EFFECT OF DENTURE CLEANSER ON COLOR STABILITY AND FLEXURAL STRENGTH OF DENTURE BASE MATERIALS

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EFFECT OF DENTURE CLEANSER ON COLOR STABILITY AND FLEXURAL STRENGTH OF DENTURE BASE MATERIALS

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ABSTRACT

The purpose of this study was to evaluate the effect of storage in denture cleanser, for various lengths of time, on the color stability and flexural strength of 3 denture base materials: 1) SR Triplex Hot, a compression-moulding acrylic resin (Ivoclar AG, Liechtenstein) 2) SR Ivocap Plus, an injection-moulding acrylic resin (Ivoclar AG, Liechtenstein) 3) Vitalflex, a nylon (Thermoplastic Comfort System Inc., USA). Three specimens were prepared for each group and stored in water or Polident solution for 15, 30 and 60 cycles. Color stability was determined by colorimeter and flexural strength was determined by universal testing machine.

Color changes (ΔE) of SR Triplex Hot and Vitaflex were not significantly affected by storage, time of storage and combination of among storage and time of storage ($p>0.05$). Howevers the color changes of SR Ivocap Plus was significantly affected by time of storage and combination among storage and time of storage ($p<0.05$).

The flexural strength of SR Triplex Hot was significantly affected by time of storage ($p<0.05$), Vitaflex was significantly affected by storage and time of storage, whereas SR Ivocap Plus was not significantly affected by any variables.

This study suggests that denture cleanser (Polident) may be the cleanser of choice for patients who use PMMA denture base. Although there were effects of Polident solution on color stability of SR Ivocap Plus, clinically, the color changes exhibited by all specimens after immersion in Polident solution for 60 cycles were clinically acceptable ($\Delta E \leq 3.3$). The use of denture cleanser in nylon causes an increase in rigidity of the denture base.

KEY WORDS : DENTURE BASE MATERIAL/ COLOR STABILITY/

FLEXURAL STRENGTH/ DENTURE CLEANSER

74 pp.

อิทธิพลของสารทำความสะอาดฟันเทียมต่อการเสถียรภาพของสีและกำลังดัดขวางของวัสดุประดิษฐ์ฐานฟันเทียม (EFFECT OF DENTURE CLEANSER ON COLOR STABILITY AND FLEXURAL STRENGTH OF DENTURE BASE MATERIALS)

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อประเมินผลของการใช้สารทำความสะอาดฟันเทียม Polident ที่มีต่อการเปลี่ยนแปลงสีและกำลังดัดขวางของวัสดุประดิษฐ์ฐานฟันเทียม 3 ชนิด คือ 1) SR Triplex Hot, a compression- moulding acrylic resin (Ivoclar AG, Liechtenstein) 2) SR Ivocap Plus, a injection-moulding acrylic resin (Ivoclar AG, Liechtenstein) และ 3) Vitalflex, a nylon (Thermoplastic Comfort System Inc., USA) นำชิ้นทดลอง 3 ชิ้น แช่ในน้ำเปล่าหรือสารละลาย Polident จำนวน 15, 30 และ 60 รอบ การเปลี่ยนแปลงสี (ΔE) จะประเมินโดยใช้ Colorimeter และกำลังดัดขวางวัดโดยใช้เครื่อง Universal testing machine

การเปลี่ยนแปลงของสีพบความแตกต่างอย่างมีนัยสำคัญทางสถิติของเวลาในการจัดเก็บและปฏิกิริยาระหว่างเวลาในการจัดเก็บและสารละลายที่ใช้จัดเก็บของ SR Ivocap Plus ที่ระดับนัยสำคัญ 0.05 แต่ไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติของเวลาในการจัดเก็บ สารละลายที่ใช้จัดเก็บ และปฏิกิริยาระหว่างเวลาในการจัดเก็บและสารละลายที่ใช้จัดเก็บของ SR Triplex Hot และ Vitaflex

ความแข็งแรงยืดหยุ่นของวัสดุประดิษฐ์ฐานฟันเทียม SR Triplex Hot และ Vitaflex พบว่ามีความแตกต่างอย่างมีนัยสำคัญทางสถิติกับเวลาในการจัดเก็บ และยังพบความแตกต่างอย่างมีนัยสำคัญกับสารละลายที่ใช้จัดเก็บของ Vitaflex ที่ระดับนัยสำคัญ 0.05

จากการศึกษานี้เห็นได้ว่าสารทำความสะอาดฟันเทียม (Polident) เป็นหนึ่งในทางเลือกหลักที่จะแนะนำให้คนไข้ที่ใช้วัสดุฐานฟันเทียมชนิด PMMA แม้จะพบว่าสารทำความสะอาดฟันปลอมมีผลต่อการเปลี่ยนแปลงสีในทางสถิติของ SR Ivocap Plus แต่ในทางคลินิกการเปลี่ยนแปลงสีของชิ้นทดลองทั้งหมดหลังจากแช่ในสารละลาย Polident อยู่ในระดับที่ยอมรับได้ ($\Delta E \leq 3.3$) การใช้สารละลาย Polident ในวัสดุประดิษฐ์ฐานฟันปลอมที่เป็น nylon อาจทำให้ฐานฟันปลอมมีความยืดหยุ่นลดลง

74 หน้า.

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LIST OF ABBREVIATIONS

μm.	micrometer
mm.	millimeter
cm^2	centimeter square
mg.	milligram
g.	gram
kg.	kilogram
ml	milliliter
N	Newton
MPa	megaPascal
min.	minute
Ltd.	Limited
Co.	Company
et al.	et alii
°C	degree celsius
SD	standard deviation

CHAPTER I

INTRODUCTION

Color stability is an important clinical character for dental restorative materials and is one factor that provides information on serviceability of denture base (1,2). Discoloration of the denture base polymers may be caused by intrinsic and extrinsic factors. Intrinsic factors involve chemical change of material. The cause of such chemical discoloration has been attributed to oxidation of amine accelerator after exposure to various energy sources and immersion in water for a long period. Extrinsic factors which contribute of discoloration include staining by adhesion or penetration of colorants as a result of exposure to exogenous sources in oral cavity such as coffee and tea, beverages and nicotine (3, 4). One or more of these factors may contribute to visibly detectable or esthetically unacceptable color changes of the prosthesis.

Flexural strength is an important physical properties of the denture base. The denture base must be strong enough to allow the prosthesis to withstand functional and parafunctional masticatory forces. Midline fractures of denture base resins are related to flexing and deformation, leading some to recommend selectively increasing the bulk of material in regions subject to deformation and fractures. A denture base that is too thick can cause discomfort feeling such as gagging or dislodgement of the denture when the patient opens wide or yawns, interfere with the coronoid process during movement of the mandible and speech problems. While minimizing the thickness of the denture base can lead to better patient acceptance, it also increases the

potential for fracture making the use of a stronger acrylic resin very important. These factors have led manufacturers to develop higher flexural strength denture base materials (5).

Generally a denture base is made from compression-moulding material that is methylmethacrylate and polymethylmethacrylate. Heat-cure acrylic resin is used due to its many advantages such as esthetic, low water sorption and ease of repair processing. However the dimensional change due to polymerization shrinkage is a major problem of this material (6). There are many factors in the laboratory procedure that can lead to alteration to the denture teeth occlusion. To overcome the problems of significant increased vertical dimension after processing associated with the technique, injection molding was developed. The injection-molding system is used to reduce polymerization shrinkage due to continuous injection method of fluid polymer can compensate for shrinkage. Poly(methyl methacrylate) and nylon is the injection-molding denture base material (7) that is available in Thailand.

Denture wearing leads to a higher prevalence of mutans streptococci, lactobacilli, staphylococci and yeasts in the oral cavity compared with non-denture-wearing subjects. Lack of denture hygiene results in malodor, poor aesthetics and denture stomatitis. Denture cleanser have been considered to be an efficacious method to prevent micro-organism and denture plaque formation. A daily use of denture cleanser can effect the color stability of heat-cure acrylic resin denture bases (8). A 24-h immersion in the disinfecting solution increased the rigidity of nylon denture base material (9).

Although there are numerous studies regarding color stability and flexural strength of compression-moulding denture base materials, there is a paucity of

evidence on effects of long term using denture cleansers on the color stability and flexural strength of denture base material. Therefore, the purpose of this study is to investigate the effect of denture cleanser on the color stability and flexural strength of several denture base materials for a simulated 15, 30 and 60-day period.

Objective of the study

1. To investigate the color stability of denture base material after immersion in the denture cleanser for 15, 30 and 60-day period.

2. To investigate the flexural strength of denture base material after immersion in the denture cleanser for 15, 30 and 60-day period.

CHAPTER II

LITERATURE REVIEW

2.1 The denture base polymeric materials

Various materials have been used in the fabrication of denture bases. Wood, bone, ivory, ceramics, metals, metal alloys and numerous polymers have been used in denture base applications (10, 11, 12, 13, 14, 15, 16, 17). Vulcanized rubber was introduced as a denture base material in 1855 (15, 18). Vulcanite is produced by heating natural rubber in the presence of sulfer. The resultant material is hard, reddish-brown rubber that exhibits many desirable properties. Nevertheless, vulcanite displayed questionable esthetic, and the fabrication process was particularly demanding. In 1937, PMMA was introduced and rapidly replaced vulcanite as the most commonly used denture base material (10, 11). PMMA provided enhanced physical and esthetic properties. In addition, PMMA was readily available, inexpensive, and easily manipulated. In the 1950s, nylon was introduced to using as a denture base material, suitably stiffened, could be extremely useful in the treatment of those patients for whom acrylic prostheses are not suitable. This would include patients who demonstrate repeated fracture of dentures and those that show tissue reactions of a proven allergic nature (16).

