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EFFECT OF CORROSION ON COLOR CHANGE AND FLEXURAL STRENGTH OF TWO RECENT HIGH TRANSLUCENT ZIRCONIA CERAMICS

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ABSTRACT

The purpose of this research was to evaluate the effect of corrosion on flexural strength and color characteristics of the two translucent zirconia materials in comparison to a monochromatic zirconia and Lithium disilicate Glass Ceramic.

Materials and Methods: In this investigation, 100 disc-shaped specimens were fabricated. The samples were split into four major groups based on the kind of ceramic material (n = 10) for monochromatic ceramics (BruxZir (Z) group and IPS e.max CAD HT (E) group, and (n = 40) for multi-layered ceramics (Kathana STML (S) group and Katana UTML (U) group). According to the number of layers in multi-layered ceramic materials, Katana STML (S) groups and Katana UTML (U) groups were separated into four subgroups (n = 10). Each subgroup was subsequently separated into two groups (n = 5) based on the degree of corrosion, with the first class receiving corrosion treatment and the second class serving as a control group that did not receive corrosion treatment. After a spectrophotometer was used to determine the color of each class's specimens, the same specimens underwent a bi-axial flexural strength test (Piston on three balls). Data were collected and tabulated for statistical analysis using Oneway ANOVA followed by Tukey HSD post hoc test for testing significance between groups.

Results: For all materials of the highest value assessed for the Katana STML and Katana UTML, corrosion resulted in a considerable weight loss. Compared to other materials, corrosion changed the hue of Katana STML and Katana UTML in a clinically undesirable way. The biaxial flexural strength of BruxZir samples significantly increased due to corrosion, although other materials were unaffected.

Conclusion: Compared to other studied ceramics, Katana STML and Katana UTML both had significant weight loss and color change. Both Katana STML and Katana UTML ranked between BruxZir and IPS e.max CAD in terms of flexural strength. Only BruxZir specimens were corroded.

KEYWORDS: Corrosion, Flexural Strength, Color , Translucent Zirconia

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INTRODUCTION

With the advancement of CAD/CAM (computer-aided design and manufacturing) technology in recent years, the process for producing dental restorations, particularly zirconia restorations, has demonstrated development toward digitization and automation. In terms of end quality, as well as in terms of cost and time savings, digital dental workflow offers a clear benefit. In the dental office, "same-day denture" has emerged as a new catchphrase with the intention of reducing the time required for restoration production. Due to its biocompatibility, excellent mechanical qualities, and premium esthetics, dental zirconia ceramics have quickly evolved and currently dominate the market. [1]

Metals were traditionally linked to corrosion, however materials made of ceramic can also degrade unintentionally when exposed to the environment. The effects of corrosion on society today and the deterioration of materials caused by corrosion have increased the complexity and diversity of material systems, including ceramics. Ceramics are not subject to electrochemical deterioration because of their poor conductivity, but rather because the material simply dissolves. [2]

The therapeutic effectiveness of "dental materials" over the long term may be correlated with biaxial flexural strength. Due to the fact that dental materials often experience multiaxial loads throughout their lifetime in the oral cavity, multiaxial flexural strength offers more relevant information than uniaxial flexural strength. However, unevenly distributed faults cause the maximum force that a specimen can sustain before fracture to vary, even under uniform test settings. [3]

Due to the complexity of teeth's multilayered structure and the fact that they are polychromatic, color is a key determining element in patient approval. Correct shade matching is influenced by several aspects, which every clinician should take into account when choosing a shade. All ceramics are prone to breaking while being loaded by the occlusal forces. As ceramics have less tensile strength than their endurance against compression, measuring flexural strength is a crucial factor in determining the strength of all ceramic materials. [4-5]

Due to its biocompatibility, corrosion resistance, and superior mechanical qualities, zirconia is the most lasting ceramic material used in restorative dentistry. [6]

