COMPARISON OF MASKING ABILITY OF TWO CERAMICS IN TWO DIFFERENT THICKNESSES UNDER VARIOUS BACKGROUNDS

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Esthetic Restorative and Implant Dentistry
Faculty of Dentistry
Chulalongkorn University
Academic Year 2015

ผลของชนิดและความหนาของเซรามิกในการปิดสีพื้นหลังชนิดต่าง ๆ

นางสาวพอรัก เศรษฐกำเนิด

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาทันตกรรมบูรณะเพื่อความสวยงามและทันตกรรมรากเทียม
คณะทันตแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2558

Thesis Title	COMPARISON OF MASKING ABILITY OF TWO CERAMICS IN TWO DIFFERENT THICKNESSES UNDER VARIOUS BACKGROUNDS
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Field of Study	Esthetic Restorative and Implant Dentistry
Thesis Advisor	Associate Professor Chalermpol Leevailoj

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พอรัก เศรษฐกำเนิด : ผลของชนิดและความหนาของเซรามิกในการปิดสีพื้นหลังชนิดต่าง ๆ (COMPARISON OF MASKING ABILITY OF TWO CERAMICS IN TWO DIFFERENT THICKNESSES UNDER VARIOUS BACKGROUNDS) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ทพ. เฉลิมพล ลี้ไวโรจน์, 51 หน้า.

วัตถุประสงค์ : เพื่อศึกษาผลของความสามารถในการปิดสีพื้นหลังของเซรามิกต่างชนิดและความหนาบนพื้นหลังชนิดต่างๆ

วิธีการศึกษา : ชิ้นงานเซรามิกขนาดเส้นผ่านศูนย์กลาง 15 มม ความหนา 0.5 และ 1.0 มม จำนวน 36 ชิ้นทำจากลิเทียมไดซิลิเกต (IPS e.max Press, n=6), เซอร์โคเนียชนิดใส (Lava Plus, n=6), และ เซอร์โคเนียชนิดใส + วัสดุทาโครงชิ้นงาน (Lava Plus + Lava Ceram, n=6) นำไปทดสอบอัตราส่วนความเปรียบต่าง (contrast ratio) และความสามารถในการปิดสีพื้นหลัง (masking ability) ขาว ดำ โลหะ เรซิน คอมโพสิตสี A2 A3 และ C4 ด้วยเครื่องวัดเทียบสี (spectrophotometer) โดยให้พื้นหลังสีขาวเป็นกลุ่มควบคุม อัตราส่วนความเปรียบต่างได้จากการวัดความแตกต่างระหว่างชิ้นงานบนพื้นหลังขาวและดำ อัตราส่วนความเปรียบต่างและค่าความสามารถในการปิดสีที่ได้นำมาวิเคราะห์ทางสถิติด้วยการวิเคราะห์ความแปรปรวนแบบจำแนกสองและสามทางและทดสอบความแตกต่างระหว่างค่าเฉลี่ยรายคู่ โดยวิธีการเปรียบเทียบด้วยการใช้การทดสอบความแตกต่างระหว่างค่าเฉลี่ยรายคู่ (post hoc test) ด้วยวิธีของ Bonferroni (Bonferroni test) ที่ระดับนัยสำคัญ .05

ผลการทดสอบ : กลุ่มของ IPS e.max Press ที่ความหนา 0.5 และ 1 มม. มีอัตราส่วนความเปรียบต่างสูงสุด (0.73 ± 4.37 และ 0.87 ± 0.58) เมื่อเปรียบเทียบกับกลุ่ม Lava Plus + Lava Ceram และ Lava Plus กลุ่มของ IPS e.max Press มีความสามารถในการปิดสีพื้นหลังสูงสุด พื้นดำ (ΔE = 11.64 ± 0.84, 5.61 ± 0.29), พื้นโลหะ (ΔE = 10.31 ± 0.60, 5.08 ± 0.27), เรซิน คอมโพสิต A2 (ΔE = 8.54 ± 0.46, 4.23 ± 0.28), เรซิน คอมโพสิต A3 (ΔE = 8.26 ± 0.40, 4.22 ± 0.29), เรซิน คอมโพสิต C4 (ΔE = 9.12 ± 0.46, 4.64 ± 0.29) จากการวิเคราะห์ทางสถิติพบว่าความหนาและชนิดของเซรามิกมีความสัมพันธ์กับอัตราส่วนความเปรียบต่างและความสามารถในการปิดสีพื้นหลังที่อย่างมีนัยสำคัญ

สรุป : ชนิดและความหนาของเซรามิกมีความสัมพันธ์กับอัตราส่วนความเปรียบต่างและความสามารถในการปิดสีพื้นหลัง เมื่อความหนาเพิ่มขึ้นอัตราส่วนความเปรียบต่างและความสามารถในการปิดสีพื้นหลังเพิ่มขึ้น กลุ่ม IPS e.max Press มีอัตราส่วนความเปรียบต่างและความสามารถในการปิดสีพื้นหลังสูงอย่างมีนัยสำคัญ รองลงมากลุ่ม Lava Plus + Lava Ceram และ Lava Plus

สาขาวิชา ทันตกรรมบูรณะเพื่อความสวยงามและทันตกรรมรากเทียม

ลายมือชื่อนิสิต ....

ลายมือชื่อ อ.ที่ปรึกษาหลัก ....

ปีการศึกษา 2558

5475830732 : MAJOR ESTHETIC RESTORATIVE AND IMPLANT DENTISTRY
KEYWORDS: LITHIUM DISILICATE CERAMICS / ZIRCONIA CERAMICS / CONTRAST RATIO / MASKING ABILITY / OPACITY

PORAK SETHAKAMNERD: COMPARISON OF MASKING ABILITY OF TWO CERAMICS IN TWO DIFFERENT THICKNESSES UNDER VARIOUS BACKGROUNDS. ADVISOR: ASSOC. PROF. CHALERMPOL LEEVAILOJ, 51 pp.

Purpose: The objective of this study was to compare and evaluate the influence of material type and thickness on masking ability under various backgrounds.

Materials and Methods: A total of 36 disc-shaped specimens (15 mm diameter × 0.5 and 1.0 mm thicknesses) were fabricated from lithium disilicate glass ceramic (IPS e.max Press, n=6), high-translucency zirconia (Lava Plus, n=6), and high-translucency zirconia with framework modifier material (Lava Plus + Lava Ceram, n=6). Contrast ratio was measured over white and black background. Color difference was measured over various backgrounds: white, black, metal, resin composite shade A2, A3, and C4. White background was used as a control group. Contrast ratio and color difference values were analyzed with two and three-way ANOVA followed by Bonferroni post hoc test ($P<.05$).

Results: Contrast ratio of IPS e.max Press at 0.5 mm and 1.0 mm showed highest value (0.73 ± 4.37 and 0.87 ± 0.58) when compared to Lava Plus + Lava Ceram and Lava Plus groups. IPS e.max Press at both thickness showed highest masking ability over various backgrounds were as follows: Black (ΔE = 11.64 ± 0.84, 5.61 ± 0.29), Metal (ΔE = 10.31 ± 0.60, 5.08 ± 0.27), A2 (ΔE = 8.54 ± 0.46, 4.23 ± 0.28), A3 (ΔE = 8.26 ± 0.40, 4.22 ± 0.29), and C4 (ΔE = 9.12 ± 0.46, 4.64 ± 0.29). Higher contrast ratio and masking ability significantly related to thicker material. Material type significantly related to masking ability.

Conclusion: Ceramic type and thickness had significant effect on contrast ratio and masking ability. Contrast ratio and masking ability increase as thickness increase. Masking ability was highest with IPS e.max Press, intermediate with Lava Plus + Lava Ceram, and lowest with Lava Plus group.

Field of Study:	Esthetic Restorative and Implant Dentistry	Student's Signature	....
		Advisor's Signature	....
Academic Year:	2015		

ACKNOWLEDGEMENTS

Foremost, I would like to express my sincere gratitude to my adviser, Assoc. Prof. Chalermpol Leevailoj for the continuous support of my master study and research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all time of research and writing of this thesis. I could not have imagined having a better adviser and mentor for my master study.

Besides my adviser, I would like to thank the rest of my thesis committees: Dr. Jaijam Suwanwela and Dr. Vanthana Sattabanasuk, for their encouragement, insightful comments, and hard questions.

My sincere thank also goes to all staffs of Dental Research center, Chulalongkorn University, Mahidol University, and all the staffs in Esthetic Restorative and Implant Dentistry clinic for your support in this research.

Most importantly, none of this would have been possible without my family. I would like to thank my family for supporting me throughout my whole life.

Last but not the least, I would like to thank Ivoclar Vivadent. Co. Ltd., and 3M ESPE Co. Ltd. For their kindly support regarding to the supply of materials used in this study.

