Evaluation of Hardness and Surface Roughness of Two Primary Esthetic Crowns after Thermocycling

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Abstract

Background

Early Childhood Caries represents the most prevalent childhood chronic disease, and is one of the leading causes of premature deciduous tooth loss so we restore tooth function by zirconia crowns, prefabricated zirconia crown brands vary in micro leakage, surface roughness, and fracture resistance.

Aim: to evaluate Hardness and Surface Roughness of Two Primary Esthetic Crowns (Nu-Smile and Elephant pedo crown) before and after Thermo cycling process to prove which is more durable and recommended to be used commercially.

Methods: Twenty four specimens were tested; and divided into 2 groups (anterior and size 5 from labial surface): Group (1) was represented by twelve Nu-smile crowns (NUS®-crowns) made of zirconia ceramic (DentaCarts*). Group (2) was represented by twelve Elephant crowns (Elephant® crowns). Made of highly translucent zirconia (Bibodent*). To study the effect of crown type and aging on hardness and surface roughness of Nu-smile and elephant pediatric crowns; t-test or an equivalent nonparametric test was used for comparison between groups.

Results: The difference of roughness NU-smile crowns, before and after thermo cycling was statistically significant p value=0. 001, the difference of roughness Elephant crown, before and after thermo cycling was statistically significant p value=0. 001, the difference of hardness Elephant crown, before and after thermo cycling. Was statistically significant p value=0. 001, There is significant higher roughness score before thermo cycling in elephant crowns compared to NU-smile crowns p=0.0001 .Moreover there is significant higher roughness score after thermo cycling in elephant crowns compared to NU-smile crowns p=0.0001. There is significant higher hardness score before thermo cycling in NU-smile crowns compared to elephant crowns p=0.01 .While there is no difference in hardness after thermo cycling in both crown types p=0. 99

Conclusion: The Nu-smile crown is more durable than the Elephant crown, the surface hardness of the Nu-Smile crown is higher than the hardness of the Elephant crown before and after the thermocycling process, The Surface roughness of the Nu-smile crown is less than the roughness of the Elephant crown before and after the thermocycling process.

Keywords: Hardness, Surface Roughness, Esthetic Crowns, Thermocycling

INTRODUCTION

Early Childhood Caries represents the most prevalent childhood chronic disease, and is one of the leading causes of premature deciduous tooth loss, the debilitating effects of tooth decay with regards to masticatory and speech function, as well as the deterioration of arch dimension stability, aesthetics, and quality of life, emphasizes the importance of effective treatment. Besides the common restorative materials, like composite resins and amalgam, prefabricated pediatric crowns represent one treatment modality for extensive multifaceted deciduous tooth carious lesions that cannot be treated with the former solutions [(1,2)] .

Pediatric crowns should be able to withstand masticatory forces, show biocompatibility, facilitate oral hygiene, present high bonding strength, and not cause damage to the antagonist teeth in addition; a high demand of aesthetics has been demonstrated to be one of the most critical issues in pediatric patients, and this has led manufacturers and clinicians to partially replace stainless steel crowns (SSC) by the recently introduced aesthetic ceramic ones [(3).]

Zirconia pediatric crowns (ZC) are considered to be a first choice in deciduous tooth restoration, which combines high strength, superior biocompatibility, improved wear resistance, and color stability, in contrast to the polycarbonate and composite or epoxy resin and thermoplastic pre-veneered stainless-steel crowns The adoption of prefabricated zirconia crowns is considered to be a promising alternative in the restoration of primary teeth, combining clinically acceptable restorations, and fulfilling aesthetics demands[(4,8)] .

