming ceramic crowns in clinic. *Chin J Stomatol (Chin)* 2000; 35: 447-449.
- Vence BS. Electroforming technology for galvanoceramic restorations. *J Prosthet Dent* 1997; 77: 444-449.
- Ringgenberg RA. Aesthetics and biocompatibility: strong, electroformed, pure gold for PFM crowns and bridge. *Dent Today* 2000; 19: 80-83.
- Haas M, Wimmer G, Polansky R. Galvanoforming for large-span fixed restorations in the treatment of periodontally compromised patients. *Int J Periodontics Restorative Dent* 2006; 26: 329-335.
- Ghazy MH, Madina MM. Fracture resistance of metal- and galvano-ceramic crowns cemented with different luting cements: *in vitro* comparative study. *Int J Prosthodont* 2006; 19: 610-612.

(Received May 5, 2008)
 Edited by LIU Dong-yun