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# EFFECT OF FINISH LINE DESIGN AND THERMO-MECHANICAL AGING ON THE FRACTURE RESISTANCE OF TWO TYPES OF MONOLITHIC ZIRCONIA CROWNS

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## *ABSTRACT*

**Objectives:** The purpose of this study was to compare the fracture resistance of two types of CAD/CAM monolithic zirconia crowns with two finish line designs after thermo-mechanical aging.

**Materials and methods:** A total of 40 zirconia crowns were milled and divided into two groups Bruxzir and Prettau zirconia (n=20). Each type of zirconia crowns was divided into two groups according to the finish line design, chisel (CH) and deep chamfer (DC) groups (n=10) After cementation of crowns to their corresponding dies, half of each group was subjected to thermo-mechanical aging, then fracture resistance was measured.

**Results:** Statistical analysis showed the highest fracture resistance mean±SD value was recorded with Bruxzir non-aged CH group (3432.22±462.4), while the lowest fracture resistance mean±SD values was recorded with Prettau aged DC group (2658.97±417.2) as indicated by three-way ANOVA test ($F= 11.8806$, $p= 0.0087<0.05$).

**Conclusion:** Within the limitations of this study, fully contoured zirconia crowns showed high resistance to failures and a minimally invasive preparation design should be determined as the optimal choice.

## INTRODUCTION

The introduction of zirconia-based ceramics to the dental field opened the way for the design and application limits of ceramic restorations. The superior mechanical performance including superior strength and fracture resistance in addition to high esthetics, excellent biocompatibility, and low thermal conductivity combined with the CAD/CAM fabrication procedures allowed the production of large and complex restorations with high accuracy and success rate. [1-4]

Similar to metal-ceramic restorations, zirconia frameworks are veneered with more esthetic feldspathic or glass ceramic materials. [5-7] Chipping

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of the veneering material is one of major problems of veneered zirconia restorations that led to the idea of fabrication of monolithic restorations made entirely from one type of ceramic material.[8,9] Monolithic, anatomic contour zirconia has developed as alternative to porcelain veneered crowns to improve the mechanical stability and to overcome the clinical failure of layered zirconia restorations[10-15]

Monolithic zirconia enables the use of more conservative finish line designs. Some articles stated that some of the advantages of monolithic zirconia are reduction of breakage possibilities, avoiding chipping, high strength, minimal occlusal adjustment, and marginal accuracy [16-18]

Despite the favorable mechanical properties of zirconia ceramics, any surface manipulations of zirconia restorations might induce superficial imperfections. Occasionally, at relatively low temperatures in humid environments, and repetitive stresses during the chewing cycles, the tetragonal phase of zirconia may transform into the monoclinic phase [4, 14] This phenomenon, known as the low temperature degradation (LTD), which characterized by formation of small and large cracks due to partial stability of the tetragonal phase at room temperature with subsequent decrease strength and degradation of the mechanical properties of zirconia [10,19-21] so that, the excellent initial mechanical properties could be affected in the long-term. [5]

The hypothesis of this study is that the fracture resistance of both monolithic zirconia crowns will be influenced by the finishing line design and thermo-mechanical aging procedures.

## MATERIALS AND METHODS

### Master Die Fabrication

Two standard circular metal dies were milled by industrial lathe milling machine to simulate the preparation for human molars. Each metal cylinder has external diameter (10 mm), 12° degree axial taper, [22] flat occlusal reduction with functional bevel, 5 mm occluso-gingival height, with two different finish line designs (one metal die with a circumferential 1mm deep chamfer, and the other with 0.3mm chisel finish line. Figure (1)

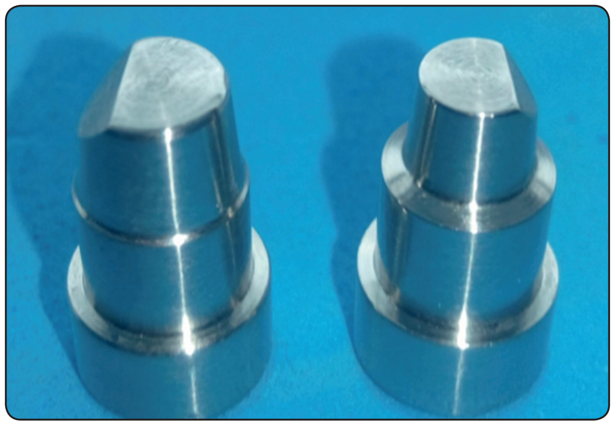

Fig. (1): Showing the metal dies used in this study.

