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Original Research Paper

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FRACTURE RESISTANCE AND WEAR RESISTANCE OF ESTHETIC CROWNS FOR PEDIATRIC POPULATION: A COMPARATIVE IN-VITRO STUDY.

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ABSTRACT

Introduction And Objectives: Restoration of extensively decayed primary teeth is a challenging task. Hence full coverage crown restorations become mandatory for teeth with multi-surface carious lesions and teeth that have undergone pulp therapy. Pediatric dentists also report pressure from parents of child patients for an esthetic restoration. The major factors that influence the final choice of the restoration are, it's strength to bear the masticatory load and esthetics. Thus, this study aimed to compare the fracture resistance and wear resistance of three preformed esthetic crowns available for primary teeth. **Materials And Methods:** The mean force required to fracture the crowns was determined using servo hydraulic test. While the wear was noted using the pin on disk wear test machine. The results obtained were statistically analysed. **Statistical Analysis:** Statistical analysis of the results received was done by using the software SPSS version 20. **Results:** Fracture resistance Zirconia crowns was significantly higher compared to the fracture resistance of Figaro crowns and the Bioflx crowns while no significant difference was noted in the fracture resistance between Figaro and Bioflx crowns. No significant difference was seen in the wear resistance between any of the three groups. **Conclusion:** Higher fracture resistance was noted with the preformed Zirconia crowns compared to the figaro crowns and Bioflx crowns which showed their fracture resistance in a comparable range. Thus, Zirconia crowns may be could be considered a better alternative, having promising properties to eliminate the traditional restorations in the coming years.

KEYWORDS : Zirconia crowns; Figaro crowns; Bioflx crowns; Fracture resistance; Wear resistance.

INTRODUCTION

Dental caries, one of the commonest chronic infectious multifactorial diseases produced by the interplay of microorganisms, largely the Streptococcus mutans, fermentable carbohydrates on the host tooth structure.[1] Current treatment concept regarding multi-surface caries states restoration of the carious lesion to preserve the integrity, restore normal form and function of the natural primary teeth until they exfoliate and the permanent teeth erupt, to improve the quality of life for the individual rather than the traditional choice of treatment for extensive carious lesions which called for extraction of the decayed primary teeth.[2] Multi-surface carious lesions in primary teeth are best restored with full coverage restorations which need to be sturdy enough and long lasting to bear the stresses created due to the pressure from the oral musculature, masticatory load, variable pH in the oral environment.[3]

The first commercially available primary crowns consisted of stainless-steel crowns. However, these crowns were unesthetic which restricted its use to the posterior teeth. Last 20 years have seen the advent of esthetic full coverage restorations due to demand by the society for natural looking teeth. Likewise, parents are urging for esthetically pleasing restorations for their little ones. Therefore, primary full coverage restorations in addition to functionality, durability and longevity necessitates the need for esthetics.[3] These restorations not only serve the purpose of restoring the form and function but give the tooth natural colour, principally for the anterior teeth.[4] Various studies have been put forth focusing on the strength and weakness of these full coverage restorations at hand for primary teeth but have yielded diverse conclusions. Although studies and researchers claim one particular crown to be better over the other the hunt for the perfect restoration still lingers.

Our study aims to evaluate and compare the thickness, fracture resistance and wear resistance of three different preformed esthetic crowns for primary teeth. Thus, this study is one contribution to assess the strengths of three newly available preformed esthetic crowns for primary teeth to know the benefits of these crowns for restoring the primary teeth.

Methodology

The formulated study design was approved by the ethical research committee of Shri Dharmasthala Manjunatheshwara University, Dharwad, Karnataka, India.

Primary mandibular right second molar size no. six crowns were selected in each of the three groups- Zirconia crowns, Figaro crowns, Bioflx crowns for measuring the thickness, fracture resistance and wear resistance parameters. Thickness of eleven crowns in each of the three groups was measured, the same eleven crowns were included in each group for measuring the fracture resistance; and five crowns were included in each of the three groups for testing the wear resistance.

