IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 22, Issue 12 Ser.4 (December. 2023), PP 14-18
www.iosrjournals.org

Fracture load of monolithic zirconia crowns prepared with different margin designs and cemented by different resin luting cements

Hend Elkawash, Nuha Elkadiki, khadiga. A.H. Mohamed, Shembeish A.H
Assistant professor Department of fixed prosthodontics, [2]Assistant professor, Department of conservative and endodontic Faculty of Dentistry,[3] Assistant professor Department of fixed prosthodontics, University of Benghazi, Benghazi, Libya.[4] Demonstrator in LIMU.

Date of Submission: 08-12-2023 Date of Acceptance: 18-12-2023

I. Introduction

Zirconia has seen widespread use in recent years because of its superior mechanical qualities. Due to the opaque tint of the zirconia core, the veneering layer was applied to improve the aesthetics of the restoration.[2,3] But this could also lead to the veneering layer's failure (cohesive or sticky).[4] By skipping the veneering porcelain layer, monolithic zirconia restorations can be used successfully in a variety of clinical settings.[5] Since the clinical guidelines are still based on those for all-ceramic and metal-ceramic crowns, the suggestion of the margin design for high strength ceramic materials, such as zirconia, is not obvious.[.6] Monolithic zirconia restorations are effective in clinical settings, particularly with patients who have a constrained interocclusal distance and who have a high occlusal load.[7,8] Thus, using monolithic high-strength ceramics can lessen the intrusive preparation of teeth[9,10]. Due to advancements in dental technology that allowed for the creation of precise restorations utilizing computer-assisted design (CAD) and computer-assisted manufacturing (CAM) procedures, zirconia restorations have become increasingly popular. [11]

The introduction of transparent zirconia into dental practices recently has challenged the material's natural aesthetic look because it can be employed as a monolithic, highly translucent zirconia repair only in the aesthetic zone. This material, which exhibits exceptional levels of strength, is being used more frequently in dental offices, particularly for the chair-side manufacturing of zirconia restorations. However, the cause of the zirconia crown's failure has been identified. The crown margin has reportedly been the source of fracture during clinical use [12]. The margin is an important part of the restoration that is tightly suited to the specific finishing region of the prepared abutment. The quality of the restoration margin is strongly tied to the method used to prepare the tooth and the process used to fabricate the restoration. The doctor can digitally create a well-contoured restoration with a good marginal fit and the right emergence profile thanks to excellent clinical skills and methods. The peripheral portions, which have little thickness, typically cause the crown to break easily [13]. It's possible that the margin design and thickness have something to do with the failure that started in the zirconia restoration's margin. [13].

Numerous studies have been conducted to determine how the margin design affects the occlusal thickness and wall thickness of zirconia restorations in relation to load-bearing capacity [12, 14–15]. By applying an occlusal load, either longitudinally or obliquely, to anatomical crowns until fracture, some studies into the fracture resistance of all ceramic restorations were conducted. The results showed that the failures of ceramic restorations were regularly indicated in the patterns by a compressive curl, hackle, wake hackle, twist hackle, and arrest lines, which helped to distinguish the crack propagation pattern and the origin. As a result, the design of the margins in restorations significantly affects the ceramic restoration's ability to resist fracture. However, it is still undoubtedly unclear how the design and restoration configuration will affect the fracture properties of a high-translucency monolithic zirconia (HTMZ) restoration.

Shape of the prepared tooth, kind of all-ceramic crown system used, thickness of the porcelain crown, flaws in the porcelain, and luting cement systems are some of the aspects that affect a ceramic crown's strength.[16-21] Zinc phosphate, zinc polycarboxylate, conventional glass ionomer cements, and resin-modified glass ionomer cements (all classified as acid-base cements) have all been recommended for use in all-ceramic crown restorations.[22-25] In comparison to non-adhesive cementation, it has been claimed that cementation utilizing adhesive luting resins enhances the mechanical qualities of definitive restorations.[26]Previous research demonstrates that when sticky resin cement was used to affix all ceramic crowns, The mean maximal masticatory forces were less than the mean fracture loads. [26,27,28]. In contrast to non-adhesive cementation.

