COLOR STABILITY, WATER SORPTION AND WATER SOLUBILITY OF VARIOUS ARTIFICIAL ACRYLIC RESIN TEETH

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เสถียรภาพของสี การดูดน้ำ และการละลายน้ำ ของวัสดุฟันเทียมอะคริลิกเรซินชนิดต่างๆ

น.ส.ปิยพร เฟื่องฟู

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เสถียรภาพสี การดูดน้ำและการละลายน้ำของฟันเทียมชนิดอะคริลิกเรซินเป็นปัจจัยทางกายภาพที่มีผลต่อความสวยงามและคุณสมบัติเชิงกลของฟันเทียม วัตถุประสงค์การวิจัยครั้งนี้เพื่อเปรียบเทียบเสถียรภาพสี การดูดน้ำ และการละลายน้ำของฟันเทียมชนิดอะคริลิกเรซิน 3 ชนิด ได้แก่ โพลีเมทิลเมทาคริเลตชนิดเส้น (NEW) คอมโพสิทเรซิน (CPX) และโพลีเมทิลเมทาคริเลตชนิดครอสลิงค์ (ANT) และอะคริลิกเรซินสีเหมือนฟันชนิดบ่มด้วยความร้อน (MAJ) เตรียมชิ้นงานทรงกระบอก (9 มม/ หนา 2 มม/ 80 ชิ้น) สำหรับทดสอบเสถียรภาพสี โดยแบ่งเป็น 2 กลุ่มเพื่อแช่ในน้ำกลั่นและสารละลายกาแฟ และชิ้นงานทรงกระบอก (9 มม/ หนา 0.5 มม/ 40 ชิ้น) สำหรับทดสอบการดูดน้ำและการละลายน้ำ เสถียรภาพสีวัดโดยสเปคโตโฟโตเมทรีภายหลังแช่ในวันที่ 1 7 28 56 และ 84 วัน สำหรับการทดสอบการดูดน้ำและละลายน้ำวัดผลในวันที่ 1 8 36 และ 92 วัน สถิติที่ใช้ในการศึกษาครั้งนี้คือการวิเคราะห์แปรปรวนแบบซ้ำแบบสองทางที่ระดับความเชื่อมั่น 95% ผลการศึกษาพบว่า MAJ มีการเปลี่ยนแปลงสีมากกว่า NEW CPX และ ANT ตามลำดับ โดยพบความแตกต่างอย่างมีนัยสำคัญตั้งแต่วันที่ 7 ถึง 84 การดูดน้ำพบว่ามีความแตกต่างอย่างมีนัยสำคัญตั้งแต่วันที่ 1 และในวันที่ 36 และ 92 พบว่า MAJ ดูดน้ำมากที่สุดตามด้วย NEW CPX และ ANT ตามลำดับ ส่วนการละลายน้ำพบว่ามีความแตกต่างอย่างมีนัยสำคัญตั้งแต่วันที่ 1 และในวันที่ 36 และ 92 พบว่า MAJ ดูดน้ำมากที่สุดตามด้วย CPX NEW และ ANT ตามลำดับ ผลการศึกษาครั้งนี้ยืนยันอิทธิพลของชนิดซี่ฟันเทียมอคริลิกเรซินมีผลต่อเสถียรภาพสี การดูดน้ำและการละลายน้ำ นอกจากนี้ยังพบว่ากระบวนการผลิตและชนิดของสารละลายมีผลต่อเสถียรภาพสีด้วย

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Piyaporn Foungfu : COLOR STABILITY, WATER SORPTION AND WATER SOLUBILITY OF VARIOUS ARTIFICIAL ACRYLIC RESIN TEETH . Advisor: Natthavoot Koottathape, Ph.D.

Color stability, water sorption and water solubility of the acrylic resin artificial teeth are the success keys to the appearance and mechanical properties of the denture teeth. The objective of the present study was to compare the color stability, water sorption and water solubility of 3 commercial artificial teeth: linear PMMA (NEW), resin composite (CPX) and cross-linked PMMA (ANT) and 1 color-liked heat-polymerized acrylic resin (MAJ). 80 colume-shaped specimens (9 mm/ 2 mm thickness) were fabricated for color stability test using a spectrophotometer after immersing in water or coffee solution at 1, 7, 28, 56 and 84 days. 40 colume-shape specimens (9 mm/ 0.5 mm thickness) were fabricated for the water sorption and water solubility tests using the weight measurement method at 1, 8, 36 and 92 days. The repeated 2-way ANOVA was calculated at the confidential level of 95. The results demonstrated the different color change depending on the type of denture teeth (MAJ>NEW>CPX>ANT) from 28 to 84 days, while the color change showed no significant difference at 1 day storage. The water sorption results demonstrated the greatest MAJ, followed by NEW, CPX and ANT respectively at 36 and 92 days, while the water solubility showed the greatest MAJ, followed by CPX, NEW and ANT respectively. This study confirmed the effect of the composition of acrylic resin denture teeth on the color stability, water sorption and water solubility. Moreover, the effect of the fabrication method as well as the type of storage solution was reported.

Field of Study:	Prosthodontics	Student's Signature ....
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Piyaporn Foungfu

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

CHAPER I

INTRODUCTION

Background and Rationale

Edentulism is described as a condition which people partially or totally loss their tooth/teeth due to dental caries, periodontitis, congenital missing and/or accident. Fixed prosthesis, removable prosthesis as well as the latest technology dental implant are the possible prosthodontic plan for restoring the appearance, phonetic, chewing ability of the edentulous patients. According to the 7th Thai national oral health survey, the 60 – 74-year-old Thai people was reported to be the most population that need both the removable partial denture (15.7%) and the full denture (20.8%), while the over 80-year-old population needed full denture (59.4%). (1). The prevalence study of the northern India population needed the removable denture data showed that the removable partial denture (12.23%) was needed rather than full denture (6.5%) (2). Nevertheless, the satisfaction study of the Dutch elderly population who worn the removable prosthesis reported the 90% of samples accepted daily use of their present prosthesis both the aspect of chewing ability and esthetics (3). Therefore, the removable prosthesis is still an alternative of choice under the reason of the comparative lower cost and acceptable appearance.

The materials which are considered to fabricate the removable prosthesis are acrylic resin, porcelain and metal alloy, especially acrylic resin that is a common used material. For selection of the materials for fabricating a removable prosthesis, the mechanical properties, physical properties including their appearance are the major considerations for predicting their duration of service, the patient satisfaction. The less toxicity, user-friendly and reasonable laboratory cost are also the consideration for materials selected. The polymeric materials are the only materials which can successfully fulfill all purposes.

The acrylic resin material was invented since the 1890s, and firstly introduced to the dental field by the early 1930s. The polymethyl methacrylate (PMMA) became famous for fabricating the denture base by 1946 according to their polymerizing method and esthetics (4). The ISO 20795-1: 2013 specified the minimum mechanical properties of the denture polymers that the flexural strength was 60 – 65 MPa, the flexural modulus; 1.5 – 2.0 GPa (5). The mechanical properties of the acrylic resin materials used in prosthesis fabrication are under the influence of their molecular structures. The simple molecular acrylic resin structure called "linear structure" present by twice lesser impact strength than the acrylic with copolymer. The polymerization method is also a factor affecting on the impact strength (6). Moreover, the acrylic resins with different type of cross-linking polymer chain and their different concentration were reported to effect on the mechanical properties (7). The acrylic with higher molecular weight showed the greatest impact strength, while the molecular weight showed no correlation with the deflection, the tensile strength and flexural modulus, but their own cross-linking agent concentration.

Apart from the mechanical properties, the physical properties which predict the appearance are the color stability, water sorption and water solubility. Several studies reported the effect of color change when acrylic resins immersed in a staining solution such as coffee, tea and red wine. That the color of denture base acrylic resins was not significantly changed after immersing in the food colorants for 6 months (8), whereas the denture base acrylic resins were significantly changed after immersing in color beverages (9). The color of the acrylic denture tooth with copolymers or filler was reported to be darker and eye perceptible after wine immersion, whereas the PMMA acrylic denture tooth could not observe color change (10). Regarding water sorption and solubility of the acrylic resin, the type and the concentration of cross-linking polymers added to the PMMA and methyl methacrylate (MMA) solution presented the correlation to these parameters (11, 12), whilst other study reported no significant difference among the up to 60% ethylene glycol dimethacrylate (EGDM) concentration of the cross-linking polymer in PMMA/MMA group comparing to no cross-linking acrylic resin group (13). On the other hand, the acrylic resin with additive fillers showed no significantly different water sorption and water solubility comparing to the acrylic resin without the additive filler (14). The color stability, the water sorption and the water solubility of the PMMA materials are the crucial concerns when the materials are used for fabricating the removable prostheses. should be retain the color over period of time. However, the color stability, the water sorption and the water solubility of the various structure acrylic resins used in dental service are still not clearly elucidated. Therefore, the aim of this study is to evaluate color stability, water sorption and water solubility among several acrylic resins with cross-linking polymers or additive filler comparing to conventional heat-curing PMMA acrylic resin.

Research Objective

The purpose of this present study is to compare the color stability, the water sorption, water solubility of various acrylic resin teeth materials.

Research Hypothesis

$H1_0$: There would be no significant difference among the color difference (ΔE^*) of various acrylic resin teeth materials immersed in water and coffee.

$H1_a$: There would be significant difference among the color difference (ΔE^*) of various acrylic resin teeth materials immersed in water and coffee.

$H2_0$: There would be no significant difference among the water sorption of various acrylic resin teeth materials.

$H2_a$: There would be significant difference among the water sorption of various acrylic resin teeth materials.

$H3_0$: There would be no significant difference among the water solubility of various acrylic resin teeth materials.

$H3_a$: There would be significant difference among the water solubility of various acrylic resin teeth materials.

Keywords

Acrylic resin teeth, Color stability, Water sorption, Water solubility

Research design

Experimental study

Proposed benefits

The proposed benefits of this study are to determine the color change phenomena of the acrylic resins teeth which are presently used for fabricating the removable dentures after a period of service. This *in vitro* study simulates the actual intra-oral environment of the patient. Moreover, the water sorption, water solubility might be a reason of ageing effect of the dentures from daily stainable beverages.

CHAPTER II

REVIEW LITERATURE

Acrylic resin

The acrylic resin is classified to be a type of polymer consisting of the repeated same molecules or the repeated same set of molecule orders with/without the additive copolymer or the additive fillers. The smallest molecular unit of the polymer is called “mer or monomer” a small and simple structural molecule which made up of many units to be a larger or complicated molecular structure. The monomer is the molecule that to forms the polymer when the polymerization reaction occurred and processed by polymerization reaction. Another type of polymer would also be combined between the main polymer molecules and more different types of monomer or small sets of polymers called the copolymers or cross-linking polymer (15, 16).

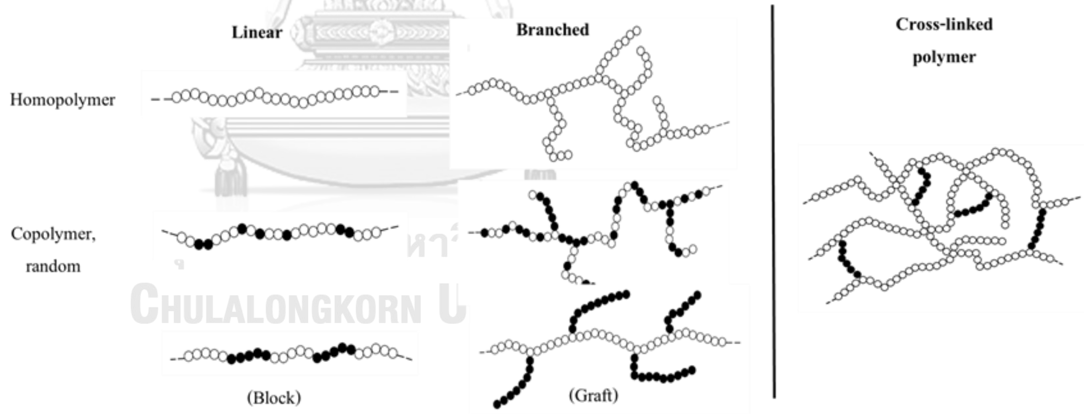

Figure 1 Type of polymer according to the type of polymer (homopolymers, copolymers) and molecular structure (linear, branched, and cross-linked).
The open circles represent one type of mer units, and the solid circles represent another type of mer unit. The dashed lines indicate the repeated segment in the same order.
Modified from Powers, J. M.; and Sakaguchi, R. L. Craig’s restorative dental materials. 13th ed. Philladelphia: Elsevier Mosby, 2012.

Generally, the polymer has different classification according to the chemical composition, molecular weight and distribution or the arrangement of small repeated units as shown in Fig 1. Considering the molecular structure, the polymers can be classified to be linear structure and branched structure. Another classification is considered by the number of additive polymers. The polymeric molecule which consists of the same mer molecule called “homopolymer”, the inserted or grafted short polymer to the main polymer molecular chain called “copolymer”, and the short polymer which combines the several parts of the main polymer chain together called “cross-linked polymer”.

Methyl methacrylate and Polymethyl methacrylate

The MMA was firstly synthesized in the early 1900s, and polymerized to be the larger polymer, PMMA, for producing the denture base in 1930’s (17, 18). The large acrylic resin molecule used in Prosthodontic treatment basically is the PMMA (polymer) consisting of the same repeated the MMA (mer). The structure of the MMA and the PMMA are shown in Fig 2.

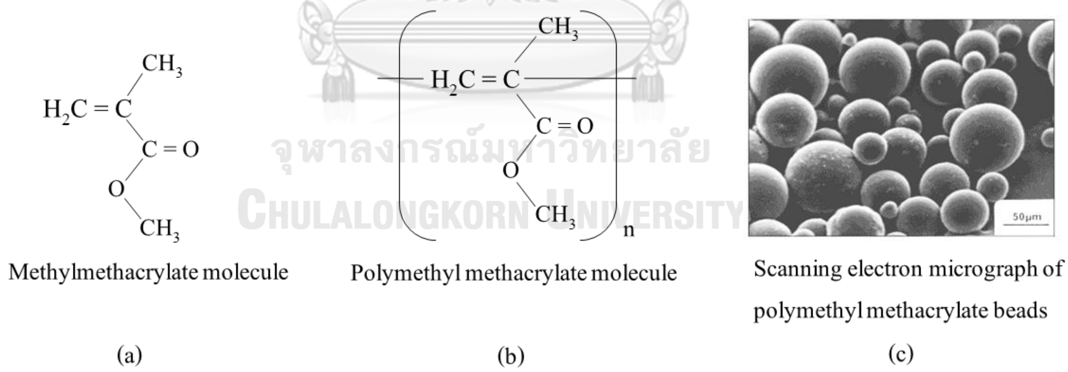

Figure 2 The MMA and the PMMA: the molecular structure of MMA (a), the molecular structure of PMMA (b), and the microscope of PMMA beads (c).

Modified from (1) Anusavice, K. J.; Shen, C., and Rawls, H. R. Phillips’ Science of dental materials. 12th ed. St. Louis: Elsevier Saunders, 2013., (2) Powers, J. M.; and Sakaguchi, R. L. Craig’s restorative dental materials. 12th ed. Philladelphia: Elsevier Mosby, 2012.,

(3) O'Brien, W. J. Dental materials and their selection. 4th ed. Chicago: Quintessence, 2008.

The commercial application of the acrylic resin commonly consists of two components, the powder and the liquid (Table 1). The main composition of powder is PMMA with the initiator such as benzoyl peroxide and the color pigments. The main composition of the liquid part is the MMA and probably cross-linking agents depending on the commercial purpose. The activator is added in the liquid part for initiating the redox reaction, while the inhibitor is used for prolong the storage time.

Table 1 The component, composition and function of acrylic resin materials

Component	Constituent	Function
Powder		
Polymer	Polymethyl methacrylate beads	Main component of acrylic resin
Initiator	A peroxide such as benzoyl peroxide	Initiate the polymerization of the monomer liquid after being added to powder
Pigment	Salt of cadmium or iron or organic dyes	Simulate tissue colors
Liquid		
Monomer	Methyl methacrylate	Main component
Cross-linking agent	Ethylene glycol dimethacrylate	Reduces the solubility and water sorption and reduces the tendency of the denture base crazing
Inhibitor	Hydroquinone	Prevent polymerization of the liquid during storage
Activator	N N'- dimethyl-p-toluidine	Speed up the peroxide decomposition and enable the polymerization of monomer at room temperature

Modified from (1) Rashid, H.; Sheikh Z.; and Vohra F. Allergic effects of the residual monomer used in denture base acrylic resins. European journal of dentistry. 9 (2015): 614 – 619., (2) Powers, J. M.; and Sakaguchi, R. L. Craig's restorative dental materials. 12th ed. Philladelphia: Elsevier Mosby, 2012.