2.1.1 Classification according to curing method (1)

Denture base polymers are categorized into the following Types and Classes:

Type 1 : Heat-polymerizable polymers

Class 1 : Powder and liquid

Class 2 : Plastic cake

Type 2 : Autopolymerizable polymers

Class 1 : Powder and liquid

Class 2 : Powder and liquid pour type resins

Type 3 : Thermoplastic blank or powder

Type 4 : Light-activated material

Type 5 : Microwave cured material

2.1.2 Classification according to fabrication method (9)

The denture base material is divided into 2 systems.

a. The compression-molding materials

b. The injection-molding materials

a. Compression-molding denture base material

Most removable denture bases are fabricated by the use of a compression - molding material (6). The properties of the materials present a compromise between physical properties, easy to use and cost on the other. Powder and liquid are mixed and compressed to mould cavity in dough stage. Then the cavity is poured to form the mould cavity. Conventional heat-cured acrylic resin is the material for compression-molding method (7).

b. Injection-molding denture base materials

The materials are filled in to the mould cavity by the injection method. This method can be used with injection-molding acrylic resin and nylon (4).

2.1.3 Acrylic denture base material

The formation of acrylic resin may be visualized in a similar manner. In this instance, each methyl methacrylate molecule may be considered a “mer”. Under the

proper conditions, individual methyl mathacrylate molecules may be linked to form a chain (Figure 2-1) (20).

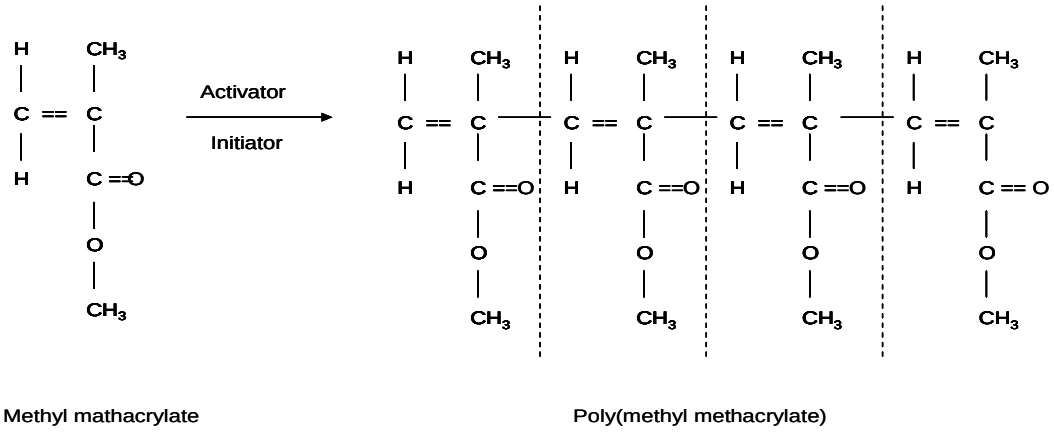

Figure 2-1 Individual methyl methacrylate molecules linked to form a chain. Segments 1 through 4 are used to illustrate the repetition of methyl methacrylate "mers" within the polymer chain.

2.1.3.1 Composition (20, 21, 22)

Most materials are supplied as a powder and liquid.

Powder

Polymer : Poly(methyl methacrylate) bead, PMMA

Initiator : A peroxide such as benzoyl peroxide

Pigments : Salts of Cadmium or Iron or organic dyes

Liquid

Monomer : Methyl methacrylate

Cross-linking agent : Ethyleneglycol dimethylacrylate

Inhibitor : Hydroquinone

Activator* : *N N'* –dimethyl - *p* – toluidine

* Only in self curing materials

The major component of the powder is beads of polymethylmethacrylate with diameters up to 100 μm. The specific gravity is 1.19. These are produced by a process of suspension polymerization in which methylmethacrylate monomer, containing initiator, is suspended as droplets in water. The initiator present in the powder may consist of peroxide remaining unreacted after the production of the beads, in addition to extra peroxide added to the beads after their manufacture.

The major component of the liquid is methylmethacrylate (MMA) monomer. This is a clear, colorless, low viscosity liquid with a melting point is -48 °C and a boiling point is 100.3°C and distinct odor exaggerated by a relatively high vapour pressure at room temperature. Its density is 0.945 gm/ml at 20 °C (12). The monomer normally contains some cross-linking agent to improve the physical properties of the set material (22).

Acrylic polymers have been modified by addition of compounds that do not enter into polymerization reaction. Butadiene-styrene rubber has been added to acrylic to improve their resistance to fracture caused by impact forces.

Acrylic denture base materials are generally low in strength, fairly flexible, brittle, high resistance to failure in fatigue, low thermal conductivity, low water sorption, low solubility, good color stability. In additional, compatibility of acrylic denture base is good. Instances of toxicity or allergic reactions have been related to excessive residual monomer. The important properties of heat-cured polymerization acrylic denture base materials is summarized in Table 2-1 (23).

Table 2-1 Properties of heat-cured polymerization acrylic denture base materials

Tensile strength	55 MPa
Compressive strength	76 MPa
Elastic modulus	3800 MPa
Impact strength	1 cm kg/cm
Elongation	2 %
Knoop hardness	15 kg/mm^2
Thermal conductivity	0.0006 (°C/cm)
Heat distortion temperature	95°C
Polymerization shrinkage	6%
Water sorption (24 hours)	0.6 mg/cm^2
Water solubility	0.02 mg/cm^2
Color stability	Good
Tissue compatibility	Good

2.1.4 Nylon

The use of nylon as a denture base material has been described in the literatures in the 1950s (24, 25, 26). Nylon is a generic name for certain types of thermoplastic polymers belonging to the class known as polyamides. These polyamides are produced by the condensation reactions between a diamine and a dibasic acid. The types of nylon are distinguished by a numerical prefix which indicates the number of methyl (-CH_2-) groups in the diamine and the total number of carbon atoms in dibasic acid. Nylon 66 is a early type, this material has a high melting – point value of 264°C, high water sorption value of 8.5 per cent. The frequency of amide groups along the

chain affects the water sorption and the chemical properties of each type of nylon, more widely spaced amide groups. It absorps lower water and has better chemical resistance. The more recently developed nylon 11 and nylon 12, both contain very long methylene chains and have relatively low melting – points and water absorption levels (27). The Nylon 12 with glass-fiber reinforcement is the most recent type because of its ability to overcome the problems of water absorption (16). The properties was improved such as water sorption at saturation is 1.2 percent, specific gravity is 1.22, tensile strength is 98 N per mm^2, modulus of elasticity is 4316 N per mm^2 and linear mould shrinkage is 0.3-0.5 percent (27).

There is an essential difference in character between acrylic and nylon polymers. Nylon is crystalline polymer whereas poly(methyl-methacrylate) is amorphous. This crystallinity accounts for the nylon characteristics of lack of solubility in solvents, high heat resistance, and high strength coupled with ductility (24).

Although nylon was not recommended for general use at that time, it was used in special circumstances such as repeated denture fracture (25, 26, 28), for the construction of orthodontic appliance (29) and using as gingival flange (4).

2.1.4.1 The processing moulding technique of nylon

Nylon is insoluble in almost all common condition. It can not be dough moulded by usual techniques, but molten material must be injected into the flask under pressure. The nylon is melted by an electric furnace to control temperature. The molten nylon is then forced into the flask by a plugger under pressure exerted by a hand or hydraulic press, the bottom of the aluminum tube is being burst (24).

There are some studies that present injection-molding denture base has more dimensional stability than compression-molding denture base, Garfunkel (30) and Anderson et al (31) studied to compare dimensional stability between compression-molding acrylic resin and injection-molding acrylic resin. There is significant linear dimensional changing of injection-molding acrylic resin lower than compression - molding acrylic resin.

There is a small risk of toxicity and hypersensitivity to the material as a result of its oxidation products and other components present in the system. Tissue reactions to acrylic resin denture base materials have been reported (31, 32, 33, 34, 35, 36). Some potential alternative materials to PMMA used in such cases are such as nylon.

After then nylon as a denture base polymer was carried out in the 1950s, there are some studies studied the property of this material. Mathews and Smith used 610 nylon for denture base. The clinical result shows the tendency of the material to deteriorate in base color, to stain, show high water absorption , and to develop a roughness of surface after a few weeks' wear (27).

Watt found the water absorption of nylon 66 and nylon 610 were overcome by using nylon 12 (25). Hargreaves compared the property of nylon12 and nylon12 with glass – fiber reinforcement . Both the strength and stiffness are increased , the coefficient of linear expansion reduced and this would enhance dimensional stability both in processing and in use. The water sorption value is lowered by a diluent effect (27).

