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Influence of the Type and Thickness of Cervical Margins on the Strength of Posterior Monolithic Zirconia Crowns: A Review

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Abstract

The aim of this research is to review the literature for the influence of the thickness and shape of cervicalmargins on the strength of posterior monolithic zirconia crowns. Studies to assess the fracture resistance of monolithic zirconia crowns with different types of cervical margins, published from 2014 to 2020, were searched using the electronic database PubMed and Google Scholar using the following keywords: "monolithic zirconia," "translucent," "shoulderless," and "margin preparation design." Analysis of studies has shown that overall the design of the margin would have a significant effect on the strength of these crowns. Monolithic zirconia crowns with a knife-edge margin have shown a breaking load higher than the maximum chewing force of humans. It would be safe to suggest the utilization of posteriormonolithic zirconia crowns with vertical preparation. As the new translucent monolithic zirconia crowns are recent, further studies would be needed to guide the selection of the appropriate minimum thickness of the knife-edge margin to meet the clinical guidelines for their use.

Keywords
- margin preparation design
- monolithic zirconia
- shoulderless
- translucent

Introduction

The yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) is widely used in dentistry for its high mechanical properties that are close to those of the ceramic-metal crown which has always been used and considered to be the golden rule in fixed prosthesis.[1] Zirconia is classified as polycrystalline ceramic; in its structure there is no vitreous phase.[2] Zirconium oxide crystals can be categorized into three crystallographic phases: monoclinic (m) at room temperature, it has weak mechanical properties; tetragonal (t) or quadratic at a temperature between 1170°C and 2370°C, it is characterized by important mechanical properties; and cubic (c) at a temperature above 2,370°C and exhibits average mechanical properties.[2]

At the sintering temperature, the zirconia is tetragonal and it is during cooling that the t–m transformation occurs accompanied by an increase in volume (~5%) that causes the zirconia to crack. To avoid the t–m transformation phenomenon during cooling, dopants must be used. The tetragonal phase is metastable and may be able to transform into the monoclinic phase if mechanical or chemical energy is supplied to the (t) grains. This is the basis of the phenomenon of reinforcement by phase transformation, but also of aging.[3]

As phase (t) has exceptional mechanical properties, it will be stabilized at room temperature by the addition of dopants (magnesium, calcium or yttrium). In dentistry, yttria has been found to have the best mechanical properties for stabilizing zirconia.[2]

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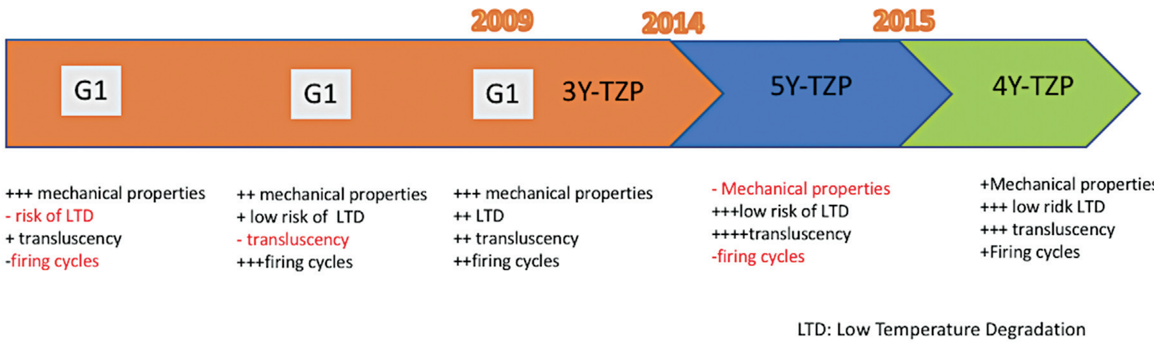

Fig. 1 Evolution and characteristics of dental zirconia types.

