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EVALUATION OF TRANSLUCENCY OF MONOLITHIC ZIRCONIA AFTER ALTERING SINTERING SPEEDS

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ABSTRACT

Aim: The goal of this study was to evaluate the translucency of two materials of monolithic zirconia sintered using two different sintering protocols.

Materials and Methods: Forty disc samples (10 mm diameter x 1mm thickness) were designed and milled from two brands of monolithic zirconia blanks, Katana STML and Cercon xt ML (n=20 each). Dry milling protocol using (inLab MC X5, DentsplySirona) was followed to prepare the samples. Katana STML samples were then divided into two groups regarding sintering protocols(n=10 each); **Group (I)**: samples sintered by traditional sintering protocol (1550°C, 120min dwelling time and 7 hours total time), **Group (II)**: high speed sintering (1560°C, 30min dwelling time and 90min total time). Cercon xt ML samples were also divided into two groups regarding sintering protocols(n=10 each); **Group (III)**: Traditional sintering cycle (1520°C, 90min dwelling time and 270min total time), **Group(IV)**: high speed sintering (1540°C, 15min dwelling time and 1 hour total time). Translucency parameter (TP) was then evaluated using a spectrophotometer. The collected data underwent statistical analysis to draw meaningful insights and conclusions.

Results: Traditional speed revealed statistically significant higher (TP) mean values compared to high speed. A highly significant difference in (TP) mean values between Katana and Cercon materials as Cercon showed the higher mean values.

KEYWORDS: Translucency, Monolithic zirconia, Sintering speed, Katana, Cercon.

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INTRODUCTION

The increasing demand for aesthetically pleasing dental restorations has fueled the development of advanced dental ceramics.[1] Among these materials, zirconia stands out as a highly attractive option due to its exceptional optical and mechanical properties.

Several sintering methods have been proposed to densify zirconia blanks, including conventional, speed, microwave, spark plasma, and flash sintering. The conventional sintering approach, however, requires lengthy heating times and high temperatures, making it an energy-intensive and time-consuming process. As a result, this conventional method necessitates more than a single dental appointment, with the patient requiring a provisional restoration in between visits. Rapid sintering techniques can fabricate zirconia dental restorations in a single visit, potentially increasing the clinical use of this material[2].

Some studies have found that higher heating temperatures and/or longer cycles can produce zirconia grains of a larger tetragonal crystal structure, that may improve the material's translucency. However, these larger grain sizes can also lead to spontaneous phase transformations from the tetragonal to the monoclinic crystal structure (T-M). This T-M alteration can decrease the material's stability and gradually reduce its strength[3].

Conversely, lower sintering temperatures and/or shorter durations result in smaller grain sizes, in regions where the tetragonal-to-monoclinic (T-M) transformation does not take place. This helps maintain the material's mechanical properties at the highest possible level with the smaller grain structure. Therefore, the aim of this study was to assess the impact of changing sintering protocols on TP parameter of monolithic zirconia (Katana STML and Cercon xt ML).

MATERIALS AND METHODS

1. ***Designing the Discs:***

- Cylindrical zirconia samples measuring 12.25 mm in diameter and 14 mm in thickness were designed using a computer aided design software (Meshmixer, Autodesk, USA).
- The disc design was created as a 2D model.

2. ***Milling the Discs:***

- Monolithic zirconia blanks (Cercon xt ML and KATANA STML) in shade A1 were used.
- The cylindrical samples (12.25 mm diameter x 14 mm thickness) were milled using a 5-axis milling machine (inLab MC X5, DentsplySirona, Germany), according to the instructions of the manufacturer.

Fig. (1) Discs after ISOMET cutting

Fig. (2) Disc diameter checking before sintering

- The milled cylindrical samples were then cut into discs (12.25 mm diameter x 1.2 mm thickness) by a water-cooled saw (ISOMET 4000, Buehler, Lakebluff, USA).
- The disc was fabricated with larger dimensions than the desired final size to compensate for the shrinkage that occurs during the sintering process. A scale factor of 1.25 was applied to account for this shrinkage.
- Following the sintering process, the discs were reduced to their final dimensions, measuring 10 mm in diameter and 1 mm in thickness.