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CHAPTER I

INTRODUCTION

Rationale and Significance of the Problem

Over the past decade, ceramics have been used for tooth color restoration of anterior teeth.[1] Many factors are involved in the final color of all-ceramic restorations, for example, thickness and translucency of the ceramic, color of the luting resin cement, and color of the supporting substrate.[2-5] The supporting substrate, such as tooth or artificial materials, play a major role in the final color of ceramic restorations.[2] Previous studies reported that the final color of a 0.5 millimeter thick veneer, was affected by the supported substrate color.[6] Dark, or high opacity substrate, resulted in a detectable change of the final color after cementation when compared to a light or low opacity substrate.[7] The thickness of material regulates the translucency of the material.[8, 9] In addition, luting resin cement also has influence on the final color of restorations.[10] Therefore, matching the final color of all-ceramic restorations to natural teeth is still considered to be a difficult task and depends on subjective feeling.[11] Ceramic selection is considered to be a crucial decision to optimize the aesthetic outcome.[1]

The translucency of all-ceramic varies among selected systems. It strongly depends on the amount of light scattering, which is predominantly affected by their microstructure and thickness.[8, 9, 12] When compared to glass-based ceramics, zirconia is considered to be less translucent.[13, 14]

Contrast ratio (CR) is considered to be one of the measuring methods for translucency of all-ceramic systems and have been used in previous studies.[15, 16] Relative opacity of ceramic can be measured by the difference between specimens over black and white backgrounds. The space system of Y^{xy} was used to measure the contrast ratio as a ratio of reflectance (Y_b/Y_w), the value of specimen placed over black background (Y_b) relative to the value from the specimen placed over white background (Y_w). As opposing, when CR decreases, the translucency of the specimen increases.[17-19]

The masking ability of all-ceramic systems can be measured by the color difference (ΔE) when the specimen is placed over different backgrounds. There will be no color difference (ΔE = 0) if the masking ability is perfect.[19] The color difference of 3.3, was considered to be clinically acceptable by the perception of one or more operators, while another study reported the value of 6.8 to be regarded as clinically acceptable.[20, 21]

Shono et al. compared contrast ratio and masking abilities of 1.0 mm and 1.5 mm thick ceramic and found that lithium disilicate had the highest CR and masking ability when compared with feldspathic and alumina porcelain. Furthermore, they concluded that none of the materials were able to completely mask a black background.[2]

Azer et al. studied the effect of substrate shades on the color of ceramic laminate veneers, and evaluated the 0.5 mm thick veneers cemented on light and dark substrates. Results showed that the specimen with 0.5 mm thickness was significantly affected by the change of a supporting substrate color.[6] Similar results were found in the study of Li et al., which showed that the underlying color of the core had significant influence on the results of all-ceramic restoration color.[5]

The study of the influence of ceramic and cement thickness on the masking of various types of opaque posts found that the final color outcome was not affected by the color of the substrate when the specimen thickness was 2.0 mm. When thickness decreased to 1.5 mm, the color of the substrate affected the final color of all-ceramic restorations.[22]

Research Questions

Do Ceramic type and thickness have a significant effect on color masking ability?

Objective of the Study

The objective of study was to investigate the influence of ceramic type and thickness on masking ability.

Statement of Hypothesis

- Null Hypothesis:

Ceramic type and thickness do not have a significant effect on color masking ability.

- Alternative Hypothesis

Ceramic type and thickness have a significant effect on color masking ability.

Conceptual Framework

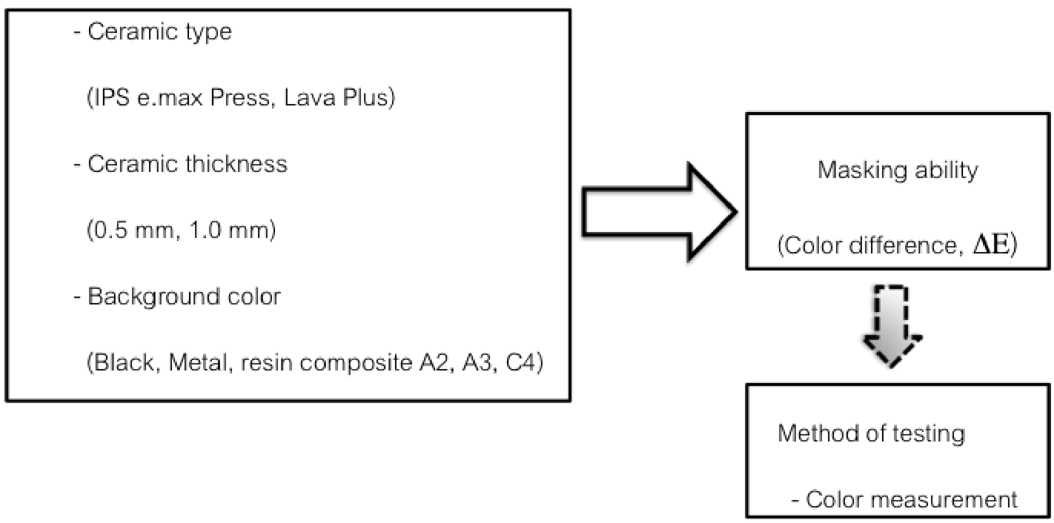

Figure 1 Diagram of conceptual framework

Basis Assumption

1. All procedures were performed under well-controlled conditions by one operator and evaluated by one examiner.
2. Ceramic specimens were fabricated according to manufacturer's instruction by one technician.
3. Lithium disilicate ceramics (IPS e.max) and zirconia (Lava Plus) were chosen in this study based on popularity using in Thailand.
4. In order to control the comparable thickness and the shininess of ceramic specimens, all ceramic specimens which used in this study were not glazed.

Study Limitation

1. This study focuses on the effect of masking ability of material not consider color factor in material. In clinical situation, color of material involved in ceramic restoration.
2. This experimental study is designed to reduce the difficulty of complex geometry of a full contour crown. Therefore, the flat plane of specimens was prepared for color measurement.

Keywords

Lithium disilicate ceramics/ Zirconia ceramics/ Contrast ratio/Masking ability/ Opacity /Translucency

The Expected Benefits

The results of this study might indicate whether the thicker and different type of ceramics have any effect on masking ability. For clinical application, it can be basic knowledge for improve the masking ability of all ceramic restoration in associated with masking the underlying dark substrates.

CHAPTER II

Review of Literatures

Dental ceramic

Ceramic have been introduced into restorative dentistry for many years. It can be classified by their microstructures which based on the amount and type of crystalline phase and glass composition. At microstructural level ceramics can be divided into four major categories and a few number of subgroups.[23]

- Category 1 – Glass-based systems (mainly silica)
- Category 2 - Glass-based system (mainly silica) with fillers
- Category 3 – Crystalline-based systems with glass fillers
- Category 4 – Polycrystalline solids

- Category 1: Glass based systems, Amorphous glass

The majority of the content is silicon dioxide (silica or quartz) with alumina. Synthetic form of aluminosilicates glasses are used for restoration in dentistry. And due to low flexural strength (60 – 70 MPa), the material of this category usually used as a veneering material.

- Category 2: Glass based systems, Crystalline second phase, Porcelain

The majority of the content is silicon dioxide. The crystal has been added to the glassy matrix which is leucite, lithium disilicate, or fluorapatite. This category can be further subdivided into three groups based on the amount and type of crystal.

Subcategory 2.1: Low-to-moderate leucite-containing feldspathic glass

Subcategory 2.2: High-leucite (approximately 50%) – containing glass, glass-ceramic

Subcategory 2.3: Lithium silicate glass-ceramic

Leucite has been added to change the coefficient of thermal expansion (CTE) an prohibit crack propagation in order to improve strength. Low-to-moderate leucite subcategory is process by the powder/liquid technique and used as a veneering material. The developed material of this subcategory was further developed into finer leucite crystals (10μm to 20 μm) with even distributed of particle. Therefore, the material occupies less abrasive with higher flexural strengths.

High-leucite containing glass mainly consists of glass matrix and surrounding with a second phase of crystals. The properties of glass ceramics subcategory based on the interaction of the crystals and glassy matrix and crystal size and amount. The second phase was added to a glass material to improve strength and fracture resistance. Empress (Ivoclar Vivadent) which fabricates through press technique has been widely used in dentistry field and also available in Empress CAD. The pressable and machinable fabricating technique has shown much higher fracture resistance when compared to the powder/liquid technique.

Lithium-disilicate subcategory is a truly glass-ceramic. The glass ceramic type was originally launched in the market as Empress II (Ivoclar Vivadent) and later this material was developed as IPS e.max. The crystal content has been increased up to 70% and the crystal size also has been further refined in order to improve flexural strength. The glass matrix of this subcategory contains lithium disilicate and micron-size of lithium disilicate (orthophosphate crystals). Even though the flexural strength is up to approximate 360 MPa but this material also displays translucency due to low refractive index of the lithium disilicate crystals. This material can serves as full-contour restorations.

