EFFECT OF AGING ON TRANSLUCENCY AND FLEXURAL STRENGTH OF DIFFERENT ZIRCONIA MATERIALS (AN IN-VITRO STUDY)

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ABSTRACT

Statement of Problem: Since ultra high translucent cubic zirconia was evolved in the market, comparison were made with high translucent tetragonal zirconia regarding translucency and flexural strength after thermal aging.

Aim of This Study : The aim of this study is to detect translucency and flexural strength changes of two different zirconia materials before and after aging.

Material and Methods: Forty Zirconia samples (n=20) from each type (Cubic and Tetragonal Zirconia) were prepared then autoclaved. The aging parameter was set to a temperature of 134 C° and a pressure of 2 bar for 10 hours of aging. A spectrophotometer device was used for measurement of translucency and contrast ratio of each group. Piston and three supporting balls test were used for flexural strength test.

Results: The results showed that Zirconia type (regardless of aging) had a statistically significant effect on mean translucent parameter and flexural strength. Aging had a statistically significant effect on mean translucent parameter and flexural strength except for the cubic zirconia which showed non-significant lower flexural strength after aging.

Conclusion: Aging (regardless of Zirconia type) had a statistically significant effect on mean translucent parameter and flexural strength. Flexural strength of cubic zirconia was not significantly affected by aging.

KEYWORDS: Thermal aging, translucency, flexural strength, zirconia microstructure

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INTRODUCTION

Translucency of dental ceramics is one of the most important parameters to achieve esthetic restoration and making it more natural by transmission of light through ceramic materials.[1, 2]

Lately 5mol% yttria high translucent partially stabilized zirconia has been developed and are available as it increases the degree of translucency through increasing the amount of cubic crystals in the material to approximately 50%. However, this increase of translucency comes often on the expense of strength and toughness. These new materials were commercially available but its resistance to aging is not yet fully established. [2, 3]

The mechanical performance of zirconia material might be weakened via transformation from tetragonal to monoclinic phase (t→m) when exposed to low temperature degradation (LTD). Water is incorporated in the beginning at the superficial grains by filling oxygen vacancies, then extents into the bulk of the material and affects adversely the flexural strength and mechanical properties of Y-TZP structures. [3, 4]

So, to overcome these problems, recent types of zirconia material have been presented in the dental market to improve mechanical properties with excellent esthetics.

This study was done to test and evaluate translucency and flexural strength of two different types of zirconia materials before and after accelerated aging.

MATERIALS AND METHODS

Forty zirconia samples (n=20) from each type (Ultra high translucent cubic zirconia DD cubex^2 and High translucent tetragonal zirconia DD Bio ZX^2) was prepared from the blanks of both groups using Isomet 4000. Shrinkage rate of zirconia blanks were calculated before cutting and added to the final dimensions required after sintering (10×10×0.8 mm) (shrinkage rate 1.23% according to the manufacturer instructions) (12×12×0.98 mm).[4]

Then zirconia discs were sintered in a zirconia sintering furnace (Tegra speed).

Diasynt plus and Diacera EVE Zirconia finishing kit (Ernst Vetter GmbH Keltern, Germany) were used for finishing and polishing all samples according to manufacturer's instructions on both surfaces. 10 samples from each zirconia type were grouped and packaged separately inside a sterilization pouch, then autoclaved by Andromeda (Gima Made in Italy). The aging parameter was set to a temperature of 134 C° and a pressure of 2 bar for 10 hours of aging. [5, 6]

All zirconia specimens were cleaned in ultrasonic cleaning device, ultrasonic cleaner (cd-4830, COXO, China) in isopropyl alcohol solution bath for a period of 10 minutes, then the samples were dried well using gentle air and stored in a labeled box for the testing step. [7]

For testing translucent parameter three measurements of L*, a*, and b* were recorded for each specimen and averaged to obtain a mean value for the following calculations. In the color space, L* indicates lightness, the a* coordinate represents the green-red range, and the b* coordinate represents the blue-yellow range. The translucency parameter (TP) of each specimen was determined by calculating the color difference between readings against black (B) and white (W) backgrounds for the same specimen, according to the following equation:

$$TP = [(L^*_B - L^*_W)^2 + (a^*_B - a^*_W)^2 + (b^*_B - b^*_W)^2]^{1/2}$$
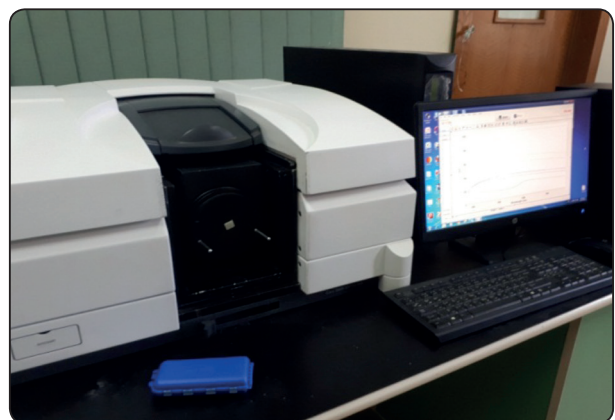
Cary 5000 spectrophotometer