2.2 The ideal properties of denture base materials (1).

1. Biocompatibility : non-toxic and non-irritant.

2. Surface characteristic : smooth surface, hard and glossy surface.
3. Color : translucent and evenly pigmented and/or, where applicable, evenly fibred.
4. Color stability : must not show more than a slight change in color, which is only perceptible with difficultly.
5. Translucency : visible from the opposite side of the test specimen plate.
6. Freedom from porosity : must not show voids.
7. Flexural strength : not less than 60-65 MPa.
8. Flexural moduli : at least 2000 MPa for heat polymerizable polymers and at least 1500 MPa for autopolymerizable polymers.
9. No residual monomer.
10. No water sorption.
11. No solubility.

2.3 Color stability

Color stability is the ability of a surface coating or pigment to resist degradation due to environmental exposure (38).

In the year 2003, Yu-lin Lai et al studied color stability and stain resistance of four polymer materials. Nylon, silicone and two polymethyl methacrylate are immersed in the distilled water, coffee and tea solutions. The coffee solution produced the highest discoloration value in the silicone material, followed by the nylon and two polymethyl methacrylate. The tea solution produced the highest discoloration value in the nylon (4).

In addition, Purnaveja et al showed that autopolymerized resins have color stability inferior to that of heat-polymerized materials. Autopolymerizing denture base resins have been found to be less stable than conventional acrylic resins. The color stability of autopolymerizing denture base acrylic resins varied with the chemical composition of the monomer (39).

McNeme studied color of heat-activated, light-activated, and autopolymerizing denture base materials after immersed in the various disinfectants showed no observable change at different interval of immersion. McNeme stated that 1% sodium hypochlorite caused no discoloration after 72 hours of immersion (40). It had been also reported by Ma et al. (41) that although the effects of chemical disinfectants on the surface characteristics and color of denture resins demonstrated statistical differences among disinfectants and resins for both measured parameters, magnitudes of change in color and roughness was most often clinically insignificant.

2.3.1 Color stability measurement

The American Dental Association (ADA) recommends the use of the CIELAB color differential system in examining various materials with regard to color. This technique is also being used extensively by researchers in dentistry. Color measurements will be quantified tristimulus values and calculated the color change (△E) (3, 4, 39, 40, 41).

The equation for calculating total color differences, ΔE is :

$$\Delta E = \{ (\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2 \}^{1/2}$$

$$\Delta L = L_{(Tn)} - L_{(T0)}$$

$$\Delta a = a_{(Tn)} - a_{(T0)}$$

$$\Delta b = b_{(Tn)} - b_{(T0)}$$

Where ΔL, Δa and Δ b are differences in the respective L, a and b values. The magnitude of the total color difference is represented by a single number, ΔE (3, 4, 39, 40, 41). The CIELAB measurements make it possible to evaluate the quantity of perceptible color changes in each specimen. The CIELAB is an approximately uniform color space with coordinates for lightness: white-black (L), redness-greenness (a), and yellowness-blueness (b).

2.4 Flexural strength

The flexural strength is the force needed to deform the material to fracture or irreversible yield. The flexural strength of denture base shall be not less than 65 MPa for Type 1, Type 3, Type 4 and Type 5 polymers and not less than 60 MPa for Type 2 polymers when tested in water at 37 ± 1 °C (1).

The flexural three-point bending test is useful in comparing denture base materials as it simulates the type of stress that is applied to the denture during mastication, although fatigue properties are clinically more relevant (42).

2.4.1 Flexural strength measurement (1)

Calculate the flexural strength, σ, in Megapascals from the following equation :

$$\sigma = \frac{3Fl}{2bh^2}$$

Where

F is the maximum load, in Newtons, exerted on the specimen;

L is the distance, in millimeters, between the supports, accurate to ±0.01mm;

B is the width, in millimeters, of the specimen measured immediately prior to water storage;

h is the height, in millimeters, of the specimen measured immediately prior to water storage.

Sandra et al. (42) showed chemical denture cleansers used according to the manufacturers' specifications did not cause flexural strength alterations or color changes in heat-polymerized acrylic resins submitted to soaking cycles simulating 30 days of use.

2.5 Denture cleanser

Denture cleansing may be performed by a number of products, which are divided into two main classes: mechanical and chemical cleansers (43).

The ideal denture cleanser should be (43)

1. Simple to use.
2. Effectively remove organic and inorganic matter from denture surface.
3. Bactericidal and fungicidal properties.
4. Be compatible with all denture base materials.

Denture cleanser is an alternative method to clean the prostheses. Many patients rely on the ability of denture cleansers to reduce or eliminate food particles and stain by placing their dentures in a container with cleanser according to directions (44). The cleanser using may be particularly appropriate for elderly people who lack manual dexterity (45). The immersion type chemical solutions for cleansing dentures may be divided into two major groups: denture cleansers and disinfectants. Commercial denture cleansers may be classified into the following groups based on their mode of

action, or main component: alkaline hypochlorites, alkaline peroxides, neutral peroxides with enzymes, enzymes, acids, crude drugs (44).

2.5.1 Classification (46)

Denture cleansers can be divided into 5 groups :

1. The alkaline peroxide
2. The alkaline hyprochlorite
3. Acid
4. Disinfectants
5. Enzymes

The alkaline peroxide is the most common of denture cleanser to be used. This product contains sodium bicarbonate, citric acid, sodium carbonate, potassium monopersulfate, sodium perborate, sodium hexametaphosphate, sodium benzoate, sodium benzoate, sodium lauryl sulfoacetate, flavor and chloride.

2.5.2 Compositions of denture cleanser

a. **Sodium bicarbonate** is the chemical compound with the formula $NaHCO_3$. Since it has long been known and is widely used, the salt has many other names including sodium hydrogencarbonate, sodium bicarb, baking soda, bread soda, cooking soda, bicarb soda or bicarbonate of soda. It is soluble in water, a white solid that is crystalline but often appears as a fine powder. It has a slight alkaline taste resembling that of sodium carbonate. It is marketed as a whitener because of its abrasive properties in some toothpaste brands (47).

b. **Citric acid** or Hydrogen citrate has the chemical formula $C_6H_8O_7$, is a weak organic acid found in citrus fruits. It is denoted by E number E330.The buffering properties of citrates are used to control pH in household cleaners and

pharmaceuticals. It also ability to chelate metals makes it useful in soaps and laundry detergents. By chelating the metals in hard water, it lets these cleaners produce foam and work better without need for water softening. Citric acid is the active ingredient in some bathroom and kitchen cleaning solutions. A solution with a 6%concentration of critic acid will remove hard water stains from glass without scrubbing (48).

c. **Sodium carbonate** is also known as washing soda or soda ash, has the chemical formula Na_2CO_3. It is a sodium salt of carbonic acid. Domestically it is used as a water softener during laundry. It competes with the ions magnesium and calcium in hard water and prevents them from bonding with the detergent being used. Without using soda, additional detergent is needed to soak up magnesium and calcium ions. Called washing soda or sal soda in the detergent section of stores, it effectively removes oil, grease and alcohol stain. Sodium carbonate is also used as a descaling agent in boilers (49).

d. **Sodium perborate** is a white, colorless , water – soluble chemical compound with chemical formula NaBO3. A saturated aqueous solution of sodium perborate gives, in effect, a solution of H_2O_2 buffered to a pH of about 10. The pH of an aqueous solution of H_2O_2 decreases only slightly from near neutrality with increasing H_2O_2 concentrations. Hence, H_2O_2 is weak acid. Thermodynamically, decomposition is favored in basic solution instead of acid solution, although additional chemical ingredients and dispersed particles determine the reaction kinetics in many instances. The decomposition of H_2O_2 in aqueous denture cleanser solutions occurs most likely via the oxidizing ability of the H_2O_2 - H_2O_2 couple. Foreign organic particles can be weakly attacked by this process (K3). Sodium perborate undergoes hydrolysis in contact with water, producing hydrogen peroside and borate. It serves as a source of

active oxygen in many detergents , laundry detergents , cleaning product and laundry bleaches. It is also present in some tooth bleaching formula. It has antiseptic properties and can act as a disinfectant. Sodium perborate is less aggressive bleach than Sodium hypochloride, causing less degradation to dyes and textiles . Borates also have some one – oxidative bleaching properties. Sodium perborate release oxygen rapidly at temperatures over 60ºC to make it active at lower temperatures (40 - 60º). It has to be mixed with a suitable activator, typically tetraacelylethylenediamine (51).

e. **Sodium hexametaphosphate** (SHMP) is correctly speaking a hexamer of composition $(NaPO_3)_6$. It is white, odorless and crystalline powder. Sodium hexametaphosphate of commerce is a mixture of polymeric metaphosphates, of which the hexamer is one, and is usually the compound referred to by this name. Sodium hexametaphosphate is used as a sequestrant and has applications in a wide variety of industries, including as a food additive. Sodium carbonate is sometimes add to SHMP to raise the pH to 8.0-8.6, which produces a SHMO products used for water softening and detergents (52).

f. **Sodium benzoate** is used as a preservative, effectively killing most yeasts, bateria, and fungi. It is effective only in acidic conditions (pH<3.6) making its use most prevalent in food such as preserves. It is also found in alcohol-based mouthwash. The taste of sodium benzoate can not be detected by around 23 percent of the population, but for those who can taste the chemical, it tends to be perceived as sweet, salty, or sometimes bitter (53).

g.. **Sodium stearate** is a chemical, made by reacting sodium with stearic acid to create the salt, sodium stearate. It has the chemical formula C_{17} $H_{35}COON$ or

$CH_3(CH_2)_{16}COONa$, is the white powder with a fatty aroma form. Sodium stearate is needed in medicine and toothpaste and as a waterproofing agent (54).

h. **Sodium lauryl sulfoacetate**, derived from coconut and palm oils; a safe, skin – friendly surfactant (foaming agent) for both skin and hair. The mild plant derived surfactant creates a rich , luxurious lather that effectively removes surface oil, dirt and bacteria, without stripping or dying sensitive skin. Sodium lauryl sulfoacetate is also hydrophilics. This mean it is attracted to water, which enables it to dissolve more readily in water (55).