Presenting a newer generation of 3Y-TZPs that could introduce more translucent monolithic restorations that could be suitable for posterior restorations in non-esthetic zones but still insufficiently reliable to show exceptional esthetics in anterior zones, in order to improve the translucency of monolithic zirconia porosity was eliminated and alumina concentration was reduced. [7-11]

At room temperature, zirconia is monoclinic; at 1170 degrees Celsius, it is tetragonal; and at 2370 degrees Celsius, it is cubic. Due to its increased yttria concentration (4 moles%), which increases the cubic phase by roughly 25%, increases particle size, and decreases porosity, 4Y-TZP exhibits greater light transmission. Although more translucent than 3Y-TZP, cubic phase displays lower flexural strength and fracture toughness, as cubic phase doesn't undergo transformation toughening, which prevents crack propagation by absorbing energy originating the crack, is not present in cubic phase. [12]

In comparison to 4Y-TZP, 5Y-TZP has a higher cubic phase percentage at around 50%. Both 5Y-TZP and 4Y-TZP are positioned at an intermediate location between ordinary zirconia and lithium disilicate, indicating their application in anterior crowns. 5Y-TZP has higher light transmission but is weaker than 4Y-TZP.

The null hypothesis of the study suggests that there will be no difference in color parameters and flexural strength between all tested ceramics.

MATERIALS AND METHODS

The items were utilized for: BruxZir Full Strength Shaded Zirconia, a monochromatic zirconia from Glidewell Laboratories in the United States, is a 3Y-TZP zirconia.

Lithium disilicate Glass Ceramic: IPS e.max CAD (Ivoclar Vivadent, Schaan, Liechtenstein, Germany), 4Y-PSZ Zirconia: Katana STML zirconia, a multi-layered zirconia (Kuraray Noritake Dental Inc., Aichi, Japan), 5Y-PSZ Zirconia: Katana UTML zirconia, a multi-layered zirconia Blocks with a high degree of translucency are made by Kuraray Noritake Dental Inc., Aichi, Japan

A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there is no difference between tested groups. The number of samples per subgroup was determined according to a power calculation based on previously attained data in an earlier study.[17]

In this investigation, 100 disc specimens with dimensions of 12 mm in diameter and 1.2 mm in thickness were fabricated. According to the kind of ceramic material, specimens were classified into four primary groups: n = 10 for monochromatic ceramics, BruxZir Full Strength Shaded group, IPS e.max CAD HT group, and n = 40 for multi-layered ceramics, Katana STML group and Katana UTML group.

According to the number of levels in the multi-layered ceramic materials (n = 10), four subgroups were created, one for each monochromatic ceramic material.

Each subgroup was subsequently separated into two classes (n = 5) based on the corrosion treatment with the first-class receiving corrosion treatment and the second class served as a control group that did not receive corrosion treatment. Following spectrophotometer color measurements for each class, the same specimens were put through a bi-axial flexural strength test (piston on three balls). Figure (1)

