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Effect of Simulated Intra-oral Adjustment on Contrast Ratio of Multi-layered Zirconia Restorations

Reham Ghanem[1*], Ahmed Adel[1] and Walid Abdelghafar Alzordok[1]
[1]*Department of Fixed Prosthodontics, Faculty of Dentistry, Mansoura University.*
**CorrespondingAuthor: RehamGhanem,*

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ABSTRACT

Background: Monolithic zirconia restorations are frequently used to minimize disadvantages such as opacity, risk of chipping, significant loss of tooth structure, and also due to esthetics, biocompatibility, and chemical stability compared to zirconia framework or traditional metal-ceramic. Intra-oral polishing seeks to produce excellent surface finish of restoration due of zirconia's uniform crystalline structure and superior polishability compared to glass ceramics and feldspathic porcelain.

Aim: This study was done to evaluate the effect of simulated intra-oral adjustment on the contrast ratio of multi-layered zirconia.

Methods: A total of 48 zirconia specimens were randomly classified into 6 groups according to the type of zirconia. The zirconia specimens were designed by special software developed by EXOCAD GmbH software with dimensions 10×10 mm and 1 mm thickness. All the specimens were abraded on one side with a diamond stone at low speed by a single operator which was performed to simulate an intraoral adjustment using low speed contra angle. All the specimens were subjected to finishing and polishing with well-defined sequence of a polishing system using straight hand peace.

Results: A statistical significant decrease in contrast ratio is detected after simulated intra-oral adjustment as compared to pre simulated intra-oral adjustment value within each of the studied zirconia materials.

Conclusion: Simulated intra-oral adjustment affect the contrast ratio of multi-layered zirconia also the different material brands can do.

Keywords:Monolithic multi-layer pre-colored zirconia ceramics, Multi-chromatic conventional zirconia.

I. INTRODUCTION

Monolithic zirconia restorations are frequently used to minimize disadvantages such as opacity, risk of chipping, significant loss of tooth structure, and also due to esthetics, biocompatibility, and chemical stability compared to zirconia framework or traditional metal-ceramic.[1] New grades of zirconia have been developed to make materials that are highly translucent but also resistant to fracture and chipping. Pre-sintered blocks are now available as preshaded materials in a variety of compositions or multilayered materials with Chroma gradients.[2]

The crystal structure of the generations of translucent dental zirconia was altered by adding more Yttria (Y_2O_3) and cubic phase, producing two polycrystalline materials: Partially stabilized zirconia with 5 mol% and 4 mol% Yttrium (5Y-TZP and 4Y-TZP).[3, 4] Recently, a new multi-layered translucent zirconia material, with a natural progression of shade and translucency, has emerged in the dental market to mimic natural teeth closely.[5] The strength and toughness of the layers with different yttria contents are expected to be different. During computer-aided design and computer-aided manufacturing (CAD/CAM) procedures, dental technicians can use different placing strategies to place the fixed dental prosthesis in multi-layered translucent zirconia blank before milling.[2, 6]

Intra-oral adjustment is usually carried out following the try in procedure, which necessitates intra-oral finishing/polishing since laboratory polishing and glazing are unfeasible. Intra-oral adjustment aims to achieve fine surface finish of restoration in order to prevent excessive antagonistic tooth wear, decrease residual defects that may cause crack propagation and ensuing biomechanical failure, reduce biofilm retention, discomfort, and coloration.[7]

Intra-oral polishing seeks to produce excellent surface finish of restoration due of zirconia's uniform crystalline structure and superior polishability compared to glass ceramics and feldspathic porcelain.[8] Contrast ratio has a significant impact on esthetics of dental restoration.[9] Monolithic multi-layer pre-colored zirconia ceramics are polychromatic and translucent and have multilayer shade and translucency gradients.[10-12] Zirconia ceramics have excellent optical characteristics; however, achieving optimal esthetic outcomes with zirconia-based restorations is still challenging due to multiple effective factors on the final color. These factors are different layers of a zirconia-based restoration and its underlying structures including: dental substrate, cement, zirconia coping, veneering ceramic, and glaze. Moreover, the laboratory procedure of these restorations' fabrication is another effective factor on the resultant color.[13]

Contrast ratio (CR) is the ratio of a material's light reflectance over a black backing to the same object's reflectance over a white backing.[14, 15]Calculating the ratio between the reflectance of each sample on the black plasticine background to that on the white plasticinebackgrund. The contrast ratio values are calculated according to the following equation

CR=Yb/Yw

The luminous reflectance of the specimens with a black (Yb) and a white background (Yw).[16]

AIM OF THE STUDY

This study was done to evaluate the effect of simulated intra-oral adjustment on the contrast ratio of multi-layered zirconia.

