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Comparative Evaluation of Fracture Resistance and Hardness of Two Esthetic Crowns for Young Permanent Teeth after Thermocycling

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ORIGINAL STUDY

Comparative Evaluation of Fracture Resistance and Hardness of Two Esthetic Crowns for Young Permanent Teeth After Thermocycling

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Abstract

Purpose: Evaluate and compare fracture resistance and micro-hardness of Nu-smile youth zirconia crowns and computer-aided design/computer-aided manufacturing zirconia crowns after thermocycling. **Patients and methods:** A total of 24 zirconia crowns for young first permanent molars were used. They were 12 ready-made Nu-Smile youth zirconia crowns and 12 custom-made Katana zirconia crowns. All crowns were positioned and cemented over a negative replica. All crowns were immersed in a mechatronic thermo-cycler. Fracture resistance was done utilizing a standard device for evaluation, while micro-hardness was measured with a Digital Display Vickers Tester. Maximum breaking loads were recorded. **Results:** Custom-made crowns exhibited a greater fracture load value (1696.65 ± 312.19 N) compared with ready-made crowns (1217.31 ± 117.65 N). Additionally, custom-made crowns demonstrated a greater hardness value (629.79 ± 11.38 kg/mm^2) than ready-made crowns (593.24 ± 36 kg/mm^2). **Conclusion:** Katana computer-aided design/computer-aided manufacturing zirconia crowns showed greater fracture resistance and microhardness values than Nu-Smile crowns.

Keywords: Computer-aided design/computer-aided manufacturing, Fracture resistance, Katana, Microhardness, Nu-smile, Zirconia crowns

1. Introduction

First permanent molars have a great functional and aesthetic role. Dental caries and non-carious lesions, such as Molar Incisor Hypomyelination (MIH), can lead to pulp injuries, infections, and tooth loss, depending on the extent of the lesion, and the child's cooperation in the management of the involved teeth [1].

It has been recommended that a full-coverage crown be used for pulpal-treated teeth or MIH-affected teeth overfillings to achieve long-term success. Crowns may be made of full metal or porcelain fused to metal (PFM). However, the metallic appearance of PFM can impair aesthetics. As a result, all-ceramic crowns, which have a 74 % survival rate, offer an aesthetic alternative to metal and PFM, making them reliable options for clinical applications [2].

Additive manufacturing is a modern technology that addresses three challenges: creating natural-looking restorations, providing sufficient strength, and enhancing tooth restoration durability and accuracy [3].

Prefabricated pediatric zirconia crowns have many favorable characteristics, like outstanding strength, toughness, biocompatibility, and increased resistance to chemicals, making them an excellent alternative to metal crowns when restoring deciduous or young permanent teeth [4]. Nu-Smile Youth ZR crowns exhibit highly polished surfaces because they are made up of high-grade monolith zirconia ceramics, making them smoother, less plaque-retentive, and more stain-resistant. Nu-smile ZR crowns save clinicians time and eliminate extra steps as they are made from a single zirconia block and come with a try-in crown [5].

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Thermocycling accelerates artificial aging of samples by estimating clinical performance by reproducing oral temperature. As temperature changes cause restorative materials to contract and expand, causing mechanical stresses and crack formations [6].

Fracture is a common failure in dental restorations, often originating at the core-veneer interface. Fracture resistance is a material's resistance to crack propagation, influenced by defects and flaws, and it reflects material behavior in the oral cavity [7]. Nu-smile zirconia crowns are designed especially for young permanent molars with questionable child cooperation and may serve as an equivalent to custom-made computer-aided design/computer-aided manufacturing (CAD/CAM) zirconia crowns that are used for adults [1].

The resistance of a material's surface to penetration or permanent indentation is known as micro-hardness. It influences finishing, cutting, scratch resistance, polishing, and overall durability during servicing [8]. Composition, water absorption, aging, and surface reactions are factors that influence micro-hardness. Thus, the goal of this investigation is to investigate and contrast the fracture resistance and micro-hardness of Nu-Smile youth zirconia crowns and CAD/CAM zirconia crowns after thermocycling.

2. Patients and methods

This investigation was done after clearance from the Research Ethical Committee, with the code REC-CL-23-12, at the Faculty of Dental Medicine for Girls, Al-Azhar University Cairo, Egypt.

A total of 24 zirconia crowns for young first permanent molars were used. They were of two types: group (A) included 12 ready-made Nu-Smile youth zirconia crowns (Nu Smile, Houston, Taxes. USA) and group (B) included 12 custom-made Katana zirconia crowns (Kuraray Noritake Dental Inc. Japan).