Biaxial flexural strength test

Piston and three supporting balls test was used for flexural strength test according to ISO 6872:2008. [8]

A universal testing machine (Instron, Illinois, USA) was used. Diameter of the supporting 3 balls was 2.5 mm. Diameter of plugger applying force was 1.4 mm. While the diameter of ring including 3 supporting balls was 10 mm. Film of non-rigid material, as a polyethylene sheet, placed in the

Instron univeral testing machine

interface between specimen and the piston has been indicated to reduce the friction effects. Compressive mode of force applied by 5000 Newton load cell at crosshead speed 1mm/min up to specimen failure.

RESULTS

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). All data showed parametric (normal) distribution. Data were presented as mean and standard deviation (SD) values. Two-way Analysis of Variance (ANOVA) was used to study the effect of Zirconia type, aging and their interaction on mean translucency parameter (TP) and contrast ratio (CR). Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test is significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp

The results showed that Zirconia type (regardless of aging) had a statistically significant effect on mean translucent parameter and flexural strength. Aging had a statistically significant effect on mean translucent parameter and flexural strength except for the cubic zirconia which showed non-significant lower flexural strength after aging.

TABLE (1) Descriptive statistics for TP values

Zirconia type	Aging	Mean	SD	Median	Minimum	Maximum	95% CI	
							Lower bound	Upper bound
Cubic zirconia	Before aging	12.1	0.22	12.11	11.82	12.45	11.94	12.26
	After aging	10.97	0.2	10.99	10.63	11.26	10.82	11.12
Tetragonal zirconia	Before aging	8.51	0.18	8.53	8.13	8.75	8.38	8.65
	After aging	6.9	0.21	6.94	6.44	7.16	6.75	7.05

TABLE (2) Descriptive statistics for flexural strength (MPa) values

| Zirconia type | Aging | Mean | SD | Median | Minimum | Maximum | 95% CI | |
							Lower bound	Upper bound
Cubic zirconia	Before aging	534.7	142.4	572.1	298.7	791.1	432.8	636.5
	After aging	444.9	118.3	468.2	241	590.6	360.3	529.6
Tetragonal zirconia	Before aging	817.4	130.5	798.6	618.1	998.7	724	910.7
	After aging	684.9	104.9	685.1	534.2	820.4	609.9	760
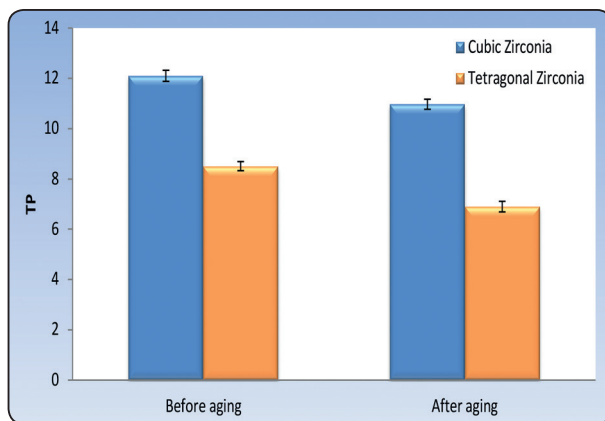
Results of Translucency:
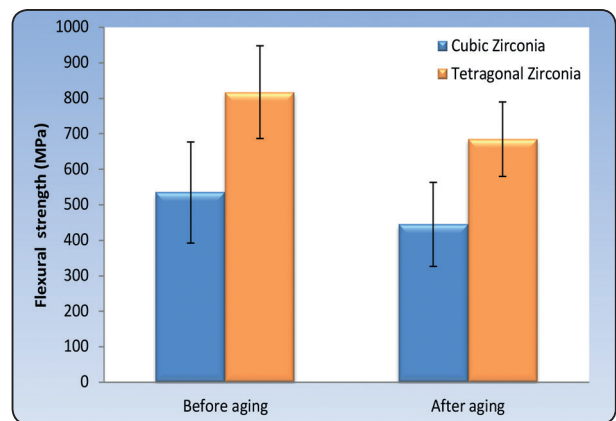
Results of flexural strength

DISCUSSION

Traditional zirconia material (3Y-TZP) has been used as a dental restorative material for over a decade, due to its high mechanical properties compared with other dental ceramics. But low translucency of conventional zirconia remains a most important problem especially when used in anterior region.[9]

This study was done to evaluate flexural strength before and after accelerating aging for two different types of zirconia material (high translucent tetragonal and ultra high translucent cubic zirconia).

