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FATIGUE AND 3-D WEAR RESISTANCE OF FIBERGLASS VERSUS STAINLESS STEEL CROWNS FOR RESTORATION OF PRIMARY TEETH

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ABSTRACT

Objectives: To compare and evaluate fatigue, fracture resistance, 3-D wear of a new pediatric fiberglass crowns. "Figaro" versus the conventional stainless steel crowns.

Study Design: A total of 24 primary posterior crowns were used in this study: 12 Figaro crowns and 12 stainless steel crowns were cemented using glass ionomer cement on standardized prepared acrylic resin dies. All crowns were subjected to fatigue by cyclic loading using ACTA type chewing simulator (250,000 cycles with 200 N load under water). 3-D images were obtained before and after fatigue using a digital scanner, and the images were superimposed using Exocad software to detect any surface wear in each specimen after the cyclic load. Finally, all specimens were axially loaded till fracture using a universal testing machine (α=0.05).

Results: Figaro crowns showed a significantly higher amount of wear and deformity compared to stainless steel crowns which demonstrated negligible amount of wear and preserved its anatomy (t=18.7, P<0.01). The Figaro crowns showed a significantly lower fracture resistant values compared to stainless steel crowns (t=14.57, P<0.001).

Recommendation: clinical studies are needed to evaluate the durability and survival rates of these new fiberglass crowns in children.

KEYWORDS: Fatigue, wear resistance, Fiberglass crown, stainless steel crowns

INTRODUCTION

Historically, full coverage restorations for primary posterior molars have been mainly in the form of stainless steel crowns (SSCs) due to its high durability long survival rates and its unique flexibility that require minimal tooth reduction with excellent retention [1,2]. Yet it often fails to meet the esthetic demands of patients [3]. Stainless steel crowns are not expensive but are "unnatural" color crown for primary teeth [4-6]. On the other hand, Zirconia Crowns are excellent esthetic dental crowns but are quite expensive and their pricing limits

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its acceptance throughout the general population, another issue with the use of a zirconia cosmetic crowns involves excessive grinding of tooth structure to compensate for the lack of flexibility [7]. Therefore, the need for a solution that provides esthetic crowns with high durability and that require minimal tooth reduction with a lower cost than Zirconia crowns is an important consideration in pediatric dentistry where cost may be even more of an issue as baby teeth would eventually fall out.

Recently white readymade crowns for primary teeth were introduced in 2018 by Figaro Crowns™ , Inc., USA [8]. These crowns, as the manufacturer claims, provide an affordable treatment option compared to the more expensive zirconia crowns. The crown utilizes either fiberglass or quartz filaments imbedded in a layer of cosmetic composite resin material forming the crown. It has a similar structure observed in fiberglass dental posts already widely used in dentistry for endodontic / restorative purposes for decades (FiberKleer® Posts from Pentron Clinical of Orange, Calif.). This composite structure offered superior strength with some degree of flexibility in addition to biocompatibility and superior esthetics.

The dental crowns include from 25 to 85 % fibers and more preferably between 30 to 70%, with the remainder being the resin and fillers. The layers of fiberglass mesh sheets vary from one to preferably three sheets. More sheets may be used up until their combined thickness makes it unneeded. Generally, more than 6 sheets may be difficult unless the sheet thickness is smaller. The fiberglass sheets are about 0.0035 inches (0.0889 mm) thick with sheet weights of about 2.4 ounces per square yard (8.1grams per square millimetre) [8].

The manufacturer claimed that testing of sample dental crowns made without fiberglass or Titanium dioxide were conducted and the average force before breaking was 27.9 pounds, while the stainless steel dental crown failed with ductile fracturing at 160 pounds, on the other hand the zirconia dental crown test failed with a brittle fracture at only 75 pounds, whereas Figaro dental crown made with epoxy and fiberglass showed highest resistance and didn't fail until a force of 199 pounds was applied. Thus, the fiberglass dental crowns absorbed 2 to 2.5 times the force of the zirconia crowns, human bite strength on chewing yields about 72 pounds of force which is close to the failure point for zirconia and well below the failure point of the inventive crowns [8]. Therefore, Figaro crowns might be the solution of combining the advantage of the aesthetic appeal of zirconia crowns and the minimal reduction and time saving of SSCs.

Although Figaro crowns are gaining popularity in the field of pediatric dentistry, yet there aren't any published studies on the longevity and durability of these crowns either clinically or laboratory, therefore the aim of the present in vitro study was to evaluate the surface wear and fracture resistance of Figaro crowns after cyclic loading.

