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Color Stability of Prefabricated Pediatric Zirconia Crowns: A Comprehensive Analysis of the Impact of Multiple Autoclave Cycles

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Abstract

When sterilizing dental restorative materials, autoclaving is essential because it guarantees the removal of potentially hazardous germs and upholds aseptic conditions. This is especially important for pediatric dentistry, where prefabricated zirconia crowns are often used because of their long-lasting and attractive qualities. Autoclaving affects the chemical and physical properties of dental materials in addition to helping to control infections. The aim of the present study is to evaluate effect of repeated autoclave cycles on the color stability of pre-fabricated pediatric zirconia crowns. A total of 30 mandibular molar crowns were used in the in-vitro study. The crowns were divided into two groups according to the brands. Group 1 (Nu-Smile), Group 2 (Kids E Crown). The color stability was measured using a spectrophotometer. Initial color readings are taken for all the 30 samples. After each cycle of sterilization color stability was measured using a spectrophotometer. The color changes in the crowns obtained from the spectrophotometer was analyzed by CEILAB method. It showed the L, A, B values of NU Smile and KIDS E zirconia material crowns during initial, after 1st and 2nd cycle of Autoclave. NU Smile value showed increase in value which indicates lightness of material and KIDS E value showed decrease in value which indicated darkness of material. There was no significant difference in the color stability of the crowns after each cycle of autoclave sterilization in both the brands. Additionally, further clinical studies with longer follow-up periods are needed.

Keywords: *Color Stability, Pedodontics, Prefabricated, Zirconia.*

Introduction

Different esthetic prefabricated crowns are now available in response to patients' and parents' increasing demand for aesthetic restoration of their deciduous dentition that have decayed and damaged [1]. For dentists who treat kids, one of the biggest obstacles is the cosmetic regeneration of badly damaged primary teeth. Caries of the teeth are thought to be the most prevalent disease in the world [2] Between 60 and 90 percent of kids worldwide suffer from this illness. If decay is not treated, it may cause significant damage to the structure of the tooth, necessitating the restoration of more than one tooth surfaces [3].

For over a decade, zirconia has been successfully applied in the field of adult dentistry [4].To provide a more demanding and aesthetically pleasing choice, this material has been modified for use in pediatric dentistry [5]. Numerous brands have developed zirconia crowns as a result of the recent increase in the use of all-ceramic restorations in pediatric dentistry (NuSmile, Kinder Crowns, Cheng Crowns,E Z Pedo crowns) [6].

The mechanical characteristics of zirconia and stainless steel are comparable. It can

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withstand pressures of up to 900–1200 MPa, and it has a 2000 MPa compression resistance [7]. There are three types of zirconia: monolithic, porcelain fused to zirconia, CAD/CAM zirconia crowns [8].

Zirconia crown indications include cavities affecting incisal margins, decay involving more than one side, dental fractures involving the proximal surface, teeth discolored following pulp treatment, nursing bottle caries. Contraindications include excessive grinding, crowding of the teeth, swelling of gingiva that surrounds the teeth [9].

Crowns may unknowingly get mixed with blood and saliva during the initial fit test. These materials may include a variety of viruses and bacteria, including hepatitis B or human immunodeficiency, which could result in cross infection if the same crown is placed on another patient. For the same reason, crowns' indirect and direct contact surfaces must be cleaned and sterilized before being used on a different patient [10].

There are various sterilization techniques that can be used, such as chemical vapor sterilization, dry heat sterilization, autoclave sterilization, ethylene oxide gas (EOG) sterilization, and chemical sterilant. Autoclaving and EOG sterilization are the frequently employed techniques among these in dentistry [11]. There are three main steps in an autoclave sterilization process: heating, exposure, and cooling. The samples' temperatures fluctuate at these stages [12]. Furthermore, variations in temperature may cause a material's shape and chemistry to change chemically [12, 13].

In order for dental materials to have a natural-looking appearance, color is a crucial aesthetic factor. Given that parental discontent is most closely correlated with the color of the restoration, color consistency is essential. Composite resin color has been researched for shade matching and long-term durability.[14] A three-dimensional description of color called a color space (L*a*b*) was established in 1976 by the Commission International de l'Éclairage (CIE). L* represents lightness or the distinction between black and white in this color space. The a* value indicates the red-green axis, and the b* represents the yellow-blue axis. Nowadays, one of the most extensively used color spaces for determining object color is the L*a*b* color space (CIELAB) [15].

Serious ion (SiO_2) is a common impurity in zirconia ceramics that can affect their color stability. Sterilization occurs when silicon dioxide particles form a layer of cristobalite on the surface of the ceramic, which can happen during manufacturing or over time due to environmental factors. This process can affect color stability in several ways like chromatic aberration, reflection and scattering surface roughness.

This study examined the effects of autoclave sterilization on the color stability of prefabricated zirconia crowns.