- Category 3 – Crystalline-based systems with glass fillers

Interpenetrating phase ceramics consist of at least two phases intertwined and extend continuously from the internal and external surface. The material forms by creating a porous matrix and filled with a second-phase material which are lanthanum aluminosilicate glass to form a dense interpenetrating material. Flexural strength of this material varies from 360 Mpa (In-ceram spinell), 450 MPa (alumina), and 650 MPa (zirconia).

- Category 4 – Polycrystalline solids

This material creates by directly sintering crystals without any intervening matrix in order to form a dense, air-free, glass-free polycrystalline structure. It can be fabricates as aluminous oxide or zirconium oxide framework. Zirconia has high flexural strength range from approximately 900 MPa to 1100MPa and can be used for either multiple-unit anterior or posterior regions.

Contrast ratio

Translucency is the ability of a material to allow the presence color of an underlying background to show through.[24] Translucency can be measured from a translucency parameter (TP) or contrast ratio (CR).[24, 25] Translucency parameter is the difference of color between a uniform thickness of a material over a white and a black background, and corresponds directly to a visual assessment of translucency.[24] Contrast ratio is the ratio of the reflectance of a specimen over a black backing to that over a white backing of a known reflectance.[25]

In previous studies contrast ratio (CR) has been used as a measuring method of translucency of all-ceramic systems.[15, 16] Measurement of ceramic specimens on white and black backgrounds can be used to determine relative opacity of ceramics. Contrast ratio assessment can be obtained from Y_{xy} color space system as the ratio of reflectance (Y_b/Y_w) when the specimen placed over black relative (Y_b) to white backgrounds (Y_w). When Y_b is the measured reflectance of a material over a black background and Y_w is the measured reflectance of a material over a white background.

Enamel and dentin are translucent materials.[26] Restoration tooth structure especially in anterior region, the optical properties of the materials must be carefully considered in order to achieve the esthetic outcome. Translucency affects the overall appearance of the tooth structure. Enamel is more translucent when compared to dentin. And the major of the overall color comes from dentin which can be modified by the thickness and translucency of enamel. When light scatters through tooth, it creates the particular light interaction patterns, restoring material must replicate this pattern in order to achieve optimal esthetic outcome .[27] There are number of factors affecting matching the color of restorations to natural teeth such as translucency, opalescence, fluorescence, surface texture, and shape.[17]

Previous study reported that there was large deviation among transparency values among human teeth. Differences in age, gender, tooth shape, and anatomical variation may be the cause of the deviation. The study also shows that translucency tens to decrease from the incisal area toward the cervical area.[26] Therefore, matching color between restoration and natural teeth is considered to be problematic.

Masking ability

Color is defined as a sensation obtained through proprioceptive mechanisms and regarded as a complex psychophysiologic process subject to numerous variable factors. It can be standardized by the colorimetric techniques and convert it into terms of numeric values.[28] Evaluating the quality of final color outcome can be described as how well the restoration masks color of the underneath backgrounds when compared to natural adjacent teeth.[29] The complexity in assessing the final color outcome has been attributed to several variables involved. The supporting tooth structure or restorative foundation acts as a major source of the color.[6] The process of reproducing the final color also dependent on multiple factors, ceramic system, material thickness, shade of selected material, supporting substrate, and resin luting agent used.[11, 30, 31]

Assuming that **ΔE** = 0 and there is no color difference if the masking ability of the material is perfect.[19] However, the color difference value approximates 3.3 – 3.7 are considered as clinically acceptable.[20, 21] And some previous study shown that even when the value is 6.8 it still regarded as clinically acceptable as well.[21] Matching color between restoration and natural teeth still be problematic since there are many possible ranges of matching or mismatching in color evaluation. Color perception system of human is a complex system which based on both subjective and objective paradox. A visual measurement is not considered to be a reliable method due to inconsistency of each individual perception which related to experience and specialty. Therefore, it is crucial to draw the definite line between matching and mismatching.

CHAPTER III

MATERIALS AND METHODS

Operational Definition

1. IPS e.max Press HO 0 ingot (Lithium disilicate ceramics, Ivoclar Vivadent, Schaan, Liechtenstein)
2. Lava Plus (Zircoia ceramics, 3M ESPE, St Paul, MN, USA)
3. Lava Ceram shade MO W2 (Zirconia oxide veneering material, 3M ESPE, St Paul, MN, USA)
4. Masking ability test – The masking ability test is conducted by using the spectrophotometer machine (Ultrascan XE, Hunter Lab, VA, USA)

Research Design

This study is an experimental study which ceramics are used to investigate. Interventions of this study are type of ceramics (IPS e.max, Lava Plus, and Lava Ceram), thickness of ceramic, and substrates (black, metal, resin composite A2, A3, and C4). White substrate was used as control. Dependent variable is color difference values (ΔE).

Diagram of study design

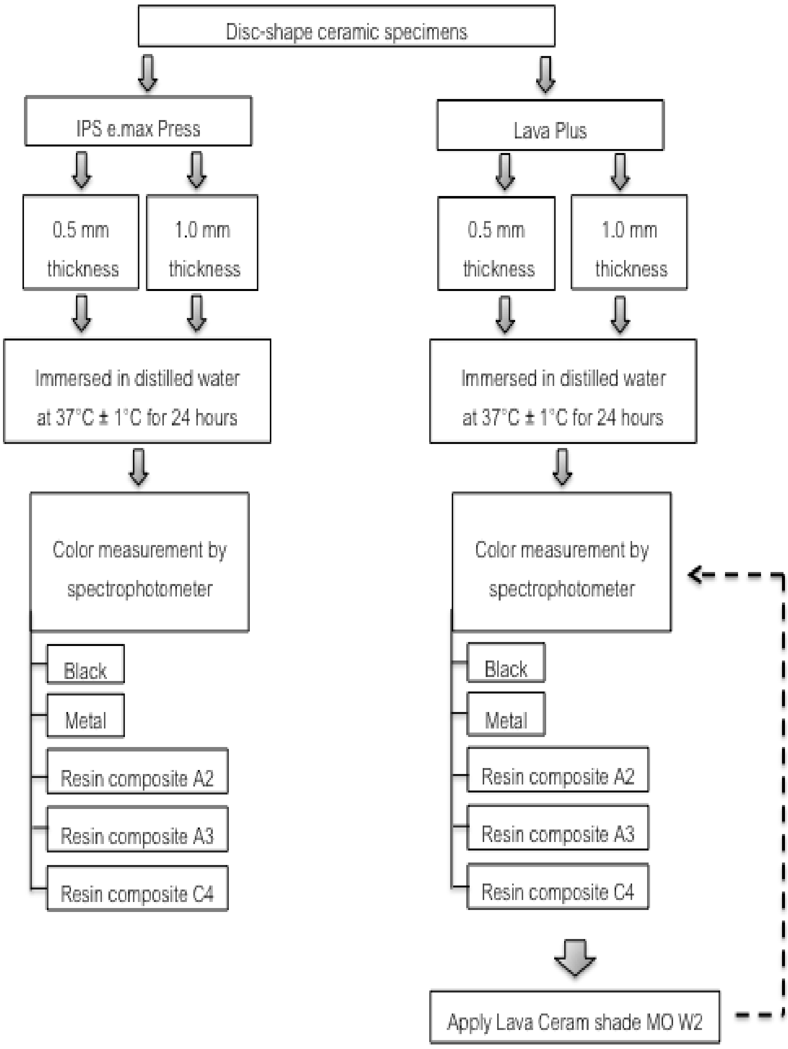

Figure 2 Diagram of study design

Sample Description

Samples of this study were 36 disc-shape specimens (IPS e.max, Lava Plus, and Lava Ceram).

Sample size estimation (n per group) was calculated from this formula

$$n = \frac{\sigma^2 Z^2}{e^2}$$

N = Sample size

σ = Standard deviation

Z = Value from standard normal distribution corresponding to desired confidence level (Z = 1.96 for 95%)

e = Expected value

According to the previous study, standard deviation was applied to calculate the sample size using STATA software (version 10). The number of sample size estimation was 30.11. Therefore, the number of specimens should be more than 30. But due to high price of the materials, the sample size of each group in this study is 6.