The null hypothesis tested was that there will be no difference between SSCs and Figaro crowns in wear or fracture resistance after cyclic loading.

METHODS

This experimental in-vitro study was conducted at Pediatric Dentistry and Dental Public Health, Dental Biomaterials Departments, Faculty of Dentistry and Faculty of Pharmacy, Alexandria University, Egypt.

A total of 24 primary posterior crowns were used in this study: 12 stainless steel crowns (SSC 3M ESPE): D crowns size 4 (n=6), and E crowns size 4 (n=6), and 12 Figaro crowns (Figaro Crowns™ , Inc., USA.)**:** D crowns size medium(n=6), and E crowns size medium (n=6).

Negative replica for each crown type was done [9], the crown was filled with acrylic resin (Cold cure acrylic resin, Acrostone, Egypt) and

was allowed to set for one hour. Then the crowns and dies were tried on to ensure a passive fit. Any visible undercuts in the dies were removed with a flamed finishing bur. Each Crown replica was then embedded in PVC "polyvinyl chloride" filled with acrylic resin (Cold cure acrylic resin, Acrostone, Egypt) and allowed to set for one hour. A negative replica of each crown type was duplicated with alginate impression (Zhermack S. p, A Tropicalgin, Italy) and was allowed to set for one hour. Thus, four negative master impressions, were used to fabricate accurate acrylic dies for each crown type and were set for one hour. The crowns were then cemented on the acrylic dies with glass ionomer cement (Micron superior II, Prevest DentPro Limited, India). and were allowed to set for 24 hours (Figure 1).

Fig. (1): Showing the 24 specimens crowns cemented on their acrylic die.

Cyclic loading: All specimens were subjected to 250000 dynamic loading cycles using a custom made pneumatic loading device (ACTA design). The applied load shifted between a maximum (150 N) and a minimum (80 N) load which resulted in an alternating compression of the loading area of the specimens. A 0.5 mm thick silicon sheet was placed between the loading cusp (natural enamel) and the surface of the specimens to prevent generation of contact surface damage which could lead to premature failure. The sheet was replaced every 20,000 cycles. The test was conducted at a rate of 15 cycles/min. At any sign of fracture, the load cells detected sudden drop in load and deactivated the device automatically.

3-D wear: In this study the 3 dimensional wear resistance was evaluated using "image superimpositioning technique" before and after fatigue [10]. Each specimen was dusted with Dentify scan powder (Dentify GmbH, Scheffelstr. 22, Germany). Digital images were recorded using optical 3D scanner (Vinyl Serianlno: SO-20900.00-17-147, Germany) (Figure 2 - 5) and the occlusal points of the crowns were recorded in the software Exocad (Germany of Amann Girrbach) for measurements and comparisons. The occlusal points on the molars were recorded in the software with a file extension in .rst format, then were transformed into stl format by the software. The occlusal thirds of these files were cropped and superimposed images were then converted into digital solid models. These solid models were put in equal axes and a specific area was chosen on the occlusal surface with a tolerance value of 0.005 mm and the volumetric loss on the surfaces was calculated (Figure 6 & 7).

Measuring Fracture resistance: Each specimen was axially loaded in a universal testing machine (5st, Tinus Olsen, England) at a crosshead speed of 1 mm/min till fracture. Maximum breaking loads, recorded in Newton, were extracted from load deformation curves [9] (Figure 8).

Statistical Analysis

Normality was checked using plots and normality tests and the variable showed normal distribution, so means and standard deviations (SD) were calculated. Comparison of the 2 types of crowns (Stainless steel and Figaro crowns) was done using independent samples t test, while comparing the two types of crowns when used on both primary molars D & E (4 groups) was done using one-way ANOVA followed by Tukey post hoc test. Significance was set at $P < 0.05$. IBM SPSS for Windows version 25.0 (IBM Corp., Armonk, N.Y., USA) was used for statistical analysis.