Materials and Methods

This in vitro study was conducted in the department of pedodontics and preventive dentistry in a private dental college, Chennai. The sample size was calculated to be 30 based on a study done by John Douglas Pate et al in 2021 [16]. The ethical clearance of this study was obtained from the Institutional Ethical Board SRB/SDC/PEDO-2202/23/161. With the allocation ratio of 1:1, the crowns were divided into two groups according to the brands. All the crowns were prefabricated primary mandibular 1st molars. Group 1 was assigned to the NU SMILE brand (Houston, Texas, USA). Group 2 was assigned to Kids E Crown (Mumbai, India). The crowns from each manufacturer were used for baseline color measurements prior to any sterilization processes. A Konica Minolta CM-700D spectrophotometer (Osaka, Japan) was used to measure color. Rectangular coordinates are used in the CIELAB system for color measurements. In this color space, the a* component shows positive values are red and negative values are green; the b* The

component shows positive values are yellow and negative values are blue. L* represents brightness, with increasing values being whiter and decreasing ones darker.

The crowns were placed on the aperture of the spectrophotometer. An attempt was made to effectively measure the same location on occlusal or incisal surfaces, by approximating the central most point for each crown. Initial color readings are taken for all the 30 samples (T0) NUSmile (Houston, Texas, USA and Kids E Crown (Mumbai, India). After the baseline, each crown was sterilized four times using an autoclave (Fomos Autoclave Foster Plus 17 L – Zhejiang, China). Each cycle lasts for 23 minutes with a voltage of 110-240v and power 1800w. The measurements were repeated following the first (T1) and fourth sterilizations (T2) by a single operator to avoid reporting bias. The measuring background was a neutral gray color. After using tissue paper to dry each crown gently, the instrument probe was positioned perpendicular to the surfaces of the crowns.

The color data obtained from the spectrophotometer can be analyzed using color difference formulas such as ΔE (Delta E), which quantifies the perceptible color change. The overall color change (ΔE) for each specimen was calculated using the equation $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{(1/2)}$, where ΔL*, Δa*, and Δb* stand for the differences in L*, a*, and b* before and after sterilization. The color change was assumed at the acceptability threshold of $\Delta E = 3.3$ based on the study done by Ebru Delikan et al, 2023 [17].

The data was analyzed in the SPSS software version 24.0. The color measurements and changes were expressed in mean and standard deviation. The Shapiro wilk test was done to determine the normality of the distribution. Mann Whitney U test was done to assess the differences in the color change between the brands/groups and Friedman test was done to assess the differences in the LAB color assessment within the groups. The Wilcoxon sign rank test was employed to evaluate the variations in ΔE among the cohort.

Results

The study contains 30 crowns which were divided into two groups (Nu Smile and Kids E). The LAB measurements of LAB through measurements T0, T1 and T2 were assessed through the Friedman test. L and B did not have any significant differences after the sterilization. The measurement A had significant changes in both brands throughout the sterilization (Table 1).

Mann Whitney U test revealed that there was no significant difference between brands in T0/T1 and T0/T2 (Table 2). Wilcoxon sign rank test revealed that in both the brands; the color change has increased from T0/T1 to T0/T4 but it was not statistically significant difference (Table 3). This denotes that both the brands had good color stability after cycles of sterilization and both brands did not have much difference between each other.

Table 1. Friedman Test Shows Significant LAB Color Differences Over 4 Sterilization Cycles

Brand	Color Measurements		Mean ± SD	P value
NuSmile	L	T0	81.03±0.58	0.568
		T1	80.8±1.77	
		T2	80.53±2.05	
	A	T0	1.76±0.28	0.04*
		T1	1.86±0.2	
		T2	2.2±0.17	
	B	T0	19.63±0.11	0.264
		T1	19.74±1.13	

		T2	19.89±1.1	
Kids E	L	T0	82.03±1.55	0.307
		T1	83.23±1.91	
		T2	83.56±1.06	
	A	T0	0.86±0.23	0.04*
		T1	0.92±0.09	
		T2	1.13±0.05	
	B	T0	10.66±0.83	0.529
		T1	10.87±0.57	
		T2	10.96±0.6	

Table 2. Mann Whitney U Test Shows Color Differences between Brands after 4 Cycles of Sterilization

Color change ΔE	**Groups**	**Mean ± SD**	**T value**	**p value**
T0/T1	NUSMILE	1.56±0.84	0.597	0.582
	KIDS E	2.07±1.22		
T0/T2	NUSMILE	1.89±0.68	0.512	0.632
	KIDS E	2.24±0.62		

Table 3. Wilcoxon Test Shows Color Changes Within the Brand Across 4 Sterilization Cycles

Groups	**Color change ΔE**	**Mean ± SD**	**p value**
NUSmile	T0/T1	1.56±0.84	0.953
	T0/T2	1.89±0.68	
Kids E	T0/T1	2.07±1.22	0.532
	T0/T2	2.24±0.62	

