Effect of Different Implant Abutment Materials on Optical Properties of Translucent Monolithic Zirconia Crowns

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EFFECT OF DIFFERENT IMPLANT ABUTMENT MATERIALS ON OPTICAL PROPERTIES OF TRANSLUCENT MONOLITHIC ZIRCONIA CROWNS

By

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Marquette University,
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ABSTRACT
EFFECT OF DIFFERENT IMPLANT ABUTMENT MATERIALS ON OPTICAL PROPERTIES OF TRANSLUCENT MONOLITHIC ZIRCONIA CROWNS

Nisha Patel BDS,MDS

Marquette University, 2019

Purpose: The purpose of this study was to evaluate the effect of implant abutment color on the final shade of monolithic translucent zirconia crowns. The null hypothesis was that abutment color or brand of zirconia would have no effect on color of monolithic translucent zirconia crowns.

Material and methods: A maxillary right central incisor implant (Nobel Replace Trilobe RP) in a dentoform model was used to mill customized abutments of titanium, gold-anodized titanium, pink-anodized titanium, and zirconium dioxide. An A2 dentin shade polymethyl methacrylate abutment was used as a control. Four types of zirconia systems (BruxZir Anterior; Glidewell Laboratories, LAVA Plus High translucency zirconia; 3M ESPE, e.max ZirCAD MT; Ivoclar, Katana Zirconia HT; Kuraray Noritake) of Y-TZP were used to make 80, monolithic CAD-CAM crowns in shade A2 with 1mm thickness (20 per group). The color measurements were made using opaque try in paste as the cementing medium. The measurements were made at the mid-facial position with a spectrophotometer using a custom positioning index for reproducibility. Color differences (ΔE^*ab) between the test and control specimens were calculated. The data were analyzed with two-way analysis of variance (ANOVA) and compared with the Tukey post hoc test ($\alpha = 0.05$).

Results: According to the 2-way ANOVA results, the type of abutment material, zirconia system, and interaction of these variables significantly influenced the ΔE values. Clinically unacceptable measurements ($\Delta E > 4.0$) were observed for all translucent zirconia systems against metallic abutments except for the Katana HT group. For the zirconia systems investigated, use of titanium or gold hued titanium did not register significant color differences.

Conclusion: Color differences for all zirconia systems were below clinically perceptible levels ($\Delta E < 2.5$) when placed on zirconia abutments. The highest color change was observed for the pink hue titanium abutment group.

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Nisha Patel, BDS, MDS

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TABLE OF CONTENTS

CHAPTER

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Esthetic dental restorations need to match the size, shape, shade, texture and translucency of the natural teeth they are replacing. Although porcelain fused to ceramic restorations have a long history of clinical success, they have metal substructures which may lead to non-optimal esthetic outcomes. Ceramic restorations may be designed with translucent cores with optical properties matching natural dentitions (1). Increasing esthetic demands have led to widespread use of all-ceramic restorations. Dental ceramics like feldspathic porcelain and glass ceramic provide acceptable esthetic results against a non-discolored abutment due to their light transmission. However, brittle nature of ceramics can cause fatigue failure after cyclic loading (2).

Zirconia has been introduced to dentistry as an alternative material due to its excellent mechanical properties. Zirconia exhibits a tetragonal-to-monoclinic phase transformation on cooling, which is accompanied by a 3% to 5% increase in volume. While this imposes residual compressive stresses and consequent transformation toughening, it also results in microcracking and compromised mechanical properties (3). Yttria stabilized tetragonal zirconia polycrystals (Y-TZP) is one of the toughest ceramic materials with a flexural strength of 1200 MPa. However, polycrystalline structure leads to higher opacity (4). Traditionally, it has been used as a high strength core material, layered with feldspathic porcelain for improved esthetics. However, fracture of layered zirconia restorations is reported to be a common clinical complication (5). Monolithic zirconia restorations have been proposed as a solution to this problem.

To enhance the translucency of zirconia restorations, residual pores and impurities must be reduced. Pores and impurities create volumes with differing refractive indices and lead to optical scattering on the surface and loss of translucency. Alumina, which may be added to zirconia improves the mechanical properties and prevents low temperature degradation (LTD), is the most common impurity. Increased translucency is obtained by decreasing alumina or by reducing grain size. While fully stabilized zirconia (cubic) has been developed for use in the esthetic zone, this polymorph does not exhibit transformation toughening and so does not exhibit the superior mechanical properties of partially stabilized zirconia (tetragonal + cubic) (6).

Newer translucent zirconia restorations have been used to fabricate full crowns without veneering porcelain. The increased translucency improves the esthetic properties of the restoration; however, the color masking ability of the restoration is decreased (7). This could lead to esthetic concerns when full contoured zirconia restorations are used with metallic abutments on implants. The optical properties of such crowns may be affected by the underlying abutment, thickness of zirconia and the thickness and color of the luting agent (8,9,10).

The masking ability of zirconia restorations can be evaluated by using a spectrophotometer. The Commission Internationale de l'Eclairage (CIE) recommended calculating color differences (ΔE) based on CIELab color parameters. The ΔE values are used to describe whether the changes in the overall shades are perceivable to the human observer. Various studies have identified acceptable ΔE values of 2.25, 2.6, 3.3 and 3.7 (11,12,13). However, Douglas et al observed mean acceptability tolerance of 4.0 by dentist observers in a clinical experiment. They reported the mean acceptability tolerance was 5.6 ΔE units for 50% of observers, and 4.0 ΔE units for 95% of observers (14). ΔE 1.6 represented the color difference that could not be detected by the human eye (15).

Anterior implants have been restored with titanium, gold anodized titanium, pink anodized titanium, gold palladium or zirconia abutments. Capa et al (16) evaluated effects of different zirconia core shades and luting cements on final color of restorations with titanium abutments and reported that ΔE for every zirconia shade with a titanium base exceeded the clinically acceptable level for ΔE (3.7). It was reported that color change was greater when using resin cement compared with polycarboxylate cement. Malkondu et al, (17) observed the least color change for the zirconia-resin modified glass ionomer combination. They also found unacceptable color changes with resin cement at 0.6 mm thickness. In a recent study by Dede et al, (18) clinically acceptable results were obtained with zirconia and gold palladium abutments with different ceramic systems. They suggested zirconia was the most suitable abutment material for implant supported ceramic restorations.

Different brands of zirconia have different translucencies; these are highly influenced by material thickness.(19). These factors make the clinical choice of an abutment and zirconia system extremely difficult in clinical dentistry.

To the best of this investigator's knowledge, no studies have been published assessing the influence of different implant abutments on the shade of commonly used translucent monolithic zirconia systems.

Purpose of the study:

The purpose of this study was to evaluate the effect of implant abutment color on the final shade of monolithic translucent zirconia crowns.

The null hypothesis was that abutment color or brand of zirconia will have no effect on color of monolithic translucent zirconia crowns.

Clinical Significance:

The results of the study may lead to recommendations regarding the use of translucent monolithic zirconia for implant restorations and it could assist clinicians with clinical decisions for choosing implant abutment for better esthetic outcomes.

CHAPTER II

LITERATURE REVIEW

ZIRCONIA

Zirconium (Zr) is a chemical element and its name originates from the Persian “Zar-Gun” meaning golden in color. Zr belongs to the transitional metals and its atomic number is 40 and its atomic mass is 91.224 g/mol. Zr is never found as a native metal in nature. It is part of igneous rocks mixed with other elements such us iron, titanium and silicon oxide. The main source of Zr is Zircon (ZrSiO4) which is found primarily in Australia, South Africa, Brazil, India, Russia, and the United States.

Zirconia (ZrO_2), an oxide of the metal, has been used since the end of the 19th century as a fireproof material in glass making. More recently, it is now used for knives, golf putter heads and is most well known in its cubic crystal phase as a gemstone for diamond-like jewelry. Since the 1970s, zirconia has been used in medicine and dentistry, due to its favorable properties such as low cytotoxicity, corrosion potential and low propensity to bacterial adhesion (20).

Zirconia is polymorphic, meaning the same elements exist in different crystal structures depending on temperature and pressure. The crystal structures or phases are monoclinic (m), tetragonal (t) and cubic (c) (Figure 1). At room temperature and upon heating up to 1170 °C, it is monoclinic. At temperature between 1170 and 2370 °C it is tetragonal and above 2370 °C and up to the melting point it is cubic (20).

Upon cooling, the transformation from the tetragonal (t) phase to the monoclinic (m) phase is characterized by a substantial increase in volume (about 4.5%). Therefore, it is impossible to use pure zirconia for biomedical applications, where undamaged structures are imperative.

Introduction of Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) has been used as a dental restorative material for over a decade. By incorporating components like yttrium oxide (Y_2O_3), calcium oxide (CaO) or magnesium oxide (MgO) into the ZrO_2-lattice, conversion to the monoclinic phase is prevented. These stabilizing dopants (dopant is an impurity added usually in minute amounts to a pure substance to alter its properties) stabilize the tetragonal and the cubic phase at room temperature as metastable phases (metastable state is an excited state of an atom or other system with a longer lifetime than the other excited states. However, it has a shorter lifetime than the stable ground state**)**. By adding different amounts of dopant (the quantity also depends on the type of stabilizer), partially or fully stabilized zirconia is formed. Fully stabilized zirconia is achieved by adding either 8 mol% Y_2O_3 or 16 mol% MgO or CaO. Due to the addition of stabilizers, ceramics with remarkable properties such as high flexural strength and toughness, high hardness and chemical resistance can be achieved.