The physical and mechanical properties of the PMMA and the MMA indicates in Table 2 and Table 3, respectively. The MMA is a polymeric transparent liquid with the boiling point temperature almost similar to water. The PMMA has greater density than the MMA after polymerization, and can also absorb surrounding water, and dissolve in water. The PMMA is a transparent acrylic resin with the flexural strengths (78 – 92 MPa), the abrasive resistance (0.595 mm in depth), the tensile strength (48 – 62 MPa), the modulus of elasticity (1.1 – 2.4 GPa) and the Knoop hardness number (15-20). The mechanical properties of the presently commercial PMMA products are acceptable according to the ISO 20795-1 for base polymers, but some products showed their flexural modulus less than the standard (5, 15, 16).

Table 2 The summarize of the physical properties of MMA and PMMA comparing the ISO 20795

Properties	MMA	PMMA	ISO 20795
Molecular weight	100	150,000	
Melting point (˚C)	48˚C	160	
Boiling point (˚C)	100.8	200	
Density (g/mL)	0.945	1.16 – 1.18	
Heat of polymerization (kcal/mol)	12.9	-	
Water sorption (mg/cm^2)	-	0.69	< 32 $\mu g/mm^3$
Water solubility (mg/cm^2)	-	0.04	< 1.6 $\mu g/mm^3$

Modified from (1) Anusavice, K. J.; Shen, C., and Rawls, H. R. Phillips' Science of dental materials. 12th ed. St. Louis: Elsevier Saunders, 2013.

Table 3 The summarize of the mechanical properties of PMMA comparing the ISO 20795

Properties	Anusavice	Craig	ISO 20795
Flexural strength (MPa)	-	78 - 92	65
Flexural modulus (GPa)	-	1.1 – 2.1	2
Abrasive resistance (μm)	-	595	N/A
Tensile strength (Mpa)	60	48 - 62	N/A
Modulus of elasticity (Gpa)	2.4	1.1 – 2.2	N/A
Knoop hardness number (KHN)	18 - 20	15	N/A

Modified from (1) Anusavice, K. J.; Shen, C., and Rawls, H. R. Phillips' Science of dental materials. 12th ed. St. Louis: Elsevier Saunders, 2013., (2) Powers, J. M.; and Sakaguchi, R. L. Craig's restorative dental materials. 12th ed. Philladelphia: Elsevier Mosby, 2012.

The methacrylate polymerization

The PMMA is synthesized by the polymerization reaction via a redox initiated system, the chain growth and termination as follows (Fig 3) (16-18).

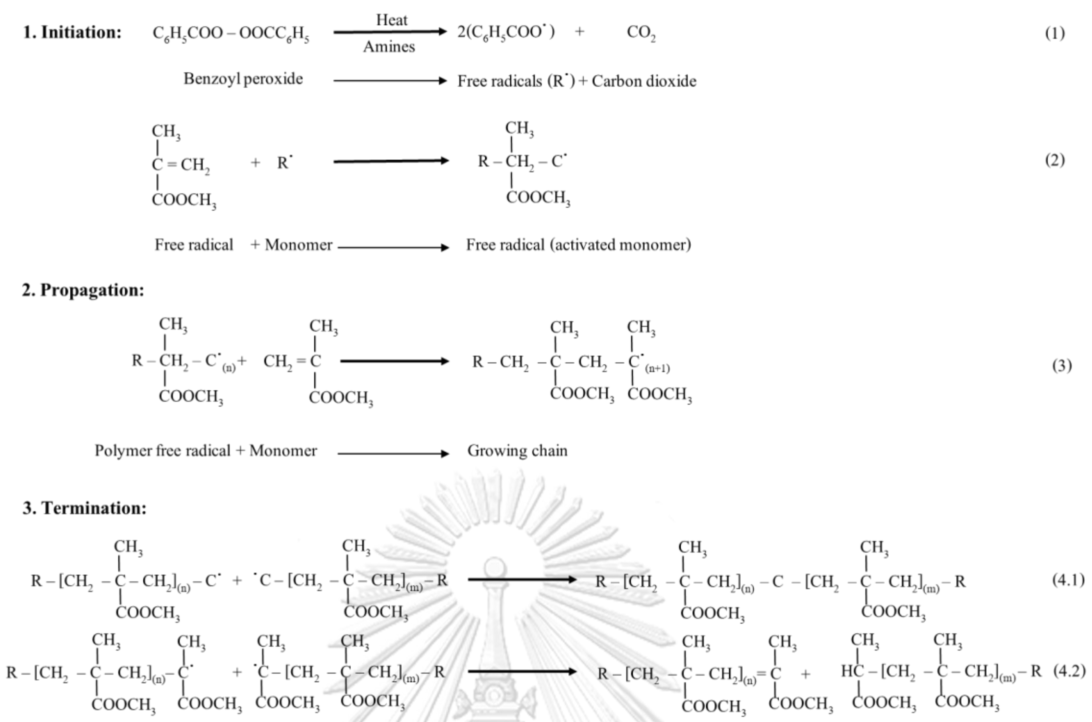

Figure 3 The polymerization reaction of methyl methacrylate

Modified from (1) O'Brien, W. J. Dental materials and their selection. 4th ed. Chicago: Quintessence, 2008., (2) Anusavice, K. J.; Shen, C., and Rawls, H. R. Phillips' Science of dental materials. 12th ed. St. Louis: Elsevier Saunders, 2013.

1.1 **Initiation**: The polymerization reaction of MMA starts from the breakdown of the initiator molecule, for example benzoyl peroxide, to be free radicals (R˙) and a by product. Subsequently, the free monomer receives the free radical and forms the molecule with an extra electron, called "activated monomer".

1.2 **Propagation**: The activated monomer combines to another free monomer at the site with the double bond carbon, resulting dimer. The reaction propagates rapidly to combine other free monomers become linear oligomer chain and passes the free radical to the combined monomer.

1.3 **Termination**: The end of elongation is inhibited by two possible reactions which are the direct combine between two polymer free radicals (Fig 3/4.1) or the exchange of hydrogen atom from one polymer free radical to another (Fig 3/4.2) (16, 18).

The acrylic resin in prosthodontics

Prior to 1900s, the natural materials, for example horns and hoof from animals or resin from insects or natural rubber, were used in prosthesis fabrication (4, 14). The invention of synthetic thermoplastic polymer in 1930's was the change point of dental treatment. The acrylic resin became widely used for fabricating the dentures due to its durability to the masticatory force and acceptable appearance. The acrylic resin presently used in prosthodontic treatment could be classified following the ISO 20795 as shown in Table 4.

Table 4 Acrylic resin classification (5)

Type	Class	Polymer
1	1	Heat-cured polymerizable materials (powder and liquid)
	2	Heat-cured polymerizable materials (plastic cake form)
2	1	Self-cured polymerizable materials (powder and liquid)
	2	Self-cured polymerizable materials (powder and liquid for pour-type resins)
3	-	Thermoplastic polymerizable materials (blank of powder)
4	-	Light-cured polymerizable materials
5	-	Microwave-cured polymerizable materials

1. Heat-cured polymerizable materials (4, 15, 16, 20)

The heat- polymerizable materials consist of powder and liquid separately. The powder part composes of polymethyl methacrylate beads with Benzoyl peroxide (Initiator), Dibutyl phthalate (plasticizer), pigments and opacifiers, while the liquid part composes of methyl methacrylate monomer with hydroquinone (inhibitor), glycol dimethacrylate (cross-linking agent) and plasticizers. During the manipulation of powder part and liquid part following the manufacturer recommendation, the MMA is converted to PMMA structure via the additional polymerization with no by-product occurs (Fig 3).

2. Chemically-cured polymerizable materials (4, 15, 16, 20)

In 1947, the chemical activators were invented and added in to the denture base materials for activating polymerization without heat. The new invented materials were also referred to the terms of cold-curing, self-curing or auto-polymerizing resins. The chemical activator, which is consisted of tertiary amine such as dimethyl-para-toluidine and benzoyl peroxide, would produce free radicals to initiate polymerization reaction at room temperature.

3. Thermoplastic polymerizable materials (19, 20)

The thermoplastic polymerizable materials, also called the injection-mold activated acrylic resin was first introduced in 1970. This system need more sophisticate machines for mixing methyl methacrylate liquid and powder, and for injecting the mixing material to the molds under continuous heat to the melting point temperature and pressure. The advantages of this material are good dimensional accuracy (19) and greater impact strength (21) comparing the heat-cured acrylic resin. However, the high cost of more sophisticated machines and special flasks are required.

4. Light-cured polymerizable materials (15, 17, 19)

These materials are mainly composed the PMMA derivative material, urethane dimethacrylate, microfine silica, and high molecular weight acrylic resin monomers, and light activator, camphorquinone as an initiator. Visible light activates the resin sheet after forming the denture base with a 3% polymerization shrinkage comparing to the conventional polymerization (7%).

5. Microwave-cured polymerizable materials

The microwave-cured polymerizable materials are polymerized by the 400-watt-microwave activation for 2.5 minutes (20). Even though the materials need quite short time processing procedure comparing to the heat-cured polymerizable materials, no significant differences of the physical and mechanical properties including the density, transverse bending strength, Knoop hardness and transverse repair strength between the materials were reported (22).

Artificial denture teeth

Artificial denture teeth are designed and manufactured for replacing the natural teeth both the masticatory function and the esthetics. The materials which are considered to be fabricated the artificial denture teeth should withstand to the masticatory force in terms of their mechanical properties including wear resistance, hardness, elastic modulus. The studies of the wear resistance and the hardness reported that the correlation between the composition of the artificial denture teeth and two physical properties were significantly reported (23, 24).The elastic modulus (24) and the surface roughness (25) among the different compositions of the artificial denture teeth were significant differences. Nevertheless, the composition of the artificial denture teeth was also reported the relation to the color stability after immersing in the different color beverages (25) and several denture cleansing agents. (26).

Regarding the ISO 22112:2017 for artificial teeth for dental prostheses, the artificial denture teeth are classified, seem to be considered the position or function of the artificial teeth, to be two types: type 1; anterior teeth, type 2; posterior teeth (27). The standard separately gives more information between the polymer tooth and the porcelain tooth. The standard considerations of the porcelain denture teeth are the radioactivity, anchorage and resistance to thermal shock; whereas, the polymer denture teeth consider to the aspects of the bonding between the artificial teeth and the denture base polymer, the resistance to blanching, distortion, crazing, color stability and dimensional stability. The mechanical properties of the artificial denture teeth are summarized as shown in Table 5.

Table 5 The mechanical properties summarize of the artificial polymer-based denture teeth

Mechanical properties	**Craig** (16)	**Suwannaroop P.** ***et al*** (23)	**Shimoyama K.** ***et al*** (28)
Compressive strength (MPa)	76	-	43.0
Elastic modulus (GPa)	2.70	5.27 – 9.56	2.76
Elastic limit (MPa)	55	-	-
Hardness	18 – 20 (Knoop's hardness)	0.37 – 0.63 (Nano hardness)	-
Wear resistance	-	0.040 – 0.693 mm^3	-
Fracture load (kN)	-	-	2.2

Several researchers were classified the artificial acrylic resin denture teeth into 3 groups according to their composition and molecular structures (23-26, 28).

1. **Commercial linear PMMA**

The commercial linear PMMA is the conventional acrylic denture teeth which the manufacturers claim to fabricate from linear polymethyl methacrylate (PMMA). The lowest abrasive resistance (23) but greatest attrition wear resistance comparing to the cross-linked polymer(24) ,the lowest hardness (23, 24), the similar elastic modulus comparing to the cross-linked polymer but not for composite resin denture teeth (24) were reported. The brand and manufactures which are available in Thai, for example, are Major dent (Major Prodotti Dentari, Italy), Yamahashi FX (Yamahashi dental Mfg. Co., Aichi, Japan), Cosmo HXL (Densply International Inc., NJ, Brazil).

2. Cross-linked PMMA

The cross-linked PMMA is produced by the copolymerization between methylmethacrylate (MMA) and dimethacrylate (presumably triethylene glycol dimethacrylate (TEGDMA)) in the presence of finely powdered PMMA for improved mechanical properties of conventional acrylic resins (12). The mechanical properties of the cross-linked PMMA are informed as mention above. The example of the cross-linked PMMA artificial teeth are SR-Antaris (Ivoclar Vivadent, NY, USA), Truebyte Bioform IPN (Dentsply International. Inc., York, PA, USA)

3. **Highly cross-link PMMA with colloidal silica**

This material consists of the combination of the cross-linked copolymer with the additive colloidal silica fillers and silane as coupling agent. This material group showed the comparatively lowest wear resistance both attrition and abrasion, and greatest hardness (23, 24). The example of the highly cross-link PMMA with colloidal silica are Yamahashi PX (Yamahashi dental Mfg. Co., Aichi, Japan) and SE Orthosit PE (Dentsply International. Inc., York, PA, USA).

Regarding the color stability, one study reported that the color of two denture teeth with the cross-linked polymer groups and the conventional group were difference when immerse in red wine, coffee comparing to the water immersing group (29). The other study reported the lowest color stain of the porcelain denture tooth comparing to the cross-linked polymer denture teeth, and the storage time affected on the color stability (30). However, the water sorption and the water solubility of acrylic resin denture teeth study has no report.

The color stability of the acrylic resins and their factors related

Color is described as a phenomenon of light or visual perception that enables one to differentiate otherwise identical objects. The difference of color is explained according to the visual response to the light to be three dimension including hue, chroma and value. The "Hue" refers to the basic of color, which is the separately-wavelengths of radiant energy quality of the observer sensation as red, green, blue, etc., but white, gray and black are considered with no hue. The "Chroma" refers to the purity of a color or the intensity of an individual hue, and the "Value" is the relative whiteness or blackness of the color that can be distinguished by an observer (31). The standard color measurement using by many researchers is firstly introduced by the Commission Internationals d'Eclairage (CIE) which presented as color difference equation. (eq 1) The CIE coordinates into three dimensional matrices such that a specified distance between two colors is more nearly proportional to the magnitude of an observed difference between regardless of their hue (31).

$$\Delta E^*_{ab}(L^*a^*b^*) = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \qquad \text{(eq 1)}$$

where ΔE* denote as color difference which the magnitude and the character of difference between two colors under specified condition, L* denote as value (blackness to whiteness), a* as the level of red (+a*) to and green (-a*) and b* as the level of yellow (+b*) to blue (-b*). The ΔE* of 1 can be observed by the half of observers, whereas the ΔE* value of 3.3 is considerable to be the clinically perceptive level (15). Color stability is considered after a service of period when an acrylic resin denture was delivered to a patient. The dairy beverage and food contain various spectrum colorants which could be absorbed into the surface of the acrylic resin or penetrated deeply, and result the color change of the denture. The color stability of the acrylic resin is a property, regarding the appearance aspect, to retain its color over a period of time, and to be the indication of ageing and damage of the acrylic resin.

The color stability is under the influence of several factors including staining agents (8, 9, 32, 33), immersion time (33), type of acrylic resin (9, 33) and polymerization methods (32-35).

1. **Staining agents**: Several studies have reported that the different types of staining agents result in different color changes such as food colorants (8, 9, 32, 33), The 3% erythrosine colorant show greater color change effect than the tartrazine and sunset yellow, but acceptable in clinic (8). Regarding the daily beverage, a study reported that tea could change the acrylic resin greater than coffee and cola (9), while the organic juice exhibited the greatest color change result comparing to coffee and cola (32). The other reported the difference color change results of the acrylic resin immersing in coffee, cola and red wine groups in each observation time period (33).

However, the coffee is the most famous beverage used in the color change test (36-38).

2. **Immersion time**: The color stability is also under the influence of the immersion time. The greater the immersion time is, the greater the color change (33-35, 37).

3. **The composition of acrylic resin**: The relationship between the composition of the acrylic resin and the color change have been reported. The cross-linked acrylic resin and the heat-polymerized acrylic resin showed the different color change after immersing in the colorant solution (8, 10), while the composite denture teeth (10), the thermoplastic nylon resin (9) and porcelain denture teeth (30) showed comparatively greater color stability than the heat-polymerized acrylic resin and the cross-linked acrylic resin.

4. **Polymerization methods**: The present acrylic resins might be polymerized from chemical free radicals, heat, light wave or microwave-length wave. Several studies reported the correlation between the polymerization method and color stability of the acrylic resins. One study reported that the heat-polymerized acrylic resin both normal set and fast set and the microwave-polymerized acrylic resin were reported significant difference (33); whereas, another reported the fast heat-polymerized acrylic resin showed the greatest color change following by the chemical-polymerized acrylic resin and the light-polymerized acrylic resin respectively (34, 35).

Color measurement methods (39)

The color perception of human consists of three main factors including the light source, the object and the observer. This visual perception happens from the reflected 400 – 700 nm of the light from an object passing through and affecting on the rod cells and the cone cells in the eyes.

