THE EFFECT OF A DENTURE CLEANSER ON THE PROPERTIES OF A FLEXIBLE THERMOPLASTIC RESIN

HAZEM MOFREH ALTARAWNEH

FACULTY OF DENTISTRY
UNIVERSITY OF MALAYA
KUALA LUMPUR

2019

THE EFFECT OF A DENTURE CLEANSER ON THE PROPERTIES OF A FLEXIBLE THERMOPLASTIC RESIN

HAZEM MOFREH ALTARAWNEH

RESEARCH REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF CLINICAL DENTISTRY (RESTORATIVE DENTISTRY IN PROSTHETIC DENTISTRY)

FACULTY OF DENTISTRY
UNIVERSITY OF MALAYA
KUALA LUMPUR

2019

UNIVERSITY OF MALAYA

ORIGINAL LITERARY WORK DECLARATION

Name of Candidate: Hazem Mofreh AlTarawneh

Matric No: DGS160004

Name of Degree: Master of clinical dentistry (restorative dentistry in prosthetic dentistry)

Title of Project Paper/Research Report/Dissertation/Thesis ("this Work"):

The effect of denture cleanser on the properties of a flexible thermoplastic resin

Field of Study:

I do solemnly and sincerely declare that:

(1) I am the sole author/writer of this Work;
(2) This Work is original;
(3) Any use of any work in which copyright exists was done by way of fair dealing and for permitted purposes and any excerpt or extract from, or reference to or reproduction of any copyright work has been disclosed expressly and sufficiently and the title of the Work and its authorship have been acknowledged in this Work;
(4) I do not have any actual knowledge nor do I ought reasonably to know that the making of this work constitutes an infringement of any copyright work;
(5) I hereby assign all and every rights in the copyright to this Work to the University of Malaya ("UM"), who henceforth shall be owner of the copyright in this Work and that any reproduction or use in any form or by any means whatsoever is prohibited without the written consent of UM having been first had and obtained;
(6) I am fully aware that if in the course of making this work, I have infringed any copyright whether intentionally or otherwise, I may be subject to legal action or any other action as may be determined by UM.

Candidate's Signature Date:

Subscribed and solemnly declared before,

Witness's Signature Date:

Name:

Designation:

[KESAN PEMBERSIH GIGI PALSU PADA SIFAT-SIFAT RESIN TERMOPLASTIK YANG FLEKSIBEL]

ABSTRAK

Tujuan: Kajian in-vitro ini dijalankan untuk menkaji kesan bahan pembersih gigi palsu pada kestabilan warna, kekasaran permukaan, dan modulus lentur bahan tapak gigi palsu fleksibel termoplastik poliamida, selepas rendaman dalam pembersih gigi palsu enzimatik peroksida neutral yang boleh didapati di pasaran. **Bahan dan Kaedah:** Enam puluh (60) segi empat tepat spesimen (64mm x 10mm x 3.3mm) diperbuat dari bahan tapak gigi palsu termoplastik poliamida (Vertex ™ ThermoSens), direndam dalam air suling (n = 25) sebagai kawalan dan juga pembersih gigi palsu (Polident 3 min ™) (n =25) , dengan simulasi 180 hari penggunaan, 10 spesimen tidak direndam dalam sebarang larutan untuk pengukuran baseline. Nilai warna (ΔE) diperolehi menggunakan Spectrophotometer. Kekasaran permukaan (Ra) ditentukan menggunakan penganalisis permukaan 3-dimensi (3D) optik. Ujian lenturan tiga titik yang dilaksanakan menggunakan mesin ujian sejagat untuk mengukur nilai modulus lenturan (ΔE) 3M dikemukakan kepada analisis statistik dengan menggunakan ujian satu-sampel, selepas itu, ujian sampel berpasangan digunakan untuk membandingkan parameter warna (L *, a * , b *). Nilai Ra dianalisa menggunakan unian sampel berpasangan. Nilai modulus lenturan dianalisa menggunakan ujian satu hala ANOVA. Semua statistik dilakukan pada tahap signifikan P = 0.05 dengan menggunakan program statistik SPSS 20.0 (SPSS Inc., Chicago, IL,USA). **Keputusan:** Bagi rendaman dalam pembersih gigi palsu, purata perubahan warna (ΔE) (0.75 ± 0.47) menunjukkan perbezaan yang signifikan secara statistik ($p < 0.05$) berbanding dengan kumpulan kawalan (0.27 ± 0.21), bagaimanapun, ia dikelaskan sebagai sedikit (0.5-1.5) apabila dikira berdasarkan Biro Piawaian Kebangsaan (NBS). Terdapat peningkatan ketara ($p < 0.05$) dalam kekasaran permukaan (Ra) dikesan selepas rendaman didalam bahan pembersih gigi palsu. Walau bagaimanapun, tidak terdapat perbezaan yang signifikan bagi modulus lentur ($p < 0.05$) di antara kumpulan kawalan, rendaman dalam pembersih gigi palsu dan tanpa rendaman. Kesimpulan**:** Penggunaan bahan pembersih gigi palsu enzimatik peroksida neutral, Polident 3 min ™, meningkatkan kekasaran permukaan material tapak gigi palsu termoplastik poliamida (Vertex ™ ThermoSens), bagaimanapun, perubahan warna adalah didalam lingkungan yang boleh diterima secara klinikal. dan perubahan modulus lenturan bahan adalah tidak signifikan.