Crowns made of zirconia are better for children's gums. Also, much as with real teeth, they help to ward against the buildup of bacteria by preventing the formation of plaque. Indirectly avoiding secondary caries, these pediatric crowns have a high survival rate thanks to their excellent retention and marginal integrity. Additionally, these crowns do not obstruct the natural emergence of traumatized teeth that are in the infra-occluded position. Zirconia pediatric crowns are an excellent restoration option for restoring baby teeth[)]. The latter might require a greater amount of tooth reduction. Whereas, their increased hardness might lead to tooth wear of the antagonist teeth [(4, 5, 6, and 9)]

Finally, bond strength and surface alteration remain challenges, and zirconia is a polymorphic material that requires stabilizers like yttrium and magnesium oxide to prevent the tetragonal/cubic phases from swinging to the monoclinic one at room temperature, which has inferior mechanical properties and affects crown compressive strength, fracture toughness, hardness, aesthetics, plaque retention, and bonding strength. Hence, zirconia-made pediatric crowns with different chemical synthesis-microstructures and manufacturing methods may have different mechanical characteristics and clinical behavior. Prefabricated zirconia crown brands vary in micro leakage, surface roughness, and fracture resistance, according to recent research [(7, 8)].

Therefore, the aim of this study was to compare the surface roughness and hardness of zirconia-made pediatric crowns from two different manufacturers

MATERIALS AND METHODS

This study was conducted in pediatric dentistry clinic at Faculty of Dental Medicine of Al-Azhar University for Girls. Ethical approval was obtained from the research and ethical committee of the Faculty of Dental Medicine of Al-Azhar University for Girls Cairo-Egypt (**REC-PE-23-07)**.

Sample size calculation

Twenty four specimens were tested; and divided into 2 groups (anterior and size 5 from labial surface): **Group (1)** was represented by twelve Nu-smile crowns (NUS®-crowns) made of zirconia ceramic (DentaCarts*).Group (2) was represented by twelve Elephant crowns (Elephant® crowns). Made of highly translucent zirconia (Bibodent*). To study the effect of

crown type and aging on hardness and surface roughness of Nu-smile and elephant pediatric crowns; t-test or an equivalent nonparametric test was used for comparison between groups. According to a previous study by **Meshramkar et al 2020 [(9)]**. The average hardness was 0.543±0.14 without aging and 0.675±0.1 after aging. A large effect size of approximately 1.24 is expected. A total sample size of 24 (12 in each group):

- Group (1) was represented by twelve Nu-smile crowns (NUS®-crowns)
- Group (2) was represented by twelve elephant crowns (Elephant® crowns)

This sample were sufficient to detect an effect size of 1.24, with a power (1- β error) of 0.8 (80%) using a two –sided hypothesis test, with a significant level (α error) 0.05 for data.

The sample size was calculated according to G*Power software version 3.1.9.5 (10)**.**

Preparing the crowns for testing

A) All the used crowns for the hardness and surface roughness measuring experiment were embedded in a block

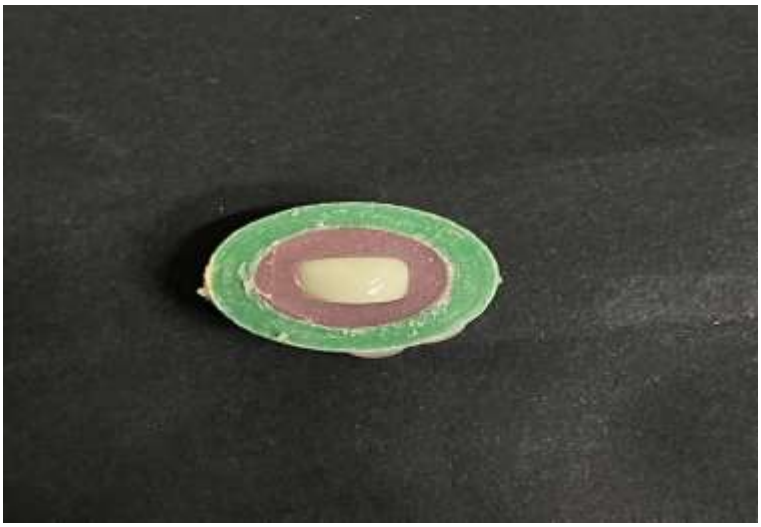

Figure 1: Embedding the crowns on an acrylic encircling a wax block

B) The block used for each crown was fabricated from a wax circle block surrounded by an acrylic circulation to maintain the strength of the block during experiments.