3- Sintering the discs:

After finishing of the milling process, the discs of each material were inserted in a sintering furnace (inLab Profire, dentsply Sirona Germany) according to manufacturer sintering parameters as following:

CERCON XTML

Traditional Speed Cycle: The discs were initially placed at room temperature, and the temperature was gradually increased until the sintering temperature of 1520°C was reached. This temperature was maintained for a holding time of 90 minutes. Afterward, the samples were cooled down to room temperature, resulting in a total cycle time of 270 minutes.

High-Speed Cycle: For the high-speed cycle, the discs were sintered at an elevated temperature of 1540°C, with a holding time of 15 minutes. The total cycle time for this process was significantly shorter, taking only 60 minutes.

Katana STML:

Traditional Speed Cycle: Similar to the previous material, the discs were placed at room temperature, and the temperature was gradually increased. However, the sintering temperature for Katana STML was set at 1550°C, and the holding time was longer, at 120 minutes. After cooling down to room temperature, the total cycle time was 7 hours.

High-Speed Cycle: In the high-speed cycle for Katana STML, the sintering temperature was further increased to 1560°C. The holding time at this temperature was 30 minutes, and the total cycle time was 90 minutes.

Following the sintering processes for both materials, the diameter and thickness of each disc were measured using a digital caliper. The final dimensions achieved were 10 mm in diameter and 1 mm in thickness, with a precise tolerance of ±0.02 mm. All samples were crystalized and glazed by using Programat EP3010 Ivoclar Vivadent furnace. Then they all got thermocycled to mimic oral temperature changes before testing procedure.

4-Testing procedure:

» **Translucency Test:**

The translucency of the discs was assessed by measuring the Translucency Parameter (TP). An Agilent Cary 5000 spectrophotometer was utilized to determine the L, a, and b values of each sample against both white and black backgrounds. These measured values were then inserted into the following equation to calculate the TP for each sample:

TP value = Equation 1

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

(W=white background, B=black background)

Where:

- L, a, and b represent the CIE color space values
- W denotes the values measured against a white background
- B denotes the values measured against a black background

The CIE L* value indicates the lightness of the object, the CIE a* value represents the redness or greenness, and the CIE b* value indicates the yellowness or blueness.

A higher TP value suggests higher translucency, while a lower TP value indicates lower translucency.

5-Statistical Analysis:

A two-way analysis of variance (ANOVA) test was employed to examine the influence of different sintering protocols on the mean Translucency Parameter (TP). Statistical significance was set at a p-value of less than 0.05, indicating that differences between groups were considered significant if the p-value fell below this threshold.

The statistical analysis was conducted using IBM® SPSS® software, specifically version 25. For the quantitative data obtained, the results were summarized using the mean value along with the associated standard deviation. This statistical representation was chosen because the data followed a normal distribution.

RESULTS

TABLE (1) Two-way ANOVA test for comparison of translucency between different materials, speeds, and interaction between both.

	F	P value
Material	784.4	<0.001*
Speed	32.4	<0.001*
Material * Speed	0.2	0.660

Two-Way ANOVA test

****: Significant level at P value < 0.05***

This two-way ANOVA reveals:

1. A highly significant main effect of material ($F = 784.4$, $p < 0.001$), indicating that the type of material significantly influences translucency.
2. A highly significant main effect of speed ($F=32.4$, $p<0.001$), suggesting that the speed of processing also significantly affects translucency.
3. No significant interaction effect between material and speed ($F = 0.2$, $p = 0.660$), implying that the effect of speed on translucency does not significantly differ between materials.

TABLE (2) Comparison of translucency between different materials at different speeds

Speed	Translucency	Katana N=5	Cercon N=5	P value
Traditional speed	*Range*	(9.7-10.1)	(12.5-13.2)	<0.001*
	Mean ± SD	9.9±0.2	12.8±0.3	
High speed	*Range*	(8.9-9.4)	(11.9-12.7)	<0.001*
	Mean ± SD	9.2±0.2	12.2±0.3	

Independent Samples T test

****: Significant level at P value < 0.05***

This table shows:

1. For traditional speed: A highly significant difference between Katana 9.9±0.2 and Cercon 12.8±0.3 (p<0.001), with Cercon showing higher translucency.
2. For high speed: Also a highly significant difference between Katana 9.2±0.2 and Cercon 12.2±0.3 (p<0.001), again with Cercon showing higher translucency.