Several earlier research found that silanization and cementation employing adhesive luting resins improved the mechanical qualities of definitive restorations. Furthermore, clinical evidence suggests that bonding ceramic restorations with resin-based luting agents rather than cementing them with zinc phosphate or traditional glass ionomer cements reduces the fracture rate of ceramic restorations. [24,26] The clinical application of adhesive is based on two ideas. This experimental study's goal was to compare the fracture load and durability time of fracture for monolithic zirconia crowns with various geometric margin designs and cement types under compressive loading. The null hypothesis was that various marginal HTMZ repair designs and various cement types had no appreciable impact on the fracture load or the long-term stability of the fracture strength.

II. Material and method

Twenty sound human maxillary first molar teeth extracted because of periodontal problem, the teeth were selected with comparable size and shape as measured with a digital caliper (POWER FIX Profi; Owim, Neckarsulm, Germany). To maintain standardization during preparation of samples, surveyor for dental use (Paraline; Dentaurum, Ispringen, Germany) with a modification to grasp a turbine hand-piece (DynaLED M600LGM4; NSK, Tokyo, Japan) was used for this purpose. **Figure 1**.

Figure 1: surveyor for dental use.

Thus, the bur that was used to prepare the axial walls of the tooth sample became parallel with the long axis of it. Both prepared teeth have a 5 mm occlusocervical height with planar occlusal reduction and this was done by using barreled-shaped bur (811 314 037; Komet, Siege, Germany) and a line was drawn 1 mm above the cemento-enamel junction (CEJ) with a marker (Staedtler; Nuremberg, Germany) and this represents the margin design. A specific criteria for each prepared tooth, one tooth was prepared for a deep chamfer margin design of 0.8 mm width with guide-pin round-end tapered fissure bur (6856P 314 018; Komet, Siege, Germany) and finishing step was done by using round-end tapered fissure bur (8856 314 016; Komet, Siege, Germany) and a total convergence of 6 degrees, the other tooth was prepared for a shoulder less(Feather) margin design with a flame shape tapered fissure bur (6862 314 012, Komet, Siege, Germany) and finishing step was done by using this type of bur (8862 314 010; Komet, Siege, Germany) with same convergence. **Figure 2.**

Impression of teeth

The prepared teeth were scanned using an intra oral 3D scanner (Medit 500 I) Girrbach AG, Koblach, Austria). zirconia crowns were fabricated for two testing groups, based on the margin designs of the restorations. **Figure 3.**

Crown fabrication

The scan was input to (Dental CAD) design software as STL file, the STL files of each restoration were transferred to the CAM to be milled with the green stage zirconia blocks (Ceramill® Zolid HT+ White; Amann Girrbach AG, Koblach, Austria). The pre-sintered milled zirconia restoration was performed in an oversize dimension for each model, in order to compensate for the dimensional shrinkage of 25–30%. then sintered in a furnace (Ceramill) 3; Amann Girrbach AG, Koblach, Austria), according to the manufacturer's recommended firing parameters, at a temperature of 1450°C for a 120-minute holding period, which concluded with a sintering process that took a total of 7.5 hours for each zirconia crown. After the sintering process, the sintered restorations were tried, adjusted, and finished on the tooth until completely seated.

Cementation of zirconia crown

After the restoration is fitted on the tooth, each group divided into two subgroups according to the type of cement used for cementation.

- Half of each group cemented by relay X unicem self-adhesive universal resin cement (3M)

- The other half of each group cemented by Gc Fuji RM GIC Glass ionomer cement.

Fracture load Test

The fracture load strength of each zirconia crown was determined on the cemented crown. zirconia crown was absolutely seated on its respective prepared tooth after cementation. The load was vertically applied from the occlusal surface of the zirconia crown along the long axis of the tooth using a universal testing machine (UTM, Lloyd®, LR30/K, Leicester, England). This machine used a round-end (10 mm diameter) hard steel punch at a crosshead speed of 0.2 mm/min, in order for the circumferential hoop stress at the crown margin to develop until fracture is happen. **Figure 4(a, b, c, d)**

III. Result

In the study, the total number of preparations was 20, divided into 10-chamfer preparation, and ten feather preparations, preparations were divided equally according to the different cement used for zirconium. In five preparations, the zirconium crown was luted with resin cement (3 M), and the other five preparations were luted with glass ionomer cement (GC Fuji HC), as shown in Table 1 below:

Table 1: Distribution of two types of preparation and two different types of luting agent.