Materials

Table 1 Materials used in this study

Material	Manufacturer
IPS e.max Press HO 0 ingot	Ivoclar Vivadent, Schaan, Liechtenstein
Lava Plus High Translucency	3M ESPE, St Paul, MN, USA
Lava Ceram M0 W2	3M ESPE, St Paul, MN, USA
Filtek Z 350 composite resin	3M ESPE, St Paul, MN, USA
Automatic polishing machine (model DPS 3200)	IMPTECH, South Africa
Dial caliper	Aura-dental, Germany
Aluminum oxide polishing paper	3M ESPE, St Paul, MN, USA
Spectrophotometer	Ultrascan XE, Hunter Lab, VA, USA

A total of 36 disc-shaped specimens were fabricated from two types of ceramics and one with veneering material; IPS e.max Press HO 0 ingot (Ivoclar Vivadent, Schaan, Liechtenstein), Lava Plus (3M ESPE, St Paul, MN, USA), and Lava Plus with Lava Ceram shade MO W2 (3M ESPE). List of materials used in this study are shown in Table 1. Each group was further divided into two groups (n=6) according to the thickness (0.5 or 1.0 mm), comprising a total of six groups. The specimens were tested over five backgrounds: black, metal, resin composite shades A2, A3, and C4 (Z350; 3MESPE). A spectrophotometer, Ultrascan XE (Hunter Lab, VA, USA) with a wavelength range from 360 to 750 nanometers and a view area size of 9.525 mm was used in this study for color measurement.

Fabrication of ceramic specimens

Plastic sheets of 0.5 mm and 1.0 mm were cut into circular discs of 15 mm diameter using a heated metal pipe. Each disc shape was attached to a ring mold with sprue. The mold was filled with phosphate investment material (IPS e.max Press VEST Speed, Ivoclar Vivadent). After the burn-out step, ingots of bleach shade HO 0 (IPS e.max Press, Ivoclar Vivadent) were heated and then pressed according to manufacturer's instructions. The investment material around the specimens was then removed by a carborundum disc.

Later, the specimens were subjected to airborne-particle abrasion with two bars of 50 μm aluminum oxide (Renfert GmbH, Hilzingen, Germany). The left over investment was cleansed ultrasonically (IPS e.max Press Invex liquid; Ivoclar Vivadent) (Fig 3).

The ceramic specimens were polished with 600, 800, 1000, and 1200 grit abrasive papers. Five measurements were made in five different locations around the center of the disc with a praecimeter (Aura-Dental GmbH, Aura an der Saale, Germany) to confirm the thickness at 0.5 ± 0.05 mm or 1.0 ± 0.05 mm. All ceramic specimens were immersed in distilled water at 37°C ± 1°C for 24 hours before color measurement.

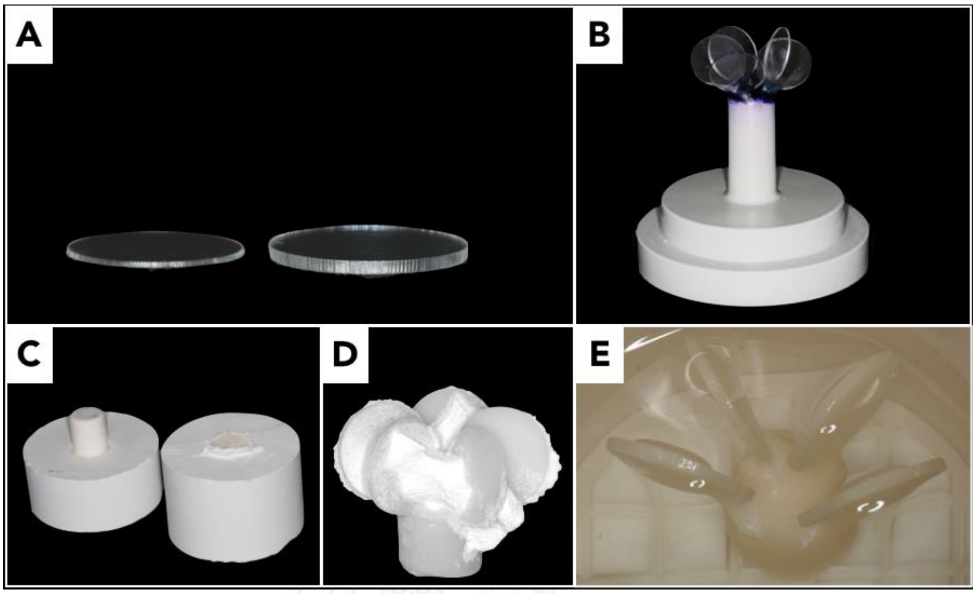

Figure 3 Plastic sheet diameter 15 mm with 0.5 and 1.0 mm thickness specimens (A), attached to a ring mold with sprue (B), remove investment with carborundum disc (C), sandblast the remaining investment with aluminum oxide D), and ultrasonically cleansed with IPS invex Press liquid (E).

The pre-sintered blocks of Lava Plus were cut into discs of 18 mm diameter with thickness of 0.6 mm and 1.2 mm in order to compensate for the shrinkage of about 20%. After sintering, the Lava Plus specimens were immersed in distilled water at 37°C ± 1°C for 24 hours, followed by polishing with aluminum oxide paper (3M ESPE) using 320, 500 and 1000 grit. A praecimeter was used to measure five points of location for all specimens to confirm the thickness. All ceramic specimens were immersed in distilled water at 37°C ± 1°C for 24 hours before color measurement.

Fabrication of backgrounds

Five different backgrounds of 37.80 mm diameter and 1.94 mm in thickness were studied: black, metal, and shades A2, A3 and C4 of resin composite. A white background was used as a control. Backgrounds were attached to the handle in front of the spectrophotometer. The black and white backgrounds were provided by Hunter Lab.

A metal sheet background was casted from non-precious metal and sandblasted with 2 bars of 50 μm aluminum oxide (Renfert GmbH) to eliminate shininess in order to simulate a metal post in endodontically treated teeth.

To simulate dentin color, the backgrounds of resin composite shades were fabricated by preparing a polyvinyl chloride (PVC) pipe mold for duplication material. A metal sheet was used as reference for the impression of the PVC mold using vinylpolysiloxane (VPS) putty (Variotime, Heraeus, Germany) and light silicone (Silagum, DMG, Germany). The metal sheet was attached to the glass slab with double-sided tape. A PVC pipe was placed above the metal sheet, which was then poured over with VPS material. The procedure was done with a vibrator to avoid void formation. After the silicone was completely set, the mold was removed from the PVC pipe.

Resin composite was preheated to facilitate flow into the silicone mold. It was then pressed on a glass slab and light cured with a visible-light-polymerization unit (Demi Plus, Kerr Corporation, Orange, Calif.) at 750 mW/cm^2 for 40 seconds. To prevent penetration of excess light, additional resin composite of 15 mm in diameter and 1.0 mm in thickness was added onto the specimen. The excess circumferential space around the specimen was compensated with clear resin.

All resin composite backgrounds were polished under water coolant in an automatic polishing machine (DPS 3200, IMTECH, Durban, South Africa) with 600, 800, 1000, and 1200 grit abrasive papers. The backgrounds were immersed in distilled water at 37°C ± 1°C for 24 hours before color measurement.

Spectrophotometric analysis

Color measurements of all the twelve Lava Plus discs were performed by spectrophotometer (Ultralscan XE, Hunter Lab). Then the discs were applied with Lava Ceram shade MO W2, according to the manufacturer's recommendations, and the color difference was measured again.

Before each measurement, the spectrophotometer was calibrated with standard black and white backgrounds according to the manufacturer's instructions. First, the white control background was placed on the handle of the spectrophotometer followed by black, then metal, resin composite shades of A2, A3, and finally with C4 backgrounds. The edges of specimens were fixed with double-sided tape to expose the view area. Each background was then placed on the handle of the spectrophotometer and was kept approximate to the specimen.

Measurements were done for each specimen with various backgrounds. The equation: $\Delta E^*_{ab} = ((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)^{½}$ was used to calculate the color difference between groups.

CHAPTER IV

RESULTS

Contrast ratio

Mean contrast ratio ± SD of 0.5 and 1.0 mm thickness sample were: 0.73 ± 4.37 and 0.87 ± 0.58 for IPS e.max Press; 0.69 ± 0.87 and 0.76 ± 1.50 for Lava Plus + Lava Ceram; and 0.67 ± 0.56 and 0.76 ± 0.51 for Lava Plus (Table 2). IPS e.max Press group revealed highest contrast ratio followed by Lava Plus + Lava Ceram and lowest in Lava Plus group (Figure 4).