THICKNESS OF THE CROWNS

A stainless-steel dental gauge caliper was used to measure the thickness of the preformed crowns at 5 different locations: mesial, distal, buccal, lingual, occlusal to ensure the accuracy of the results. The measurements on the smooth surfaces were made in the area of intersection of the middle thirds in the mesiodistal dimension and the occluso-gingival dimension and central fossa on the occlusal surface. Two operators were appointed to measure the thickness of the crowns in the above-mentioned areas to avoid the bias. The results obtained from both the operators were averaged and tabulated.

SPECIMEN PREPARATION:

The crowns to be tested for fracture resistance and wear resistance were mounted on acrylic blocks of dimension 8mm x 8mm x 30mm (Figure 1).

Wax blocks of the dimension 8mm x 8mm x 30mm were made using modelling wax no. 2 (Hindustan Dental Products, India). Regular set Putty (Aquasil Soft Putty, Dentsply Sirona, Germany) impressions were made of the wax block. Cold cure

acrylic (Dental Products Of India Ltd., India) was poured in the putty impressions and allowed to set. Once set the acrylic blocks were retrieved from the putty impressions, polished and checked for the final dimensions. The crowns were filled with cold cure acrylic and mounted onto the prepared acrylic blocks, access material was removed using a sharp instrument and the specimens were allowed to set. Once the crowns were set, the specimen was polished and ready for testing for the fracture resistance ad wear resistance.

Figure no. 1: Specimen preparation

FRACTURE RESISTANCE TEST

Fracture resistance of the study samples in all the three groups were tested using a Servo Hydraulic Test Machine (Jain Engineers, India).

A specimen was mounted on the servo hydraulic test machine between the fixed and movable jaws (Figure 2). The compressive load was applied gradually directed along the long axis of the crown until failure. The maximum load applied to fracture the crowns was noted (Figure 3). The results achieved were arranged in a tabular form and sent for statistical analysis.

Figure no. 2: Sample mounted on the Servo hydraulic test machine

Figure no. 3: Fractured Zirconia crown, Figaro crown and Bioflx crown

WEAR RESISTANCE TEST

Wear resistance was evaluated using Pin-On-Disk Wear Resistance Test Machine (Magnum Engineers, India).

The weight of the specimen was noted before mounting it onto the test machine. The specimen was fixed in the pin holder using align key (Figure 4). The 0.5kg load was applied on to the pan. The specimen was run for three different cycles for 1 minute, 3 minutes, 5minutes, with the speed and load kept constant at 105 rpm and 0.5 kg respectively. The weight of the specimen was noted after each of the three cycles (Figure 5). The difference in the weight was considered to be the wear shown by the crown. The results achieved were arranged in a tabular form and sent for statistical analysis.

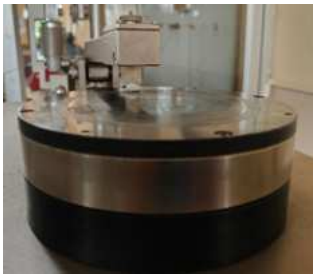

Figure no. 4: Sample mounted on the pin-on-disk wear test machine

Figure no. 5: Samples after wear test. Zirconia crown, Figaro crown, Bioflx crown.

Statistical Analysis

Descriptive statistics: mean, median and standard deviation were done for all the three groups.

Interquartile range was derived for all the three groups.

Interferential statistics:

Inference of fracture resistance between the three groups was done by Kruskall wallis ANOVA test (non-parametric). Individual group was compared to the other two using Mann whitney test. Inference of the wear resistance between the three groups was done by Kruskall wallis ANOVA test (non-parametric) while within group comparison was done by Friedman Test. The correlation of the thickness and the fracture resistance was done by Spearman's rho test. Probability value standardized for less than 0.05 was considered statistically significant. Statistical analysis of the results received was done by using the software SPSS version 20.

RESULTS

Table 1 explains descriptive analysis for fracture resistance between three different groups of esthetic crowns. Eleven crowns in each group were subjected to the load to evaluate their fracture resistance. The Zirconia crowns required an average load of 3.35 ± 1.37 KN to fracture with the values ranging between 1.25 KN to 5.55 KN within the samples. The Figaro crowns however fractured under a much lower load, with an average load required was noted to be 0.84 ± 0.30 KN while the values for samples ranged between 0.30 KN and 1.46 KN. The average load required to fracture Bioflx crowns was 1.19 ± 0.34 KN with the values for samples spread over a

range of 0.56 KN to 1.67 KN which though was quite lower than the values obtained for the Zirconia crowns but minor difference was seen compared to the load required to fracture the Figaro crowns.

