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FRACTURE RESISTANCE AND FAILURE MODE OF MONOLITHIC ANTERIOR CROWNS WITH TWO FINISH LINE THICKNESSES (AN INVITRO STUDY)

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ABSTRACT

Statement of the problem: The effect of marginal finish line design and configuration on fracture resistance of all ceramic restorations has been previously evaluated for different ceramic materials. However, studies comparing fracture resistance for different finish line thicknesses of monolithic restorations as BruxZir anterior and e.max cad and analyzing their mode of failure are still scarce. Still, to the current knowledge, this point hasn't been thoroughly investigated.

Purpose: The purpose of this study was to evaluate the fracture resistance and investigate the failure mode of monolithic anterior crowns made from zirconia (BruxZir anterior) and lithium disilicate (e.max CAD) having two thicknesses of finish line (0.8, 1.2 mm)

Materials and Methods A total of 20 anterior fully anatomical CAD/CAM ceramic crowns were designed and fabricated in the current research; they were divided into two equal groups (n = 10) according to the type of ceramic material used. Group 1 constructed from monolithic lithium disilicate(IPS e.max CAD) and group 2 constructed from monolithic zirconia (BruxZir Anterior zirconia) . Each group was further subdivided into two subgroups (n=5) according to finish line thickness. Subgroup 1 consisting of anterior crowns with 0.8 mm finish line thickness and subgroup 2 having anterior crowns with 1.2 mm finish line thickness. Two metal dies simulating prepared maxillary central incisor were designed and milled following the recommended parameters for all ceramic anterior crown. The first die was designed to have a deep chamfer finish line with 0.8 mm thickness and the second die had a deep chamfer finish line with 1.2 mm thickness. Scanning, designing, and milling of ceramic crowns then followed. The dies were duplicated into epoxy dies over which the crowns were adhesively cemented. Each crown die assembly was loaded in a universal testing machine where fracture resistance test was done by compressive mode of load applied at 135 degrees angle palatally using a metallic rod with round tip until fracture occurred. Fracture resistance values were recorded in Newtons followed by statistical analysis. Failure modes were analyzed by viewing under digital microscope.

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Results: Regarding the effect of finish line thickness on fracture resistance values; there was no significant difference in fracture resistance within BruxZir crowns with 0.8mm and 1.2mm finish line thicknesses ($p = 0.555$) while e.max crowns with 1.2mm finish line thickness showed significantly higher fracture resistance than with 0.8mm finish line thickness ($p<0.001$).Regarding the effect of ceramic types on fracture resistance values at both finish line thicknesses, BruxZir showed significantly higher fracture resistance than e.max ($p<0.001$)

Conclusions: Within the limitations of this study, it was concluded that: 1) All anterior crowns constructed from monolithic zirconia and lithium disilicate glass ceramics in the current study revealed fracture resistance values falling far above the range of normal masticatory forces with higher significant values for zirconia crowns. 2. Monolithic lithium disilicate anterior ceramic crowns are recommended to be used with finish line thickness of 1.2 mm rather than 0.8mm thickness to ensure maximum mechanical performance of the material. 3. When choosing monolithic zirconia ceramic to restore anterior teeth, since increased margin thickness did not have any significant effect on fracture loading, a less invasive preparation design becomes the optimal choice especially in young patients to conserve tooth structure. 4. In general lithium disilicate glass ceramics showed more favorable mode of failure when compared to zirconia ceramics.

INTRODUCTION

Conservatism is one of the utmost concerns in recent restorative concepts [1]. This concept is not only applied in tooth preparations confined to enamel but also should be taken into consideration even in cases requiring full coverage restorations. It is well known that in planning tooth preparation to receive full coverage crowns, it is inevitable to remove healthy tooth structure to ensure structural durability and reestablish normal anatomy, function and esthetics. Besides, tooth reduction aims to decrease stresses, enhance the marginal adaptation to guarantee restoration's longevity and preserve health of periodontium [2,3]. UpToDate, ceramic restorations with high strength and esthetics became a common practice in anterior zone particularly in cases subjected to high stresses requiring superior mechanical properties. Classic preparation of teeth to receive a ceramic restoration usually involve from 1to1.5mm axial reduction,1.5 to 2 mm occlusal reduction and a finish line of 1.2mm [4,5]. However, following these guidelines in teeth preparation resulted in increased tooth reduction by 75% [6]. By virtue of introduction of tougher ceramics and enhanced adhesive protocols, conservative marginal designs as chamfer and mini-chamfer were suggested for the sake of tooth structure preservation [7-10].

