The effect of surface finishing on translucency and color stability of Polymer-infiltrated ceramic network material

BY

PHAKPHUM	SRINUAN
MINTRA	SUJJAPONG
NOPPASORN	KIATTIKHEEREE
SUMITTRA	TAWEEPORNKITKUN
PORNPIMOL	PHONGLUMJEAK
PANYANAT	YINGCHAROENWATTANA
JANTANEE	LEELANARATHIWAT

A THEMATIC PAPER SUMMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR DOCTOR OF DENTAL SURGERY

FACULTY OF DENTAL MEDICINE, RANGSIT UNIVERSITY

ACADEMIC YEAR 2017

การศึกษาผลของการตกแต่งพื้นผิวต่อความโปร่งแสง และเสถียรภาพทางสีของเซรามิกที่มีพอลิเมอร์แทรกอยู่

โดย

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จันทนี	ลีลานราธิวัฒน์

สารนิพนธ์ฉบับนี้เป็นส่วนหนึ่งของการศึกษาตาม
หลักสูตรทันตแพทยศาสตร์บัณฑิต
คณะทันตแพทยศาสตร์ มหาวิทยาลัยรังสิต
ปีการศึกษา 2560

Acknowledgement

This research was supported by Academy of Dentistry, Rangsit University. we would like to thank Dental Biomaterial Analysis and Research Center, Faculty of Dentistry, Mahidol University and Dental Material Science Research Center, Faculty of Dentistry, Chulalongkorn University for providing many instruments that useful in this research.

PHAKPHUM SRINUAN

MINTRA SUJJAPONG

NOPPASORN KIATTIKHEEREE

SUMITTRA TAWEEPORNKITKUN

PORNPIMOL PHONGLUMJEAK

PANYANAT YINGCHAROENWATTANA

JANTANEE LEELANARATHIWAT

คำสำคัญ : ความโปร่งแสง, เสถียรภาพทางสี, เซรามิกที่มีโพลิเมอร์แทรกอยู่

ภาคภูมิ ศรีนวล, มินตรา สัจจพงษ์, นภสร เกียรติคีรี, สุมิตรา ทวีพรกิจกุล, พรพิมล ผ่องลำเจียก, ปัญญนัฏฐ์ ยิ่งเจริญวัฒนา, จันทนี ลีลานราธิวัฒน์

บทคัดย่อ

ปัญหาที่พบ : ความโปร่งแสงกับความเสถียรภาพของสีเป็นคุณสมบัติที่มีความสำคัญต่อความสวยงามของวัสดุทางทันตกรรมอย่างยิ่ง ซึ่งการขัดวัสดุทางทันตกรรมจะมีผลต่อคุณสมบัติดังกล่าว แต่ยังมีการศึกษาเพียงเล็กน้อยที่ศึกษาถึงผลของการเคลือบ และการขัดผิวที่ส่งผลต่อค่าความโปร่งแสงกับความเสถียรภาพของสีของวัสดุที่เพิ่งพัฒนามาอย่างพอลิเมอร์อินฟิวเตรตเซรามิกเน็ตเวิร์ค

วัตถุประสงค์ : เพื่อเปรียบเทียบค่าความโปร่งแสง และความแตกต่างของสี (ΔE) ของพอลิเมอร์อินฟิวเตรตเซรามิกเน็ตเวิร์คกับการปรับสภาพผิวที่แตกต่างกัน

วิธีการทดลอง และวัสดุอุปกรณ์ : ชิ้นทดสอบทั้งหมดจำนวน 36 ชิ้น ทำจากพอลิเมอร์อินฟิวเตรตเซรามิกเน็ตเวิร์คที่เรียกว่า วิตา อีนามิค ซึ่งชิ้นทดสอบมีรูปร่างสี่เหลี่ยมขนาด 2x10x12 มิลลิเมตร ใช้ทดสอบหาค่าความโปร่งแสง และค่าสัดส่วนความคมชัด ชิ้นทดสอบทั้งหมดจะถูกแบ่งออกเป็น 3 กลุ่ม ตามลักษณะการปรับสภาพพื้นผิวได้แก่ กลุ่มควบคุมที่ไม่ได้รับการปรับสภาพพื้นผิว, กลุ่มที่ปรับสภาพพื้นผิวโดยการขัดอย่างเดียว และกลุ่มที่ปรับสภาพพื้นผิวโดยการขัดร่วมกับการเคลือบผิว การขัดผิวจะใช้เครื่องจับหัวขัดร่วมกับชุดขัดของ วิตา อีนามิค การเคลือบผิวจะทำตามที่บริษัทแนะนำโดยใช้ 5 เปอร์เซ็นต์ กรดโฮโดรฟลูออริกในการกัดพื้นผิว จากนั้นทาไซเลนต่อด้วยการเคลือบผิว และฉายแสง ค่าอัตราส่วนความคมชัด และค่าคามแตกต่างของสี จะใช้เครื่องสเปคโตรโฟโตมิเตอร์เป็นตัวช่วยในการบันทึกค่า ซีไออีเอลเอบี (CIELAB) ซึ่งค่าความแตกต่างของสีจะคำนวณจากค่าที่ทำการบันทึกก่อนการแช่ไวน์ (T0) และหลังการแช่ไวน์ไปแล้ว 14 วัน (T14) และ 28 วัน (T28) ในส่วนของค่าอัตราส่วนความคมชัดจะทำการบันทึกค่าก่อนการแช่ไวน์ (T0) และหลังการแช่ไวน์ไปแล้ว 7 วัน (T7), 14 วัน (T14) และ 28 วัน (T28) ในระหว่างกระบวนการแช่ไวน์ จะมีการนำชิ้นทดสอบขึ้นมาล้าง และเปลี่ยนไวน์ทุกๆ7 วัน

ผลการวิจัย : ในทุกกลุ่มการทดลองจะมีค่าอัตราส่วนความคมชัดเพิ่มมากขึ้นหลังจากการแช่ไวน์แดง แต่พบว่ามีความแตกต่างอย่างมีนัยสำคัญ เมื่อเปรียบเทียบค่าอัตราส่วนความคมชัดระหว่างกลุ่มควบคุมและกลุ่มที่ขัดพื้นผิวหลังจากแช่ในไวน์แดง 14 วัน และ28 วัน รวมไปถึงการเปรียบเทียบระหว่างกลุ่มควบคุม และกลุ่มที่เคลือบพื้นผิวหลังจากแช่ในไวน์แดง 28 วัน ในส่วนของค่าความแตกต่างของสีพบว่า

มีความแตกต่างอย่างมีนัยสำคัญระหว่างกลุ่มควบคุม และกลุ่มขัดพื้นผิวหลังจากแช่ในไวน์แดง 28 วัน นอกเหนือจากนี้พบว่าไม่แตกต่างอย่างมีนัยสำคัญ

สรุปผลการวิจัย : ค่าความแตกต่างของสี และค่าอัตราส่วนความคมชัดของวัสดุกลุ่มที่ขัดพื้นผิวร่วมกับการเคลือบผิว และกลุ่มที่มีการขัดพื้นผิวเพียงอย่างเดียว ไม่มีความแตกต่างกันอย่างมีนัยสำคัญ เมื่อวัดที่วันที่ 14 และ 28 หลังจากแช่ในไวน์แดง

ส่วนที่เกี่ยวข้องกับทางคลินิก : การขัดผิวเซรามิก เป็นกระบวนการที่ใช้เวลาซึ่งการปรับสภาพพื้นผิวที่แตกต่างกันก็จะมีผลต่อค่าความโปร่งแสงกับความเสถียรภาพของสีของพอลิเมอร์อินฟิวเตรตเซรามิกเน็ตเวิร์คซึ่งสำคัญในการเลือกการขัดพื้นผิวของพอลิเมอร์อินฟิวเตรตเซรามิกเน็ตเวิร์คเพื่อให้ได้ความสวยงามอันคงทนของวัสดุและลดค่าใช้จ่ายรวมถึงเวลาที่ใช้ในขั้นตอนดังกล่าว

KEY WORD: PICN, VITA ENAMIC, Color stability, Translucency, Ceramic, Composite

PHAKPHUM SRINUAN, MINTRA SUJJAPONG, NOPPASORN KIATTIKHEEREE, SUMITTRA TAWEEPORNKITKUN, PORNPIMOL PHONGLUMJEAK, PANYANAT YINGCHAROENWATTANA, JANTANEE LEELANARATHIWAT

Abstract

Statement of the problem: Translucency and color stability play the important role in the esthetic dental restoration. Surface finishing of the restorative material may affect these properties. There has been a little study concerning the effect of glazing and polishing on the translucency and color stability of newly developed polymer infiltrated ceramic network (PICN).