Table 1: Overall comparison of the fracture resistance between the 3 different groups.

Groups	Number of samples	Mean (KN)	S.D.	Minimum (KN)	Maximum (KN)
Zirconia	11	3.35	1.37	1.25	5.55
Figaro	11	0.84	0.30	0.30	1.46
Bioflx	11	1.19	0.34	0.56	1.67
Total	44	2.45	1.73	0.30	6.30

*KN- kilo newton; *S.D.- Standard deviation, *p-value- < 0.05.

Table 2 explains the inferential statistics for the fracture resistance of three different esthetic crowns. Comparison of the load required to fracture the Zirconia with that of Figaro crowns showed a mean difference of 2.507± 0.375 KN load (p value- 0.000) while the average difference obtained by comparing the load values required to fracture Zirconia with Bioflx crowns was noted to be 2.154 ±0.375 KN (p value- 0.000). No appreciable difference i.e. 0.352 ± 0.375 KN was noted on comparing the load values for Bioflx and Figaro crowns (p value- 1.000).

Table 2: Pairwise comparison of the fracture resistance between the three different groups.

Groups	Mean difference	S.E.	P value	95% Confidence Interval	
				Lower bound	Upper bound
Zirconia vs Figaro	2.507*	0.375	0.000	1.4648	3.5498
Zirconia vs Bioflx	2.154*	0.375	0.000	1.1120	3.1970
Bioflx vs Figaro	0.35273	.37556	1.000	-.6898	1.3952

*p-value- < 0.05; *S.E.-Standard error

Table 3: Comparison of wear resistance within groups.

Descriptive analysis												
Group	Time (min)	N	Mean	S.D.	Min	Max	Percentiles			Chi square	df	P value
							25th	50th Median	75th			
Zirconia	1	5	0.000	0.000	0	0.000	0.000	0.000	0.000		2	
	3	5	0.000	0.000	0	0.000	0.000	0.000	0.000			
	5	5	0.000	0.000	0	0.000	0.000	0.000	0.000			
Figaro	1	5	0.000	0.000	0	0.000	0.000	0.000	0.000	4.667	2	0.097
	3	5	0.000	0.000	0	0.001	0.000	0.000	0.000			
	5	5	0.004	0.005	0	0.010	0.000	.001	0.010			
Bioflx	1	5	0.000	0.000	0	0.000	0.000	0.000	0.000	3.200	2	0.202
	3	5	0.000	0.000	0	0.002	0.000	0.000	0.001			
	5	5	0.000	0.000	0	0.002	0.000	0.001	0.001			

*N: sample size; *df- degree of freedom, *p-value- < 0.05.

Table 3 shows that descriptive analysis for the wear resistance within each of the three groups of esthetic crowns at three different time intervals. Five samples were test for the amount of wear shown at time intervals 1 minute, 3 minutes and at 5 minutes. No wear was noted after 1 minute of testing in any of the sample groups. At the end of 3 minutes cycle Bioflx crowns showed a maximum wear of 0.002 grams while Figaro showed a maximum wear of 0.001 grams. No wear was noted in with the Zirconia crowns even at the of the 5 minutes cycle while the figaro showed the most wear i.e. a maximum of 0.010 grams followed by Bioflx which showed a maximum wear of 0.002 grams. Nevertheless, all the values received did not show noticeable difference in the wear.

Table 4 shows the comparison of wear resistance between the three groups of esthetic crowns at three different time intervals. Wear noted in all the three groups at the end of 1 minute cycle was null. Towards the end of the 3 minutes cycle no wear was seen w.r.t the Zirconia crowns while negligible wear was seen with Bioflx and Figaro crowns. Zirconia crowns did not wear even following the 5 minutes cycle while Bioflx and Figaro crowns again showed negligible wear after the 5 minutes cycle which was similar to wear shown after the 3 minutes cycles. Table 4 shows that the mean ranks obtained for all the three different groups at different time intervals is in the comparative range and no considerable difference was observed.