II. MATERIALS AND METHODS

Materials

Materials, product name, batch number, composition and manufacturer utilized in this study were presented in **Table 1**:

Table (1): Materials used in the current study.

Materials	Product name	Batch number	Composition	Manufacturer
Un-colored conventional zirconia	CeramillZolid ht+White	200700155	$ZrO_2 + HfO_2 + Y_2O_3$: ≥ 99.0 Y_2O_3: 6,7 - 7,2 HfO_2: ≤ 5 Al_2O_3: ≤ 0.5 Other oxides: ≤ 1	AmannGirrbac h AG Austria
Mono-chromatic conventional zirconia	CeramillZolid ht+ Preshade	2004001	$ZrO_2 + HfO_2 + Y_2O_3$: ≥ 99.0 Y_2O_3: 6,0 - 7,0 HfO_2: ≤ 5 Al_2O_3: ≤ 0.5 Other oxides: ≤ 1	AmannGirrbac h AG Austria
Multi-chromatic conventional zirconia1	CeramillZolidf x Multilayer	1909002	$ZrO_2 + HfO_2 + Y_2O_3$: ≥ 99.0 Y_2O_3: 8.5 – 9.5 HfO_2: ≤ 5 Al_2O_3: ≤ 0.5 Other oxides: ≤ 1	AmannGirrbac h AG Austria
Multi-chromatic conventional zirconia 2	VITA YZ XT Multicolor	XZM2129 004	ZrO_2: 86-91 Y_2O_3: 6-8 HfO_2: 1-3 Al_2O_3: 0-1 Pigments 0-1	VITA Zahnfabrik Germany
Multi-chromatic multi composition zirconia 1	IPS e.maxZirCAD Prime	Z03DZY	ZrO_2 : 88– 95.5 Y_2O_3: 4.5–7.0 HfO_2: ≤ 5.0 Al_2O_3: ≤ 1.0 Other oxides: ≤ 1.5	IvoclarVivade nt Liechtenstein
Multi-chromatic multi composition zirconia 2	KATANA YML Yttria Multi Layered	EIVIS	ZrO_2: 87-92%. Y_2O_3: 8_11 HfO_2: ≤ 5.0 Al_2O_3: ≤ 1.0 Other oxides: ≤ 1.5	Kuraray Noritake Japan

Methods

A total of 48 zirconia specimens were randomly classified into 6 groups according to the type of zirconia:

- Group 1 (n=8): Un-colored conventional zirconia (CeramillZolidht+White).
- Group 2 (n=8): Mono-chromatic conventional zirconia (CeramillZolidht+ Preshade)

- Group 3 (n= 8): Multi-chromatic conventional zirconia (CeramillZolidfx Multilayer)
- Group 4 (n= 8): Multi-chromatic conventional zirconia (VITA YZ XT Multicolor)
- Group 5 (n= 8): Multi-chromatic, multi composition zirconia (IPS e.maxZirCAD Prime)
- Group 6 (n=8): Multi-chromatic multi composition zirconia (KATANA YML Yttria Multi Layered)

Preparation of the Specimens

Zirconia specimens fabrication: The zirconia specimens were designed with dimensions 10×10mm in dimensions and 1 mm thickness [17]. With the aid of EXOCAD designing software were able to check the accuracy of the specimen dimension before milling and apply effects to highly smooth the surface and round the edges of the model. The blanks were secured to the CAD/CAM milling machine using the blank holder, with the option of dry milling.