Objective: To compare the translucency (contrast ratio) and color difference (ΔE) of PICN specimen with different surface treatment

Material and Method: 36 rectangular shaped 2x10x12 mm PICN specimens for contrast ratio and color stability from vita Enamic block (Vita Zahnfabrik, Bad Sackingen, Germany). They were divided to three groups of surfaces treatment: no surface treatment (control), polishing and glazing. The polishing process was performed using Customized polishing machine with Vita Enamic polishing set technical. The glazing process was done follow the manufacture recommendation including 5% hydrofluoric etching, silanization, glaze application and polymerization with light curing unit. The contrast ratio and color different were record the data by spectrophotometer. Color different was calculated from data that record before immersed in red wine (T0), 14 days after immersed in red wine (T14), 28 days after immersed in red wine (T28). Contrast ratio calculated from data that record before immersed in red wine (T0), 7 days after immersed in red wine (T7), 14 days after immersed in red wine (T14), 28 days after immersed in red wine (T28). Specimens were rinsed with distilled water and change red wine every 7 days

Result : The CR values were increased by the wine-immersion time in all specimen groups .The couple of control-polished group were significantly different among the day 14 and 28 after immersion specimens in wine and the couple of control-glazed group were statistically significant

different in the day 28 after immersion in wine. Similarly, The ΔE^* value were statistically significant difference among control and polished groups in the day 28 after immersion specimen in wine compared to the day before the specimen was immersed in wine because the p-value was 0.028 ($P<0.05$) while others were not significant different.

Conclusion: color stability and contrast ratio of polished group and glazed group were no significant different at 14 days and 28 days after immersion in red wine.

Clinical implication: Finishing the surface of ceramic material can be time-consuming process and different surface treatment process may also affect the translucency and color stability of PICN.
It is important to choose the appropriate surface finishing process for PICN to achieve the optimal esthetic longevity of restoration and also reduce the laboratory time and expenses.

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Chapter 1: Introduction

Background

Nowadays, there are many tooth-colored materials for the aesthetic zone(1). In prosthodontics, all-ceramic is considered as one of the most popular restorative materials. Its physical properties encompass the advantages of biocompatibility, low heat conduction, and wear resistance that retains the structural integrity of materials over time(2). However, the property of wear resistance also gives ceramic a disadvantage as it leads to the occlusal wear of the opposing tooth(3). Another disadvantage includes the low fracture strength of ceramic, which makes it prone to cracking or breaking. In addition to ceramic, resin composite is the alternative tooth-colored material, which has the advantage over ceramic in a sense that it is less brittle than ceramic. However, resin composite has a relatively low color stability when compared to ceramic(4).Accordingly, the polymer infiltrated ceramic network (PICN) material has been developed to combine the benefits of both ceramic and resin composite together. So, there are the development of composition between resin composite and ceramic by collecting the advantage of both material, that is PICN which consist of ceramic part and polymer part. The ceramic part composed of SiO_2, Al_2O_3, NaO_2, K_2O, ZrO_2. The Polymer part composed of UDMA and TEGDMA. Various researches were regarding conducted to study the mechanical property (flexural strength) and physical properties (color stability, surface roughness, and translucency) of PICN materials(5). The physical properties of PICN materials were found to have low brittleness, high flexural strength with rigidity, and similar physical features to the structure of primary teeth. Moreover, PICN materials caused less tooth wear than dental ceramics and were easy to mill in the CAD/CAM system.

"Color stability" is the resistance of materials to change color that can be caused by light or aging(6); and "Translucency" refers to the characteristic of a substance that partially allows light to pass through(7). Indeed, both properties are considered as an important factor in aesthetic dental restoration. The higher color stability of the restorative material, the longer time it can be used as an aesthetic material in oral cavity. Likewise, the higher translucency of material, the more efficient it will be mimic natural tooth appearance(8). The ceramic restoration has higher color stability than resin composite,

concerning the fact that the composite has multifactorial effects on its color stability, such as intrinsic discoloration and extrinsic staining(9)

The incomplete polymerized composite resins illustrate reduced mechanical properties and higher discoloration susceptibility. The translucency of dental ceramics is mostly affected by their thickness(10), filler particles, resin matrix composition, polymerization, and aging(11, 12)[6]. Porcelain translucency is usually measured with either the translucency parameter (TP) or the contrast ratio (CR)(10). CR is defined as the ratio of illuminance (Y) of the test material when it is placed over a black background (Yb) to the illuminance of the same material when it is placed over a white background (Yw)(10). Alternatively, TP is defined as the color difference (ΔE) between a uniform thickness of a material over a white and a black backing(10).

Finishing is the process that involves removing marginal irregularities, defining anatomic contours, and smoothening the surface roughness of the restoration(13). Meanwhile, polishing is the process that is carried out after the finishing margination steps of the finishing procedure to remove minute scratches from the surface of a restoration and obtain a smooth, light-reflective luster. In addition, the polishing process is conducted in order to create a homogeneous surface with minimal microscopic scratches and deflects. The rough surface of restoration material increased plaque accumulation and abrasive wear of the opposing dentition. The effectiveness of any finishing or polishing device and the resultant surface roughness of the restoration is determined by a number of factors(14), including: 1) the structure and mechanical properties of the substrate being finished or polished (such as composite resin, polyacid modified composite resin or the so-called “compomer”, glass ionomer, amalgam, and porcelain–ceramic materials); 2) difference in hardness between the abrasive device and substrate; 3) particle hardness; 4) size and shape of abrasive used in the device; and 5) physical properties of the backing or bonding material used to carry the abrasive material or substance (such as rigidity, elasticity, flexibility, thick ness, softness, and porosity). The objective of glazing is primarily to seal the open pores in the surface of the fired porcelain. The rough surface of restorative materials increases plaque accumulation and abrasive wear of the opposing dentition. Glazing creates uniform shine and smooth surface, whereas a polished surface is smooth and textured. Glazing yields a homogenous reflection that is a smooth surface on the restoration. When surface sealants are applied on the tooth surface, it gives a momentary glaze, but a polished textured surface lasts longer(15). The aim of glazing is to seal the open pores in the surface of fired porcelain. There has been some studies

focusing on the effect of surface treatment on the optical behavior of restorative material. There has been no studies focusing on the effect of polishing, glazing on the optical behavior of PICN

Various researchers studied about the mechanical property (flexural strength) and physical properties (color stability, surface roughness, and translucency) of PICN materials. However, only few studies had experimented on the physical properties of PICN materials. Hence, the researchers decided to conduct an experiment on the physical properties of PICN materials by dividing the sample into three groups (A, B, and C). Group A acts as a control group and comprises of PICN materials with non-polished and non-glazed surfaces. Group B comprises of PICN materials with polished surfaces and Group C contains PICN materials with both polished and glazed surfaces. Meanwhile, the dependent variables are the differences in the values of color stability and contrast ratio before and after testing. Other factors that must be controlled include the shade and size of PICN specimens, temperature, soaking time and polishing machine.

Objectives

1. To compare the translucent (contrast ratio) of polymer infiltrated ceramic network specimens obtained from different surface treatment (Glazed and polished)
2. To compare the color different (ΔE) of polymer infiltrated ceramic network specimens obtained from different surface treatment (Glazed and polished) after immersion in red wine.

Expected benefits

To know the different result of polished and glazed that effect the translucent and color stability of PICN. The result of the translucency and color stability study on PICN after polished and glazed to the most accurate and efficient way to use PICN material.

Chapter 2: Literature review

Polymer infiltrated ceramic network

The polymer infiltrated ceramic network (Vita Enamic, Vita Zahnfabrik, Bad Sackingen, Germany) consists of 86 wt. % or 75 vol. % inorganic phase and 14 wt. % or 25 vol. % organic phase. The inorganic phase is a feldspathic ceramic, whereas the organic phase is composed of dimethacrylates (UDMA and TEGDMA) (Polymer infiltrated ceramic network structures for resistance to fatigue fracture and wear, Haifa El Zhawi et al.). The advantages of PICN materials are lower brittleness, greater rigidity and hardness, improved flexibility, higher fracture toughness, and better machinability as compared to ceramics (16).

Table 1 Composition of polymer infiltrated ceramic network (Vita Enamic Vita Zahnfabrik, Bad Sackingen, Germany) (16)

Feldspathic Ceramic	86%
- SiO_2	- 58-63%
- Al_2O_3	- 20-23%
- NaO_2	- 9-11%
- K_2O	- 4-6%
- ZrO_2	- 0-1%
Polymer	14%
- UDMA	
- TEGDMA	

Instrumental Measurement of Color and Translucency: Spectrophotometer

Spectrophotometer is an instrument that measures the number of photons (the intensity of light) absorbed after it passes through sample solution. With spectrophotometer, the amount of a known chemical substance (concentration) can also be determined by measuring the intensity of light detected. Depending on the range of wavelength of the light source, spectrophotometer can be classified into two different types:

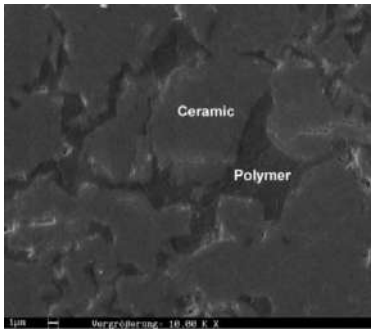


Fig.1 microstructure of Enamic showing the polymer matrix part and ceramic filler (a) (5)

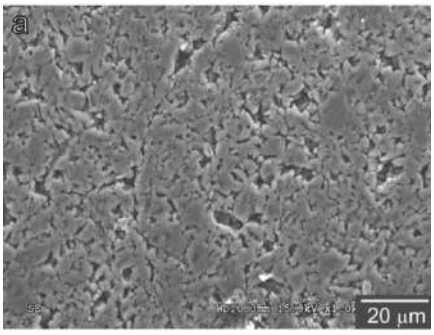


Fig.2 Microstructure of ENAMIC observed by SEM. (17)

Table 2 The mechanical properties of polymer infiltrated ceramic network compare with IPS-EMAX

Mechanical properties	VITA ENAMIC	IPS-EMAX
Elastic modulus (GPa)	21.5(1.6) (18)	67.2(1.3) (18)
Fatigue of maximum stress (MPa)	73.8 (20)	168.4(20)
Fracture strength (MPa)	1.41(0.17) (21)	2.27(0.16) (21)
Fracture load (KN)	0,25±0,06(19)	0,44±0,10(19)
Hardness (HV)	157.2(14.0) (18)	452.9(16.2) (18)
Wear (mm^3)	0.21(0.06) (18)	0.329(0.18) (18)
Flexural strength (MPa)	202.1(17.9) (18)	376.9(76.2) (18)

1) UV-visible spectrophotometer, which uses light over the ultraviolet range (185-400 nm) and visible range (400-700 nm) of the electromagnetic radiation spectrum.
2) IR spectrophotometer, which uses light over the infrared range (700-15000 nm) of the electromagnetic radiation spectrum.