Table 4: comparison of wear resistance between groups

Ranks						
Time	Group	N	Mean Rank	Chi square	Df	P value
1 min	Zirconia	5	10.50	0.000	3	1.000
	Figaro	5	10.50			
	Bioflx	5	10.50			
	Total	15				
3 min	Zirconia	5	9.50	2.116	3	0.549
	Figaro	5	11.40			
	Bioflx	5	11.60			
	Total	15				
5 min	Zirconia	5	7.00	4.911	3	0.178
	Figaro	5	13.40			
	Bioflx	5	12.20			
	Total	15				

*N:sample size; *Df- degree of freedom, *p-value- < 0.05.

Table 5 shows the correlation of fracture resistance with the thickness of the three different esthetic crowns. The 11 samples in each group that were used to check for the fracture resistance were measured for their thickness on five different surfaces (mesial, distal, buccal, lingual, occlusal) before subjecting them to the load and an average of these of these observations was made. Zirconia crowns and Bioflx crowns showed no positive correlation between the fracture resistance and thickness of the crowns. On the other hand, Figaro crowns showed positive correlation with the average thickness of the crowns where distal and mesial surfaces were the ones contributing.

Table 5: Correlation Of Fracture Resistance To The Thickness Of 5 Crown Surfaces And The Average Crown Thickness

Group	Surface		Fracture_resistance
Zirconia	Buccal	Correlation Coefficient	-.255
		P value	.450
		N	11
	Lingual	Correlation Coefficient	-.391
		P value	.235
		N	11
	Mesial	Correlation Coefficient	-.378
		P value	.252
		N	11
	Distal	Correlation Coefficient	.131
		P value	.701
		N	11
	Occlusal	Correlation Coefficient	-.370
		P value	.263
		N	11
	Overall thickness	Correlation Coefficient	-.459
		P value	.156
		N	11

Figaro	Buccal	Correlation Coefficient	.301
		P value	.368
		N	11
	Lingual	Correlation Coefficient	.502
		P value	.116
		N	11
	Mesial	Correlation Coefficient	.682*
		P value	.021
		N	11
	Distal	Correlation Coefficient	.724*
		P value	.012
		N	11
	Occlusal	Correlation Coefficient	.009
		P value	.978
		N	11
	Overall thickness	Correlation Coefficient	.656*
		P value	.028
		N	11
Bioflx	Buccal	Correlation Coefficient	-.123
		P value	.718
		N	11
	Lingual	Correlation Coefficient	.014
		P value	.966
		N	11
	Mesial	Correlation Coefficient	-.509
		P value	.110
		N	11
	Distal	Correlation Coefficient	.280
		P value	.405
		N	11
	Occlusal	Correlation Coefficient	-.197
		P value	.562
		N	11
	Overall thickness	Correlation Coefficient	-.160
		P value	.639
		N	11

*N: sample size; *p-value- < 0.05

DISCUSSION

Longevity of the preformed crowns have always been a question because of the heavy occlusal forces in the child's mouth relative to the time duration of an average of 8 years that these crowns will be seated in the child's mouth.

Fracture resistance is the term used to describe how articles fail due to fatigue and have been interchangeably used with more accurate terms like fracture toughness, critical stress intensity factor, crack growth resistance by scientists and engineers. Knott in 1973 said that fracture toughness is the basic requirement to access the effectiveness of any article.[5]

Wear is the damage, deformation, or withdrawal of the material against any solid surfaces. Wearing off of the materials occur by plastic rearrangement of surface and sub-surface material and by dislodgement of material that are framed as the wear remnants. The particle size varies from millimetres to nanometres. This process may occur by contact with other metals, non-metallic solids, flowing liquids, solid particles or liquid droplets entrained in flowing gasses. Wear resistance is the ability of the material to withstand loss when subjected to some mechanical action.[6]

When the tooth is severely damaged, a crown acts as a protective shell protecting the tooth from further destruction and preserving the left-over sound tooth structure. The crowns are particularly used to restore teeth lost due to extensive decay, grinding habits, trauma. Crowns should be designed to withstand the strong masticatory forces as well as the physiologic and pathologic wear and tear in the oral cavity.