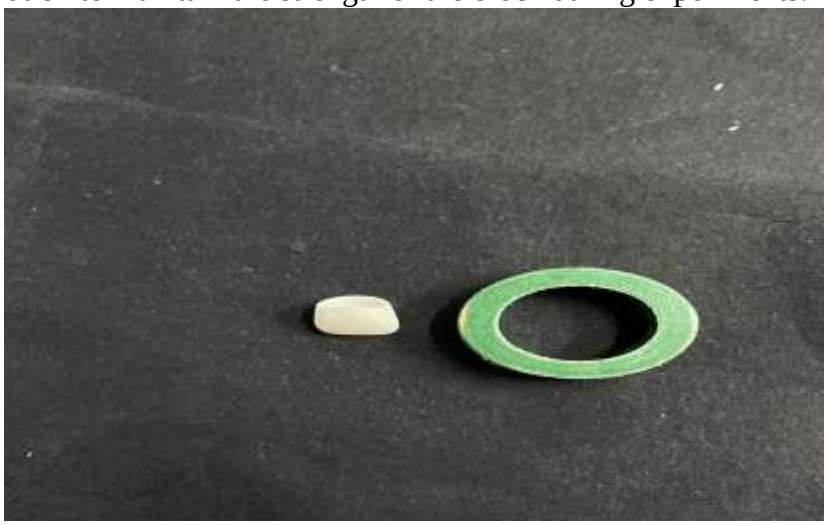

Figure 2: The acrylic block

C) The labial surface of each crown was positioned in a parallel position to the acrylic base of the whole block, to gain more accurate results during measuring the hardness and surface roughness of each crown. As Labial surface was tested to measure hardness and surface roughness of each group.

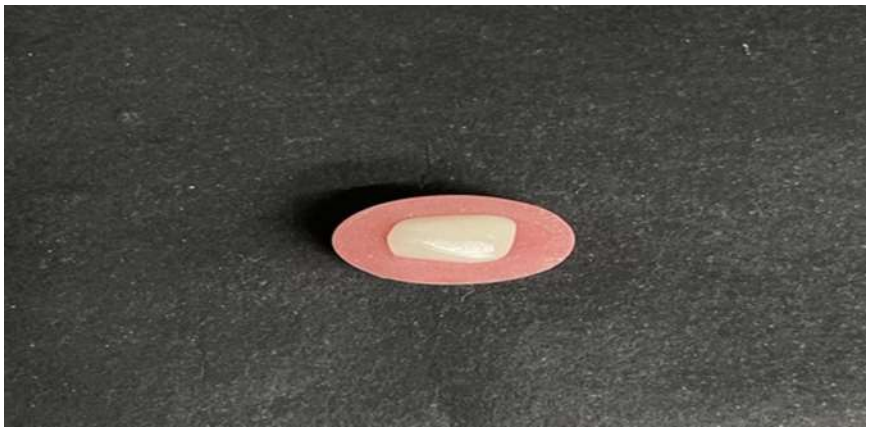

Figure 3: the final shape of the wax block and the Parallelism of the labial surface of the crown to the base of the block

Measuring of hardness by Wilson hardness tester model TUKON 1102 Germany

The both groups of crowns were indented using Wilson Microhardness tester (Tukon 1102 Wilson Microhardness tester Buehler) [(11).] Three indentations were performed per tooth at 100 grams' load with a dwell time of 10 seconds. The average score of the three readings were recorded for each group of the crowns

Figure 4 Wilson Micro-hardness tester

Measuring of surface roughness by SJ-210 surface roughness tester Mitutoyo Japan

Roughness Testing Methodology [(12)]

Each specimen was fitted to the specimen holder in which the surface to be measured in horizontal direction, then the specimen holder moves in vertical direction up to the specimen surface just touch the measuring tip. Device calibration was done using the standard calibration specimen before use.