### Crowns Fabrication

A 20 Polyether impression (Impregum, 3M ESPE, Germany) were taken using custom made trays and 20 master resin dies were fabricated for each metal die.

All resin dies were sprayed by shera scan spray (Dentech Lab Supplies Ltd PO Box 87262 Meadow-bank, Auckland 1742) then, scanned via blue LED 3D dental scanner named Medit Identica Hybrid (Medit Company, 19 Inchon-ro 22-gil, Seongbuk-gu, Seoul, Korea82-2-2193-9600). The crowns were designed by Exocad cad system (Exocad GmbH, Julius-Reiber-Str. 37, D-64293 Darmstadt, Germany). The data of the completed design is merged and saved in a file, a 5-axis dental milling machine Roland DWX-51D (ROLAND DGA CORP. | 15363 BARRANCA PARKWAY | IRVINE, CALIFORNIA) was used to mill 40 zirconia crowns out of zirconia blanks

### Crowns Assignment

Forty monolithic zirconia crowns were fabricated for this study, 20 crowns of (Bruxzir monolithic zirconia), and 20 crowns of (Prettau monolithic zirconia). Each 20 crowns were divided into two groups of 10 crowns according to the finish line design. DC group (1mm deep chamfer) and CH group (0.3mm chisel).

All crowns were cemented to their corresponding dies using dual-curing self-adhesive resin cement (Theracem, BISCO, inc, Schaumburg, IL60193 U.S.A.) according to the manufacturer recommendation; half of each group was subjected to thermo-mechanical aging.

**Thermo-Mechanical Aging**

Thermo-mechanical aging was conducted using the newly developed four stations multi-modal ROBOTA chewing simulator integrated with thermo-cyclic protocol operated on servo-motor (Model ACH-09075DC-T, AD-Tech Technology CO., LTD., Germany). ROBOTA chewing simulator which has four chambers simulating the vertical and horizontal movements simultaneously in the thermodynamic condition. A weight of 5 kg which is comparable to 49 N of chewing force was exerted. The test was repeated 75000 times to clinically simulate the 6 months chewing condition. [23]

**Fracture Resistance Test**

All samples 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). Samples were secured to the lower fixed compartment of testing machine by tightening screws. Fracture test was done by compressive mode of load applied occlusally using a metallic rod with round tip (5 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 minimization of the transmission of local force peaks. The load at failure 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

**Statistical Analysis**

Data analysis was performed in several steps. Initially, descriptive statistics for each group results. Three-way analysis of variance ANOVA test of significance was done for comparing variables (Zrconia ceramic, margin design, and thermo-mechanical aging) affecting mean values. One-way ANOVA followed by pair-wise Tukey's post-hoc tests were performed if it showed significance between subgroups. Student t-test was performed to detect interaction between main groups with each margin and aging. Statistical analysis was performed using Asistat 7.6 statistics software for Windows (Campina Grande, Paraiba state, Brazil). P values ≤ 0.05 are considered to be statistically significant in all tests.

## RESULTS

**Fracture resistance**

Descriptive statistics showing mean values, standard deviations (SD) for fracture resistance measured in (N) recorded for both Zr ceramic groups as function of margin design summarized in table (2) and graphically represented in figure (2).

**For Bruxzir crowns**

It was found that the highest fracture resistance mean±SD values were recorded with ***non-aged CH margin design*** group followed by ***aged DC*** group then ***aged CH*** group while the lowest fracture resistance mean±SD values were for ***non-aged DC margin design*** group. The difference between margin design subgroups was statistically ***non-significant*** as indicated by one-way ANOVA test (F=1.58, p=.2332>0.05).

**For Prettau crowns**

It was found that the highest fracture resistance mean±SD values were recorded with ***non-aged DC margin design*** group followed by ***aged CH*** group then ***non-aged CH*** group while the lowest fracture resistance mean±SD values were for ***aged DC margin design*** group. The difference between margin design subgroups was statistically ***non-significant*** as indicated by one-way ANOVA test (F=0.8539, p=.4848>0.05).