Partially stabilized zirconia (PSZ) has been widely studied and commercially used. The ceramics (PSZ) consist mainly of cubic phase with tetragonal intra-granular zirconia precipitates generated during tempering while cooling. Parameters such as particle size and shape, content of dopant and temperature will influence the t-to-m transformation (21). Tetragonal phase can only be preserved at room temperature in partially stabilized zirconia (2-3 mol% Y_2O_3), when particle size ranges between 0.2-1 μm (22). The adjusted cooling procedure leads to the formation of a tetragonal phase of a defined size with a homogenous distribution within the cubic-matrix. If metastable tetragonal particles are too small or too large, they will lose the ability of transformation or transform immediately into the monoclinic phase.

The quantity of dopant utilized is mentioned in front of abbreviations like 3Y-TZP when 3 mol% Y_2O_3 is used. It was discovered that high strengths go along with high tetragonal phase content, whereas a high amount of monoclinic phase leads to low strengths (21). However, remarkable changes result from transformation of the metastable tetragonal phase to the monoclinic phase including, (1) transformation toughening and (2) increased crack resistance. If the grain size shrinks below a critical size, the material loses its ability for t-to-m transformation during crack development and therefore its toughness decreases (23).

GENERATIONS OF ZIRCONIA

For dental restorations, different types of medical grade zirconia have been used that can be distinguished by their chemical composition and more important, via the content of the stabilizer Y_2O_3. Up until 2014, only high-strength 3Y-TZP was used for fabricating restorations. The first-generation 3Y-TZPs contained 0.25 % (wt) alumina (Al_2O_3) which resulted in high opacity due to inherent birefringence of noncubic zirconia. High reflectability led to mirror-like surface that was shinier than natural teeth and resulting in poor esthetics.

To increase translucency of monolithic zirconia, the next generation of 3Y-TZP was refined by reducing the alumina concentration and eliminating porosity by high temperature sintering. This slightly improved translucency associated with restorations made from 3Y-TZP (3mol% Y_2O_3).

The next stage in monolithic zirconia development came with a move to include a transparent phase in the final product that reduced opacity. The new translucent dental zirconias involved increasing the content of Y_2O_3, which resulted in 2 crystalline materials: 4Y-TZP (4 mol% Y_2O_3) and 5Y-TZP (5 mol% Y_2O_3). Due to the increased Y_2O_3 content, the cubic phase occurred alongside the metastable tetragonal phase. The quantity of the cubic phase increases from around 25% in 4Y-TZP materials to up to 50% in 5Y-TZP materials. The latter sometimes contains the cubic phase as the main phase (more than 50%) which is why 5Y-TZP is sometimes referred to as partially stabilized zirconia (5Y-PSZ). (21). The grains in 4Y-TZP and 5Y-TZP are larger than in 3Y-TZP, resulting in fewer grain boundaries, less birefringence and scattering of light. The material is thus more translucent than 3Y-TZP. One limitation of these new translucent ZrO_2 materials is lower fracture toughness compared to 3Y-TZP. The translucent materials have smaller amounts of tetragonal phase (75% in 4Y-TZP and ~50% in 5Y-TZP), leading to a reduced possibility of t-to-m transformation and therefore less transformation toughening (21).

OPTICAL PROPERTIES OF ZIRCONIA

Enamel and dentin have different refractive indices that result in selective transmission of specific wavelengths. Enamel consists of small hydroxyapatite crystals that selectively scatter shorter wavelengths. Dentin has a complex structure made of organic and inorganic components (24). This makes it challenging for any ceramic to replicate the optical properties of enamel and dentin.

The most important characteristic that makes a restoration look natural is its translucency. Translucency of dental porcelain is primarily based on light scattering (25). The greatest light scattering occurs when the refractive indices of the transparent matrix and the small particles (metallic oxides and grains of differing composition) are most different. Scattering is also dependent on particle size. Maximum scattering occurs when the particle size is the same wavelength of light (26).

A small particle sized material that allows light to pass through despite scattering from increased number of particles appears less opaque. Large particles reflect light, cause more scattering and the material appears more opaque. However, a material with fewer large particles will scatter less light and appears less opaque. Optimal results are obtained when particles are slightly greater in size than the wavelength of light are dispersed in a matrix with a different refractive index (26).

Zirconia based ceramics have been widely used in clinical practice during the last 10 years due to biocompatibility, high mechanical strength and fracture toughness. It has a polycrystalline structure which offers greater strength than feldspathic porcelain. However, increased crystal contents result in higher opacity. 3Y-TZP zirconia appears opaque due to birefringence at the grain boundaries. To make zirconia transparent, yttria content has been increased to create cubic zirconia with 8 mol% or more. However, this leads to compromised mechanical properties with reduced strength (approximately 50%) for partially stabilized zirconia (27).

Promising results have been obtained with the use of nanocrystalline 3Y-TZP, which has acceptable mechanical and esthetic properties. However, fabrication of nanocrystalline 3Y-TZP without porosity is difficult (28,29).

FACTORS AFFECTING OPTICAL PROPERTIES OF ZIRCONIA

1. Alumina sintering additive

   Alumina has a refractive index of 1.76; significantly different than that of zirconia at 2.21. Impurities with differing refractive indexes relative to zirconia results in reduced translucency (30). Many manufacturers have discontinued adding alumina to reduce opacity.
2. Pore size and pore population

   Pores adversely affect translucency. Pore size of 200-400 nm and porosity of 0.05% has been found to be detrimental to zirconia translucency (31).
3. Shaded Zirconia Blocks

   Shaded zirconia is partially translucent. Significant differences in translucency measurements were identified between specific shades (7).
4. Coloring Liquid

   Coloring liquid is applied to zirconia before the sintering process to create a natural appearance. It has little effect on translucency of monolithic crowns (32).
5. Sintering Parameters

Increasing sintering temperature and time, leads to enhanced color reproduction and translucency of shaded monolithic nanozirconia ceramic (10).

6. Thickness

   There is no consensus regarding optimal ceramic thickness for masking discolored backgrounds. An inverse relationship exists between translucency, irradiant energy, and zirconia thickness; the amount was found to be brand dependent (33).

7. Polishing and glazing

   Sulaiman et al reported that polishing monolithic zirconia restorations increased its surface gloss. The degree of surface gloss was brand dependent; thickness had no effect on the gloss (33). However, in another study by Lee et al, polished surfaces of zirconia crowns were found to be rougher than glazed surfaces (P=.002), which resulted in larger and more perceptible color differences between no treatment and polishing (34).

   Glazing slightly reduced the opalescence of zirconia. It also results in favorable tissue response (9).

8. Cement

   Using more opaque and/or white luting cements or increasing thickness of the cement layer helps mask or modify the color of the underlying material (16).

   Different types of cement may adversely affect the final color of monolithic zirconia restorations, particularly when the material is thin (0.6mm) (17).

9. Substructure

   Different abutments materials affect the color of translucent monolithic zirconia crown restorations. The intensity of substrate impact on color depends on the amount of light transmission through the ceramic material. Zirconia ceramics have shown 30% to 50% light transmission through 1mm thickness and have been considered semi-translucent (8). High survival rates for zirconia fixed dental prosthesis (FDPs) on teeth and implants have been reported despite some color mismatch (35). Kumagai et al reported that the translucency of a Y-TZP based all-ceramic crowns may influence its esthetic outcome when it is used on a discoloured abutment tooth (19). Harada et al found that translucency levels of high translucency zirconia varied depending on the brand (36). Carrillo de Albornoz et al conducted a randomized trial on the aesthetic outcomes of implant-supported restorations with zirconia or titanium abutments (37). They found that zirconia abutments resulted in better esthetic outcomes for anterior implant restorations, although the difference between zirconia and titanium abutments was not significant. Jung et al (38) concluded that zirconia showed less color change in patients with thinner mucosa.

Another study by Dede et al (39) evaluated the effects of different abutment materials and luting cements color on the final color of implant-supported all-ceramic restorations. IPS e.max ceramic (translucent, universal and white opaque) discs were examined on zirconia, titanium and gold palladium abutments. They concluded that using titanium or gold-palladium abutments for implant supported all ceramics was esthetically questionable and white opaque cement may be helpful to mask the dark color of titanium abutment. Dede et al (18) concluded that implant abutment materials may influence the final color of translucent ceramic systems more than opaque ones. They observed clinically acceptable results ($\Delta E_{00} < 2.25$) for the tested ceramic systems with zirconia and gold-palladium abutments. Clinically unacceptable results were observed for lithium disilicate ceramics with titanium abutments.

Tabatabaian et (2028) evaluated the effect of coping thickness and background type on the masking ability of a zirconia ceramic. They reported that an ideal masking could be achieved with zirconia coping thickness of 0.6 mm for amalgam and 0.8 mm for nickel-chromium alloy (40).