The development of computer-assisted design/computer-assisted manufacturing (CAD/CAM) has further increased the use of zirconia. But its major problem remained its unsightly appearance. Due to its high opacity, tetragonal zirconia stabilized at 3 mol% yttrium has been used in "bilayered" prostheses as a porcelain-veneered Y-TZP crown cores. This type of restoration has shown a fairly high initial stability and the most favorable in the long term.[4] Despite its aesthetic success and its strong resistance, its major failure was the chipping of the ceramic covering.[5]

The advent of monolithic zirconia stabilized at 4 and 5 mol% yttrium resolved this failure by eliminating the veneer ceramic (►**Fig. 1**). In addition, this monolithic zirconia has allowed the development and improvement of the aesthetics of zirconia, by modifying its structure and making it more translucent.[6] But, this zirconia did not achieve the translucency found in natural dentition. Lately, the brand new "multilayer" monolithic zirconia has been developed, and it is characterized by its different layers, each with a different translucency, giving it a more aesthetic appearance while preserving the high mechanical properties of the zirconia.[7]

The cervical margin of a tooth is the surface that connects the intact part of the tooth and the prepared part of the tooth.[8] The junction between the crown and the surface of the prepared tooth is always a potential site for recurrent caries due to the dissolution of the cement and the inherent interface roughness. Good marginal adaptation is necessary to reduce the risk of recurrence of caries or periodontal involvement.[9]

The marginal fit may be influenced by the design of the cervical margin.[10] Some authors have suggested that a marginal gap between 100 and 150 µm is acceptable for various restorations.[11]

Smooth and precisely placed margins are particularly important when restorations are fabricated by CAD/CAM.[9]

In the literature, we find different types of margin designs, such as the chamfer margin that gives volume to the cervical limit, the shoulder margin one of the oldest cervical limits that can have different angulations: 90 degrees shoulder, 120 to 135 degrees obtuse angle shoulder, and rounded internal angle shoulder, with or without bevel,[12] and the knife-edge margin that entails minimal preparation and gradually joins the crown and the tooth.[8] To support the veneered ceramic crown, the recommended margin design were fairly wide chamfers or shoulders; these margins were then taken as a reference for all-ceramic crowns.[8] With high strength ceramics, it is possible to make more conservative margin preparations without compromising the fracture resistance of the ceramic (►**Figs. 2**–**3**). Some authors advocate the use of a knife-edge cervical margin with high strength monolithic zirconia crown.

The design of the knife-edge is considered to be the most conservative margin as it preserves a maximum amount of healthy tooth structure. This type of preparation is especially recommended for teeth with reduced periodontium, vital teeth in young people or endodontically treated teeth,[8] it requires a less thickness of cement, it ensures good retention,[12] and it presents a good marginal adaptation: the mean values of the marginal hiatus measurements for the knife-edge type (68 ± 9 µm) were significantly lower than those for the chamfer (128 ± 10 µm), shoulder (95 ± 9 µm), and mini chamfer (97 ± 12 µm).[13] However, it is important to assess the mechanical behavior of zirconia with this margin design since the strength of all-ceramic

Fig. 2 Research on the development of 0.3mm thickness margins with multilayered monolithic zirconia posterior crowns (Courtesy of Dr. Camille Haddad).

Fig. 3 Measurement of the marginal thickness of a monolithic zirconia crown (0.3 mm).

crowns depends not only on the mechanical properties of the material but also on the type of preparation and the thickness of the material.[14]

What is the ideal margin design for monolithic zirconia crowns?

To answer this question, the research was based on numerous readings of studies dealing with the strength of monolithic zirconia with different types of preparation.

The purpose of this article is to review the literature on the influence of the thickness and shape of cervical margins on the strength of posterior monolithic zirconia crowns.

Methods

The targeted question was formulated on the basis of the PICO model: (1) Population: Monolithic zirconia crowns. (2) Intervention: Knife-edge margins. (3) Comparison: All other types of cervical margins. (4) Outcomes: Fracture resistance. The targeted question of the review presented was: "Do knife-edge margins give monolithic zirconia crowns the same or different fracture resistance than other types of cervical margins?"

Studies to assess the fracture resistance of monolithic zirconia crowns with different types of cervical margins, published from 2014 to 2021, were searched using the electronic database PubMed and Google Scholar using the following keywords: "monolithic zirconia," "translucent," "shoulderless," and "margin preparation design." Any irrelevant publication has been excluded and the articles chosen must meet the selection criteria.