Spectrophotometer, in general, consists of two devices: a spectrometer and a photometer. A spectrometer is a device that produces, typically disperses, and measures light. A photometer indicates the photoelectric detector that measures the intensity of light.

Spectrometer produces a desired range of wavelength of light. First, the collimator (lens) transmits a straight beam of light (photons) that passes through a monochromatic (prism) to split it into several component wavelengths (spectrum). Then, a wavelength selector (slit) transmits only the desired wavelengths. After the desired range of wavelength of light passes through the solution of a sample in cuvette, the photometer detects the number of photons that is absorbed and then sends a signal to a galvanometer or a digital display.

Color Stability

The importance property of esthetic restorative materials is their long-term color stability. Accordingly, unacceptable color matching is the primary reason for replacement composite resin restoration. Esthetic restorative material should be duplicate natural tooth appearance. The success of esthetic restoration depends primarily on the color match and subsequently on the color stability of material.

However, a major disadvantage is the discoloration of restorative material after prolonged exposure to oral environment. The structure of resin matrix and characteristics of filler particles directly affect surface smoothness and susceptibility to extrinsic staining. The staining susceptibility may be explained by the nature of the resin matrix, and may be correlated with the dimension of the filler particles. The resin plays a major role in the color stability of aesthetic restorative materials. The affinity of a resin for stains is modulated by its conversion rate and its chemical characteristics, water sorption rate being particularly important.

Various in vitro studies have demonstrated that common food substances, such as coffee, cola or red wine, as well as tea, fruit juices, soy sauce, mustard, and ketchup could cause significant change in the surface color of composite resin materials. Contrariwise, all restorative materials showed clinically perceptible color differences after immersion in coffee. Coca-Cola and red wine did not have significant influence on the color stability of the restorative materials.

Discoloration usually occurs because of water sorption by the resin component of the material. The type of resin matrix plays a vital role in the color sustainability of the material. According to the manufacturer, Vita Enamic consists primarily of 66 wt. % hydrophobic urethane dimethacrylate (UDMA) and 33 wt. % hydrophilic triethylene glycol dimethacrylate (TEGDMA). Previous studies have shown that water uptake by Bis GMA-based resins increased from 3 to 6% as the proportion of TEGDMA was increased from 0 to 1%, respectively. Accordingly, the high wt. % of

TEGDMA in Vita Enamic blocks may have resulted in a greater water sorption, which may have permitted the penetration of any hydrophilic colorant into the resin matrix. Since UDMA is more hydrophobic than BIS-GMA, it is therefore more color stable. Nevertheless, it has been reported that dimethacrylates form cross-linked networks with entrapped unreacted monomers that serve as plasticizers. Such plasticization forms a more open structure, which may facilitate additional water sorption. This may explain how the resin matrix could have contributed to the higher discoloration values obtained by Vita Enamic.

PICN materials were developed to overcome the problems associated with both resin and ceramic block materials when solely used. The increased patient awareness led to the need, not only for aesthetic materials that provide a close reproduction of the tooth color, but also for materials that maintain such color. The changes in color were investigated following immersion in beverages, such as coffee and red wine, which are known of their abilities to stain resin-based restorative materials. Previous studies showed that the coffee may adversely affect the color of Vita Enamic, which may consequently compromise aesthetics.

CIELAB scale was used as the measurement of color parameter. CIELAB is a color system which indicates value with three axes: L*, a*, b* as shown in Fig.3 Color stimuli is translated into different between light-dark, red-green, blue-yellow. CIELAB defined the different into number in three axis Vertical axis (L*) is black (0) to white (100)

a – a' axis (a*) is red (+) to green (-),

b - b' axis (b*) is blue (+) to yellow (-),

Zero is neutral gray for both axis

The difference of the starting and ending value identify the variance of color, which can be calculated by the following formula:

$$\Delta E = \sqrt{(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2}$$

Whereas, ΔE denotes the difference in color.

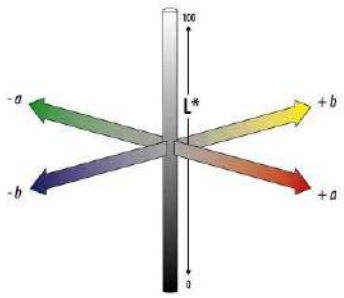


Fig.3 The CIELAB color coordinates system

Translucency

Translucency is considered as one of the primary factors in controlling the aesthetic outcome because it makes ceramic and resin-based restorations appear more natural. As translucency permits the passage of light and disperses light, it could be described as the state between complete opacity and transparency that the light being diffused rather than reflected or absorbed.

An error in the brightness of teeth is considered the most noticeable aesthetic error because the human eye is more sensitive to the differences in value (brightness) than hue or chroma. In addition, the translucency of ceramics is closely related to the light transmission and polymerization efficiency of the underlying resin-based luting agents. In general, the translucency of dental ceramics is influenced by factors such as crystalline structure, grain size, pigments, number, size, and distribution of defects, and porosity. If the crystals are smaller than the wave- length of visible light (400-700 nm), the glass will appear transparent. However, in the case of light scattering and diffuse reflection, the material will appear opaque.

However, some studies found that the translucency of dental ceramics is mostly affected by their thickness (Brodbelt et al., 1980; Chu et al., 2007; Heffernan et al. Part I, 2002; O'Keefe et al., 1991; Ozturk et al., 2008; Yu & Lee, 2009). It can also be affected by the number of firings (Ozturk et al., 2008), the luting agent (Barath et al., 2003; Terzioglu et al., 2009), the background shade (Barath et al., 2003; Li et al., 2009), and the illuminant (Yu & Lee, 2009). If the thickness of specimen is increased, the contrast ratio will decrease correspondingly.

The greatest influence on the measured translucency was exerted by thickness (partial eta squared hP2=.988), closely followed by material, and the pretreatment method. The surface roughness was strongly influenced by the parameters pretreatment method and material. How far the translucency correlated with the surface roughness depended greatly on the kind of material, even though no statistically significant correlation between the parameters could be ascertained in general

(P=.056). For the resin-based materials, no correlation could be found between translucency and surface roughness. However, a strong inverse correlation was found for the CAD/CAM ceramics.

Regarding the translucency of the resins, great differences were revealed. As with the ceramics, numerous parameters affected the light transmission in composite resin restorations. For example, thickness, filler particles, resin matrix composition, polymerization, and aging. Moreover, the translucency seemed to be material specific because no clear correlation amongst the mentioned parameters could be found in the latest studies. Especially, the filler size was well discussed; almost all authors stated that smaller filler size results in higher translucency, although occasionally the opposite was stated.

Measurement of Translucency

Three major methods of translucency measurement were found to be contrast ratio, transmittance, and translucency parameter. While more modern direct composite materials were described by the CR based on luminous reflectance.CR was defined as the ratio of the luminous reflectance of a translucent material on a black backing to the luminous reflectance of the same material on a white backing. Four important concepts should be noted from the definition of CR. First, the thickness of the transparent material will significantly affect CR, as the thickness of the material will affect its reflectance on each of these backings. Second, the reflectance values of the backings will affect the calculated CR, as the reflectance of the backing and the optical continuity between the translucent material and the backing each affects the reflectance of the material on that backing. Third, because luminous reflectance is a function of the illuminant and the observer used for the luminous reflectance calculations, each of these parameters must be described when using CR based on luminous reflectance values; and fourth, although CR was commonly based on luminous reflectance values, it is possible to calculate CR as a function of wavelength because the reflectance on each backing can easily be described as a function of wavelength.

Similar to CR, the thickness to produce a certain transmittance can also be calculated because the relationship between thickness and transmittance is known. Moreover, the luminous transmittance is based on CIE colorimeter. Hence, the luminous transmittance descriptions must include the illuminant and the observer used for the calculation. Finally, the transmittance may also be spectra, so it can be expressed at the wavelengths of interest when such wavelength or wavelength range has a

special meaning with regards to the material system being studied, as well noted in the case of the light-curing of an adhesive layer under an aesthetic material.

The translucency parameter (TP) was provided as a direct measure of translucency, initially for maxillofacial elastomeric materials where such parameter was defined as the color difference found for the material at a specified thickness, whereby the color difference was between the materials when in optical contact with ideal black and white backings. It was later described as corresponding directly to common visual assessments of translucency when applied to changes in esthetic restorative materials during and after curing.