Kata kunci: poliamida, pembersih dentur, sifat fizikal.

[THE EFFECT OF DENTURE CLEANSER ON THE PROPERTIES OF A FLEXIBLE THERMOPLASTIC RESIN]

ABSTRACT

Purpose: This *in-vitro* study was carried out to evaluate the effect of a denture cleanser on the color stability, surface roughness, and the flexural modulus of a flexible polyamide thermoplastic denture base material, following immersion in a commercially available neutral peroxide enzymatic denture cleanser**. Materials and methods:** Sixty **(**60) rectangular specimens (64mm x 10mm x 3.3mm) of polyamide thermoplastic denture base material (Vertex™ ThermoSens) were prepared and immersed in distilled water (n=25) as control, and a denture cleanser (Polident 3 min™), simulating 180 days of usage (n=25), 10 specimens were not immersed in any solution for baseline measurements. Color measurements (ΔE) were obtained using Spectrophotometer. The surface roughness (Ra) was determined using an optical 3-dimensional (3D) surface analyzer. Three-point bending test executed using a universal testing machine to measure the flexural modulusΔE values were submitted to statistical analysis by means of One-sample test, then the Paired sample test was used to compare the color parameters (L*, a*, b*). The Ra values were analyzed using the Paired sample test. The flexural modulus values were submitted to One-way ANOVA test. All the statistics were done at a significant level of P=0.05 with the aid of the statistical program SPSS 20.0 (SPSS Inc., Chicago, IL,USA). **Results:** Following the immersion in the denture cleanser, the mean of the color changes (ΔE) (0.75±0.47) showed statistically significant difference ($p<0.05$) compared to the control group (0.27±0.21), however, it was classified as slight (0.5-1.5) when quantified by the National Bureau of Standards (NBS). There was a significant increase ($p<0.05$) in the surface roughness (Ra) was detected after the immersion. However, there was no significant difference in the flexural modulus ($p<0.05$) between the control, the test and non-immersed groups. **Conclusion:** The use of the neutral peroxide enzymatic denture cleanser Polident 3 min™ significantly increases the surface roughness of the polyamide thermoplastic denture base material (Vertex™ ThermoSens), however, the color changes were within the clinically accepted range, and the changes in the flexural modulus of the material were not significant.

Keywords: polyamide, denture cleanser, physical properties.

ACKNOWLEDGEMENTS

First and foremost, praises and thanks to The Almighty God, the Most Gracious, the Most Merciful, who gave me the capability to overcome all the difficulties in conducting this study.

Also, I shall remain grateful to my family, whom without I will not be able to pursue my dream and proceed my studies.