Selection

In vitro studies evaluating the strength of monolithic zirconia crowns with different types of cervical margins, especially with knife-edge margins, were selected.

Exclusion criteria involved studies of partial restorations, feldspathic ceramic-coated zirconia copings, bridges, implant-supported crowns, studies comparing fracture resistance without considering the type of margin and studies that compare different types of cervical margins without investigating crown fracture resistance.

Results

All the studies chosen are in vitro studies performed on monolithic zirconia crowns with different types of preparation (see ►**Table 1**). The research focuses on the vertical cervical limits called the knife edge and studies selected is limited to nine.

Among These Studies

Two Studies Compared the Shoulder Margin and Vertical Preparation

The first study showed that the highest mean values of fracture resistance were recorded in kilonewton and the highest value was recorded by subgroup A1(shoulder margin) (2.903) followed by subgroup A2(feather-edge) (2.3), subgroup B1(shoulder margin) (1.854), and subgroup B2 (feather-edge) (1.523). Group A represents the traditional monolithic zirconia and group B represents the translucent monolithic zirconias.[15]

The second study showed that (insignificant) the highest mean value was recorded with the vertical (Celtra Duo VCD, Dentsply Sirona, Germany) CD group (482.5 ± 103.8 N) and the vertical K (KATANA VK, Noritaka, Japan) group (1347.6 ± 177.4 N) versus the horizontal CD group (471 ± 107.6 N) and the horizontal K group (1255.6 ± 121.3 N).[16]

Three Studies Compared the Chamfer Margin and Vertical Preparation

The first study showed that the highest mean fracture load was recorded by the shoulderless subgroup (1 mm occlusal thickness) (3,992.5 N), followed by the shoulderless subgroup (3,244.4 N) and the slightly chamfered subgroup (2,811 N).[17]

The second study showed that the mean values of fracture resistance varied between 3,414 N (low temperature degradation; 0.8 mm chamfer preparation) and 5,712 N (control group; shoulderless preparation).[18]

The third study showed that the highest mean of fracture load was recorded by chamfer (2,969.8 N), followed by modified vertical (2,899.3 N) and the lowest mean of fracture load was recorded by vertical (2,717.9 N).[19]

Two Studies Compared the Shoulder Margin and the Chamfer Margin

The first study showed that the mean values of fracture resistance for CAD/CAM group showed $1{,}367.250 + 178.967$ N

Table 1 Representation of the characteristics and the results of the included studies

