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The Comparison of Fracture Resistance between Low Translucent and Ultra-High Translucent Monolithic Zirconia Crown

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Abstract

Objective From the beginning of its discovery, the monolithic zirconia crown was highlighted for its remarkable strength; therefore, only available in opaque color. During the past decade, the translucent monolithic zirconia crown was manufactured to meet the aesthetic and restoration demand but was thought to be the cause of decreasing its strength. This study aimed to compare the fracture resistance between two types of translucent monolithic zirconia crowns, that is, low translucent monolithic zirconia (LT) and ultra-high translucent monolithic zirconia (UHT).

Material and Methods The premolar crown model was prepared using a computer-aided design/computer-aided manufacturing system, producing 1 mm of thickness. Ten crown samples were divided into LT and UHT. Then, each sample was measured for its fracture resistance using Universal Testing Machine until a fracture occurred. The differences in fracture resistance were analyzed using an independent *t*-test with $p < 0.05$.

Result The LT showed a higher fracture resistance than UHT ($p < 0.05$).

Conclusion The LT monolithic zirconia crown has strength and can be used for posterior crown restoration.

Keywords
- fracture resistance
- low translucent
- monolithic zirconia
- ultra-high translucent
- restoration

Introduction

In recent years, public awareness has increased for nonmetal restorations and have been highly in demand.[1] Ceramic crowns have become very popular because they have excellent aesthetics, biocompatibility, and strength.[2] From all available ceramic materials, full zirconia crowns have the best fracture resistance for crown restorations.[3–5]

Yttrium cation-doped tetragonal zirconia polycrystal (Y-TZP) crown is the most widely used crown. Crowns made of Y-TZP material have been used for anterior and posterior restorations.[6] Although the strength of zirconia as a framework is excellent and has high resistance, some studies report fractures in the veneer material that covers it; thus, a monolithic crown was developed. Back then, zirconia restorations were less translucent and only available in low translucent (opaque) colors. Nowadays, they are available in low-translucent monolithic zirconia (LT) and high-translucent monolithic zirconia (HT), making monolithic zirconia crowns an aesthetic and therapeutic option.[7–10] LT contains 3 mol% of Y-TZP, while HT contains 8 mol% yttria, which results in materials with completely different structures, optical and mechanical properties.[11] Increased translucency of the zirconia crown raises doubts about fracture resistance; therefore, research was performed to confirm it.[3] Monolithic zirconia was the first choice for a single posterior crown, and lithium disilicate was the first choice for a single anterior crown.[12] However, a zirconia crown was developed

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with much better transparency, namely, ultra-high translucent monolithic zirconia (UHT). It aims to obtain the mechanical properties of zirconia and the aesthetic properties of lithium disilicate.

The difference between LT and UHT lies in the composition of the transformation phase.[13] The UHT contains significantly more cubic phases than other zirconia, so it has excellent translucency.[14] The high content of cubic phase grains will reduce the mechanical properties of HTZ zirconia, especially fracture resistance.[15] Based on those problems, it is needed to compare the mechanical properties, especially the fracture resistance between LT and UHT crowns.

Materials and Methods

Monolithic Zirconia

The monolithic zirconia used in this study was LT (Katana Zirconia, Kuraray Noritake Dental Inc, Aichi, Japan) and HT (Katana Zirconia, Kuraray Noritake Dental Inc).

Crown Sample Model

This study used 10 crown models divided into two groups: five crowns of LT monolithic zirconia and five crowns of UHT monolithic zirconia. The research model was made similar to the premolar tooth using a computer-aided design (CAD)/computer-aided manufacturing system. The premolar tooth was prepared in a crown preparation with a thickness of 1 mm. Chamfer shape was chosen for cervical margin preparation. Prepared premolar teeth are duplicated with wax. The tooth model is then cast in metal form (►**Fig. 1A and B**).

The model cast was then scanned and transferred to the CAD system for making the crown design with a thickness of 1 mm (►**Fig. 1C and D**). Milling was performed on the zirconia block. Then proceed with the process of sintering and glazing. After completing the crown, we planted the research models into acrylic resin, followed by cementing the monolithic zirconia crown on the tooth model.