I would like to offer my sincerest gratitude to my supervisor Associate prof. Dr. Wan Adida Azina Binti Mahmood, for all the guidance and support throughout the preparation of this project. And I acknowledge that this work would not have been completed or written without her encouragement and efforts.

I would also like to thank my co-supervisor Dr. Nosizana Binti Mohd Salleh, for her insightful comments and consolation, she has been very helpful in completing my research.

I am also grateful to Dr. Azwatee Binti Abdul Aziz for sharing her expertise, and valuable guidance in statistical analysis and interpretation of the data for this research.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

Polyamide resin material was first suggested as a denture base material in 1950s. However, the use was limited at that time since polyamide was only superior in flexibility but low in rigidity. It was used in circumstances where repeated denture fracture was reported (Watt, 1955). To date, new generations of polyamide thermoplastic resins are produced and becoming more common in the production of complete and partial removable dentures (Fueki et al., 2014a; Parlani et al., 2018; Yunus et al., 2005).

Since then, following improvement of the material, the use of thermoplastic resins for the construction of removable appliances becoming popular. Added several advantages such as non-metal clasp dentures. They are biocompatible allergic free since no residual monomer. They are low in density which make the prosthesis light. Apart from flexibility as one of the most valuable features, other important features of these resins are, the reflective capacity of the color of gingival tissue beneath, due to high light transparency; thus providing high-quality aesthetic properties in cases where patients have high aesthetic demand (Fueki et al., 2014a, 2014b; Porwal et al., 2017). Often times, polyamide as temporary prosthesis are prescribed.

The superior flexibility and low rigidity of this material indicated for bruxism cases and elderly patients with low motor capacity in particular. Patients with hard and soft tissue undercuts, in thin mucosa and excessive bone resorption would find comfort in the flexible denture (Fueki et al., 2014b; Parlani et al., 2018; Sagsoz et al., 2014).

Denture hygiene is indispensable for oral health. Failing to practice good denture hygiene, would attract adhesion of microorganisms to the denture base. Undesirable effects are expected such as bad odor, unpleasant staining, and most importantly plaque and calculus accumulation on the denture which can lead to denture stomatitis, angular cheilitis, and poor oral health in general (BUDTZ-JöRGENSEN, 1974).

Mechanical methods in cleaning the denture biofilm and removing microorganisms using soft toothbrush and warm water are proven to be efficient, however some people do not have the ability to apply sufficient denture hygiene. This applies mainly in cases for patients with limited motor ability and elderly patients who face difficulty in cleaning the prosthesis with mechanical methods. The use of inappropriate toothbrush may lead to surface roughness, which allows more microbial colonization (Kulak-Ozkan et al., 2002). Therefore, the use of denture cleansers is essential as an adjunct to maintain the denture hygiene for these patients. Providing that, proper concentration and duration of soaking is followed, it is sufficient in removing microorganisms colonization from the denture surface (Okubo et al., 1998).

There are several types of denture cleansers available commercially. These can be classified based on the chemical ingredient and mode of action or main components such as hypochlorites, peroxides, neutral peroxides with enzyme, enzymes and acids (Koopmans et al., 1988; Nikawa et al., 1995).

Denture bases are subjected to numerous types of stresses. Intra-orally, repeated masticatory forces lead to fatigue of the denture base, while extra-orally high-impact forces may happen as a result of dropping the prosthesis, leading to fracture of the denture base. Mechanical properties of the denture base material should not allow plastic deformation, as a result of the stress during mastication (Durkan et al., 2013).

Although a denture base should be rigid enough to withstand occlusal loads and allow even distribution of forces throughout the material, some degree of flexibility should be accepted and could be an advantage in some cases where there is gross undercuts or limited mouth opening (Koopmans et al., 1988).

An aesthetically acceptable denture base should have a smooth and glassy surface and be able to mimic the natural appearance of soft tissues. The denture base is recommended to be translucent for the best aesthetic effect. Color and translucency should be preserved throughout the processing procedure. It should not be stained or discolored during use (Nikawa et al., 1995). Furthermore, color alteration of prosthodontic materials is of great concern and may lead to patient dissatisfaction also an additional cost for the replacement.