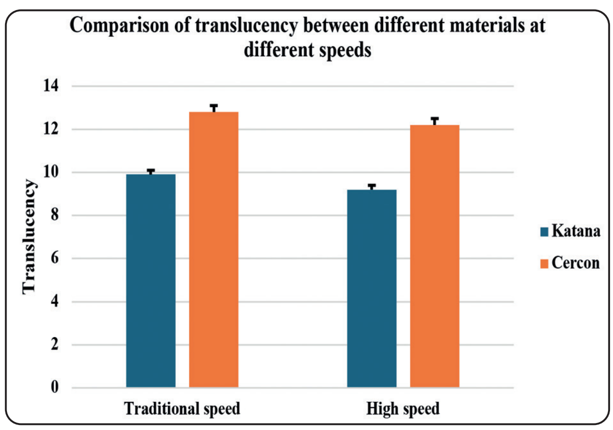

Fig. (3) Showing Comparison of translucency between different materials at different speedsv

TABLE (3) Comparison of translucency between different speeds at different materials

Material	Translucency	Traditional speed	High speed	P value
		N=5	N=5	
Katana	*Range*	(9.7-10.1)	(8.9-9.4)	0.001*
	Mean ± SD	9.9±0.2	9.2±0.2	
Cercon	*Range*	(12.5-13.2)	(11.9-12.7)	0.013*
	Mean ± SD	12.8±0.3	12.2±0.3	

Independent Samples T test

****: Significant level at P value < 0.05***

This table shows:

1. For Katana: A significant difference between speeds (p = 0.001), with traditional speed showing higher translucency 9.9±0.2 compared to high speed 9.2±0.2.
2. For Cercon: A significant difference between speeds (p=0.013), again with traditional speed showing higher translucency 12.8±0.3 compared to high speed 12.2±0.3.

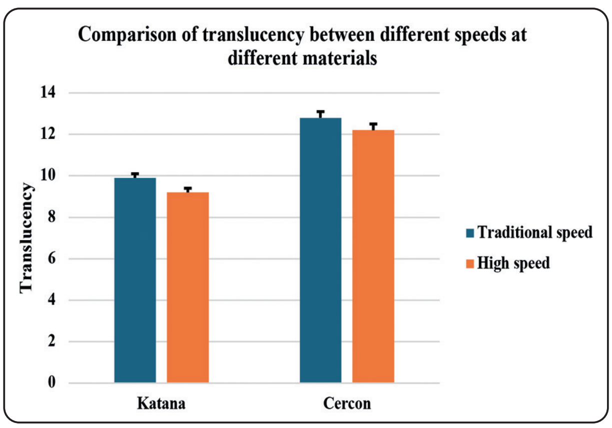

Fig. (3) Showing a comparison of translucency between different speeds at different materials

DISCUSSION

The goal of this research was to assess the influence of speed sintering on translucency of monolithic zirconia to provide a framework for these time and energy saving sintering protocols, in order to enable dentists nowadays to deliver chairside zirconia restorations.

Monolithic translucent zirconia has emerged as a promising dental material due to its advantageous optical and mechanical properties.(4)

The zirconia-based ceramics, Katana and Cercon, are greatly used in contemporary dental practice because of their favorable mechanical and optical properties and their biocompatibility. However, variations in these properties necessitate a detailed investigation to understand how these properties can be optimized through different processing techniques. **Ahmed W M, et al 2019; Liu H, et al 2023.**(5,6) have highlighted the importance of microstructural characteristics and sintering protocols in influencing these properties.

The samples of zirconia were divided into two main groups regarding the type of zirconia used, followed by further subdivision based on sintering speeds and testing parameters. This factorial design allows for a comprehensive assessment of the impact of different variables on the material properties. **El-Shrkawy et al. 2016; Galab et al. 2023** (7,8) have utilized similar grouping methodologies to ensure a detailed analysis of material performance under varied conditions.