It is documented that preparation geometry strongly affects the fracture resistance and durability of fixed restorations. One of the most important preparation features is the marginal area since functional load ultimately is transmitted to it thus it should be resisted by durable restorative material [7,11]. Traditionally, former studies recommended thick finish lines for ceramic restorations to obtain more favorable stress distribution under functional loading [12,13]. However, studies done on this point yielded inconsistent results. Some researches couldn't relate finish line designs to fracture strength of ceramic restorations [13,14], while others revealed significant results regarding this research point [15]. Besides previous invitro studies rejected the assumption that increased ceramic bulk automatically increases restoration strength. For example, a former invitro study done on glass ceramics and glass-infiltrated alumina crowns reported that their fracture resistance was irrespective of preparation design[16]. However, regarding recent monolithic zirconia-based restorations, there is a lack of scientific data.

Basically, zirconia was fabricated as a bilayered restoration composed of a core material veneered with glass ceramics. However, many studies analyzed failure patterns in veneered zirconia restorations and found that fractures usually happen in veneer layer [17]. Another study attributed the failures of bilayered restorations in general to the weak bond strength between ceramic veneer and core material [18]. As a result, monolithic anatomic contour restorations have been introduced and became increasingly popular to override complications of bilayered restorations [19] . Former studies revealed 5 year fracture rate for veneered zirconia crowns as 3.25% compared to 0.71% for monolithic restorations might explain the increased shift rate in using monolithic restorations.[20,21]

A recent example of monolithic zirconia ceramics is BruxZir Solid Zirconia which was introduced lately to the market. As a result of its high mechanical properties and superior fit, it quickly invaded the dental practice. Being monolithic in nature, it revealed low fracture incidences. Lately, BruxZir Anterior was launched in the dental market to be specifically used in the anterior region as it meets functional and esthetic requirements of anterior restorations. Besides it showed a friendly behavior to opposing dentition for patients suffering from parafunctional activity. [22]

So after reviewing many studies, we can declare that although the effect of marginal finish line designs and configurations on fracture resistance of all ceramic restorations has been previously evaluated for different ceramic materials, however, studies comparing fracture resistance for different finish line thicknesses of recent types of monolithic restorations as BruxZir anterior and e.max cad and analyzing their mode of failure are still scarce. Still, to the current knowledge, this point hasn't been thoroughly investigated.

Thus, this study was conducted to measure the fracture resistance and investigate the failure mode of monolithic anterior crowns made from zirconia (BruxZir anterior) and lithium disilicate (e.max CAD) having two thicknesses of finish line (0.8, 1.2 mm)

Two hypotheses were stated for the current study:

1) Fracture resistance values for zirconia anterior crowns might show higher values when compared to lithium disilicate crowns.
2) There would be no significant difference between subgroups with different finish line thicknesses within each ceramic group.

MATERIALS AND METHODS

A total of 20 anterior fully anatomical CAD/CAM ceramic crowns were designed and fabricated in the current research; they were divided into two equal groups (n = 10) according to the type of ceramic material used. Group 1 constructed from monolithic lithium disilicate (IPS e.max CAD) and group 2 constructed from monolithic zirconia (BruxZir Anterior zirconia). Each group was further subdivided into two subgroups (n=5) according to finish line thickness. Subgroup 1 consisting of anterior crowns with 0.8 mm finish line thickness and subgroup 2 having anterior crowns with 1.2 mm finish line thickness.

I. Metal die construction

Two metal stainless steel dies simulating prepared maxillary central incisor were designed and milled using an engineering lathe machine. Designing of the dies followed the recommended parameters for all ceramic anterior crown [23] having 12 degrees of total incisal convergence and 6 mm inciso-gingival height . The first die was designed to have a deep chamfer finish line with 0.8 mm thickness and the second die had a deep chamfer finish line with 1.2 mm thickness.