Surface properties of denture base material are measured by surface roughness. A rough surface can be a source of discomfort to patients as well as prone to staining and discoloration of the prosthesis. It promotes plaque formation and microbial colonization. It was proven that there is a direct relation between the surface roughness and plaque accumulation in addition to Candida albicans adherence (Roberts, 1956).

The use of denture cleansers should not affect the physical and mechanical property of the denture base. Effervescent denture cleanser which releases oxygen is claimed to have a high dissolving effect and loosens debris through mechanical means. However, the use of this denture cleanser causes hydrolysis and decomposition of the polymerized resin itself, which can lead to noticeable color changes and surface damage (Koopmans et al., 1988).

1.1 AIM AND OBJECTIVES

This study aims to evaluate the effect of a denture cleanser on some of the physical and mechanical properties of a flexible thermoplastic denture base material.

The objectives of this study are:

1. To compare color changes on a flexible thermoplastic denture base material before and after immersion in a denture cleanser simulating 180 days.
2. To compare the surface roughness of a flexible thermoplastic denture base material before and after immersion in a denture cleanser simulating 180 days.
3. To compare the flexural modulus of a flexible thermoplastic denture base material with and without being immersed in a denture cleanser simulating 180 days.

1.2 HYPOTHESIS

The hypothesis tested in this study was that the immersion in the denture cleanser for a period simulating 180 days would affect the color stability, the surface roughness and flexural modulus of the thermoplastic denture base material.

CHAPTER 2: LITERATURE REVIEW

The construction of dentures was primarily described in the 15^{th} century, various materials were used such as wax or ivory, but none of which was ideal (Johnson, 1959). Various materials were suggested to produce denture bases throughout the past century, in order to achieve a natural appearance, high strength, and stable dimensions with accurate surface details. Denture base should be made from biocompatible material, free of toxins and odour. Maintenance of the denture base such as handling, and repair should be easy and economical with a high shelf life.

2.1 VARIOUS TYPES OF DENTURE BASE

2.1.1 POLYMETHYL METHACRYLATE

The most popular material used for denture fabrication is the polymethyl methacrylate (PMMA). PMMA as a denture base was introduced in 1936 (Schwartz, 1950), Despite the early difficulties faced for the processing accuracy, PMMA had several advantages and the problems were rapidly overcome. It had acceptable color stability, and a significant improvement made which could mimic either the gingiva or teeth. It was also inert and translucent.

However, PMMA is not ideal, in terms of the mechanical requirement for the prosthesis. This is reflected by a large number of frequent fracture and repair of the denture base annually in the Dental practice report 1997, Eastbourne, UK. In general, fractures in dentures result from two different types of forces, namely, flexural fatigue and impact (Wiskott et al., 1995). Those mechanical properties of PMMA, make this material difficult to insert in undercut areas. Another issue raised regarding PMMA, that the residual monomer resulting from incomplete polymerization has been suggested to be an allergen in contact stomatitis (McCabe, 1976).

2.1.2 THERMOPLASTIC DENTURE BASE MATERIAL

In recent years thermoplastic resins have attracted attention as a denture base material. Currently, there are multiple flexible thermoplastic resins commercially available that are known for the superior aesthetic and physical properties. Table 2.1 includes some of the flexible thermoplastic resins, subcategories with examples of the commercially available brands.

Table 2.1: Examples of thermoplastic resins

Generic name	Product name
Polyamide	**Bioplast®** **Valplast®** **Flex Star V™** **BIOTONE®** **Lucitone FRS® Ultimate** **Vertex™ ThermoSens**
Polyester	**EstheShot Bright®** **EstheShot®**
Polycarbonate	**Reigning N®** **Reigning®** **JET CARBO-S®** **JET CARBO RESIN®**

2.1.2.1 POLYAMIDE

Polyamide resin was first proposed as a denture base in the 1950s (Watt, 1955). It is produced by the condensation reaction of diamine NH2-(CH2)6-NH2 and a dibasic acid CO2H-(CH2)4-COOH (Munns, 1962), during that time as compared to polymethyl methacrylate, polyamide or nylon material were less rigid, highly resilient, resistant to abrasion and practically unbreakable. Nylon is a generic name for certain types of thermoplastic polymers belonging to the class of polyamides. There were disadvantages of the early forms of nylon polyamides such as the tendency of the base color to deteriorate, staining, high water sorption, surface roughness after a few weeks, wear and difficulty in processing. Its use was limited to selected conditions such as recurring denture fractures, proven allergy to polymethylmethacrylate, lack of neuromuscular coordination and construction of orthodontic appliance (Hargreaves, 1971; Munns, 1962; Roberts, 1956).