There are two color measurement or shade specification methods, as follow.

1. **Visual method**

The visual measurement method bases on “the Munsell color system”. Three variables are used to determine the difference between two observed colors. The “value” indicates the lightness from white to black, the “chroma” indicate saturation of color, and the “hue” indicates basic color (red/green/blue). This system relies on human experience to measure color.

2. **Spectrophotometric and colorimetric measurement methods**

The explanation of the spectrophotometric and colorimetric measurement methods imitates the visual perception of the human eyes which consist of the illumination, the object and the observer sensor. The data of color measurement will be determined following the CIE system as mention above. Comparing to the visual perception of the human eyes, the illumination unit should involve the entire wavelength of day light (380 – 780 nm). The observer sensor should interprete into the tristimulus which contain three-dimensional axis (X, Y, Z), and then the coordinated results will transform to be the three dimension of color according to the CIE L* a* b* system which L* is the lightness and which a* and b* are two different distinct color axes representing the RGB color system. The example of the spectrophotometry measuring the color in quantitative data is Hunter Lab (UltraScan PRO, Hunter Associates Laboratory, Inc., Virginia, USA)

The water sorption of the acrylic resins and their factors related

The water sorption could effect on the dimensional change of the polymer via the reversible and repeatable cycles between expansion and contraction. The expansion of the material is from the water immersion, and the contraction is from drying in the air. The result of the repeatable expansion/contraction cycle is that the warpage effect. (15) The water sorption might represent in term of adsorption which is the water sorption on the material surface, and in term of absorption which the water absorbs into the body of the material. The relation between the water sorption and the mechanical properties such as the surface hardness (40) and the transverse bond strength (41) are reported. The surface hardness and the transverse bond strength of acrylic resins were reduced after a period of water immersion.

According to ISO specification No 20795, the water sorption of the polymer was specified should not be greater than 32 µg/mm^3. The water sorption measurement can be performed by weighting specimen after stored in water solution with an analytic balancer with the accuracy of 0.0001 g. The calculation of the water sorption is used following the eq 2.

$$W_{sp} = (m_2 - m_3)/V \qquad \text{(eq 2)}$$

where m_2 is the constant mass of wet specimens, m_3 the constant mass of reconditioned specimens and V the specimen volume in mm^3.

Factors related the water sorption are the type of acrylic resin (11, 12, 42-46), storage solution (44), polymerization temperature, pressure and time (47, 48), the presence of copolymer or additive fillers (11-14).

1. Type of acrylic resin and copolymers

Several studies have reported that the different types of acrylic resin and copolymer showed the different results of the water sorption (11, 12, 42-46). The water sorption data of the different additive copolymers were also significantly different, especially the quantity of absorbed water and the behavior of water sorption. The additive triethylene glycol dimethacrylate (TGDMA) showed the increase of the absorbed water comparing the acrylic resin without TGDMA group (11, 12), while the reduced water sorption results were reported in the acrylic resin with other copolymers, for example 1,4- butanediol dimethacrylate (1,4 BDMA), 1,6-hexanediol dimethacrylate (1,6 HDMA) and trimethylol-propane trimethacrylate (TMPT) (11).

Apart from the additive copolymers, the water sorption also might be under the influence of the polymerizing method, probably in term of the acrylic resin composition (42-46). A previous study reported the greater water sorption of thermoplastic acrylic resin rather than that of the heat-cured acrylic resin (43);

whereas, the others reported that the heat-polymerized acrylic resin showed greater water sorption than the thermoplastic acrylic resin (42, 45).

2. Storage solution

One of the routine doctor suggestions after the delivery of the dental acrylic resin appliances is that the storage condition of the appliances during the bed time. The acrylic resin dentures are stored in the oral cavity with the saliva during the day time, and the distill water or the denture cleansing solution at night. The amount of water sorption of acrylic resin were differences when the acrylic resins were stored in the different storage media (44).

3. The storage condition

The relationship between the storage condition, especially temperature, pressure and time and the water sorption of acrylic resin was reported (47). The temperature was presented to be the most importance water absorbed factor comparing the pressure and the time. Furthermore, this relation was still ongoing until 90°C, and then the relation between the storage time and the water sorption was not significant.

The water solubility of the acrylic resins and their factors related

The water solubility is the property of the chemical substance called “Solute” to dissolve in water called “Solvent”. According to ISO specification No 20795, the water solubility of the polymer was specified should not be greater than 1.6 μg/mm^3, whereas that of the auto-polymerizing acrylic resin should not be greater than 8.0 μg/mm^3. The water solubility measurement can be performed by weighting specimen before and after stored in water solution with an analytic balancer with the accuracy of 0.2 mg. The calculation of the water sorption is used following the eq 3.

$$W_{sol} = (m_1 - m_3)/ V \qquad \text{(eq 3)}$$

where m_1 is the constant mass of the specimens, m_3 the constant mass of reconditioned specimens and V the specimen volume in mm^3.

Several factors affecting the water solubility of the acrylic resins are the type of acrylic resin (11, 12, 42-46), storage solution (44), polymerization temperature, pressure and time (47, 48), the presence of copolymer or additive fillers (11-14).

1. Type of acrylic resin and the additive copolymers

Several studies have reported that the different types of acrylic resin and the additive copolymer resulted the different water solubility (11, 42, 43, 45). The increasing copolymer including ethylene glycol dimethacrylate (EGDMA), 1,4-butanediol dimethacrylate (1,4-BDMA), 1,6-hexaneiol dimethacrylate (1,6-HDMA) and Trimethylol-propane trimethacrylate (TMPT) caused the decrease of the water solubility. (11) In addition the different type of the main acrylic resins also showed the different behavior of their water solubility. Several studies reported that the heat-polymerized acrylic resin were greater the water solubility than the thermoplastic nylon resin. (42, 43, 45)

2. Polymerization method

The polymerization methods including the heat polymerization and chemical polymerization resulted the difference of the water solubility. Several studies reported that the heat-polymerized acrylic rein has lower water solubility than the auto-polymerized acrylic resin (41, 45, 46).

3. Additive fillers

A previous study reported that the additive fillers effect on the water solubility of acrylic resin. The study showed acrylic resins with addition reinforced glass-fiber fillers had the higher water solubility than the acrylic resin without the reinforced fillers (14).

CHAPTER III

RESEARCH AND METHODOLOGY

Part I: Specimen preparation

The materials used in this study are presented in table 6.

Table 6 The materials used in the study

กลุ่มทดลอง	ตัวย่อ	สี	ยี่ห้อ	บริษัทผู้ผลิต	Batch No.
Commercial linear PMMA	NEW	A3	New Ace	Yamahashi Dental MFG.Co., Aichi, Japan	GC0241
Cross-linked PMMA with colloidal silica	CPX	A3	Crown PX	Yamahashi Dental MFG.Co., Aichi, Japan	DC1049
Cross-linked PMMA	ANT	A3	Anteriores	Ivoclar Vivadent., New York, USA	UR0869
Heat-cured dentine acrylic resin	MAJ	3F	Major C&B	Major Dental., Piemonte, Italy	1102CH

Color stability specimen fabrication

Regarding the specimens for color stability test, TRI group (n = 20) will be prepared by the loss wax technique with the disc-shaped silicones with 9.0±0.1 mm in diameter and 2.0±0.1 mm in thickness in the plaster stone molds. The heat-polymerized acrylic resin will be sieved the nylon threats out before mixing according to the manufacturer recommendation, and then packed into the molds before heat-polymerization under 80°C for 8 hours. All specimens will be consequently polished using the SiC abrasive papers until the #1000 grid and the alumina suspension in water. All specimens is cleaned using an ultrasonic cleanser, and stored in distilled water at 37°C for 24 hours before testing.

Apart to the artificial polymeric teeth groups, the 20 specimens of each group are prepared from the upper maxillary central incisors to be 9.0±0.1-mm-in diameter and 2.0±0.1-mm- in thickness cylindrical specimens using a low speed cutting machine (Isomet 1000, Buehler, Lake Bluff, USA). All specimens will be polished using the SiC abrasive papers until the #1000 grid, cleaned with the ultrasonic cleansing machine, and then stored in distilled water at 37°C for 24 hours before testing.

Water sorption and water solubility specimen fabrication

All specimen groups will be prepared in the same manner of the color stability, but not specimen size. The size and shape of the specimens for the water sorption and the water solubility test is the 9.0±0.1 mm in diameter and 2.0±0.1 mm in thickness column.

Part II: The physical properties measurements

The color stability measurement

All specimens in each groups randomly divide into 2 group interventions. One group is immersed in the coffee solution at 37°C, while the other is immersed in the distilled water at 37°C incorporating with an orbital shaker incubator (ES-20 Biosan, Medical-Biological Research & technologies, Liga, Latvia) at 37±2°C and the frequency of 1 Hz. All specimens are placed perpendicular and parallel each other on the acrylic resin racks. The coffee solution is changed every 24 hours. The color difference (ΔE) will be measured with a spectrophotometry (UltraScan PRO, Hunter Associates Laboratory, Inc., Virginia, USA) and automatically calculated by comparing the difference of specimen color before and after immersion in the solution following the eq 1. The results will be record every 1 hour for 24 hours, and then every week for 3 months.

Figure 4 Spectrophotometer (UltraScan PRO USP 2086)

Water sorption and water solubility specimen fabrication

All specimen groups will be prepared in the same manner of the color stability, but not specimen size. The size and shape of the specimens for the water sorption and the water solubility test is the 9.0±0.1 mm in diameter and 2.0±0.1 mm in thickness column.

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The color stability measurement

All specimens in each groups randomly divide into 2 group interventions. One group is immersed in the coffee solution at 37°C, while the other is immersed in the distilled water at 37°C incorporating with an orbital shaker incubator (ES-20 Biosan, Medical-Biological Research & technologies, Liga, Latvia) at 37±2°C and the frequency of 1 Hz. All specimens are placed perpendicular and parallel each other on the acrylic resin racks. The coffee solution is changed every 24 hours. The color difference (ΔE) will be measured with a spectrophotometry (UltraScan PRO, Hunter Associates Laboratory, Inc., Virginia, USA) and automatically calculated by comparing the difference of specimen color before and after immersion in the solution following the eq 1. The results will be record every 1 hour for 24 hours, and then every week for 3 months.

The water sorption and water solubility measurement

The water sorption specimens will be dried for 24 hours at 37± 2°C in desiccator, removed to a similar desiccator at room temperature for 1 hour, and then weighted with a balancer with a precision of 0.2 mg. This cycle will be repeated until the weight loss of each specimen was not greater than 0.5 mg in any 24-hour period (M_1). The specimens will be immersed in the solution at 37±2°C for 7 days. The specimens will be removed from the solution using tweezers, wiped with a clean, dry hand towel until devoid of visible moisture, waved in the air for 15 seconds, and weighted within 1 minute after removed from the solution (M_2). After water sorption test, the specimens will be reconditioned in the dessicator for 24 hrs and followed by additional 1 hour in a separate dessicator. The specimens were then removed and weighed. The dehydration cycle was repeated until a constant weight was attained, that was until the weight loss of each disc was not more than 0.5 mg in any of 24 hrs period. The discs were finally weighed and the reading was noted (M3). The water sorption and the water solubility equation are shown in eq 2 and eq3, respectively.

CHAPTER IV
RESULTS

The results of this experiment are separately explained into three parts: color stability, water sorption and water solubility. The color of the experimental specimens was recorded before immersed in the solution and shown in Table 7. The selected color of NEW, ANT and CPX groups were A3 following VITA shade guide, and that of MAJ was 3F, comparing to the A3 of the VITA shade guide. The L* values of all specimen groups showed the significant difference; whereas, the a* and b* values showed no significant difference.

Table 7 The L*, a* and b* values (Means (SD)) of the experiment groups before immersion

Group	NEW	MAJ	ANT	CPX
L*	90.56 (1.37)^{a}	81.77 (0.33)^{b}	72.02 (1.26)^{c}	87.90 (0.77)^{d}
a*	1.93 (0.23)^{a}	1.88 (0.05)^{a}	1.90 (0.17)^{a}	2.00 (0.16)^{a}
b*	32.72 (0.26)^{a}	30.49 (0.79)^{a}	29.72 (0.79)^{a}	32.10 (0.46)^{a}

The different lower-case letters show the significant difference of L*, a* and b* among the experimental groups in the same row ($\alpha < 0.05$).

Regarding the repeated two-way analysis of varience (Table 8), the interception between the material and storage solution factors and their individual factors are significantly different in day 7 – 84, not for 1- day storage.

Considering the ΔE values after immersion in water for 1-84 days (Table 9), no significant difference of ΔE was observed in each period. The greatest ΔE was observed in MAJ (1.61±0.11), and the lowest value was observed in NEW (1.44±0.35) and CPX (1.47±0.17) at the period of 84 days. The ΔL and Δa of all groups in water continuously became lesser, while the Δb became greater comparing the baseline data. (Table 10 – 12) Apart to the experimental groups stored in coffee solution, the significant color changes (ΔE) among all materials were observed at 7-, 14-, 28-, 56 and 84-days immersion (Table 9). The ANT showed the lowest ΔE and ΔL, while the MAJ showed the greatest ΔE and ΔL in each observed period. Both Δa and Δb showed the lowest values in ANT, followed by CPX and NEW. MAJ showed the greatest (Table 9-12).

Table 8 Repeated two-way ANOVA of ΔE* at day7

Source	Type III Sum of Squares	*df*	Mean Square	F	Sig.
Corrected Model	1309.84^{a}	7	187.12	352.00	< 0.01
Intercept	2022.67	1	2022.66	3804.96	< 0.01
Material	75.65	3	25.22	47.43	< 0.01
Solution	1152.16	1	1152.16	2167.41	< 0.01
Material*Storage solution	82.03	3	27.35	51.44	< 0.01
Error	38.27	72	0.53		
Total	3370.78	80			
Corrected Total	1348.12	79			

Table 9 The ΔE* (mean (SD)) of the experimental groups after immersed in water and coffee at 1d, 7d, 28d, 56d and 84d

Group	ΔE* (Mean (SD))									
	water^{A}					coffee^{B}				
	1d	7d	28d	56d	84d	1d	7d	28d	56d	84d
NEW	0.92^{a} (0.17)	1.34^{a} (0.26)	1.22^{a} (0.27)	1.46^{a} (0.33)	1.44^{a} (0.35)	2.19^{a} (0.31)	9.48^{a} (0.28)	12.22^{a} (1.22)	15.60^{a} (0.86)	16.53^{a} (0.64)
MAJ	0.80^{a} (0.12)	1.14^{a} (0.16)	1.20^{a} (0.13)	1.50^{a} (0.07)	1.61^{a} (0.11)	2.13^{a} (0.18)	10.50^{b} (0.49)	14.91^{b} (0.60)	17.44^{b} (0.43)	18.95^{b} (0.52)
ANT	0.83^{a} (0.10)	1.30^{a} (0.17)	1.32^{a} (0.18)	1.52^{a} (0.10)	1.57^{a} (0.08)	2.10^{a} (0.33)	5.45^{c} (0.32)	9.45^{c} (0.40)	10.54^{c} (0.66)	10.73^{c} (0.93)
CPX	0.98^{a} (0.14)	1.16^{a} (0.17)	1.24^{a} (0.28)	1.31^{a} (0.36)	1.47^{a} (0.17)	2.56^{a} (0.12)	9.86^{a,b} (1.92)	11.31^{a} (1.78)	13.15^{d} (2.27)	13.43^{d} (2.12)

The different upper-case letters show the significant difference of ΔE* between immerse solution ($\alpha < 0.05$)

The different lower-case letters show the significant difference of ΔE* among the experimental groups in the same column ($\alpha < 0.05$).

Table 10 The ΔL* (mean (SD)) of the experimental groups after immersed in water and coffee at 1d, 7d, 28d, 56d and 84d.

Group	ΔL* (Mean (SD))									
	water^{A}					coffee^{B}				
	1d	7d	28d	56d	84d	1d	7d	28d	56d	84d
NEW	-0.64^{a}	-0.88^{a}	-0.86^{a}	-1.02^{a}	-1.05^{a}	-2.13^{a}	-7.71^{a}	-11.55^{a}	-14.79^{a}	-15.85^{a}
	(0.22)	(0.43)	(0.34)	(0.38)	(0.39)	(0.30)	(0.25)	(0.58)	(0.59)	(0.74)
MAJ	- 0.48^{a}	-0.64^{a}	-0.73^{a}	-0.88^{a}	-0.94^{a}	-2.09^{a}	-8.52^{a}	-13.02^{b}	-15.67^{b}	-16.97^{b}
	(0.05)	(0.15)	(0.14)	(0.11)	(0.14)	(0.23)	(0.44)	(0.59)	(0.39)	(0.78)
ANT	-0.53^{a}	-0.79^{a}	-0.87^{a}	-0.97^{a}	-1.02^{a}	-2.05^{a}	-5.26^{b}	-8.47^{c}	-9.22^{c}	-9.56^{c}
	(0.09)	(0.14)	(0.15)	(0.09)	(0.08)	(0.35)	(0.33)	(0.43)	(0.70)	(0.76)
CPX	- 0.58^{a}	-0.72^{a}	-0.78^{a}	-0.85^{a}	-0.83^{a}	-1.16^{b}	-7.95^{a}	-9.77^{d}	-11.38^{d}	-11.77^{d}
	(0.16)	(0.20)	(0.22)	(0.28)	(0.14)	(0.77)	(1.92)	(1.78)	(1.72)	(1.64)

The different upper-case letters show the significant difference of ΔL* between immerse solution ($\alpha < 0.05$)
The different lower-case letters show the significant difference of ΔL* among the experimental groups in the same column ($\alpha < 0.05$).