Jirajariyavej et al examined effects of thicknesses of 1.0 mm, 1.5 mm, 2.0 mm, and 2.5 mm glass ceramic systems on zirconia, yellow zirconia and titanium abutments. They found that increasing thickness decreased the color mismatch. Yellow shaded zirconia best mimicked the dentin (41).

PROPERTIES OF ZIRCONIA BRANDS STUDIED

Table 1: Materials used

Material	**Code**	**Type**	**Manufacturer**
BruxZir Anterior	BA	5Y-TZP	Glidewell Laboratories
KATANA Zirconia HT	KA	3Y-TZP	Kuraray Noritake
LAVA Plus High translucent	LP	3Y-TZP	3M ESPE
e.max ZirCAD MT	EZ	4Y-TZP	Ivoclar Vivadent

1. BruxZir Anterior – BruxZir Anterior by Glidewell Laboratories is 5Y-PSZ, 5 mol% yttria partially stabilized zirconia with a flexural strength of 650 MPa. It is available in 5 base shades plus white. It has an increased amount of yttria in zirconium oxide and only needs staining and glazing for clinical use. Material specifications recommend 1 mm as ideal reduction; however, the minimum requirement is 0.8 mm.

2. Katana HT – Katana High Translucent zirconia by Kuraray Noritake is 3Y-TZP Zirconia with a flexural strength of approximately 1100 Mpa. It is available in 3 basic shades HT10, HT 12 and HT13 corresponding to shades A1, A2, A3 on the Vita shadeguide.

External staining is advised for improved shade matching. Noritake has 2 more translucent zirconias UTML and STML, however they are not indicated for use with a metallic core/abutments.

3. IPS e.max ZirCAD MT Multi- e.max ZirCAD Multi by Ivoclar Vivadent is zirconia with medium translucency and shade gradations with a flexural strength of 850MPa. IPS e.max ZirCAD MT by Ivoclar is 4Y-PSZ, 4 mol% yttria partially stabilized zirconia. The blocks are available in shades - BL1, A1, A2, A3, B1, B2, C2, D2. Restorations can be fabricated with surface staining, brush infiltration with MT coloring and Effect Liquids or cut-back techniques. The manufacturer recommends the sintering programs of the Programat S1/S1 1600 sinter furnace from Ivoclar Vivadent, as it has been coordinated with the optical and mechanical properties of IPS e.max ZirCAD restorations and lead to the best possible results.

4. Lava Plus - Lava Plus zirconia by 3M ESPE is 3Y-TZP zirconia with a reported flexural strength of 1200 MPa. 3M offers it as a high translucency zirconia combined with a shading system that gives full control to create highly esthetic monolithic or layered restorations. The wide range of 18 dyeing liquids provides an excellent match to the 16 VITA® classical A1-D4 shades, plus 2 bleach shades. Shading occurs before the restoration is sintered. All-zirconia restorations and frameworks can be produced with monochrome dip shading. The manufacturer claims that the unique technology used in the Lava™ Plus Dyeing Liquids preserves translucency after shading. Lava Plus Zirconia has >80% tetragonal phase crystals resulting in 30% light transmission

COLOR MEASUREMENT

Success of a restoration depends on the ability to match the restoration's color to the surrounding dentition. Goldstein and Lancaster found that subjects who were dissatisfied with their smile had tooth color as the prominent complaint (42).

The most common method of color determination is by visual comparison of a target color to a shade guide. However, Paul et al., found that shade assessment of 3 dentist observers was 33% less accurate than a spectrophotometer (43).

The Commission Internationale de l'Eclairage (CIE) recommended calculating color difference (ΔE) based on CIELab color parameters, introduced in 1978 (44). The ΔE values are used to describe whether changes in the overall shade are perceivable to the human observer. The CIELab color system uses three color attributes L*, a*, b; in which L* represents lightness, a* represents chromaticity coordinates for red-green (+a* is the red direction and –a* is the green direction), and b* represents the chromaticity coordinate for yellow-blue (+b* is the yellow direction and –b* is the blue direction). To determine a color difference or change in the CIELab system, the following equation is used: $\Delta Eab=[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$

ΔE*ab is widely used in dentistry due to its simplicity. Different studies have reported a range of values for acceptability thresholds: 2, 2.72, 3.3, 3.7. (8,45,46,47,48) There is lack of clarity on the actual difference between the perceptibility and acceptability (49). However, color difference of 3.7 ΔE was identified to be a poor visual match (8,48). In another clinical study 1.6 ΔE represented the color difference that could not be detected by the human eye (15). An intraoral experiment by Douglas et al attempted to determine the acceptability and perceptibility tolerances for shade mismatch. Investigators measured the ΔE color difference between a restoration and adjacent teeth to evaluate the color match. Then the ΔE was compared with human eyes' thresholds for perceptibility ($\Delta > 2.6$) and acceptability ($\Delta E < 5.5$). It was reported that at predicted color difference of 2.6 ∆E units, dentists could perceive a color difference; and at 5.5 ∆E, the dentists would remake the restoration. Mean acceptability tolerance for 95% observers was 4.0 ∆E (14).

CHAPTER III

MATERIAL & METHODS

SAMPLE PREPARATION:

A single implant (Nobel Replace Trilobe RP, Nobel Biocare) was secured in the maxillary right central incisor position on a dentoform model (Figure 1). It was scanned using a 3Shape lab scanner (E3, 3Shape). Dental System (3Shape) software was used to simultaneously design the implant abutment (Figure 2) and the crown (Figure 3) to control crown thickness (Figures 4 and 5). The abutment was designed with the following parameters: 11 degree axial taper; chamfer margins (0.6.mm thick); 6 mm axial wall height and 2 plane incisal third reduction. The design file was used to mill customized abutments from titanium and zirconium dioxide (Glidewell Laboratories) (Figure 6). A control abutment was made from Shade A2 polymethyl methacrylate (Alike, GC America) using polyvinyl siloxane (Imprint™, 3M) index of the milled abutment. Four types of zirconia systems (BruxZir Anterior; Glidewell Laboratories, LAVA Plus High translucency zirconia; 3M ESPE, e.max ZirCAD MT; Ivoclar, KATANA Zirconia HT; Kuraray Noritake) of Y-TZP were used to make 80 crown restorations, 20 in each group. The crowns were monolithic CAD-CAM in Vita shade A2. Dimensions of the CAD/CAM designed full contour crowns included 1 mm thickness at the middle third of the facial surface. An 80 µm cement space was incorporated into all specimens. All crowns were fabricated per manufacturers' recommendations by the same laboratory (Figure 7).

Figure 1: Nobel RP Trilobe implant in dentoform model

Figure 2: Abutment design

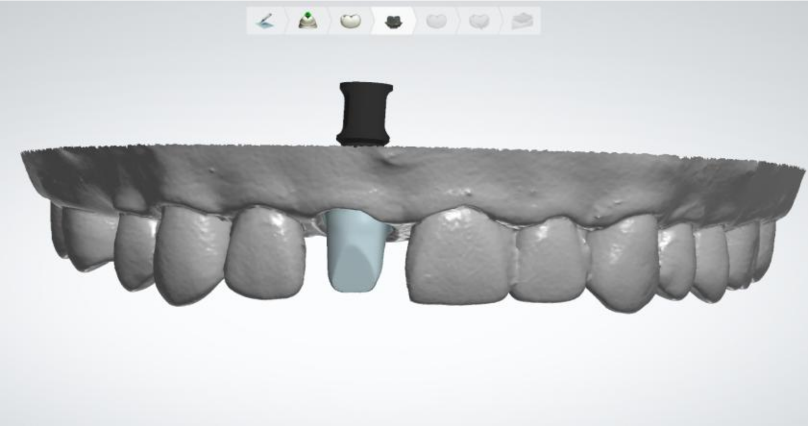


Figure 3: Crown design in Dental System software (3Shape)

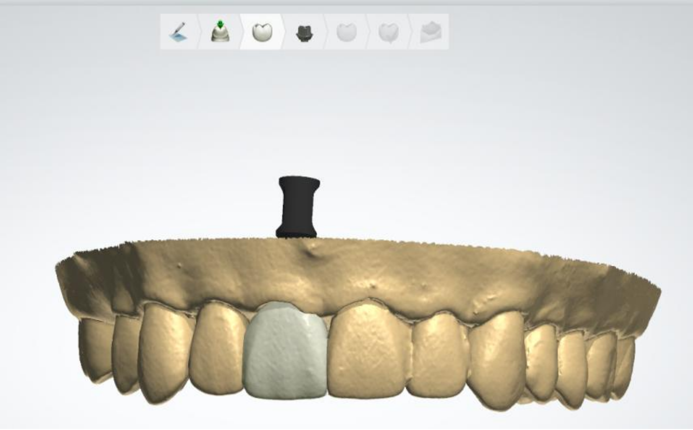
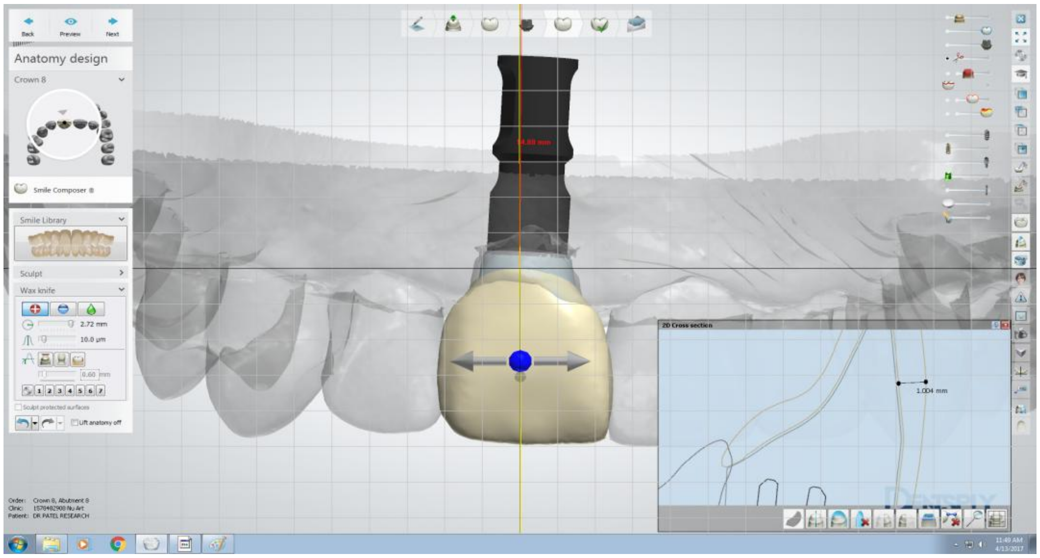


