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REVIEW

The role of shoulder and chamfer margin design on the fracture resistance of zirconia crown

Andri Corentus Leo,[1] Ariyani,[2]* Syafrinani[2]

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ABSTRACT

In recent years, zirconia all-ceramic restorations are widely used in crown and bridge treatment due to their superior mechanical properties and aesthetics. Zirconia is the strongest ceramic material, thus it is the treatment of choice for posterior dental restorations. One factor that affects the fracture resistance of zirconia restoration is the margin design. The shoulder and chamfer are the recommended margin design to obtain maximum fracture resistance from zirconia restoration. Shoulder is recommended because it has greater fracture resistance while chamfer is more conservative and able to withstand maximum masticatory load. However, there is still a difference of opinion regarding the fracture resistance of zirconia crown with shoulder and chamfer margin designs. This literature review aims to discuss the role of chamfer and shoulder margins design on the fracture resistance of zirconia crown. The shoulder margin design results in a wide ledge, space for adequate restoration contours and maximum aesthetics that provide resistance to occlusal forces and minimizes stress that can cause fracture. The chamfer margin design on zirconia crown has a difference in the rounded internal angle of the preparation resulting in better force distribution, better marginal fit and more resistance to fracture compared to the shoulder margin design. Chamfer margin design is more conservative and resistant to fracture due to better marginal fit which distribute stress more evenly. (IJP 2024;5(2):98-101)

Introduction

All-ceramic zirconia restorations have been widely used in recent years for crown and bridge restorations due to their superior mechanical and aesthetic properties. Zirconia is the strongest ceramic material so it is a treatment option in posterior tooth restorations. However, fractures remain a complication for all ceramic restoration in clinical practice.[1-3]

Margin design is one of the factors which have been widely investigated concerning its impact on fracture resistance of all-ceramic restoration. The most common margin designs used for all ceramic restoration include chamfer, deep chamfer, chamfer with collar, round end shoulder & shoulder.[4] Shoulder and chamfer are recommended designs to achieve maximum fracture resistance from zirconia restoration. Shoulders are indicated for planning aesthetic restorations but require more preparation of the tooth structure than other design margins.5,6 The wide ledge provides resistance to occlusal forces and minimizes stresses that might lead to fracture.6 On the other hand, chamfer is also the best choice that can also provide space for sufficient material thickness for restoration strength and can form precise axial anatomical contours and has good adaptability. The preparation of margin design chamfers requires precision at the time of preparation to avoid leaving a lip of unsupported enamel.[5,6]

Some studies have shown different results regarding the effect of shoulder and chamfer margin design on zirconia crown fracture resistance. Evaluated the effect of chamfer and shoulder margin design on the fracture resistance of the Inceram all-ceramic crown and reported that the strength of the shoulder margin design was better. On the other hand, the study showed that the fracture resistance of the chamfer design margin is higher. Then the study of Sadan et al. reported that the margin design of the shoulder and chamfer have the same fracture resistance value.[7]

Therefore, this literature review aims to discuss the effect of different margin designs, chamfer and shoulder, on zirconia crown fracture resistance.

Literature Studies

Zirconia

Dental ceramics have been applied as restorative materials for decades due to their superiority to other materials in terms of properties and their natural tooth mimicking ability. Zirconia has been introduced and widely used for load bearing as dental crowns, fixed partial dentures (FPDs) and dental implants.1,2 Zirconia was suggested as the first candidate for full contour monolithic restorations due to its significant advantages, such as excellent mechanical properties, superior to those of other ceramic systems, esthetic performance comparable to that of metal-ceramic restorations, radiopacity, low corrosion potential, good chemical properties, volumetric stability and elastic modulus values comparable to steel. According to in-vitro

1Specialist Program in Prosthodontics, Faculty of Dentistry, Universitas Sumatera Utara, Medan, Indonesia
2Department Prosthodontics, Faculty of Dentistry, Universitas Sumatera Utara, Medan, Indonesia
*Corresponding author: ariyani@usu.ac.id