Table 11 The Δa* (mean (SD)) of the experimental groups after immersed in water andcoffee at 1d, 7d, 28d, 56d and 84d

Group	Δa* (Mean (SD))									
	water^{A}					coffee^{B}				
	1d	7d	28d	56d	84d	1d	7d	28d	56d	84d
NEW	-0.17^{a}	-0.29^{a}	-0.30^{a}	-0.28^{a}	-0.28^{a}	0.25^{a}	0.32^{a}	0.54^{a}	0.75^{a}	1.06^{a}
	(0.08)	(0.10)	(0.12)	(0.10)	(0.13)	(0.07)	(0.10)	(0.10)	(0.18)	(0.15)
MAJ	- 0.28^{a}	-0.43^{a}	-0.46^{a}	-0.56^{a}	-0.61^{a}	0.24^{a}	0.64^{b}	0.69^{b}	0.88^{a,b}	1.63^{b}
	(0.07)	(0.08)	(0.06)	(0.08)	(0.08)	(0.05)	(0.06)	(0.06)	(0.28)	(0.15)
ANT	-0.21^{a}	-0.49^{a}	-0.49^{a}	-0.57^{a}	-0.63^{a}	0.24^{a}	0.34^{a}	0.41^{c}	0.57^{a,c}	0.59^{c}
	(0.05)	(0.06)	(0.07)	(0.05)	(0.07)	(0.07)	(0.04)	(0.05)	(0.06)	(0.09)
CPX	- 0.37^{a}	-0.61^{a}	-0.55^{a}	-0.70^{a}	-0.64^{a}	0.27^{b}	0.36^{a}	0.49^{a,c}	0.62^{a}	0.68^{c,d}
	(0.16)	(0.20)	(0.22)	(0.17)	(0.17)	(0.17)	(0.18)	(0.16)	(0.21)	(0.30)

The different upper-case letters show the significant difference of Δa* between immerse solution ($\alpha < 0.05$)
The different lower-case letters show the significant difference of Δa* among the experimental groups in the same column ($\alpha < 0.05$).

Table 12 The Δb* (mean (SD)) of the experimental groups after immersed in water and coffee at 1d, 7d, 28d, 56d and 84d

Group	Δb* (Mean (SD))									
	water[A]					coffee[B]				
	1d	7d	28d	56d	84d	1d	7d	28d	56d	84d
NEW	0.47[a] (0.24)	0.85[a] (0.39)	0.78[a] (0.30)	0.93[a] (0.34)	0.96[a] (0.30)	0.59[a] (0.09)	5.05[a] (0.40)	5.28[a] (0.71)	6.64[a] (0.87)	7.72[a] (0.76)
MAJ	0.56[a] (0.14)	0.83[a] (0.14)	0.83[a] (0.13)	1.08[a] (0.07)	1.09[a] (0.07)	0.40[a] (0.05)	6.09[b] (0.53)	7.24[b] (0.45)	7.57[b] (0.72)	8.22[b] (0.65)
ANT	0.54[a] (0.10)	0.90[a] (0.19)	0.86[a] (0.14)	1.00[a] (0.14)	1.07[a] (0.11)	0.37[a] (0.04)	2.03[c] (0.30)	4.14[c] (0.61)	5.05[c] (0.48)	4.81[c] (0.79)
CPX	0.67[a] (0.16)	0.60[a] (0.29)	0.76[a] (0.25)	0.85[a] (0.32)	1.05[a] (0.21)	0.53[a] (0.19)	5.50[a] (0.24)	5.76[a] (1.98)	5.88[a] (0.36)	6.73[a] (0.45)

The different upper-case letters show the significant difference of Δb* between immerse solution ($\alpha < 0.05$)
The different lower-case letters show the significant difference of Δb* among the experimental groups in the same column ($\alpha < 0.05$).

Regarding the water sorption of the acrylic resin (Table 13), there was no significant difference among all groups at day 1, except MAJ which showed significantly greater than CPX. Thereafter, MAJ demonstrated the greatest water uptake, followed by NEW, CPX and ANT, subsequently.

Table 13 The water sorption (mean (SD)) of the experimental groups after immersion 1-92d.

Group	Water sorption (μg/mm³)			
	1d	8d	36d	92d
NEW	9.41(2.13)[a]	20.43(3.99)[a]	27.34(3.65)[a]	24.51(2.88)[a]
MAJ	10.04(2.03)[a,b]	25.14(2.66)[b]	29.85(2.67)[a]	29.22(3.65)[b]
ANT	7.47(2.33)[a]	11.00(2.22)[c]	16.30(3.79)[b]	15.40(2.32)[c]
CPX	7.42(2.17)[a,c]	18.22(5.09)[a]	21.35(4.63)[b]	21.05(5.35)[a]

The water solubility of the groups trended to be different from the water sorption. In day 1, MAJ (0.66±0.23) ANT (0.53±0.21) and CPX (0.49±0.22) showed greater water solubility comparing to NEW (0.25±0.12); whereas, ANT (0.87±0.23) showed comparatively lowest rather than the others. NEW, MAJ and CPX had no significant difference at day 8. At day 36 and 92, all groups showed significant difference in the same order (ANT < NEW < CPX < MAJ).

Table 14 The water solubility (mean (SD)) of the experimental groups after immersion 1-92d.

Group	**Water solubility (μg/mm^3)**			
	1d	8d	36d	92d
NEW	0.25(0.12)^{a,d}	1.94(0.87)^{a}	2.52(0.42)^{a}	2.89(0.39)^{a}
MAJ	0.66(0.23)^{b,c,d}	2.45(0.52)^{a}	4.65(0.41)^{b}	5.62(0.40)^{b}
ANT	0.53(0.21)^{b,c,d}	0.87(0.23)^{b}	1.63(0.25)^{c}	1.53(0.32)^{c}
CPX	0.49(0.22)^{a,c,d}	2.77(0.80)^{a}	3.8(0.40)^{d}	4.56(0.50)^{d}

CHAPTER V
DISCUSSION AND CONCLUSION

According to the results of color stability of three acrylic resin teeth (linear PMMA, cross-linked PMMA and composite resin) and one heat-cured acrylic resin (heat-cured dentine color acrylic resin) immersed in coffee solution and water, the null hypothesis of color stability was partially rejected. The specimen surface roughness of all specimen groups were similar (0.11±0.01 μm), observed with a contact profilometry (Talyscan150, Leicester, England). The baseline color of all specimens were observed before the experiment, and found that the hue (a* and b*) of NEW, ANT and CPX with the same VITA shade (A3) including the MAJ which uses the different color system (3F, Major Dent system) were similar, but not for the value (brightness). The difference of L*could be explained in the presence of additive fillers, the difference of resin composition and the fabrication process. That the presence of additive fillers would increase the surface roughness due to the distribution of exposed fillers on the specimen surface and that the difference of resin compostition would induce the colour change due to the photochemical process were reported (18). The effect of fabrication and polishing system could be explained in the difference L* between NEW with the heat-pressed method and MAJ with the lost wax method and free hand polishing (49).

The color stability of acrylic denture teeth is under influence of various factors including the beverage, acrylic resin composition, storage time as well as the interaction among the factors. Similar to the other previous studies (10, 29, 50) reported that the significant color change of the resin-based materials after immersed in the different color solutions were observed after 7 days storage. However, one study found the interaction between type of denture tooth (2 porcelain denture teeth, 2 reinfoced acrylic resin denture teeth and 2 acrylic resin denture teeth) and storage solution (filtered coffee, tea, cola and distilled water) since 1 day storage (37). After immersing in the colour solutions, the water with some colloidal colorant would adsorpt on the acrylic resin surface as extrinsic staining and /or absorpt in the deeper layer of the acrylic resin teeth as intrinsic stain; however, the presence of the porcelain denture teeth which were much less water sorption than acrylic resin denture teeth and the various of storage solutions might be the reasons of the different result, comparing the present study.

Regarding the color stability of the specimens stored in distilled water, the results were similar to the previous studies (30, 37). All color parameters of the experimental groups showed no significant difference in each immersion period. However, all specimen groups consequently became less value, more greenish and more yellowish after the periods of immersion.

Considering the study groups immersed in coffee solution, ΔE* showed significant difference from day 7. MAJ showed the greatest ΔE*, and that of ANT showed the lowest ΔE* in each period. The ΔE* of NEW and CPX demonstrated similar at 7d and 28 d, and then the ΔE* became significant different at 56 d and 84 d. The explaination of this phenomenon would be under the influence of denture tooth composition and the fabrication method. NEW and MAJ consist of the linear PMMA with different fabrication methods. MAJ was fabricated by the lost wax technique in dental laboratory which the polymerization reaction was complete with much residual monomer, comparing NEW (51). Several studies reported the different result in the denture tooth with cross-linker. Some showed the reduction of color change (29, 37, 51), while only one showed the increase of color change (10). Our present study was supported by the result of ANT that decreased the color change. The higher molecular wieght of ANT exhibited the lower hydrophiliciy rather than NEW and MAJ. The higher degree of conversion and the fewer residual monomer from manufacturing process would also reduce the color change. Interestingly, the ΔE* of NEW and CPX showed no significant different in the period of 1 to 28 day. The manufaturer claimed that their product exhibited not only high mechanical properties by the additive fillers, but also color change resistance by presence of fluoride containing resin matrix. Moreover, a study (10) reported the similar ΔE* between the PMMA denture tooth and resin composite denture tooth after immersed in coffee for 7 days.

ΔL* and Δa* in coffee solution groups were significant different at day 1 storage, while Δb* showed significant different at 7 days storage. Under the present of the low molecular mass pigments (Fig 5) in both the hand-brew coffee and the constant coffee turned all specimen groups to be darker, more redness and more yellowish (52). These low molecular structure colorants were isolated and identified to be furans compounds, pyrroles, pyridines, 1,4-quinones derivative in aliphatic structure, and present the color of yellow, deep orange and red. The low molecular weight with polarity of the colorants might adsorpt to the surface of the denture teeth in the different level that depend on the composition of the denture tooth. Δa* showed significant different since day 1 period, but not for Δb* could explain by the polarity of the low molecular red and yellow. The red color molecular colorant with polarity could turn to be ionic from that would be easier to penetrate into the acrylic resin surface than the yellow color molecular colorant. That the turbidity of the color pigments which are extract from the coffee, especially constant coffee, is not only make the color of the specimen change, but also greater darkness (ΔL*). The difference in composition of the acrylic resin denture teeth would allow the penetrattion of the coffee pigments through their surface in the different level as already mention above.

According the color solution used in this study, coffee was selected even many color solutions have been suggested including the beverages such as coffee, tea, red wine and the synthetic color solution such as cola and food-staining color (8). The coffee is the most popular selected in the comparable color stability experiments, and mimic the human beverage consumption behavior. This in vitro study could represent the actual coffee drinker behavior that drinks 3.2 120-ml glasses per day for 6.9 years compairing at 84 day storage (50). The human color diffence perception threshold of 50% population is ΔE* 3.3 (53) comparing to the 7-day storage in the present study. This present study (ΔE*= 10.73 – 18.95 at 84 day storage) was supported by a comparable clinical study (54) that the 1.83 – 11.03 of ΔE* in complete prostheses wearer for 5 years was observed.

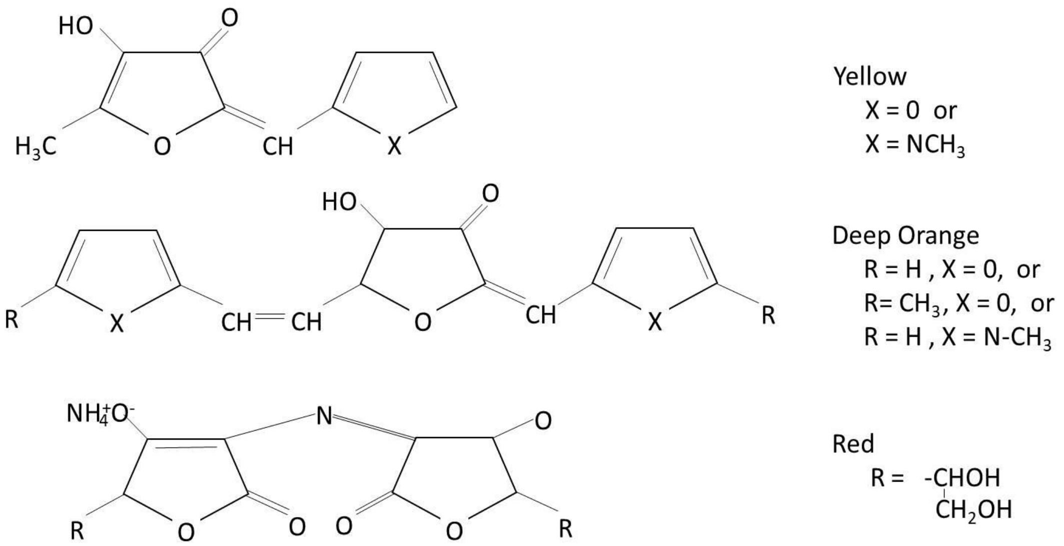

Figure 5 The low molecular mass pigments isolated from model systems
Modified from Clifford, M. N. and Wilson, K. C. Coffee Botany and Production of Beans and Beverage, Westport, Connecticut, USA: The AVI Publishing Company, Inc., 1985, 344.

Water sorption and water solubility of the denture teeth are also observed in this study. The null hypotheses of these physical properities were rejected. The linear PMMA groups (MAJ and NEW) demonstrate the greatest water sorption rather than CPX and ANT with cross-linker polymer. Several studies (11-13) reported that the different cross-linkers could present the different trend of water sorption. Some (11) reported the water sorption reduction when 1,6 HDMA and 1,4 BDMA were added in different amount, while higher water sorption were reported after TEGDMA, DEGDMA added in different amount (11-13). The water sorption result of PMMA with EGDMA were not still illucidiated depend on each studies (11-13). However, ANT claimed to be a PMMA with cross-linker denture tooth by the manufacturer demonstrated the lowest water sorption in this study. The water sorptions of composite resin denture tooth (CPX) showed similar to that of the linear PMMA (NEW), but significantly lower than lost wax technique linear PMMA (MAJ). Therefore, the fabrication method (41, 44, 48) and the remaining residual monomer (46, 55) would affect on the water sorption of acrylic resin denture tooth.

The water solubility of the acrylic resin denture tooth also depends on their composition as well as the fabrication method. At 1 day storage NEW and CPX showed significantly lower water solubility than MAJ and ANT. Thereafter, ANT showed the lowest water solubilitiy through 92 days storage, followed by NEW CPX and MAJ. The presence of cross-linker in ANT could reduce the hydrolysis and degradation of denture tooth (11); whereas, the additive organic fillers in CPX increased water solubility. One study (14) that added the fiber glass in to the acrylic resin also reported the increase of water solubility comparing the control. The explanation of the water solubility of composite resin denture tooth was the type of fillers, the silane treatment. The organic fillers in CPX that its manufacturer claimed to be Bis-GMA and UDMA filler, as well as its resin would be degraded after the attack of water. The solubility of resin composite study (55) reported the leached out of the resin matrix and unbounded substances after periods of water storage. The remaining of higher residual monomer or the lower degree of conversion would be the reason of the greatest water solubililty in MAJ (41).

This *in vitro* study focused on the material and color solution that affect on the color stability, water sorption and water solubility. Several factors, for example the storage temperature, pH of the daily food as well as the cleaning methods (26, 51, 56) also affect on the color stability. The correlation between the remaining residual monomer or degree of conversion after polymerization and the color stability, water sorption and water solubility would be considered. Moreover, no research has been reported on the comparative between *in vitro* and *in vivo* color stability and the correlation between the color change and water sorption or water solubilty.

Conclusion

Within the limitation of the present study, the color stability, the water sorption and the water solubilty were under the influence of the acrylic resin tooth materials after stored in coffee solution.