**Bruxzir vs. Prettau**

With ***non-aged DC margin;*** it was found that Prettau crowns recorded statistically non-significant higher fracture resistance mean values than Bruxzir as indicated by t-test (t=0.6662, p=0.5240 > 0.05)

With ***aged DC margin;*** it was found that Bruxzir crowns recorded statistically significant higher fracture resistance mean values than Prettau as indicated by t-test (t=2.487, p=0.0377 <0.05)

With ***non-aged CH margin;*** it was found that Bruxzir crowns recorded statistically significant higher fracture resistance mean values than Prettau as indicated by t-test (t=3.718, p=0.0205<0.05)

With ***aged CH margin;*** it was found that Bruxzir crowns recorded statistically non-significant higher fracture resistance mean values than Prettau as indicated by t-test (t=0.7719, p=0.4833 >0.05)

*Totally, irrespective of margin design or aging, it was found that Bruxzir crowns recorded statistically significant higher fracture resistance mean values than Prettau as indicated by three-way ANOVA test (F= 11.8806, p= 0.0087<0.05).*

*Totally, regardless to Zirconia ceramic group or aging, it was found that DC margin design group recorded statistically non-significant higher fracture resistance mean values than CH margin design group as indicated by three-way ANOVA test (F= 0.046, p= 0.8345>0.05).*

*Totally, irrespective of Zirconia ceramic or margin design, it was found that non-aged group recorded statistically non-significant higher fracture resistance mean values than aged group as indicated by three-way ANOVA test (F= 0.9443, p= 0.3455>0.05).*

TABLE (2) Fracture resistance results (Mean values ±SD) for both Zirconia ceramics as function of margin design and aging

| Variable | | Margin design | | | |
|---|---|---|---|---|---|
| | | DC | | CH | |
| | | Non-aged | Aged | Non-aged | Aged |
| Zirconia ceramic | Bruxzir | 2987.90±157.3 | 3320.99±81.1 | 3432.22±462.4 | 3021.73±269.7 |
| | Prettau | 3063.54±149.1 | 2658.97±417.2 | 2706.16±310.5 | 2724.78±381.9 |
| t-test | P value | 0.5240 ns | 0.0377* | 0.0205* | 0.4833 ns |

***Significant minimum difference (smd) for columns = 505.7429***

***smd for rows = 595.9534***

****; significant (p>0.05) ns; non-significant (p>0.05)***

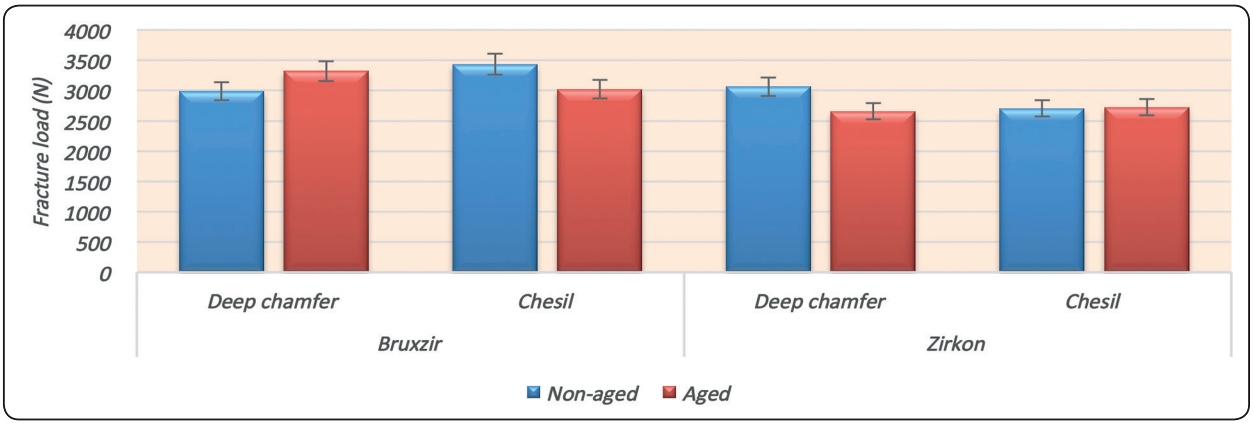


Fig. (2) Column chart showing fracture resistance mean values for both Zirconia ceramic as function of margin design and aging

## DISCUSSION

In this study standardized metal dies were used and duplicated with epoxy resin to allow for fabrication of identical dies followed by production of the crowns by the aid of CAD/CAM technology to ensure identical geometries for the crowns which is important for a reliable comparison of different groups. [21]