Although chemical denture cleansers have been considered to be an efficacious method to prevent C. *albicans* colonization and denture plaque formation, a dialy use of denture cleansers can affect the physical properties of denture acrylic resin bases and soft liners (56).

CHAPTER III

MATERIALS AND METHODS

3.1 Materials

3.1.1 Materials for testing

a. Specimen :

Table 3-1 Materials used in the study

Material	Type	Processing method	Manufac-turer	Lot number
SR Triplex Hot (Figure3-1)	PMMA	Compression-moulded technique, Heat-cured polymerization at 70°C for 90 min and at 100°C for 30 min	Ivoclar Vivadent, Liechtenstein	H 12031
SR Ivocap Plus (Figure3-2)	PMMA	Injection-moulded technique, Heat-cured polymerization for 35 min at 100°C under 6 bar air pressure	Ivoclar Vivadent, Liechtenstein	D55588
Vitaflex (Figure3-3)	Nylon	Injection-moulded technique, Pre-heated in the furnace for 8 min at 248.8-265.5°C under 5 bars for 3 minutes	Thermoplastic Comfort System Inc., USA	110211

b. Solution :

Tap water

Denture cleanser (Polident® 5-Minute Anti-Bacterial Denture Cleanser, Lot No.5T06252A) (Figure 3-4)

3.1.2 Materials and instruments for specimens and solution preparing

a. Plastic model discs with 3 mm thickness and 22 mm in diameter
b. Plastic model rectangular with 3 mm thickness, 66 mm length and 12 mm width
c. Dental stone
d. Separating agent
e. Pink wax for making injection channel for injection technique
f. Hanau dental flask (Figure 3-5)
g. Flask compression unit (Figure 3-6)
h. polyethylene sheet
i. Hanau curing bath (Figure 3-7)
j. SR Ivocap flask (Figure 3-8)
k. Cap Vibrator for mixing the SR Ivocap powder and liquid (Figure 3-9)
l. Clamping frame for SR Ivocap system (Figure 3-10)
m. Hydraulic press (Figure 3-11)
n. Pressure apparatus (Figure 3-12)
o. Furnace for heating nylon material (Figure 3-13)
p. Vitaflex injection unit (Figure 3-14)
q. Micro engine
r. Carbide bur

s. Sand paper No.800, 1000, 1200, 1500, 2000 and 2400

t. Ultrasonic cleansing machine

u. Beaker

v. Plastic cup for immersion

3.1.3 Instruments for measurement

a. Color stability measurement

Colorimeter: Color flex® (Hunter Lab, Model 4510 Reston, USA) (Figure 3-15)

b. Flexural strength measurement

Instron testing machine (Instron Universal Testing machine, model 5566, USA). **(**Figure 3-16)

3.2 Methods

3.2.1 Specimens preparation

Stone moulds were prepared by placing plastic model measuring 22 × 3 mm for color stability testing and 66 × 12 × 3 mm for flexural strength testing into their respective flasks. A powder:liquid ratio of 100 g of stone to 30 ml of water was used to prepare the moulds for eighteen discs specimens and sixty-three rectangular specimens (Table 2). After it hardened, the plastic models were removed and a separating agent will be applied to the mould.

Table 3-2 Number of specimens for color stability testing

Immersion / Material	**Tap water** (cycles)				**Polident solution** (cycles)			
	0	15	30	60	0	15	30	60
SR Triplex Hot	**3**				**3**			
SR Ivocap Plus	**3**				**3**			
Vitaflex	**3**				**3**			

Table 3-3 Number of specimens for flexural strength testing

Immersion / Material	0 cycles	**Tap water** (cycles)			**Polident solution** (cycles)		
		15	30	60	15	30	60
SR Triplex Hot	**3**	**3**	**3**	**3**	**3**	**3**	**3**
SR Ivocap Plus	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Vitaflex	**3**	**3**	**3**	**3**	**3**	**3**	**3**

SR Triplex Hot

The conventional compression molding technique using Hanau flasks were employed to prepare SR Triplex Hot specimens**.** The powder (23.4 g) and liquid (10 ml) were mixed until the material was in dough stage and then poured into the spaces in the stone mould. The lower flask was covered with a polyethylene sheet. The lower half was of the flask joined face to face with the upper half of the flask. The whole flask was put under bench press for 10 minutes. Excess acrylic resin and the polyethylene sheet were removed and the trial pack process was repeated until no excess was seen. The flask was fixed using knot and rings, they put in water at 70°C

for 90 minutes and then heated up to 100°C and maintained at temperature for 30 minutes. The flask was benched cooled to room temperature and separated. The acrylic specimens were removed from the flask.

SR Ivocap Plus

Specimens for SR Ivocap Plus was processed using an injection system provided by the manufacturer. Prior to investing the upper half of the flask the injection channels was formed with pink wax (3-5 mm diameter) and each plastic models was provides with a channel.

After investing, removed pink wax channel and all plastic models and applied separating agent, the powder and liquid of SR Ivocap Plus was contained in capsule: 20 g polymer and 30 ml monomer and was mixed by the Cap Vibrator for 5 min at room temperature. The plastic injection capsule was used to carry the mixture for injection. Two halves of the flask were joined together and slid the flask vertically into the clamping frame with the clamp uppermost in the center of the hydraulic press and then applied 3 tons pressure. The injection process will be carried out in the injection unit for at least 5 minutes at a pressure of 6 bars. Placed the SR Ivocap assembly in a polymerization bath. After completion of the 35-minutes polymerization time, removed the SR Ivocap assembly from the boiling water and immediately cool in cold water for 30 minutes. The acrylic specimens were removed from the flask.

Vitaflex

Nylon material was supplied as a single component in a cartridge form. As the nylon was melted in a furnace, which had been pre-heated to a temperature of 248.8-265.5 °C, the stone mould was exposed under the heat lamps. The mould was

uniformly heated for 10 min to a temperature between 204.4 and 232.2 °C. The flask halves were assembled with brackets and together with the cartridge containing melted nylon; they were placed on to the injection unit. The injection moulding pressure was maintained at a pressure of 5 bars for 3 minutes and immediately after that, the assembly was removed and disengaged. The dental flask was bench-cooled for 30 minutes before deflasking. The blanks were removed from the moulds and the sprues were removed with a cut-off disc.

The specimens were cut by carbide bur and finished to the dimensions of 20 mm in diameter by 2 mm thickness for color stability testing (Figure 3-17) and 64 × 10 × 2.5 mm for flexural strength testing (Fig. 3-18) as specified in the International Standard Organization (1) for the testing of denture base materials. The surfaces of the specimens were wet polished on polishing machine with sand paper No. 800, 1000, 1200, 1500, 2000 and 2400 respectively.

3.2.3 Solution preparation

Tap water

Pure tap water 200 ml. at 37°C

Polident solution

The denture cleanser solution was prepared with one tablet of Polident put into 200 ml of tap water at 37°C. (Figure 3-19)

3.2.4 Method of experiment

Immediately after polishing and before immersion (T_0), color value and flexural strength were measured from three specimens of each material for standard value. The specimens in one group (n=3) were immersed in Polident solution for 5 minutes, removed from the solution, rinsed in running water for 30 seconds, immersed in tap

water for 5 minutes and re-immersed in fresh solution (Figure 3-20). The specimens in the other group were immersed in tap water only. The specimens were measured by Colorimeter (Figure 3-21) and Instron Universal Testing Machine (Figure 3-22) at time was for 15, 30 and 60 cycles of immersion.

a. Color stability measurement

The color and color difference (△E) of each specimen was determined and measured by Colorflex® colorimeter with a 12.7 mm measuring head aperture diameter. Specimen was centered on the measuring head of this machine. Three shade reading were made for one reading time. The mean values were calculated and recorded on the CIELAB color scale. The average of the three readings of each specimen were recorded and the mean of each material was used for calculation.

The value of color difference was multiplied by 0.92 in order to get the value of the National Bureau of Standards (NBS) (Table 3-3) (57), which is the way color change is evaluated by the human eye.

Table 3-4 NBS Rating

NBS Unit	Critical remarks of color differences
0.0 ~ 0.5	Extremely slight change/ Trace
0.5 ~ 1.5	Slight change/ Slight
1.5 ~ 3.0	Perceivable change/ Noticeable
3.0 ~ 6.0	Marked change/ Appreciable
6.0 ~ 12.0	Extremely marked change/ Much
12.0 or more	Change to other color/ Very much

b. Flexural strength measurement

All specimens were measured for flexural strength after 15, 30 and 60 cycles of immersion. A flexural three-point bending test was carried out in a water bath at 37 °C, on an Instron testing machine (Instron Universal Testing machine, model 5566). The dimensions of each specimen was entered into the program for computation.