Sintering Procedure

Sintering of zirconium oxide was one of the most important process steps in the fabrication of dental restorations. The porous white body condenses under the influence of high temperatures and the blank achieves its final mechanical (strength) and optical (translucency) properties. Too low or too high sintering temperatures and/or too short or too long sintering times negatively affect the above properties. Sintering of the milled specimens of zirconia was performed afterwards using high temperature furnace (TABEO mihmvogt, Germany)) based on the manufacturer's instructions for each brand.

Glazing and finishing of specimens

All specimens were glazed, glaze layer evenly distributed on the surfaces using normal glaze brush with favorable diameter. The glazed specimen were inserted into ceramic furnace using porcelain furnace according to the firing program recommended by the manufacturer for each brand.

Contrast ratio measurement

The first contrast ratio measurement was done after the glaze firing (before simulated intra-oral adjustment) using a spectrophotometer**.**

The contrast ratio (CR) was measuredunder the light source of CIE illuminant D65 with color temperature of 6,504 K. The measurement was performed three times in flashing mode for 0.1 s with an interval of 3 s. Subsequently, the software calculated the mean values, where contrast ratios were measured from the luminous reflectance (Y) of the specimens with a black (Yb) and a white background (Yw). In all calculations, "0" value was considered as transparent and "1" as opaque. The contrast ratio values are calculated according to the following equation

CR=Yb/Yw

The luminous reflectance of the specimens with a black (Yb) and a white background (Yw).

Reflectance Measurements

Because the sample was smaller in size than what the instrument was designed to measure, a black disk with a small aperture was attached and centered to the front port of the sphere. It was ideal to use an aperture area of 8 mm diameter to minimize the front port aperture and under fill the sample area.

Simulated Intra Oral Adjustment

All the specimens were abraded on one side with a green diamond stone at low speed by a single operator which was performed to simulate an intraoral adjustment using low speed contra angle. A single operator performed the grinding and polishing steps manually, to better simulate clinical procedures. During grinding, the operator applied uniform pressure (finger pressure) and uniform application time to standardize the procedure. The direction of grinding was fixed from left to right.

Finishing and polishing procedures

All the specimens were subjected to finishing and polishing with well-defined sequence of a polishing system using straight hand peace. The polishing procedure was carried out by a sequential use of pre polishing and high shine polishing using EVE DIACERA for zirconium oxide. Eve (RA 105 Diamond, Eve, Ernst Vetter, GmbH, Germany).

Second contrast ratio measurements

The second contrast ratio was performed of all specimens after the simulated intra oral adjustment was done. The previous same procedure and under the same condition as previously mentioned for the initial measurements were repeated and the contrast ratio was calculated as previously.

III. RESULTS

Contrast ratio

One-way ANOVA test **(Table 2)** demonstrates a statistical significant difference between studied zirconia materials as regard

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contrast ratio before and after simulated intra-oral adjustment.

The lowest mean contrast ratio before simulated intra-oral adjustment is detected among Vita YZ XT followed by Zolidht White, Zolidht Pre-Shaded, Zolidfx Multi-layer, ZirCAD Prime and Katana YML (0.712 ±0.002, 0.717±0.002, 0.741 ±0.002, 0.789 ±0.003, 0.789 ±0.003 and 0.819±0.002, respectively). Post Hoc Tukey test illustrates non statistically significant difference between ZirCAD Prime and Zolidfx Multi-layer.

The lowest mean contrast ratio after simulated intra-oral adjustment is detected among Vita YZ XT followed by Zolidht White, Zolidht Pre-Shaded, Zolidfx Multi-layer, ZirCAD Prime and Katana YML (0.722 ±0.002, 0.731 ±0.002, 0.749 ±0.001, 0.797 ±0.003, 0.801 ±0.003 and 0.823 ±0.003, respectively). Post Hoc Tukey test illustrates statistically significant difference between all studied zirconia pairs.

Table (2): Comparison of contrast ratio between different zirconia materials

	Zolidht White	Zolidht Pre-Shaded	Zolidfx Multi-layer	Vita YZ XT	ZirCAD Prime	Katana YML	test of significance
Before	0.72 ±0.002	0.74 ±0.002	0.79 ±0.003^{A}	0.71 ±0.002	0.79 ±0.002^{A}	0.82± 0.002	F=2594.91 P<.001
After	0.73 ±0.002	0.75 ±0.001	0.80 ±0.003	0.72 ±0.002	0.80 ±0.003	0.82± 0.003	F=2600.06 P<.001

F: One Way ANOVA test, *statistically significant, parameters described as mean±SD, similar superscripted letters denote non-significant difference between groups by Post Hoc Tukey test

IV. DISCUSSION

The results of the present study support rejection of the null hypothesis because the contrast ratio parameter of monolithic multi-layered zirconia was affected by simulated intra-oral adjustment.