Two types of monolithic zirconia crowns were used in this study where, in the last few years, full-contour zirconia crowns have become popular owing to their high flexural strength (<1000 MPa),[13] these strength values exceed the maximal occlusal loads during normal chewing, making them well-suited for clinical use in areas of high stress. [15]

A less-invasive 0.3 mm chisel in addition to conventional 1mm deep chamfer finishing line designs were used in this study because the conservative tooth reduction became an important requirement for a modern restoration material. **Mitov et al.** [7] found that the differences in substance loss are also reflected in the calculated volumes for 3 different restoration designs. While the crown, generated for the shoulderless preparation had a volume of 244 $mm^3$, for the 0.4 mm chamfer preparation the crown volume was 280 $mm^3$ and for the 0.8 mm chamfer 298 $mm^3$

The results of this *in vitro* study rejected the hypothesis, that the fracture resistance of both monolithic zirconia crowns will be influenced by the finishing line design and thermo-mechanical aging procedures.

The results of this study showed that the finish line design and thermo- mechanical aging has no effect on the fracture resistance of both monolithic zirconia crowns however, there was a significant difference between the two zirconia materials.

The reason of increased fracture resistance main value of Bruxzir than prettau zirconia crowns are the difference in their chemical structure, the way of the manufacture of the zirconia material. The Glidewell Laboratories used the Colloidal technology in the manufacture of Bruxzir zirconia unlike the way of manufacture used by Zirkonzahn Company to manufacture the Prettau zirconia. This was in contrast with **Coelho et al** [6] who were found that despite the differences in materials formulation and processing between LAVA and Cercon specimens, no significant differences were observed in the reliability for a 50,000 cycles mission at a 200N load.

The increased finishing line thickness with subsequent increased material thickness did not show a significant increase of crowns strength where, the mean values of fracture load in each of the tested groups were recorded at over 2600 N even though the minimal finish line thickness of the crowns was non-definite chisel finishing line, which are much higher than maximum bite force in the molar regions reported in literatures. [24-26] This suggests the possibility of the application of monolithic zirconia crowns with thin thickness in the posterior region.

The absence of failures during thermo-mechanical aging as well as the high fracture resistance of all tested groups investigated in this study may be explained by the high mechanical properties of zirconia, especially strength, hardness, and resistance to crack propagation [10] **Studart et al.** [21] found that partially stabilized zirconia can withstand cyclic loading and wet conditions typically applied in the posterior region of the mouth. The high resistance to fracture of full-contour zirconia crowns after thermo-mechanical aging may be due to the reduction of crack to grow as the tetragonal phase transformed in to monoclinic with subsequent volume increase by 3 to 5% which places the region in compression and prevents the crack from further spreading which called (transformation toughening). [13] These results are in accordance with **Mitov et al** [7] who was found that the monolithic zirconia crowns showed generally high fracture load values regardless of the type of tooth preparation and aging simulation design.

## CONCLUSIONS

Within the limitations of this *in vitro* study, the following conclusions could be drawn:

1- Regardless the finishing line design and thermo-mechanical aging the fully-contoured zirconia crowns showed high resistance to failures.

2- Both finish line design and thermo-mechanical aging have no significant effect on the fracture resistance of the tested zirconia crowns

3- A minimal invasive Chesil preparation margin design should be determined as the optimal choice for monolithic zirconia restorations.

4- Bruxzir zirconia represent higher fracture resistance than Prettau

## RAFERENCES

1- Sundh A, Sjögren G. Fracture resistance of all-ceramic zirconia bridges with differing phase stabilizers and quality of sintering. Dent Mater 2006;22:778–84.

2- Denry I, Kelly JR. State of the art of zirconia for dental applications. Dent Mater 2008; 24: 299-307.

3- Vichi A, Louca C, Corciolani G, Ferrari M. Color related to ceramic and zirconia restorations: a review. Dent Mater 2011;27:97–108.

4- Tabari K, Jaberi Ansari Z, Amiri Siavashani M, Eskandarion S. Effect of Thermal and Mechanical Aging on Flexural Strength of Zirkonzahn and Mamut Zirconia Ceramics. J Dent Sch 2014; 32(3): 132-8.

5- Sundh A, Molin M, Sjogren G. Fracture resistance of yttrium oxide partially-stabilized zirconia allceramic bridges after veneer and mechanical fatigue testing. Dent Mater 2005;21:476-82.