3.2.5 Data analysis

The color stability and flexural strength data were analyzed using SPSS 11.5 for Windows (SPSS Inc., Chicago, Illinois, USA). Each subject was tested under only one treatment combination (storage and time of storage). Levene's test were used to determine the normality of the data distribution and equality of variances of each group.

The color stability data were analyzed using Split-plot ANOVA to test the factor in the experiment has repeated measures. The flexural strength data were analyzed

using two-way ANOVA to test the factor in the experiment has not repeated measures.

Tukey's honestly significantly different (HSD) test was used to identify which of the time of storage differed significantly. All statistical analyses were conducted at 5% level of significance.

Figure 3-1 Compression - moulding acrylic resin material (SR Triplex Hot)

Figure 3-2 Injection – moulding acrylic resin material (SR Ivocap Plus)

Figure 3-3 Injection – moulding nylon material (Vitaflex)

Figure 3-4 Denture cleanser (Polident)

Figure 3-5 Hanau dental flask

Figure 3-6 Flask compression unit

Figure 3-7 Hanau curing bath

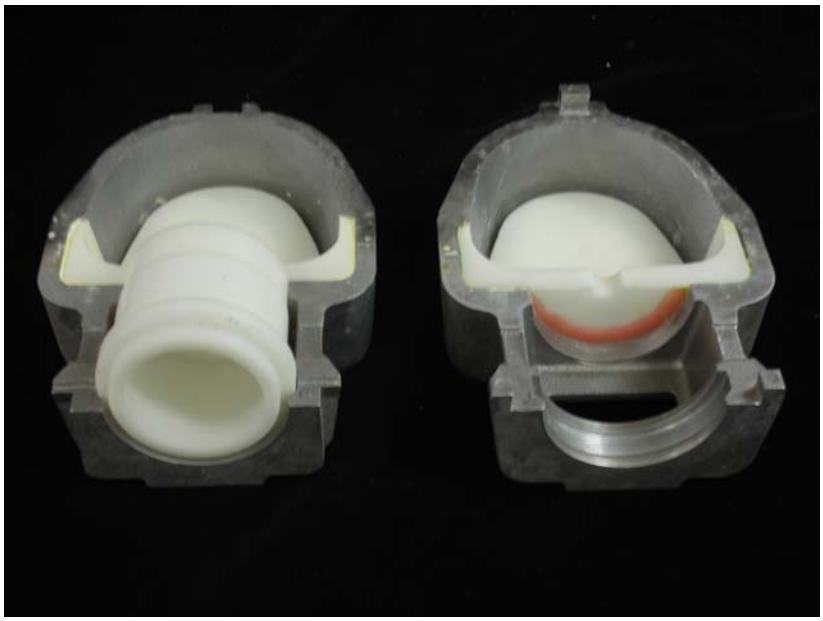

Figure 3-8 SR Ivocap flask

Figure 3-9 Cap Vibrator

Figure 3-10 Clamping frame

Figure 3-11 Hydraulic press

Figure 3-12 Pressure apparatus

Figure 3-13 Furnace for heating nylon material

Figure 3-14 Vitaflex injection unit

Figure 3-15 Colorimeter (Color Flex®, Model 4510 Reston)

Figure 3-16 Instron testing machine (Instron Universal Testing Machine, model 566)

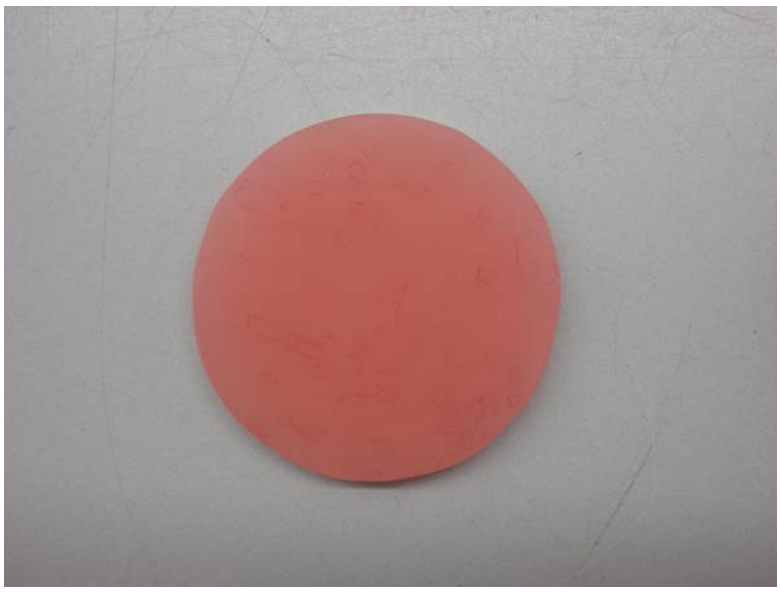

Figure 3-17 Disc specimen for color stability study

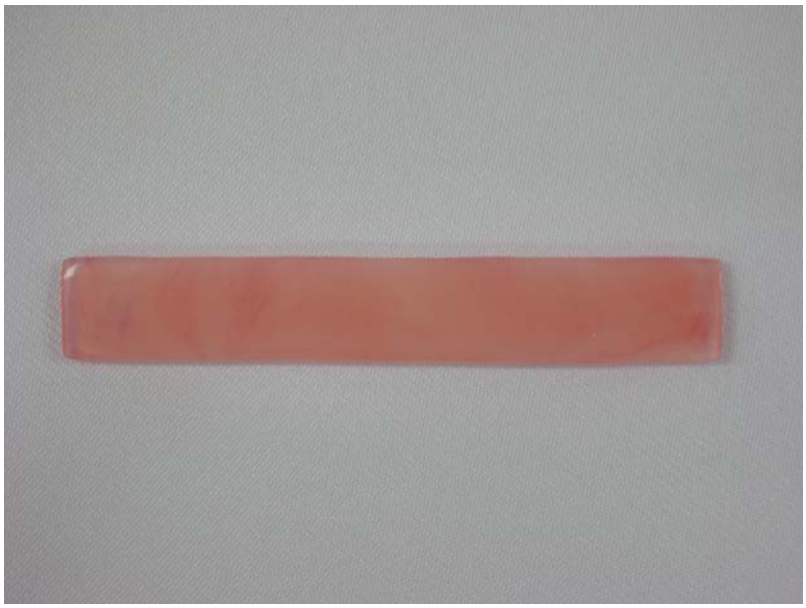

Figure 3-18 Rectangular specimen for flexural strength study

Figure 3-19 Polident solution

Figure 3-20 Specimen Immersion

Figure 3-21 Color stability testing

Figure 3-22 Flexural strength testing

CHAPTER IV

RESULTS

4.1 Color stability

The color changes (ΔE) for the denture base materials immersed in tap water and Polident solution for 15, 30 and 60 cycles are summarized in Table 4-1. Statistical analysis of SR Triplex Hot, SR Ivocap Plus and Vitaflex were presented in Table 4-2, Table 4-3 and Table 4-4 respectively, that showed color changes of SR Triplex Hot, SR Ivocap Plus and Vitaflex was not significantly affected by storage ($p>0.05$).

Table 4-1 The mean ΔE and standard deviation of the specimens after immersion in tap water and Polident solution (5 minutes) for 15, 30 and 60 cycles, n=3

Material	**Time** / **Solution**	**15 cycles**	**30 cycles**	**60 cycles**
SR Triplex Hot	Tap water	$0.37_{A,a}\pm0.16$	$0.75_{A,a}\pm0.28$	$0.88_{A,a}\pm0.39$
	Polident	$1.06_{A,a}\pm0.41$	$1.19_{A,a}\pm0.62$	$1.00_{A,a}\pm0.37$
SR Ivocap Plus	Tap water	$2.04_{A,a}\pm1.36$	$2.35_{B,b}\pm1.47$	$2.12_{C,c}\pm1.02$
	Polident	$1.70_{D,d}\pm0.42$	$1.21_{E,e}\pm0.54$	$0.89_{F,f}\pm0.72$
Vitaflex	Tap water	$1.93_{A,a}\pm1.41$	$2.40_{A,a}\pm2.07$	$1.98_{A,a}\pm1.56$
	Polident	$1.09_{A,a}\pm0.17$	$1.17_{A,a}\pm0.42$	$1.30_{A,a}\pm0.75$

Means with the same letter were not significantly different at the p=0.05.
Capital letters (vertically) showed differences between treatments. Small letters (horizontally) show differences between times.
No comparison made among materials.

Table 4-2 Tests of between subjects effects of SR Triplex Hot

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	13.786	1	13.786	124.462	.000
STORAGE	.797	1	.797	7.195	.055
Error	.443	4	.111		

Table 4-3 Tests of between subjects effects of SR Ivocap Plus

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	52.800	1	52.800	18.045	.013
STORAGE	3.631	1	3.631	1.241	.328
Error	11.704	4	2.926		

Table 4-4 Tests of between subjects effects of Vitaflex

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	48.693	1	48.693	11.531	.027
STORAGE	3.840	1	3.840	.909	.394
Error	16.891	4	4.223		

Split-plot ANOVA of each material were presented in Table 4-5, Table 4-6 and Table 4-7, that showed color changes of SR Triplex Hot and Vitaflex was not

significantly affected by time of storage and interaction among the combination of storage and time of storage ($p>0.05$). For SR Ivocap Plus, color changes was significantly affected by time and interaction among the combination of storage and time of storage ($p<0.05$).

