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The Fracture Resistance of Full Contour Monolithic-Zirconia Dental Crowns from Cyclic Loading: A Function of Lifetime Extension of Dental Restorations

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Abstract: An ex-vivo study aimed to investigate the fracture resistance of monolith- single layer zirconia of 1.5 mm thickness for dental molar crowns concerning simulating failure behavior under simulated cyclic loading with an extended lifetime of up to 5 million cycles. Sixteen molar crowns were scanned after preparation through computer-aided manufacturing (CAD/CAM) technology to recreate the zirconia crowns, which have a uniform occlusal surface thickness of 1.5 mm. All the samples went through thermal aging by putting them through 6000 thermo-cycles for 3 minutes with the use of distilled water at a temperature range between 5 ˚C and 55 ˚C. All samples were placed under cyclic fatigue loading using the SD Mechatronik chewing simulator and afterward subjected to two-dimensional movements for almost five million cycles. Tests were carried out in distilled water at room temperature. The sample was observed, tested, and photographed every five hundred thousand cycles. The surface cracks were observed within the vicinity of the contact area only and extended with increasing cycles. Minor wear depth was observed in the crowns relative to the damage observed in the Ni-Cr alloy steel flat indenter. No chipping or complete failure was observed in all tested samples which suggested that full-contour zirconia crowns are good for extending the long life service of dental restorations.

Keywords: Zirconia monolayer, Dental crowns, Flat indenter, Chewing simulator, Thermal aging.

Introduction

Dental crowns went through several stages of advancement over the last decades. It starts with just a metal layer, then porcelain fused to metal (PFM), after which the all-ceramic double layer is used in the form of fused porcelain over a zirconia substrate. More recently, all zirconia single-layer restoration was introduced to overcome the interface problems between the two layers and to benefit from the excellent properties of the zirconia (Zarone et al., 2011; Goodacre et al., 2011). In the case of worn detention conditions, increasing the vertical occlusion dimension is not workable in all circumstances (Dawson, 1989; Stewart, 1998). In the case of using bilayer crowns, to overcome this issue, the thickness of ceramic coating could be increased which improves the performance of the veneering layer by increasing the load-bearing capacity of the restorations (Guess et al., 2011; Lin et al., 2012). On the other hand, using a single layer of zirconia the variability of the thickness is not an issue of concern. To increase the contact pressure several researchers used hard spherical indenters on flat specimens or dental restoration replicas. The crack patens observed between using spherical indenters and flat indenters are well documented (Zhang et al., 2012).

In this study, a flat indenter is used to increase the points of contact with crown cusps on the occlusal top surface of the crown. Most of the work done so far in cyclic loading testing was up to 1.25 million cycles which represents five years of chewing (Qasim et al., 2018), due to the lengthy process of testing and failure which was observed in porcelain fused to zirconia sample which was detected at the low number of cycles. In this study, since no visible failure was observed at the low number of cycles, the author extended the number of

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cycles to 5 million cycles. No catastrophic damage was observed in all samples tested which indicates that a single zirconia layer restoration is visible for long-life restorations. The downside of using a single zirconia layer is the changing color influenced by cyclic loading. This is in agreement with the finding of (Panagiota-Eirini et al., 2016).

Materials and Methods

Following general practice at dental laboratories, the crowns were fabricated from one layer of zirconia with a thickness of 1.5 mm at the occlusal surface. As in our previous studies. Noritake Katana Zirconia (Kurary Noritake, Germany) is used, according to manufacturer specifications properties, the Flexural strength is 1,200 MPa; Fracture toughness (K1C) ≧5 MPa m1/2 CTE 10.4×10-6/℃, and the chemical composition is ZrO_2 / Y2O3 95/5. Before fixing the specimen to the testing cyclic loading machine, all specimens were subjected to thermal aging for 6000 thermo-cycles for 3 minutes using distilled water having a temperature range between 5 ˚C and 55 ˚C. The specimens were then fixed to the testing chamber in the chewing simulator (SD Mechatronik, Germany) in the same manner as in our previous studies as shown in (Figure 1). The insertion on the top shows the indenter cycle movement along with the distance and speed moved during each cycle. The settings used in our previous studies are used in this study for comparative results and consistency (Qasim et al., 2018).

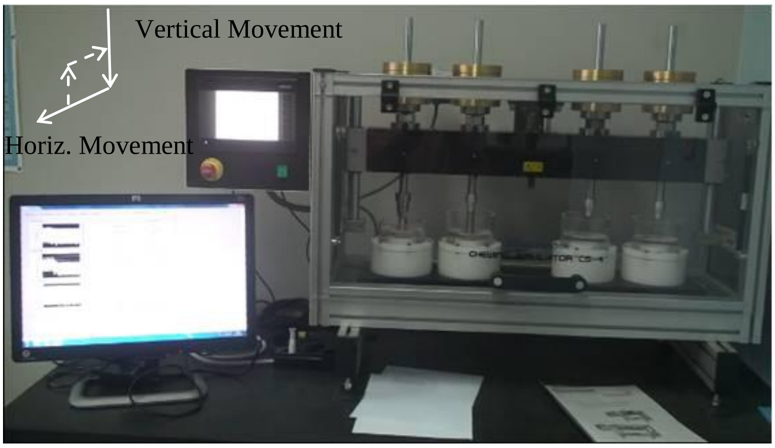

Figure 1. Chewing simulator showing complete setup including load cell and computer monitoring software.