II. Ceramic crowns construction

Each die was sprayed using telescan spray powder (brakon, Germany) to be ready for scanning process which was carried out by Identica scanner (Identica scanner, MEDIT Seoul, Korea) to produce a three dimensional virtual image of the scanned die. Design was carried out by EXOCAD software (EXOCAD software, exocad, GmbH, Germany). Once the scanned image of the die was calculated, finish line tracing then started, followed by insertion axis determination. The spacer thickness was adjusted to be 60 um for the two groups. After the final design was confirmed, it was sent to the milling machine. The Roland Milling Unit(Roland DWX 50, Roland DGA Corp, California, USA) was used to mill the anterior crowns of both subgroups from BruxZir Anterior blanks (Glidwell Dental Labs, Prismatik DentalCraft Inc. USA). While for milling the two subgroups of IPS e.max CAD anterior crowns, The CAM 5-S1 IMPRESSION (CAM 5-S1 IMPRESSION, Henry Schein, UK) was used to mill the restorations from IPS e.max CAD blocks IvoclarVivadent, Schaan, Liechtenstein).

After finishing the milling process, sintering of the zirconia crowns was carried out using Nabertherm sintering oven (Nabertherm GmbH, Germany) following the manufacturer instructions. The sintering temperature was programmed for an increase from 25^0 C to 1200^0 C at a rate of 15^0C /minute and was held for one hour. Then the temperature was raised to 1300 ^{0}C at a rate of 2 ^{0}C /minute, and then raised again to 1530^0 C at a rate of 10 ^{0}C /minute and held constant for 150 minutes. This was followed by a long cooling cycle where the temperature was dropped to 155^0C at a rate of decrease of 15^0C /minute. The crowns were then removed from the furnace and allowed to bench cool to room temperature.Glazing of the zirconia crowns then followed using a glazing paste (IPS e.max Ceram Glaze, Ivoclar Vivadent AG, Schaan, Liechtenstein) that was applied and fired following the recommended manufacturer's protocol where the temperature was raised up to 950°C at the firing rate of 30°C/min, and maintained for 30 seconds then cooled down to 300°C at 15°C/min. For the e.max CAD restorations, final crystallization and glazing of the milled crowns was carried out following the manufacturer's instruction using IVOCLAR VIVADENT furnace (Programat P310, Ivoclar Vivadent, Germany) with temperature of 840^0C and dwell time of 7 minutes. Finally, the fit of the milled zirconia and e.max cad crowns was evaluated on their corresponding dies.

III. Duplication of the metal dies:

The metal dies were duplicated into twenty epoxy resin dies using autopolymerizing resin (Chemapoxy resin, CMB Chemicals, Egypt). The material was mixed according to the manufacturer's instructions and poured under vibration into a silicone mold. The produced resin dies were left to polymerize for 24 hours. The restorations were checked once more for proper fit on their corresponding epoxy resin dies. (Figure 1)

Fig. (1): Checking of the ceramic crowns on the duplicated resin dies

IV. Adhesive cementation of the restorations:

For the zirconia restorations, the intaglio surface of each crown was sandblasted with 50-µm Al2O3 using bioart microblaster (Bioart Dental, Australia) applied perpendicular to the surface for 15 seconds at a 10 mm distance. It was then cleaned with alcohol followed by air drying. Zirconia primer (Z prime,Bisco,USA) was then applied on the internal surface and air dried for 5 seconds. A dual cure adhesive resin cement (RelyX™ Ultimate,3M, USA) was then applied in the inner side of the crown. Mixing and polymerization followed the manufacturer's instructions. Cementation load and seating of the restoration on its corresponding die was done using a specially fabricated cementation jig to apply a standard load of 2 kilograms for 30 seconds during the bonding procedure.