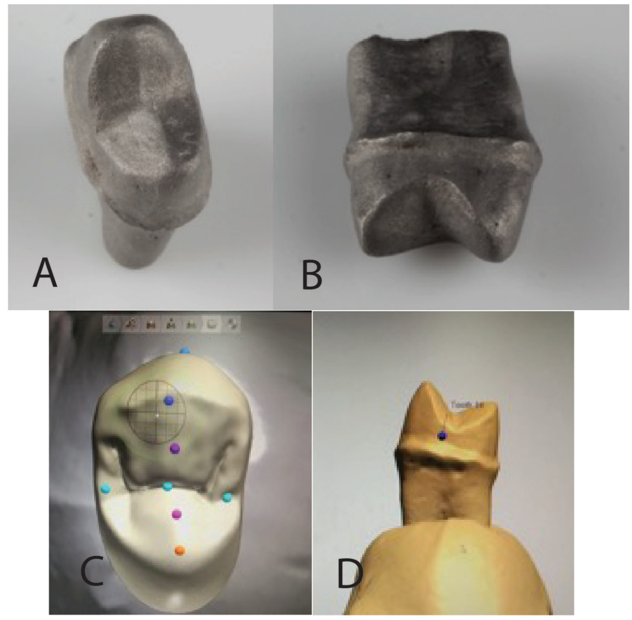

Fig. 1 (**A**) The model of toot was created from metal, (**B**) and the model of preparation with a thickness of 1 mm and Chamfer shape was chosen for cervical margin preparation. (**C,D**) Then, a scanning model was prepared for zirconia crown casting.

Fracture Resistance

The fracture resistance test was performed with UTM test equipment. Two groups of samples were placed below the pressing equipment with the tip of the load test instrument positioned on the fissure of the crown. All the samples were pressed using a starting load test at a speed of 0.225 mm/minute until a fracture occurred; after that, data from the experiment were collected for statistical calculation.

Statistics Analysis

An independent *t*-test was conducted to determine the fracture resistance between the LT and UHT monolithic crown. The significance level used in this test was 0.05 or 95%; the significance was determined based on a *p*-value of < 0.05.

Results

The fracture resistance from pressure in LT was 3527 ± 20.59 mm/minute and UHT was 2972.2 ± 19.95 mm/minute. The LT showed a higher fracture resistance than UHT ($p = 0.046$) ►**Fig. 2**.

Discussion

This study compared the LT and UHT zirconia crown seen from the mechanical properties of fracture resistance. It is similar to the research conducted by Johansson et al[16] and Nordahl et al,[3] which compared LT, UHT, and monolithic lithium disilicate crowns. The results of this study indicate that the LT monolithic zirconia crown has higher fracture resistance than the UHT monolithic zirconia crown. This was caused by manipulation of grain size and dopant changes can affect the mechanical properties of zirconia crowns.[3] LT monolithic zirconia crowns have a polymorphic structure. With the change of phase from the tetragonal phase to the monolithic phase, there will be an increase in volume, which will cause cracks at room temperature.[11] Adding a stabilizer will prevent cracks due to the addition of volume. The purpose of adding stabilizers is to prevent cracks; this addition mechanism also improves the mechanical properties of zirconia, which makes the LT zirconia crown to have the highest fracture resistance properties compared with other types of ceramics.[17–20] It was also proved in the study by Nordahl et al, who stated that monolithic zirconia crowns had higher fracture resistance than monolithic lithium disilicate crowns.[3]

The composition of the phase changes in the UHT monolithic zirconia crown differs from the LT monolithic zirconia crown. The yttria (Y_2O_3) stabilizer content in UHT monolithic zirconia is around 9.42 wt%, while in the LT it is around 5.15 wt%, which makes this zirconia contain cubic phase (c-ZrO_2) resulting in lower alumina content.[21,22] The higher content of the cubic phase makes the UHT monolithic