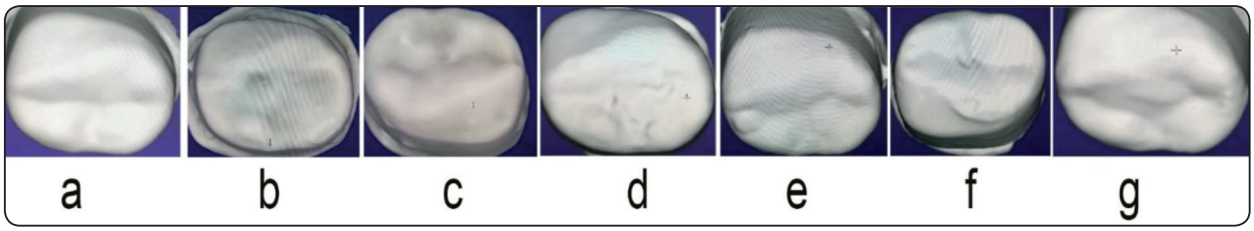

Fig. (2): images showing the deformity and wear in Figaro crown "D Mrduim": a. before cyclic loading, b-g. after the cyclic loading

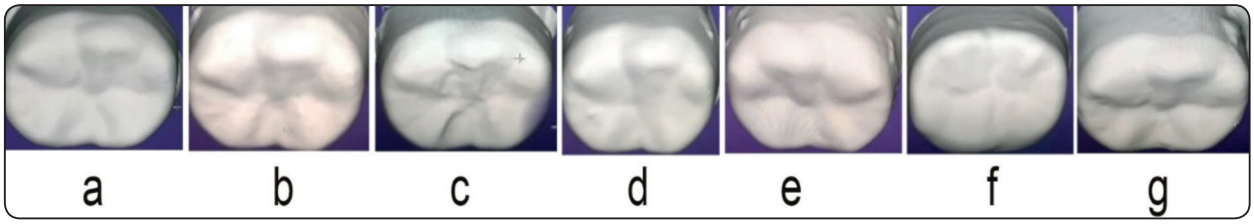

Fig. (3): Images showing the deformity and wear in Figaro crown "E Mrduim": a.before cyclic loading, b-g. after the cyclic loading.

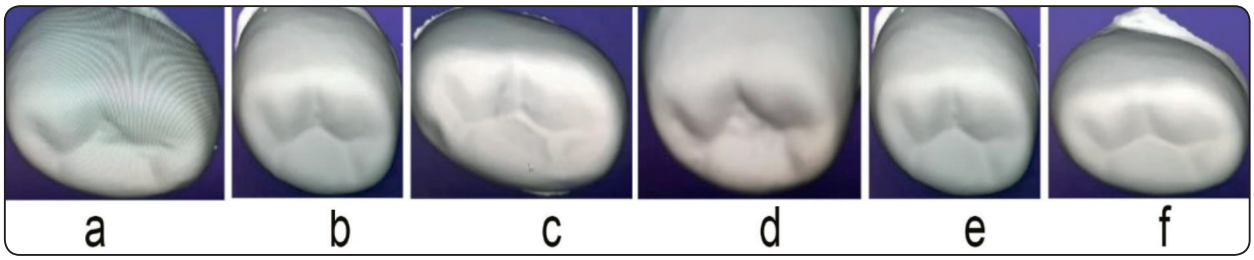

Fig. (4): Images showing SSC crown "D 4": a. before cyclic loading, b-f. after the cyclic loading

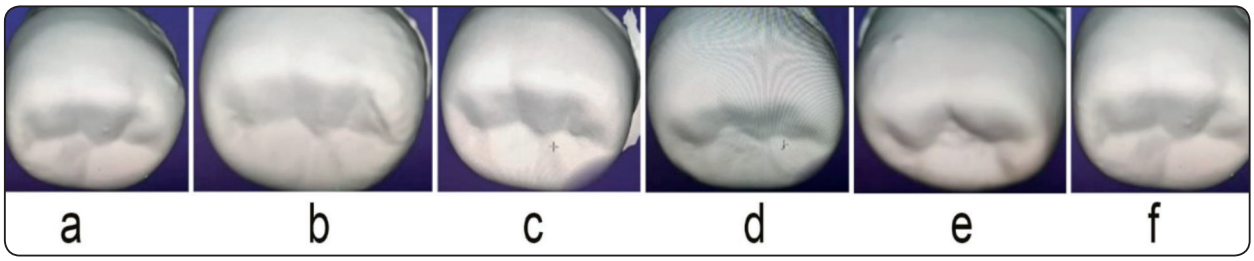

Fig. (5): Images showing SSC crown "E 4": a. before cyclic loading, b-f. after the cyclic loading