Figure 4: Crown cross section

Figure 5: Cross section showing average crown thickness 1 mm



Order: Crown 8, Abutment 8
Clinic: 1578482908 Nu Art
Patient: DR PATEL RESEARCH

Figure 6: Milled abutment

Figure 7: Milled crown

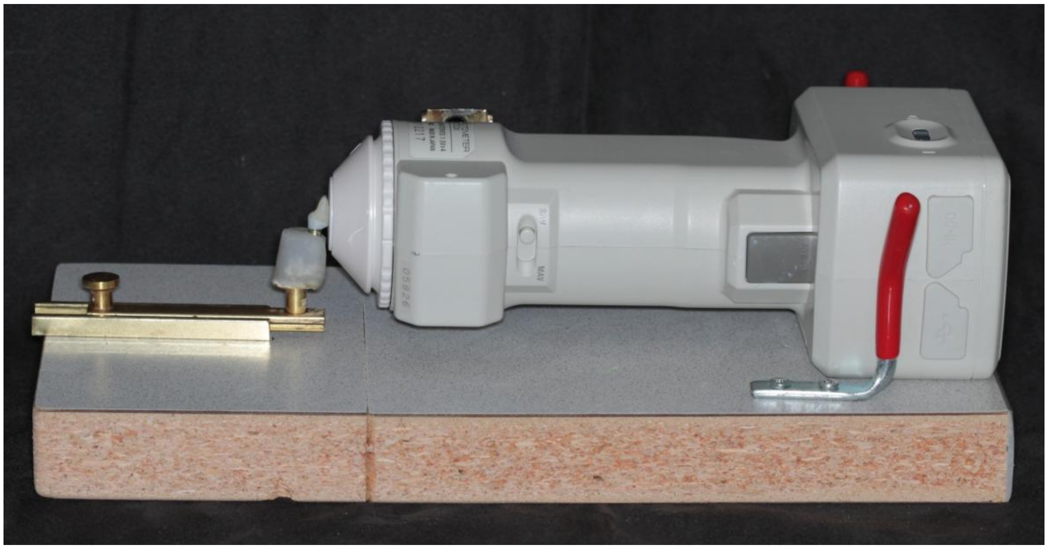
The titanium abutment was anodized with a titanium anodizer (Painful Pleasures) to obtain a gold hue abutment (60 voltage) and later to obtain pink hue abutment (70 voltage).

OPTICAL MEASUREMENTS:

A total of 80 specimens were placed on 4 different implant abutments (zirconia, titanium, pink anodized titanium and gold anodized titanium) using opaque try in paste (Multilink Automix; Ivoclar Vivadent AG). The shade was evaluated at the middle third of the crowns with a spectrophotometer (CM-700D; Konica Minolta) using a 3 mm measuring tool. The device was calibrated with a white calibration plate before the color measurements.

For repeatability of measurements, a custom positioning instrument (Figure 8) was fabricated for the repeatable positioning of the spectrophotometer and the restoration. Before placing the crown on its respective abutment, it was ultrasonically cleaned for 5 minutes and air dried for 20 seconds. The device was set to record color measurements (L,*a, *b) 3 times and displayed their averages. The measurements were made at mid-facial location, using standard illuminant D65 at 10 degree observer angle, using aperture with 3mm measurement area. The spectrophotometer recorded the spectral reflectance of the color and converted into the Commission International de l’Eclairage color system (CIELab). In this system, color is expressed as 3 coordinates: L* value is the lightness of the object, the a* value represents the red or green chroma and the b* value represents yellow or blue chroma.

Figure 8: Positioning device for spectrophotometer



Statistical method:

1. $\Delta E = [\ (\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\ ]^{1/2}$ where ΔL^*, Δa^*, Δb^* are differences between CIE Lab* parameters with different abutment color for each zirconia system.
2. ΔE was measured against the control group, for each zirconia system.
3. Two-way Analysis of variance (ANOVA) and the Tukey post hoc test (SPSS Statistics v20; IBM Corp) were used to identify significant differences in ΔE values among groups ($\alpha = 0.05$)

CHAPTER IV

RESULTS

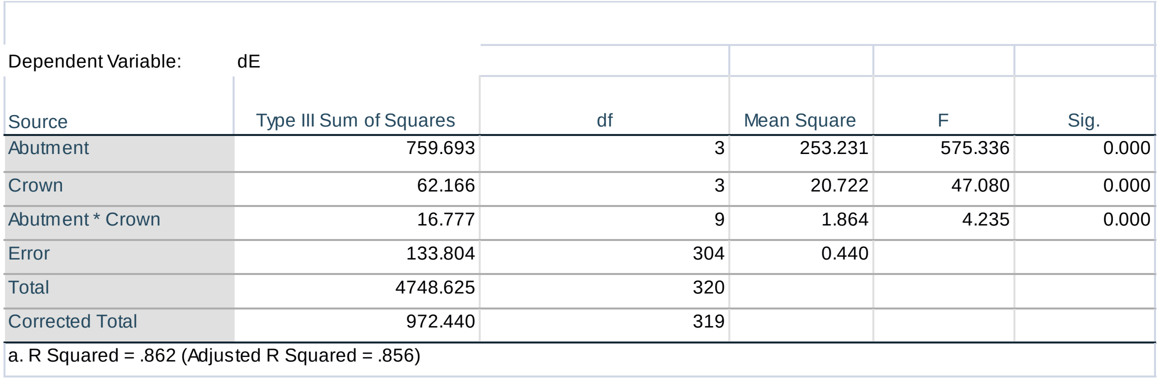
The L, a, and b values are shown in Table 2.

Table 2: CIE Lab values for test groups

		L	a	b
KA				
	Control	75.42	0.86	11.40
	TI	73.41	0.16	9.12
	Ti Gold	73.25	(0.01)	8.95
	Ti Pink	73.00	0.28	8.78
	Zr	75.41	0.55	10.99
BA				
	Control	71.42	(0.68)	6.02
	TI	68.36	(1.44)	3.57
	Ti Gold	68.15	(1.41)	3.58
	Ti Pink	67.23	(0.96)	3.05
	Zr	71.19	(1.13)	5.55
LP				
	Control	72.80	(0.20)	11.98
	TI	70.05	(1.15)	8.48
	Ti Gold	69.81	(1.08)	8.70
	Ti Pink	69.84	(0.62)	8.39
	Zr	72.64	(0.73)	11.54
EZ				
	Control	75.84	(0.56)	11.71
	TI	72.62	(1.54)	8.52
	Ti Gold	72.45	(1.47)	8.59
	Ti Pink	72.17	(1.10)	8.39
	Zr	75.52	(1.08)	11.18

According to the 2-way ANOVA results (Table 3), the type of abutment material, zirconia system, and interaction of these variables significantly influenced the ΔE values.

Table 3: Two-way ANOVA results of mean ΔE



Dependent Variable: dE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Abutment	759.693	3	253.231	575.336	0.000
Crown	62.166	3	20.722	47.080	0.000
Abutment * Crown	16.777	9	1.864	4.235	0.000
Error	133.804	304	0.440		
Total	4748.625	320			
Corrected Total	972.440	319			

a. R Squared = .862 (Adjusted R Squared = .856)

The mean color difference of all zirconia systems was higher than clinically perceptible level (<2.6) against all abutments except zirconia abutment (Table 4). The ΔE value for Katana zirconia HT was below the threshold (<4.0) against all types of abutments. All other zirconia systems exhibited clinically unacceptable color difference against all metallic abutments.