Title and year	Types of crown	Types of margins	Fracture resistance measurement method	Results
"Influence of preparation design on fracture resistance of different monolithic zirconia crowns: A comparative study"[15] 2019	Group A: Traditional monolithic zirconia (IPS e.max ZirCAD LT A3, W89335, Ivoclar Digital) Group B: Translucent monolithic zirconia (IPS e.max ZirCAD MT Multi A3, X29480, Ivoclar Digital)	Human maxillary premolars divided into groups. (A1, B1): the shoulder margin of 1 mm; (A2, B2): the feather-edge margin	Compressive axial load until fracture by a universal testing machine Thermocycling by an automatic thermocycling device	Higher breaking load with a shoulder margin compared with the feather-edge margin Higher breaking load of traditional monolithic crowns compared with translucent monolithic
"Influence of the preparation design and artificial aging on the fracture resistance of monolithic zirconia crowns"[18] 2016	Monolithic zirconia crowns (ZenoTec Zr Blank, Wieland)	Three different preparation designs: shoulderless preparation, 0.4 mm chamfer and 0.8 mm chamfer preparation	1—TCML: 5,000 cycles of thermocycling 5–55°C and chewing simulation (1,200,000 cycles, 50 N) 2—Simulation LTD: autoclave treatment at 137°C, for 3 hours and chewing simulation 3—No pretreatment Then the crowns were loaded until fracture in a universal testing machine	The highest mean fracture loads were observed for the shoulderless preparation in the control group The lowest mean breaking load was observed for the preparation for leave after LTD
"Effect of Reduced Occlusal Thickness with Two Margin Designs on Fracture Resistance of Monolithic Zirconia Crowns"[17] 2020	Monolithic zirconia crowns (IPS e.max ZirCAD MT A2 98.514 mm; Ivoclar digital)	Group A: slight chamfer margin of 0.5 mm in width. Group B: shoulderless margin. Two subgroups according to occlusal thickness (0.5 and 1 mm)	Thermocycling: at (5 and 55°C) for 500 cycles (each cycle 30 seconds) Static load until failure in a universal testing machine	The highest mean fracture load (3,992.5 N) was recorded with the shoulder-less margins (1mm of occlusal thickness) The lowest mean of fracture load (1,632.9 N) was recorded with the slight chamfer (0.5 mm of occlusal thickness)
"Fracture resistance of monolithic zirconia molar crowns with reduced thickness"[22] 2015	Monolithic zirconia crowns (Lava Plus Zirconia, 3M/ESPE) with specified thicknesses and lithium disilicate crowns of regular thickness	Plastic models of tooth 46 prepared with chamfer margin (width: 0.5, 0.7, and 1.0 mm) The occlusal thickness was defined as 0.5, 1, and 1.5 mm	In a universal testing machine, a compressive load at a speed of 0.5 mm/min until failure The thicknesses of all samples were evaluated with micro-CT	The fracture load is higher with large occlusal thicknesses No significant difference in fracture load between different axial thicknesses
"An evaluation of the influence of different finishing lines on the fracture strength of full contour zirconia CAD/CAM and heat press all-ceramic crowns"[20] 2015	Monolithic zirconia crowns (Zolid, Ceramill Systems, Amann Girrbach GmbH, Pforzheim, Germany and heat press ceramic crowns (Cergo Kiss, DeguDent, Hanau-Wolfgang, Germany)	Thirty-two maxillary first premolars were divided into groups: shoulder margin (1.2 mm thick) and deep chamfer margin (1 mm)	The cemented crowns are stored in water at room temperature, then subjected to a thermal cycle Then loaded vertically in the universal testing machine (0.5 mm/min) until fracture	The lowest fracture resistance was recorded by the group of heat-pressed Ceramix crowns with a deep chamfer margin. The highest fracture resistance was with the CAD/CAM monolithic zirconia crowns with a 90-degree shoulder margin

Table 1 (*Continued*)

Title and year	Types of crown	Types of margins	Fracture resistance measurement method	Results
"Evaluation of zirconia and zirconia-reinforced glass ceramic systems fabricated for minimal invasive preparations using a novel standardization method"[16] 2020	Two groups of crowns: zirconia-reinforced glass ceramic (Celtra Duo) and monolithic zirconia group K (KATANA)	Forty maxillary premolars divided into two groups: Horizontal group H: shoulder margin (1 mm) Group V (vertical): feather-edge margin. (0.5 mm)	The samples were subjected to 5,000 thermal cycles, then loaded until fracture Types of fracture are assessed using SEM	No significant difference in fracture load between horizontal and vertical preparations There is a significant difference in the breaking load between the two types of crowns (Celtra Duo) and (KATANA)
"Effect of Marginal Designs on Fracture Strength of High Translucency Monolithic Zirconia Crowns"[23] 2020	High Translucency Monolithic Zirconia Crowns (Ceramill Zolid HT +)	Two stainless steel dies to simulate a molar abutment one with a slight chamfer margin (CL) of 0.8 mm and another with a wide chamfer margin (CH) of 1.2 mm	The crowns placed on a metal matrix are loaded vertically until fracture in the universal testing machine and a speed of 0.2 mm/min	The fracture load is greater with the deep chamfer margin compared with the slight chamfer The collar has no impact on the strength of the crown
"The Influence of the Cervical Finish Line Designs on the Fracture Resistance of CAD/CAM Monolithic Zirconia Crowns, an in Vitro Study"[21] 2018	Monolithic zirconia crowns (WHITEPEAKS/ Germany)	Two acrylic maxillary premolars, one with a deep chamfer margin of 1 mm and the other with a shoulder margin of 1.3 mm, occlusal reduction for both of 1.5 mm	The load was applied to the center of each crown in a universal testing machine	The highest mean value of fracture load was with the deep chamfer margin. The lowest mean value of fracture load was with the shoulder margin
"Fracture of Monolithic Zirconia Crowns with Modified Vertical Preparation"[19] 2021	Zirconia blanks (IPS e.max Zir-CAD LT; Ivoclar Digital, Germany)	Three groups ($n = 10$) with the preparation design: A: deep chamfer finish line(0.8 mm); B: vertical preparation; and C: modified vertical preparation (a reverse shoulder of 1 mm on the buccal surface)	A vertical load was applied on each zirconia crown at a cross-head speed of 0.5 mm/min in a universal testing machine	The highest mean of fracture load was recorded by chamfer which followed by modified vertical and the lowest mean of fracture load was recorded by vertical