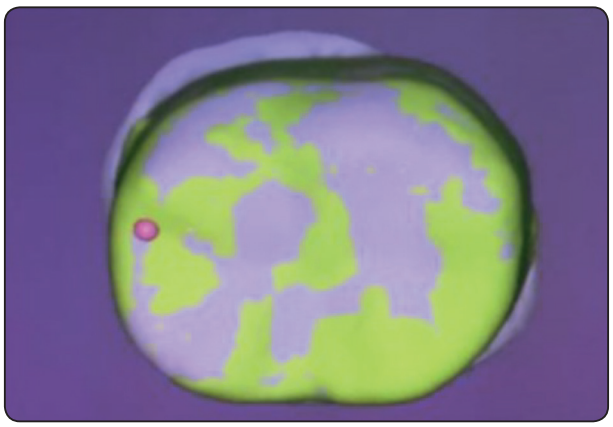

Fig. (6): Superimposed image of Figaro crown showing areas of 3-D wear in white color compared to orginal dimensions in green.

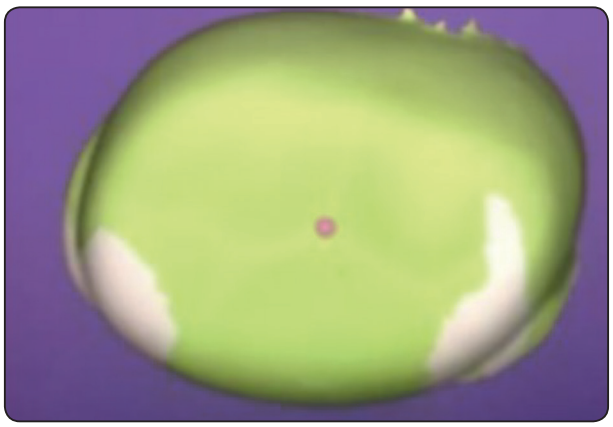

Fig. (7): Superimposed image of stainless steel crown showing areas of 3-D wear in white color compared to orginal dimensions in green.

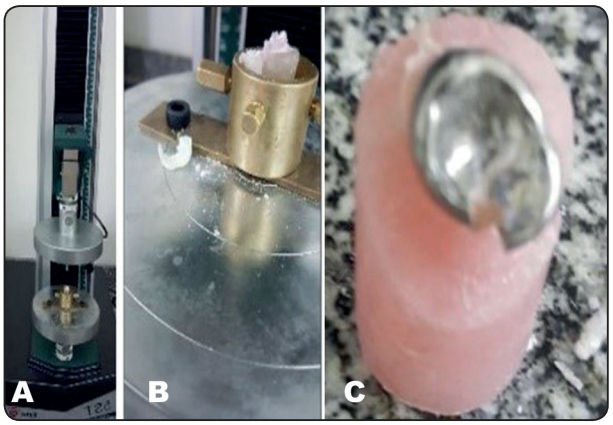

Fig. (8): a. Universal testing machine, b. fractured Figaro crown, c. fractured SSC.

RESULTS

Figaro crowns showed a significantly higher amount of 3-D wear compared to stainless steel crowns 0.88 ± 0.2 mm^3 and 0.09± 0.02 mm^3 respectively (P<0.01).

Figaro crowns showed a significantly lower fracture strength values compared to stainless steel crowns with mean value of 68.25 ± 5.58, and 27.04 ± 8.06 respectively (P<0.001) (Table1).

Table 2 shows the comparison between the 4 study groups: SSCs (D&E) and Figaro crowns (D&E), there was a significant difference between the SSC (D or E) and its counterpart in Figaro group (f=64.37, P<0.001), but there was no significant difference between the D crowns and the E crowns either in the SSC or the Figaro group.

TABLE (1) Comparison of Fracture Resistance (Newton/mm^2) of Stainless Steel (SSC) and Figaro Crowns

	SSC (n=12)	Figaro Crowns (n=12)
Mean ± SD	68.25 ± 5.58	27.04 ± 8.06
T test P Value	14.57 **<0.001***	

**** Statistically significant at P value < 0.05***

TABLE (2) Comparison of Fracture Resistance of SSC and Figaro Crowns Used on 1st and 2nd Primary Molars (D and E)

	SSC on D (n=6)	SSC on E (n=6)	Figaro Crown on D (n=6)	Figaro Crown on E (n=6)
Mean ± SD	68.17 ± 6.34 [a]	68.33 ± 5.32 [a]	26.83 ± 8.37 [b]	27.25 ± 8.52 [b]
F of ANOVA P Value	64.37 **<0.001***			

****statistically significant at P value < 0.05.***

[a,b] different letters denote statistically significant difference between groups using Tukey post-hoc test.