Table 4: Descriptive statistics for mean ΔE values of different abutments and zirconia

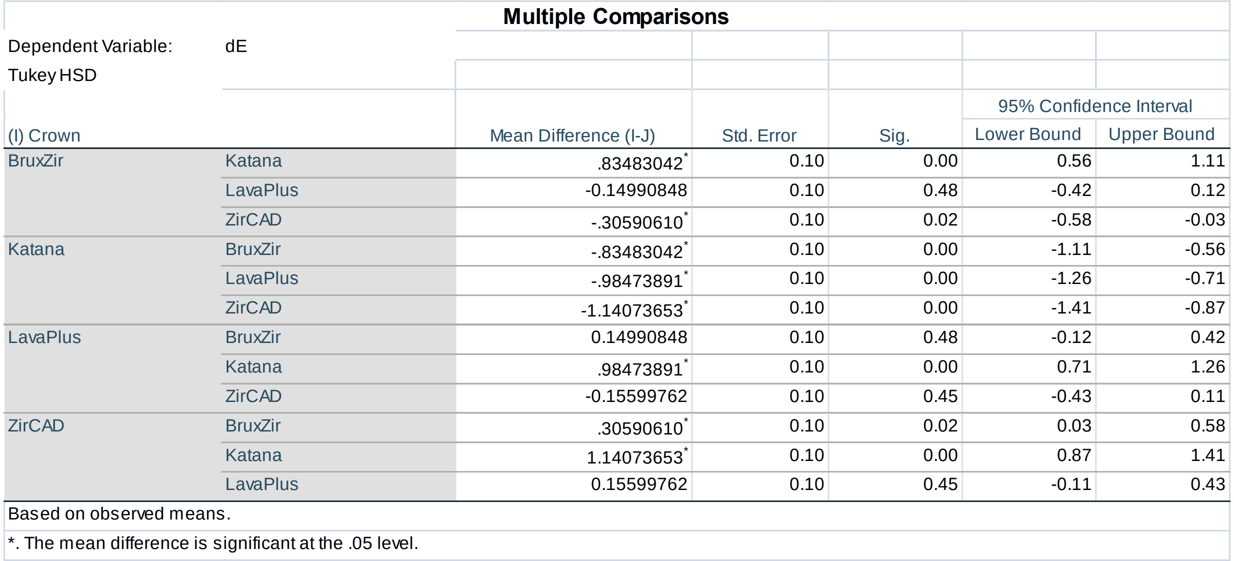
Abutment * Crown

Dependent Variable: dE

Abutment		Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Gold	BruxZir	4.15	0.15	3.86	4.45
	Katana	3.39	0.15	3.10	3.68
	LavaPlus	4.54	0.15	4.25	4.83
	ZirCAD	4.73	0.15	4.44	5.02
Pink	BruxZir	5.15	0.15	4.86	5.44
	Katana	3.63	0.15	3.34	3.92
	LavaPlus	4.74	0.15	4.45	5.03
	ZirCAD	5.01	0.15	4.71	5.30
Ti	BruxZir	4.00	0.15	3.71	4.29
	Katana	3.20	0.15	2.91	3.49
	LavaPlus	4.60	0.15	4.30	4.89
	ZirCAD	4.67	0.15	4.38	4.97
Zr	BruxZir	0.82	0.15	0.53	1.11
	Katana	0.56	0.15	0.27	0.85
	LavaPlus	0.84	0.15	0.55	1.13
	ZirCAD	0.94	0.15	0.64	1.23

The multiple comparisons (Table 5) showed that the ΔE values were significantly different for all zirconia systems except BruxZir x LavaPlus and LavaPlus x ZirCAD.

Table 5: Multiple comparisons between zircon



Multiple Comparisons

Dependent Variable: dE

Tukey HSD

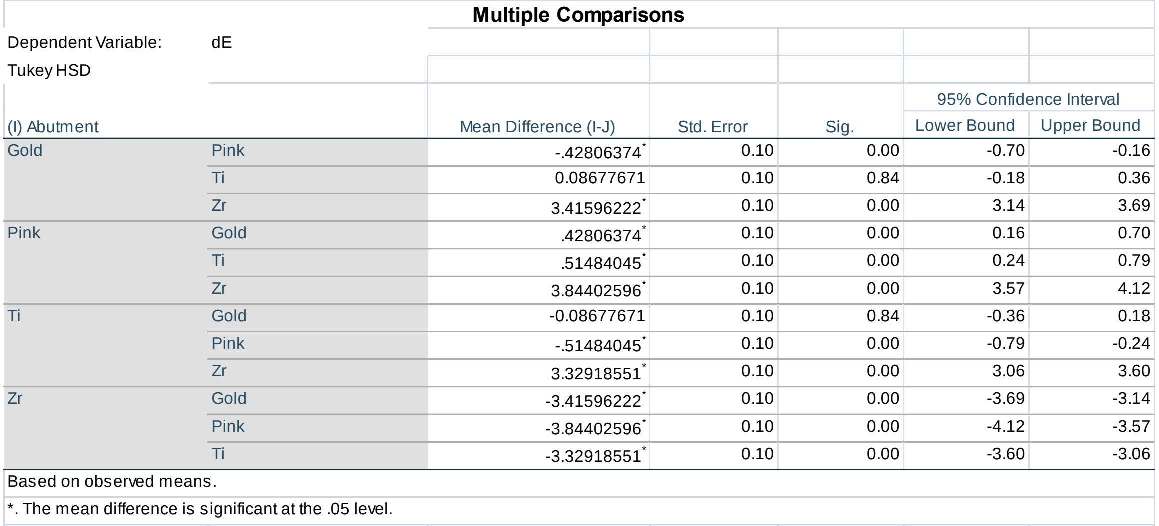
(I) Crown		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
BruxZir	Katana	.83483042*	0.10	0.00	0.56	1.11
	LavaPlus	-0.14990848	0.10	0.48	-0.42	0.12
	ZirCAD	-.30590610*	0.10	0.02	-0.58	-0.03
Katana	BruxZir	-.83483042*	0.10	0.00	-1.11	-0.56
	LavaPlus	-.98473891*	0.10	0.00	-1.26	-0.71
	ZirCAD	-1.14073653*	0.10	0.00	-1.41	-0.87
LavaPlus	BruxZir	0.14990848	0.10	0.48	-0.12	0.42
	Katana	.98473891*	0.10	0.00	0.71	1.26
	ZirCAD	-0.15599762	0.10	0.45	-0.43	0.11
ZirCAD	BruxZir	.30590610*	0.10	0.02	0.03	0.58
	Katana	1.14073653*	0.10	0.00	0.87	1.41
	LavaPlus	0.15599762	0.10	0.45	-0.11	0.43

Based on observed means.

*. The mean difference is significant at the .05 level.

Multiple comparisons between the abutments (Table 6) showed that the ΔE was significantly different between all abutments except for the titanium and gold hue titanium abutments.

Table 6: Multiple comparisons between abutments



Multiple Comparisons

Dependent Variable: dE
Tukey HSD

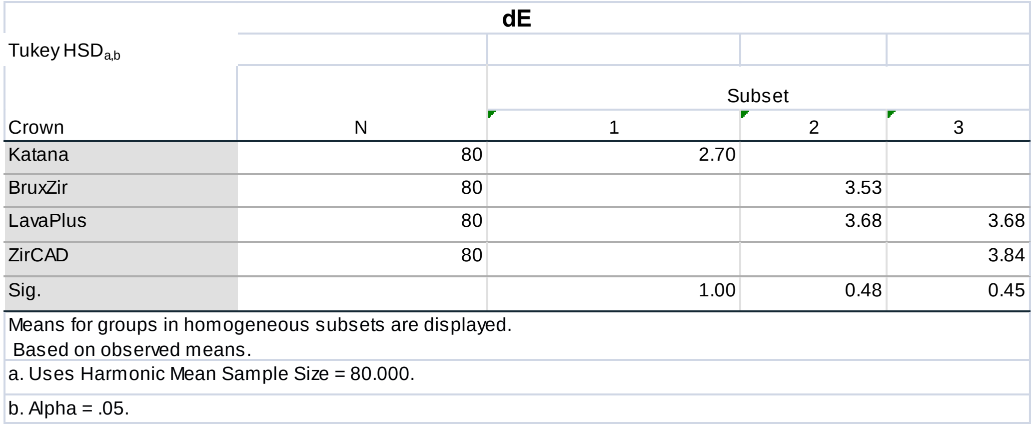
(I) Abutment		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Gold	Pink	-.42806374*	0.10	0.00	-0.70	-0.16
	Ti	0.08677671	0.10	0.84	-0.18	0.36
	Zr	3.41596222*	0.10	0.00	3.14	3.69
Pink	Gold	.42806374*	0.10	0.00	0.16	0.70
	Ti	.51484045*	0.10	0.00	0.24	0.79
	Zr	3.84402596*	0.10	0.00	3.57	4.12
Ti	Gold	-0.08677671	0.10	0.84	-0.36	0.18
	Pink	-.51484045*	0.10	0.00	-0.79	-0.24
	Zr	3.32918551*	0.10	0.00	3.06	3.60
Zr	Gold	-3.41596222*	0.10	0.00	-3.69	-3.14
	Pink	-3.84402596*	0.10	0.00	-4.12	-3.57
	Ti	-3.32918551*	0.10	0.00	-3.60	-3.06

Based on observed means.

*. The mean difference is significant at the .05 level.