The sample size was estimated using the outcomes of a prior research [9] utilizing G power statistical power analysis program (version 3.1.9.4) was employed to establish the specimen size and after adjustment by 10 % increase to compensate for sampling error. To evaluate fracture resistance and Micro-hardness of readymade Nus-mile Youth and costume-made CAD/CAM crowns after thermocycling, a *t*-test or an analogous nonparametric analysis was employed to compare groups. A sample size of 20 (10 for each category) was adequate for identifying a big effect size, with an actual power (1-β error) of 0.8 (80 %) and a significance threshold (α error) of 0.05 (5 %) for two-sided hypothesis testing. A dual-sided hypothesis evaluation yielded an impact size of 0.8 (80 %) with an actual power (1-β error) of 0.8 and a degree of significance (α error) of 0.05 (5 %).

Production of epoxy resin dies: An acrylic artificial molar for the upper first permanent molar was prepared with diamond stone using a low-speed handpiece (NSK-Jaban). Silicon molds for acrylic artificial molars were created using duplicating of additional silicon material (Zermack, Rovigo, Italy), then epoxy resin material (Kema poxy, CMB International, Giza-Egypt) was mixed and poured into the silicon molds and left in place for 24 h.

Selection of ready-made zirconia crown: Nu-smile Youth ZR crowns were selected from their kit (Fig. 1) according to the mesiodistal width of the prepared epoxy die, and a trial fit was done prior to cementation.

Fabrication of custom-made zirconia crowns: katana zirconia crowns were manufactured by scanning the epoxy die using a smart optics scanner (Scan Box Pro, Germany), then designed by software (Exocad, GmbH, Germany), and milled by a milling machine (Roland Dwx-510-Japan), then the crowns placed in a zircon sintering furnace (Teboe S1, Him Vogt, Germany), after that, the surfaces of the crowns were smoothed. Both types of crowns were the same size. Cementation of the crowns to their corresponding epoxy dies was accomplished by employing glass ionomer cement (Brahmana, Indi) (Fig. 2a and b).

Fig. 1. Nu-smile youth ZR zirconia kit.

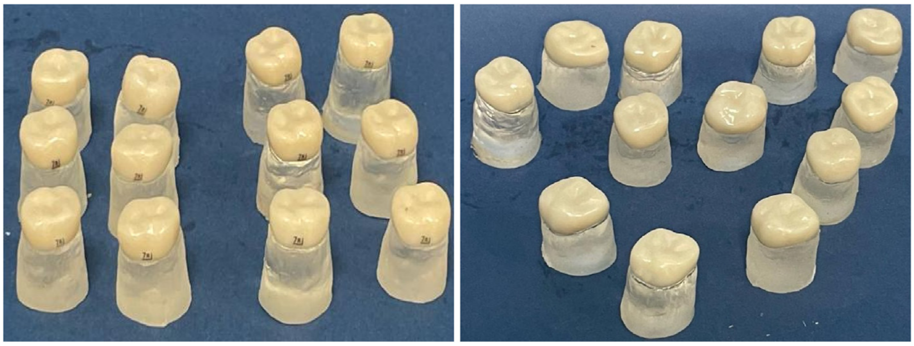

Fig. 2. (a): 12 Nu-smile zirconia (b): 12 katana zirconia crowns cemented on epoxy dies. Cemented on epoxy dies.

Thermo-cycling: All crowns were subjected to 5000 cycles of thermocycling which corresponded to 6 months clinically. Each crown was placed in an automatic thermal cycling unit of thermocycling machine (ROBOTA automated thermo-cycle, BILGE, Türkiye), and transferred between thermostatically controlled 5 °C and 55 °C water baths.

2.1. Testing procedures

2.1.1. Fracture resistance test

Each specimen was separately subjected to a 5 N load cell utilizing a standard analyzing apparatus (Model 3345; Instron Industrial Products, Norwood, MA, USA), measurements have been captured with a specialized program (Blue Hill Lite Software, Instron). The test was carried out by compressive approach with the load delivered occlusal utilizing a metal bar with a round tip 5.6 mm diameter, swinging at a velocity of 1 mm/min with a piece of tin foil in between to produce homogeneous stresses transmission (Fig. 3).