A spectrophotometer is a valuable device for color measurements in dentistry. It is helpful for the color analysis of different restorations and verification of their shade.[18]Considering the benefits of this device, it was decided in our study to use a spectrophotometer to detect color changes in different zirconia samples before and after simulated intra-oral adjustment.

In the present study six groups of four different compositions have used to compare the effect of simulated intra-oral adjustment on contrast ratio which are uncolored conventional zirconia CermaillZolidht+ White with 6.7 to7.2 % ytrria content and zirconia cotent more than 99%, mono-chromatic conventional zirconia CeramillZolidht+ Pre shade with 6 to7 % ytrria content and zirconia content more than 99%, multi-chromatic conventional zirconia CeramillZolidfx Multilayer with 8.5 to 9.5 % ytrria content and zirconia content more than 99%, multi-chromatic conventional zirconia another brand VITA YZ XT Multilayer with 6 to 8 % ytrria content and zirconia content 86-91%, multi-chromatic multi composition zirconia IPS e.maxZirCad Prime with 4.5 to 7 % ytrria content and zirconia content 88-95.5% and multi-chromatic multi composition zirconia another brand KATANA YML ytrria Multi-layered with 8 to 11 % ytrria content and zirconia content 87-92% .[19, 20]

Yttrium oxide-containing zirconia has high strength, but the translucency decreases with the increase in sintering temperature after 1400°C due to the segregation of yttrium oxide to zirconia grain boundaries and sintering.[21-23]Occlusal adjustment, which can obviously increase the roughness of the restoration surface, is an unavoidable operation in clinical dentistry. Different grinding tools, pressure, temperature, and time have important effects on grinding and polishing.[24]

Polishing is a process that high or low-speed rotating tools rub the ceramic surface under a certain pressure.[24] Specifically, the cutting action of sharp abrasive particles on the tool surface is utilized to remove surface bulges and shallow materials, thereby smoothing ceramic surface.[25] Most of polishing experiments have shown that appropriate polishing can achieve clinically acceptable roughness on the surface of restorations and achieve the surface that is similar to or even smoother than glazing.[26, 27]

A statistical significant decrease in contrast ratio is detected after simulated intra-oral adjustment as compared to pre simulated intra-oral adjustment value within each of the studied zirconia materials with lowest contrast ratio is for Zolidht White changed from 0.72 ±0.002 to 0.73 ±0.002. In this study contrast ratio is still between 0-1 which is within clinically acceptable range.[16] This may be as a result of many zirconiamanufacturers tend to increase the final

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sintering temperature with the expectation of decreased contrast ratio. According to a previous study, the fact has to be considered that the flexural strength and stability of zirconia decrease when it was sintered above the temperature of 1450°C,[28] or grain size this is in agreement with **Stawarczyk et al (2014)**[29] who conducted the significant correlation between contrast ratio and grain size

V. LIMITATIONS

The methodology-associated limitations of the included studies are important to recognize. Among the limitations of the present study, one major limitation is in vitro design. Restorations can act differently in the oral cavity due to the presence of saliva. Furthermore, tooth brushing might change the color stability of restorations in vivo.

Most of the studies used zirconia from a single shade A2. An amalgamation varying shades and types of monolithic zirconia from multiple manufacturers is recommended since materials from different manufacturers may behave differently. Hence, it is recommended to use zirconia from multiple manufacturers with multiple shades in future experiments. Further research should be performed to simulate aging in presence of water or vapor with temperature over an extended period in the presence of different conditions, such as colored drinks, cigarettes, saliva, and different enzymes for a better reflection of clinical life of the prosthesis.

VI. CONCLUSION

Althoug the simulated intra-oral adjustment affect the contrast ratio of studied multi-layered zirconia, they were within the clinically accepted range.

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