Table 4-5 Split-plot ANOVA of SR Triplex Hot

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	.229	2	.114	.627	.559
	Greenhouse-Geisser	.229	1.068	.214	.627	.481
	Huynh-Feldt	.229	1.503	.152	.627	.523
	Lower-bound	.229	1.000	.229	.627	.473
TIME * STORAGE	Sphericity Assumed	.237	2	.119	.650	.547
	Greenhouse-Geisser	.237	1.068	.222	.650	.473
	Huynh-Feldt	.237	1.503	.158	.650	.513
	Lower-bound	.237	1.000	.237	.650	.465
Error(TIME)	Sphericity Assumed	1.460	8	.182		
	Greenhouse-Geisser	1.460	4.272	.342		
	Huynh-Feldt	1.460	6.013	.243		
	Lower-bound	1.460	4.000	.365		

Table 4-6 Split-plot ANOVA of SR Ivocap Plus

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	.454	2	.227	4.565	.048
	Greenhouse-Geisser	.454	1.562	.291	4.565	.065
	Huynh-Feldt	.454	2.000	.227	4.565	.048
	Lower-bound	.454	1.000	.454	4.565	.099
TIME * STORAGE	Sphericity Assumed	.707	2	.353	7.105	.017
	Greenhouse-Geisser	.707	1.562	.452	7.105	.028
	Huynh-Feldt	.707	2.000	.353	7.105	.017
	Lower-bound	.707	1.000	.707	7.105	.056
Error(TIME)	Sphericity Assumed	.398	8	.050		
	Greenhouse-Geisser	.398	6.247	.064		
	Huynh-Feldt	.398	8.000	.050		
	Lower-bound	.398	4.000	.099		

Table 4-7 Split-plot ANOVA of Vitaflex

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	.226	2	.113	.443	.657
	Greenhouse-Geisser	.226	1.657	.136	.443	.625
	Huynh-Feldt	.226	2.000	.113	.443	.657
	Lower-bound	.226	1.000	.226	.443	.542
TIME * STORAGE	Sphericity Assumed	.241	2	.121	.473	.640
	Greenhouse-Geisser	.241	1.657	.145	.473	.609
	Huynh-Feldt	.241	2.000	.121	.473	.640
	Lower-bound	.241	1.000	.241	.473	.530
Error(TIME)	Sphericity Assumed	2.040	8	.255		
	Greenhouse-Geisser	2.040	6.627	.308		
	Huynh-Feldt	2.040	8.000	.255		
	Lower-bound	2.040	4.000	.510		

The value of color difference (ΔE) were multiplied by 0.92 in order to get the value of the National Bureau of Standards (NBS), which is the way color change is evaluated by the human eye. The NBS rating of specimens after immersion in tap water and Polident solution for 15, 30 and 60 cycles were showed in Table 4-8.

Table 4-8 The NBS rating of specimens after immersion in tap water and Polident solution for 15, 30, 60 cycles.

Material	**Time** / **Solution**	**15 cycles**	**30 cycles**	**60 cycles**
SR Triplex Hot	Tap water	0.34 : Trace	0.69 : Slight	0.81 : Slight
	Polident	0.98 : Slight	1.10 : Slight	0.92 : Slight
SR Ivocap Plus	Tap water	1.87 : Noticeable	2.16 : Noticeable	1.95 : Noticeable
	Polident	1.57 : Noticeable	1.11 : Slight	0.82 : Slight
Vitaflex	Tap water	1.78 : Noticeable	2.21 : Noticeable	1.83 : Noticeable
	Polident	1.00 : Slight	1.07 : Slight	1.19 : Slight

4.2 Flexural strength

The flexural strength at start time and after immersion in tap water and Polident solution for 15, 30 and 60 cycles were shown in Table 4-9.

Table 4-9 The mean maximum load and standard deviation of the specimens after immersion in tap water for 15, 30 and 60 days, mean, n=3.

Material	**Time / Solution**	**0 cycles**	**15 cycles**	**30 cycles**	**60 cycles**
SR Triplex Hot	Water	$67.43_{A,a}$±2.93	$68.66_{A,B,a}$±0.51	$71.85_{A,B,a}$±5.74	$76.29_{A,B,a}$±5.11
	Polident		$69.31_{A,B,a}$±3.99	$68.38_{A,B,a}$±2.19	$71.4_{A,B,a}$±.77
SR Ivocap Plus	Water	$60.89_{A,a}$±0.77	$61.23_{A,a}$±0.88	$64.09_{A,a}$ ±2.28	$64.60_{A,a}$±2.21
	Polident		$63.54_{A.a}$ ±1.41	$62.21_{A,a}$ ±4.08	$63.29_{A,a}$±0.50
Vitaflex	Water	$20.72_{A,a}$±0.44	$21.65_{A,B,b}$±1.08	$23.04_{A,B,c}$±1.18	$23.88_{B,d}$±1.41
	Polident		$26.10_{A,B,e}$±3.84	$24.97_{A,B,f}$±2.76	$26.62_{B,g}$ ±5.16

Means with the same letter were not significantly different at the p=0.05.
Capital letters (vertically) showed differences between treatment. Small letters (horizontally) show differences between times.
No comparison made among materials.

Statistical analysis of SR Triplex Hot, SR Ivocap Plus and Vitaflex were presented in Table 4-10, Table 4-11 and Table 4-12 respectively, that showed flexural strength of SR triplex Hot, SR Ivocap Plus and Vitaflex was not significantly affected by interaction among the combination of storage and time of storage ($p>0.05$).

The flexural strength of SR triplex Hot was significantly affected by time of storage ($p<0.05$). For SR Ivocap Plus, flexural strength was not significantly affected

by storage and time of storage. For Vitaflex, flexural strength was significantly affected by storage and time of storage.

Table 4-10 Two-way ANOVA of SR Triplex Hot

Tests of Between-Subjects Effects

Dependent Variable: STRENGTH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	188.927[a]	7	26.990	2.153	.097
Intercept	117929.931	1	117929.931	9406.804	.000
STORAGE	22.105	1	22.105	1.763	.203
TIME	134.724	3	44.908	3.582	.037
STORAGE * TIME	32.097	3	10.699	.853	.485
Error	200.587	16	12.537		
Total	118319.444	24			
Corrected Total	389.513	23			

Table 4-11 Two-way ANOVA of SR Ivocap Plus

Tests of Between-Subjects Effects

Dependent Variable: STRENGTH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	46.378[a]	7	6.625	1.712	.177
Intercept	94023.074	1	94023.074	24288.791	.000
STORAGE	.293	1	.293	.076	.787
TIME	30.529	3	10.176	2.629	.086
STORAGE * TIME	15.555	3	5.185	1.339	.297
Error	61.937	16	3.871		
Total	94131.388	24			
Corrected Total	108.314	23			

Table 4-12 Two-way ANOVA of Vitaflex

Tests of Between-Subjects Effects

Dependent Variable: STRENGTH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	113.809[a]	7	16.258	2.416	.068
Intercept	13209.341	1	13209.341	1963.291	.000
STORAGE	31.193	1	31.193	4.636	.047
TIME	67.226	3	22.409	3.331	.046
STORAGE * TIME	15.391	3	5.130	.762	.531
Error	107.651	16	6.728		
Total	13430.800	24			
Corrected Total	221.460	23			

Tukey's HSD test of SR Triplex Hot and Vitaflex showed there were significantly different between before (0 cycle) and after immersion (15, 30 and 60 cycles) in tap water or Polident solution. There were no significantly different among 15, 30 and 60 cycles after immersion in tap water or Polident solution.

CHAPTER V

DISCUSSION

Materials

In this study, each denture base material was chosen according to its composition and the method of processing. SR Triplex Hot is compression-molding acrylic resin whereas SR Ivocap is injection-molding acrylic resin. The polymerization under pressure and injection method improve strength and dimensional stability so this material is claimed to possess improved mechanical properties such as strength and dimensional stability. Vitaflex consists of diamine and dibasic acid and fillers were added to reinforce strength and decrease water absorption. This material is claimed to possess improved mechanical and physical properties such as strength and water absorption (16,28).

In this study, tap water and Polident solution were used to evaluated their effects on color stability and flexural strength of the denture base materials. Polident solution is a denture cleanser, which consists of sodium bicarbonate, citric acid, sodium carbonate, potassium monopersulfate, sodium perborate, sodium hexametaphosphate, soudium benzoate and flavour. Polident is claimd to effectively remove organic and inorganic matter from denture surface and reduce or eliminate food particles and stain. The denture cleanser containing sodium perborate can lead to an increased surface hardness and roughness (58).

Validity of test methods

In this study, delta E (ΔE) was selected to evaluate the color change of denture base materials because all colors in nature are obtained through the blending of 3 basic colors such as red, blue and green in certain proportions. CIELAB system is recommended by the International Commission on Illumination (57). The advantage of this color system is that its arrangement is an approximately uniform three dimensional color space whose element are equally spaced on the basis of visual color perception (3). Colorimeter and spectrophotometer are instruments to measure the color of specimens. In this study, colorimeter was selected to measure the color change of denture base materials because the delta E value correlate with human eye-brain perception. For spectrophotometer, is an instrument for physical analysis-provides wavelength by wavelength spectral analysis of the reflecting property of the objects without interpretation by human. The National Bureau of Standards (NBS) also was selected to evaluate the color change of denture base in the way of the human eye observation.