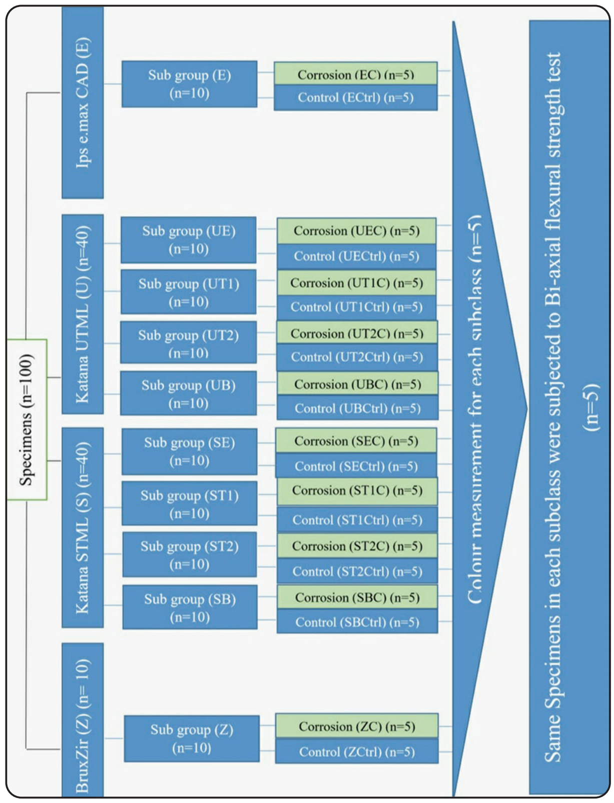

Fig. (1) Factorial design

In order to achieve all layers of multi-layered zirconia within each cylinder, a cylinder was first built using digital software with the intention that it would be vertically aligned within zirconia pucks and IPS e.max CAD HT blocks. According to design imported data, cylinders were milled in a milling machine (Roland-DWX510-Japan) for zirconia and IN LAB MCXL (Sirona Co; New York, USA) for IPS e.max CAD HT blocks.

One hundred discs were produced from their corresponding pre-sintered cylinders using a low-speed diamond saw rotating at 2500 rpm while being cooled by a "Isomet 4000 precision cut, Buehler, USA" cooling system.

As per the manufacturer's recommendations, discs were made from the whole height of each monochromatic cylinder and from each layer of multi-layered cylinders with a 20–25% larger thickness to account for zirconia's sintering shrinkage.

Zirconia discs were sintered inside sintering furnace (TABEO-1/5/ZIRKON-1000-Germany) following the sintering schedule according to manufacturer instructions, while IPS e.max CAD specimens were crystallized inside crystallization furnace "Programat P310 ceramic furnace " (Ivoclar Vivadent, AG, Schaan/Liechtenstein). Under cooling water, specimens were completed using a rotary finishing kit (Eve-Diasynt plus and Diacera zirkonoxid zirconia Germany). For 5 minutes, an ultrasonic cleaner (Codyson Digital Ultrasonic CD-4820) was used to clean all specimens and eliminate any remaining material. The samples were prepared for testing (Figure 2).

Fig. (2) Disc specimens

Corrosion test

According to ISO 6872 Standards for hydrolytic resistance of dental ceramic materials [13], specimens were weighed by Electronic Sensitive Balance (Bioevopeak Co.,Ltd, Shandong ,China) and then placed in test tubes with the same amount of 4% acetic acid solution. The corrosive solution was heated slowly to avoid micro cracking till reaching storage temperature of 80˚C ± 2˚C where kept fixed for 16 hours. At the end of the test, samples were allowed to gradually cool to room temperature before being removed, cleaned with distilled water, then dipped in ethyl alcohol, dried, and weighed. The amount of weight lost in proportion to each specimen's surface area was determined.

Color parameters measurement

Vita simple shade (Vita Zahnfabrik, Bad Säckingen, Germany) was used to assess various color characteristics (CIEL*a*b*) on a gray backdrop for all specimens (exposed and not subjected to corrosion). This gadget is capable of shade matching to the most recent Vita Classic 3D Master Shade Guide regardless of lighting conditions. Device was initially calibrated against a calibration block until a triple peep sound and a green light flashing in the center of the base indicated that calibration had concluded. Measurements were based on reflected wavelength estimates in three color parameters L*, a*, and b*, where: Each specimen was scanned in accordance with manufacturer instructions. Results were approved after two consecutive readings that were similar.

a* represents redness by plus reading, gray by zero and greenness by minus.

b* represents the yellowness by plus reading, gray by zero and blueness by minus.

L* represents the lightness, where 100 is white and 0 is black.

After color measurement for all specimens.

Bi-axial Flexural Strength Test

As a final test, all specimens (corrosion and control specimens) were put through a piston on three ball bi-axial flexural strength test in accordance with DIN EN ISO 6872:2019[14] . Specimens were mounted centrally on three balls (=3.2mm) mounted equally apart on a support circle (=10mm), and the base of the copper plate form was fixed to the lower part of the universal testing machine (INSTRON, model 3345 Universal testing machine)[31] (Figure 3).