2.1.2. Micro hardness test

Uniform fracture pieces of zirconia crowns were embedded and flushed in acrylic resin blocks. Surface micro-hardness was calculated via Digital Display Vickers Micro-hardness Tester (Model HVS-50, Laizhou Huayin Testing Instrument Co., Ltd. China), with a Vickers diamond indenter and a 20 × objective lens (Fig. 4). A load of 200 g was applied to the surface for 15 s. Three marks were evenly distributed around a perimeter that was no closer than 0.5 mm to the neighboring marks on the surface. The diagonal length of the marks was determined using the integrated microscope, and Vickers measurements were translated to microhardness measurements. Microhardness had been determined via using the subsequent equation: $HV = 1.854\,P/d^2$ where, HV is Vickers hardness in $Kgf./mm^2$, P is the load in Kgf and d is the length of the diagonals in mm.

2.2. Statistical analysis

Data from both sets were gathered and sorted utilizing Excel for Microsoft Office (version 365). A

Fig. 3. Specimen at Universal testing machine.

Fig. 4. Sample mounted onto Vickers hardness tester.

Student *t*-test was employed to determine if there was a statistical difference between the groups at 1st crack sound load, failure load, and hardness results. The statistical assessment was carried out using Windows version 3.06 of the Graph-Pad Instate analytical program. *P* values less than 0.05 were statistically significant in all tests. The statistical evaluation was carried out on Windows with Graph-Pad in-state statistics program (version 3.06). *P* values less than 0.05 indicated statistical significance in every analysis.

3. Results

3.1. Fracture resistance test results

At first crack sound load: it was found that ready-made Nu-smile crowns (group A) confirmed larger mean values ± SD value of 1st crack load (1151.42 ± 88.34 N) than custom-made katana crowns (group B) mean ± SD value (1090.09 ± 148.85 N). The difference between the two groups was statistically insignificant, as demonstrated by the Student *t*-test ($P = 0.5583 > 0.05$).

Failure load: it was discovered that the custom-made group (B) reported a greater mean values ± SD value of failure load (1696.65 ± 312.19 N) than the ready-made group (A) mean ± SD value (1217.31 ± 117.65 N). Both groups' differences were of statistical significance as revealed by Student *t*-test ($P = 0.00\ 3 < 0.05$) (Table 1), and (Fig. 5).

It was discovered that custom-made group (B) reported higher average mean values than the ready-made group (A), This was statistically significant as revealed by the Student *t*-test ($P = 0.0174 < 0.05$).

3.2. Hardness test results

It was found that custom-made group (B) recorded a higher mean ± SD value of hardness (629.79 ± 11.38 kg/mm^2) than ready-made group (A) mean ± SD value (593.24 ± 36 kg/mm^2). The Student

Table 1. Comparison of fracture resistance test outcomes (mean values±SDs) measured at first crack sound load and failure load (Newton) for both groups after thermal aging.

Variable	Restoration type						Statistics
	Ready-made			Custom made			
	Mean ± SD	95 % CI		Mean ± SD	95 % CI		
		Low	High		Low	High	*P* value
Fracture resistance							
1st crack load	1151.42 ± 88.34	931.98	1370.9	1090.09 ± 148.85	853.24	1326.94	0.5583ns
Failure load	1217.31 ± 117.65	1108.5	1326.12	1696.65 ± 312.19	1369.03	2024.27	0.003[a]
Statistics							
P value	0.4149 ns			0.0073[a]			

[a] Significant ($P < 0.05$) ns; nonsignificant ($P > 0.05$).

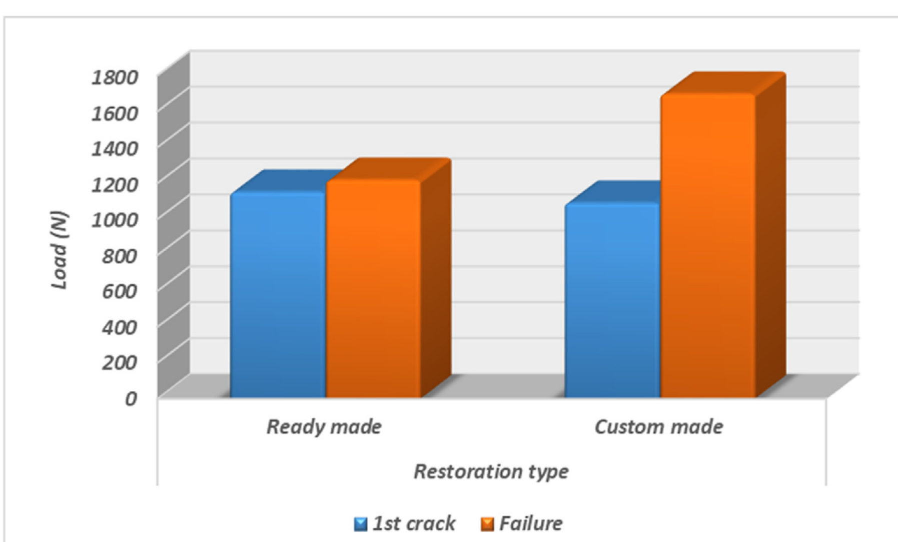

Fig. 5. Column chart comparing first crack sound load and failure load (Newton) for both groups after thermal aging.