The main and exceptional property of polyamide is high fatigue resistance. The flexural modulus of polyamide is significantly lower compared with both the compression-molded, heat- and microwave polymerized PMMA polymers. In the evaluation of flexural properties of a polyamide denture base material (Lucitone FRS®) compared with a conventional compression molded heat-polymerized resin (Meliodent®), a compression molded microwave-polymerized resin (Acron™ MC) and an injection-molded microwave-polymerized resin (Lucitone 199®) PMMA polymers, Polyamide has the lowest flexural modulus of 1714 MPa. Following disinfection with an oxygen-releasing disinfectant solution, it was to have higher value of 1937 MPa, whereas the rest of the other PMMA denture base materials tested in that study (Meliodent®, Acron™ MC, Lucitone 199®) had flexural modulus values exceeded 3000 MPa whether disinfected or not (Yunus et al., 2005).

For the tensile strength, a high significant difference was observed between heat cure acrylic (PMMA) and polyamide (Vertex™ ThermoSens) denture base material; Thermosens had higher tensile strength than PMMA. This showed that, Thermosens can withstand stress through an extensive degree of deflection (Hussain et al., 2011).

Three polyamides (Valplast®, Lucitone FRS® and Flexite®) were tested after being soaked in food and beverage i.e. coffee and curry for 60 hours. And the results showed considerable changes in the color after soaking, compared to PMMA (Takabayashi, 2010).

A study was conducted to evaluate the effect of two different alkaline peroxide cleansing agents (Corega™ and Fittydent®), on color stability of two thermoplastic denture base materials (Vertex™ ThermoSens and Breflex™), concluded no effect for the denture cleansers on the denture bases materials. That was for the reason that these new materials have long chains molecular arrangement, that decreases the liability for water molecules to disturb the chemical structure of the material, which affect the color stability of the denture base material (Mahmoud Nabil Helaly, 2018).

A rough surface can be the reason for discoloration, also discomfort to patients; it has a close relation to microbial colonization and biofilm formation. Polyamide (Flexiplast) in comparison with PMMA (Vertex™ RS), was found to have a rougher surface than PMMA, before and after the polishing. However, this result of surface roughness for the polyamide was within the norm and accepted clinically after polishing (Abuzar et al., 2010).

Once more, one polyamide (Valplast®) was found to be significantly high in roughness than from heat-polymerized acrylic denture base material (Paladon® 65) (Polychronakis et al., 2015). Again, after comparing the surface roughness of another polyamide (Vertex Thermosens) with heat cure acrylic resin, results showed highly rough surface for the polyamide, and the difference was significant (Mohsin H.A, 2017).

Similarly, Kawara et al. (2014) evaluated the surface roughness using scratch test for four thermoplastic resins (polyamide: Valplast®, Lucitone FRS®, polyethylene terephthalate: EstheShot®, and EstheShot Bright®) and two conventional acrylics (Heatpolymerizing: Urban®, and Pour type auto-polymerizing: Pro-Cast DSP®), where he compared the depth and width of the scratches with a 3D laser microscope. It was found that the surface of thermoplastic denture base resins was scratched easier compared to PMMA, however the polyamide showed the least scratch depth amongst the tested thermoplastic resins (Kawara et al., 2014).