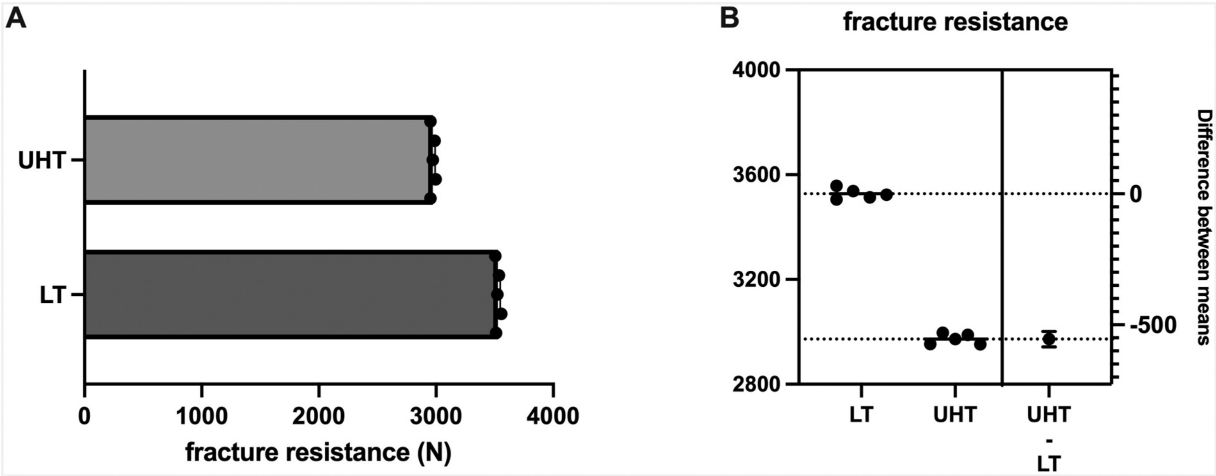

Fig. 2 (A) Low-translucent monolithic zirconia (LT) and ultra-high translucent monolithic zirconia (UHT) zirconia crown model of fracture resistance value (B), and the fracture resistance difference between the two types of crown.

zirconia crown more stable hydrothermally because the zirconia grains in the cubic phase (c-ZrO_2) do not change to the monoclinic zirconia (m-ZrO_2) phase at room temperature. The reduced transformation of the zirconia phase from the tetragonal phase to the monoclinic phase will undoubtedly reduce the mechanical properties of UHT monolithic zirconia because this transformation increases the strength of the zirconia. Thus, the higher cubic phase content in UHT monolithic zirconia will affect the decreased mechanical properties, especially in strength and fracture resistance.[23]

One method for increasing the mechanical strength of ceramics is to add alumina. Alumina is a rigid and opaque-colored material that is less susceptible to cracking when compared with ceramics. The mechanism of increasing strength with alumina is that alumina will act as a “crack stopper” that can prevent the spread of cracks to all parts of the restoration. The high modulus of elasticity of alumina is 350 GPA which will ensure that the interface between the ceramic surface and alumina particles is free from stress or tension, so it does not trigger the spread of cracks around alumina particles.[24] Lower alumina content in the UHT monolithic zirconia makes the mechanical properties of fracture resistance lower than the crown of LT in this study.

The microstructural analysis also revealed that the crown grain size of the UL and UHT monolithic zirconia were distributed differently. The UHT monolithic zirconia crown contains larger grain sizes because the grain size in the cubic phase was greater than the grain size in the tetragonal phase. In addition, the temperature in the sintering process will also affect the size of the zirconia grains.[25] Higher temperatures in the sintering process will result in larger grain sizes. In manufacturing, the UHT monolithic zirconia was sintered at 1550°C, while the LT crown was sintered at 1450°C. However, zirconia grain sizes produced by different zirconia brands sintered at the same temperature will make different grain sizes.[21] In principle, the increase of the crown’s translucence will decrease its strength. The limitation of this study was that the test was not conditioned in the oral environment. Future research needs to be performed to evaluate its strength or fracture resistance in different types of anterior and posterior teeth.

Conclusion

The LT monolithic zirconia has higher strength than UHT monolithic zirconia and can be used for posterior crown restoration.

Ethical Approval
Not required – the study did not involve human subjects.

Conflict of Interest
None declared.

References

1 Finck NS, Paiva Jda M, Werneck RD, Freitas MIM, Guimarães PS. Próteses parciais fixas metal free em região posterior – revisão da literatura considerando a longevidade, material cerâmico usado e principais falhas. Full Dentist Sci 2021;12(47):113–125
2 Silva NRFA, Sailer I, Zhang Y, et al. Performance of zirconia for dental healthcare. Materials (Basel) 2010;3(02):863–896
3 Nordahl N, Vult von Steyern P, Larsson C. Fracture strength of ceramic monolithic crown systems of different thickness. J Oral Sci 2015;57(03):255–261
4 Maziero Volpato CA, Altoe Garbelotto LGD, Celso M, Bondioli F. Application of zirconia in dentistry: biological, mechanical and optical considerations. In: Advances in Ceramics - Electric and Magnetic Ceramics, Bioceramics, Ceramics and Environment [Internet]. InTech; 2011. Accessed February 14, 2023, at: http://www.intechopen.com/books/advances-in-ceramics-electric-and-magnetic-ceramics-bioceramics-ceramics-and-environment/application-of-zirconia-in-dentistry-biological-mechanical-and-optical-considerations
5 Kurtulmus-Yilmaz S, Ulusoy M. Comparison of the translucency of shaded zirconia all-ceramic systems. J Adv Prosthodont 2014;6(05):415–422
6 Pekkan G, Pekkan K, Bayindir BÇ, Özcan M, Karasu B. Factors affecting the translucency of monolithic zirconia ceramics: a review from materials science perspective. Dent Mater J 2020;39(01):1–8