t-test showed that there was a difference in statistical significance between the two groups ($P = 0.0067 < 0.05$) (Table 2), and (Fig. 6).

4. Discussion

Progression of dental caries can cause pulp injuries, periapical infections, and tooth loss. Therefore, management of carious permanent molars is important for the quality of life and growth processes of children and adolescents. Pulpal exposure that results from dental caries has to be treated with a suitable treatment option, whether it is pulp capping, pulpotomy, pulpectomy, apixogensis, or apexification [10].

Despite caries is the most common cause of dental tissue destruction, other lesions can also cause disintegration of the teeth's hard tissues. Developmental tooth deformity may potentially necessitate intervention. MIH is a widespread juvenile dental disorder characterized by well-defined regions of hypo mineralized enamel on one or more first permanent molars and central incisors. As a result, these teeth may be extremely sensitive, experience post-eruptive tissue breakdown, and be more prone to caries. It is also connected with opacities on anterior teeth, that are less prone to possess functional complications but can cause aesthetic and mental disorders [11].

Table 2. Correlation of the two groups' post-thermal aging hardness outcomes (mean values +/−SDs).

Variables	Mean±SDs	95 % CI		Statistics
		Low	High	
Restoration type				
Ready-made	593.24 ± 36	567.94	618.99	*P* value
Custom-made	629.79 ± 11.38	621.65	637.93	0.0067[a]

[a] Significant ($P < 0.05$) ns; nonsignificant ($P > 0.05$).

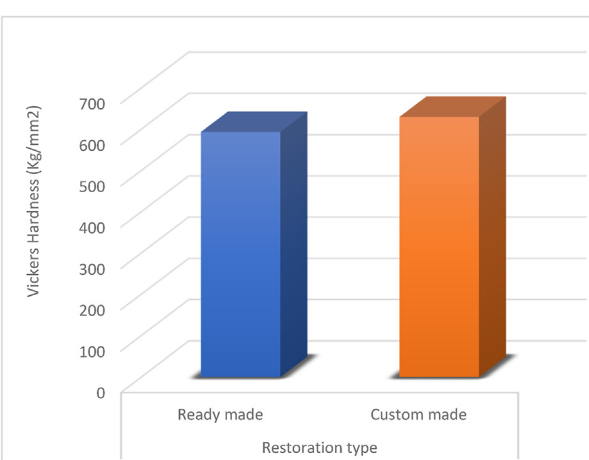

Fig. 6. Column chart comparing hardness mean values for both groups after thermal aging.

Rehabilitation of severely decaying, endodontically treated teeth or teeth with congenital deformities including MIH is required not only to meet the cosmetic requirements of the patient but also to meet the functional and emotional demands of the kid. Treatment of the impacted teeth relies on the degree of the abnormality and the child's willingness to comply. Affected teeth can be treated by either fluoride varnish, fissure sealant, micro abrasion, resin infiltration, direct restoration, or a full coverage crown [12].

The adoption of full-coverage crowns enables long-term success. Their use is frequently less complicated and quicker than traditional rebuilding, particularly in multi-surface defects. They are also an excellent solution for recovering brittle non-vital teeth, keeping primary teeth intact until their permanent successors emerge, and providing an effective option for those with atypical hard tissue advancement, such as MIH. Crowns can be the greatest solution when looks are important [13].

It could be made with a variety of materials and processes. Full metal crowns, the most robust and most durable form, possess limited use due to aesthetic considerations. PFM, the gold standard in prosthetics, produces satisfactory biomechanical and cosmetic outcomes. They are biocompatible and have a high long-term survival rate (75.5 % average over 20 years). Nevertheless, the metal framework can have an impact on aesthetic appearance, appearing as a metallic shadow in very aesthetic places. All ceramic crowns are an aesthetic alternative to PFM. Good clinical outcomes (survival rate of 74 % after 104 months) have established them as viable choices for clinical use [14].