2.1.2.2 POLYESTER

Polyester or Polyethylene terephthalate, only few types exist. EstheShot® and EstheShot Bright® are examples of Polyethylene terephthalate. EstheShot Bright® was introduced, and the manufacturer data claims that it has lower flexural modulus (1493MPa) than EstheShot® (2069MPa) and has been developed to have both strength and flexibility. Likewise, the flexural modulus of EstheShot Bright® and EstheShot® was found to be 1590±21 MPa and 1980±80 MPa respectively (I Hamanaka et al., 2012).

During evaluating the color stability of thermoplastic resins, the polyester exhibited staining after soaking, particularly in the curry solution, suggesting that the color stability needs to be improved in these materials (Takabayashi, 2010)

Applying the scratch test on available polyesters, and comparing EstheShot®, and EstheShot Bright®, the later was worse in scratch width and better in pileup height than EstheShot®. Scratch test results revealed that the surface of polyester denture base was more prone to damage compared to PMMA (Kawara et al., 2014).

However, polyesters most important characteristic is that they bond well to self-curing resins. Which means that repair, adding lost teeth, and reline can be performed at the chair side (Takahashi, 2009). Also, EstheShot® fitting accuracy was described to be the best of all the different types of resins (Hishimoto et al., 2008).

2.1.2.3 POLYCARBONATE

Polycarbonate is a polymer chain of bisphenol-A carbonate. Reigning® is a pigment-containing thermoplastic resin used for denture base that has polycarbonate resin as its main ingredient. This denture base material is considered to have moderately high flexural strength, high modulus of elasticity, and high impact strength, compared to other types of thermoplastic resins (Ippei Hamanaka et al., 2011).

Again, after testing two polycarbonate resins (Reigning® and Jet Carbo Resin®), similar results were obtained regarding the flexural strength and modulus of elasticity. Polycarbonate showed significantly high flexural modulus where Reigning® scored 2700±120MPa and Jet Carbo Resin® flexural scored 3097±234MPa, which makes less flexible than other the remaining thermoplastic resins (Takabayashi, 2010).

Polycarbonates (Reigning® and Jet Carbo Resin®) color stability was evaluated and compared with polyamides and polyesters. After soaking in curry solution and coffee polycarbonates showed more color stability than the other thermoplastic resins (Takabayashi, 2010).

2.2 PHYSICAL AND MECHANICAL PROPERTIES OF THERMOPLASTIC RESINS

2.2.1 COLOR CHANGES

Color stability for the denture base material can be a source of patient dissatisfaction. Color changes may be an indication of increased porosity and further water absorption. In order to evaluate the color changes different methods used to measure changes in shade, such as visual means but are considered highly subjective, digital analysis, projection of photographic slides, visual group ranking, and shade guide matching (Joiner, 2004).

Color assessments by visual judgment have been shown to be unreliable due to the inconsistencies in color sensitivity specifications amongst observers. Instrumental measurements eliminate the subjective interpretation of visual color comparison. Most commonly used methods to measure the color change in dental materials are Colorimeters and spectrophotometers (Okubo et al., 1998). In the same way, color measurements of the denture base were determined by a portable colorimeter (Peracini et al., 2010; Sagsoz et al., 2014)

Digital analysis and spectrophotometric analysis are obtained as numerical values and it detects the visible light through the color spectrum (400 - 700 nm) (Horn et al., 1998).

In order to perform the color measurements, the Commission Internationale de l'Eclairage (CIE) introduced $L^*a^*b^*$ uniform color scale (CIE, 1986), where an approximately uniform color space with coordinates for lightness; that is, white-black ($L*$), redness-greenness ($a*$), and yellowness-blueness ($b*$). The color systems with rectangular coordinates are quantitative systems, and they have a meaningful relation to the human visual perception of color differences (CIE, 1986).

In order to find the color differences (ΔE), in terms of L, a, and b, the calculations can be obtained from the following equation:

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

In which ΔL, Δ a, and Δb are the differences of L, a, and b values before and after immersion.

To transmit the color differences (ΔE) to clinically understandable values, the color data were quantified by the National Bureau of Standards (NBS) units, using the formula NBS units = ΔE × 0.92.

It was reported that if ΔE value more than 2 considered visually noticeable, whereas an NBS unit of greater than 3 was considered unacceptable (Lai et al., 2003).