Testing parameters:

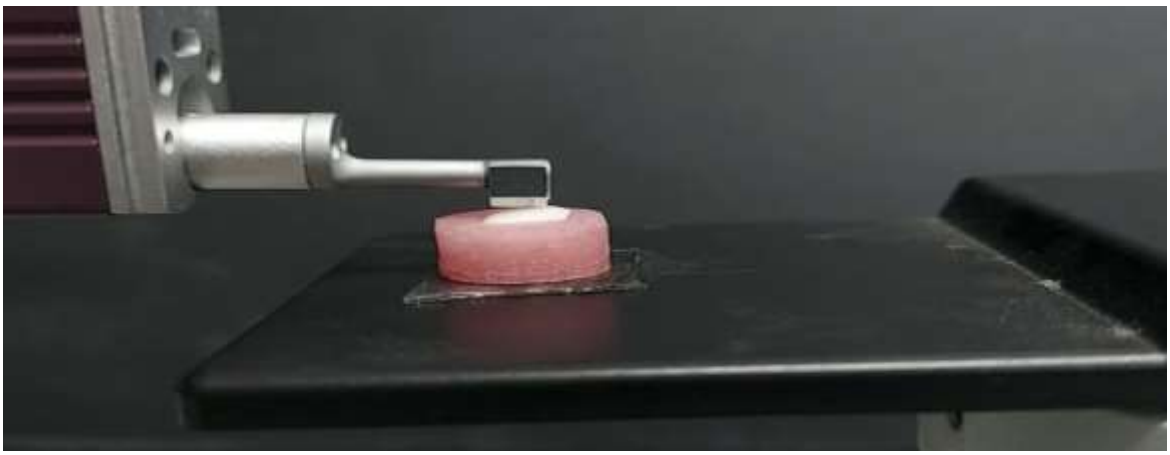

Figure 5 Photograph showing testing the samples under the surface roughness tester

1- Measuring distance 4 mm
2- Measuring Speed 0.5 mm/s. Returning 1 mm/s
3- Measuring force 0.75 MN
4- Stylus profile: tip radius 2-micron, tip angle 60 degree
5- Evaluation parameter Ra values expressed in microns 5 readings were recorded for each specimen at a distance 500 microns each

SD MECHATRONIC THERMOCYCLER

- Working mechanism of the thermocycler:

1. Cold water bath immersion for 30 seconds at 5 degrees
2. Hot water bath immersion for 30 seconds at 55 degrees
3. Dwell time 10 seconds

Figure 6: Thermocycling device (German-made 100 SD mechatronic thermocycler)

Thermocycling of the two sets of crowns (subgroup A and B of both groups (1&2)) to simulate the clinical settings to which the restorations were exposed in the laboratory. Throughout the course of 5000 cycles of thermocycling, or around six months of clinical care, was completed.

The process of thermal aging was carried out with the help of a German-made 100 SD mechatronic thermocycler. Immersion in water at 5 degrees Celsius for 30 seconds, followed by immersion in water at 55 degrees Celsius for 30 seconds, with a 10-second dwell period in each [13].