Since TP is also based on CIE colorimeter, the illumination, the observer, and the color difference formula used for the color difference calculations must also be presented. In addition, the thickness of the translucent material will significantly affect the color difference, as the thickness of the material will affect its color on each of these backings.

VITA Enamic achieved the lowest T% values, which may be due to the relatively high amount of Al_2O_3 (approximately 23 wt.%) (VITA Zahnfabrik H). However, the color 3M2-T cannot be seen as an absolute equivalent to the color A2 from the VITA classic color scale and may appear slightly darker.

Contrast ratio (CR) is one of the methods used to measure the translucency of all-ceramic systems and has been used in previous studies. The relative opacity of ceramics can be measured by the differences between specimens over black and white backgrounds. The space system Yxy was used to measure the contrast ratio as a ratio of reflectance (Yb/Yw), with the value from the specimen placed over a black background (Yb) relative to the value from the specimen placed over a white background (Yw). In contrast, when CR decreases, the translucency of the specimen increases; and when thickness increases, both contrast ratio and color difference values decrease. Previous studies reported that different types of materials and thicknesses resulted in different contrast ratio (22).

Finishing and Polishing

Finishing and polishing refer to gross contouring of the restoration to obtain the desired anatomy, and the reduction and smoothening of the roughness and scratches created by finishing instruments.

Finishing is the process that involves removing marginal irregularities, defining anatomic contours, and smoothening surface roughness of a restoration. Finishing includes the process of margination. Margination is the specific step of the finishing process that involves the removal of excess restorative material at the junction of the tooth structure and the restorative material, and the application of various finishing techniques to establish a smooth, uniform, and well-adapted cavosurface margin. The resultant junction should conform in shape and normal anatomic characteristics. Optimally, the adjacent natural tooth structure should not be damaged or excessively removed in this procedure. The finish lines of a preparation are often critical to the longevity of many direct and indirect restoratives because forces of polymerization, mastication, and thermal expansion and contraction are transferred to the marginal aspects of the restoration.

Polishing is the process carried out after the finishing and margination steps of the finishing procedure to remove minute scratches from the surface of a restoration and obtain a smooth, light-reflective luster. The polishing process is also intended to produce a homogeneous surface with minimal microscopic scratches and deflects. The effectiveness of any finishing or polishing device, and the resultant surface roughness of the restoration, is determined by a number of factors, including:

1) Structure and mechanical properties of the substrate being finished and polished (such as composite resin, polyacid-modified composite resin or the so-called “compomer”, glass ionomer, amalgam, and porcelain-ceramic materials)

2) Difference in the hardness between the abrasive device and the substrate

3) Particle hardness

4) Size and shape of abrasive used in the device

5) Physical properties of the backing or bonding material used to carry the abrasive material or substance (such as rigidity, elasticity, flexibility, thickness, softness, and porosity)

6) Speed and pressure at which the abrasive is applied to the substrate

7) Lubrication and the use of lubricants during the application of the abrasive (such as water, water-soluble polymers, glycerol, silicon grease, and petroleum jelly).

Significant reasons for careful finishing and polishing are to:

1) Remove excess flash and refine the margins of the restoration

2) Reduce the risk of fracture since a rough surface may be more likely to fracture

3) Reduce surface imperfections and subsequently the surface area and the risk of surface breakdown and corrosion
4) Produce a smooth surface that is less likely to retain plaque
5) Improve oral function and mastication since food slides more easily over polished tooth surfaces
6) Produce smooth surfaces that facilitate oral hygiene procedures with access to all surfaces, marginal areas, and interproximal areas through normal tooth brushing and use of dental floss
7) Produce smooth restoration contacts leading to less wear on opposing and adjacent teeth
8) Produce a more aesthetic, light-reflecting restoration for patients.

Accordingly, the roughness of porcelain surfaces should be subject to finishing and polishing procedures. Moreover, the color of porcelain restoration is also affected by the surface roughness because a rough surface reflects light irregularly and less than a glazed surface. As such, polishing is important for porcelain, both in the aspects of functionality and aesthetics (19)(23).

Glazing

The objective of glazing is to seal the open pores on the surface of fired porcelain. Dental glazes comprise of colorless glass powder, which are applied to the fired crown surface in order to create a glossy appearance.

The glazed ceramic specimens appear to have a smoother surface than polished specimens, concerning the fact that polishing surfaces contain many pitted areas with numerous surface irregularities. Rough surfaces on dental restoration increase plaque accumulation and abrasive wear of the opposing dentition. Effective polishing can prevent the discoloration of rough surfaces.

Irregular porcelain surfaces may concentrate stresses and begin cracking propagation, which further result in premature fracture of the porcelain. To increase the long-term success of restoration, rough surfaces must be smoothened by polishing or glazing materials. According to various studies, finishing and polishing materials can be used to obtain a clinically acceptable smoothness of surfaces when compared to glazing materials. Nonetheless, other studies have shown that polished surfaces are rougher than glazed surfaces. It appears that glaze materials can significantly decrease the surface roughness and color change (23).

Effect of polishing and glazing to translucency and color stability

Glazed ceramic (IPS EMAX) showed significantly higher translucency compared with polished ceramic 16(24). Glazed specimens of feldspathic and low-fusing porcelain materials demonstrated less color change than polished specimens

Smoother surfaces were achieved with polishing or glazing than with those with no treatment. Furthermore, the surface morphologies of glazed specimens appeared smoother than those of polished specimens. There was evidence of striated patterns created by manually controlled instruments on the polished surfaces that were not present on the glazed surfaces. The relationship between translucency and surface roughness of feldspathic porcelains in their study, a smoother surface displayed a higher reflectance and lower transmittance and TP values although polished porcelains have been demonstrated to exhibit surface smoothness similar to that of glazed porcelains. (24)

Significant differences were found in the color change of feldspathic and low-fusing porcelain materials subjected to the different polishing techniques evaluated. The Mark II, Matchmaker MC, and VMK 95 porcelain materials tested were found to be more color-stable than the Ceramco III porcelain. The largest color difference was observed with the Ceramco III porcelain material. These differences were found to be significant. Glazed specimens demonstrated less color change than polished specimens for all porcelain materials tested. Glazed and polished specimens with different polishing materials demonstrated that ΔE values were at an acceptable level for all the porcelain materials tested (25).

Chapter 3: Materials and Methods

Specimen preparation

The composition of polymer infiltrated ceramic network (VitaEnamic)[18] shown in Table 1. Specimens are polymer infiltrated ceramic network (Vita Enamic, Vita Zahnfabrik, Bad Sackingen, Germany) as shown in Fig.4a. Vita Enamic blocks were cut by diamond disc (Diamond Cut-off Wheel MOD15, Struers, Cleaveland, United States) which attached to a cutting machine (IsoMet Low speed, Buehler, Lake Bluff, IL, USA) as shown in Fig.4c. Specimens were cut under water coolant. The specimens' dimension for translucency and color stability measurement were 2x10x12 mm.

All specimens were controlled surface by polished with silicon carbide paper, using polishing machine as shown in Fig.4b (NANO 2000, PACE TECHNOLOGIES, USA) with P400, P600, P800, P1000, and P1200 silicon carbide paper at 300 rpm.

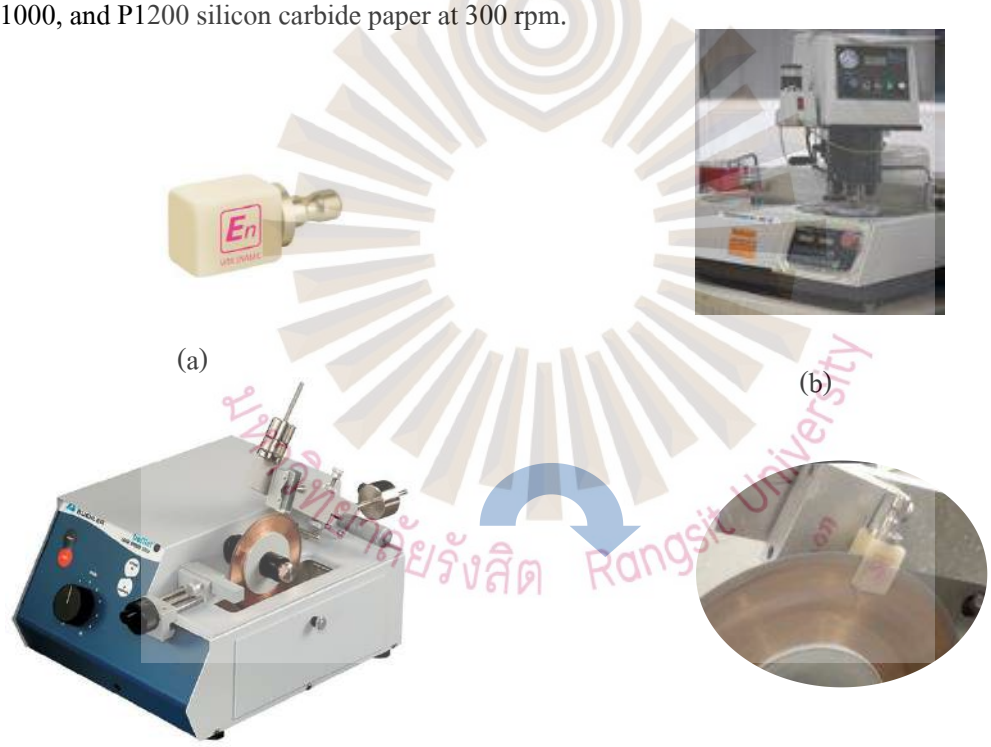
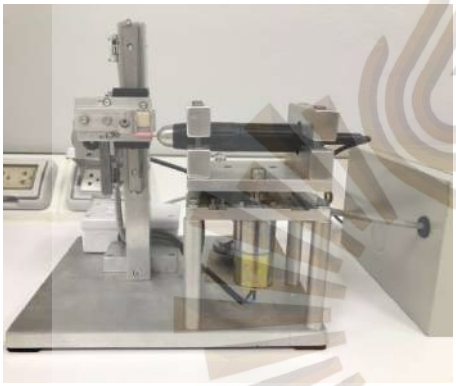


Fig.4 Vita Enamic block (Vita zahnfabrik, Bad sackingen, Germany)(a), Polishing machine (NANO 2000, PACE TECHNOLOGIES, USA)(b), Cutting machine (IsoMet Low speed, Buehler, Lake Bluff, IL, USA)(c)

For both translucency and color stability measurement, the specimens were separated into 3 groups: controlled group, polished group and glazed group.