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studies, zirconia restorations exhibit flexural or bending strength values of 900–1200 MPa and resistance to fracture of 9–10 MPa.10 With the advances in digital technology, intraoral scanners and CAD/CAM, it has become possible to create dental restorations digitally with easy processes and designs and high accuracy.[19]

Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) is widely used in dentistry due to its superior mechanical properties, similar to ceramic metal crowns and considered the golden rule in fixed prostheses. Zirconia is classified as a polycrystalline ceramic. Zirconium oxide crystals can be categorized into three crystallographic phases: monoclinic (m) at room temperature, has weak mechanical properties; tetragonal (t) at temperatures between 11700C – 23700C, characterized by the best mechanical properties; and cubic (c) at temperatures above 23700C and exhibiting average mechanical properties. Since phase (t) has the most excellent mechanical properties, it will be stabilized at room temperature by the addition of stabilizers/dopants (magnesium, calcium or yttrium). In dentistry, yttrium has been found to have the best mechanical properties for stabilizing zirconia.[20]

Regarding the fabrication of monolithic zirconia crowns, the marginal areas are areas of minimal thickness that frequently lead to the easy fracture of the crown. The source of the failure originating in the margin of the zirconia restoration may relate to the margin design, as well as the thickness of the margins. Several investigations have been carried out with regard to the effect of the margin design on the load-bearing capacity of zirconia restoration in relation to occlusal thickness and wall thickness.12 Other factors including restoration thickness, occlusal load, the patient's oral habits like bruxism, and the cement type also influenced the ultimate strength of restoration.[7,11]

Margin Design

Margin design is one of the factors which have been widely investigated concerning its impact on strength of all-ceramic restoration.[7] Margin failures may be related to the design and thickness of the crown margins. Multiple studies have been performed in order to evaluate the effect of margin design on load at fracture, but the results are inconclusive. Several studies find that the margin design has an effect on the fracture resistance, while others see no such effect.

The fracture pattern of crowns fractured during clinical use demonstrates fracture origins in the cervical margin of the crown and often occur at the proximal area of the crown, where the finish line curves toward the occlusal surface over the gingival papilla. Clinical recommendations for margin design are based on previous experiences with all-ceramic crowns and also on the design of metal-based crowns.

It is not evident whether these recommendations are optimal for the modern high-strength zirconia restorations. Most manufacturers of dental ceramics advise dentists to remove up to 0.5–1.5 mm of tooth substance to make room for a bilayer ceramic crown. A preparation depth of 1.5 mm increases the risk of negative effects on tooth vitality. Based on mechanical properties, zirconia crowns can probably be made using a minimal invasive slice preparation technique, as suggested by some manufacturers and in scientific papers. However, it is still uncertain which design provides optimal balance between crown strength and tooth vitality.[8]

The most commonly used margin designs for all-ceramic restorations include chamfer, deep chamfer, chamfer with collar, round end shoulder & shoulder.[4] Shoulder and chamfer are the most widely used designs for zirconia crown. The shoulder has long been the finish line of choice for the all-ceramic crown. The wide ledge provides resistance to occlusal forces and minimizes stresses that might lead to fracture of the porcelain. It produces the space for healthy restoration contours and maximum esthetics. However, it does require the destruction of more tooth structure than any other finish line. The sharp, 90-degree internal line angle associated with the classic variety of this finish line concentrates stress in the tooth and is conducive to coronal fracture. The shoulder generally is not used as a finish line for cast metal restorations.[6]

Some studies shown that zirconia crown with chamfer margin design has increased fracture resistance. Chamfer is a concave extra coronal margin design that provides greater angulation than the knife-edge design and a smaller width than the shoulder design. The advantage of chamfer design is more conservative, has clear margins and easy to identify. Chamfer is the best for providing the bulk needed for strength while still allowing good adaptation.6 Various studies have different results regarding the effect of the type of margin design on the fracture resistance of zirconia crowns. 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, the same margin designs were assessed on zirconia cores and chamfer margin was found to have more increased the restoration strength than shoulder margin. On the other hand, 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.