Statistical Analysis

For statistical analysis, data were gathered and tabulated using IBM-SPSS® Statistics Version 25 software. Shapiro-Wilk test was used to assess the distribution's normality. For parametric data, descriptive statistics using the mean and standard deviation were used. One-way ANOVA was used in the statistical analysis to compare parametric data with solubility, color, and flexural strength as dependent factors and corrosion as an independent variable. The Tukey HSD post hoc test was then used to determine if there was a difference between the two groups. A 0.05 P value was used.

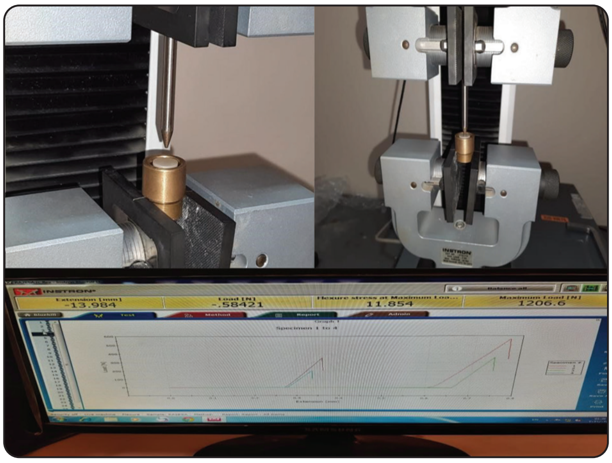

Fig. (3) Specimen placed centrally on three balls and loaded with piston till fracture.

RESULTS

TABLE (1) Description of the codes in Statistical diagram:

Code	Description
Z	BruxZir full strength specimens.
E	Ips e.max CAD specimens.
SE	Katana STML specimens fabricated from Enamel layer.
ST1	Katana STML specimens fabricated from Transition layer 1.
ST2	Katana STML specimens fabricated from Transition layer 2.
SB	Katana STML specimens fabricated from Body layer.
UE	Katana UTML specimens fabricated from Enamel layer.
UT1	Katana UTML specimens fabricated from Transition layer 1.
UT2	Katana UTML specimens fabricated from Transition layer 2.
UB	Katana UTML specimens fabricated from Body layer.

Corrosion Results (weight loss)

Regarding weight loss, Katana UTML subgroups showed the greatest weight loss compared to other tested materials except with Katana STML body layer (SB). The relation between all subgroups was statistically significant P value (<0.05) except between Katana UTML transition 1 layer (UT1) and Katana UTM L transition 2-layer (UT2) P value (0.335) (Figure 4).

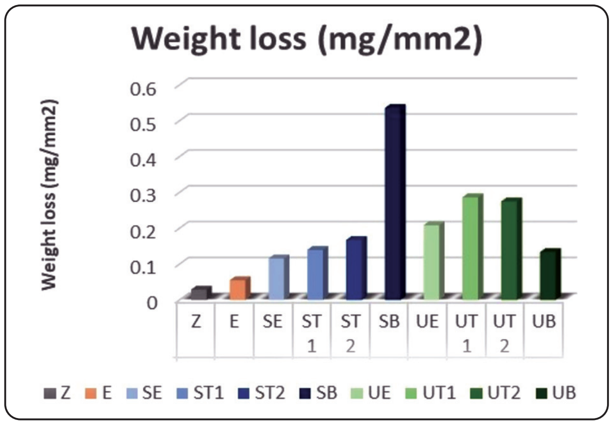

Fig. (4) Comparison of weight loss of all subgroups

Color measurements

Both Katana STML and Katana UTML experienced clinically unacceptable color change after corrosion ($\Delta E>3.7$) except with Katana STML body layer (SB). Katana UTML subgroups experienced the greatest color change compared to other tested materials except with Katana STML transition 1 layer (ST1). Both BruxZir and IPS e.max CAD HT experienced clinically acceptable color change ($\Delta E < 3.7$) (Figure 5).