Statistical analysis:

All data were collected, tabulated and statistically analyzed using IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.. Quantitative data were expressed as the mean ± SD & (range), and qualitative data were expressed as number & (percentage). t test was used to compare between two group of normally distributed variables. Mann whitnney u test was used to compare between two groups of not normally distributed variables. Paired t test was used to compare between paired of normally distributed variables. All tests were two sided. P-value < 0.05 was considered statistically significant, p-value ≥ 0.05 was considered statistically insignificant

RESULTS:

Table1 :Comparison NU-smile crowns Roughness before and after thermo cycling

Roughness		NU-smile crowns n.12				
		Mean	SD	SE	minimum	Maximum
Before thermo cycling		0.0916	0.0066	0.0019	0.08	0.1
After thermo cycling		0.1357	0.0138	0.004	0.11	0.15
Paired t	t	12.15				
	p	0.0001*				

t:paired t test of significant , *p<0.05:significant

NU-smile crowns:

hardness NU-smile crowns, before thermo cycling ranged between a minimum value1149.7 to maximum value 1249.67 with a mean (±SD) of1198.3±36.799 . However after thermocycling ranged between a minimum value 980.95 to maximum value 1177.9 with a mean (±SD) of1079.7±74.3. The difference of roughness NU-smilecrowns, before and after thermo cycling. was statistically significant p value=0. 001, as revealed by paired t test

Table2 : Comparison NU-smile crowns hardness before and after thermo cycling

Hardness		NU-smile crowns n.12				
		Mean	SD	SE	minimum	Maximum
Before thermo cycling		1198.3	36.799	10.62	1149.7	1249.67
After thermo cycling		1079.7	74.3	26 1.4	980.95	1177.9
Paired t	t	9.87				
	p	0.0001*				

t:paired t test of significant , *p<0.05:significant

Elephant crowns:

Roughness Elephant crowns, was tested before and after thermo cycling

Roughness Elephant crown, before thermo cycling ranged between a minimum value 0.32 to maximum value 0.51 with a mean (±SD) of 0.3906±0.0638.

However after thermo cycling ranged between a minimum value 0.45 to maximum value 0.57 with a mean (±SD) of 0.5077±0.045

The difference of roughness Elephant crown, before and after thermo cycling. was statistically significant p value=0. 001, as revealed by paired t test

Table3 : Comparison Elephant crown crowns Roughness before and after thermo cycling

Roughness		Elephant crown N.12				
		Mean	SD	SE	minimum	Maximum
Before thermo cycling		0.3906	0.0638	0.0184	0.32	0.51
After thermo cycling		0.5077	0.045	0.0129	0.45	0.57
Paired t	t	7.64				
	p	0.0001*				

t:paired t test of significant , *p<0.05:significant

Elephant crowns:

Hardness Elephant crown, was tested before and after thermo cycling

hardness Elephant crown, before thermo cycling ranged between a minimum value 1038.7 to maximum value 1219.5 with a mean (±SD) of1128.7±77.15 . However after thermo cycling

ranged between a minimum value 1037.1 to maximum value 1158.9 with a mean (±SD) of 1079.9±44.92

The difference of hardness Elephant crown, before and after thermo cycling. was statistically significant p value=0. 001, as revealed by paired t test

Table 4 : Comparison Elephant crown crowns hardness before and after thermo cycling

Hardness		Elephant crown(n.12)				
		Mean	SD	SE	minimum	Maximum
Before thermo cycling		1128.7	77.15	22.27	1038.7	1219.5
After thermo cycling		1079.9	44.92	12.96	1037.1	1158.9
Paired t	t	2.15				
	p	0.054				

t:paired t test of significant , p>0.05 no:significant

Table 5: Comparison NU-smile crowns and elephant crown roughness before and after thermo cycling

Roughness	NU-smile crowns n.12		elephant crowns n.12		t	p
	Mean	SD	Mean	SD		
Before thermo cycling	0.0916	0.0066	0.3906	0.0638	16.15	0.001*
After thermo cycling	0.1357	0.0138	0.5077	0.045	27.37	0.001*

t:Student t test of significant ***p<0.05: significant**

Table, Shows there is significant higher roughness score before thermo cycling in elephant crowns compared to NU-smile crowns p=0.0001 .Moreover there is significant higher roughness score after thermo cycling in elephant crowns compared to NU-smile crowns p=0.0001.