Fracture Resistance

All-ceramic restorations have been widely applied in prosthodontics as metal-free restorations because of their good esthetics and excellent biocompatibility. However, fractures remain a complication for all-ceramic restorations in clinical practice. Fracture resistance depends on the elastic modulus of the abutment, the properties of the luting agent, tooth preparation design, surface roughness and restoration thickness. The tooth preparation design is an especially important factor in determining the strength of all-ceramic crowns. Additionally, the elastic modulus of restoration materials is an important factor in crack initiation and propagation within a dental ceramic. The stress in all-ceramic crowns during mastication has been reported to be higher near the cervical margin than on the occlusal surface. During clinical use, cracks may be induced from the occlusal surface to the thin margin. However, little is known regarding the influence of a margin design with zirconia on the fracture resistance of all-ceramic crowns.[9]

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Some investigations into the fracture resistance of all ceramic restorations were carried out by applying an occlusal load, either longitudinally or obliquely, on anatomical crowns until fracture, indicating that the fracture was possibly influenced by the design of the margin in the restoration.[12] It has been reported that monolithic zirconia crowns exhibit fracture resistance that can withstand occlusal loading, even with a limited thickness, when compared to conventional ceramic materials. It is well known that the marginal accuracy is one of the key factors affecting the long-term prognosis of a prosthesis.[13]

Discussion

In the literature, data showed that differences in the margin design clearly affect the fracture resistance of the crown restoration. Most studies of fracture resistance in single crown restorations have shown that the cervical area has high stress. The best choice of margin design for zirconia crown is still uncertain.

That chamfer finish line design has the greatest stability for posterior all ceramic crowns. The effect of finish line design on fracture resistance of composite-reinforced ceramic restorations and demonstrated that the fracture resistance of chamfer finish line design samples was significantly higher than shoulder finish design. That for long lasting restorations in posterior region it is advisable to make a chamfer with collar preparation.

The effect of two marginal designs (shoulder and chamfer) on the fracture resistance of all ceramic restorations, INCERAM. The mean value of fracture resistance for the chamfer samples were 610.18 ± 58.79 N and 502.72 ± 105.83 N for the shoulder samples. This study reveals that the chamfer margin has more fracture resistance than shoulder margin. A chamfer margin could improve the biomechanical performance of posterior single crown alumina restorations. This may be because of a much better marginal fitness in chamfer margin that happens because of a curve in the chamfer finishing line and that causes a better spread in the load. However, we do not have such a condition in a 90o in shoulder margin that have sharp endings. d = D cos b and d = D sin a. D is vertical discrepancy between the restoration and tooth and d is horizontal discrepancy between the restoration and tooth. In addition we know that horizontal discrepancy is more important than vertical discrepancy, which is the real gap between the restoration and teeth. The lower horizontal discrepancy makes better fitness between the restoration and teeth. In chamfer margin horizontal discrepancy < vertical discrepancy. But in the shoulder margin horizontal discrepancy = vertical discrepancy. In this situation we have the worse marginal fitness in addition there is not a strong unity between the restoration and teeth that makes a lower fracture resistance than the chamfer margin does. Furthermore, in chamfer finishing line we have an angled cut of enamel that makes the higher width of enamel in exposure to etch and bonding, so we have strong bonding and unity between the restoration and teeth that makes higher fracture resistance than shoulder margin because as we know in this finishing line we have the lower width of enamel that is important in the bonding of the restoration and teeth.

The effect of two marginal designs namely deep chamfer and shoulder margin design on the fracture resistance of monolithic zirconia crowns. Results showed that the highest fracture resistance values were recorded with Deep chamfer finish line. That zirconia crowns made for a chamfer preparation fracture at significantly higher loads than similar crowns made for a slice preparation design. Heavy chamfer margins provided a stronger and more durable zirconia crown than light chamfer margin. Nevertheless, both heavy and light chamfer margins were capable of withstanding a fracture load that is higher than the maximum masticatory force of humans.

The fracture resistance of chamfer and shoulder margins under a cyclic load of Inceram crowns. The mean ± standard deviation for the resistance of fracture came out to be 610.1880±58.79526 N for chamfer margin and 502.7270±105.83233 N for that of shoulder margin. Fracture resistance of the two groups are more than biting forces so we could use both marginal designs successfully in the posterior all ceramic crowns. But there is a statistically significant difference between the two groups that reveals that the chamfer margin has more fracture resistance than shoulder margin. This may be because of a much better marginal fitness in chamfer margin that happens because of a curve in the chamfer finishing line and that causes a better spread in the load.