Bi-axial flexural strength

Bi-axial flexural strength of all tested materials followed the following order: BruxZir > Katana STML > Katana UTML > IPS e.max CAD with no significant difference between layers of both multi-layered zirconia materials. Corrosion resulted in significant increase of bi-axial flexural strength for BruxZir specimens, however caused no change for all other subgroups (Figure 6).

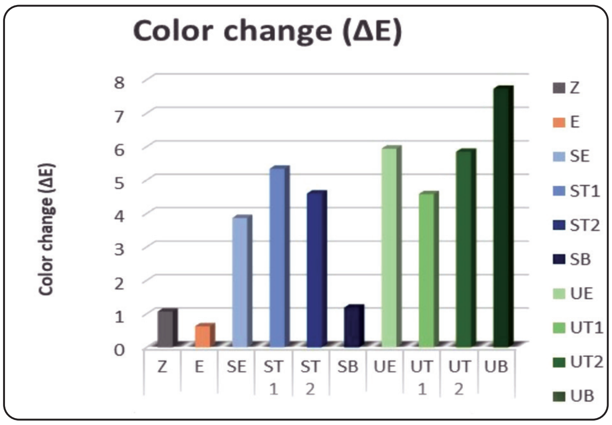

Fig. (5) Comparison of the color change (ΔE) of all subgroups

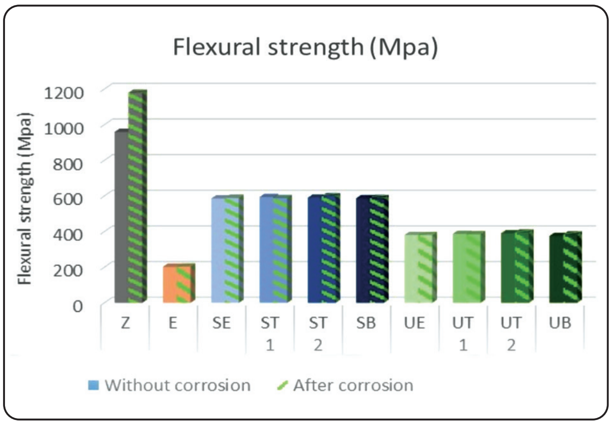

Fig. (6) Comparison of Bi-axial flexural strength of all subgroups without and after corrosion

DISCUSSION

Rapid-sintered 5Y-PSZ ceramics have been created to suit the demands of dentists, technicians, and patients for the aesthetic and quick fabrication of zirconia restorations. Over 3Y-TZP, 5Y-PSZ materials have benefits in both mechanical and aesthetic aspects. Metal-ceramic and glass-ceramic restorations can be directly replaced with very transparent monolithic zirconia restorations without a veneer, especially when the occlusal space is inadequate. [1]

In this study, corrosion's effects on two transparent zirconia materials' flexural strength and color characteristics are evaluated in comparison to monochromatic zirconia and lithium disilicate glass ceramic. The theory for the color shift was accepted in light of the findings of the present investigation. The null hypothesis could only be partially rejected since there was a considerable variation in flexural strength across material types. With gray serving as a neutral backdrop that negates the impact of background shade on specimen color, color parameters were measured using the CIELAB color coordinate system. [18]

In contrast to uni-axial 3-point or 4-point tests, the bi-axial flexural strength method (Piston on Three Ball) offered more accurate findings and had a less impact on specimen preparation. [14]

With tensile stresses created in the core loading region, bi-axial loading was more comparable to the multi-axial stresses that a restorative material was subjected to; fractures were not of a specific direction, and the unfavourable impact of edge failure was avoided. [19]

The higher yttria concentration in these materials, where Katana UTML had 5.4mol% yttria and Katana STML had 4.8mol% yttria, may be the cause of the greater solubility of the Katana STML and Katana UTML subgroups compared to BruxZir. [20,21]

As 4% acetic acid at 80 °C led to yttria ion depletion[22] and decreased Y2O3, ZrO2, and HfO2 concentration for Katana STML after 16 hours of immersion. [23] The greater grain size of these materials, which improved acid transport and diffusion-related change, may have also contributed to their solubility.[24]These may account for the Katana UTML subgroups' increased solubility when compared to the subgroups (SE, ST1 and ST2).