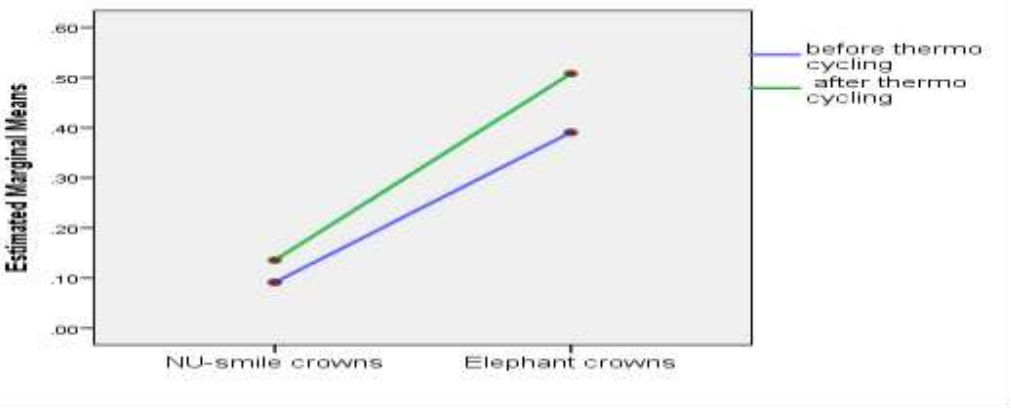

Figure 7: NU-smile crowns and elephant crown roughness before and after thermo cycling

Table 6 : Comparison NU-smile crowns and elephant crown hardness before and after thermo cycling

Hardness	NU-smile crowns n.12		elephant crowns n.12		t	p
	Mean	SD	Mean	SD		
Before thermo cycling	1198.3	36.799	1128.7	77.15	2.82	0.01*
After thermo cycling	1079.7	74.3	1079.9	44.92	0.013	0.99

t:Student t test of significant ***p<0.05: significant**

Table, Shows there is significant higher hardness score before thermo cycling in NU-smile crowns compared to elephant crowns p=0.01 .While there is no difference in hardness after thermo cycling in both crown types p=0. 99.

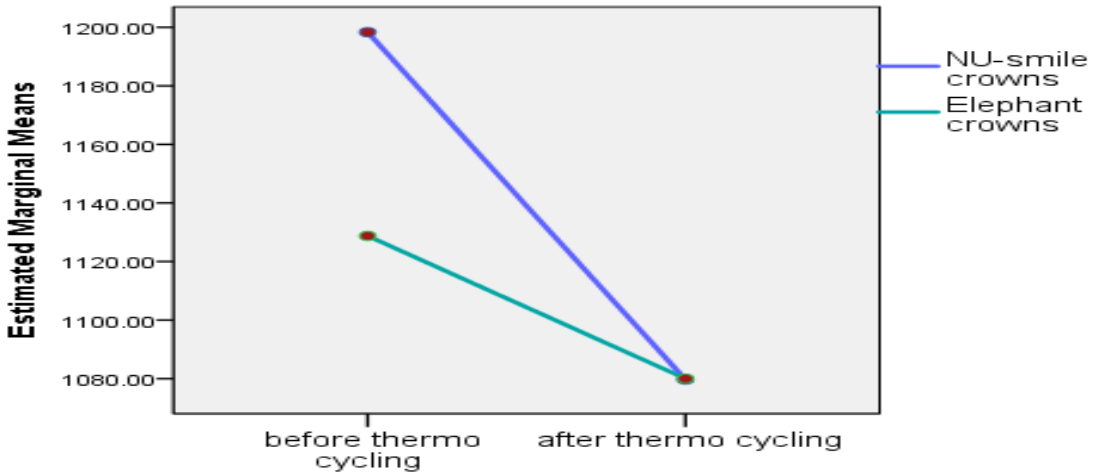

Figure 8: NU-smile crowns and elephant crown hardness before and after thermo cycling