There is an increasing demand for aesthetic restorations of posterior teeth owing to the constant growth in socioeconomic levels. The beneficial mechanical, biological, and aesthetic properties of zirconia make it a good dental restoration material [3]. This investigation compared the fracture resistance and micro-hardness of ready-made and costume-made aesthetic crowns for young first permanent molars after thermocycling, as the first permanent molar is the key to occlusion, the most affected tooth by dental caries, first posterior tooth to erupt and exerts highest force during mastication [1].

Ready-made zirconia crowns were utilized in the current study due to their simplicity and quick procedure, and this agrees with Anuradha [15], who found tooth preparation, impression taking, milling, and crown cementation to be a time-consuming and complex process that can be overwhelming for children. The only ready-made crowns available for young first permanent molars are Nu-Smile zirconia crowns, and they can function effectively in an adult's oral environment in terms of fracture resistance and strength [1].

Katana zirconia crowns were compared with Nu-Smile ZR crowns, as Katana zirconia has the best balance of aesthetics and strength [1]. According to Ontonasaki [16] Katana zirconia crowns offer superior aesthetic appearance, elasticity, strength, and easy milling properties. To standardize crowns and avoid variations between groups, three-dimensional-printed dies were used in this study. Due to varying storage conditions, ages, sizes, and shapes, natural teeth dies were impractical as reported by El-Hawari [17]. The finish line produced by the crown preparation is a feather-edge finish line, which is compatible with both ready-made and custom-made zirconia crowns, similar to a study conducted by El Shahawy [1].

To simulate oral environmental conditions and replicate years of aging for the crowns in a short period, thermocycling technique was adopted in this study, and this comes in line with Yang [13], who accelerated the aging process of restorative materials by using thermal cycling, as he considered it a valid in vitro method, and in agreement with a study where the crowns were cemented into epoxy dies and assessed fracture resistance by using the static load, which was measured using axial force at a 90° angle, as lateral forces are always present during chewing [18].

In this study the fracture resistance of Nu-smile Youth ZR zirconia crowns ranged between 1072.52 N and 1393.78 N with an average 1184.36 N, which aligns with findings from a study [19], while the fracture resistance of Katana CAD/CAM zirconia crowns ranged between 941.24 N and 2789.31 N with an average 1588.73 N, which is consistent with findings from a study [20]. The mean fracture resistance values for Katana CAD/CAM zirconia crowns were significantly higher than those for Nu-Smile Youth zirconia crowns. This finding corresponds with the findings of a study [21], but contrary to a study that found that the difference was not statistically significant, as custom-made crowns were slightly higher in fracture resistance than prefabricated ones [1].

The micro-hardness of all samples was assessed by utilizing HV test, as it is widely used to evaluate the hardness of brittle materials [1]. The increasing hardness of dental fillings leads to greater enamel loss. So HV's most significant clinical impact is wear on antagonist teeth [22].

The current study found that katana zirconia crowns had a micro-hardness of 629.79 ± 11.38 kg/mm^2 after Themo-cycling, similar to a study [23]. The current study found that CAD/CAM zirconia crowns have a significantly higher mean value of microhardness than Nu-Smile ZR crowns. However, a study done to evaluate the wear resistance of tooth-like materials employed for crown repair for deciduous molars and discovered that prefabricated zirconia crowns (Nu-Smile) were the most wear-resistant material, followed by milled nano-hybrid ceramic crowns and three-dimensional printed resin crowns, which had the lowest wear resistance [24].

One of the challenges of this *in-vitro* study is that there have been very few studies on the micro-hardness of zirconia crowns, and none have compared the micro-hardness of Katana CAD/CAM and Nu-Smile ZR zirconia crowns.

4.1. Conclusion

Custom-made Katana CAD/CAM zirconia crowns offer superior fracture resistance and microhardness compared with ready-made Nu-Smile Youth ZR crowns.

4.2. Recommendations

It is recommended to complete the results of this investigation with in vivo studies to examine fracture resistance and micro-hardness inside the oral cavity.

Ethics information

Approval was granted by the Research Ethics Committee of the Faculty of Dental Medicine, Al-Azhar University, Cairo, Egypt [REC-CL-23-12]. The ethical board of the Faculty of Dental Medicine for Girls at Al-Azhar University was established and functions in accordance with ICH GCP criteria, as well as appropriate regional and organizational rules and norms governing IRB functioning.

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Biographical information

The study was done at faculty of dental medicine for girls Al Azhar University, Cairo, Egypt.

Conflict of interest

There is no conflict of interests.

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