1. The different compositions of acrylic resin teeth effect on color stability; Heat-cured acrylic resin has the greatest color change followed by linear PMMA, composite resin teeth and the least color change was cross-linked PMMA.
2. The different compositions of acrylic resin teeth effect on water sorption; Heat-cured acrylic resin has the greatest water sorption followed by linear PMMA, composite resin teeth and the least color change was cross-linked PMMA.
3. The different compositions of acrylic resin teeth effect on water solubility; Heat-cured acrylic resin has the greatest water solubility followed by composite resin teeth, linear PMMA and the least was cross-linked PMMA.

APPENDIX

L*,a* and b* before immersion

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
L	7.668	3	76	.000
a	14.132	3	76	.000
b	2.456	3	76	.069

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
L	Welch	1858.863	3	39.457	.000
a	Welch	2.222	3	36.776	.102
b	Welch	1.907	3	41.762	.143

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
L	Between Groups	4065.133	3	1355.044	1658.374	.000
	Within Groups	62.099	76	.817		
	Total	4127.232	79			
a	Between Groups	.102	3	.034	1.306	.279
	Within Groups	1.988	76	.026		
	Total	2.091	79			
b	Between Groups	6.231	3	2.077	1.818	.151
	Within Groups	86.800	76	1.142		
	Total	93.031	79			

Multiple comparisons

Dependent Variable				Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
L*	Games-Howell	Linear PMMA	Filler PMMA	2.66050*	.27298	.000	1.9133	3.4077
			Cross-link PMMA	18.54100*	.30639	.000	17.6985	19.3835
			Heat cured dentine	8.79700*	.14740	.000	8.4001	9.1939
		Filler PMMA	Linear PMMA	-2.66050*	.27298	.000	-3.4077	-1.9133
			Cross-link PMMA	15.88050*	.37642	.000	14.8684	16.8926
			Heat cured dentine	6.13650*	.26371	.000	5.4093	6.8637
		Cross-link PMMA	Linear PMMA	-18.54100*	.30639	.000	-19.3835	-17.6985
			Filler PMMA	-15.88050*	.37642	.000	-16.8926	-14.8684
			Heat cured dentine	-9.74400*	.29816	.000	-10.5694	-8.9186
		Heat cured dentine	Linear PMMA	-8.79700*	.14740	.000	-9.1939	-8.4001
			Filler PMMA	-6.13650*	.26371	.000	-6.8637	-5.4093
			Cross-link PMMA	9.74400*	.29816	.000	8.9186	10.5694
a*	Games-Howell	Linear PMMA	Filler PMMA	-.06950	.06950	.751	-.2597	.1207
			Cross-link PMMA	-.01350	.03457	.979	-.1073	.0803
			Heat cured dentine	.02900	.03082	.783	-.0565	.1145
		Filler PMMA	Linear PMMA	.06950	.06950	.751	-.1207	.2597
			Cross-link PMMA	.05600	.06544	.827	-.1257	.2377
			Heat cured dentine	.09850	.06354	.428	-.0795	.2765
		Cross-link PMMA	Linear PMMA	.01350	.03457	.979	-.0803	.1073
			Filler PMMA	-.05600	.06544	.827	-.2377	.1257
			Heat cured dentine	.04250	.02006	.172	-.0123	.0973
		Heat cured dentine	Linear PMMA	-.02900	.03082	.783	-.1145	.0565
			Filler PMMA	-.09850	.06354	.428	-.2765	.0795
			Cross-link PMMA	-.04250	.02006	.172	-.0973	.0123

b*	Games-Howell	Linear PMMA	Filler PMMA	.62050	.36885	.350	-.3801	1.6211
			Cross-link PMMA	.09300	.28391	.988	-.6700	.8560
			Heat cured dentine	.57950	.29089	.209	-.2027	1.3617
		Filler PMMA	Linear PMMA	-.62050	.36885	.350	-1.6211	.3801
			Cross-link PMMA	-.52750	.37922	.514	-1.5531	.4981
			Heat cured dentine	-.04100	.38447	1.000	-1.0795	.9975
		Cross-link PMMA	Linear PMMA	-.09300	.28391	.988	-.8560	.6700
			Filler PMMA	.52750	.37922	.514	-.4981	1.5531
			Heat cured dentine	.48650	.30393	.390	-.3301	1.3031
		Heat cured dentine	Linear PMMA	-.57950	.29089	.209	-1.3617	.2027
			Filler PMMA	.04100	.38447	1.000	-.9975	1.0795
			Cross-link PMMA	-.48650	.30393	.390	-1.3031	.3301

*. The mean difference is significant at the 0.05 level.

Color stability : coffee solution

ΔE^*

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
DE1d	.708	3	36	.553
DE7d	10.361	3	36	.000
DE28d	7.110	3	36	.001
DE56d	6.971	3	36	.001
DE84d	6.424	3	36	.001

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
DE1d	Between Groups	.807	3	.269	2.936	.056
	Within Groups	3.296	36	.092		
	Total	4.103	39			
DE7d	Between Groups	157.364	3	52.455	51.099	.000
	Within Groups	36.955	36	1.027		
	Total	194.319	39			

DE28d	Between Groups	155.158	3	51.719	51.235	.000
	Within Groups	36.340	36	1.009		
	Total	191.498	39			
DE56d	Between Groups	269.887	3	89.962	55.080	.000
	Within Groups	58.799	36	1.633		
	Total	328.686	39			
DE84d	Between Groups	385.792	3	128.597	85.161	.000
	Within Groups	54.362	36	1.510		
	Total	440.154	39			

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
DE1d	Welch	2.386	3	19.166	.101
DE7d	Welch	367.861	3	18.919	.000
DE28d	Welch	187.327	3	19.004	.000
DE56d	Welch	237.737	3	18.576	.000
DE84d	Welch	192.507	3	18.979	.000

a. Asymptotically F distributed.

Multiple Comparisons

Dependent Variable				Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
DE1d	Games-Howell	Linear PMMA	FillerPMMA	-.26600	.14894	.312	-.6876	.1556
			Cross-linked PMMA	.09200	.14417	.918	-.3156	.4996
			Heat cured dentine	.06600	.11444	.937	-.2649	.3969
		FillerPMMA	LinearPMMA	.26600	.14894	.312	-.1556	.6876
			Cross-linked PMMA	.35800	.15340	.127	-.0757	.7917
			Heat cured dentine	.33200	.12586	.083	-.0354	.6994
		Cross-linked PMMA	LinearPMMA	-.09200	.14417	.918	-.4996	.3156
			FillerPMMA	-.35800	.15340	.127	-.7917	.0757
			Heat cured dentine	-.02600	.12018	.996	-.3752	.3232
		Heat cured dentine	LinearPMMA	-.06600	.11444	.937	-.3969	.2649
			FillerPMMA	-.33200	.12586	.083	-.6994	.0354
			Cross-linked PMMA	.02600	.12018	.996	-.3232	.3752

DE7d	Games-Howell	Linear PMMA	FillerPMMA	-.38300	.61371	.922	-2.2832	1.5172
			Cross-linked PMMA	4.03200*	.13434	.000	3.6516	4.4124
			Heat cured dentine	-1.02600*	.17766	.000	-1.5408	-.5112
		FillerPMMA	LinearPMMA	.38300	.61371	.922	-1.5172	2.2832
			Cross-linked PMMA	4.41500*	.61567	.000	2.5133	6.3167
			Heat cured dentine	-.64300	.62655	.739	-2.5546	1.2686
		Cross-linked PMMA	LinearPMMA	-4.03200*	.13434	.000	-4.4124	-3.6516
			FillerPMMA	-4.41500*	.61567	.000	-6.3167	-2.5133
			Heat cured dentine	-5.05800*	.18431	.000	-5.5870	-4.5290
		Heat cured dentine	LinearPMMA	1.02600*	.17766	.000	.5112	1.5408
			FillerPMMA	.64300	.62655	.739	-1.2686	2.5546
			Cross-linked PMMA	5.05800*	.18431	.000	4.5290	5.5870
DE28d	Games-Howell	Linear PMMA	FillerPMMA	.90700	.59312	.454	-.8819	2.6959
			Cross-linked PMMA	2.76500*	.22152	.000	2.1313	3.3987
			Heat cured dentine	-2.69900*	.26326	.000	-3.4432	-1.9548
		FillerPMMA	LinearPMMA	-.90700	.59312	.454	-2.6959	.8819
			Cross-linked PMMA	1.85800*	.57834	.040	.0852	3.6308
			Heat cured dentine	-3.60600*	.59558	.000	-5.3980	-1.8140
		Cross-linked PMMA	LinearPMMA	-2.76500*	.22152	.000	-3.3987	-2.1313
			FillerPMMA	-1.85800*	.57834	.040	-3.6308	-.0852
			Heat cured dentine	-5.46400*	.22802	.000	-6.1181	-4.8099
		Heat cured dentine	LinearPMMA	2.69900*	.26326	.000	1.9548	3.4432
			FillerPMMA	3.60600*	.59558	.000	1.8140	5.3980
			Cross-linked PMMA	5.46400*	.22802	.000	4.8099	6.1181
DE56d	Games-Howell	Linear PMMA	FillerPMMA	2.45600*	.76820	.035	.1618	4.7502
			Cross-linked PMMA	5.06300*	.34447	.000	4.0833	6.0427
			Heat cured dentine	-1.84000*	.30558	.000	-2.7341	-.9459
		FillerPMMA	LinearPMMA	-2.45600*	.76820	.035	-4.7502	-.1618
			Cross-linked PMMA	2.60700*	.74829	.024	.3386	4.8754
			Heat cured dentine	-4.29600*	.73120	.001	-6.5473	-2.0447
		Cross-linked PMMA	LinearPMMA	-5.06300*	.34447	.000	-6.0427	-4.0833
			FillerPMMA	-2.60700*	.74829	.024	-4.8754	-.3386
			Heat cured dentine	-6.90300*	.25138	.000	-7.6247	-6.1813
		Heat cured dentine	LinearPMMA	1.84000*	.30558	.000	.9459	2.7341
			FillerPMMA	4.29600*	.73120	.001	2.0447	6.5473
			Cross-linked PMMA	6.90300*	.25138	.000	6.1813	7.6247
DE84d	Games-Howell	Linear PMMA	FillerPMMA	3.10900*	.69975	.005	.9912	5.2268
			Cross-linked PMMA	5.80100*	.35791	.000	4.7767	6.8253
			Heat cured dentine	-2.41200*	.26162	.000	-3.1543	-1.6697
		FillerPMMA	LinearPMMA	-3.10900*	.69975	.005	-5.2268	-.9912
			Cross-linked PMMA	2.69200*	.73183	.014	.5288	4.8552
			Heat cured dentine	-5.52100*	.68987	.000	-7.6280	-3.4140

	Cross-linked PMMA	LinearPMMA	-5.80100*	.35791	.000	-6.8253	-4.7767
		FillerPMMA	-2.69200*	.73183	.014	-4.8552	-.5288
		Heat cured dentine	-8.21300*	.33819	.000	-9.1946	-7.2314
	Heat cured dentine	LinearPMMA	2.41200*	.26162	.000	1.6697	3.1543
		FillerPMMA	5.52100*	.68987	.000	3.4140	7.6280
		Cross-linked PMMA	8.21300*	.33819	.000	7.2314	9.1946

ΔL*

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
DL1d	3.893	3	36	.017
DL7d	6.201	3	36	.002
DL28d	2.527	3	36	.073
DL56d	4.646	3	36	.008
DL84d	3.083	3	36	.039

*. The mean difference is significant at the 0.05 level.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
DL1d	Between Groups	6.558	3	2.186	10.116	.000
	Within Groups	7.779	36	.216		
	Total	14.336	39			
DL7d	Between Groups	71.920	3	23.973	15.997	.000
	Within Groups	53.952	36	1.499		
	Total	125.872	39			
DL28d	Between Groups	119.387	3	39.796	63.227	.000
	Within Groups	22.659	36	.629		
	Total	142.045	39			
DL56d	Between Groups	270.563	3	90.188	91.399	.000
	Within Groups	35.523	36	.987		
	Total	306.086	39			
DL84d	Between Groups	360.800	3	120.267	108.523	.000
	Within Groups	39.896	36	1.108		
	Total	400.696	39			

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
DL1d	Welch	4.446	3	19.226	.016
DL7d	Welch	132.281	3	18.115	.000
DL28d	Welch	136.069	3	19.309	.000
DL56d	Welch	211.782	3	18.740	.000
DL84d	Welch	177.668	3	19.604	.000

Multiple Comparisons

Dependent Variable				Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
DL1d	Games-Howell	Linear PMMA	FillerPMMA	-.97200*	.26256	.014	-1.7550	-.1890
			Cross-linked PMMA	-.07600	.14497	.952	-.4865	.3345
			Heat cured dentine	-.04100	.12063	.986	-.3839	.3019
		Filler PMMA	LinearPMMA	.97200*	.26256	.014	.1890	1.7550
			Cross-linked PMMA	.89600*	.26810	.025	.1044	1.6876
			Heat cured dentine	.93100*	.25576	.018	.1570	1.7050
		Cross-linked PMMA	LinearPMMA	.07600	.14497	.952	-.3345	.4865
			FillerPMMA	-.89600*	.26810	.025	-1.6876	-.1044
			Heat cured dentine	.03500	.13226	.993	-.3438	.4138
		Heat cured dentine	LinearPMMA	.04100	.12063	.986	-.3019	.3839
			FillerPMMA	-.93100*	.25576	.018	-1.7050	-.1570
			Cross-linked PMMA	-.03500	.13226	.993	-.4138	.3438
DL7d	Games-Howell	Linear PMMA	FillerPMMA	.23700	.75460	.989	-1.9421	2.4161
			Cross-linked PMMA	-2.67100*	.65484	.011	-4.6954	-.6466
			Heat cured dentine	.81200	.66157	.625	-1.2181	2.8421
		Filler PMMA	LinearPMMA	-.23700	.75460	.989	-2.4161	1.9421
			Cross-linked PMMA	-2.90800*	.40223	.000	-4.1330	-1.6830
			Heat cured dentine	.57500	.41309	.529	-.6632	1.8132
		Cross-linked PMMA	LinearPMMA	2.67100*	.65484	.011	.6466	4.6954
			FillerPMMA	2.90800*	.40223	.000	1.6830	4.1330
			Heat cured dentine	3.48300*	.17333	.000	2.9889	3.9771
		Heat cured dentine	LinearPMMA	-.81200	.66157	.625	-2.8421	1.2181
			FillerPMMA	-.57500	.41309	.529	-1.8132	.6632
			Cross-linked PMMA	-3.48300*	.17333	.000	-3.9771	-2.9889
DL28d	Games-Howell	Linear PMMA	FillerPMMA	-1.78300*	.44484	.008	-3.0962	-.4698
			Cross-linked PMMA	-3.08200*	.22765	.000	-3.7303	-2.4337
			Heat cured dentine	1.46600*	.26132	.000	.7274	2.2046
		Filler PMMA	LinearPMMA	1.78300*	.44484	.008	.4698	3.0962
			Cross-linked PMMA	-1.29900*	.42834	.048	-2.5878	-.0102

			Heat cured dentine	3.24900*	.44715	.000	1.9320	4.5660
		Cross-linked PMMA	LinearPMMA	3.08200*	.22765	.000	2.4337	3.7303
			FillerPMMA	1.29900*	.42834	.048	.0102	2.5878
			Heat cured dentine	4.54800*	.23213	.000	3.8859	5.2101
		Heat cured dentine	LinearPMMA	-1.46600*	.26132	.000	-2.2046	-.7274
			FillerPMMA	-3.24900*	.44715	.000	-4.5660	-1.9320
			Cross-linked PMMA	-4.54800*	.23213	.000	-5.2101	-3.8859
DL56d	Games-Howell	Linear PMMA	FillerPMMA	-3.40900*	.57443	.000	-5.1357	-1.6823
			Cross-linked PMMA	-5.57400*	.29033	.000	-6.3971	-4.7509
			Heat cured dentine	.88100*	.22281	.006	.2416	1.5204
		Filler PMMA	LinearPMMA	3.40900*	.57443	.000	1.6823	5.1357
			Cross-linked PMMA	-2.16500*	.58741	.014	-3.9102	-.4198
			Heat cured dentine	4.29000*	.55714	.000	2.5828	5.9972
		Cross-linked PMMA	LinearPMMA	5.57400*	.29033	.000	4.7509	6.3971
			FillerPMMA	2.16500*	.58741	.014	.4198	3.9102
			Heat cured dentine	6.45500*	.25442	.000	5.7155	7.1945
		Heat cured dentine	LinearPMMA	-.88100*	.22281	.006	-1.5204	-.2416
			FillerPMMA	-4.29000*	.55714	.000	-5.9972	-2.5828
			Cross-linked PMMA	-6.45500*	.25442	.000	-7.1945	-5.7155
DL84d	Games-Howell	Linear PMMA	FillerPMMA	-4.08100*	.57036	.000	-5.7641	-2.3979
			Cross-linked PMMA	-6.29200*	.33535	.000	-7.2399	-5.3441
			Heat cured dentine	1.11800*	.33963	.019	.1579	2.0781
		Filler PMMA	LinearPMMA	4.08100*	.57036	.000	2.3979	5.7641
			Cross-linked PMMA	-2.21100*	.57266	.010	-3.8979	-.5241
			Heat cured dentine	5.19900*	.57517	.000	3.5078	6.8902
		Cross-linked PMMA	LinearPMMA	6.29200*	.33535	.000	5.3441	7.2399
			FillerPMMA	2.21100*	.57266	.010	.5241	3.8979
			Heat cured dentine	7.41000*	.34348	.000	6.4392	8.3808
		Heat cured dentine	LinearPMMA	-1.11800*	.33963	.019	-2.0781	-.1579
			FillerPMMA	-5.19900*	.57517	.000	-6.8902	-3.5078
			Cross-linked PMMA	-7.41000*	.34348	.000	-8.3808	-6.4392

*. The mean difference is significant at the 0.05 level.