The Tukey honest significant difference post hoc test results indicated that the least color difference (ΔE 2.70) was observed with Katana zirconia HT (Table 7). BruxZir Anterior and Lava Plus were not significantly different from each other and their ΔE was lower than the clinically acceptable threshold (<4.0). Significant color differences ($p<0.5$) were also observed between BruxZir Anterior and ZirCAD crowns.

Table 7: Tukey post hoc test results of mean ΔE values between different zirconia



dE

Tukey HSD$_{a,b}$

Crown	N	Subset 1	Subset 2	Subset 3
Katana	80	2.70		
BruxZir	80		3.53	
LavaPlus	80		3.68	3.68
ZirCAD	80			3.84
Sig.		1.00	0.48	0.45

Means for groups in homogeneous subsets are displayed.
Based on observed means.

a. Uses Harmonic Mean Sample Size = 80.000.

b. Alpha = .05.

With respect to the abutments, significant color differences ($p<0.5$) were observed between zirconia and the other abutments (Table 8). Zirconia abutments showed ΔE of 0.78 which was lower than the recognized clinically perceptible threshold (<2.5). Titanium and gold hue Ti abutments showed no significant difference.

Table 8: Tukey post hoc test results of mean ΔE values between abutments

dE

Tukey HSD$_{a,b}$

Abutment	N	Subset		
		1	2	3
Zr	80	0.79		
Ti	80		4.12	
Gold	80		4.20	
Pink	80			4.63
Sig.		1.000	0.842	1.000

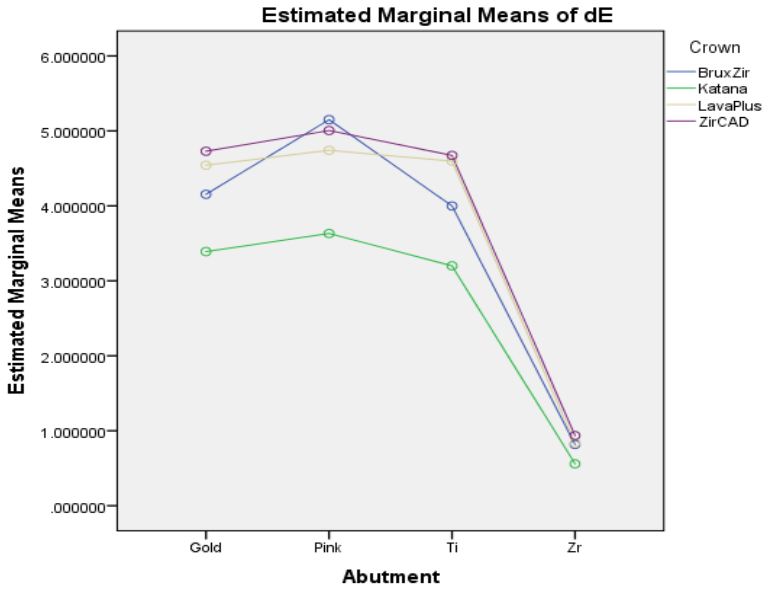
Means for groups in homogeneous subsets are displayed.
Based on observed means.

a. Uses Harmonic Mean Sample Size = 80.000.

b. Alpha = .05.

The graph (Figure 9) represents the mean ΔE values for all zirconia systems against the different abutment systems studied. The least color differences were observed with zirconia abutments for all types of zirconia crowns. The least color difference was observed when Katana Zirconia HT was placed against any type of abutment.

Figure 9: Mean ΔE values of test groups on different abutments



CHAPTER V

DISCUSSION

The results of this study suggested that abutment material and brand of zirconia significantly affected the final color of the tested zirconia crowns; therefore, the null hypothesis was rejected.

For this experiment, 4 commonly used zirconia crowns that have been commercially promoted for translucency were selected for use against implant abutments. It is worth noting that 2 zirconia systems (Katana zirconia HT and Lava Plus HT) were 3Y-TZP, 1 (e.max ZirCAD) was 4Y-TZP and 1 (BruxZir Anterior) was 5Y-TZP. Differences in perceived translucency may relate to zirconia's grain size, yttria content and percentage of chemical impurities (21).

Surface texture affects color of dental ceramic restorations, especially the CIE L* value. Smooth surfaces reflect a greater amount of light than do rough surfaces, which results in increased value of the restorations (50). Sulaiman et al (33) reported that polishing monolithic zirconia restorations increased its surface gloss. However, Lee et al reported that polished surfaces were rougher than glazed surfaces (34). Kim et al reported that the surface texture of monolithic zirconia ceramics did not affect their translucency whereas glazing slightly reduced their opalescence (9). In the present study, this variable was eliminated by using milled crowns without surface treatments.

The study design attempted to simulate complex clinical conditions by using complete, anatomically contoured crowns instead of flat discs. Sun et al (51) reported that monolithic zirconia crowns, 1 mm thick, had fracture strengths equal to metal-ceramic crowns. In a study by Malkondu et al, (17) on the influence of cement type on color and translucency of monolithic zirconia crowns, a significant increase in translucency was observed with decreased zirconia thickness from 1.0 to 0.6 mm. They also reported that the influence of cement on color increased. In a recent study, a minimum thickness of 0.9 mm of monolithic zirconia ceramic was recommended to gain an acceptable final color (52). Hence, in the present study, crown thickness of 1 mm on facial surfaces was established to evaluate color changes.

A reflection spectrometer (CM-700D; Konica Minolta) was used to measure the effect of different implant abutments on monolithic zirconia ceramics. The color parameters were recorded in the L*a*b* color space as established by the Commission Internationale de L'Eclairage (CIE) in 1978. This system is related to human color perception in all 3 dimensions or directions of color space. Equal distances in the color space represent approximately equally perceived steps. L* is a lightness variable, proportional to Munsell's Value; a* and b* are chromaticity coordinates (53). ΔE*ab formula was selected as it has been commonly used in the dental literature, which enabled the authors to compare results to previous investigations.

The selected instrument utilized diffuse, that is, 8° illumination geometry. It featured an optical device which provided diffuse illumination. Differences in surface condition (texture and/or gloss level) do not influence the measuring value. Through an opening at the top of the sphere, the sensor viewed the surface being measured with an angle of 8° to the vertical (54). D65 illuminant was selected as it represents daylight.

$\Delta E > 2.6$ and $\Delta E < 4.0$ are accepted as the threshold values for perceptible and acceptable color changes for dental professionals (14).

To simulate clinical situations, try in paste was utilized to fix the crowns to the abutments. In a study by Xing et al (55), no perceptible difference was observed between resin cements and the corresponding try in paste. Various studies have recommended using more opaque/white cements and increasing cement layer thickness to help mask the effect of underlying abutments (39,55,56).

Hence, an opaque try in paste was selected to fill the 80 μm cement spaces established between abutments and crown restorations.

Abutment materials affect the color of translucent monolithic zirconia crown restorations. The intensity of substrate and its impact on color depends on the amount of light transmission through the ceramic material. Zirconia ceramics have shown 30-50% light transmission through 1 mm thickness and have been considered semi-translucent (8). In the present study, different zirconia systems were used with different translucency based on their composition. The results showed that implant abutments had significant effect on the final color of the translucent zirconia crown restorations. Similar findings were observed in studies which found that translucent materials reflected the color of the substructure more than opaque ceramic systems (19,57,58).

According to the results of this study, the least color differences were observed when Katana Zirconia HT crowns were placed against any type of abutment. Katana zirconia HT is a 3Y-TZP material which is marketed as a translucent material. This feature could be attributed to its relative low translucency when compared to e.max ZirCAD which is 4Y-TZP and BruxZir Anterior which is 5Y-TZP translucent zirconia. This finding was consistent with the study by Harada et al. They found that translucency levels of high translucency zirconia varied depending on the brand (36).

Among the tested zirconia systems, zirconia abutments showed a mean ΔE of 0.78 which was lower than Δ1.6. The latter value can be recognized by the human eye (15). This was consistent with the reported findings of Dede et al, which showed, using zirconia abutments resulted in visually imperceptible color differences ($\Delta E \leq 1.30$). Carrillo de Albornoz et al (37) indicated that zirconia abutments resulted in better esthetic outcomes for anterior implant restorations, although the difference between zirconia and titanium abutments was not significant in their study.

Clinically unacceptable color differences (>4.0 ΔE) were observed for all zirconia systems against all metallic abutments. The pink hue titanium caused the highest color change, irrespective of the zirconia system used. Similar results were previously reported by Capa et al, who found ΔE >3.7 for all zirconia shades with titanium base (16). The ΔL value increased with titanium substructures, indicating it led to darker appearances. The greatest ΔL value increase was seen with pink hue titanium abutments. In a recent study by Gil et al it was reported that peri-implant mucosa surrounding pink colored titanium abutments was significantly more red when compared with gray abutments and that was perceived to be a better match for gingiva (59). However, the effect of pink hue abutments on zirconia crowns hasn't been investigated. In another study by Jung et al, (38) zirconia abutments showed less color change in patients with thinner mucosa.

There are many reports that have investigated the influence of implant substructures on different ceramic crown systems that included zirconia. However, there have been no reported studies that have evaluated the effect on translucent monolithic zirconia on implant abutments. This study is first of its kind which should help clinicians choose esthetic translucent complete contour crowns for implant restorations.

