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Original Article

The Effect of Finish Line Design on the Fracture Strength of Zirconia Copings

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ABSTRACT

Statement of the Problem: One of the major concerns about all ceramic crowns is their fracture resistance.

Purpose: The purpose of this *in vitro* study was to evaluate the effect of two marginal designs (shoulder 90°, shoulder 135°) on the fracture resistance of zirconia copings.

Materials and Method: In this *in vitro* study, 20 brass dies were prepared using milling machine: 10 with 1mm width shoulder 90° marginal design and the other 10 with 1mm width shoulder 135° finish line design. Zirconia cores with 0.5mm thickness and 30μm cement space were fabricated on brass dies. The copings were cemented on the dies and fracture test was done using a universal testing machine. Data were analyzed using Mann-Whitney test.

Results: The mean value of fracture resistance for shoulder 90° finish line design were 368.3±109.4 N and for shoulder 135° finish line design were 518.4±115.5 N. Data analysis revealed a statistically significant difference between groups ($p< 0.05$).

Conclusion: The results of this study showed that the finish line design of zirconia copings influences their fracture resistance. A 135° shoulder finish line design can improve the fracture resistance of zirconia crowns.

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Introduction

Requests for all-ceramic crowns are increasingly rising since they are superior to their metal-ceramic counterparts in terms of esthetic and biocompatibility [1]. However, the inherent weakness of ceramic against tensile forces restricts the application of these crowns particularly in posterior teeth [2]. Along with the developments in ceramic structure and broad application of high strength ceramics, these restorations are routinely employed in posterior teeth, although they are still less strong than metal ceramic restorations [3-4]. Nevertheless, the inherent ceramic weakness is not the one and only effective factor in failure of an all-ceramic restoration. Other factors including restoration thickness, the residual stresses remaining from the restoration fabrication procedures, the patient's oral habits like bruxism, margin preparation design, and the cement type also influenced the ultimate strength of restoration [1-3, 5-7].

Margin design is one of the factors which have been widely investigated concerning its impact on strength of all-ceramic restoration. To name a few, Jalalian *et al.* [5] evaluated the effect of chamfer and shoulder marginal designs on the fracture resistance of Inceram all-ceramic restorations and concluded that the strength created by the former is higher. In a different study by the same researcher [6], the same margin designs were assessed on zirconia cores and chamfer margin was found to have more increased the restoration strength than shoulder margin.

The fracture resistance of chamfer margin was also remarkably higher in a study enrolled by Cho *et al.* [8].

On the other hand, Di Lorio *et al.* [9] carried out a study on the effects of 50° chamfer and 90°shoulder margin designs on the fracture resistance of Procera all- ceram cores (with 0.4mm thickness) and reported that shoulder margin design is more resistant than chamfer. However, Sadan *et al.* [10] found both margin designs to be equally resistant.

Beuer *et al.* [11] investigated the effects of five different preparation design (shoulder-less, slight and pronounced deep chamfer, beveled and non-beveled shoulder) on the fracture resistance of zirconia copings with a wall thickness of 0.4mm. They observed the maximum fracture resistance in shoulder preparation, and also recommended the slight chamfer only for endodontically treated teeth with thin wall.

In a finite element analysis study, Shinya *et al.*[12] assessed the influences of four preparation designs (knife edge, chamfer, deep chamfer, and shoulder with rounded internal angles) on marginal stress distribution in ceramic and hybrid composite resin crowns. They concluded that the tensile and compressive stresses in margins of composite restorations were less than ceramics, besides that the stress was more evenly distributed in shoulder margin with rounded internal angles compared with knife edge. That study also reported deep chamfer as a favorable margin for ceramic crowns.

Reich *et al.* [13] studied the chamfer and knife edge preparations as well as the effect of cement thickness on the fracture resistance of zirconia crown copings. They reported the fracture resistance of zirconia copings finishing with knife edge margins was significantly higher than chamfer. Moreover, decreasing the thickness from 0.5 to 0.3mm has increased the resistance.

Diversity of the obtained results might be due to the various types of ceramic used in these studies, different core thickness and designs in margin area such as having collar. As mentioned above, there are widely divergent types of ceramic, each of which requires to be independently studied regarding most of the named factors.