Table 7 : Mean difference in NU-smile crowns and elephant crown due to thermo cycling

	NU-smile crowns n.12		elephant crowns n.12		u	p
	Median	Minimum -maximum	Median	Minimum - maximum		
roughness	0.044	0.03-0.06	0.11	0.06-0.2	3.8	0.0001*
Hardness	109.6	71.73-173.63	36.5	65.87-93.21	2.31	0.021*

U:Mann whitnney u test of significant ***p<0.05: significant**

Table, Shows there is significant higher hardness due to thermo cycling in elephant crowns p=0.0001 .However there is higher hardness after thermo cycling in NU-smile crowns p=0.021

DISCUSSION

While deciding on a pediatric crown, it's vital to keep in mind the notion of the "triangle of agreement," which states that the physician, the parent, and the kid (when old enough) should all agree on the optimal treatment option. In today's aesthetically focused world, both parents and children are concerned about how their teeth look[14]

Correcting the main tooth back to a healthy condition in terms of function and appearance is essential since dental deformity may significantly influence a child's normal psychological development, leading to emotional and behavioral issues that often end in lower self-esteem [14]

The purpose of this study was to contrast the surface roughness and hardness of pediatric crowns

constructed of zirconia from two different suppliers.

In spite of the increased use of in vivo inquiry data, such studies are prohibitively expensive, difficult to carry out, and must adhere to strict ethical guidelines. This in vitro approach was designed with the purpose of comparing two aesthetically acceptable pediatric crowns before and after they had been subjected to thermocycling in terms of their levels of surface roughness and levels of hardness.

Because of their vast surface area, which is appropriate for the laboratory testing of surface roughness and surface hardness, all of the crowns that were employed in this research, including the NUS crowns and the Elephant crowns, were intended for the labial surface of anterior teeth crowns of size 5 which gives better result, But another study used occlusal surface such as Pittayachawan et al. (2009) showed that there was a statistically significant difference in mean Ra values on the four different groups' level for the occlusal surface of first molar and second molar crowns. On Tukey's HSD test the mean score for Kinder Krowns first molar and second molar crowns presented a significantly different Ra scores compared to Cheng, Sprig EZCrowns and NuSmile crowns for the occlusal surface. A similar observation was also seen for the occlusal edges level of first molar and second molar crowns. Tukey's HSD test revealed mean Ra scores of Kinder Krowns first molar and second molar to be significantly different from other three brands at occlusal edge [(19)].

Thermocycling of the two sets of crowns nu-smile and elephant crowns to simulate the clinical settings to which the restorations were exposed in the laboratory. Throughout the course of 5000 cycles of thermocycling, or around six months of clinical care, was completed. The process of thermal aging was carried out with the help of a German-made 100 SD mechatronic thermocycler. Immersion in water at 5 degrees Celsius for 30 seconds, followed by immersion in water at 55 degrees Celsius for 30 seconds, with a 10-second dwell period in each,In a study by Ayaz et al. (2015), they aimed to evaluate the effects of thermal cycling on the surface roughness, hardness and flexural strength of denture resins. There was a significant difference between the PMMA and PA groups in terms of surface roughness, hardness and transverse strength before and after thermal cycling (p0.001) [(13, 17)].

Surface hardness is used to estimate the wear of restorative dental materials. It seems that excessive hardness typically results in more wear of the opposite tooth enamel and the hardness of the metal is associated with the wear of the opposite tooth enamel, A Wilson Microhardness tester was used to make indentations in the crowns of both sets of teeth (Tukon 1102 Wilson Microhardness tester Buehler). Each tooth was indented three times with a load of 100 grams and a dwell duration of 10 seconds. For each set of crowns, the mean of the three readings was recorded ,Although in a previous study, the highest degree of hardness is observed in the Nu Smile crown, and the higher hardness can be a well characteristic of a crown, it can also cause the wear of the opposite tooth enamel especially in children with severe bruxism. Also, the highest compressive strength and fatigue strength of the crowns were obtained by Nu Smile > 3M > Kids Crown > KTR crowns, respectively. This difference can be due to the different composition of the alloy in these four crowns [(11,15 and 16)].