For the e.max CAD crowns, the inner surfaces were etched with hydrofluoric acid (IPS Ceramic etching gel; Ivoclar-Vivadent, Schaan, Liestenstein) for 20 seconds, water rinsed for 40 seconds and then dried for 30 seconds with oil free air. This step was followed by application of silane-coupling agent (Monobond S; Ivoclar Vivadent) that was left to dry for 60 seconds.The resin adhesive system (RelyX™ Ultimate, 3M, USA) was used following manufacturer's instructions to cement the restorations to their corresponding dies.

The same cementation jig and load were also used for bonding the e.max restorations on their corresponding dies. A light-polymerizing unit (Elipar LED curing unit, 3M ESPE) with curing power of 1200 mW/cm^2 was used to cure the cement. Initial curing was done for 2 seconds at each surface. Removal of the excess cement then followed. It was held on the buccal, mesial, lingual, distal and incisal surfaces for 40 seconds each to complete cement curing.

V. Fracture Resistance Test:

This test was performed using Bluehill Lite Software from Instron®. The crown dies assembly were individually mounted on a computer controlled materials testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) with a loadcell of 5 kN and data were recorded using computer software (Instron® Bluehill Lite Software). Tightening screws were used for securing the assembles to the lower compartment of the testing machine. Fracture resistance test was done by compressive mode of load applied at 135 degrees angle (through fixing the sample in specially designed 45 degrees angle jig) palatally using a metallic rod with round tip (3.4 mm diameter) attached to the upper movable compartment of testing machine traveling at cross-head speed of 1mm/min with tin foil sheet in-between to achieve homogenous stress distribution and minimize local force transmission peaks. The load at failure was manifested by an audible crack and confirmed by a sharp drop at load-deflection curve recorded using computer software (Bluehill Lite Software Instron® Instruments) The load required to fracture was recorded in Newton

VI. Failure Mode analysis:

After fracture resistance test, all specimens in the test groups were viewed using a USB digital-microscope (U500x Digital Microscope, Guangdong, China), magnification x35 under illumination achieved with 8 LED lamps with a color index close to 95 %. The images were captured and transferred to a IBM personal computer equipped with the Image-tool software (Image J 1.43U, National Institute of Health, USA) to determine failure mode pattern according to the following categorization[(24)]

- Type I: complete or partial debonding of the restoration without fracture (favorable failure)
- Type II: fracture of the restoration without fracture of the tooth (favorable failure)
- Type III: fracture of the restoration/die complex above the height of bone level simulation (acceptable failure)
- Type IV: fracture of the restoration/die complex below the height of bone level (catastrophic failure)

RESULTS

Data were tested for normality using Shapiro Wilk test and Kolmogrov Smirnov test. Homogeneity of variance was tested using Levene's test. After meeting the assumptions, two-way ANOVA was used to test the main and interaction effects of ceramic type and finish line thickness on fracture resistance with a significance level of 0.05 followed by pairwise comparison with Bonferroni correction.

Statistical analysis was performed using SPSS software (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.)

Descriptives

BruxZir crowns with 1.2mm finish lines showed the highest mean fracture resistance followed by BruxZir crowns with 0.8mm finish lines then e.max crowns with 1.2mm finish lines and finally e.max crowns with 0.8mm finish lines.

Main effects

The results of two way ANOVA revealed that ceramic type has a significant effect on fracture resistance (p<0.001), finish line thickness has a significant effect on fracture resistance (p<0.001) and the interaction between ceramic type and finish line thickness has a significant effect on fracture resistance (p<0.001).(Table 1)

Interactions

a) Effect of different finish line thicknesses on fracture resistance for each ceramic type:

Pair wise comparisons revealed that there was no siginificant difference in fracture resistance within BruxZir crowns with 0.8mm and 1.2mm finish line thicknesses (p = 0.555) while e.max crowns with 1.2mm finish line thickness showed significantly higher fracture resistance than with 0.8mm finish line thickness (p<0.001) (Table 2,Figure 2)

b) Effect of different ceramic types on fracture resistance for each finish line thickness:

At both 0.8mm and 1.2 mm finish line thicknesses, BruxZir showed significantly higher fracture resistance than e.max (p<0.001). (Table 2, Figure 2)