Zirconia is among those ceramics, which has been extensively used in recent years, replacing other ceramics in most cases. Studies have also been performed on the effects of different margin designs such as slight chamfer, deep chamfer, shoulder, and beveled shoulder on the resistance of this ceramic [9, 11, 14]. One of the finish lines used in margin area is 135°shoulder, which benefits from the advantage of beveling in marginal area and subsequently having adequate preparation. This margin design is frequently used for metal-ceramic restorations; though it has not been assessed in all-ceramic restorations. The aim of this study was to evaluate the effect of 135° shoulder and 90° shoulder margin design on the fracture resistance of zirconia copings. The null hypothesis was that margin design does not influence the fracture resistance of zirconia copings.

Materials and Method

Fabrication of master dies

In this *in vitro* study, 20 standard brass dies were designed and prepared by CNC milling machine (CNC 350; Arix Co. Tainan Hesin, Taiwan) (Figure 1). Preparation was standardized using a wide smooth continuous margin, free of any irregularities. Each die was made to provide 6° occlusal convergence angle, and axial occluso-gingival height of 6.4mm, 5.5mm base width and 1.2mm margin thickness; half of the samples had a 135° shoulder margin (Figure 2a) and the other half with a 90° shoulder margin (Figure 2b) (n=10). The brass dies were visually inspected for any possible irregularities by a single operator utilizing a binocular loupes (Heine HR-C 2.5*; Heine, Herrsching, Germany).

Figure 1: Master dies

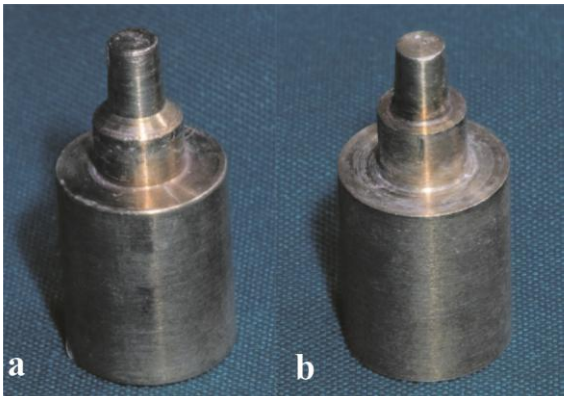

Figure 2a: Master die with 135 shoulder margin, **b:** Master die with 90 shoulder margin

Fabrication of copings

The dies were coded and transferred to laboratory to fabricate zirconia copings. They were first sprayed with an opaque spray to be prepared for the scanning process. Then they were scanned by laser scanner (3Shape D810; 3Shape, Copenhagen K, Denmark). The data were converted into a computer software (3Shape's CAD Design software; 3Shape, Copenhagen K, Denmark), in which the copings were designed with a thickness of 0.6 mm considering the 30 µm spacer 1mm short of margin. Copings were machined out of partially-sintered zirconia blocks (Vita In-ceram YZ-14, vient, Germany) in a milling machine (CORiTEC 340i; Imes-icore GmbH, Eiterfeld, Germany).

Before sintering, copings were steam cleaned. Then they were placed in the sintramat high-temperature sintering furnace (Ivoclar, Vivadent, Germany) for 8 hours at a temperature of 1540˚c to have copings sintered. The machined copings, which had to be 25% larger than master dies (to compensate sintering shrinkage), were transformed back into their original size after sintering. They were then placed over their related dies with respect to their codes, and were checked to be fit on the dies by use of a probe. Those samples that were not fit have been returned to the lab for refabricating. The thickness of the cores was measured with gauge in all dimensions. Then the dies were cleaned with alcohol-soaked cotton roll. The internal surface was cleansed and rinsed and air-dried with air/water spray for 15 seconds.

The copings were cemented with glass-ionomer luting cement (GC Corporation; Tokyo, Japan) which was mixed based on the manufacturer's instruction. It was inserted into the crown by use of an applicator and the copings were mounted on brass dies (Figure 3). The excessive cement was removed by using a probe and the final samples were stored in normal saline at room temperature for 24 hours.