Δa^*

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
DA1d	5.586	3	36	.003
DA7d	4.639	3	36	.008
DA28d	2.700	3	36	.060
DA56d	6.562	3	36	.001
DA84d	5.302	3	36	.004

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
DA1d	Between Groups	.024	3	.008	.808	.498
	Within Groups	.359	36	.010		
	Total	.383	39			
DA7d	Between Groups	.669	3	.223	19.094	.000
	Within Groups	.420	36	.012		
	Total	1.089	39			
DA28d	Between Groups	.403	3	.134	12.824	.000
	Within Groups	.377	36	.010		
	Total	.779	39			
DA56d	Between Groups	.569	3	.190	4.633	.008
	Within Groups	1.473	36	.041		
	Total	2.042	39			
DA84d	Between Groups	6.707	3	2.236	60.561	.000
	Within Groups	1.329	36	.037		
	Total	8.036	39			

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
DA1d	Welch	2.397	3	19.064	.100
DA7d	Welch	59.563	3	18.450	.000
DA28d	Welch	40.801	3	18.828	.000
DA56d	Welch	5.593	3	17.005	.007
DA84d	Welch	115.577	3	18.575	.000

a. Asymptotically F distributed.

Multiple Comparisons

Dependent Variable				Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
DA1d	Games-Howell	LinearPMMA	FillerPMMA	-.01900	.05745	.987	-.1889	.1509
			Cross-linked PMMA	.01200	.03146	.981	-.0770	.1010
			Heat cured dentine	-.05300	.02738	.254	-.1316	.0256
		FillerPMMA	LinearPMMA	.01900	.05745	.987	-.1509	.1889
			Cross-linked PMMA	.03100	.05688	.946	-.1380	.2000

			Heat cured dentine	-.03400	.05472	.923	-.2002	.1322
		Cross-linked PMMA	LinearPMMA	-.01200	.03146	.981	-.1010	.0770
			FillerPMMA	-.03100	.05688	.946	-.2000	.1380
			Heat cured dentine	-.06500	.02616	.101	-.1398	.0098
		Heat cured dentine	LinearPMMA	.05300	.02738	.254	-.0256	.1316
			FillerPMMA	.03400	.05472	.923	-.1322	.2002
			Cross-linked PMMA	.06500	.02616	.101	-.0098	.1398
DA7d	Games-Howell	LinearPMMA	FillerPMMA	-.04200	.06464	.914	-.2288	.1448
			Cross-linked PMMA	-.02200	.03548	.924	-.1278	.0838
			Heat cured dentine	-.31800*	.03771	.000	-.4277	-.2083
		FillerPMMA	LinearPMMA	.04200	.06464	.914	-.1448	.2288
			Cross-linked PMMA	.02000	.05700	.984	-.1545	.1945
			Heat cured dentine	-.27600*	.05841	.003	-.4521	-.0999
		Cross-linked PMMA	LinearPMMA	.02200	.03548	.924	-.0838	.1278
			FillerPMMA	-.02000	.05700	.984	-.1945	.1545
			Heat cured dentine	-.29600*	.02219	.000	-.3594	-.2326
		Heat cured dentine	LinearPMMA	.31800*	.03771	.000	.2083	.4277
			FillerPMMA	.27600*	.05841	.003	.0999	.4521
			Cross-linked PMMA	.29600*	.02219	.000	.2326	.3594
DA28d	Games-Howell	LinearPMMA	FillerPMMA	.05400	.06004	.805	-.1188	.2268
			Cross-linked PMMA	.13300*	.03530	.011	.0291	.2369
			Heat cured dentine	-.14200*	.03722	.008	-.2496	-.0344
		FillerPMMA	LinearPMMA	-.05400	.06004	.805	-.2268	.1188
			Cross-linked PMMA	.07900	.05292	.475	-.0814	.2394
			Heat cured dentine	-.19600*	.05423	.017	-.3581	-.0339
		Cross-linked PMMA	LinearPMMA	-.13300*	.03530	.011	-.2369	-.0291
			FillerPMMA	-.07900	.05292	.475	-.2394	.0814
			Heat cured dentine	-.27500*	.02411	.000	-.3435	-.2065
		Heat cured dentine	LinearPMMA	.14200*	.03722	.008	.0344	.2496
			FillerPMMA	.19600*	.05423	.017	.0339	.3581
			Cross-linked PMMA	.27500*	.02411	.000	.2065	.3435
DA56d	Games-Howell	LinearPMMA	FillerPMMA	.13000	.08870	.478	-.1211	.3811
			Cross-linked PMMA	.17800	.06186	.062	-.0079	.3639
			Heat cured dentine	-.12800	.10731	.640	-.4362	.1802
		FillerPMMA	LinearPMMA	-.13000	.08870	.478	-.3811	.1211
			Cross-linked PMMA	.04800	.06965	.899	-.1628	.2588
			Heat cured dentine	-.25800	.11198	.137	-.5771	.0611
		Cross-linked PMMA	LinearPMMA	-.17800	.06186	.062	-.3639	.0079
			FillerPMMA	-.04800	.06965	.899	-.2588	.1628
			Heat cured dentine	-.30600*	.09219	.033	-.5886	-.0234
		Heat cured dentine	LinearPMMA	.12800	.10731	.640	-.1802	.4362
			FillerPMMA	.25800	.11198	.137	-.0611	.5771

			Cross-linked PMMA	.30600*	.09219	.033	.0234	.5886
DA84d	Games-Howell	LinearPMMA	FillerPMMA	.38500*	.10819	.015	.0701	.6999
			Cross-linked PMMA	.47100*	.05812	.000	.3015	.6405
			Heat cured dentine	-.56700*	.07052	.000	-.7664	-.3676
		FillerPMMA	LinearPMMA	-.38500*	.10819	.015	-.6999	-.0701
			Cross-linked PMMA	.08600	.09896	.821	-.2144	.3864
			Heat cured dentine	-.95200*	.10672	.000	-1.2641	-.6399
		Cross-linked PMMA	LinearPMMA	-.47100*	.05812	.000	-.6405	-.3015
			FillerPMMA	-.08600	.09896	.821	-.3864	.2144
			Heat cured dentine	-1.03800*	.05533	.000	-1.1986	-.8774
		Heat cured dentine	LinearPMMA	.56700*	.07052	.000	.3676	.7664
			FillerPMMA	.95200*	.10672	.000	.6399	1.2641
			Cross-linked PMMA	1.03800*	.05533	.000	.8774	1.1986

*. The mean difference is significant at the 0.05 level.

Δb*

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
DB1d	6.622	3	36	.001
DB7d	29.464	3	36	.000
DB28d	11.047	3	36	.000
DB56d	10.570	3	36	.000
DB84d	12.114	3	36	.000

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
DB1d	Between Groups	.146	3	.049	4.039	.014
	Within Groups	.434	36	.012		
	Total	.580	39			
DB7d	Between Groups	955.798	3	318.599	229.298	.000
	Within Groups	50.020	36	1.389		
	Total	1005.819	39			
DB28d	Between Groups	1305.294	3	435.098	347.768	.000
	Within Groups	45.040	36	1.251		
	Total	1350.335	39			
DB56d	Between Groups	1487.810	3	495.937	281.152	.000
	Within Groups	63.502	36	1.764		
	Total	1551.312	39			
DB84d	Between Groups	1637.602	3	545.867	285.811	.000
	Within Groups	68.756	36	1.910		
	Total	1706.358	39			

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
DB1d	Welch	2.117	3	18.477	.133
DB7d	Welch	1034.679	3	18.806	.000
DB28d	Welch	756.886	3	19.023	.000
DB56d	Welch	525.200	3	18.728	.000
DB84d	Welch	666.951	3	19.360	.000

a. Asymptotically F distributed.

Multiple Comparisons

Dependent Variable				Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
DB1d	Games-Howell	LinearPMMA	FillerPMMA	-.13500	.06692	.233	-.3326	.0626
			Cross-linked PMMA	.01600	.02941	.946	-.0714	.1034
			Heat cured dentine	-.00600	.03106	.997	-.0963	.0843
		FillerPMMA	LinearPMMA	.13500	.06692	.233	-.0626	.3326
			Cross-linked PMMA	.15100	.06212	.136	-.0405	.3425
			Heat cured dentine	.12900	.06292	.233	-.0633	.3213
		Cross-linked PMMA	LinearPMMA	-.01600	.02941	.946	-.1034	.0714
			FillerPMMA	-.15100	.06212	.136	-.3425	.0405
			Heat cured dentine	-.02200	.01858	.645	-.0750	.0310
		Heat cured dentine	LinearPMMA	.00600	.03106	.997	-.0843	.0963
			FillerPMMA	-.12900	.06292	.233	-.3213	.0633
			Cross-linked PMMA	.02200	.01858	.645	-.0310	.0750
DB7d	Games-Howell	LinearPMMA	FillerPMMA	.44900	.71989	.922	-1.7709	2.6689
			Cross-linked PMMA	-7.08200*	.15933	.000	-7.5358	-6.6282
			Heat cured dentine	-11.14700*	.21140	.000	-11.7488	-10.5452
		FillerPMMA	LinearPMMA	-.44900	.71989	.922	-2.6689	1.7709
			Cross-linked PMMA	-7.53100*	.71491	.000	-9.7470	-5.3150
			Heat cured dentine	-11.59600*	.72828	.000	-13.8234	-9.3686
		Cross-linked PMMA	LinearPMMA	7.08200*	.15933	.000	6.6282	7.5358
			FillerPMMA	7.53100*	.71491	.000	5.3150	9.7470
			Heat cured dentine	-4.06500*	.19376	.000	-4.6270	-3.5030
		Heat cured dentine	LinearPMMA	11.14700*	.21140	.000	10.5452	11.7488
			FillerPMMA	11.59600*	.72828	.000	9.3686	13.8234
			Cross-linked PMMA	4.06500*	.19376	.000	3.5030	4.6270

DB28d	Games-Howell	LinearPMMA	FillerPMMA	.47600	.66508	.889	-1.5170	2.4690
			Cross-linked PMMA	-9.41900*	.29742	.000	-10.2614	-8.5766
			Heat cured dentine	-12.52000*	.26700	.000	-13.2881	-11.7519
		FillerPMMA	LinearPMMA	-.47600	.66508	.889	-2.4690	1.5170
			Cross-linked PMMA	-9.89500*	.65510	.000	-11.8752	-7.9148
			Heat cured dentine	-12.99600*	.64186	.000	-14.9619	-11.0301
		Cross-linked PMMA	LinearPMMA	9.41900*	.29742	.000	8.5766	10.2614
			FillerPMMA	9.89500*	.65510	.000	7.9148	11.8752
			Heat cured dentine	-3.10100*	.24107	.000	-3.7882	-2.4138
		Heat cured dentine	LinearPMMA	12.52000*	.26700	.000	11.7519	13.2881
			FillerPMMA	12.99600*	.64186	.000	11.0301	14.9619
			Cross-linked PMMA	3.10100*	.24107	.000	2.4138	3.7882
DB56d	Games-Howell	LinearPMMA	FillerPMMA	.24300	.79433	.990	-2.1338	2.6198
			Cross-linked PMMA	-10.68400*	.31386	.000	-11.5961	-9.7719
			Heat cured dentine	-13.20400*	.35653	.000	-14.2151	-12.1929
		FillerPMMA	LinearPMMA	-.24300	.79433	.990	-2.6198	2.1338
			Cross-linked PMMA	-10.92700*	.76057	.000	-13.2650	-8.5890
			Heat cured dentine	-13.44700*	.77915	.000	-15.8042	-11.0898
		Cross-linked PMMA	LinearPMMA	10.68400*	.31386	.000	9.7719	11.5961
			FillerPMMA	10.92700*	.76057	.000	8.5890	13.2650
			Heat cured dentine	-2.52000*	.27315	.000	-3.3032	-1.7368
		Heat cured dentine	LinearPMMA	13.20400*	.35653	.000	12.1929	14.2151
			FillerPMMA	13.44700*	.77915	.000	11.0898	15.8042
			Cross-linked PMMA	2.52000*	.27315	.000	1.7368	3.3032
DB84d	Games-Howell	LinearPMMA	FillerPMMA	.65100	.81209	.852	-1.8032	3.1052
			Cross-linked PMMA	-10.53000*	.34634	.000	-11.5089	-9.5511
			Heat cured dentine	-13.93800*	.31776	.000	-14.8382	-13.0378
		FillerPMMA	LinearPMMA	-.65100	.81209	.852	-3.1052	1.8032
			Cross-linked PMMA	-11.18100*	.81424	.000	-13.6378	-8.7242
			Heat cured dentine	-14.58900*	.80250	.000	-17.0323	-12.1457
		Cross-linked PMMA	LinearPMMA	10.53000*	.34634	.000	9.5511	11.5089
			FillerPMMA	11.18100*	.81424	.000	8.7242	13.6378
			Heat cured dentine	-3.40800*	.32322	.000	-4.3244	-2.4916
		Heat cured dentine	LinearPMMA	13.93800*	.31776	.000	13.0378	14.8382
			FillerPMMA	14.58900*	.80250	.000	12.1457	17.0323
			Cross-linked PMMA	3.40800*	.32322	.000	2.4916	4.3244

*. The mean difference is significant at the 0.05 level.

Color stability ; water solution

ΔE*

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
DE1d	1.932	3	36	.142
DE7d	.816	3	36	.494
DE28d	.624	3	36	.604
DE56d	6.159	3	36	.002
DE84d	3.173	3	36	.036

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
DE1d	Between Groups	.137	3	.046	2.038	.126
	Within Groups	.805	36	.022		
	Total	.942	39			
DE7d	Between Groups	.314	3	.105	2.855	.051
	Within Groups	1.319	36	.037		
	Total	1.633	39			
DE28d	Between Groups	.078	3	.026	.517	.673
	Within Groups	1.801	36	.050		
	Total	1.878	39			
DE56d	Between Groups	.151	3	.050	.751	.529
	Within Groups	2.416	36	.067		
	Total	2.567	39			
DE84d	Between Groups	.106	3	.035	1.196	.325
	Within Groups	1.068	36	.030		
	Total	1.174	39			

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
DE1d	Welch	2.068	3	19.457	.138
DE7d	Welch	2.467	3	19.796	.092
DE28d	Welch	.969	3	19.133	.428
DE56d	Welch	.400	3	18.036	.754
DE84d	Welch	1.039	3	18.686	.398

a. Asymptotically F distributed.