Abbreviations: CAD/CAM, computer-assisted design/computer-assisted manufacturing; LTD, low temperature degradation; micro-CT, micro-computed tomography; SEM, scanning electron microscopy; TCML, thermal cycling and mechanical loading.

for 90 degrees shoulder margins and 1,109.250 + 252.455 N for the deep chamfer margins.[20]

The second study showed that that the highest fracture resistance values were recorded with deep chamfer finish line 3,070.72 N and the lowest fracture resistance with shoulder finish line 2,287.57 N.[21]

Two Studies Compared Two Different Thicknesses of Chamfer Margins

The first study showed that the values between the different thicknesses were not significant for the same occlusal thickness of 1.5 mm, and the fracture resistance of certain crowns for axial thicknesses of 0.5 mm, 0.7 mm, and 1 mm was greater than 10kN.[22]

The second study showed that the mean ± standard deviation values of the compressive load at the point of fracture (N) of the zirconia crowns with light chamfer and heavy chamfer designs were 3055 ± 1012 and 4362 ± 909, respectively.[23]

Marginal Thickness

On the marginal thickness, the 0.5 mm margin was considered as the ideal conservative thickness as the values of the fracture resistance of the crown were superior to the maximum mastication force of humans (850 N).[16,17,22]

Discussion

Zirconia is a dental material of great resistance; in fact, its mechanical properties are better compared with aesthetic ceramics: lithium disilicate[6] and feldspathic ceramic.[24] Most studies show a decrease in mechanical properties with increasing translucency of zirconia, but they remain superior to the properties of aesthetic ceramics.[6] This great resistance allows a reduction in its thickness and consequently the realization of more conservative dental preparations. However, clinical recommendations for the design of cervical margins are based on previous experience with all-ceramic crowns and ceramic metal crowns asserting the advantage of knife-edge margins.[25]

A few studies have evaluated the strength of the monolithic zirconia crown with different types and thicknesses of cervical margins. The results are very inhomogeneous due to variations in instrumentation, the brand of zirconia, the thickness of the samples, and the parameters evaluated (►**Table 1**).

A study by Jasim et al[17] tested the effects of two types of margins (shoulderless and a slight chamfer) with two occlusal thicknesses (1 mm and 0.5 mm) on the fracture resistance of monolithic zirconia crowns. The highest mean fracture strength value of monolithic crowns was recorded by the shoulderless group (occlusal thickness 1mm) (3,992.5 N) and the lowest mean fracture value was recorded by the slight chamfer group (occlusal thickness 0.5 mm) (1,632.9 N). The authors concluded that the shoulderless margin has a favorable outcome than a slight chamfer. Although the crown with reduced occlusal thickness has a fracture resistance less than 1mm occlusal thickness, 0.5mm restorations are able to tolerate occlusal forces.

Mitov et al[18] evaluated the tensile strength of monolithic zirconia crown (MZC) according to the preparation design and the aging simulation method. The highest mean fracture loads were observed for the shoulderless preparation in the nonsimulated aging group (5,712 N). Among the chamfer margin groups, the increased material thickness did not show a significant impact on the breaking load. Therefore, a minimally invasive preparation design should be considered the optimal choice.