In order to test the fracture strength, the samples were placed in Universal Testing Machine (Zwick 20; Zwick/ Roll, Germany). Harden steel balls (5mm in diameter) applied a perpendicular force at a crosshead speed of 0.5mm/min on the occlusal surface of each coping until failure occurred. The force leading to fracture of each sample was recorded by computer.

Statistical analysis

After collecting data and determining the mean and standard deviation values, the data were analyzed using Mann-Whitney test. All statistical analyses were performed using SPSS 16.0 for windows (SPSS 16.00 for windows; SPSS Inc, Chicago, USA).

Results

The mean ± standard deviation (SD) force leading to failure in 135° shoulder margin was 518.4±115.5 N and in 90° shoulder margin was 368.3±109.4 N. The maximum force tolerated was 712 N, observed in samples of 135° shoulder margin and the minimum was 250 N in 90° shoulder margin. Fracture strength was compared between the two groups by using Mann-Whitney test and statistically significant difference was detected ($p< 0.05$).

Discussion

The null hypothesis of this study was rejected because the margin design was found to have significantly affected the fracture strength of zirconia copings, and copings with 135° shoulder margin were significantly more resistant than those with 90° shoulder.

Figure 3: Zirconia copings placed on master dies

The minimum and maximum forces resulting in fracture were respectively 250 N in 90° shoulder margin and 712 N in 135° shoulder margin.

Several factors might have contributed in increasing the fracture resistance of zirconia restoration with 135° in comparison with those with 90° shoulder finishing lines including the presence of sharp internal angle in 90° shoulder margin. Shillingburg [16] proposed that due to the omitted internal sharp angles and the subsequently decreased concentration of stress inside the tooth and crown, radial shoulder margin is better than 90° shoulder for all-ceramic restorations [17]. In two other studies also, Jalalian *et al.* [5-6] observed that chamfer margin was more resistant than shoulder in zirconia and Inceram crown copings. They attributed this difference to the rounded internal angle as well as better force distribution and marginal fit of chamfer margin compared with 90° shoulder. In the current study, although the internal angle of 135° shoulder was not round, it was wider than 90° shoulder and subsequently stress may be less concentrated.

Presence of slope in 135° shoulder margin and better marginal fit can be considered as the second contributing factor. To debate on to bevel or not to bevel, Shillingburg [16] concluded that beveled margins have better fit and the vertical distance between the restoration and preparation margin is less. Similar interpretation can be proposed for 135° shoulder; i.e. this margin design consists of inclination, thus the vertical distance between the die and margin inclination area is less than the same distance in 90° shoulder. Consequently, die support better fits on zirconia core in margin area and the force would be more evenly distributed. Therefore, the fracture strength of crown complex with 135° shoulder margin is higher. Shillingburg [16] and also Rosential [17] believed that porcelain demands 90° shoulder margin to resist the occlusal forces; however, this hypothesis seems to be based on studies performed on ceramics of lower strength such as feldespathic ones. Increased strength of ceramics, particularly in zirconia, might have omitted the restricting factor of margin design in application of ceramics.

Easier removal of excess cement in 135° shoulder margin can be regarded as the third significant factor. When cementing the cores in our study, a considerable hydraulic pressure was produced between the cores and dies finishing with 90° margin, which might have been due to the form of margin and the impossibility of excess cement escape. The hydraulic pressure was so high in some samples that completely prevented the seating, so they were fractured and refabricated. Meanwhile, the hydraulic pressure was far less in cores with 135° shoulder margin, so the cores were easily cemented in place and the excessive cement was removed. This ease of cement removal can result in more perfect seating, better fit in margin area, and improved support of core by the metal die, which altogether enhances the crown resistance against the applied forces. Due to the inclination, 135° margin design has the advantage of better fit of beveled margins and can be easily prepared. Like the shoulder margin, 135° shoulder provides the suitable space for placement of core and veneer. This study suggests using this type of margin for zirconia restorations; however, the mass of difference between the strength of various ceramics does not allow generalizing the obtained results to other ceramics. Hence, further research must be conducted on other types of ceramics.