Marginal accuracy and fracture resistance between deep chamfer and shoulder margin. Mean values of marginal accuracy after cementation for deep chamfer 40.38 ± 9.47 μm and shoulder margin groups 77.4 ± 14.3 μm. The mean value of fracture resistance for deep chamfer 1874 ± 723 N and shoulder margin 1069 ± 288 N. They concluded that deep chamfer margin shows better fracture resistance than shoulder margin for zirconia copings. They suggested that this could be because of a curve in the chamfer finish line that causes a better spread in the load. However, such a condition does not exist in a 90º shoulder margin that has sharp endings. The deep chamfer margin showed better marginal accuracy than the shoulder margin for zirconia coping restoration. It is because the deep chamfer used in this study, apparently facilitated the escape of cement early in the cementation process & thus offered a better seal.

The resistance to fracture under a cyclic load applied to chamfer margin and shoulder margin Procera® All Ceram cores. The mean values of fracture resistance for the chamfer samples were 406.10 ± 67.271 N and 643.90 ± 32.912 N for the shoulder samples. The results of this in vitro study indicate a relationship between the cervical thickness of the alumina cores and their fracture resistance. A shoulder margin could improve the biomechanical performance of posterior single crown alumina restorations.

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 0.4 mm. They observed the maximum fracture resistance in shoulder preparation, and also recommended the slight chamfer only for endodontically treated teeth with thin wall.

Evaluated and compared the fracture resistance of monolithic zirconia crowns with two preparation designs, shoulder margin

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design and feather-edge margin design. Teeth were randomly divided into two groups (n = 20), according to the material used: Group A monolithic traditional zirconia (IPS e.max ZirCAD LT A3, W89335, Ivoclar Digital, Liechtenstein, Germany) and Group B monolithic translucent zirconia (IPS e.max ZirCAD MT Multi A3, X29480, Ivoclar Digital, Liechtenstein, Germany). They were further subdivided into two subgroups (n = 10) according to the type of margin design: subgroup A1 and B1 shoulder margin design and subgroup A2 and B2 feather-edge margin design. Even though all the tested crowns fractured at a higher level than the maximum occlusal forces s (850 N), the shoulder margin design was better than the feather-edge margin design. They found that monolithic traditional zirconia with shoulder margin design has higher fracture load than monolithic traditional zirconia with feather-edge margin design in both groups. It might be because the stress distribution pattern in the shoulder margin design as the circumferential shoulder withstands occlusal forces and results in less concentration of stress on axial walls. Furthermore, an increase in the crown margin and axial wall thickness lead to fracture at a higher load.

Evaluate the effect of two marginal designs (shoulder 90°, shoulder 135°) on the fracture resistance of zirconia copings. 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. They 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. 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. Internal angle of 135° shoulder 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. 135° shoulder margin consists of inclination, thus the vertical distance between the die and margin inclination area is less than 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.

That rounded shoulder margins and deep chamfer margins combined with monolithic zirconia crowns, potentially have optimal geometry to minimize occlusal force. Sadan et al. (2005) proposed that chamfer and shoulder margin design are considered to be adequate for the tooth.

Conclusion and Suggestion

It is concluded that shoulder and chamfer finish line design still the main choice in fixed partial denture. Wide ledge of shoulder design provides resistance to occlusal forces and gives space to healthy restoration with maximum esthetic but it is less conservative of tooth structure and stress concentration at 90° internal angle of finish line hence conducive to coronal fracture. Chamfer finish line has concave form. It provides greater angulation than knife edge and less width than shoulder. Chamfer are more conservative with distinct margin and easy to identified and also improve biomechanical performance compared to preparation with a shoulder finish line. The choice of margin design has an influence on the fracture resistance for a long-term crown restoration. Careful planning of the margin design and selection of restorative materials is important before treatment. Based on the data, it can be concluded that the chamfer margin design is more conservative and resistant to fracture because it has better marginal fittings so that it can distribute pressure more evenly.