- Controlled group; specimens were not polished and glazed.

- Polished group; specimens were polished by used customized polishing machine with Vita Enamic polishing set (Technical kit) as shown in Fig.5a, b. The specimens were polished with pink polisher and grey polisher by control speed, polishing times, force and direction follow the manufacture instruction. Firstly use pink polisher speed 10,000 rpm, 30 times, 250 N followed by grey polisher speed 8,000 rpm, 30 times, 200 N. The desired specimen thickness were verified using digital micrometer (Mitutoyo corporation, tokyo, japan) as show in Fig.5c



(a)

(b)

(c)

Fig.5 Customized polishing macnine (a), Enamic polishing bur (b), Digital micrometer (Mitutoyo corporation, Tokyo, japan) (c)

Glazed group: specimens were polished and checked for the desired dimension same as a polished group. The specimen surface was conditioned as the manufacturer recommendation as shown in Fig.6 The micro brush was used to apply 5% hydrofluoric acid gel 60 seconds. Acid etchant was completely removed with distilled water. Silane (VITASIL,Vita Zahnfabrik, BadSackingen, Germany) as shown in Fig.7a was applied for 1 minutes and air dry. VITA Enamic Glaze as shown in

Fig.7b (Vita Zahnfabrik, Bad Sackingen, Germany) was apply a single coat of Enamic glaze by micro brush and use celluloid strip to obtain the thin and even layer on specimen surface. The glaze was polymerized for 10 minutes by Light Curing Unit (Polylux PT) at wavelength 400-500 nm. The glazed procedure was performed by one operator and measurement with micrometer to control thickness of specimens.

All the specimens were cleaned with ultrasonic cleaner (Ultrasonic Cleaner 5210, BRANSONIC, Germany) as shown in Fig.8 for 5 minutes before immersion in 4 ml of red wine (Jacob Creek, South Australia, Australia) and stored in incubator Fig.9 (Memmert, Schwabach, Germany) at 37°C for 28 days. Every 7 days, the specimens were rinsed with distilled water and air dry then specimen were immersed in fresh solution of red wine for preventing contamination from yeast and bacteria.

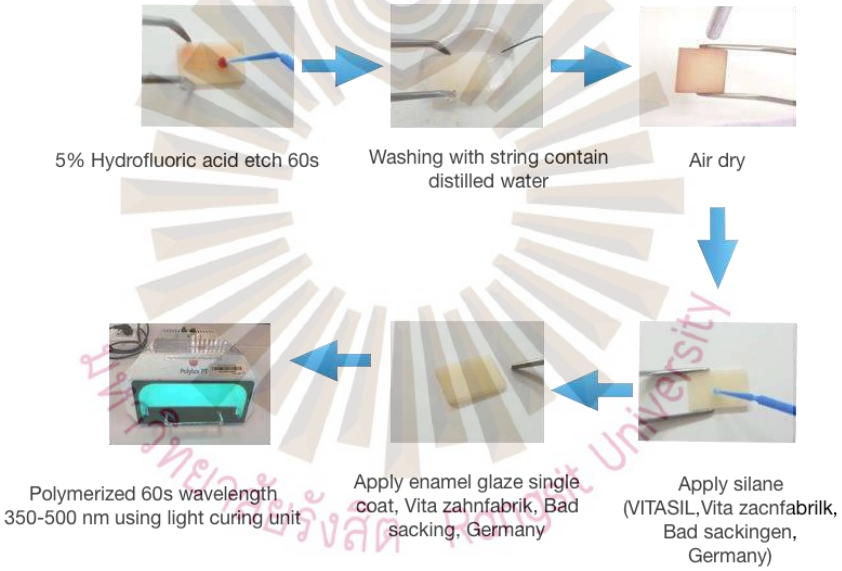


Fig.6 Glazing procedure

(a) (b)

Fig.7 VITASIL (Vita Zahnfabrik, Bad Sackingen, Germany) (a), VITA ENAMIC glaze (b)

Fig.8 Ultrasonic (Ultrasonic Cleaner 5210, BRANSONIC, Germany)

Fig.9 Incubator (Memmert, Schwabach, Germany).

Smoother restoration surface decreases the effect of plaque accumulation and discoloration, smooth surface of restoration can prevent the formation of biofilm layers and extrinsic stains. The survival rate and aesthetic appearance of ceramic restorations depends on color stability and translucency. Sarikaya et al. reported that increased delta E values were observed in hybrid ceramic specimens stored in a coffee solution compared to the specimens stored in a tea or cola solution. Both of the resin nanoceramic specimens stored in coffee and tea had higher delta E values than resin nanoceramic specimens stored in the cola. The TP values of both hybrid ceramic and resin nanoceramic specimens stored in the coffee solution decreased. This experiment use Vita Enamic technical set, Shofu polisher, medium and fine rubber wheels and sof-Lex polishing discs were used as polishing instrument

Translucency measurement

The schematic diagram of translucency measurement is shown in Fig.7a. The CIELAB coordinates (L*, a* , b*) of 12 specimens in each group (controlled group, polished group, and glazed group) were recorded using spectrophotometer (Ultrascan Pro, Hunter Lab, USA) as shown in Fig.10b. The instrument was calibrated against the white and black standard discs before each measurement session.

The specimens were measured with 45°/0° geometry. Each specimen was placed at the center of the specimen port having a diameter of 4 mm. with white background and black background. Data

was analyzed with a software to calculate luminous reflectance with CIE illuminant D65 (Minolta CR 300, Minolta Camera) and the 2-degree observer function.

Contrast ratio was calculated from equation 1

$$CR = Y_B/Y_W \quad \text{.....Equation 1}$$

Y_B is value recorded when specimen is on black background,

Y_W is value recorded when specimen is on white background

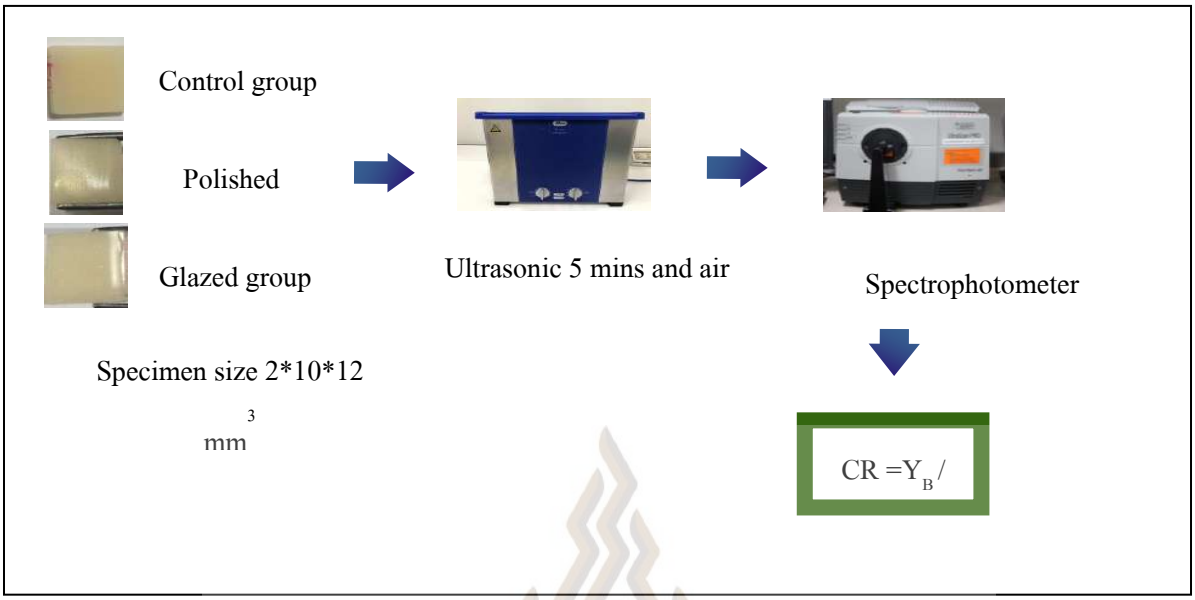
Y is spectral reflectant calculated from equation 2

$$Y = [(L^* + 16)/116]^3 \times Y_n ; Y_n = 100 \quad \text{.....Equation 2}$$

Color stability measurement

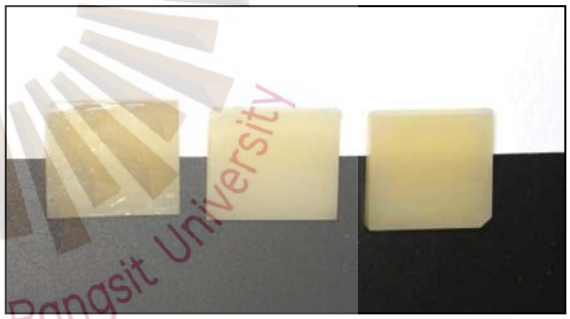
The schematic diagram of the color stability measurement is shown in Fig.8.The CIELAB coordinates (L*,a*,b*) of 12 specimens in each group (controlled group, polished group and glazed group) will be recorded using spectrophotometer (Ultrascan Pro, Hunter Lab, USA) After that the specimens will After 7,14,28 days the CIELAB coordinates (L*, a*, b*) will be recorded with spectrophotometer (Ultrascan Pro, Hunter Lab, USA) The different in color (ΔE) after immersion will be calculated using equation 3.