The current study utilized only white zirconia abutments. The study could be repeated to include shaded zirconia abutments, as well as gold palladium abutments to evaluate color differences. Another limitation of the present study was only using opaque try in paste. Studies have concluded that cement has significantly affected the final color of zirconia restorations (16,17). The effect of cement type, shade or thickness was not investigated in the study. Further investigations should also be performed by fabricating crown restorations with different zirconia thicknesses, shades of zirconia and surface treatment.

CHAPTER VI

CONCLUSIONS

Within the limitations of this in vitro study of 4 different zirconia systems, the following conclusions have been drawn:

1. The color of zirconia was brand dependent and was influenced by abutment color.
2. Color difference was below perceptible levels ($\Delta E < 2.5$) for all zirconia systems against zirconia abutments. Zirconia was the most suitable abutment, relative to color, for implant restorations.
3. Clinically unacceptable color differences ($\Delta E > 4.0$) were observed for all translucent zirconia systems against metallic abutments except for crowns made with Katana HT.
4. Highest color changes were observed for the pink hue titanium abutment group.
5. For the zirconia systems investigated, use of titanium or gold hue titanium did not result in significant color differences.

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APPENDIX

Table: CIE Lab values for BruxZir Anterior zirconia

Ti	L	a	b		Ti Gold	L	a	b		Ti Pink	L	a	b		Zr	L	a	b		Control	L	a	b
1	67.61	-1.49	3.18			68.00	-1.40	3.49		1.00	66.95	-0.98	2.97			70.59	-1.13	5.25		1.00	70.64	-0.57	6.22
2	68.21	-1.50	3.84			68.81	-1.46	4.00		2.00	69.23	-1.19	4.34			71.61	-1.13	6.16		2.00	71.76	-0.73	6.24
3	67.73	-1.36	3.69			68.31	-1.39	3.90		3.00	65.78	-0.56	2.51			71.01	-1.07	5.70		3.00	70.33	-0.64	5.74
4	68.99	-1.40	3.67			67.94	-1.41	3.31		4.00	68.27	-1.11	3.33			71.55	-1.07	5.52		4.00	71.74	-0.64	5.88
5	67.46	-1.42	3.57			67.73	-1.39	3.80		5.00	66.41	-0.87	3.02			70.36	-1.09	5.64		5.00	71.48	-0.66	6.18
6	67.78	-1.49	3.23			67.72	-1.43	3.35		6.00	66.71	-0.97	2.73			71.08	-1.16	5.32		6.00	70.70	-0.64	5.73
7	68.91	-1.45	3.66			68.64	-1.37	3.38		7.00	67.16	-0.97	2.62			71.37	-1.11	5.34		7.00	72.09	-0.68	5.74
8	68.09	-1.46	3.27			66.84	-1.30	3.08		8.00	67.58	-0.98	3.15			71.14	-1.07	5.61		8.00	70.88	-0.77	5.90
9	67.34	-1.43	3.84			67.75	-1.43	4.19		9.00	65.44	-0.75	3.05			70.34	-1.05	6.00		9.00	70.14	-0.60	6.41
10	68.23	-1.34	3.59			66.64	-1.32	3.20		10.00	66.31	-0.83	2.76			70.90	-1.10	5.43		10.00	71.49	-0.61	6.02
11	69.07	-1.70	3.46			69.59	-1.76	3.92		11.00	67.66	-1.25	2.96			71.74	-1.41	5.50		11.00	71.80	-0.92	6.08
12	68.88	-1.37	3.51			69.36	-1.36	3.99		12.00	68.36	-1.08	3.39			71.63	-1.10	5.70		12.00	71.51	-0.71	6.00
13	68.62	-1.50	3.48			68.82	-1.44	3.51		13.00	66.18	-0.77	2.59			71.79	-1.11	5.72		13.00	72.29	-0.74	6.17
14	67.73	-1.43	3.52			68.55	-1.45	3.74		14.00	66.56	-1.00	3.11			70.65	-1.16	5.39		14.00	71.24	-0.71	6.02
15	68.42	-1.46	3.31			69.14	-1.39	3.86		15.00	68.63	-1.14	3.43			71.37	-1.16	5.40		15.00	72.30	-0.77	6.08
16	68.62	-1.30	3.63			67.47	-1.39	3.44		16.00	67.10	-0.86	2.94			70.54	-1.10	5.34		16.00	71.04	-0.68	6.03
17	69.28	-1.33	4.02			67.21	-1.38	3.18		17.00	67.35	-0.92	3.03			71.77	-1.12	5.49		17.00	71.74	-0.69	5.93
18	67.99	-1.33	4.02			67.19	-1.31	3.55		18.00	67.02	-0.95	3.54			70.99	-1.02	5.81		18.00	70.82	-0.53	6.10
19	69.62	-1.60	3.41			69.40	-1.54	3.31		19.00	68.66	-1.11	2.78			72.43	-1.25	5.26		19.00	73.08	-0.89	5.80
20	68.64	-1.43	3.48			67.86	-1.32	3.45		20.00	67.16	-0.85	2.81			70.87	-1.11	5.39		20.00	71.29	-0.51	6.03

Table: CIE Lab values for Lava Plus zirconia

Ti	L	a	b		Ti Gold	L	a	b		Ti Pink	L	a	b		Zr	L	a	b		Control	L	a	b
1	68.48	-1.07	8.51			68.25	-1.02	9.17		1.00	68.77	-0.61	8.96		1.00	72.10	-0.67	11.73		1.00	72.17	-0.12	12.57
2	69.14	-1.11	7.44			70.93	-1.15	9.28		2.00	72.83	-0.95	10.59		2.00	72.46	-0.79	11.58		2.00	72.71	-0.15	12.22
3	71.62	-1.26	7.53			71.76	-1.21	8.05		3.00	72.36	-0.91	8.27		3.00	73.93	-0.90	10.25		3.00	74.41	-0.52	10.71
4	69.98	-1.04	9.04			69.59	-1.05	9.10		4.00	69.69	-0.58	8.22		4.00	72.10	-0.67	11.72		4.00	72.10	-0.22	11.99
5	70.22	-1.17	8.37			70.41	-1.12	8.43		5.00	71.07	-0.66	7.65		5.00	72.82	-0.73	10.77		5.00	72.89	-0.20	11.84
6	71.11	-1.20	8.65			71.25	-1.14	8.96		6.00	71.98	-0.85	9.26		6.00	72.95	-0.81	11.26		6.00	73.78	-0.43	12.17
7	70.55	-1.09	8.03			69.73	-1.04	8.37		7.00	69.74	-0.65	8.00		7.00	72.58	-0.70	10.78		7.00	71.98	-0.10	11.03
8	70.16	-1.03	8.27			70.28	-0.99	8.68		8.00	69.39	-0.47	8.01		8.00	72.48	-0.55	12.02		8.00	72.93	-0.10	11.98
9	70.77	-1.00	9.25			69.24	-1.09	9.62		9.00	68.97	-0.54	8.89		9.00	71.81	-0.66	12.41		9.00	72.36	0.01	12.57
10	70.69	-1.22	8.99			69.70	-1.16	8.46		10.00	70.89	-0.81	8.55		10.00	73.28	-1.01	11.67		10.00	73.12	-0.34	12.14
11	70.28	-1.19	9.46			70.59	-1.12	9.05		11.00	69.06	-0.48	8.55		11.00	73.15	-0.67	11.84		11.00	72.75	-0.07	12.12
12	70.40	-1.07	7.98			69.31	-0.99	8.60		12.00	69.94	-0.52	8.01		12.00	72.50	-0.63	11.79		12.00	72.75	-0.11	12.30
13	68.80	-1.14	8.46			69.18	-1.06	8.79		13.00	68.51	-0.45	8.07		13.00	71.86	-0.58	11.76		13.00	71.96	-0.01	12.07
14	70.40	-1.10	7.59			68.18	-1.03	8.03		14.00	67.27	-0.41	7.84		14.00	72.10	-0.71	11.29		14.00	72.12	-0.12	11.85
15	69.23	-1.21	9.28			70.36	-1.01	8.99		15.00	70.34	-0.75	9.50		15.00	72.76	-0.75	12.13		15.00	73.74	-0.21	12.24
16	69.38	-1.09	8.28			68.88	-0.88	8.50		16.00	67.84	-0.24	7.55		16.00	72.38	-0.66	11.42		16.00	72.33	-0.01	11.91
17	69.09	-1.23	8.39			67.99	-1.05	7.91		17.00	68.04	-0.38	7.24		17.00	72.58	-0.76	11.61		17.00	72.86	-0.23	12.32
18	69.32	-1.13	8.63			69.47	-1.01	8.49		18.00	69.31	-0.55	8.39		18.00	72.50	-0.59	11.72		18.00	72.37	-0.15	11.84
19	71.20	-1.31	8.99			70.92	-1.26	8.85		19.00	70.53	-0.78	8.11		19.00	73.46	-0.85	1.73		19.00	73.24	-0.38	12.03
20	70.22	-1.40	8.54			70.26	-1.23	8.75		20.00	70.30	-0.78	8.08		20.00	72.92	-0.92	11.27		20.00	73.45	-0.45	11.79