Table 2 Mean contrast ratio values and standard deviations (±SD)

Ceramic materials	Thickness (mm)	Mean contrast ratio
IPS e.max Press	0.5	0.73 ±4.37
	1.0	0.87 ±0.58
Lava Plus + Lava Ceram	0.5	0.69 ±0.87
	1.0	0.76 ±1.50
Lava Plus	0.5	0.67 ±0.56
	1.0	0.76 ±0.51

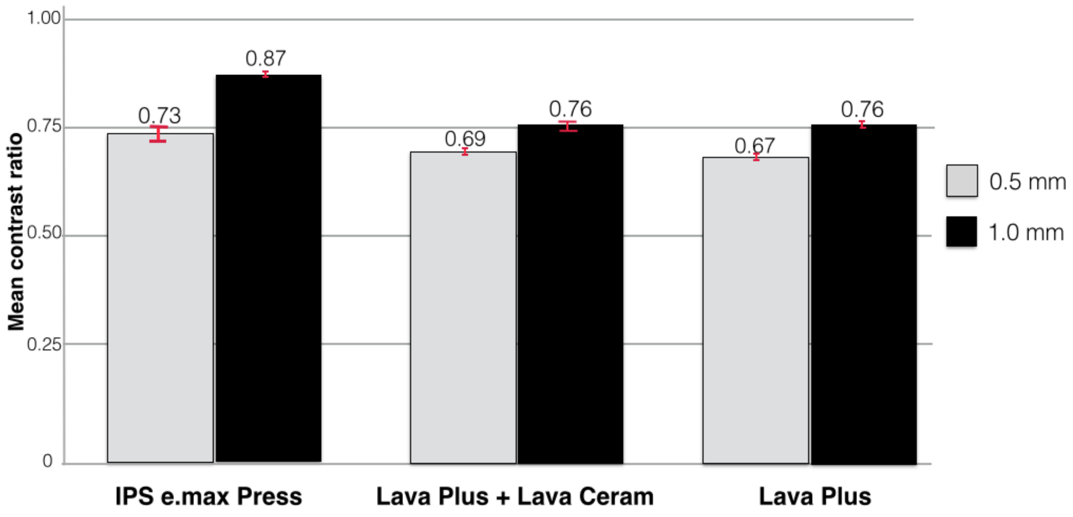

Figure 4 Graph showing mean contrast ratio values for all ceramic specimens.

Table 3 Two-Way ANOVA results for comparison of contrast ratio

	Sum of Square	*df*	Mean Square	F value	Sig
Materials	495.14	2	247.57	64.66	0.0001
Thickness	911.03	1	911.03	237.95	0.0001
Materials*Thickness	72.55	2	36.28	9.47	0.0001

The mean difference is significant at the 0.05 level.

R Squared = .882

Two-way ANOVA showed significant difference in contrast ratios between different materials. IPS e.max Press group presented significantly higher contrast ratios than Lava Plus and Lava Plus + Lava Ceram groups (*P*<0.0001). No significant difference was found between Lava Plus + Lava Ceram and Lava Plus group. Similarly, a significant difference (*P*<0.0001) was found in two different thicknesses. Ceramics with a thickness of 1.0 mm showed significantly higher contrast ratios than 0.5 mm (Table 3).

Masking ability

ΔE values of 0.5 mm thickness sample over black, metal, A2, A3, and C4 backgrounds (Table 4) were lowest in IPS e.max Press (11.64 ± 0.84, 10.31 ± 0.60, 8.54±0.46, 8.26±0.40, 9.12 ± 0.46) followed by Lava Plus + Lava Ceram (12.48 ± 0.50, 10.98 ± 0.51, 8.83 ± 0.52, 8.62 ± 0.42, 9.71 ± 0.44), and highest in Lava Plus group (13.61 ± 0.28, 11.89 ± 0.27, 9.20 ± 0.57, 9.44 ± 0.34, 10.35 ± 0.52).

Table 4 Mean color difference (ΔE) values and standard deviations (±SD) between specimens of different backgrounds

Groups	Thickness (mm)	Mean color difference values				
		Black	Metal	A2	A3	C4
IPS e.max Press	0.5	11.64±0.84	10.31±0.60	8.54±0.46*	8.26±0.40*	9.12±0.46
	1.0	5.61±0.29	5.08±0.27	4.23±0.28*	4.22±0.29*	4.64±0.29
Lava Plus + Lava Ceram	0.5	12.48±0.50	10.98±0.51	8.83±0.52*	8.62±0.42*	9.71±0.44
	1.0	9.29±0.16	8.07±0.28	6.71±0.29*	6.39±0.31*	7.09±0.13
Lava Plus	0.5	13.61±0.28	11.89±0.27	9.20±0.57*	9.44±0.34*	10.35±0.52
	1.0	10.04±0.34	8.90±0.21	7.04±0.32*	7.10±0.23*	7.95±0.22

* No significant differences were found in the same row or column.

For 1.0 mm thickness samples, ΔE values over black, metal, A2, A3, and C4 backgrounds (Table 4) were lowest in IPS e.max Press (5.61 ± 0.29, 5.08 ± 0.27, 4.23 ± 0.28, 4.22 ± 0.29, 4.64 ± 0.29) followed by Lava Plus + Lava Ceram (9.29 ± 0.16, 8.07 ± 0.28, 6.71 ± 0.29, 6.39 ± 0.31, and 7.09 ± 0.13), and highest in Lava Plus group (10.04 ± 0.34, 8.90 ± 0.21, 7.04 ± 0.32, 7.10 ± 0.23, and 7.95 ± 0.22). From the results revealed, IPS e.max Press has the highest degree of masking ability followed by Lava Plus + Lava Ceram and lowest in Lava Plus group (Figure 5).

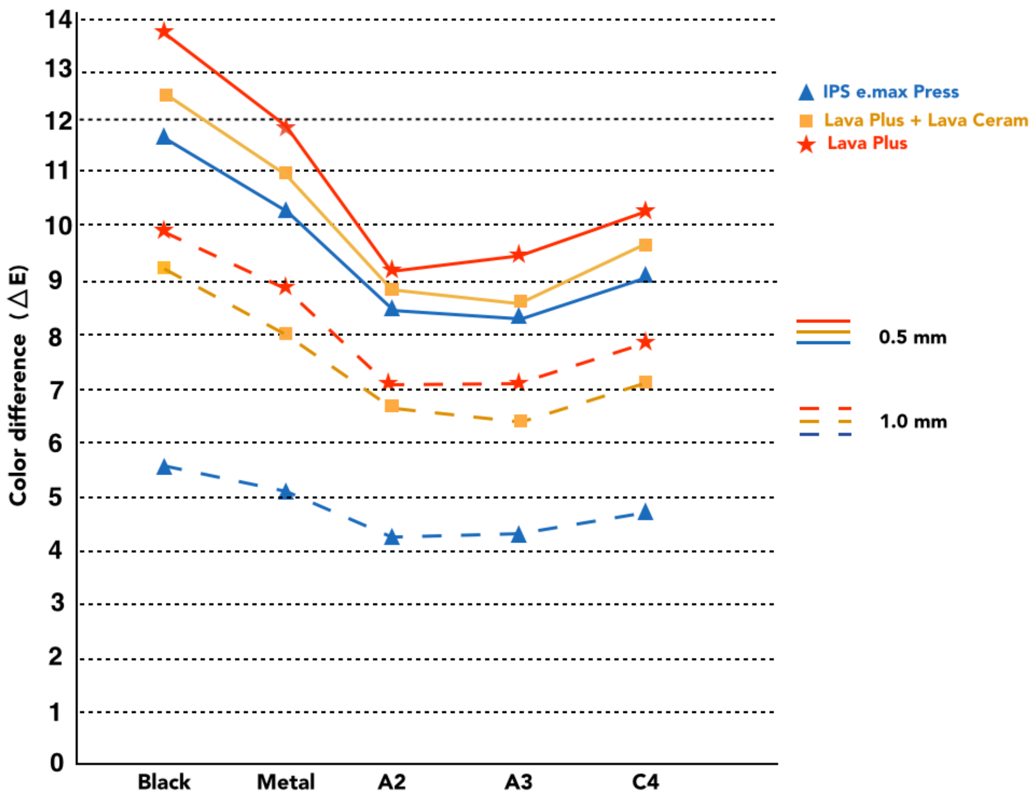

Figure 5 Graph showing mean color difference values for all ceramic specimens

Three-way ANOVA results (Table 5) indicated statistically significant effects for materials, thickness, and backgrounds. The results showed three-way interaction between materials, thicknesses, and backgrounds. Bonferroni post hoc test showed no significant difference in ΔE values between resin composite shade A2 and A3 backgrounds, regardless to material or thickness.

Table 5 Three-Way ANOVA results of color difference (ΔE) values comparison followed by Bonferroni post hoc test

	Sum of Square	*df*	Mean Square	F value	Sig
Materials	181.37	2	90.69	575.328	0.0001
Thickness	509.44	1	509.44	3232.017	0.0001
Backgrounds	252.03	4	63.01	399.736	0.0001
Materials*Thickness	47.45	2	23.73	150.522	0.0001
Materials*Background	9.32	8	1.17	7.391	0.0001
Thickness*Background	12.41	4	3.10	19.686	0.0001
Materials*Thickness*Background	1.24	8	0.16	0.984	0.4503

The mean difference is significant at the 0.05 level.