$$\Delta E = \sqrt{(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2} \quad \text{.....Equation 3}$$



(a)

(b)



(c)

Fig.10 The schematic diagram of the translucency (a), Spectrophotometer (UltrascanPro,HunterLab,USA) (b), Specimen on white background and black background (c)

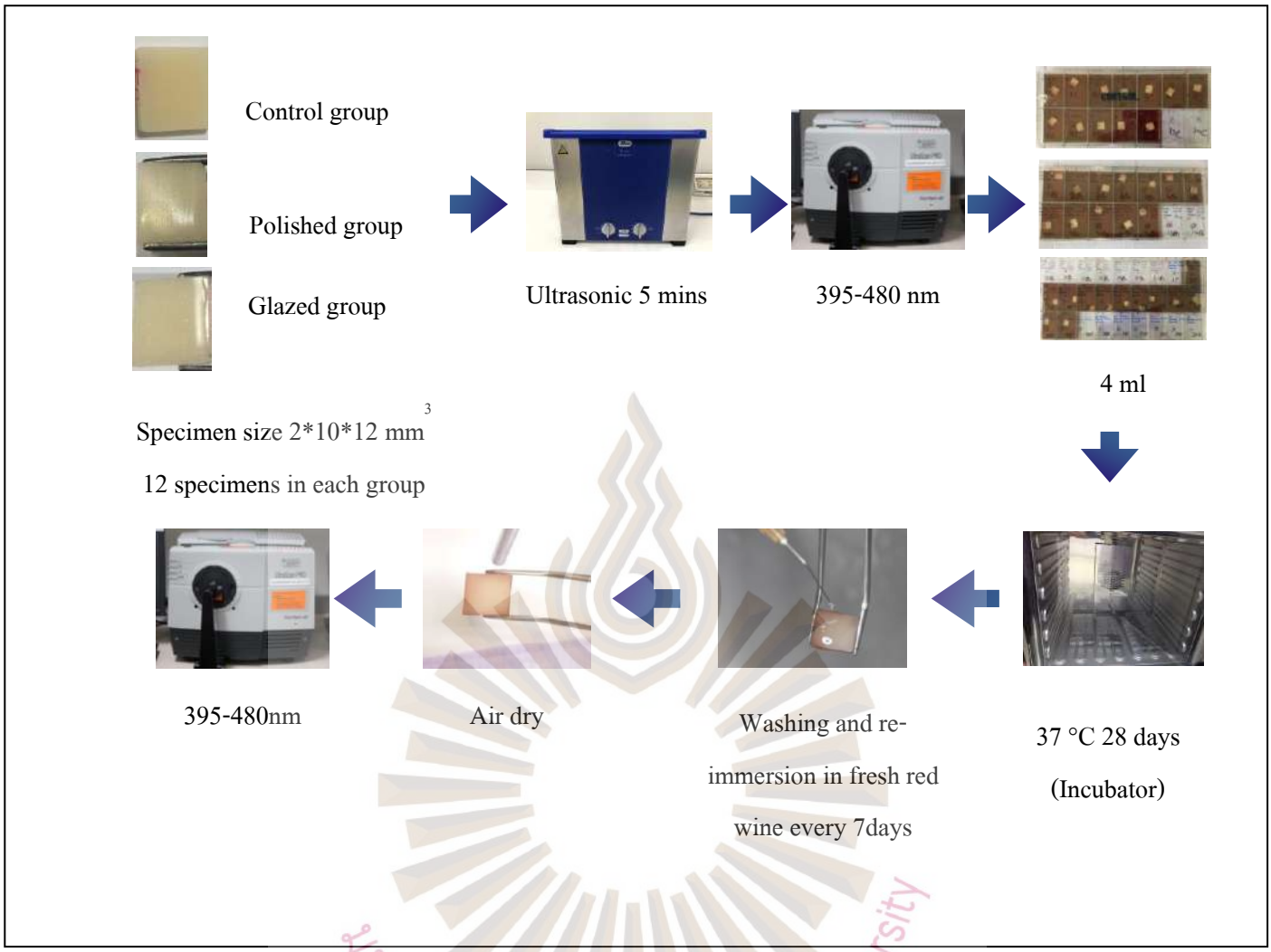


Fig.11 The schematic diagram of the color stability measurement

Statistical analysis

The Independent variables are surface treatment process of PICN material which divided into 3 groups: controlled group, polished group, glazed group. Dependent variables are contrast ratio (CR) and ΔE.

Calculations and statistical analysis will be carried out using SPSS 18.0 for Windows (SPSS Inc., IL, USA). The mean contrast ratio and mean Delta E of each surface treatment group will be checked for a normal distribution by Kolmogorov-Smirnov test (K-S test). One-way ANOVA will be used to test difference in contrast ratio and ΔE of three difference surface treatment processes. If there is the different between three surface treatment group, subsequent multiple comparison using Tukey's

honestly significant difference (HSD) test will be used to detect differences between the groups. The level of significance was set to $\alpha = 0.05$. The Null hypothesis and alternative hypothesis as the following

H_0: $\mu_{A1} = \mu_{B1} = \mu_{C1}$

$H_{1:}$ $\mu_{A1} \neq \mu_{B1}$ or $\mu_{A1} \neq \mu_{C1}$ or $\mu_{B1} \neq \mu_{C1}$

When μ_{A1} = mean of contrast ratio in controlled group

μ_{B1} = mean of contrast ratio in polished group

μ_{C1} = mean of contrast ratio in glazed group

H_0: $\mu_{A2} = \mu_{B2} = \mu_{C2}$

$H_{1:}$ $\mu_{A2} \neq \mu_{B2}$ or $\mu_{A2} \neq \mu_{C2}$ or $\mu_{B2} \neq \mu_{C2}$

When μ_{A2} = mean of ΔE in controlled group

μ_{B2} = mean of ΔE in polished group

μ_{C2} = mean of ΔE in glazed group

Chapter 4: Result

Contrast ratio

The means and standard deviation of contrast ratio in each group of surface treatment in the different immersion time were shown in table 3. The means of three surface finishing groups before immersion and at 7-, 14- and 28-days immersion time were similar. It can be implied that the surface treatment did not affect to the translucency of the specimens. The increased contrast ratio can be observed when the immersion time increased in every surface treatment group. The more immersion time, the more increased contrast ratio. It can be implied that the wine immersion time affected the contrast ratio of every specimens group.

Table 3 The mean contrast ratio (CR) and standard deviation of three surface finishing specimens at different immersion time (T)

		T0	T7	T14	T28
Control group	Mean CR	0.843117	0.864567	0.900685	0.908711
	Standard deviation	0.009684	0.013830	0.010198	0.008120
Polished group	Mean CR	0.846118	0.881701	0.911808	0.920206
	Standard deviation	0.004185	0.008562	0.006101	0.009961
Glazed group	Mean CR	0.838528	0.872710	0.907344	0.918667
	Standard deviation	0.005025	0.020960	0.011574	0.006406

Shapiro-Wilk and Levene test were used respectively to determine whether the contrast ratio was normal distributed and homogenized in variance. The contrast ratio value was normal distributed data and homogenized in variance. Consequently, One-way ANOVA was used to determine the different in mean contrast ratio among three surface finishing groups.

There was no statistically significant different in mean contrast ratio of three different finishing groups before immersion and at 7 days immersion time. Conversely, there was statistically significant different in mean contrast ratio of three different surface finishing groups at 14 and 28 Then, the Turkey test was used for determining which couple were different as shown in Table.4.