Table: CIE Lab values for e. max ZirCAD zirconia

Ti	L	a	b		Ti Gold	L	a	b		Ti Pink	L	a	b		Zr	L	a	b		Control	L	a	b
1	73.10	-1.63	9.03			74.26	-1.55	9.22		1.00	73.60	-1.23	8.76		1.00	75.87	-1.12	11.56		1.00	76.12	-0.68	11.32
2	72.56	-1.63	7.42			72.49	-1.51	7.40		2.00	71.82	-1.01	7.21		2.00	75.73	-1.16	9.98		2.00	76.40	-0.77	10.46
3	71.99	-1.49	8.61			71.91	-1.38	8.42		3.00	72.17	-1.21	8.23		3.00	74.95	-1.02	11.18		3.00	76.12	-0.57	11.88
4	73.83	-1.61	9.44			73.22	-1.55	9.12		4.00	73.10	-1.20	9.15		4.00	76.06	-1.13	11.58		4.00	76.17	-0.61	12.04
5	72.20	-1.47	8.13			71.53	-1.43	8.16		5.00	71.98	-1.00	8.24		5.00	75.27	-1.08	10.88		5.00	75.42	-0.56	11.59
6	73.12	-1.49	8.54			72.57	-1.45	8.25		6.00	72.40	-1.41	8.33		6.00	75.44	-1.11	11.00		6.00	76.65	-0.56	10.97
7	73.55	-1.46	8.82			73.29	-1.46	9.28		7.00	72.59	-1.11	8.80		7.00	75.32	-1.04	11.48		7.00	75.87	-0.66	11.74
8	72.21	-1.41	8.77			71.31	-1.38	8.70		8.00	71.32	-1.01	8.71		8.00	74.98	-0.90	11.56		8.00	75.40	-0.51	12.08
9	72.35	-1.54	7.80			72.19	-1.48	8.22		9.00	71.99	-1.11	8.42		9.00	75.33	-1.11	10.80		9.00	75.85	-0.65	11.66
10	72.74	-1.58	8.51			72.59	-1.44	8.14		10.00	72.47	-1.18	8.16		10.00	75.68	-1.10	10.69		10.00	75.71	-0.62	11.22
11	73.68	-1.70	8.90			71.84	-1.52	8.10		11.00	71.51	-1.03	8.11		11.00	76.23	-1.17	11.36		11.00	76.37	-0.74	12.08
12	72.34	-1.51	8.47			71.81	-1.40	8.50		12.00	71.47	-0.94	8.19		12.00	75.39	-1.02	11.37		12.00	75.90	-0.53	12.10
13	72.89	-1.61	9.00			73.16	-1.57	9.14		13.00	73.62	-1.18	8.95		13.00	75.74	-1.07	11.47		13.00	75.98	-0.65	12.09
14	71.18	-1.52	7.76			71.48	-1.48	8.60		14.00	70.93	-0.89	7.89		14.00	75.15	-1.09	11.13		14.00	75.76	-0.61	11.88
15	73.27	-1.43	8.50			72.87	-1.49	9.13		15.00	72.61	-1.31	8.82		15.00	75.44	-1.06	11.37		15.00	75.09	-0.63	11.67
16	72.22	-1.54	9.08			72.26	-1.42	9.15		16.00	72.27	-1.04	9.81		16.00	75.58	-0.97	12.13		16.00	75.02	0.51	12.95
17	72.00	-1.63	7.46			74.16	-1.55	8.79		17.00	71.59	-1.05	7.36		17.00	75.88	-1.13	10.23		17.00	75.77	-0.61	10.76
18	72.74	-1.52	9.04			72.20	-1.46	8.61		18.00	72.19	-0.92	7.71		18.00	75.25	-1.14	11.14		18.00	76.09	-0.61	11.76
19	72.49	-1.55	8.57			72.05	-1.45	8.44		19.00	71.93	-1.07	8.43		19.00	75.86	-1.06	11.43		19.00	75.77	-0.54	11.92
20	71.89	-1.54	8.48			71.72	-1.43	8.34		20.00	71.90	-1.04	847.00		20.00	75.22	-1.02	11.34		20.00	75.42	-0.63	12.00

Table: CIE Lab values for Katana HT zirconia

Ti	L	a	b		Ti Gold	L	a	b		Ti Pink	L	a	b		Zr	L	a	b		Control	L	a	b
1	73.47	0.00	9.22			73.08	-0.02	9.05		1.00	72.24	0.28	8.62		1.00	75.62	0.58	11.28		1.00	75.53	0.86	11.46
2	73.64	0.01	9.42			73.53	-0.03	9.16		2.00	73.11	0.27	8.69		2.00	73.91	0.49	10.69		2.00	75.53	0.87	11.52
3	73.65	0.05	9.15			73.44	-0.04	9.05		3.00	72.53	0.26	8.58		3.00	75.57	0.52	11.00		3.00	75.28	0.92	11.29
4	74.27	0.23	10.01			74.01	0.16	9.50		4.00	73.53	0.40	9.33		4.00	75.85	0.69	11.39		4.00	75.34	0.99	11.45
5	72.66	-0.12	8.54			73.54	0.01	9.17		5.00	73.40	0.23	8.97		5.00	75.30	0.46	10.85		5.00	75.50	0.82	11.24
6	73.79	-0.03	9.43			73.88	-0.01	9.43		6.00	73.06	0.21	8.31		6.00	75.63	0.55	11.03		6.00	75.72	0.89	11.43
7	73.21	-0.03	8.83			72.77	-0.07	8.72		7.00	72.64	0.29	8.32		7.00	75.32	0.50	10.79		7.00	75.46	0.83	11.39
8	73.46	0.01	8.61			72.60	-0.06	8.61		8.00	75.39	0.38	10.69		8.00	75.34	0.57	11.08		8.00	75.48	0.89	11.36
9	72.77	-0.01	8.68			72.68	-0.08	8.55		9.00	72.95	0.26	8.72		9.00	75.39	0.50	11.04		9.00	75.48	0.80	11.38
10	73.87	3.00	9.28			73.19	-0.05	8.86		10.00	73.12	0.28	8.65		10.00	75.47	0.53	10.95		10.00	75.70	0.86	11.44
11	74.20	0.04	9.09			73.93	0.06	9.09		11.00	73.06	0.27	9.02		11.00	75.19	0.54	10.99		11.00	75.16	0.82	11.26
12	73.11	0.00	9.04			72.86	0.03	8.94		12.00	72.45	0.31	0.48		12.00	75.37	0.58	11.01		12.00	75.59	0.85	11.44
13	73.61	-0.04	9.24			73.26	-0.03	8.72		13.00	72.97	0.23	8.66		13.00	75.81	0.54	10.78		13.00	75.56	0.87	11.38
14	73.36	0.06	9.28			73.15	0.04	8.97		14.00	72.50	0.27	8.58		14.00	75.01	0.55	10.87		14.00	74.75	0.85	11.56
15	73.02	0.01	9.12			73.06	-0.02	8.84		15.00	73.30	0.28	8.91		15.00	75.36	0.56	10.92		15.00	75.11	0.87	11.43
16	72.95	-0.06	8.87			73.63	0.01	9.27		16.00	72.01	0.28	8.16		16.00	75.19	0.54	10.95		16.00	75.30	0.84	11.40
17	73.61	0.05	9.13			73.19	0.03	8.86		17.00	73.20	0.26	8.76		17.00	75.40	0.56	10.92		17.00	75.41	0.86	11.28
18	73.50	0.03	9.25			73.24	-0.03	8.80		18.00	73.01	0.24	8.98		18.00	75.22	0.56	10.98		18.00	75.40	0.78	11.38
19	73.21	-0.01	9.09			72.88	-0.07	8.61		19.00	72.90	0.27	8.55		19.00	75.57	0.52	10.99		19.00	75.69	0.83	11.54
20	72.87	-0.03	9.04			73.15	0.03	8.88		20.00	72.60	0.23	8.59		20.00	75.38	0.58	11.02		20.00	75.40	0.84	11.34

Table : Mean ΔE values for zirconia system on each type of abutment

Descriptive Statistics

Dependent Variable: dE

Abutment		Mean	Std. Deviation	N
Gold	BruxZir	4.15	0.74	20
	Katana	3.39	0.49	20
	LavaPlus	4.54	0.74	20
	ZirCAD	4.73	0.91	20
	Total	4.20	0.89	80
Pink	BruxZir	5.15	0.85	20
	Katana	3.63	0.81	20
	LavaPlus	4.74	1.14	20
	ZirCAD	5.01	0.77	20
	Total	4.63	1.07	80
Ti	BruxZir	4.00	0.47	20
	Katana	3.20	0.50	20
	LavaPlus	4.60	0.70	20
	ZirCAD	4.67	0.66	20
	Total	4.12	0.83	80
Zr	BruxZir	0.82	0.25	20
	Katana	0.56	0.12	20
	LavaPlus	0.84	0.21	20
	ZirCAD	0.94	0.31	20
	Total	0.79	0.27	80
Total	BruxZir	3.53	1.75	80
	Katana	2.70	1.36	80
	LavaPlus	3.68	1.82	80
	ZirCAD	3.84	1.82	80
	Total	3.44	1.75	320