Surface roughness was measured by SJ-210 surface roughness tester Mitutoyo Japan, Each specimen was fitted to the specimen holder in which the surface to be measured in horizontal direction, then the specimen holder moves in vertical direction up to the specimen surface just touch the measuring tip. Device calibration was done using the standard calibration specimen before use ,In Bamdadian et al. (2019) study, the resistance of four types of stainless steel crowns to abrasive forces was evaluated by measurement of the weight loss, and it was determined which crown undergoes faster abrasion against chewing forces and probably will be punctured. The wear rate of the crowns was observed from low to high in Nu Smile < 3M < Kids Crown < KTR crowns respectively. In this study, KTR crown had the highest wear and the least compressive and fatigue strengths [(12, 18)].

In this study, the testing results of the NU-smile crowns before and after thermocycling shows that low surface roughness, as the majority of the NU-smile before and after thermal cycling, there was a statistically significant (p.001) change in the roughness of NU-smile crowns with t-value 12.15, so the $p<0.05$: significant. Moreover, the Nu-Smile crowns showed before thermo-cycling that hardness values were ranged between a minimum value 1149.7 to maximum value 1249.67 with a mean (±SD) of 1198.3±36.799, while after thermo-cycling ranged between a minimum value 980.95 to maximum value 1177.9 with a mean (±SD) of1079.7±74.3. The paired t test demonstrated a statistically significant (p.001) difference in the roughness of NU-smile crowns before and after thermal cycling.

While testing the roughness of the Elephant crowns before the thermos-cycling the readings varied from a low of 0.32 to a high of 0.51, with a mean (standard deviation) of 0.39060.0638. But after the thermos-cycling ranged between a minimum value 0.45 to maximum value 0.57 with a mean (±SD) of 0.5077±0.045. The difference of roughness Elephant crown, before and after thermos-cycling was statistically significant p value=0. 001, as revealed by paired t test which means that the Elephant crows have a high surface roughness.

The hardness of an Elephant Crown was measured before and after being subjected to thermal cycling, and it was found to have a minimum value of 1038.7 and a maximum value of 1219.5, with a mean (SD) of 1128.777.15. The values before and after the thermal cycling experiment were 1037.1, 1158.9, and 1079.9, respectively, with a mean (SD) of 44.92. A paired t test demonstrated a statistically significant (p.001) difference in Elephant crown hardness before and after thermal cycling. Which means that it has a low surface hardness.

The roughness test reveals that elephant crowns have a much greater roughness score than NU-smile crowns do prior to thermos-cycling (p0.0001). Also, following thermal cycling, elephant crowns had a much greater roughness score than NU-smile crowns (p0.0001). Compared to elephant crowns, the hardness score of NU-smile crowns is significantly greater before thermal cycling (p=0.01). While p=0.99 indicates that there is no change in hardness across crown types following thermal cycling. Thermo-cycling also causes a notable increase in hardness in elephant tusks (p0.0001). Thermo-cycling, however, increases hardness in NU-smile crowns (p=0.021).

CONCLUSION

The Nu-smile crown is more durable than the Elephant crown. The surface hardness of the Nu-Smile crown is higher than the hardness of the Elephant crown before and after the thermocycling process. The Surface roughness of the Nu-smile crown is less than the roughness of the Elephant crown before and after the thermocycling process

From the results of this research, we can conclude that the Nu-smile crowns are more recommended than the Elephant crown in usage for the pediatric teeth for the following reasons:

1- High esthetical (color stability and full coverage which protects the primary tooth until the shedding of the permanent one).

2- It is highly durable because of its high surface hardness and less surface roughness.

3- Elephant crown price is cheaper

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