Type of preparations	type of cementation		Number of teeth prepared	
Chamfer	Resin cement (3 M)	Resin cement (3 M)	(5)	(5)
Feather	Resin cement (3 M)	Resin cement (3 M)	(5)	(5)

The result of two-way ANOVA showed that the type of cement materials and preparations was statistically significant $P \leq 0.05$; in a table: 2

Table2: chi test showed the statistically significant difference between different types of preparations and cement

		N	Correlation	Sig.
Pair 1	CH-R & FE-R	5	.960	.009
Pair 2	CH-G & FE-G	5	.369	.541

The chamfer preparation showed a higher mean value of fracture load in both types of cementations (5288, 3402) for resin cement and glass ionomer cement intervals. Moreover, the resin cement in both types of preparations (chamfer, feather) showed a higher mean value (5288, 4103). The mean fracture load and slandered deviation are presented in Table: 3

Table 3: two-way analysis of variance of experiment groups

Preparation (type of cement)	N	Minimum	Maximum	Mean	Std. Deviation
Chamfer (resin)	5	5000.00	5712.00	5288.4000	339.40065
Chamfer (glass)	5	3002.00	4003.00	3402.0000	542.27392
Feather (resin)	5	3989.00	4300.00	4103.8000	150.16890
Feather (glass (	5	1987.00	3001.00	2738.8000	426.65818
Valid N (list wise)	5				

IV. Discussion:

Several variables, including loading condition, the elastic modulus of the supporting die, and cementation, influence the resistance to fracturing of the clinical crown. [29,30] As demonstrated by this comparative study, the margin design has a significant effect on the fracture resistance of monolithic zirconia crowns; the feather margin design failed at a higher load than the slight chamfer margin design, despite having the same occlusal thickness. [31]

stress distribution through increasing the load on the crown in the feather margin design as this force would be transmitted to the axial walls rather than the margin of the supporting die, resulting in stress concentration on the occlusal surface of the crown rather than the margin area as the fracture mode and fractographic analysis showed. [32]

In terms of marginal adaption, ceramic crowns with chamfer finish lines performed much better than those with feather finish lines. In addition, ceramic crowns that had chamfers demonstrated much greater internal adaptability than those that had a feather end line. [33,34] When resin cement was used as the adhesive medium, the two finish line designs became equivalent in strength and resistant to fracture. The marginal adaptation of ceramic crowns that used two different finish-line designs showed a little difference, but this variation did not have a significant impact on the clinical outcome. [34,35] When compared to GIC cements, microleakage ratings for resin luting agents were much lower.

According to the results of the investigation, resin cements appear to be on par with GIC luting agents in terms of their ability to establish an adhesive interface while simultaneously exhibiting reduced levels of volumetric microleakage. Therefore, in terms of the interfacial integrity of cemented indirect ceramic restorations, resin cement has better longevity than other types of cement and can be utilized with finish line designs that are less rigorous such as feather finish lines. [36] Overall, all monolithic crowns demonstrated fracture resistance greater than the maximum occlusal forces; thus, both preparation designs were recommended and may be successful in clinical settings; however, the idea goes toward the preservation of a maximum amount of sound structure, especially in periodontally treated cases. [37,38]

According to previous research, the aging mechanism reduces the fracture resistance of monolithic zirconia crowns [39,40,41,42] .

References:

[1]. Denry I, Kelly JR. State Of The Art Of Zirconia For Dental Applications. Dent Mater 2008;24(3):299–307
[2]. Zhang Y. Making Yttria-Stabilized Tetragonal Zirconia Translucent. Dent Mater 2014;30(10):1195–1203
[3]. Rashid H, Sheikh Z, Misbahuddin S, Kazmi MR, Qureshi S, Uddin MZ. Advancements In All-Ceramics For Dental Restorations And Their Effect On The Wear Of Opposing Dentition. Eur J Dent 2016;10(4):583–588
[4]. Church TD, Jessup JP, Guillory VL, Vandewalle KS. Translucency And Strength Of High-Translucency Monolithic Zirconium Oxide Materials. Gen Dent 2017;65(1):48–52
[5]. 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.J Adv Prosthodont 2016;8(1):30–36
[6]. Skjold A, Schriwer C, Øilo M. Effect Of Margin Design On Fracture Load Of Zirconia Crowns. Eur J Oral Sci 2019;127(1):89–96
[7]. Jang GW, Kim HS, Choe HC, Son MK. Fracture Strength And Mechanism Of Dental Ceramic Crown With Zirconia Thickness. Procedia Eng 2011; 10:1556–1560
[8]. Nakamura K, Harada A, Inagaki R, Et Al. Fracture Resistance Of Monolithic Zirconia Molar Crowns With Reduced Thickness. Acta Odontol Scand 2015;73(8):602–608
[9]. Poggio CE, Dosoli R, Ercoli C. A Retrospective Analysis Of 102 Zirconia Single Crowns With Knife-Edge Margins. J Prosthet Dent 2012;107(5):316–321
[10]. Schmitz JH, Cortellini D, Granata S, Valenti M. Monolithic Lithium Disilicate Complete Single Crowns With Feather-Edge Preparation Design In The Posterior Region: A Multicentric Retrospective Study Up To 12 Years. Quintessence Int 2017; 48:601–608
[11]. V. Preis, M. Behr, C. Kolbeck, S. Hahnel, G. Handel, And M. Rosentritt, "Wear Performance Of Substructure Ceramics And Veneering Porcelains," Dental Materials, Vol. 27, No. 8, Pp. 796–804, 2011.
[12]. M. Øilo, C. Schriwer, B. Flinn, And N. R. Gjerdet, "Monolithic Zirconia Crowns—Wall Thickness, Surface Treatment And Load At Fracture," Biomaterial Investigations In Dentistry, Vol. 6, No. 1, Pp. 13–22, 2019.
[13]. S. S. Scherrer, G. D. Quinn, And J. B. Quinn, "Fractographic Failure Analysis Of A Procera Allceram Crown Using Stereo And Scanning Electron Microscopy," Dental Materials, Vol. 24, No. 8, Pp. 1107–1113, 2008.
[14]. A. Skjold, C. Schriwer, And M. Øilo, "Effect Of Margin Design On Fracture Load Of Zirconia Crowns," European Journal Of Oral Sciences, Vol. 127, No. 1, Pp. 89–96, 2019.
[15]. K. Nakamura, A. Harada, R. Inagaki Et Al., "Fracture Resistance Of Monolithic Zirconia Molar Crowns With Reduced Thickness," Acta Odontologica Scandinavica, Vol. 73, No. 8, Pp. 602–608, 2015.
[16]. M. Groten And L. Probster: Int. J. Prosthodont., 1997, 10, 169–177.
[17]. Q. Zhu, G. D. De With, L. J. Dortmans And F. Feenstra: J. Biomed. Mater. Res. B, 2003, 65B, 233–238.
[18]. C. Leevailoj, J. A. Platt, M. A. Cochran And B. K. Moore: J. Prosthet. Dent., 1998, 80, 699–707.
[19]. S. S. Scherrer, W. G. De Rijk And U. C. Belser: Int. J. Prosthodont., 1996, 9, 580–585.
[20]. V. P. Thompson And D. E. Rekow: J. Appl. Oral. Sci., 2004, 12, 26– 36.
[21]. O. Addison And G. J. Fleming: Dent. Mater. 2004, 20, 286–292.
[22]. G. J. Fleming And O. Narayan: Dent. Mater., 2003, 19, 69–76.
[23]. P. Mojon, R. Kaltio, D. Feduik, E. B. Hawbolt And M. I. Macentee: Dent. Mater., 1996, 12, 83–87.
[24]. A. J. Feilzer, A. I. Kakaboura, A. J. De Gee And C. L. Davidson: Dent. Mater., 1995, 11, 186–190.
[25]. L. A. Knobloch, R. E. Kerby, R. Seghi, J. S. Berlin And J. S. Lee: J. Prosthet. Dent., 2000, 83, 204–209.
[26]. A. Attia, K. M. Abdelaziz, S. Freitag And M. Kern: J. Prosthet. Dent., 2006, 95, 117–123.
[27]. J. W. Hwang And J. H. Yang: J. Oral. Rehabil., 2001, 28, 678–683.
[28]. F. Komine, M. Tomic, T. Gerds And J. R. Strub: J. Prosthet. Dent., 2004, 92, 359–364.
[29]. Campbell SD. A Comparative Strength Study Of Metal Ceramic And All-Ceramic Esthetic Materials: Modulus Of Rupture. J Prosthet Dent 1989;62(4):476–479
[30]. Yucel MT, Yondem I, Aykent F, Eraslan O. Influence Of The Supporting Die Structures On The Fracture Strength Of All-Ceramic Materials. Clin Oral Investig 2012;16(4):1105–1110.
[31]. Reich S, Petschelt A, Lohbauer U. The Effect Of Finish Line Preparation And Layer Thickness On The Failure Load And Fractography Of Zro2 Copings. J Prosthet Dent 2008;99(5):369–376
[32]. 4.Beuer F, Aggstaller H, Edelhoff D, Gernet W. Effect Of Preparation Design On The Fracture Resistance Of Zirconia Crown Cop-ings. Dent Mater J 2008;27(3):362–367
[33]. Nakamura K, Harada A, Inagaki R, Et Al. Fracture Resistance Of Monolithic Zirconia Molar Crowns With Reduced Thickness. Acta Odontol Scand 2015;73(8):602–608
[34]. Pan, C.-Y.; Lan, T.-H.; Liu, P.-H.; Fu, W.-R. Comparison Of Different Cervical Finish Lines Of All-Ceramic Crowns On Primary Molars In Finite Element Analysis. Materials 2020, 13, 1094. Https://Doi.Org/10.3390/Ma13051094.
[35]. Sasse M, Krummel A, Klosa K, Kern M. Influence Of Restoration Thickness And Dental Bonding Surface On The Fracture Resistance Of Full-Coverage Occlusal Veneers Made From Lithium Disilicate Ceramic. Dent Mater 2015;31(8):907–915.