The three points flexure test was used to evaluate the strength of denture base materials because it simulates the actual loading conditions in the mouth to the denture base better than other test methods.

Control of variables

Any identified variables, which may interfere with the experiment, have been controlled to ensure the validity of the results. In this study, the powder and liquid potion of the polymer of SR Triplex Hot was accurately weighed. For SR Ivocap and Vitaflex, the powder and liquid were acculately prepared in capsules before mixing. Variation in this ratio would result in the variation of the amount of water uptake and solubility. The specimen was measured to ensure that they have the same thickness.

The specimens with thickness over 2 mm were discarded as they might affect the color stability and flexural strength. The curing process was carried out according to the manufactures.

Color stability

Color changes became an esthetic problem when a long service is required and are affected by many parameters including the type of denture base material (4), polymerization process (59, 60), oral fluid, diet (2, 3), oral hygiene of the patient and the use of denture cleanser (61). Color changes may be assessed visually or by instruments such as colorimeter and spectrophotometer (4, 59, 62). Colors and discoloration are difficult to reproduce in color photograph. Discoloration of denture base can be evaluated usually on by colorimeter. Colorimetric measurements permit a reproducible means of color determination and eliminate the subjective interpretation of visual color comparisons. When change in color occur below visual perception levels, colorimeter measurements also allow reproducible results. The sensitivity of the human eye in observing color differences is limited. Johnston and Kao evaluating the assessment of appearance match by visual observation and clinically by colorimetry, stated that the mean color difference ΔE between compared teeth that were rated as match in the oral environment was 3.7 (62). They observed that, if ΔE is less than 1, this chromatic value is seem to be slight. Seghi et al. also presumed that an acceptable color difference can often be 2 or 3 times greater than the detectable limits (63). The upper limit of acceptability in subjective visual evaluations has been confirmed by Ruyter et al. who suggested that a perceptible discoloration must be referred to as acceptable up to the value of ΔE is equal to 3.3 (64). In those studies, discoloration low or above value of ΔE equal 3.3 was referred to as acceptable or unacceptable

respectively. In this study, the color changes exhibited by all specimens after immersion in tap water and Polident solution for 15, 30 and 60 cycles are clinically acceptable when these specimens evaluated by CIELAB system ($\Delta E = 0.37 – 2.4$).

The color changes of SR Triplex Hot and Vitaflex was not significantly different between immersion in tap water and Polident solution for 60 cycles. The result of this study was agreement with those of Yanus et al. (9), in that used denture cleansers according to manufacturers' instructions did not effect on color stability of conventional PMMA and nylon materials.

Color changes of SR Ivocap Plus was significantly affected by time and combination of time and storage, but clinically acceptable. This result may have been the effect of butadiene-styrene rubber that is included to improve their resistance to fracture cause by impact forces. This modification SR Ivocap Plus increase color changes slightly at 24 hours in ultraviolet light when compared between typical acrylic but showed slightly changed that would be clinically insignificantly (23).

It was surprising that the Vitaflex had lower value of color changes than the SR Ivocap Plus. Nylon generally absorpt more water and leached out of plasticizers than PMMA, result to change in color. Although the color changes value observed from Vitaflex showed no significant different between storage solution and time of immersion ($p>0.05$), the possible explanation of this finding should be done with caution. It may be due to the limitation of this study that the time for experiment was short and the sample size may be too small.

Sandra et al. stated the denture cleansers did not cause the whitening effect when denture cleansers were used according to the manufacturers' instructions. These findings are consistent with those of previous investigations, which attributed to the

whitening effect on chemically cleansed acrylic resin denture base to excessively high temperature of the water rather than the denture cleanser itself (42).

The color change values showed variability in standard deviations, this may be related to randomized area evaluated. The fiber pigment may be cause of color value or delta E different (59).

Flexural strength

Flexural strength of SR Triplex Hot and Vitaflex was affected by storage time. There was significantly different between before (0 cycle) and after immersion (15, 30 and 60 cycles) in tap water and Polident solution. This result may caused from water absorption and solubility of the material. When denture base materials are stored in a solution. They absorb water and release soluble components. The absorption behavior of denture base materials depended upon the balance between loss of plasticizers are leached out. At equilibrium, it is assumed that most or all soluble matters have been dissolved and denture base materials are saturated with water (65), the softness is slowly lost and the material becomes rigid (66) and causing it to higher flexural strength (67).

The amount of water uptake varies for the different denture base materials (68). The flexural strength of Vitaflex was the highest increasing, this difference may have been the most hydrophilic of Vitaflex. It was the result of the amide groups along the chain of polyamide (27) and result to the highest water uptake and leached out of plasticizers. The flexural strength of Vitaflex was also significantly affected by storage, this result may have been the higher potassium and sodium ionic concentration of Polident solution compared to the tap water (69) led to higher release of soluble component and plasticizers.

The flexural strength of SR Ivocap Plus was not significantly affected by time of storage, storage and interaction among time of storage and storage. It was the result of butadiene-styrene rubber in composition of acrylic (23), which are hydrophobic and replace the hydrophilic resin, resulting in the decrease in water uptake.

Vitaflex exhibited the lowest flexural strength. The low maximum load exhibited by nylon means that it is less rigid than acrylic resin. Nylon is promoted as a denture base material on the basis of its flexibility. The result of this study was agreement with those of Stafford et al. (16), Yunus et al. (9) and MacGregor et al. (70), in that nylon was found to be more flexible than acrylic resin.

CHAPTER VI

CONCLUSION

Within the parameters of the present study, designs and material tests, the following conclusions were made:

1. There is no statistically effect of Polident solution on color stability of SR Triplex Hot and Vitaflex.

2. There is statistically effect of time of storage and interaction among time of storage and Polident solution on color stability of SR Ivocap Plus.

3. The color changes of SR Triplex Hot, SR Ivocap Plus and Vitaflex after immersion in Polident solution for 60 cycles are clinically acceptable.

4. There is no statistically effect of Polident on flexural strength of SR Ivocap Plus.

5. There is statistically effect of Polident solution on flexural strength of Vitaflex.

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APPENDIX

APPENDIX A. Data for calculation of color stability

A.1 Data for calculation of color stability of specimens after immersion in tap water

A.2 Data for calculation of color stability of specimens after immersion in Polident soludent

APPENDIX B. Data of flexural strength

APPENDIX C. Statistical analysis

A.1 Data for calculation of color stability of specimens after immersion in tap water

Table 1: At 0 cycle

Specimen	L	a	b
Triplex 1	57.75	25.68	18.23
Triplex2	58.16	23.6	15.09
Triplex 3	57.82	23.93	15.53
SR Ivocap1	55.35	25.83	18.38
SR Ivocap2	54.75	28.82	17.48
SR Ivocap3	55.73	28.88	17.21
Vitaflex1	61.77	18.19	9.47
Vitaflex2	59.51	18.13	10.17
Vitaflex3	53.82	24.07	11.63

Table 2: At 15 cycles

Specimen	L	a	b
Triplex 1	57.35	26.01	18.42
Triplex2	58.07	23.78	14.91
Triplex 3	57.62	23.88	15.32
SR Ivocap1	55.65	25.78	18.03
SR Ivocap2	55.29	26.08	17.76
SR Ivocap3	56.1	26.07	17.38
Vitaflex1	58.39	19.08	8.94
Vitaflex2	59.7	17.68	9.46
Vitaflex3	54.52	23.38	10.63

Table 3: At 30 cycles

Specimen	L	a	b
Triplex 1	57.34	25.82	18.47
Triplex2	57.51	23.64	15.31
Triplex 3	56.78	23.77	15.59
SR Ivocap1	54.8	26.19	18.46
SR Ivocap2	55.7	25.98	17.67
SR Ivocap3	55.39	25.53	16.94
Vitaflex1	57.51	19.79	9.16
Vitaflex2	59.38	18.03	9.76
Vitaflex3	54.91	22.78	10.21

Table 4: At 60 cycles

Specimen	L	a	b
Triplex 1	56.49	26.01	18.55
Triplex2	57.47	23.73	15.31
Triplex 3	57.34	23.75	15.27
SR Ivocap1	54.44	25.74	18.26
SR Ivocap2	55.17	26.28	18.12
SR Ivocap3	55.45	26.22	17.76
Vitaflex1	58.18	19.14	9.35
Vitaflex2	59.3	17.66	9.71
Vitaflex3	54.48	23.16	10.57

A.2 Data for calculation of color stability of specimens after immersion in Polident solution

Table 1: At 0 cycle

Specimen	L	a	b
Triplex1	58.55	23.17	15.12
Triplex2	57.77	23.9	15.24
Triplex3	58.49	23.53	15.01
SR Ivocap1	54.72	25.11	16.75
SR Ivocap2	54.55	26.13	16.84
SR Ivocap3	55.8	25.41	16.85
Vitaflex1	57.66	17.33	7.34
Vitaflex2	60.42	17.46	7.38
Vitaflex3	61.71	16.88	7.74