Results and Discussion

All sample was tested under 50±5 N (~4 kg dead weight) and photographed at intervals of 250 thousand cycles to see the extent of the damage. (Figure 2) shows the same sample at 1 million cycles (A), 2 million cycles (B), and 3 million cycles (C). Comparison between Fig. 2 (A) and (B) shows clear extensive wear up to 2 million cycles, after that the contact area remains the same size regardless of the number of cycles compared to (B) and (C) in (Figure 2).

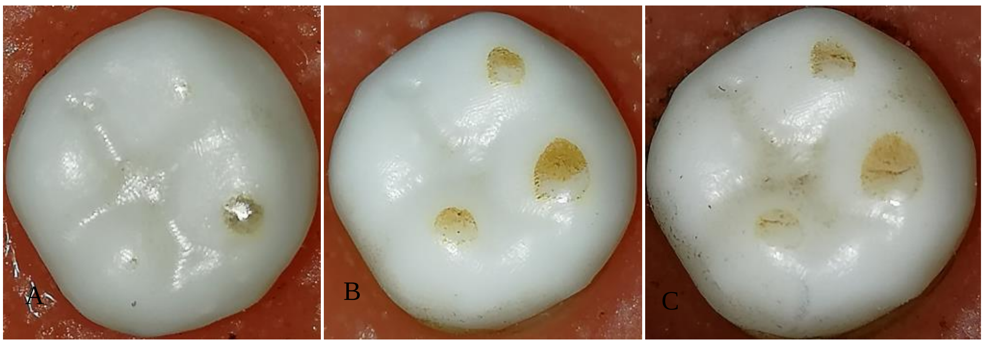

Figure 2. Influence of the number of cycles on the same specimen. (A) 1 million, (B) 2 million, and (C) 5 million cycles

Noting that the sample presented in (Figure 2 (C)) has a well-established crack within (under) the contact area, no propagation of this crack is outside the contact area where observed this suggested that the material reaches max hardness.

Figure 3 shows the effect of cyclic loading on the flat Ni-Cr alloy indenter as the number of cycles increases from 1 million cycles in Fig. 3(A) to 5 million cycles in (Figure 3 (B)). The damage to the indenter increased as the number of cycles increased in tow fold, the contact area increased and the depth of damage also increase. This can be attributed to the friction generated between the zirconia and the surface of the indenter during sliding motion. Noting that this behavior was not seen on the zirconia surface, as mentioned in (Figure 2). Where the damage after 2 million cycles is restricted within the contact area without any further increase in contact area or wear depth.

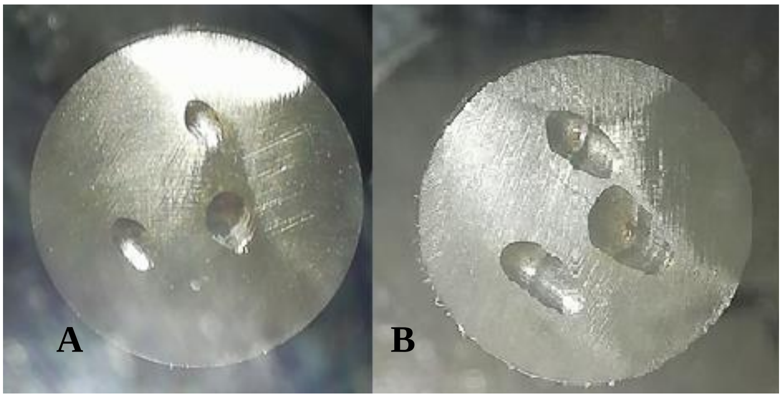

Figure 3. Damage is observed to the indenter as the number of cycles increases. (A) 1 million and (B) 5 million cycles.

Conclusion

This ex-vivo-study shows that a single layer of partially stabilized zirconia is an appropriate choice for dental restorations with a caution that the zirconia crown should not be in direct contact with the opposing tooth, since severe damage was noted in the Ni-Cr alloy indenters. This finding agreed with the results of (André et al., 2007). Increasing the number of cycles over 5 million cycles with low cyclic loading, would not be beneficial to study since the damage observed to be localized at the cusp are without any fracture extending.

Recommendations

It is recommended that all tested samples be subjected to continuous mono-loading to measure extreme loading conditions after cyclic loading. In addition, the aesthetic concern of changing the color of the zirconia surface area should be looked at.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPHELS journal belongs to the author.

Acknowledgements or Notes

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