It is possible that the higher grain sizes of the materials 'n the Katana STML and Katana UTML subgroups, which resulted in greater acidic diffusion in these materials[21], are to blame for the increased color change.[24] Another element that may have contributed to their vulnerability to acidic corrosion was the presence of oxides in their chemical composition. [8] Increased acidic diffusion may have caused greater color pigment degradation due to the heat effect of the corrosive medium[25] and alkali ion leaking out through chemical reactions[8]. This might explain how exposure to an uncolored acidic corrosive substance could cause considerable color changes in monolithic zirconia and lithium disilicate, which could be viewed as a different influencing factor from the extrinsic color addition of drinks that stain food and clothing. Therefore, the color shift for these materials may have been enhanced by an inherent influence on pigments.[26]

Variable pigment contents, such as those found in iron and titanium oxides, may have contributed to the variable corrosion patterns and aging resistance documented for various material layers.[21]

Some variables, such as a high sintering temperature and a greater stabilizer content, may be the cause of the increased cubic phase and bigger grain size in both materials, which may explain why Katana UTML and Katana STML are less strong than BruxZir.[27] With no transformation toughening effect to prevent fracture propagation, the increased yttria concentration in these materials may have increased the non-birefringent cubic phase at the expense of the tetragonal phase, causing a drop in strength.[28] When transmitting stimuli from one grain to the next, larger grains were primarily responsible for a more prolonged limit for dislocations on the grain borders, which resulted in a relative reduction in the amount of stress needed to cause plastic deformation or fracture in brittle materials.[29]

In terms of flexural strength, there were no appreciable differences between the various Katana STML and Katana UTML layers. This might be explained by the fact that layers had the same yttria content and phase composition as one another[30], and that variations in layers only occurred in the pigment oxides.[21]

The relatively brief period of acid immersion in this study, which may have restricted the transformation to the specimen surface and generated compressive stresses that could have prevented crack propagation, may have outweighed the phase transformation's detrimental effect (strength degradation effect), increasing the flexural strength of corroded BruxZir.

Corrosion had no effect on the flexural strength of Katana STML or Katana UTML in this testing. The decreased quantity of tetragonal phase and higher composition of the cubic phase may be the cause of this. While Katana STML, which resisted spontaneous phase transition in a humid environment even after 12 hours in the autoclave at 134°C and monoclinic volume fraction 1% after 100 hours in the autoclave, had a cubic content of around 70 weight percent, Katana UTML had a cubic content of approximately 75 weight percent.[21]

Among the limitations of this study is being in vitro, laboratory results are therefore should be circulated with caution and randomized clinical trials along with laboratory results are still recommended for long-term evaluation of the different properties of these substances.

CONCLUSION

1. Both translucent multi-layered zirconia specimens lost the most weight due to corrosion, which was followed by lithium-disilicate and 3Y-TZP zirconia specimens.

2. Corrosion resulted in significant color change (ΔE) for all tested materials which was clinically acceptable (ΔE<3.7) for lithium disilicate and 3Y-TZP. Corrosion resulted in clinically unacceptable color change (ΔE>3.7) for both 4Y-PSZ and 5Y-PSZ with different color change (ΔE) values for different material layers.

3. Among the studied ceramic materials, lithium disilicate had the lowest bi-axial flexural strength;while 3Y-TZP had the highest values. Both the 4Y-PSZ and 5Y-PSZ specimens' bi-axial flexural strength values fell between those of lithium disilicate and 3Y-TZP.

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