Table 2: At 15 cycles

Specimen	L	a	b
Triplex1	57.79	23.29	15.25
Triplex2	56.52	23.17	14.76
Triplex3	57.63	23.42	15
SR Ivocap1	56.02	25.77	17.12
SR Ivocap2	56.71	26.02	16.62
SR Ivocap3	57.2	25.6	16.85
Vitaflex1	58.43	17	6.46
Vitaflex2	61.12	17.09	6.54
Vitaflex3	62.46	17.36	7.73

Table 3: At 30 cycles

Specimen	L	a	b
Triplex1	56.7	23.03	15.49
Triplex2	56.89	23.96	15.65
Triplex3	57.87	23.4	15.33
SR Ivocap1	55.89	25.4	16.62
SR Ivocap2	56.14	25.77	16.22
SR Ivocap3	56.45	25.35	16.72
Vitaflex1	58.61	17.44	6.484
Vitaflex2	60.71	17.2	6.8
Vitaflex3	63.19	16.6	7.89

Table 4: At 60 cycles

Specimen	L	a	b
Triplex1	57.85	23.07	15.15
Triplex2	56.38	23.62	15.18
Triplex3	57.61	23.63	15.04
SR Ivocap1	54.75	25.9	17.1
SR Ivocap2	56.09	26.33	17.3
SR Ivocap3	55.73	25.42	17.01
Vitaflex1	57.57	17.75	7.62
Vitaflex2	58.57	17.01	6.77
Vitaflex3	62.52	17.51	8.67

B. Data of flexural strength

	Control				Polident		
Specimens	T0	T1	T2	T3	T1	T2	T3
Triplex1	70.31	68.944	65.545	81.832	70.013	68.115	72.033
Triplex2	64.453	68.957	76.762	75.274	65.024	70.692	69.428
Triplex3	67.537	68.072	73.25	71.758	72.905	66.345	72.806
Ivocap1	60.124	60.379	63.416	66.001	62.094	59.605	62.989
Ivocap2	60.885	62.138	62.219	62.048	64.917	60.102	63.862
Ivocap3	61.655	61.173	66.63	65.75	63.595	66.914	63.023
Vitaflex1	20.516	22.869	24.342	24.181	23.122	28.143	22.268
Vitaflex2	21.213	21.274	22.046	22.336	30.426	23.562	25.284
Vitaflex3	20.415	20.8	22.744	25.108	24.749	23.191	32.316

C. Statistical analysis

C.1 Comparison of variance color stability

Table 1: Levene's test of SR Triplex Hot

	F	df1	df2	Sig.
T15	4.919	1	4	.091
T30	2.721	1	4	.174
T60	.022	1	4	.889

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a.

Design: Intercept+STORAGE
Within Subjects Design: TIME

Table 2 : Test of between subjects effect of SR Triplex Hot

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	13.786	1	13.786	124.462	.000
STORAGE	.797	1	.797	7.195	.055
Error	.443	4	.111		

Table 3 : Split-plot ANOVA of SR Triplex Hot

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	.229	2	.114	.627	.559
	Greenhouse-Geisser	.229	1.068	.214	.627	.481
	Huynh-Feldt	.229	1.503	.152	.627	.523
	Lower-bound	.229	1.000	.229	.627	.473
TIME * STORAGE	Sphericity Assumed	.237	2	.119	.650	.547
	Greenhouse-Geisser	.237	1.068	.222	.650	.473
	Huynh-Feldt	.237	1.503	.158	.650	.513
	Lower-bound	.237	1.000	.237	.650	.465
Error(TIME)	Sphericity Assumed	1.460	8	.182		
	Greenhouse-Geisser	1.460	4.272	.342		
	Huynh-Feldt	1.460	6.013	.243		
	Lower-bound	1.460	4.000	.365		

Table 4: Levene's test of SR Ivocap Plus

	F	df1	df2	Sig.
T15	7.039	1	4	.057
T30	4.742	1	4	.095
T60	.945	1	4	.386

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a.

Design: Intercept+STORAGE
Within Subjects Design: TIME

Table 5 : Test of between subjects effects of SR Ivocap Plus

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	52.800	1	52.800	18.045	.013
STORAGE	3.631	1	3.631	1.241	.328
Error	11.704	4	2.926		

Table 6 : Split-plot ANOVA of SR Ivocap Plus

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	.454	2	.227	4.565	.048
	Greenhouse-Geisser	.454	1.562	.291	4.565	.065
	Huynh-Feldt	.454	2.000	.227	4.565	.048
	Lower-bound	.454	1.000	.454	4.565	.099
TIME * STORAGE	Sphericity Assumed	.707	2	.353	7.105	.017
	Greenhouse-Geisser	.707	1.562	.452	7.105	.028
	Huynh-Feldt	.707	2.000	.353	7.105	.017
	Lower-bound	.707	1.000	.707	7.105	.056
Error(TIME)	Sphericity Assumed	.398	8	.050		
	Greenhouse-Geisser	.398	6.247	.064		
	Huynh-Feldt	.398	8.000	.050		
	Lower-bound	.398	4.000	.099		

Table 7 : Levene's test of Vitaflex

	F	df1	df2	Sig.
T15	9.057	1	4	.040
T30	3.183	1	4	.149
T60	2.064	1	4	.224

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a.

Design: Intercept+STORAGE
Within Subjects Design: TIME

Table 8 : Test of between subjects effects of Vitaflex

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	48.693	1	48.693	11.531	.027
STORAGE	3.840	1	3.840	.909	.394
Error	16.891	4	4.223		

Table 9 : Split-plot ANOVA of Vitaflex

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	.226	2	.113	.443	.657
	Greenhouse-Geisser	.226	1.657	.136	.443	.625
	Huynh-Feldt	.226	2.000	.113	.443	.657
	Lower-bound	.226	1.000	.226	.443	.542
TIME * STORAGE	Sphericity Assumed	.241	2	.121	.473	.640
	Greenhouse-Geisser	.241	1.657	.145	.473	.609
	Huynh-Feldt	.241	2.000	.121	.473	.640
	Lower-bound	.241	1.000	.241	.473	.530
Error(TIME)	Sphericity Assumed	2.040	8	.255		
	Greenhouse-Geisser	2.040	6.627	.308		
	Huynh-Feldt	2.040	8.000	.255		
	Lower-bound	2.040	4.000	.510		

C.2 Comparison of Variance flexural strength

Table 1: Levene's test of SR Triplex Hot

Dependent Variable: STRENGTH

F	df1	df2	Sig.
1.694	7	16	.181

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept+STORAGE+TIME+STORAGE * TIME

Table 2 : Two-way ANOVA of SR Triplex Hot

Tests of Between-Subjects Effects

Dependent Variable: STRENGTH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	188.927[a]	7	26.990	2.153	.097
Intercept	117929.931	1	117929.931	9406.804	.000
STORAGE	22.105	1	22.105	1.763	.203
TIME	134.724	3	44.908	3.582	.037
STORAGE * TIME	32.097	3	10.699	.853	.485
Error	200.587	16	12.537		
Total	118319.444	24			
Corrected Total	389.513	23			

a. R Squared = .485 (Adjusted R Squared = .260)

Table 3 : Tukey's test of SR Triplex Hot

STRENGTH

	TIME	N	Subset 1	Subset 2
Tukey B[a,b]	T0	6	67.4333	
	T1	6	68.9858	68.9858
	T2	6	70.1182	70.1182
	T3	6		73.8552

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 12.537.

a. Uses Harmonic Mean Sample Size = 6.000.

b. Alpha = .05.

Table 4 : Levene's test of SR Ivocap Plus

Dependent Variable: STRENGTH

F	df1	df2	Sig.
4.667	7	16	.005

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept+STORAGE+TIME+STORAGE * TIME

Table 5 : Two-way ANOVA of SR Ivocap Plus

Tests of Between-Subjects Effects

Dependent Variable: STRENGTH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	46.378[a]	7	6.625	1.712	.177
Intercept	94023.074	1	94023.074	24288.791	.000
STORAGE	.293	1	.293	.076	.787
TIME	30.529	3	10.176	2.629	.086
STORAGE * TIME	15.555	3	5.185	1.339	.297
Error	61.937	16	3.871		
Total	94131.388	24			
Corrected Total	108.314	23			

a. R Squared = .428 (Adjusted R Squared = .178)

Table 6 : Levene's test of Vitaflex

Dependent Variable: STRENGTH

F	df1	df2	Sig.
4.352	7	16	.007

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept+STORAGE+TIME+STORAGE * TIME

Table 7 : Two-way ANOVA of Vitaflex

Tests of Between-Subjects Effects

Dependent Variable: STRENGTH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	113.809[a]	7	16.258	2.416	.068
Intercept	13209.341	1	13209.341	1963.291	.000
STORAGE	31.193	1	31.193	4.636	.047
TIME	67.226	3	22.409	3.331	.046
STORAGE * TIME	15.391	3	5.130	.762	.531
Error	107.651	16	6.728		
Total	13430.800	24			
Corrected Total	221.460	23			

a. R Squared = .514 (Adjusted R Squared = .301)

Table 8 : Tukey's test of Vitaflex

STRENGTH

	TIME	N	Subset 1	Subset 2
Tukey B[a,b]	T0	6	20.7147	
	T1	6	23.8733	23.8733
	T2	6	24.0047	24.0047
	T3	6		25.2488

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 6.728.

a. Uses Harmonic Mean Sample Size = 6.000.

b. Alpha = .05.

BIBIOGRAPHY

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