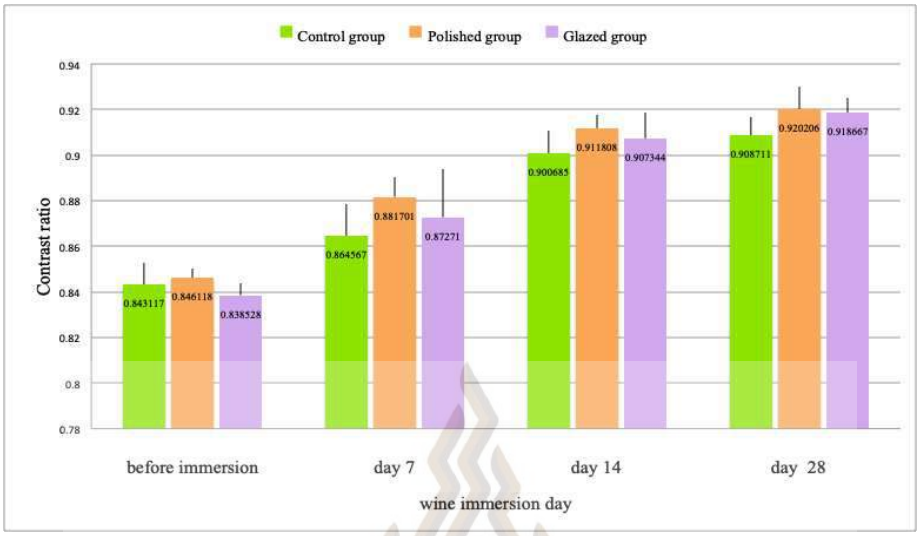


Fig. 12 The mean contrast ratio (CR) and standard deviation of three surface finishing specimens at different immersion time (T)

The result as shown in table3, was the mean value of contrast ratio after immersion in wine for 14 days of control and polished group were statistically significant different because the p-value was 0.039 which less than 0.05.

At day 14 immersion time, there was statistically significant different between contrast ratio of control and polished group, whereas there was not statistically significant different between contrast ratio of glazed and polished group.

At day 28 immersion time, there was statistically significant different between contrast ratio of control and polished group, and control and glazed group

The independent t-test was used to determine the different between mean of contrast ratio in each surface treatment group at different immersion time.

There were statistically significant different between mean of contrast ratio berfore immersion and 7,14- and 28-days immersion time.

Table 4 The mean contrast ratio in three groups of all specimens depending on wine immersion time

	CR_{T0}	CR_{T7}	CR_{T14}	CR_{T28}
Control group	0.843117 ^{A}	0.864567^{A}	0.900685 ^{A}	0.908711 ^{A}
Polished group	0.846118 ^{A}	0.881701 ^{A}	0.911808 ^{B}	0.920206 ^{C}
Glazed group	0.838528 ^{A}	0.87271 ^{A}	0.907344 ^{A,B}	0.918667 ^{C}

Note: the different superscript letter represents statistically significant difference

Color stability

Shapiro-Wilk and Levene test were used respectively to determine whether the delta E was normal distributed and homogenized in variance. The delta E was normal distributed data and homogenized in variance. Consequently, One-way ANOVA was used to determine the different in mean delta E among three surface finishing groups.

The means of delta E (ΔE) of control group were 5.6145 and 8.3734 when immersion for 14 and 28 days respectively as shown in table 5.The delta E of every group of surface finishing specimen after immersed in wine for 14 and 28 days were comparable. They were approximately 5 and 8 respectively. It represented that the surface treatment did not affect on the color stability of specimen.

It can be observed that the delta E (ΔE) were increased by the time. The delta E at day 28 was greater than the delta E at day14. From these data, it can be implied that the immersion time decrease the color stability of the specimen.

Table 5 The mean delta E standard deviation of three surface finishing specimens at different immersion time (T)

		14 days	28 days
Control group	Mean	8.373386	0.864567
	Standard deviation	1.122262	0.013830
Polished group	Mean	7.225920	0.881701
	Standard deviation	0.671943	0.008562
Glazed group	Mean	7.625451	0.872710
	Standard deviation	0.953025	0.020960

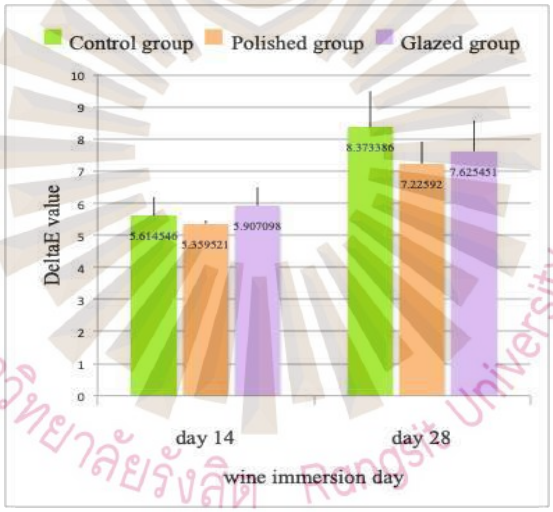


Fig.13. The mean delta E of three surface finishing specimens at different immersion time (T)

There was not statistically significant different in mean delta E of three different finishing groups at 14-day immersion time. Conversely, there was statistically significant different in mean delta E of three different surface finishing groups at 28-day immersion time. Then, the Turkey test was used for determining which couple were different as shown in Table.6.

At day 28 immersion time, there was statistically significant different between delta E of control and polished group, whereas there was not statistically significant different between delta E of glazed and polished group, glazed and control group as shown in Table 6

The independent t-test was used to determine the different between mean of color stability value (delta E; ΔE) in each surface treatment group at different immersion time. There were statistically significant different between mean of ΔE_{0-14} and ΔE_{0-28} .The ΔE_{0-14} and ΔE_{0-28} were the values which compared the color stability before specimens were immersed in wine and color stability were measured at day14 and 28 after specimens were immersed in wine respectively.

Table 6 The mean delta E of three surface finishing specimens at different immersion time

	$\Delta E_{14\ days}$	$\Delta E_{28\ days}$
Control group	5.614546 ^{A}	8.373386 ^{A}
Polished group	5.359521 ^{A}	7.225920 ^{B}
Glazed group	5.907098 ^{A}	7.625451 ^{A,B}

Note: the different superscript letter represents statistically significant difference.

CIELAB is the color stability measurement which has three axes (L, a and b axis). The L axis means the brightness-darkness value which zero means white and one hundred means black. The a axis evaluated the green-red value which negative value means specimen tend to green color and positive value means specimen tended to red color. The b axis represented the blue-yellow color which negative value means specimen tend to blue color and positive value means specimen tended to yellow color. Our specimens tended to darkness, greenness and yellowness which can be indicated by the different value of L, a and b value in the day before wine immersion and 28 days after wine immersion respectively. The control group had the maximum change in the darkness indicated by the ΔL (Before wine immersion-L28 days after wine immersion) is 9.06. The glazed group had the

minimum change in L axis which measured ΔL is 5.3. Including the a axis, the control group had the maximum change which measured -3.26 and the glazed had the minimum change which measured -0.66.In contrast , there are maximum change of the b axis in glazed group which is +3.75 .But this value(+3.75)which is the different of b value in day 28 after wine immersion and day 0 before wine immersion, is less than +4.19 which is the different of b value in day 14 after wine immersion and day 0 before wine immersion. The control group had the minimum change in b axis which is +1.41 at day 28 after wine immersion.

Chapter 5: Conclusion

1. No significant difference of color stability and contrast ratio between polish and glazed group.
2. Color stability and contrast ratio relate to immersion time of specimen in red wine, increase immersion time cause of decrease in translucence but increase in color stability.
3. The result from our study found that no significant difference between color stability and contrast ratio between polish and glazed group within 28 days

Chapter 6: Discussion

Color stability

From our experiment, it was found that there was a change in color of our specimen, PICN, after being immersed in red wine. A comparison was made using delta E value. The delta E values of the polished group after being immersed in red wine for 14 days and 28 days were 5.359 and 7.225, respectively. As for the glazed group, the values were 5.907 and 7.625, respectively. These results were similar to those of another experiment done where PICN were immersed in red wine for 7 days with delta E value being 6.23 (26). However, they were different from the other experiment where PICN were immersed in the red wine for 14 days, having delta E value as 13.6 (27).

When compared to experiment done with composites, the deltaE values were similar to that of our experiment. After immersing different types of composite in red wine for 24 hours, the deltaE values were in the range between 5.1-6.3 (28). It can also be noted that composites needed lesser immersed time for a change in colour to occur than PICN. After immersing in red wine for 7 days, the deltaE value for compostie that were not polished was 11.3 (29). In experiment where composites were immersed for 4 weeks, the deltaE value was > 5.5 (30) and the average deltaE value was between 5.40-6.75 (31).

There has been some studies also found that red wine causes the most change in color of the PICN as compared to cola, coffee, tea, and distilled water (26); as well as curry, cress, and distilled water (27). The same goes for when the specimens were composites. Red wine causes the most change in color as compared to cola, orange juice, and distilled (31); as well as cola, tea, coffee, and water (28); cola, and coffee (29).

Furthermore, our experiment has shown that the change in color gradually increases as the period of time the specimen is immersed in red wine increases. This can be seen from the delta E values that increases after 28 days. This is similar to Sasipin's experiment where the specimens were immersed in coffee for 1 day, 1 week, and 1 month: the delta E value being 0.5, 0.8, and 1.4 respectively (32).