The optimal design margin to achieve fracture resistance of zirconia crowns still varies, especially with the rapid development of zirconia. Therefore, further research is needed to determine the optimal margin design to achieve the best fracture resistance in zirconia crown restorations.

References

1. Gautam C et al. Zirconia based dental ceramics: structure, mechanical properties, biocompatibility and applications. The Royal Society of Chemistry. 2016
2. Shaker M Hakami et al. CAD/CAM Zirconia: Case Report and Narrative Review of Present and Future of Dental Restorations in the Aesthetic Zone. Saudi J Oral Dent Res. 2021; 6(7): 292-299.
3. McLaren EA, Giordano RA. Zirconia-Based Ceramics: Material Properties, Esthetics, and Layering Techniques of a New Veneering Porcelain, VM9. Quintessence of Dental Technology. 2005: 99-111.
4. Neha M et al. To Evaluate the Effect of Different Margin Designs on Marginal Accuracy and Fracture Resistance of Zirconia Core Restorations. Int J Cur Res Rev. 2021; 13(21): 116-123
5. Stephen F. Rosenstiel, Martin F. Land JF. Contemporary fixed prosthodontics. 2016. 5th ed.. http://evolve.elsevier. com/Rosenstiel/prosthodontics/
6. Shillingburg HT. Fundamentals of fixed prosthodontics; 2012. 4 th ed. Chicago: Quintenssence.
7. Hashemi Ardakani Z, et al. The Effect of Finish Line Design on the Fracture Strength of Zirconia Copings. J Dent Shiraz Univ Med Sci. 2019; 20(4): 271-275.
8. Skjold et al. Effect of margin design on fracture load of zirconia crowns. Eur J Oral Sci 2019; 127: 89–96
9. Miura et al. Effect of finish line design on stress distribution in bilayer and monolithic zirconia crowns: a three-dimensional finite element analysis study. Eur J Oral Sci. 2018; 1–7.
10. E. Kontonasaki et al. Strength and aging resistance of monolithic zirconia: an update to current knowledge, Japanese Dental Science Review. 2020; 56: 1–23.
11. Soleimani F et al. Retention and Clinical Performance of Zirconia Crowns: A Comprehensive Review. International Journal of Dentistry. 2020; 1-6.
12. Juntavee N, Kornrum S. Effect of Marginal Designs on Fracture Strength of High Translucency Monolithic Zirconia Crowns. International Journal of Dentistry. 2020; 1-6.
13. Kim SH et al. Fracture Resistance of Monolithic Zirconia Crowns Depending on Different Marginal Thicknesses. Materials. 2022; 15(4861): 1-10.
14. Alzahrani AM et al. The Influence of the Cervical Finish Line Designs on the Fracture Resistance of CAD/CAM Monolithic Zirconia Crowns, an in Vitro Study. IJHSR. 2018; 8(2): 101-110.
15. Jalalian E et al. The effect of two marginal designs (chamfer and shoulder) on the fracture resistance of all ceramic restorations, Inceram: An in vitro study. Journal of Prosthodontic Research. 2011; 55: 121–125.
16. Findakly et al. Influence of preparation design on fracture resistance of different monolithic zirconia crowns: A comparative study. J Adv Prosthodont. 2019; 11: 324-330.
17. Di Iorio et al. Effect of Margin Design on the Fracture Resistance of Procera® All Ceram Cores: An in vitro Study. The Journal of Contemporary Dental Practice. 2008; 9(2): 1-9.
18. Ravishankar K et al. Comparative Evaluation of the Effect of Chamfer and Shoulder on the Fracture Resistance of all Ceramic Restorations: An in Vitro Study (Chamfer vs Shoulder). Glob Acad J Dent Oral Health. 2020; 2(1): 4-9
19. Kongkiatkamon S et al. Current classification of zirconia in dentistry: an updated review. PeerJ. 2023; 11(15669): 1-19.
20. Haddad C, Azzi K. Influence of the Type and Thickness of Cervical Margins on the Strength of Posterior Monolithic Zirconia Crowns: A Review. Eur J Gen Dent. 2022; 11:73–80.

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