R squared = .977

IPS e.max Press group revealed significantly lower ΔE values when compared to Lava Plus+ Lava Ceram and Lava Plus groups. For all groups, ΔE were significantly decreased when the thickness was increased from 0.5 mm to 1.0 mm.

CHAPTER V

DISCUSSIONS AND CONCLUSIONS

Discussions

The study investigated the contrast ratios and masking ability of different ceramic types with two different thicknesses. The null hypothesis stated that ceramic type and thickness do not have a significant effect on masking ability. However, the results revealed that there was significant difference of the ceramic type and thickness on contrast ratios and masking ability. Therefore, the null hypothesis was rejected.

The result showed that the IPS e.max Press exhibited significantly higher contrast ratio values than the Lava Plus or Lava Plus + Lava Ceram, consistent with the strong correspondence of contrast ratios and masking ability reported by others.[32, 33] This result could be due to the translucency type chosen for the ceramic groups, as high opacity of IPS e.max Press has the lowest translucency when compared with other shades in the same group.

Lava Plus exhibits more translucent properties when compared to the traditional Lava. Moreover, the Lava Ceram coat applied on the Lava Plus ceramic exhibits low opacity. This explains the results showed no significant difference between Lava Plus and Lava Plus with Lava Ceram coating. In addition, color may influence the level of translucency. A study done by Kurtulmus-Yilmaz et al. reported a decrease in translucency of such materials as color saturation increased.[34] Furthermore, Aboushelib et al. found that when a white zirconia framework was replaced with a colored framework, it was able to mask the underlying dark background.[35]

All three ceramic groups in this study demonstrated the strong influence of thickness on increasing contrast ratios, as described previously.[12, 18, 26, 36] Antonson et al. showed thickness and contrast ratios to have a direct linear relationship.[37] Other studies also found contrast to be significantly affected by an additional 0.5 mm thickness of various ceramics. Contrast ratio increases as thickness increases respectively.[6, 37, 38]

In our study, contrast ratios are also strongly correlated with color difference values, which was in agreement with a previous study showing strong correlation of contrast ratios and masking ability.[32, 33]

In regard to matching color (ΔE = 3.3), IPS e.max Press group demonstrated the greatest degree of masking ability among the three ceramics compared, followed by the Lava Plus with Lava Ceram and Lava Plus groups. Therefore, it was expected beforehand that the contrast ratios of Lava Plus with or without Lava Ceram groups would not be significantly different. However, these groups of samples did differ significantly on masking ability. This unexpected outcome could be due to the increased thickness of the Lava Plus after Lava Ceram was applied. Also, Lava Ceram confers some slight opacity, which have helped masked the underlying background.

Lava Plus with Lava Ceram group exhibited significantly higher masking ability when compared to Lava Plus group. The result showed that Lava Ceram has masking ability property which benefits in masking the underlying backgrounds. Lava Ceram can be used as a framework color modifier in order to enhance the framework color and mask the color of the underlying substrates.

The 1.0 mm thickness was significantly better in masking the underlying background than the 0.5 mm thickness. This was probably a simple direct result of the increased 0.5 mm distance that light must penetrate.[39] Regarding color differences, all but the A2 and A3 backgrounds differed significantly from each other. The similarity of these two shades probably explained this finding.

Higher translucency reinforces other features of ceramic to produce teeth with natural looking characteristics. Meanwhile, low translucency material was able to mask the underlying dark backgrounds but might not create the natural tooth characteristics at the same time. To mimic and gain supreme esthetic result, restorative materials should have proper opacity which can mask the underlying color of substrates and should offer optimum translucency to represent the natural translucency of the teeth.[40]

In order to increase masking ability, some further reduction of tooth structure may be required, which might lead to pulpal injury. Ceramic core thickness can be used in conjunction with a veneering material thickness to obtain the final color.[8] Core material should be chosen with extra care as it affects the final color outcome.[41]

Clinically acceptable of color differences vary in practical daily life, as color perception varies among individuals. In this study, the smallest color difference was 5.61, which is worse than the clinically acceptable color difference range from 3.3 to 3.7,[19-21, 42] although some studies suggest values 5.0 are clinically acceptable. Others reported values up to 6.8.[21] Another disagreed with masking the tooth color, even though its color differences were less than 10.[43] From this study, the results showed that none of the materials tested were able to completely mask the underlying dark backgrounds.

Our finding of differences between the lithium disilicate glass and high-translucency zirconium-oxide based materials that were studied was in contrast to previous studies which showed no significant effect of using different materials being manufactured from different companies. [28, 34, 41, 44]

The selection and use of resin luting cement can be challenging in achieving an optimal aesthetic outcome of an underlying tooth shade, given its interaction with the ceramic used.[6, 29, 45] A study found that a luting agent without opaque qualities did not enhance masking of a darkened background.[29] Another reported that the shade of cement used significantly affected the final outcome of the ceramic at 0.5 mm thickness.[6]

The limitation in this study use only one color measurement equipment (UltraScan XE) and only one shade, with no chroma involved. The color measurement machine was not designed for antireflective coating solution. Therefore, the solution was not used in this study. Further studies are necessary to study and investigate the effect of color of core material, opaque coat, and cement color.

Conclusion

Within the limitations of this in study on two ceramic core systems, conclusions could be drawn that

- At both 0.5 mm and 1.0 mm thicknesses, the IPS e.max Press (lithium disilicate) material was the most opaque, with the highest contrast ratio and masking ability.
- Increased thickness significantly improved contrast ratio and masking ability.

Clinical Implications

Increased ceramic thickness could benefit masking ability. IPS e.max Press HO ingot are recommended in masking underlying dark backgrounds when compared with Lava Plus.

REFERENCES

1. Kelly JR, Nishimura I, Campbell SD. Ceramics in dentistry: historical roots and current perspectives. J Prosthet Dent. 1996;75(1):18-32.

2. Shono NN, Al Nahedh HN. Contrast ratio and masking ability of three ceramic veneering materials. Oper Dent. 2012;37(4):406-16.

3. Bichacho N. Porcelain laminates: integrated concepts in treating diverse aesthetic defects. Practical periodontics and aesthetic dentistry : PPAD. 1995;7(3):13-23.

4. Calamia JR, Calamia CS. Porcelain laminate veneers: reasons for 25 years of success. Dental Clin N AM. 2007;51(2):399-417.

5. Li Q, Yu H, Wang YN. Spectrophotometric evaluation of the optical influence of core build-up composites on all-ceramic materials. Dental Mater. 2009;25(2):158-65.

6. Azer SS, Rosenstiel SF, Seghi RR, Johnston WM. Effect of substrate shades on the color of ceramic laminate veneers. J Prosthet Dent. 2011;106(3):179-83.

7. Chaiyabutr Y, Kois JC, Lebeau D, Nunokawa G. Effect of abutment tooth color, cement color, and ceramic thickness on the resulting optical color of a CAD/CAM glass-ceramic lithium disilicate-reinforced crown. J Prosthet Dent. 2011;105(2):83-90.

8. Michael J. Heffernan SAA, Ana M. Diaz-Arnold, Debra R. Haselton, Clark M. Stanford, and Marcos A. Vargas. Relative translucency of six all-ceramic systems. Part II core and veneer materials. J Proshtet Dent. 2002;88(1).

9. Seghi RR, Johnston WM, O'Brien WJ. Spectrophotometric analysis of color differences between porcelain systems. J Prosthet Dent. 1986;56(1):35-40.

10. Turgut S, Bagis B. Effect of resin cement and ceramic thickness on final color of laminate veneers: an in vitro study. J Prosthet Dent. 2013;109(3):179-86.

11. Wee AG, Monaghan P, Johnston WM. Variation in color between intended matched shade and fabricated shade of dental porcelain. J Prosthet Dent. 2002;87(6):657-66.

12. Brodbelt RH, O'Brien WJ, Fan PL. Translucency of dental porcelains. J Dent Res. 1980;59(1):70-5.

13. Michael J. Heffernan SAA, Ana M. Diaz-Arnold, Debra R. Haselton, Clark M. Stanford, and Marcos A. Vargas. Relative translucency of six all-ceramic systems. Part I: Core materials. J Prosthet Dent. 2002;88(1).

14. Chen YM, Smales RJ, Yip KH, Sung WJ. Translucency and biaxial flexural strength of four ceramic core materials. Dent Mater. 2008;24(11):1506-11.

15. Johnston WM. Review of translucency determinations and applications to dental materials. J Esthet Restor Dent. 2014;26(4):217-23.

16. Seghi RR, Hewlett ER, Kim J. Visual and instrumental colorimetric assessments of small color differences on translucent dental porcelain. J Dent Res. 1989;68(12):1760-4.

17. Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part I: core materials. J Prosthet Dent. 2002;88(1):4-9.

18. Antonson SA, Anusavice KJ. Contrast ratio of veneering and core ceramics as a function of thickness. The Int J Prosthodont. 2001;14(4):316-20.

19. Chu FC, Chow TW, Chai J. Contrast ratios and masking ability of three types of ceramic veneers. J Prosthet Dent. 2007;98(5):359-64.

20. Ruyter IE, Nilner K, Moller B. Color stability of dental composite resin materials for crown and bridge veneers. Dent Mater. 1987;3(5):246-51.

21. Johnston WM, Kao EC. Assessment of appearance match by visual observation and clinical colorimetry. J Dent Res. 1989;68(5):819-22.

22. Vichi A, Ferrari M, Davidson CL. Influence of ceramic and cement thickness on the masking of various types of opaque posts. J Prosthet Dent. 2000;83(4):412-7.

23. Giordano R, McLaren EA. Ceramics overview: classification by microstructure and processing methods. Compend Contin Educ Dent. 2010;31(9):682-4, 6, 8.

24. Johnston WM, Ma T, Kienle BH. Translucency parameter of colorants for maxillofacial prostheses. The Int J Prosthodont. 1995;8(1):79-86.

25. Miyagawa Y, Powers JM, O'Brien WJ. Optical properties of direct restorative materials. J Dent Res. 1981;60(5):890-4.

26. Bin Yu J-SA, Yong-Keun Lee. Measurement of translucency of tooth enamel and dentin. Acta Odontol Scand. 2009;67.

27. Raptis NV, Michalakis KX, Hirayama H. Optical behavior of current ceramic systems. Int J Periodontics Restorative Dent. 2006;26(1):31-41.

28. Bagis B, Turgut S. Optical properties of current ceramics systems for laminate veneers. J Dent. 2013;41.

29. de Azevedo Cubas GB, Camacho GB, Demarco FF, Pereira-Cenci T. The Effect of Luting Agents and Ceramic Thickness on the Color Variation of Different Ceramics against a Chromatic Background. Eur J Dent. 2011;5(3):245-52.

30. Dozic A, Kleverlaan CJ, Meegdes M, van der Zel J, Feilzer AJ. The influence of porcelain layer thickness on the final shade of ceramic restorations. J Prosthet Dent. 2003;90(6):563-70.

31. Lee YK, Cha HS, Ahn JS. Layered color of all-ceramic core and veneer ceramics. J Prosthet Dent. 2007;97(5):279-86.

32. Chu FC, Sham AS, Luk HW, Andersson B, Chai J, Chow TW. Threshold contrast ratio and masking ability of porcelain veneers with high-density alumina cores. The Int J Prosthodont. 2004;17(1):24-8.

33. Karine T.L. Barizon CB, Marcos A. Vargas, Fang Qiand, Deborah S. Cobb, David G. Gratton, Saulo Geraldeli. Ceramic Materials for porcelain veneers. Part I: Correlation between translucency parameters and contrast ratio. J Prosthet Dent. 2013;110(5).

34. Kurtulmus-Yilmaz S, Ulusoy M. Comparison of the translucency of shaded zirconia all-ceramic systems. J Adv Prosthodont. 2014;6(5):415-22.

35. Aboushelib MN, Dozic A, Liem JK. Influence of framework color and layering technique on the final color of zirconia veneered restorations. Quintessence Int. 2010;41(5):e84-9.

36. Yaman P, Qazi SR, Dennison JB, Razzoog ME. Effect of adding opaque porcelain on the final color of porcelain laminates. J Prosthet Dent. 1997;77(2):136-40.

37. O'Keefe KL, Pease PL, Herrin HK. Variables affecting the spectral transmittance of light through porcelain veneer samples. J Prosthet Dent. 1991;66(4):434-8.

38. Ozge Ozturk AU, Volkan, Gozde Celik. The effect of ceramic thickness and number of firings on the color of two all-ceramic systems.J Prosthet Dent. 2009;100(2).

39. Ilie N, Stawarczyk B. Quantification of the amount of light passing through zirconia: the effect of material shade, thickness, and curing conditions. J Dent. 2014;42(6):684-90.

40. Fabbri G, Mancini R, Marinelli V, Ban G. Anterior discolored teeth restored with procera all-ceramic restorations: a clinical evaluation of the esthetic outcome based on the thickness of the core selected. Eur J Esthet Dent. 2011;6(1):76-86.

41. Kim JH, Kim KB, Kim WC, Kim HY, Kim JH. Evaluation of the color reproducibility of all-ceramic restorations fabricated by the digital veneering method. J Adv Prosthodont. 2014;6(2):71-8.

42. Vichi A, Ferrari M, Davidson CL. Color and opacity variations in three different resin-based composite products after water aging. Dent Mater. 2004;20(6):530-4.

43. Aki Yoshida SI-N, John D. Da Silva. Opacity Control of Zirconia Restorations. Quintessence Dent Technol. 2010;33:173.

44. Fazi G, Vichi A, Corciolani G, Ferrari M. Spectrophotometric evaluation of color match to VITA classical shade guide of four different veneering porcelain systems for metal ceramic restorations. Am J Dent. 2009;22(1):19-22.

45. Denry I, Kelly JR. State of the art of zirconia for dental applications. Dent Mater. 2008;24(3):299-307.

APPENDIX

Opacity

No. of specimen	Opacity
IPS e.max Press 0.5 mm thickness	
1	0.70
2	0.71
3	0.73
4	0.70
5	0.71
6	0.81
IPS e.max Press 1.0 mm thickness	
1	0.86
2	0.86
3	0.88
4	0.87
5	0.87
6	0.86
Lava Plus 0.5 mm thickness	
1	0.68
2	0.68
3	0.68
4	0.67
5	0.67
6	0.66

No. of specimen	Opacity
Lava Plus 1.0 mm thickness	
1	0.75
2	0.76
3	0.75
4	0.76
5	0.76
6	0.76
Lava Plus + Lava Ceram 0.5 mm thickness	
1	0.68
2	0.67
3	0.69
4	0.69
5	0.70
6	0.69
Lava Plus + Lava Ceram 1.0 mm thickness	
1	0.76
2	0.74
3	0.78
4	0.75
5	0.76
6	0.78

Masking Ability

No. of specimens	ΔL	Δa	Δb	ΔE
IPS e.max Press 0.5 mm thickness on black background				
1	-11.75	0.08	-4.06	12.43
2	-11.59	0.03	-3.86	12.22
3	-10.32	0.05	-1.16	10.39
4	-10.99	0.00	-3.72	11.60
5	-10.17	0.04	-3.92	10.90
6	-11.71	0.07	-3.78	12.31
IPS e.max Press 0.5 mm thickness on metal background				
1	-10.30	0.27	-3.36	10.84
2	-10.12	0.20	-3.20	10.62
3	-9.55	0.17	-0.60	9.57
4	-9.83	0.21	-3.10	10.31
5	-9.01	0.15	-3.28	9.59
6	-10.46	0.16	-3.13	10.92
IPS e.max Press 0.5 mm thickness on A2 background				
1	-8.54	0.35	-2.14	8.81
2	-8.46	0.39	-2.07	8.72
3	-8.01	0.48	0.64	8.05
4	-8.47	0.30	-2.05	8.72
5	-7.54	0.36	-2.28	7.89
6	-8.80	0.34	-1.98	9.03

No. of specimens	ΔL	Δa	Δb	ΔE
IPS e.max Press 0.5 mm thickness on A3 background				
1	-8.31	0.58	-1.75	8.51
2	-8.23	0.54	-1.67	8.42
3	-8.42	0.47	0.44	8.44
4	-7.80	0.59	-1.36	7.94
5	-7.34	0.46	-1.90	7.60
6	-8.49	0.57	-1.54	8.65
IPS e.max Press 0.5 mm thickness on C4 background				
1	-9.26	0.62	-2.08	9.51
2	-8.59	0.75	-1.42	8.74
3	-8.95	0.47	0.09	8.96
4	-9.09	0.49	-2.04	9.33
5	-8.18	0.55	-2.24	8.50
6	-9.49	0.54	-1.90	9.69
IPS e.max Press 1.0 mm thickness on black background				
1	-5.13	-0.21	-2.85	5.87
2	-5.66	-0.08	-1.92	5.99
3	-4.47	-0.17	-2.87	5.31
4	-4.80	-0.21	-2.94	5.63
5	-4.38	-0.17	-2.95	5.28
6	-5.07	-0.15	-2.31	5.57
IPS e.max Press 1.0 mm thickness on metal background				
1	-4.71	-0.14	-2.51	5.34
2	-5.16	0.01	-1.59	5.41
3	-4.10	-0.11	-2.49	4.80
4	-4.38	-0.14	-2.63	5.11
5	-3.94	-0.11	-2.63	4.75
6	-4.66	-0.03	-2.02	5.08