TABLE (1): Results of two-way ANOVA for effect on ceramic type and finish line on fracture resistance:

	df	F	*P* - Value
Ceramic type	1	138.23	<0.001*
Finish line thickness	1	26.712	<0.001*
Ceramic type * Finish line thickness	1	18.62	0.001*

Failure pattern characteristics of each specimen were defined and classified according to the four failure modes shown in Table 3 and represented in Figure 3

TABLE (2): Descriptive mean, standard deviation values of fracture resistance for ceramic types (BruxZir and e.max) and finish line thicknesses (0.8mm and 1.2mm)

	0.8mm	**1.2mm**	**Mean diff (95% CI)**	***P* - Value**
	Mean (SD)	**Mean (SD)**		
BruxZir	426.32 (19.26)	431.97 (18.89)	-5.65 (-25.49, 14.19)	0.555
e.max	319.80 (8.97)	382.56 (8.22)	-62.75(-82.59, -42.91)	<0.001*
Mean diff (95% CI)	106.52 (86.68, 126.35)	49.41 (29.57, 69.25)		
***P* - Value**	<0.001*	<0.001*		

Significant at p<0.05

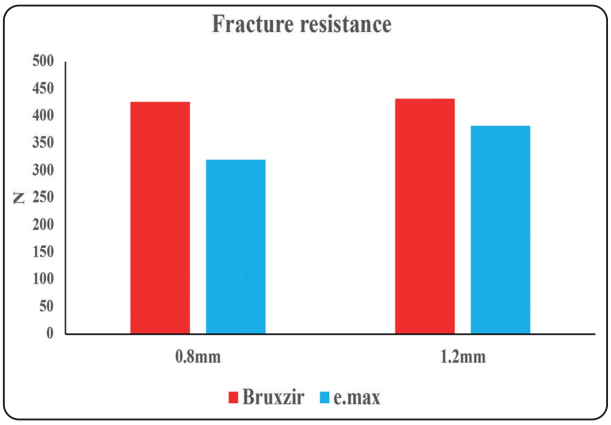

Fig. (2): Bar chart representing the mean fracture resistance of BruxZir and e.max crowns with 0.8 and 1.2mm finish lines.

TABLE (3) Failure mode for the groups and subgroups (%) under study:

		Mode of failure			
Material	Finish line thickness	Type 1	Type 2	Type 3	Type 4
Bruxir	0.8mm	0%	0%	30%	70%
	1.2mm	0%	0%	20%	80%
e.max	0.8mm	0%	60%	40%	0%
	1.2mm	0%	30%	50%	20%

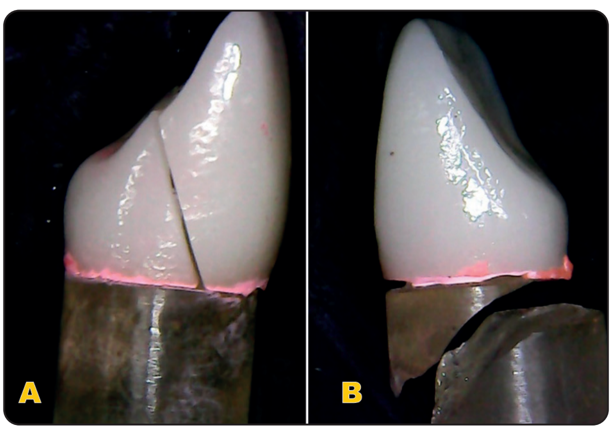

Fig. (3) : A) Type 2 favorable fracture in e.max group with 0.8 mm finish line thickness B) Type 4 catastrophic fracture in BruxZir group with 1.2 mm finish line thickness

DISCUSSION

According to the results of the present study, the first hypothesis expecting that fracture resistance of zirconia anterior crowns would have higher values than lithium disilicate crowns was accepted. Regarding the second hypothesis stating that there would be no significant difference between subgroups with different finish line thicknesses was accepted for the zirconia crowns and rejected for the lithium disilicate crowns.

The field of fixed prosthodontics has recently witnessed a paradigm shift by the introduction of recent advancements in adhesive dentistry and ceramic technology. [25,26] These changes have dramatically influenced the way clinicians can deal with teeth preparation designs. By modifying the dentists' concepts in terms of conserving vital tooth structure, conventional restorative options advocating removal of healthy dental tissues have been altered to promote tooth conservation.