[36]. . Jasim HH, Findakly MB, Mahdi NA, Mutar MT. Effect Of Reduced Occlusal Thickness With Two Margin Designs On Fracture Resistance Of Monolithic Zirconia Crowns. Eur J Dent. 2020 Mar;14(2):245-249. Doi: 10.1055/S-0040-1709342. Epub 2020 Jun 5. PMID: 32503065; PMCID: PMC7274823.

[37]. Sun T, Zhou S, Lai R, Et Al. Load-Bearing Capacity And The Recommended Thickness Of Dental Monolithic Zirconia Single Crowns. J Mech Behav Biomed Mater 2014; 35:93–101

[38]. 9.Findakly MB, Jasim HH. Influence Of Preparation Design On Fracture Resistance Of Different Monolithic Zirconia Crowns: A Comparative Study. J Adv Prosthodont 2019;11(6):324–330

[39]. Flinn BD, Degroot DA, Mancl LA, Raigrodski AJ. Accelerated Aging Characteristics Of Three Yttria-Stabilized Tetragonal Zirconia Polycrystalline Dental Materials. J Prosthet Dent 2012;108(4):223–230

[40]. 11 Cotes C, Arata A, Melo RM, Bottino MA, Machado JP, Souza RO. Effects Of Aging Procedures On The Topographic Surface, Structural Stability, And Mechanical Strength Of A Zro2-Based Dental Ceramic. Dent Mater 2014;30(12): E396–E404.

[41]. Pan, C.-Y.; Lan, T.-H.; Liu, P.-H.; Fu, W.-R. Comparison Of Different Cervical Finish Lines Of All-Ceramic Crowns On Primary Molars In Finite Element Analysis. Materials 2020, 13, 1094. Https://Doi.Org/10.3390/Ma13051094

[42]. Vohra F, Altwaim M, Alshuwaier AS, Et Al. Bond Integrity And Microleakage Of Dentin-Bonded Crowns Cemented With Bioactive Cement In Comparison To Resin Cements: In Vitro Study. Journal Of Applied Biomaterials & Functional Materials. 2020;18. Doi:10.1177/2280800020905768