2.2.2 SURFACE ROUGHNESS

Microorganisms are a normal part of the oral cavity. However, a rough surface of the prosthesis may cause discoloration, as well as being a source of discomfort to the patient. Surface roughness may enable plaque formation and microbial retention, and which can lead to infections. The unpolished surface will permit more bacterial colonization, as both Streptococcus *oralis* and Actinomyces *viscosus* adhered to rough denture surfaces (Kagermeier-Callaway et al., 2000).

Therefore, surface roughness should be kept to a minimum degree (Quirynen et al., 1990; Verran & Maryan, 1997).

It was suggested that the threshold level of the surface roughness for the dental material that is used in the oral cavity should be Ra= 0.2µm, under that level no plaque reduction is expected (Quirynen & Bollen, 1995).

"The value of Ra describes the overall roughness of a surface and is defined as the mean value of all absolute distances of the roughness profiles from the mean line within the measuring distance." (Berger et al., 2006)

To measure surface roughness, a profilometer was used, which can measure small surface differences by moving a diamond stylus in contact with the surface while moving laterally across the sample (Abuzar et al., 2010; Mohsin H.A, 2017). Whereas 3-D surface roughness was measured by a noncontact optical interferometric profilometer (Polychronakis et al., 2015).

2.2.3 FLEXURAL PROPERTIES

During mastication and function, denture base material is subjected to forces that may cause flexural deformation. Flexural strength is a measure to know the resistance of the polymer to flexural deformation that indicates the limit of elastic behavior and the beginning of plastic behavior. Flexural modulus is resistance to being deformed elastically (non-permanently) when stresses are applied to it. A denture base material should have flexural properties that do not allow plastic deformation to result from the stress during mastication (Craig et al., 1975).

Multiple studies in the literature used the three-point bending test to evaluate the flexural properties of thermoplastic resins (Ippei Hamanaka et al., 2011; Takabayashi, 2010; Yunus et al., 2005) where the distance was 50 mm between the two supporting points and the crosshead speed was 5 mm/min. The tested sample on the three-point binding machine is required to have specific dimensions, where the International Organization for Standardization (ISO) 20795-1:2013(ISO, 2013) suggested the dimensions to be 64 mm long, 10,0 ± 0,2 mm wide and 3,3 ± 0,2 mm in height.

According to the International Organization for Standardization (ISO) 20795-1:2013(ISO, 2013), the ultimate flexural strength shall be not less than 65 MPa, and the flexural modulus of the processed polymer shall be at least 2000 MPa, for the thermoplastic polymers. However, most of the thermoplastic resins flexural modulus results, including polyamides, were lower than 2000MPa, which indicated increased flexibility of the martial (Ippei Hamanaka et al., 2011; Takabayashi, 2010; Takahashi, 2009; Yunus et al., 2005).

2.3 DENTURE CLEANSERS

2.3.1 INTRODUCTION

Plaque and microorganisms on the fitting surface of the denture are considered as a significant factor to cause denture stomatitis (Budtz-Jørgensen., 1979). Therefore, good oral and denture hygiene should be essential to remove microorganisms. Although mechanical methods in cleaning the denture biofilm and removing microorganisms are proven to be efficient, some people do not have the ability to apply sufficient denture hygiene. This applies mainly in cases for patients with limited motor ability and elderly patients who face difficulty in cleaning the prosthesis with mechanical methods. Also, the use of inappropriate toothbrush may lead to surface roughness, which allows more microbial colonization (Kulak-Ozkan et al., 2002).

There are multiple types of denture cleansers commercially available in the market, and they usually contain alkaline peroxide, neutral enzymatic peroxide solution, sodium hypochlorite, acids, and enzymes.