Multiple Comparisons

Dependent Variable				Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
DE1d	Games-Howell	LinearPMMA	FillerPMMA	-.05900	.08119	.885	-.2894	.1714
			Cross-linked PMMA	.06200	.07048	.815	-.1444	.2684
			Heat cured dentine	.09300	.07309	.594	-.1185	.3045
		FillerPMMA	LinearPMMA	.05900	.08119	.885	-.1714	.2894
			Cross-linked PMMA	.12100	.06002	.226	-.0520	.2940
			Heat cured dentine	.15200	.06305	.114	-.0279	.3319
		Cross-linked PMMA	LinearPMMA	-.06200	.07048	.815	-.2684	.1444
			FillerPMMA	-.12100	.06002	.226	-.2940	.0520
			Heat cured dentine	.03100	.04849	.918	-.1064	.1684
		Heat cured dentine	LinearPMMA	-.09300	.07309	.594	-.3045	.1185
			FillerPMMA	-.15200	.06305	.114	-.3319	.0279
			Cross-linked PMMA	-.03100	.04849	.918	-.1684	.1064
DE7d	Games-Howell	LinearPMMA	FillerPMMA	.20000	.09540	.198	-.0739	.4739
			Cross-linked PMMA	.07200	.09740	.880	-.2065	.3505
			Heat cured dentine	.21100	.09401	.156	-.0599	.4819
		FillerPMMA	LinearPMMA	-.20000	.09540	.198	-.4739	.0739
			Cross-linked PMMA	-.12800	.07627	.363	-.3437	.0877
			Heat cured dentine	.01100	.07190	.999	-.1923	.2143
		Cross-linked PMMA	LinearPMMA	-.07200	.09740	.880	-.3505	.2065
			FillerPMMA	.12800	.07627	.363	-.0877	.3437
			Heat cured dentine	.13900	.07453	.278	-.0719	.3499
		Heat cured dentine	LinearPMMA	-.21100	.09401	.156	-.4819	.0599
			FillerPMMA	-.01100	.07190	.999	-.2143	.1923
			Cross-linked PMMA	-.13900	.07453	.278	-.3499	.0719

DE28d	Games-Howell	LinearPMMA	FillerPMMA	.03300	.12320	.993	-.3157	.3817
			Cross-linked PMMA	-.04700	.09919	.964	-.3309	.2369
			Heat cured dentine	.07300	.09157	.854	-.1950	.3410
		FillerPMMA	LinearPMMA	-.03300	.12320	.993	-.3817	.3157
			Cross-linked PMMA	-.08000	.10782	.879	-.3911	.2311
			Heat cured dentine	.04000	.10086	.978	-.2578	.3378
		Cross-linked PMMA	LinearPMMA	.04700	.09919	.964	-.2369	.3309
			FillerPMMA	.08000	.10782	.879	-.2311	.3911
			Heat cured dentine	.12000	.06951	.342	-.0782	.3182
		Heat cured dentine	LinearPMMA	-.07300	.09157	.854	-.3410	.1950
			FillerPMMA	-.04000	.10086	.978	-.3378	.2578
			Cross-linked PMMA	-.12000	.06951	.342	-.3182	.0782
DE56d	Games-Howell	LinearPMMA	FillerPMMA	.14600	.15897	.795	-.3062	.5982
			Cross-linked PMMA	0.00000	.10211	1.000	-.3074	.3074
			Heat cured dentine	.01400	.09954	.999	-.2905	.3185
		FillerPMMA	LinearPMMA	-.14600	.15897	.795	-.5982	.3062
			Cross-linked PMMA	-.14600	.13015	.685	-.5429	.2509
			Heat cured dentine	-.13200	.12814	.737	-.5270	.2630
		Cross-linked PMMA	LinearPMMA	0.00000	.10211	1.000	-.3074	.3074
			FillerPMMA	.14600	.13015	.685	-.2509	.5429
			Heat cured dentine	.01400	.03971	.984	-.0994	.1274
		Heat cured dentine	LinearPMMA	-.01400	.09954	.999	-.3185	.2905
			FillerPMMA	.13200	.12814	.737	-.2630	.5270
			Cross-linked PMMA	-.01400	.03971	.984	-.1274	.0994
DE84d	Games-Howell	LinearPMMA	FillerPMMA	-.09100	.10036	.802	-.3793	.1973
			Cross-linked PMMA	-.14100	.08772	.415	-.4071	.1251
			Heat cured dentine	-.10100	.09109	.691	-.3716	.1696

		FillerPMMA	LinearPMMA	.09100	.10036	.802	-.1973	.3793
			Cross-linked PMMA	-.05000	.05971	.836	-.2263	.1263
			Heat cured dentine	-.01000	.06456	.999	-.1957	.1757
		Cross-linked PMMA	LinearPMMA	.14100	.08772	.415	-.1251	.4071
			FillerPMMA	.05000	.05971	.836	-.1263	.2263
			Heat cured dentine	.04000	.04231	.781	-.0809	.1609
		Heat cured dentine	LinearPMMA	.10100	.09109	.691	-.1696	.3716
			FillerPMMA	.01000	.06456	.999	-.1757	.1957
			Cross-linked PMMA	-.04000	.04231	.781	-.1609	.0809

ΔL*

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
DL1d	8.767	3	36	.000
DL7d	8.020	3	36	.000
DL28d	7.059	3	36	.001
DL56d	4.650	3	36	.008
DL84d	18.705	3	36	.000

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
DL1d	Between Groups	.142	3	.047	2.160	.110
	Within Groups	.789	36	.022		
	Total	.931	39			
DL7d	Between Groups	.791	3	.264	3.999	.510
	Within Groups	2.372	36	.066		
	Total	3.163	39			
DL28d	Between Groups	.130	3	.043	.862	.470
	Within Groups	1.811	36	.050		
	Total	1.942	39			
DL56d	Between Groups	.188	3	.063	1.025	.393
	Within Groups	2.201	36	.061		
	Total	2.389	39			
DL84d	Between Groups	.134	3	.045	.915	.443
	Within Groups	1.754	36	.049		
	Total	1.887	39			

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
DL1d	Welch	2.458	3	18.038	.096
DL7d	Welch	3.003	3	19.308	.056
DL28d	Welch	1.547	3	19.368	.234
DL56d	Welch	2.010	3	18.570	.148
DL84d	Welch	1.885	3	17.767	.169

a. Asymptotically F distributed.

Multiple Comparisons

Dependent Variable				Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
DL1d	Games-Howell	LinearPMMA	FillerPMMA	-.06700	.08742	.868	-.3165	.1825
			Cross-linked PMMA	-.11700	.07655	.452	-.3446	.1106
			Heat cured dentine	-.16000	.07292	.190	-.3830	.0630
		FillerPMMA	LinearPMMA	.06700	.08742	.868	-.1825	.3165
			Cross-linked PMMA	-.05000	.05870	.829	-.2203	.1203
			Heat cured dentine	-.09300	.05388	.357	-.2552	.0692
		Cross-linked PMMA	LinearPMMA	.11700	.07655	.452	-.1106	.3446
			FillerPMMA	.05000	.05870	.829	-.1203	.2203
			Heat cured dentine	-.04300	.03347	.586	-.1398	.0538
		Heat cured dentine	LinearPMMA	.16000	.07292	.190	-.0630	.3830
			FillerPMMA	.09300	.05388	.357	-.0692	.2552
			Cross-linked PMMA	.04300	.03347	.586	-.0538	.1398
DL7d	Games-Howell	LinearPMMA	FillerPMMA	-.30000	.14857	.232	-.7375	.1375
			Cross-linked PMMA	-.22900	.14164	.409	-.6562	.1982
			Heat cured dentine	-.37600	.14344	.093	-.8056	.0536
		FillerPMMA	LinearPMMA	.30000	.14857	.232	-.1375	.7375
			Cross-linked PMMA	.07100	.07605	.788	-.1465	.2885

			Heat cured dentine	-.07600	.07935	.775	-.3015	.1495
		Cross-linked PMMA	LinearPMMA	.22900	.14164	.409	-.1982	.6562
			FillerPMMA	-.07100	.07605	.788	-.2885	.1465
			Heat cured dentine	-.14700	.06545	.149	-.3322	.0382
		Heat cured dentine	LinearPMMA	.37600	.14344	.093	-.0536	.8056
			FillerPMMA	.07600	.07935	.775	-.1495	.3015
			Cross-linked PMMA	.14700	.06545	.149	-.0382	.3322
DL28d	Games-Howell	LinearPMMA	FillerPMMA	-.08000	.12628	.920	-.4430	.2830
			Cross-linked PMMA	.01200	.11622	1.000	-.3314	.3554
			Heat cured dentine	-.12600	.11519	.700	-.4678	.2158
		FillerPMMA	LinearPMMA	.08000	.12628	.920	-.2830	.4430
			Cross-linked PMMA	.09200	.08281	.688	-.1450	.3290
			Heat cured dentine	-.04600	.08137	.941	-.2797	.1877
		Cross-linked PMMA	LinearPMMA	-.01200	.11622	1.000	-.3554	.3314
			FillerPMMA	-.09200	.08281	.688	-.3290	.1450
			Heat cured dentine	-.13800	.06465	.180	-.3208	.0448
		Heat cured dentine	LinearPMMA	.12600	.11519	.700	-.2158	.4678
			FillerPMMA	.04600	.08137	.941	-.1877	.2797
			Cross-linked PMMA	.13800	.06465	.180	-.0448	.3208
DL56d	Games-Howell	LinearPMMA	FillerPMMA	-.16300	.14936	.699	-.5884	.2624
			Cross-linked PMMA	-.03200	.12339	.994	-.4084	.3444
			Heat cured dentine	-.13700	.12454	.697	-.5146	.2406
		FillerPMMA	LinearPMMA	.16300	.14936	.699	-.2624	.5884
			Cross-linked PMMA	.13100	.09457	.533	-.1534	.4154
			Heat cured dentine	.02600	.09606	.993	-.2604	.3124
		Cross-linked PMMA	LinearPMMA	.03200	.12339	.994	-.3444	.4084
			FillerPMMA	-.13100	.09457	.533	-.4154	.1534
			Heat cured dentine	-.10500	.04630	.144	-.2361	.0261

		Heat cured dentine	LinearPMMA	.13700	.12454	.697	-.2406	.5146
			FillerPMMA	-.02600	.09606	.993	-.3124	.2604
			Cross-linked PMMA	.10500	.04630	.144	-.0261	.2361
DL84d	Games-Howell	LinearPMMA	FillerPMMA	.07500	.13111	.938	-.3172	.4672
			Cross-linked PMMA	.16300	.12456	.579	-.2220	.5480
			Heat cured dentine	.08800	.13047	.905	-.3034	.4794
		FillerPMMA	LinearPMMA	-.07500	.13111	.938	-.4672	.3172
			Cross-linked PMMA	.08800	.04960	.330	-.0587	.2347
			Heat cured dentine	.01300	.06299	.997	-.1650	.1910
		Cross-linked PMMA	LinearPMMA	-.16300	.12456	.579	-.5480	.2220
			FillerPMMA	-.08800	.04960	.330	-.2347	.0587
			Heat cured dentine	-.07500	.04790	.431	-.2163	.0663
		Heat cured dentine	LinearPMMA	-.08800	.13047	.905	-.4794	.3034
			FillerPMMA	-.01300	.06299	.997	-.1910	.1650
			Cross-linked PMMA	.07500	.04790	.431	-.0663	.2163

*. The mean difference is significant at the 0.05 level.

Δa^*

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
DA1d	4.271	3	36	.011
DA7d	3.770	3	36	.019
DA28d	4.176	3	36	.012
DA56d	9.409	3	36	.000
DA84d	3.818	3	36	.018

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
DA1d	Between Groups	.052	3	.017	2.604	.067
	Within Groups	.238	36	.007		
	Total	.290	39			
DA7d	Between Groups	.071	3	.024	2.659	.063
	Within Groups	.319	36	.009		
	Total	.389	39			

DA28d	Between Groups	.107	3	.036	2.289	.095
	Within Groups	.562	36	.016		
	Total	.669	39			
DA56d	Between Groups	.083	3	.028	2.513	.074
	Within Groups	.395	36	.011		
	Total	.477	39			
DA84d	Between Groups	.020	3	.007	.582	.631
	Within Groups	.403	36	.011		
	Total	.422	39			

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
DA1d	Welch	3.081	3	19.404	.052
DA7d	Welch	2.868	3	19.452	.063
DA28d	Welch	1.887	3	19.116	.166
DA56d	Welch	2.889	3	19.060	.062
DA84d	Welch	.767	3	19.537	.526

a. Asymptotically F distributed.

Multiple Comparisons

Dependent Variable				Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
DA1d	Games-Howell	LinearPMMA	FillerPMMA	.07500	.04258	.337	-.0515	.2015
			Cross-linked PMMA	.01000	.02339	.973	-.0561	.0761
			Heat cured dentine	.07800	.02846	.063	-.0034	.1594
		FillerPMMA	LinearPMMA	-.07500	.04258	.337	-.2015	.0515
			Cross-linked PMMA	-.06500	.04284	.457	-.1919	.0619
			Heat cured dentine	.00300	.04581	1.000	-.1294	.1354
		Cross-linked PMMA	LinearPMMA	-.01000	.02339	.973	-.0761	.0561
			FillerPMMA	.06500	.04284	.457	-.0619	.1919
			Heat cured dentine	.06800	.02885	.126	-.0143	.1503
		Heat cured dentine	LinearPMMA	-.07800	.02846	.063	-.1594	.0034
			FillerPMMA	-.00300	.04581	1.000	-.1354	.1294

			Cross-linked PMMA	-.06800	.02885	.126	-.1503	.0143
DA7d	Games-Howell	LinearPMMA	FillerPMMA	.10300	.05141	.235	-.0475	.2535
			Cross-linked PMMA	.07200	.02930	.103	-.0112	.1552
			Heat cured dentine	.01400	.03304	.974	-.0794	.1074
		FillerPMMA	LinearPMMA	-.10300	.05141	.235	-.2535	.0475
			Cross-linked PMMA	-.03100	.04947	.921	-.1783	.1163
			Heat cured dentine	-.08900	.05177	.352	-.2402	.0622
		Cross-linked PMMA	LinearPMMA	-.07200	.02930	.103	-.1552	.0112
			FillerPMMA	.03100	.04947	.921	-.1163	.1783
			Heat cured dentine	-.05800	.02994	.250	-.1432	.0272
		Heat cured dentine	LinearPMMA	-.01400	.03304	.974	-.1074	.0794
			FillerPMMA	.08900	.05177	.352	-.0622	.2402
			Cross-linked PMMA	.05800	.02994	.250	-.0272	.1432
DA28d	Games-Howell	LinearPMMA	FillerPMMA	.14300	.07306	.252	-.0707	.3567
			Cross-linked PMMA	.08300	.04028	.208	-.0322	.1982
			Heat cured dentine	.05200	.03842	.546	-.0591	.1631
		FillerPMMA	LinearPMMA	-.14300	.07306	.252	-.3567	.0707
			Cross-linked PMMA	-.06000	.06905	.821	-.2672	.1472
			Heat cured dentine	-.09100	.06798	.560	-.2969	.1149
		Cross-linked PMMA	LinearPMMA	-.08300	.04028	.208	-.1982	.0322
			FillerPMMA	.06000	.06905	.821	-.1472	.2672
			Heat cured dentine	-.03100	.03011	.735	-.1163	.0543
		Heat cured dentine	LinearPMMA	-.05200	.03842	.546	-.1631	.0591
			FillerPMMA	.09100	.06798	.560	-.1149	.2969
			Cross-linked PMMA	.03100	.03011	.735	-.0543	.1163
DA56d	Games-Howell	LinearPMMA	FillerPMMA	.12800	.06101	.210	-.0537	.3097
			Cross-linked PMMA	.07300	.02682	.066	-.0040	.1500

			Heat cured dentine	.06200	.03075	.219	-.0249	.1489
		FillerPMMA	LinearPMMA	-.12800	.06101	.210	-.3097	.0537
			Cross-linked PMMA	-.05500	.05864	.786	-.2337	.1237
			Heat cured dentine	-.06600	.06054	.702	-.2471	.1151
		Cross-linked PMMA	LinearPMMA	-.07300	.02682	.066	-.1500	.0040
			FillerPMMA	.05500	.05864	.786	-.1237	.2337
			Heat cured dentine	-.01100	.02574	.973	-.0846	.0626
		Heat cured dentine	LinearPMMA	-.06200	.03075	.219	-.1489	.0249
			FillerPMMA	.06600	.06054	.702	-.1151	.2471
			Cross-linked PMMA	.01100	.02574	.973	-.0626	.0846
DA84d	Games-Howell	LinearPMMA	FillerPMMA	.05900	.05860	.748	-.1137	.2317
			Cross-linked PMMA	.04700	.03236	.485	-.0446	.1386
			Heat cured dentine	.03200	.03432	.788	-.0650	.1290
		FillerPMMA	LinearPMMA	-.05900	.05860	.748	-.2317	.1137
			Cross-linked PMMA	-.01200	.05740	.997	-.1828	.1588
			Heat cured dentine	-.02700	.05853	.966	-.1996	.1456
		Cross-linked PMMA	LinearPMMA	-.04700	.03236	.485	-.1386	.0446
			FillerPMMA	.01200	.05740	.997	-.1588	.1828
			Heat cured dentine	-.01500	.03224	.966	-.1063	.0763
		Heat cured dentine	LinearPMMA	-.03200	.03432	.788	-.1290	.0650
			FillerPMMA	.02700	.05853	.966	-.1456	.1996
			Cross-linked PMMA	.01500	.03224	.966	-.0763	.1063

*. The mean difference is significant at the 0.05 level.

Δb^*

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
DB1d	1.850	3	36	.156
DB7d	3.110	3	36	.038
DB28d	1.876	3	36	.151
DB56d	5.670	3	36	.003
DB84d	5.624	3	36	.003

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
DB1d	Between Groups	.182	3	.061	2.507	.074
	Within Groups	.873	36	.024		
	Total	1.055	39			
DB7d	Between Groups	.460	3	.153	1.749	.174
	Within Groups	3.156	36	.088		
	Total	3.616	39			
DB28d	Between Groups	.064	3	.021	.447	.721
	Within Groups	1.731	36	.048		
	Total	1.796	39			
DB56d	Between Groups	.188	3	.063	1.023	.394
	Within Groups	2.208	36	.061		
	Total	2.397	39			
DB84d	Between Groups	.107	3	.036	.917	.442
	Within Groups	1.398	36	.039		
	Total	1.505	39			

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
DB1d	Welch	2.623	3	18.701	.081
DB7d	Welch	2.158	3	18.156	.128
DB28d	Welch	.473	3	19.173	.705
DB56d	Welch	.941	3	17.879	.442
DB84d	Welch	.592	3	17.996	.628

Asymptotically F distributed.