No. of specimens	ΔL	Δa	Δb	ΔE
IPS e.max Press 1.0 mm thickness on A2 background				
1	-3.74	0.09	-1.68	4.11
2	-4.58	0.06	-1.04	4.71
3	-3.55	-0.02	-2.07	4.11
4	-3.55	0.05	-1.85	4.00
5	-3.41	0.00	-2.12	4.02
6	-4.16	0.05	-1.55	4.45
IPS e.max Press 1.0 mm thickness on A3 background				
1	-4.05	0.12	-1.90	4.48
2	-4.47	0.15	-0.86	4.55
3	-3.44	0.03	-1.85	3.91
4	-3.79	0.06	-1.94	4.26
5	-3.33	0.10	-1.91	3.85
6	-4.05	0.15	-1.38	4.29
IPS e.max Press 1.0 mm thickness on C4 background				
1	-4.35	0.05	-2.15	4.86
2	-4.85	0.15	-1.09	4.97
3	-3.77	0.08	-2.13	4.34
4	-4.04	0.01	-2.18	4.59
5	-3.66	0.02	-2.19	4.27
6	-4.51	0.12	-1.64	4.80
Lava Plus 0.5 mm thickness on black background				
1	-13.75	0.47	-2.57	14.00
2	-13.12	0.45	-2.84	13.43
3	-12.93	0.56	-2.62	13.20
4	-13.33	0.51	-2.72	13.61
5	-13.59	0.48	-2.45	13.82
6	-13.26	0.52	-2.88	13.58

No. of specimens	ΔL	Δa	Δb	ΔE
Lava Plus 0.5 mm thickness on metal background				
1	-12.17	0.66	-1.94	12.34
2	-11.63	0.59	-2.20	11.85
3	-11.32	0.60	-1.88	11.49
4	-11.75	0.63	-2.02	11.94
5	-11.80	0.62	-1.71	11.94
6	-11.58	0.61	-2.21	11.80
Lava Plus 0.5 mm thickness on A2 background				
1	-9.21	0.78	-0.07	9.25
2	-8.73	0.82	-0.41	8.79
3	-8.49	0.81	-0.18	8.54
4	-9.85	0.83	-0.83	9.93
5	-8.83	0.78	0.05	8.87
6	-9.74	0.78	-1.03	9.84
Lava Plus 0.5 mm thickness on A3 background				
1	-9.98	0.93	-0.20	10.04
2	-9.24	0.96	-0.37	9.31
3	-9.18	0.92	-0.29	9.24
4	-9.36	0.91	-0.27	9.42
5	-9.54	0.90	-0.03	9.59
6	-9.01	0.96	0.22	9.07
Lava Plus 0.5 mm thickness on C4 background				
1	-11.00	1.01	-0.57	11.06
2	-10.55	0.96	-0.87	10.63
3	-9.59	1.22	0.04	9.68
4	-9.85	1.26	0.00	9.94
5	-10.03	1.21	0.27	10.11
6	-10.59	0.95	-0.94	10.67

No. of specimens	ΔL	Δa	Δb	ΔE
Lava Plus 1.0 mm thickness on black background				
1	-10.06	0.40	-3.18	10.56
2	-9.99	0.40	-3.14	10.48
3	-9.41	0.40	-2.98	9.88
4	-9.35	0.45	-2.99	9.83
5	-9.91	0.36	-3.03	10.37
6	-9.59	0.34	-2.96	10.04
Lava Plus 1.0 mm thickness on metal background				
1	-8.59	0.54	-2.49	8.96
2	-8.72	0.49	-2.53	9.09
3	-8.18	0.48	-2.45	8.55
4	-8.65	0.58	-2.30	8.97
5	-8.73	0.49	-2.46	9.08
6	-8.40	0.51	-2.41	8.75
Lava Plus Press 1.0 mm thickness on A2 background				
1	-7.26	0.65	-1.54	7.45
2	-6.61	0.74	-1.00	6.73
3	-6.97	0.59	-1.55	7.16
4	-6.62	0.76	-0.82	6.71
5	-6.76	0.70	-1.00	6.87
6	-7.15	0.64	-1.49	7.33
Lava Plus 1.0 mm thickness on A3 background				
1	-6.95	0.70	-1.15	7.08
2	-7.10	0.77	-1.12	7.23
3	-6.56	0.67	-0.97	6.67
4	-7.14	0.81	-0.98	7.25
5	-7.19	0.75	-1.02	7.30
6	-6.97	0.72	-1.16	7.10

No. of specimens	ΔL	Δa	Δb	ΔE
Lava Plus 1.0 mm thickness on C4 background				
1	-7.77	0.86	-1.51	7.96
2	-7.88	0.83	-1.52	8.07
3	-7.38	0.72	-1.45	7.56
4	-7.86	0.88	-1.41	8.03
5	-8.05	0.79	-1.43	8.21
6	-7.71	0.74	-1.47	7.88
Lava Plus + Lava Ceram 0.5 mm thickness on black background				
1	-11.24	0.13	-3.69	11.83
2	-11.82	013	-3.50	12.33
3	-12.29	0.31	-3.43	12.76
4	-11.76	0.22	-3.06	12.15
5	-12.02	0.16	-3.71	12.58
6	-12.85	0.16	-3.22	13.25
Lava Plus + Lava Ceram 0.5 mm thickness on metal background				
1	-9.87	0.30	-3.09	10.35
2	-10.29	0.31	-2.85	10.68
3	-10.97	0.44	-2.71	11.31
4	-10.74	0.39	-2.44	11.02
5	-10.31	0.29	-2.94	10.72
6	-11.52	0.31	-2.46	11.78
Lava Plus + Lava Ceram 0.5 mm thickness on A2 background				
1	-8.25	0.41	-1.87	8.47
2	-8.56	0.51	-1.66	8.73
3	-8.19	0.67	-0.85	8.26
4	-8.62	0.58	-1.28	8.73
5	-8.82	0.41	-1.84	9.02
6	-9.66	0.52	-1.22	9.75

No. of specimens	ΔL	Δa	Δb	ΔE
Lava Plus + Lava Ceram 0.5 mm thickness on A3 background				
1	-7.94	0.55	-1.43	8.09
2	-8.66	0.48	-1.42	8.79
3	-8.63	0.81	-1.01	8.73
4	-8.28	0.68	-0.75	8.34
5	-8.35	0.64	-1.38	8.49
6	-9.26	0.60	-0.68	9.30
Lava Plus + Lava Ceram 0.5 mm thickness on C4 background				
1	-8.81	0.62	-1.78	9.01
2	-9.63	0.59	-1.71	9.80
3	-9.75	0.91	-1.38	9.89
4	-9.66	0.73	-1.20	9.76
5	-9.30	0.65	-1.65	9.47
6	-10.25	0.76	-1.12	10.34
Lava Plus + Lava Ceram 1.0 mm thickness on black background				
1	-8.88	0.18	-2.98	9.37
2	-8.31	0.08	-3.52	9.03
3	-8.40	-0.01	-3.72	9.19
4	-8.84	0.15	-3.36	9.46
5	-8.78	0.22	-3.33	9.39
6	-8.61	0.12	-3.49	9.29
Lava Plus + Lava Ceram 1.0 mm thickness on metal background				
1	-7.95	0.34	-2.36	8.30
2	-7.18	0.22	-2.84	7.72
3	-7.12	0.12	-3.14	7.78
4	-7.97	0.21	-2.68	8.41
5	-7.70	0.37	-2.73	8.18
6	-7.46	0.28	-2.86	7.99

No. of specimens	ΔL	Δa	Δb	ΔE
Lava Plus + Lava Ceram 1.0 mm thickness on A2 background				
1	-7.08	0.47	-1.48	7.25
2	-6.12	0.38	-1.96	6.44
3	-6.14	0.21	-2.22	6.53
4	-6.51	0.44	-1.72	6.75
5	-6.48	0.51	-1.79	6.74
6	-6.28	0.42	-1.86	6.56
Lava Plus + Lava Ceram 1.0 mm thickness on A3 background				
1	-6.82	0.62	-1.22	6.96
2	-5.90	0.53	-1.69	6.16
3	-5.75	0.39	-1.95	6.08
4	-6.23	0.53	-1.37	6.40
5	-6.24	0.60	-1.42	6.43
6	-6.07	0.53	-1.64	6.31
Lava Plus + Lava Ceram 1.0 mm thickness on C4 background				
1	-7.01	0.79	-1.17	7.15
2	-6.64	0.54	-2.09	6.98
3	-6.49	0.36	-2.31	6.90
4	-6.97	0.55	-1.83	7.23
5	-6.94	0.67	-1.79	7.20
6	-6.78	0.54	-1.89	7.06

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