7 Malkondu Ö, Tinastepe N, Akan E, Kazazoğlu E. An overview of monolithic zirconia in dentistry. Biotechnol Biotechnol Equip 2016;30(04):644–652
8 Madfa AA, Al-Sanabani FA, Al-Qudami NH, Al-Sanabani JS, Amran AG. Use of zirconia in dentistry: an overview. Open Biomat J 2014; 5(01):1–7
9 Choi YS, Kim SH, Lee JB, Han JS, Yeo IS. In vitro evaluation of fracture strength of zirconia restoration veneered with various ceramic materials. J Adv Prosthodont 2012;4(03):162–169
10 Nakamura K, Mouhat M, Nergård JM, et al. Effect of cements on fracture resistance of monolithic zirconia crowns. Acta Biomater Odontol Scand 2016;2(01):12–19
11 Kontonasaki E, Giasimakopoulos P, Rigos AE. Strength and aging resistance of monolithic zirconia: an update to current knowledge. Jpn Dent Sci Rev 2020;56(01):1–23
12 Kwon SJ, Lawson NC, McLaren EE, Nejat AH, Burgess JO. Comparison of the mechanical properties of translucent zirconia and lithium disilicate. J Prosthet Dent 2018;120(01):132–137
13 Kolakarnprasert N, Kaizer MR, Kim DK, Zhang Y. New multilayered zirconias: composition, microstructure and translucency. Dent Mater 2019;35(05):797–806
14 Alkatheeri M, Altahtam AA, Abukhalaf A, Almaslokhi T, Almusalam A, Almohareb T. Translucency of recently introduced extra high translucency zirconia. J Res Med Dent Sci 2020;8(01):175–180
15 Almansour HM, Alqahtani F. The effect of in vitro aging and fatigue on the flexural strength of monolithic high-translucency zirconia restorations. J Contemp Dent Pract 2018;19(07):867–873
16 Johansson C, Kmet G, Rivera J, Larsson C, Vult Von Steyern P. Fracture strength of monolithic all-ceramic crowns made of high translucent yttrium oxide-stabilized zirconium dioxide compared to porcelain-veneered crowns and lithium disilicate crowns. Acta Odontol Scand 2014;72(02):145–153
17 Jung YS, Lee JW, Choi YJ, Ahn JS, Shin SW, Huh JB. A study on the in-vitro wear of the natural tooth structure by opposing zirconia or dental porcelain. J Adv Prosthodont 2010;2(03): 111–115
18 Lameira DP, Buarque e Silva WA, Andrade e Silva F, De Souza GM. Fracture strength of aged monolithic and bilayer zirconia-based crowns. BioMed Res Int 2015;2015:418641
19 Komine F, Blatz MB, Matsumura H. Current status of zirconia-based fixed restorations. J Oral Sci 2010;52(04):531–539
20 Subaşı MG, Demir N, Kara Ö, Ozturk AN, Özel F. Mechanical properties of zirconia after different surface treatments and repeated firings. J Adv Prosthodont 2014;6(06):462–467
21 Vanlıoğlu BA, Kulak-Özkan Y. Minimally invasive veneers: current state of the art. Clin Cosmet Investig Dent 2014;6:101–107
22 Al-Juaila E, Osman E, Segaan L, Shrebaty M, Farghaly EA. Comparison of translucency for different thicknesses of recent types of esthetic zirconia ceramics versus conventional ceramics … (in vitro study). Future Dental J 2018;4(02):297–301
23 Mao L, Kaizer MR, Zhao M, Guo B, Song YF, Zhang Y. Graded ultra-translucent zirconia (5Y-PSZ) for strength and functionalities. J Dent Res 2018;97(11):1222–1228
24 Abdelbary O, Wahsh M, Sherif A, Salah T. Effect of accelerated aging on translucency of monolithic zirconia. Future Dental J 2016;2(02):65–69
25 Wang CJ, Huang CY, Wu YC. Two-step sintering of fine alumina–zirconia ceramics. Ceram Int 2009;35(04):1467–1472