Multiple Comparisons

Dependent Variable				Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
DB1d	Games-Howell	LinearPMMA	FillerPMMA	.16620	.08479	.241	-.0748	.4072
			Cross-linked PMMA	.00200	.07143	1.000	-.2115	.2155
			Heat cured dentine	.04900	.07969	.926	-.1799	.2779
		FillerPMMA	LinearPMMA	-.16620	.08479	.241	-.4072	.0748
			Cross-linked PMMA	-.16420	.05787	.060	-.3341	.0057
			Heat cured dentine	-.11720	.06779	.339	-.3094	.0750
		Cross-linked PMMA	LinearPMMA	-.00200	.07143	1.000	-.2155	.2115
			FillerPMMA	.16420	.05787	.060	-.0057	.3341
			Heat cured dentine	.04700	.05009	.785	-.0980	.1920
		Heat cured dentine	LinearPMMA	-.04900	.07969	.926	-.2779	.1799
			FillerPMMA	.11720	.06779	.339	-.0750	.3094
			Cross-linked PMMA	-.04700	.05009	.785	-.1920	.0980
DB7d	Games-Howell	LinearPMMA	FillerPMMA	-.24600	.15227	.397	-.6800	.1880
			Cross-linked PMMA	-.01500	.15839	1.000	-.4643	.4343
			Heat cured dentine	.01600	.12944	.999	-.3730	.4050
		FillerPMMA	LinearPMMA	.24600	.15227	.397	-.1880	.6800
			Cross-linked PMMA	.23100	.13531	.349	-.1518	.6138
			Heat cured dentine	.26200	.09990	.087	-.0321	.5561
		Cross-linked PMMA	LinearPMMA	.01500	.15839	1.000	-.4343	.4643
			FillerPMMA	-.23100	.13531	.349	-.6138	.1518
			Heat cured dentine	.03100	.10900	.992	-.2923	.3543
		Heat cured dentine	LinearPMMA	-.01600	.12944	.999	-.4050	.3730
			FillerPMMA	-.26200	.09990	.087	-.5561	.0321
			Cross-linked PMMA	-.03100	.10900	.992	-.3543	.2923
DB28d	Games-Howell	LinearPMMA	FillerPMMA	-.01300	.12469	1.000	-.3663	.3403

			Cross-linked PMMA	.08600	.10527	.845	-.2235	.3955
			Heat cured dentine	.05400	.10350	.952	-.2525	.3605
		FillerPMMA	LinearPMMA	.01300	.12469	1.000	-.3403	.3663
			Cross-linked PMMA	.09900	.09234	.711	-.1691	.3671
			Heat cured dentine	.06700	.09031	.878	-.1972	.3312
		Cross-linked PMMA	LinearPMMA	-.08600	.10527	.845	-.3955	.2235
			FillerPMMA	-.09900	.09234	.711	-.3671	.1691
			Heat cured dentine	-.03200	.06075	.951	-.2039	.1399
		Heat cured dentine	LinearPMMA	-.05400	.10350	.952	-.3605	.2525
			FillerPMMA	-.06700	.09031	.878	-.3312	.1972
			Cross-linked PMMA	.03200	.06075	.951	-.1399	.2039
DB56d	Games-Howell	LinearPMMA	FillerPMMA	-.08600	.14889	.938	-.5070	.3350
			Cross-linked PMMA	.07800	.11655	.907	-.2700	.4260
			Heat cured dentine	.08200	.11180	.881	-.2602	.4242
		FillerPMMA	LinearPMMA	.08600	.14889	.938	-.3350	.5070
			Cross-linked PMMA	.16400	.10972	.470	-.1620	.4900
			Heat cured dentine	.16800	.10466	.418	-.1515	.4875
		Cross-linked PMMA	LinearPMMA	-.07800	.11655	.907	-.4260	.2700
			FillerPMMA	-.16400	.10972	.470	-.4900	.1620
			Heat cured dentine	.00400	.04868	1.000	-.1364	.1444
		Heat cured dentine	LinearPMMA	-.08200	.11180	.881	-.4242	.2602
			FillerPMMA	-.16800	.10466	.418	-.4875	.1515
			Cross-linked PMMA	-.00400	.04868	1.000	-.1444	.1364
DB84d	Games-Howell	LinearPMMA	FillerPMMA	.08900	.11540	.866	-.2412	.4192
			Cross-linked PMMA	.12700	.10350	.622	-.1793	.4333
			Heat cured dentine	.12600	.09772	.589	-.1727	.4247
		FillerPMMA	LinearPMMA	-.08900	.11540	.866	-.4192	.2412
			Cross-linked PMMA	.03800	.07737	.960	-.1848	.2608

			Heat cured dentine	.03700	.06944	.949	-.1715	.2455
		Cross-linked PMMA	LinearPMMA	-.12700	.10350	.622	-.4333	.1793
			FillerPMMA	-.03800	.07737	.960	-.2608	.1848
			Heat cured dentine	-.00100	.04710	1.000	-.1378	.1358
		Heat cured dentine	LinearPMMA	-.12600	.09772	.589	-.4247	.1727
			FillerPMMA	-.03700	.06944	.949	-.2455	.1715
			Cross-linked PMMA	.00100	.04710	1.000	-.1358	.1378

Water sorption

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
watersorptionD1	.616	3	36	.609
watersorptionD7	4.549	3	36	.008
watersorptionD28	1.204	3	36	.322
watersorptionD56	2.788	3	36	.055

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
watersorptionD1	Between Groups	53.895	3	17.965	4.308	.011
	Within Groups	150.116	36	4.170		
	Total	204.011	39			
watersorptionD7	Between Groups	1039.435	3	346.478	24.978	.000
	Within Groups	499.361	36	13.871		
	Total	1538.796	39			
watersorptionD28	Between Groups	1114.374	3	371.458	26.404	.000
	Within Groups	506.458	36	14.068		
	Total	1620.832	39			
watersorptionD56	Between Groups	1017.656	3	339.219	24.387	.000
	Within Groups	500.743	36	13.910		
	Total	1518.399	39			

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
watersorptionD1	Welch	4.239	3	19.902	.018
watersorptionD7	Welch	48.738	3	19.227	.000
watersorptionD28	Welch	29.923	3	19.616	.000
watersorptionD56	Welch	38.659	3	19.376	.000

Asymptotically F distributed.

Multiple Comparisons

Dependent Variable				Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
watersorption D1	Games-Howell	LinearPMMA	FillerPMMA	1.98400	.86605	.139	-.4739	4.4419
			Cross-linked PMMA	1.94500	.97926	.230	-.8235	4.7135
			Heat cured dentine	-.62800	.92956	.905	-3.2558	1.9998
		FillerPMMA	LinearPMMA	-1.98400	.86605	.139	-4.4419	.4739
			Cross-linked PMMA	-.03900	.89658	1.000	-2.5898	2.5118
			Heat cured dentine	-2.61200*	.84203	.029	-4.9978	-.2262
		Cross-linked PMMA	LinearPMMA	-1.94500	.97926	.230	-4.7135	.8235
			FillerPMMA	.03900	.89658	1.000	-2.5118	2.5898
			Heat cured dentine	-2.57300	.95808	.066	-5.2836	.1376
		Heat cured dentine	LinearPMMA	.62800	.92956	.905	-1.9998	3.2558
			FillerPMMA	2.61200*	.84203	.029	.2262	4.9978
			Cross-linked PMMA	2.57300	.95808	.066	-.1376	5.2836
watersorption D7	Games-Howell	LinearPMMA	FillerPMMA	2.20200	2.04376	.707	-3.6065	8.0105
			Cross-linked PMMA	9.42600*	1.44321	.000	5.2347	13.6173
			Heat cured dentine	-4.71200*	1.57111	.037	-9.1886	-.2354
		FillerPMMA	LinearPMMA	-2.20200	2.04376	.707	-8.0105	3.6065
			Cross-linked PMMA	7.22400*	1.75501	.006	2.0331	12.4149
			Heat cured dentine	-6.91400*	1.86161	.010	-12.3022	-1.5258
		Cross-linked PMMA	LinearPMMA	-9.42600*	1.44321	.000	-13.6173	-5.2347
			FillerPMMA	-7.22400*	1.75501	.006	-12.4149	-2.0331

			Heat cured dentine	-14.13800*	1.17110	.000	-17.4735	-10.8025
		Heat cured dentine	LinearPMMA	4.71200*	1.57111	.037	.2354	9.1886
			FillerPMMA	6.91400*	1.86161	.010	1.5258	12.3022
			Cross-linked PMMA	14.13800*	1.17110	.000	10.8025	17.4735
watersorption D28	Games-Howell	LinearPMMA	FillerPMMA	5.99300*	1.86482	.024	.6941	11.2919
			Cross-linked PMMA	11.04300*	1.66352	.000	6.3407	15.7453
			Heat cured dentine	-2.51200	1.42961	.328	-6.5887	1.5647
		FillerPMMA	LinearPMMA	-5.99300*	1.86482	.024	-11.2919	-.6941
			Cross-linked PMMA	5.05000	1.89302	.069	-.3208	10.4208
			Heat cured dentine	-8.50500*	1.69116	.001	-13.4038	-3.6062
		Cross-linked PMMA	LinearPMMA	-11.04300*	1.66352	.000	-15.7453	-6.3407
			FillerPMMA	-5.05000	1.89302	.069	-10.4208	.3208
			Heat cured dentine	-13.55500*	1.46621	.000	-17.7450	-9.3650
		Heat cured dentine	LinearPMMA	2.51200	1.42961	.328	-1.5647	6.5887
			FillerPMMA	8.50500*	1.69116	.001	3.6062	13.4038
			Cross-linked PMMA	13.55500*	1.46621	.000	9.3650	17.7450
watersorption D56	Games-Howell	LinearPMMA	FillerPMMA	3.45800	1.92266	.315	-2.1390	9.0550
			Cross-linked PMMA	9.11200*	1.17134	.000	5.7864	12.4376
			Heat cured dentine	-4.71300*	1.47056	.024	-8.8906	-.5354
		FillerPMMA	LinearPMMA	-3.45800	1.92266	.315	-9.0550	2.1390
			Cross-linked PMMA	5.65400*	1.84425	.042	.1965	11.1115
			Heat cured dentine	-8.17100*	2.04738	.005	-14.0337	-2.3083
		Cross-linked	LinearPMMA	-9.11200*	1.17134	.000	-12.4376	-5.7864

		PMMA	FillerPMMA	-5.65400*	1.84425	.042	-11.1115	-.1965
			Heat cured dentine	-13.82500*	1.36645	.000	-17.7553	-9.8947
		Heat cured dentine	LinearPMMA	4.71300*	1.47056	.024	.5354	8.8906
			FillerPMMA	8.17100*	2.04738	.005	2.3083	14.0337
			Cross-linked PMMA	13.82500*	1.36645	.000	9.8947	17.7553

*. The mean difference is significant at the 0.05 level.

Water solubility

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
watersolubilityD1	2.535	3	36	.072
watersolubilityD7	3.556	3	36	.024
watersolubilityD28	1.325	3	36	.281
watersolubilityD56	1.035	3	36	.389

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
watersolubilityD1	Between Groups	.868	3	.289	6.189	.002
	Within Groups	1.683	36	.047		
	Total	2.552	39			
watersolubilityD7	Between Groups	20.680	3	6.893	15.091	.000
	Within Groups	16.445	36	.457		
	Total	37.125	39			
watersolubilityD28	Between Groups	53.783	3	17.928	125.439	.000
	Within Groups	5.145	36	.143		
	Total	58.928	39			
watersolubilityD56	Between Groups	46.619	3	15.540	94.886	.000
	Within Groups	5.896	36	.164		
	Total	52.515	39			

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
watersolubilityD1	Welch	8.246	3	19.191	.001
watersolubilityD7	Welch	33.045	3	18.054	.000
watersolubilityD28	Welch	149.373	3	19.444	.000
watersolubilityD56	Welch	97.224	3	19.783	.000

a. Asymptotically F distributed.

Multiple Comparisons

Dependent Variable				Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
watersolubility D1	Games-Howell	LinearPMMA	FillerPMMA	-.21800	.08135	.074	-.4532	.0172
			Cross-linked PMMA	-.28000*	.07859	.013	-.5065	-.0535
			Heat cured dentine	-.40700*	.09658	.005	-.6909	-.1231
		FillerPMMA	LinearPMMA	.21800	.08135	.074	-.0172	.4532
			Cross-linked PMMA	-.06200	.09684	.918	-.3358	.2118
			Heat cured dentine	-.18900	.11193	.359	-.5068	.1288
		Cross-linked PMMA	LinearPMMA	.28000*	.07859	.013	.0535	.5065
			FillerPMMA	.06200	.09684	.918	-.2118	.3358
			Heat cured dentine	-.12700	.10994	.662	-.4398	.1858
		Heat cured dentine	LinearPMMA	.40700*	.09658	.005	.1231	.6909
			FillerPMMA	.18900	.11193	.359	-.1288	.5068
			Cross-linked PMMA	.12700	.10994	.662	-.1858	.4398
watersolubility D7	Games-Howell	LinearPMMA	FillerPMMA	-.83400	.38472	.170	-1.921	.2534
			Cross-linked PMMA	1.06200*	.28947	.017	.1884	1.9356
			Heat cured dentine	-.51500	.32091	.406	-1.442	.4124
		FillerPMMA	LinearPMMA	.83400	.38472	.170	-.2534	1.9214
			Cross-linked PMMA	1.89600*	.28237	.000	1.0451	2.7469

			Heat cured dentine	.31900	.31453	.744	-.5882	1.2262
		Cross-linked PMMA	LinearPMMA	-1.06200*	.28947	.017	-1.935	-.1884
			FillerPMMA	-1.89600*	.28237	.000	-2.746	-1.045
			Heat cured dentine	-1.57700*	.18632	.000	-2.119	-1.034
		Heat cured dentine	LinearPMMA	.51500	.32091	.406	-.4124	1.4424
			FillerPMMA	-.31900	.31453	.744	-1.226	.5882
			Cross-linked PMMA	1.57700*	.18632	.000	1.0344	2.1196
watersolubility D28	Games-Howell	LinearPMMA	FillerPMMA	-1.28600*	.18390	.000	-1.805	-.7662
			Cross-linked PMMA	.88200*	.15451	.000	.4359	1.3281
			Heat cured dentine	-2.13500*	.18568	.000	-2.659	-1.610
		FillerPMMA	LinearPMMA	1.28600*	.18390	.000	.7662	1.8058
			Cross-linked PMMA	2.16800*	.15064	.000	1.7342	2.6018
			Heat cured dentine	-.84900*	.18247	.001	-1.364	-.3333
		Cross-linked PMMA	LinearPMMA	-.88200*	.15451	.000	-1.328	-.4359
			FillerPMMA	-2.16800*	.15064	.000	-2.601	-1.734
			Heat cured dentine	-3.01700*	.15280	.000	-3.457	-2.576
		Heat cured dentine	LinearPMMA	2.13500*	.18568	.000	1.6102	2.6598
			FillerPMMA	.84900*	.18247	.001	.3333	1.3647
			Cross-linked PMMA	3.01700*	.15280	.000	2.5763	3.4577
watersolubility D56	Games-Howell	LinearPMMA	FillerPMMA	-.72500*	.17589	.003	-1.222	-.2278
			Cross-linked PMMA	1.28900*	.15798	.000	.8408	1.7372
			Heat cured dentine	-1.66700*	.19886	.000	-2.232	-1.101
		FillerPMMA	LinearPMMA	.72500*	.17589	.003	.2278	1.2222
			Cross-linked PMMA	2.01400*	.16113	.000	1.5563	2.4717
			Heat cured dentine	-.94200*	.20137	.001	-1.513	-.3704
		Cross-linked PMMA	LinearPMMA	-1.28900*	.15798	.000	-1.737	-.8408
			FillerPMMA	-2.01400*	.16113	.000	-2.471	-1.556

			Heat cured dentine	-2.95600*	.18594	.000	-3.490	-2.421
		Heat cured dentine	LinearPMMA	1.66700*	.19886	.000	1.1017	2.2323
			FillerPMMA	.94200*	.20137	.001	.3704	1.5136
			Cross-linked PMMA	2.95600*	.18594	.000	2.4213	3.4907

*. The mean difference is significant at the 0.05 level.

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