6- Coelho PG, Silva NR, Bonfante EA, Guess PC, Rekow ED, Thompson VP (2009) Fatigue testing of two porcelain-zirconia all-ceramic crown systems. Dent Mater 2009;25:1122-7.

7- Mitov G, Anastassova-Yoshida Y, Nothdurft FP, von See C, Pospiech P. Influence of the preparation design and artificial aging on the fracture resistance of monolithic zirconia crowns authors . J Adv Prosthodont 2016;8:30-6.

8- Fasbinder DJ. Clinical performance of chairside CAD/CAM restorations. J Am Dent Assoc 2006; 137 Suppl: 22S-31S.

9- Nakamura K, Mouhat M, Nergård JM, Lægreid SJ, Kanno T, Milleding P et al. Effect of cements on fracture resistance of monolithic zirconia crowns. Acta biomaterialia Odontologica Scandinavica 2016;2(1):12-9.

10- Preis V, Behr M, Hahnel S, Handel G, Rosentritt M, Engineer. In vitro failure and fracture resistance of veneered and full-contour zirconia restorations. J Dent 2012;40:921–8.

11- Beuer F, Stimmelmayr M, Gueth J-F, Edelhoff D, Naumann M. In vitro performance of full-contour zirconia single crowns. Dent Mater 2012;28:449-56.

12- Zhang Y, Lee JJW, Srikanth R, Lawn BR. Edge chipping and flexural resistance of monolithic ceramics. Dent Mater 2013;29:1201-8.

13- Abo El-Naga A A, El-fallal A A, Ibraheim SAA, Alaraby H A. Fracture Strength of Two Zirconia All-ceramic Crown Systems: Influence of Intaglio Surface Conditioning. Mansoura Journal of Dentistry 2014;1(3):67-71.

14- Baladhandayutham B, Lawson NC, Burgess JO. Fracture load of ceramic restorations after fatigue loading. J Prosthet Dent 2015;114:266-71.

15- Øilo M, Kvam K, Roar Gjerdet R. load at fracture of monolithic and bilayered zirconia crowns with and without a cervical zirconia collar. J Prosthet Dent 2016; 115(5):630-6.

16- Lazetera A. Extreme class II full arch zirconia implant bridge. Australasian Dental Practice, 2009; 7: 170-74.

17- Guess PC, Att W, Strub JR. Zirconia in fixed implant prosthodontics. Clinical Implant Dentistry and Related Research, 2012; 14(5): 633-45.

18- Carames J, Suinaga LT, Yu YCP, Pérez A, Kang M. "Clinical Advantages and Limitations of Monolithic Zirconia Restorations Full Arch Implant Supported Reconstruction: Case Series". Int J Dent.2015

19- Kawai Y, Uo M, Wang Y, Kono S, Ohnuki S, Watari F. Phase transformation of zirconia ceramics by hydrothermal degradation. Dent Mater 2011; 30: 286-92.

20- Mochales C, Maerten A, Rack A, Cloetens P, Mueller WD, Zaslansky P, et al. Monoclinic phase transformations of zirconia-based dental prostheses, induced by clinically practised surface manipulations. Acta Biomaterialia 2011;7:2994–3002.

21- Studart AR, Filser F, Kocher P, Gauckler LJ. Fatigue of zirconia under cyclic loading in water and its implications for the design of dental bridges. Dent Mater;23:106-14.

22- Sagsoz NP, Yanikoğlu N, Sagsoz O. Effect of Die Materials on the Fracture Resistance of CAD/CAM Monolithic Crown Restorations. OHDM 2016;15: No. 3._

23- Nawafleh N, Hatamleh M, Elshiyab S, Mack F.Lithium Disilicate Restorations Fatigue Testing Parameters: A Systematic Review.J Prosthodont. 2016 Feb;25(2):116-26.

24- Anusavice KJ. Mechanical properties of dental materials. In: Anusavice KJ, Shen C, Rawls HR, editors. Phillips' science of dental materials. 12th ed. St. Louis (MO): Saunders; 2013. p. 48-68.

25- Vallittu PK, Kononen M. Biomechanical aspects and material properties. In: Nilner K, Karlsson S, Dahl BL, editors. A textbook of fixed prosthodontics: the Scandinavian approach. 2nd ed. Stockholm: Gothia Fortbildning; 2013. p. 1521-71.

26- Yilmaz H, Aydin C, Gul BE. Flexural strength and fracture toughness of dental core ceramics. J Prosthet Dent 2007; 98:120-8.