Discussion

Color change was analyzed at baseline for all groups by recording the individual crowns measurements and comparing them to the post sterilization. A spectrophotometer or a colorimeter, among other instrumental tools, can be used to measure color changes in addition to being visually assessed. Because color perception varies so much, visual color assessment is not dependable. Color changes are frequently measured using instrumental methods since they do not require subjective judgment. The data are analyzed based on color differences using the baseline threshold ΔE value. Three limit intervals have been proposed for the detection of color differences by the human eye: $\Delta E < 1$ meaning that it cannot be detected by the human eye, $1 < E < 3.3$ meaning that it can be detected by trained operators and is considered clinically acceptable, and $\Delta E > 3.3$ meaning that it can be detected by patients and untrained observers and is deemed clinically unfavorable [18].

This study assessed how sterilization cycles affected the color stability of prefabricated Zirconia crowns. Based on the findings, the study's null hypothesis regarding color stability was disproved. Following autoclaving, it was noted that both groups' colors were stable and showed no appreciable modifications.

Numerous investigators often use experimental test specimens to assess the mechanical characteristics of dental materials. It can establish an appropriate setting that

enables the examination of material qualities in standardized specimens and imitate the oral environment from various angles. Other benefits of in vitro testing include increased speed, precision, uniformity, and ease of experiment conduction [19].

Zirconia crowns are highly sought after by parents who desire more cosmetically pleasing dental work done on their children's primary teeth. Over the years, many methods of tooth restoration have been tried. Stainless steel crowns (SSC), polycarbonate crowns, acid-etched crowns, strip crowns, open-faced SSCs with veneer on the chair side, and commercially available pre-veneered SSCs are a few of them [4, 20]. Studies have been conducted to evaluate and contrast the characteristics of zirconia crowns for primary teeth with those of other comparable restorations, like stainless steel crowns [21]. In their investigation, Manthra et al. evaluated the frequency of use of zirconia and stainless-steel crowns in the back teeth of children across various age groups. They discovered that among juvenile patients under the age of five, stainless steel crowns were the most often used type for full coverage restoration of primary molars, with a preference for male children.

The resistance to wear, abrasiveness, color stability, and displacement resistance of zirconia and PEEK milled crowns were examined in a study by Simon Shah et al in comparison to PEEK, zirconia was shown to be more color stable. However, PEEK is a viable substitute for zirconia crowns because it has less abrasion, and greater stress modulation through plastic deformation [22].

In the present study, the color change increased before and after the 2nd cycle of sterilization but it was not significantly different. Similarly, there was no difference between both the groups. NU Smile showed DE minor changes in color stability after 2nd sterilization when compared to KIDS E. In a similar study done by Mohammed Saifullah evaluated and compared the color stability of veneered zirconia crowns and monolithic multi-layered zirconia crowns before and after thermocycling age. The results showed that whereas the shade of veneered zirconia looked to be darker during thermal cyclic aging, the shade of monolithic multi-layered zirconia changed lighter [23].

Gülce Alp evaluated the impact of shading technique and thickness on the translucency and color stability of translucent zirconia following the thermocycling of coffee in a different study. It was determined that the hue of translucent zirconia was unaffected by shading technique or tested thicknesses. The RTP (Relative Translucency Parameter) of transparent zirconia was impacted by thickness and shading approach. The thickness of the material had an inverse effect on the RTP. For specimens thicker than 1 mm, externally shaded zirconia displayed a greater RTP than pre shaded zirconia [24].

Zirconia crowns have a great degree of color stability, according to studies [25–27]. When presenting zirconia to parents as an aesthetic alternative to other crowns, such resin-coated stainless-steel crowns, this factor might be taken into account. The extremely polished surface of zirconia crowns keeps color retention and discoloration at bay [28]. Zirconia crowns had the lowest rate of color changes, crazing, and fractures among the examined groups after using sterilizing procedures [29].

The fact that this study was limited to examining color stability alone was one of its limitations. Clinical efficacy of pediatric zirconia crowns is good, according to findings and in vivo studies. While clinical long-term and future studies are essential to determine whether zirconia is highly reliable and aesthetically pleasing. For deciduous teeth, zirconia crowns can be a successful full-coverage repair. More clinical research with extended follow-up times is also required. The duration of the operation, high cost, and dentist expertise need to be taken into account while evaluating zirconia crowns as a replacement to

other materials and crowns for deciduous teeth, particularly for those that are primary.

Conclusion

The present study concluded that zirconia crowns show great promise as a substitute for crowns and other restorative materials in the area of pediatric dentistry in terms of color stability. In terms of several clinical dimensions, they demonstrated superior qualities and efficacy together with high levels of parental approval. There is no significant difference in the color changes after each cycle of autoclave sterilization in Nu smile crowns and Kids E crown and both are equally effective in showing color stability.

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Conflict of Interest

The author declares that there was no conflict of interest in the present study.

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