Thus, fracture resistance and wear resistance were the two parameters evaluated in this study to access the strength of three different esthetic crowns.

The results yielded showed significant as well as nonsignificant differences between the three different esthetic crowns for the parameters evaluated.

Fracture resistance test showed that the force required to fracture Zirconia crowns was significantly higher compared to the force required to fracture the Figaro and Bioflx crowns. However, there was no significant difference observed between the load required to fracture the Figaro and Bioflx crown.

The mean force required to fracture Zirconia crowns was 3.35KN while that required to fracture Figaro crowns was 0.84 KN which was comparable to a study by Oguz et al. in 2022 where they calculated 5.57KN and 0.91 KN to be the mean force required to fracture Zirconia and Figaro crowns respectively.[7]

Our study is also in harmony with a clinical study by Talekar et al. in 2021 which concluded that Zirconia crowns have a better resistance to fracture compared to the Figaro crowns since 21% of the Figaro crowns showed chipping off of the crown material and 9% showed complete loss of the crowns after 12 months while no Zirconia crowns showed chipping of the material and only 6% showed complete crown loss.[8] El Habashy et al. in 2021 revealed that Figaro crowns have significantly lower fracture resistance in study which compared fracture resistance of Figaro crowns and Stainless-steel crowns where stainless steel crown showed a much higher fracture resistance of 68.25 N/mm^2 compared to the 27.04 N/mm^2 fracture resistance shown by Figaro crowns.[9]

On the contrary, studies by Zülfikar Zahit Çiftçi et al. in 2021 and Arab et al. in 2023 exhibited that Figaro crowns had significantly higher fracture resistance than Zirconia crowns. Zülfikar Zahit Çiftçi et al. in their study reported the fracture resistance of Zirconia crowns to be in the range of 617.9 N to 1011.5 N which was significantly higher than that of Zirconia crowns which was reported to be between 2260.3 N to 2515.8 N.[10] Arab et al. found fracture resistance of Figaro crowns to be 1850.7 N which was significantly higher compared to the fracture resistance of Zirconia which was found to be 820.46 N.[11] Abushanan et al. in 2022 reported in their study, where they compared three different brands of Zirconia crowns - NuSmile primary Zirconia crowns, Cheng crowns zirconia, and Sprig EZ crowns that altogether Zirconia crowns have good fracture resistance to withstand the forces in the oral environment which was again compared to our study which found Zirconia crown to be a good full coverage restorative option, while among the three brands Cheng crowns showed higher resistance to fracture with an average load of 1990.63 N while the NuSmile crowns fractured under an average load of 1013N. Sprig crowns required the least load to fracture i.e. an average of 661 N indicating least fracture resistance among the three.[12]

Braun et al. and Gavio et al. studies on the biting force in young children revealed mean biting force in six years to eight years old children, 10 years to 12 years old children and three years to six years old children. Braun et al. found the average biting force in six to eight old children to be 78 N while he said that it can go up to 106 N in 10years to 12 years old. Gavio et al studied the average biting force in three years to six years old children to be 235.12 N. Zirconia crowns tested in our study required much larger load to fracture compared to the biting forces reported while the load required to fracture Bioflx and Figaro was in the range comparable to the masticatory load reported by Braun et al and Gavio et al.[13]

The calibrated fracture resistance of all the three crowns was further correlated to their thickness measured on the five different surfaces- occlusal, mesial, distal, buccal, lingual- and also to the average of these readings. Only Figaro crowns happened to demonstrate a positive correlation between the thickness and the fracture resistance i.e. fracture resistance of Figaro crowns was directly proportional to the thickness of the Figaro crowns indicating that more the thickness of Figaro crowns better is the fracture resistance. This could be attributed to the integral strength of the material; fiberglass being a weaker material relies on the bulk of the material for its strength. No other studies were found evaluating the thickness of Figaro crowns and Bioflx crowns; while a single study by Townsend et al. has been published on Zirconia crowns which evaluated the thickness of three different brands of Zirconia crowns and correlated it with their fracture resistance. The results obtained reflected positive correlation among the samples stating that the crown with highest thickness i.e. the EZ-Pedo crowns had the highest fracture resistance of 1091 N among the three crowns followed by the NuSmile with fracture resistance of 691 N and second highest average thickness, while the least fracture resistance of 576 N and minimum thickness was seen with the Kinder crowns.[13]