Conclusion

Within the limitations of this study, it can be concluded that marginal design of zirconia cores significantly influences their fracture resistance. The two marginal designs (shoulder 90°, shoulder 135°) had clinically acceptable fracture resistance. A 135° shoulder finish line design can improve the fracture resistance of the zirconia crowns.

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Conflict of Interest

The authors report no conflicts of interest.

References

[1] Ferracane JL. Using posterior composites appropriately.

J Am Dent Assoc. 1992; 123: 53-58.

[2] Etemadi S, Smales RJ. Survival of resin-bonded porcelain veneer crowns placed with and with-out metal reinforcement. J Dent. 2006; 34: 139-145.

[3] McLaren EA, White SN. Survival of In-Ceram crowns in a private practice: a prospective clinical trial. J Prosthet Dent. 2000; 83: 216-222.

[4] Webber B, McDonald A, Knowles J. An in vitro study of the compressive load at fracture of Procera AllCeram crowns with varying thickness of veneer porcelain. J Prosthet Dent. 2003; 89: 154-160.

[5] Jalalian E, Atashkar B, Rostami R. The effect of preparation design on the fracture resistance of zirconiacrown copings (computer associated design/ computer associated machine, CAD/CAM system). J Dent (Tehran). 2011; 8: 123-129.

[6] Jalalian E, Aletaha NS. The effect of two marginal designs (chamfer and shoulder) on the fracture resistance of all ceramic restorations, Inceram: an in vitro study. J Prosthodont Res. 2011; 55: 121-125.

[7] Ahmadzade A, Golmohammadi F. Comparison of fracture resistance in two marginal design in IPS Emax restorations. J Mash Dent Sch. 2015; 39: 109-116.

[8] Cho L, Choi J, Yi YJ, Park CJ. Effect of finish line variants on marginal accuracy and fracture strength of ceramic optimized polymer/fiber-reinforced composite crowns. J Prosthet Dent. 2004; 91: 554-560.

[9] Di Iorio D, Murmura G, Orsini G, Scarano A, Caputi S. Effect of margin design on the fracture resistance of Procera all ceram cores: an in vitro study. J Contemp Dent Pract. 2008; 9: 1-8.

[10] Sadan A, Blutz MB, Lang B. Clinical consideration for densly sintered alumina and zirconia restorations. Part1. International Journal of Periodontics and Restorative Dentistry. 2005; 25: 213-219.

[11] Beuer F, Aggstaller H, Edelhoff D, Gernet W. Effect of preparation design on the fracture resistance of zirconiacrown copings. Dent Mater J. 2008; 27: 362-367.

[12] Shinya A, Lassila LV, Vallittu PK. The effect of preparation design on the marginal stress of resin-bonded metal-free crowns: a finite element study. Int J Prosthodont. 2008; 21: 445-447.

[13] Reich S, Petschelt A, Lohbauer U. The effect of finish line preparation and layer thickness on the failure loadand fractography of ZrO2 copings. J Prosthet Dent. 2008; 99: 369-376.

[14] Jalali H, Sadighpour L, Miri A, Shamshiri AR. Comparison of Marginal Fit and Fracture Strength of a CAD/CAM Zirconia Crown with Two Preparation Designs. J Dent (Tehran). 2015; 12: 874-881.

[15] Monaco C, Rosentritt M, Llukacej A, Baldissara P, Scotti R. Margin-al Adaptation, Gap Width, and facture strength of teeth Restored with different all-ceramic Vs Metal Ceramic Crown Systems: An in Vitro Study. Eur J Prosthodont Restor Dent. 2016; 24: 130-137.

[16] Shillinburg HT. Fundamentals of fixed prosthodontics. 4th ed. Quintessence: USA; 2012. p. 142.

[17] Vojdani M, Safari A, Mohaghegh M, Pardis S, Mahdavi F. The effect of porcelain firing and type of finish line on the marginal fit of zirconia copings. J Dent (Shiraz). 2015; 16: 113-120.

[18] Fujimoto J, Land MF, Rosensteil SF. Contemporary fixed prosthodontics. 4th ed. Mosby Elsevier: USA; 2006. p. 324.