The null hypothesis of this study that there is no difference in flexural strength between HT tetragonal and UHT cubic zirconia before and after aging is rejected.

Basílio M, et al (2016) stated that aging of zirconia material by low temperature degradation is usually conducted in an autoclave, through the effect of pressure of water vapor, temperature and time. This humid environment increase t-m transformation leads to volume increase of surface grains causes stress propagation from one transformed grain to the others, this is responsible to initiate microcracks helping water to penetrate into the bulk of the material and significantly reduce the mechanical properties. [10] There are some controversies between the aging periods in the literature. Periods were widely different in the studies. The aging periods were (5, 10, 20, 30, 80, 100 hours).[11, 12, 13, 14, 15, 16] Camposilvan E, et al (2018) stated that one hour of accelerated aging at 134°C is approximately equal to 2 - 4 years at 37 °C in the oral cavity. [4] In our study aging was done for 10 hours at 134C° and a

pressure of 2 bar. This represents average 30 years inside patient mouth.

In our study biaxial flexural strength test was performed through three piston and supporting balls and a significant difference was showed between HT and UHT before and after aging.

Results of UHT cubic zirconia showed that statistically significantly higher mean TP (12.1 ± 0.22) than HT tetragonal Zirconia (8.51 ± 0.18) regardless Zirconia type; the mean translucent parameter value before aging showed statistically significantly higher value (10.31±1.85) than after aging (8.93±2.1). These results agree with results of Alghazzawi T (2016) who found that the mean translucent parameter value before aging showed statistically significantly higher value than after aging and contrast ratio before aging showed statistically significantly lower value than after aging. This could be explained due to transformation from tetragonal to monoclinic phase with associated surface roughness which caused an increase in light scattering. [17]

After aging UHT cubic Zirconia showed statistically significantly higher mean translucent parameter (10.97± 0.2) than HT tetragonal Zirconia (6.9±0.21) and UHT cubic Zirconia showed statistically significantly lower mean contrast ratio (0.704±0.005) than HT tetragonal zirconia (803±0.005). This is in agreement with the results of Klimke J, et al (2011) could be due to the presence of cubic phase and stable birefringence that leads to less diffuse scattering at the grain boundaries, pores and high alumina contents that was responsible for formation of secondary phase. Translucency of tetragonal zirconia increased by reducing alumina content without effect on mechanical properties. [3]

Regarding flexural strength test, UHT cubic zirconia showed statistically significantly lower mean value (489.8 ±135.5) than HT tetragonal Zirconia (751.1 ± 133.8). These results came in agreement with Kwon S, et al (2018) who showed

that tetragonal zirconia recorded flexural strength mean value higher than cubic zirconia. This could be due to lower potential for transformation toughening of UHT cubic than HT tetragonal. The results showed different values than our study due to different specimen shapes that were used (bar versus square). [11]

Aging had no significant effect on flexural strength of cubic zirconia in our study, mean value before aging was (534.7±142.4) and after aging (444.9±118.3). This was in agreement with results of Camposilvan E, et al (2018) who stated that the presence of cubic phase has main advantages of complete absence of degradation. [7]

This was not in agreement with the results of Guilardi L, et al (2017) who showed that mean flexural strength for control group of zirconia was 932 MPa and after aging was 1018.8 MPa. But the cause of increasing flexural strength after aging procedures was not explained. [12]

Mean flexural strength of HT tetragonal zirconia; before aging (817.4±130.5) showed statistically significantly higher value than after aging (684.9±104.9). This agreed with the results of Zhuang Y, et al (2018) that could be due to transformation from tetragonal to monoclinic phase. However the degree of transformation varied between the groups, so the percentage of monoclinic phase increased with aging time. The grain size after autoclaving varied between different groups according to the thickness of the specimen suggested and the depth of the LTD was influenced by the Y-TZP thickness. Micro cracks formed at the surface layer lead to decrease the flexural strength and fracture strength with increase depth of the transformation zone.[14]

Limitations of present study

The specimens shape were selected as square to facilitate cutting and decreasing the inherited flaws within the specimen, despite that number of studies

showed no difference in stress distribution or flexural strength values, yet the ISO standard (6872:2008) stated a circular shape should be utilized.

This study was comparative between different zirconia microstructures regardless the anatomical shape and thickness of restorations. Anatomical crowns are expected to have different flexural strength values

Moreover, lack of mechanical aging and thermo-cycling may have affected the translucent parameter and flexural strength if compared to clinical conditions.

CONCLUSIONS

Within the limitations of this in-vitro study, the following conclusions could be drawn:

1. Ultra high translucent cubic zirconia has more significant translucency after aging than high translucent tetragonal zirconia.

2. UHT zirconia has significantly less flexural strength after aging than HT zirconia.

3. Flexural strength of UHT zirconia has no significant affect by aging. Aging affects significantly the translucency of zirconia regardless the type used.

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