Contrast ratio

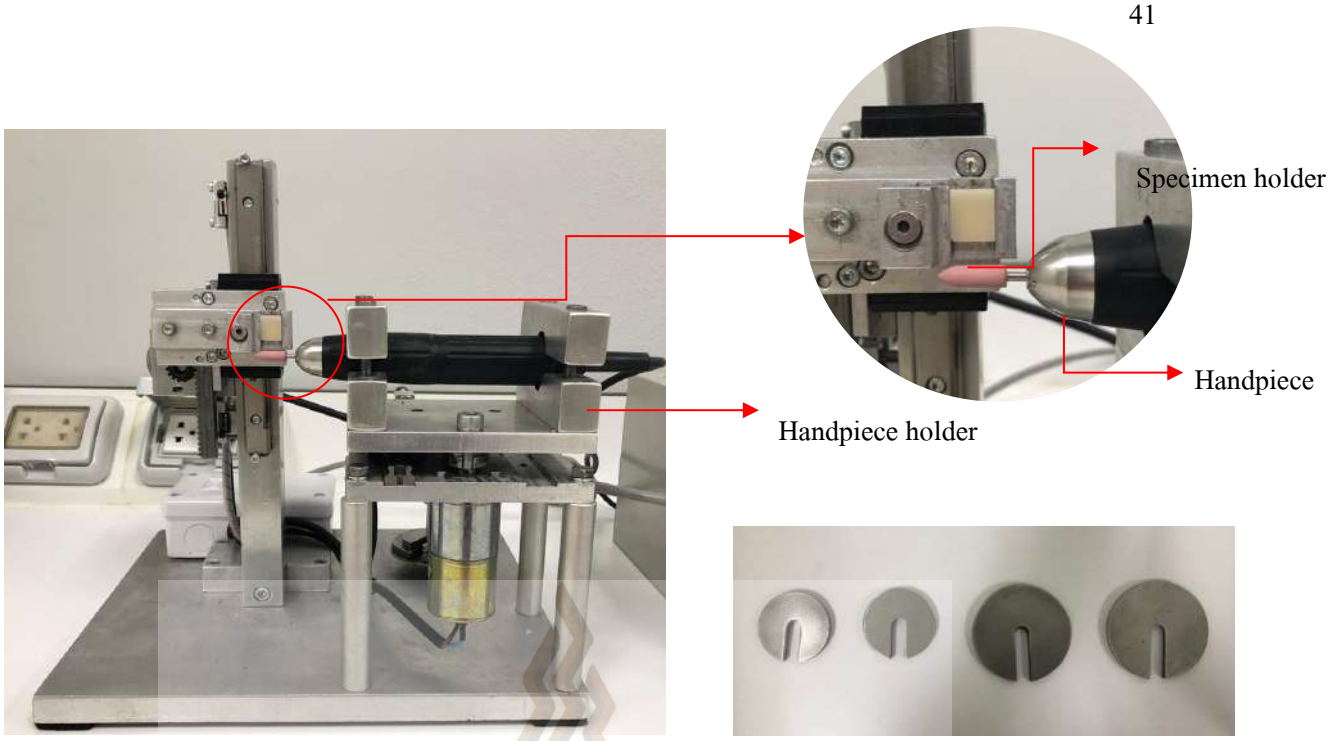
The contrast ratios of day 7, 14, and 28 of our experiment in the polishing group were 0.88, 0.91, 0.92 respectively; and in the glazed group were 0.87, 0.90, and 0.91 respectively. This shows that there was a decrease in translucency after the specimens were immersed in red wine. Other experiments using PICN (26, 27) also show a similar pattern, with the delta TP value being -3.29 after immersed in red wine for 7 days (26); and -0.1, -0.3, and -0.7 after immersed in coffee for 1 day, 1 week, and 1 month respectively (32).

Comparison between polished and glazed

After comparing between polished and glazed group, there were no significant difference in color stability (delta E) or contrast ratio in our experiment. This result is the same as previous study where specimens used were separated into 4 groups (controlled, technical, clinical, and glazed group) and were immersed in distilled water, coffee, and red wine for 28 days, then the translucency parameter was measured before and after being immersed in red wine for 24 hours, 7 days, and 28 days (33).

Method

There are many studies about the effect of polishing to the color stability and contrast ratio. However, most of these studies did not control the force used when polishing, which makes it hard to identify whether the force used to polish each specimens were the same or not. Our experiment, on the other hand, used a Customized polishing machineas shown in Fig.14 where force and pressure used to polish all our specimens can be and were controlled to be the same.



(a) (b)

Fig.14Composition of customized polishing machine(a), weight 50 g. and 100 g.(b)

The advantage of polishing by a machine versus manually is being able to control the force, pressure, and direction of polishing. However, in reality, we may not be able to use a machine to polish in every case. Therefore, some adjustments may be done to achieve the same result as much as possible, e.g. having one person to polish all the specimens and increasing the number of specimens at the same time to decrease the chance of error that could occur.

From our experiment, there was a slight difference between delta E value and contrast ratio of the control, glazed, and polished group. The control group was supposed to have a more distinct difference in the delta E and contrast ratio value, however, the method we use to do surface treatment was by polishing every group with silicon carbide paper from 400 until 1,200 grits, resulting the control group to have certain smoothness to start off with. This caused the delta E and contrast ratio value of the controlled group to be only slightly different from the polished and glazed group. Even so, it was noted that the area around the specimen had the most change in color as this area did not go through any surface treatments as shown in Fig.15.

The glazing process was controlled by having the same person to control the thickness of the glaze for each specimen. Once glazed, the thickness was also measured to get the thickness of the specimens within the range we have decided on. The direction of glazing was also controlled by using micro brush from the company to glaze in one direction. However, after glazing with micro brush, it

(a)

(b)

(c)

Fig.15 Specimen's corners after it was immersed in red wine of the controlled group where no surface treatment was done (a) compared with the area that was not immersed in red wine (b) and the area that has gone through surface treatment before it was immersed in red wine (c)

The glazing process was controlled by having the same person to control the thickness of the glaze for each specimen. Once glazed, the thickness was also measured to get the thickness of the specimens within the range we have decided on. The direction of glazing was also controlled by using micro brush from the company to glaze in one direction. However, after glazing with micro brush, it was found that the glazed surface was not as smooth as it should be and there were marks of the micro brush. Therefore, we decided to use celluloid strip to help gain a smoother surface. Using micro brush to glaze may also cause the specimen's surface to have an increased surface roughness, resulting in more color being stained (34, 35).

As for the immersing time of the specimen in red wine, we have used the period of time of 28 days (in vitro), which is equivilent to 28 months (in vivo), as 24 hours of being exposed to drink in vitro corresponds to 1 motnh (36). Our study has chosen red wine as the medium for specimens to immerse in seeing as many studies have claimed that red wine has the ability to stain the easiest (26, 27, 31, 28, 29). This is because red wine contains tartaric acid (31) with a pH of 3.7 (29, 37), and 3.41(31) . This low pH and alcohol will soften the resin matrix, causing some ion lost, and creating stains on the material's surface (29, 38, 37).

Factors affecting color stability and translucency were thought of whenforming the method we used in our experiment. For example, choosing red wine as the medium to immerse our specimens in, treatment surface method by polishing and glazing to decrease surface roughness, hence decrease the amount of staining.

Factors affecting color stability are extrinsic factors, intrinsic factors, and surface smoothness. Extrinsic factors are the food and beverages we intake, e.g. tea, coffee, and red wine.

Intrinsic factors are those such as incomplete polymerized composite resin part, the structure of resin matrix (Bis-GMA, UDMA, TUGMA), and the characteristic of filler particles (39).

Factors affected translucency are thickness, number of firing, filler particles, and resin matrix composition, polymerization, and surface smoothness (40, 41).

Effect of surface roughness

There was a study that shows that surface roughness has an effect on color stability and contrast ratio (42, 33, 34). This came from a study that said a polished and glazed surface has similar surface roughness (43), therefore, the delta E and contrast ratio value of polished and glazed group were quite similar. Our study can conclude that there was no significant difference in delta E and contrast ratio values between the polished and glazed group. Therefore, polishing the surface alone is enough without having to glaze it, since both results in similar surface roughness.

In present study

After having completed our experiment, there were some recommendations for the experiment to produce more accurate results if we were to do it again. For example, using artificial saliva instead of distilled water to immerse our specimen in before any measurements to mimic intraoral environment; use more varieties of beverages to compare deltaE and contrast ratio values of other beverages; use glass slit to create a smooth glaze instead of celluloid strip; measure surface roughness of specimen once polished and glazed before measuring deltaE and contrast ratio value and choose specimens with similar surface roughness on all its surfaces to get a more accurate reading, as specimens may have some area with more or less roughenss, causing errors to the deltaE and contrast ratio values.

Methodological limitations

Our experiment is an in vitroexperiment. This cannot be compared to invivo experiment as experimenting in real patients will have many factors we would not be able to control, e.g. moisture, and intraoral environment is always changing. However, in the lab, we can control the environment to be as we desire. Therefore, the values resulting from different ways of experimenting may be different. Furthermore, if we were to experiment in real patients, we must also keep in mind the ethics to do it.

Further study

We are interested in studying the effect of surface treatment on surface roughness as we want to know which method of surface treatment would be the most suitable for PICN, resulting in the least surface roughness. The next interesting topic is the effect of accelerate aging on physical properties of PICN. This is because we want to know how the physical properties of PICN changed over time as the material has been used, The last aspect that seems intriguing to look into is a clinical study (in vivo), a study in real patients to get more accurate values of delta E and contrast ratio. In further study, in surface roughness measurement, we will use profilometer to measure the best polished specimen.

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