The pin on disk machine required the adjustments of a number of parameters namely the load to which the sample will be exposed, the time period and the speed at which the sample will be running the circular motion on the pin on disk machine. The load was set at 5N based on the results obtained with our pilot study with same samples. Samples were subjected to multiple loads where loads higher than 5N lead to the perforation through the occlusal surface of the crown even wearing off the acrylic underneath, thus a lower load 5 N was set to evaluate the wear resistance. The speed 105 rpm based on the fact that chewing rate was reported to be 1.76 chews/sec which equals to 105.6 chews/minute.[14] Here chewing rate/ minute was presumed as revolution per minute. Hence the speed was set as 105 rpm.

Wear resistance test shows no significant difference in the wear at shown by Zirconia crowns at 1 minute, 3 minutes and 5 minutes of time interval. No significant difference was observed with the Bioflx crowns at 1 minute, 3 minutes and 5 minutes of time interval. Figaro crowns also showed no significant difference in the wear at 1 minute, 3 minutes, 5 minutes time interval. The comparison between the 3 groups showed no significant difference at 1 minute, 3 minutes as well as at 5 minutes. The insignificant results could be attributed to the following reasons; (1) lower sample size, (2) lower load (3) no simulation of the oral environment i.e. no thermal aging of the sample before testing, the material against which the crown was subjected to wear did not simulate the natural tooth or any restorative material like in the oral cavity, nor was there any lubricant during the wearing off process.

A study was done by El Habashy et al. in 2021 comparing the wear of Figaro crowns and stainless-steel crowns where they saw significant wear with Figaro crowns of 0.88 ± 0.2 mm^3 while negligible wear of 0.09 ± 0.2 mm^3 with stainless steel crowns.[9] Wear resistance of Stainless-steel Crown and Nano Zirconia Coated Stainless Steel crowns was compared by Nagaranjan et al. in 2021 where Nano Zirconia Coated Stainless Steel crowns showed more resistance to wear compared to the stainless-steel crowns.[15] Möhn et al. in 2021 concluded that Zirconia crowns had the least wear resistance than the other esthetic crowns (resin composite or hybrid ceramic crowns) and stainless crowns compared in their study where no wear was seen on the surface of the Zirconia crowns, stainless steel crowns showed plastic deformation with bulging of the crown structure while the hybrid ceramic crowns showed cracking and loss of the material. The composite pediatric esthetic crowns showed significantly lower wear compared to stainless steel and hybrid ceramic crowns.[16]

The studies by Talekar et al. in 2021, Elsayed et al. in 2021, Mostafa et al. in 2021, Farooq et al in 2024 on Figaro crowns have observed crown structure losses on follow up intervals of 6 months, 12 months, and 18 months with minimal chipping off of the crown structure to large amount of crown structure loss.[8],[17],[18],[19]

No similar in vitro studies are done yet on Bioflx crowns evaluating the fracture resistance, wear resistance or the thickness of the crowns owing to the fact that they are newly introduced esthetic crowns for primary teeth in 2022. Although a few vivo studies are on-going one of which is by Rahate et al, evaluating the clinical performance of the Bioflx crowns and comparing these with Zirconia crowns and Stainless-steel crowns and also the parental and child satisfaction.[20]

CONCLUSION

Based on the results of the present study Zirconia crowns showed better strength. Thus, Zirconia crowns could be good alternative to the traditional full coverage restorations in terms of strength in the modern society which seeks for esthetics. Figaro crowns could be made stronger by increasing the thickness of the crowns especially on the distal surfaces. These finding may further be evaluated and confirmed with long term clinical studies. Bioflx crowns also require a lot more research on the aspect of its thickness, strength, clinical performance, being the newly introduced crowns in the market.

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