Earlier ceramic restorations necessitated significant tooth removal to match with the material physical properties, retention, and resistance form and achieve high esthetic outcome. However, evolution of recent ceramics enabled their use in thinner sections without compromising durability and esthetics, meanwhile preserving maximum amount of healthy tooth structure.[26]

An example of these ceramics is BruxZir anterior zirconia monolithic restorations which was the reason of their use in the present study. Since e.max glass ceramics are considered very popular restorations especially in the anterior teeth as they meet functional and esthetic requirements of this area, thus they were chosen to be compared to zirconia ceramics in terms of fracture resistance when both ceramics were used with different finish line thicknesses.[22]

The finish line thicknesses used in the current study were selected to simulate different clinical conditions. 1.2 mm deep chamfer finish line is usually prepared under normal conditions with sufficient tooth dimensions. However, in real practice, ceramic crowns are challenging when prepared for teeth with reduced dimensions or with specific morphology, such as mandibular incisors or premolars due to large difference in their axial height and cervical circumference which might endanger the pulp in case of conventional preparations. Thus, a thinner finish line (0.8mm) was chosen in this study as it becomes a strongly recommended option in these cases to conserve tooth structure and provide sufficient ceramic thickness in transition from cervical to occlusal region respecting esthetics, periodontal health and anatomical contours [(27)] However, data on how finish line thickness affects the fracture resistance and failure mode of recent ceramic restorations with different microstructures are still missing and needed further studies. Accordingly , the aim of our study was to investigate this point.

In the current study, metal dies were milled using a high precision engineering machine to simulate prepared anterior teeth following recommended guidelines by different authors[(23)] . The metal dies offered several advantages over natural teeth as standardized preparation parameters. Although using natural teeth achieves more clinical simulation than metal dies, yet the variation in their structure, dimensions and storage time and media following extraction hinder achieving standardized preparation [(28)].

The metal dies were then duplicated in resin dies to facilitate the fracture resistance testing of the ceramic crowns as this test depends on modulus of elasticity of the abutment material [(29)]. Former studies measured the fracture strength of ceramic restorations using different die materials as metal, brass, acrylic resin, epoxy resin and dentin [(30-37),] They concluded that the chosen abutment material should behave elastically as natural dentin does. [(29)]. Thus, the load at fracture for the ceramic crowns was done following bonding to epoxy resin dies due to their resemblance to dentine regarding modulus of elasticity. [(29,38).]

The mean fracture resistance values for all the crowns included within the study were far above the normal incising forces exerted in the anterior region of the mouth, based on the fact that mean mastica-tory force in the anterior region ranges from 89 to 111 N, with an added safety boundary of 200 N [(39)].

When discussing the statistically significant results in our present study, fracture resistance of lithium disilicate crowns with 1.2mm thickness showed higher statistically significant mean value compared to 0.8mm thickness. This was consistent with previous studies concluding that fracture load increases with the margin thickness for glass ceramic crowns [(40)] . These results were also comparable to a study by Yu et al in 2017 who studied the effect of different ceramic thicknesses (0.5,0.8,1,1.2,1.5mm) on fracture resistance of monolithic lithium disilicate ceramic crowns. The study showed that a significant increase in the fracture resistance for lithium disilicate crowns was attained when ceramic thickness increased. [(41)]

Knowing that several factors might influence the mechanical performance of ceramic crowns including bonding technique, tooth substrate, ceramic microstructure, and restoration thickness[(42-45)], it was pointed out that thickness played a major role in determining the fracture resistance of ceramic restorations especially those constructed from brittle ceramic types as glass ceramics.

A reason why the thicker crown margins in our research showed higher fracture loads than thinner margins might be due to higher energy needed to reduce the initiation of cracks with increased bulk of material [(46,47)] .

Another explanation might be due to the fact that upon incisal loading, stress peaks are usually generated at regions of geometrical changes as cervical circumference of crowns which are better resisted by increased margin thickness [48] Therefore reduction in margin thickness for glass ceramic restorations results in a higher susceptibility to fracture.