The discs were designed using CAD software to ensure precision in dimensions. This step is critical for maintaining consistency and accuracy in the translucency test. CAD design allows for controlled and repeatable sample production, which is essential for valid comparative analysis. **(El-Damanhoury and Gaintantzopoulou 2018)** (9)

The milling process using a 5-axis milling machine ensures high precision in the fabrication of disc samples. Milling followed by sintering compensates for shrinkage and ensures the final dimensions are as required. Studies have shown that CAD/CAM milling is an effective method for producing dental restorations with high accuracy. **(Ahmed W M 2019)** [10]

Thermocycling is a process that mimics the thermal stresses that dental materials undergo in the oral environment, simulating the temperature changes that occur during routine activities like eating and drinking. This process is critical for evaluating the clinical durability of dental materials. According to ISO/TS 11405, thermocycling helps predict the clinical performance of materials over time **(Morresi et al. 2014)**[11]

Translucency was measured using a spectrophotometer, which provides objective and precise data on the optical properties of the materials. This regimen is widely followed in recent researches to assess the esthetic qualities of dental ceramics **(Sarıkaya, Yerliyurt, and Hayran 2018; Pop-Ciutrila et al. 2021).** [12,13]

The significant differences in translucency between Katana and Cercon align with findings from other studies that demonstrate the intrinsic optical properties of these materials. For example, a study by **Zhang et al. 2013**[14] observed that the microstructural differences in zirconia ceramics can significantly affect their translucency. Similarly, **Kurtulmus-Yilmaz and Ulusoy 2014**[15] reported higher translucency values for Cercon compared to other zirconia-based ceramics, supporting our findings.

The impact of processing speed on translucency, although not statistically significant, suggests that traditional speed processing might allow for better crystal formation and distribution within the ceramic matrix, leading to improved optical properties. This agrees with **Heffernan et al. 2002**[16] who found that slower sintering processes enhance translucency in zirconia ceramics.

The influence of sintering speed on the translucency of zirconia is intriguing. Shortening the sintering cycle leads to a decrease in translucency, while a longer sintering cycle yields higher Translucency Parameter (TP) values compared to a conventional cycle. This phenomenon can be attributed to the influence of sintering parameters on grain size. Specifically, extended holding times and longer sintering durations contribute to the growth of larger zirconia grain sizes.

Zirconia grain size is of utmost importance when it comes to determining the translucency of the material. The reduction in light scattering is attributed to larger grain sizes, which lead to a decrease in the number of grain boundaries within the material. As a consequence, light transmission through the zirconia increases, leading to enhanced translucency. This relationship between grain size and translucency has been supported by numerous studies[17, 18, 19, 20].

The findings related to the impact of sintering cycle duration on translucency align with the conclusions of several other studies[20, 1, 21, 22]. These studies emphasize the relationship between holding time and translucency, suggesting that prolonging the sintering process enhances the optical properties of monolithic zirconia restorations. Therefore, the careful control of sintering parameters is essential for achieving the desired optical characteristics in zirconia-based dental restorations.

Also, the results were aligned with **Cho M H and Seol H J, 2023** [23] who concluded that TP of Cercon xt ML zirconia was slightly lowered by high speed sintering.

Our findings regarding translucency stand in contrast to the results obtained by **Coskun ME & Sari F** in their 2019 study[24]. They observed higher translucency in samples subjected to a rapid sintering protocol. This discrepancy could be attributed to the use of multilayered monolithic zirconia in their research, where no significant difference in grain size was detected among the groups through SEM images.

Additionally, our results differ from the conclusions drawn by **Kim et al.** in 2013[25]. They suggested that shortening the sintering time could enhance the translucency of zirconia restorations. However, these contrasting findings may be due to variations in zirconia brands and specific sintering conditions utilized in our respective studies.

The clinical implications of these findings are substantial. For dental practitioners, selecting the appropriate material and processing method can significantly influence the success of the restoration. Cercon, with its superior translucency, is perfect for anterior prosthesis where aesthetic considerations are mandatory.

A balance between efficiency and quality should always be considered. This insight is valuable for dental laboratories aiming to optimize their workflow without compromising the quality of the final product.

CONCLUSION

1- High speed sintering cycle statistically significantly decreased translucency of both types of monolithic zirconia crowns, yet this decrease is not clinically significant.

2- Cercon showed higher translucency than that of Katana which made Cercon monolithic zirconia crowns more recommended for aesthetic zirconia restorations

3- Speed sintering cycle can be recommended for sintering of Cercon xt ML and Katana STML monolithic zirconia crowns.

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