A study evaluated the influence of different marginal designs (deep chamfer, vertical, and modified vertical with reverse shoulder) on the fracture strength of monolithic zirconia crowns and found that the mean values of fracture strength of monolithic zirconia crowns of all groups were higher than the maximum occlusal forces in the premolar region. In addition, the modification of the vertical preparation with a reverse shoulder placed at the buccal surface improved the fracture strength until it was close to the fracture resistance of the chamfer margin.[19]

A study by Nakamura et al[22] tested the effect of the axial and occlusal thickness of monolithic zirconia crowns on the fracture load. The fracture resistance of monolithic zirconia crowns of reduced thickness was compared with that of monolithic lithium disilicate crowns of regular thickness. The breaking load test revealed that the breaking load of zirconia crowns with an occlusal thickness of 0.5 mm (5,558 N) was significantly higher than that of lithium disilicate crowns with an occlusal thickness of 1.5 mm (3,147 N). The axial wall thickness did not affect the fracture strength of MZCs. Based on this study, it may be recommended to use a monolithic zirconia crown with a 0.5 mm chamfer and 0.5 mm occlusal thickness in the molar region.

Findakly and Jasim[15] compared the fracture resistance of traditional monolithic and translucent "multilayer" zirconia crowns with two different types of margins: knife-edge and shoulder. Traditional monolithic zirconia with a shoulder margin showed the highest fracture resistance among all the samples studied. The highest average breaking load was 2.9 KN. The authors concluded that the shoulder margin provided better strength than the "feather-edge" margin and traditional monolithic zirconia withstands higher loads than translucent monolithic zirconia. However, the two types of margins as well as the two types of crowns provided a breaking load greater than the maximum chewing forces (850 N) and therefore the "feather-edge" margin with translucent zirconia can be used in the clinical practice.

Unlike the previous study, Kasem et al[16] have shown that between a shoulder margin and a knife-edge margin, there is no significant difference in the breaking load. On the other hand, between the zirconia-reinforced glass ceramic crown (Celtra Duo) and the monolithic zirconia crown (KATANA), the latter showed high breaking load for both types of margins. So, the monolithic zirconia crown can be employed in the premolar region with a margin thickness of 0.5 mm.

Juntavee and Kornrum[23] determined the fracture resistance of a highly translucent monolithic zirconia crown with different types of margins in terms of marginal thickness and collar height. The authors found that the deep chamfer margin (1.2 mm) provided a stronger zirconia crown than the slight chamfer (0.8 mm) but both types of margins gave a breaking load higher than the maximum chewing force of humans. Therefore, the slight chamfer margin would be clinically acceptable for high translucency monolithic zirconia crowns.

Al-Joboury and Zakaria[20] have shown that monolithic zirconia CAD/CAM crowns with a 90-degree shoulder margin have a higher average breaking load than with a deep chamfer margin. However, these two types of margins are considered to be suitable in the premolar and molar regions. For hot-pressed ceramic crowns, the 90 degrees shoulder preparation is recommended in the premolar region because these crowns with a deep chamfer have tensile strength values lower than the average bite force in this region.

Unlike the results of the previous study, Alzahrani et al[21] in their study showed that the deep chamfer margin can increase the breaking load of monolithic zirconia crowns.

A retrospective study evaluated clinical outcomes for 73 teeth after vertical preparation of zirconia crowns with knife-edge margin and has shown favorable outcomes for 72 teeth after vertical preparation for knife-edge crowns. This study shows that the technique is a viable procedure with potential advantages.[26]

Conclusion

Analysis of studies evaluating the influence of the type and thickness of margin on the strength of monolithic zirconia crowns has shown that:

- Overall the design of the margin would have a significant effect on the strength of these crowns.
- Monolithic zirconia crowns with knife-edge margins have shown superior fracture resistance at maximum occlusal forces.
- The knife-edge cervical margin (down to 0.5 mm) may be recommended for posterior monolithic zirconia crowns.

As the new translucent monolithic zirconia are recent, further studies would be needed to reach a more concrete conclusion on the recommended minimum thickness for knife-edge margins.

Conflict of Interest
None.

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