Another possible reason for our results was that the incisal forces were much borne by the thicker margins leading to less stress concentration on the axial walls of the preparation compared to thinner margins. [49]

Furthermore, a study conducted by Ahmadzadeh et al in 2015 showed controversial results to ours as they concluded that finish line thickness and design had no significant effect on fracture resistance of lithium disilicate crowns[50] . In addition, a study performed by Bakeman et al in 2015 showed no significant effect of restoration thickness on the fracture resistance of lithium disilicate crowns[51] A possible explanation for this inconsistency might be due to difference in restoration design , manufacturing technique and variation in selected thicknesses

When comparing the results of both ceramic materials, zirconia showed significantly higher fracture resistance values than lithium disilicate crowns for 0.8- and 1.2-mm finish line thickness. The same results was obtained by previous studies [52-55] .

A logic explanation for these findings appears upon comparing the microstructure of BruxZir anterior zirconia and e.max lithium disilicate glass ceramic. The yttrium-stabilized zirconia, being glass-free, high-strength polycrystalline ceramic material with a flexural strength reaching 650MPa [22] are less liable to fatigue deterioration than glass ceramics reaching flexural strength of 440 MPA[56]. In a former study, it was proved that the crack propagation within glass based ceramics occured only within the glass matrix that is absent in zirconia based ceramics and did not spread through the crystal[57].

Another study conducted by Al-Joboury and Zakaria in 2015 showed similar results to our study. They attributed the higher fracture resistance of monolithic zirconia compared to glass ceramic restorations to its finer grain size and the tetragonal-monoclinic transformation toughening mechanism in zirconia creating compressive stresses in the restoration which reduces crack propagation throughout the material[58].

Our results regarding effect of ceramic material on fracture resistance values were inconsistent to a study made by Choo et al in 2021 who studied fatigue resistance of monolithic anterior crowns [59] . Their results showed that monolithic zirconia anterior crowns had a statistically lower fracture load than lithium disilicate crowns. The reasons for this inconsistency in results might be due to application of dynamic loading in their study unlike static load that was used in the present study. Also fracture resistance testing was conducted on titanium abutments in their study while epoxy resin dies were used in the current study.

It worth mentioning that analyzing the fracture modes adds a clinical value to invitro studies and provides a valuable tool to predict restorability of tooth following failure of restoration. In this study, majority of fractures in the lithium disilicate groups were observed in the restoration itself (favorable) or in the restoration die complex above the height of bone level simulation (acceptable). Similar fracture modes were observed for glass ceramic restorations in previous studies [60,61].

On the other hand, fractures in zirconia crowns were mainly classified as catastrophic failures involving restoration tooth complex below the height of bone level simulation. This difference in fracture modes of both ceramics might be due to lower rigidity of glass ceramic restorations compared to zirconia-based ceramics [62,63]

Being laboratory in nature, this study had some limitations. The load applied to the ceramic crowns during fracture testing was static and do not imitate the dynamic clinical loading situation. Also, artificial dies were used instead of natural teeth for purpose of standardization. However, they are different from dentine regarding microstructure, bonding mechanism and mechanical strength. Finally, in vivo studies are recommended to determine the effect of more complex oral environmental factors on mechanical properties of variable ceramic restorations despite of difficulty in standardization and controlling the variables.

CONCLUSIONS

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

1. All anterior crowns constructed from monolithic zirconia and lithium disilicate glass ceramics in the current study revealed fracture resistance values falling far above the range of normal masticatory forces with higher significant values for zirconia crowns.
2. Monolithic lithium disilicate anterior ceramic crowns are recommended to be used with finish line thickness of 1.2 mm rather than 0.8mm thickness to ensure maximum mechanical performance of the material.
3. When choosing monolithic zirconia ceramic to restore anterior teeth, since increased margin thickness did not have any significant effect on fracture loading, a less invasive preparation design becomes the optimal choice especially in young patients to conserve tooth structure.
4. In general lithium disilicate glass ceramics showed more favorable mode of failure when compared to zirconia ceramics.

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