DISCUSSION

The null hypothesis of the present study was rejected, since there was significant difference between SSCs and Figaro crowns in wear and fracture resistance after cyclic loading.

In this study Figaro crowns D and E size medium were tested, and their equivalent sizes in SSC (D4 and E4) served as a control to exclude any change in sizes that might affect the results of wear or fracture resistance. Two types of posterior crowns D and E were tested in this study, to give a more comprehensive results on different type of teeth with different morphology that might affect the outcome.

A common way to gather failure data for a material is to perform a direct static test that shows failure load, but in this study we expanded upon other researches that included fatigue component and then tested load to failure, this would help to clarify the reason for the failure of the crowns clinically [11]. Fatigue of a dental restoration is produced by masticatory forces [12-14] over a period of time, since this study was an in-vitro study therefore, cyclic loading was done to imitate the masticatory forces effect on the tested crowns equivalent to one-year period. Fatigue results in a process involving "nucleation, propagation, and

coalescence of cracks" in the regions of stress accumulation leading to "scratches" on the surface, or "voids" in the interior which can affect the longevity of the restoration [11].

3-D wear evaluation is a non-destructive test compared to the "stereo or scanning" microscopical evaluation that requires sectioning of the specimens. It has been proved to be a very accurate test that provides volumetric reading covering the entire surface of the restoration. Moreover, Digital images could be further processed to evaluate external marginal adaptation and surface defects [10].

In this study, marked differences were found between the 2 types of crowns. Figaro crowns (D & E) showed statistically higher amount of wear and deformity of the occlusal surface compared to the SSCs that showed no or negligible amount of wear and were able to preserve their occlusal anatomy. Our findings were in accordance with other studies that showed high wear behaviour of fiberglass crowns compared to other crown types: Ohlmann B, et al [15] evaluated the clinical wear behaviour of posterior, metal-free polymer crowns, with and without a glass-fiber framework, and compared it with that of metal–ceramic crowns, within a 12-month observation period they found that the mean total wear of posterior polymer crowns with and without a glass-fiber framework was significantly greater than metal–ceramic crowns. Moreover, Mohammadzadeh et al [16] compared the clinical performance of costumed made fiberglass crowns and SSCs in primary molars, they concluded that the SSCs showed significantly higher durability 100%, compared to only 89.7% FRCs at the end of the 1-year assessment. In another clinical study done by Behr. M, et al [17] on adult patients using fiber reinforced composite crowns for a follow up period of 3 years, they concluded that because of the increasing wear, discoloration, and fiber exposure, fiber-reinforced composites should only be used for provisional restorations.

In the present study SSCs also showed a significant higher fracture resistance than Figaro crowns whether D or E. This finding was not in accordance with the manufacturer's claims [8] that Figaro crowns showed the highest fracture resistance than both SSC and zirconia crowns, where in their test stainless steel dental crown failed with ductile fracturing at 160 pounds, while zirconia dental crown failed with a brittle fracture at only 75 pounds, and Figaro dental crown didn't fail until a force of 199 pounds. Our justification for the different findings goes to the cyclic load that was done in this study before the fracture resistance test, whereas the Figaro crowns company tested the fracture resistance of the three types of crowns without cyclic loading. Thus, it can be assumed that Figaro crowns can tolerate a single high load due to its considerable elasticity, the crown can" bend" without fracture but upon repetition the stresses accumulate and eventually the crowns break at a very low fracture points. Since cyclic loading resembles the masticatory forces in the oral cavity, and since the daily activity of mastication creates repetitive sub threshold stresses to the restorations that ultimately leads to failure [18-21], therefore, Fatigue produced by cyclic loading in the present study provided a better insight to the performance of the crowns and gave more realistic values that could predict short clinical lifetime of the crowns tested.

CONCLUSION

From the limitation of the present study it was concluded that stainless steel crowns showed superior mechanical properties than Figaro crowns. Figaro crowns showed high deformity in surface anatomy after cyclic loading and very low fracture point, this might be an indicator for low durability and short survival rates in their clinical application.

RECOMMENDATION

More studies are needed both clinically and laboratory to test the durability of the new Figaro crowns to determine if modifications and improvements are needed in the materials used to add more strength and durability to the crowns. Short survival restoration is a big problem especially when dealing with children, repeating a procedure in a child is a step back in child behaviour, very annoying to the parents, and a great burden to the pedodontist.

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None

DISCLOUSURE OF INTEREST

The authors report no conflict of interest.

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