1. Alkaline peroxides are very common denture cleansers which can be powder or tablets. After dissolving in water, they become alkaline solutions of hydrogen peroxide. This type of cleanser typically combines alkaline detergents, to decrease surface tension and agents (sodium perborate or percarbonate) that release oxygen from the solution. The oxygen bubbles are thought to apply a mechanical cleansing effect (Budtz-Jørgensen., 1979). Effervescent tablets yielding an alkaline peroxide dilution with water are claimed to be favoured denture cleansers because they can simply deliver enough cleansing without producing damage to surface resins (Fernandes et al., 2011).
2. Neutral enzymatic peroxide solution, for instance, Polident 3 min ™ (GlaxoSmithKline Healtcare, Moon Township, PA) effervescent tablet, consist mainly of Sodium bicarbonate, citric acid, potassium monopersulfate, sodium carbonate, sodium percarbonate. Agents like sodium perborate or percarbonate, which release oxygen from the solution, are thought to apply a mechanical cleansing effect (Budtz-Jørgensen, 1979). Again, this denture cleanser (Polident 3 min™) was found to have a strong effect in removing biofilm on different denture resin bases, including polyamides (Hayran et al., 2018; Okubo et al., 1998).
3. Hypochlorites are useful as denture cleansers because they remove stains, dissolve mucin and other organic substances, and are bactericidal and fungicidal. It is believed that hypochlorite acts directly on the organic matrix of plaque, causing the dissolution of the polymer structure. Hypochlorite does not dissolve calculus, but it may inhibit calculus formation on dentures by dissolving the plaque organic matrix. However, it has a corroding and tarnishing effect on metal components of the denture as well as bleaching effect on the denture base (Neill, 1968)

4. Acids, commercial solution cleansers with bases of diluted acids (hydrochloric acid or phosphoric acid) are active against calculus and stains on dentures. They will, however, cause corrosion of metal components in dentures. Care must be taken in the handling and storage of these products, since they may be damaging to fabrics and harmful to eyes and skin (Neill, 1968).
5. Enzymes, protease-containing cleansers that aim to breakdown the glycoproteins and mucoproteins and the mucopolysaccharides of plaque. When using an enzyme-containing cleanser alone, it was effective, but that when soaking was used in combination with brushing, the denture became significantly cleaner (Ödman, 1992).

2.3.2 ANTI-MICROBIAL EFFECT

The denture cleanser use demonstrated broad antimicrobial activity against gram-negative anaerobic rods (*Fusobacterium* sp.), gram-positive facultative cocci (streptococci), and gram-negative anaerobic cocci (*Veillonellu* sp.), as well as total recoverable microorganisms, which were all reduced by the denture-cleanser treatment in a clinical trial conducted by Dills et al. (1988), comparing the antimicrobial capability of mechanical cleansing and chemical denture cleanser (alkaline peroxide, Efferdent®).

Yet again, a significant reduction on total microorganisms count in RPD biofilm after the use of neutral enzymatic peroxide-based denture cleanser (Polident 3 min™) (Lucena-Ferreira et al., 2013).

Furthermore, after testing three brands of cleanser: acidic oxygen producer (Denture Brite®), neutral enzymatic peroxide (Polident™) and alkaline peroxide (Efferdent®) on geriatric Patients in long-term care institutions showed similar results, there was a significant reduction in the number of colony-forming units (CFUs) of Candida species as well as Streptococcus *mutans*. Reduction of plaque, stain, and food was generally observed (Gornitsky et al., 2002).

Moreover, a significant decrease in both C. *albicans* and C.*glabrata* was observed after evaluating two denture cleansers (neutral enzymatic peroxide, Polident 3 Min™, and alkaline peroxides, Corega® Tabs) effect on the biofilm formed on polyamide surface and PMMA (Fernandes et al., 2011).

2.3.3 DENTURE CLEANSERS EFFECT ON PHYSICAL AND MECHANICAL PROPERTIES

2.3.3.1 EFFECT ON COLOR STABILITY

Several studies evaluated the effect of denture cleansers on the color stability of different denture base material (Durkan et al., 2013; Mahmoud Nabil Helaly, 2018; Peracini et al., 2010; Polychronakis et al., 2015; Porwal et al., 2017; Sagsoz et al., 2014).

The results of the studies range from noticeable effect to no effect at all, and that can be due to the differences in the methodology where the immersion procedure varies, different type of the denture cleansers and the temperature of the cleanser solution. Peracini et al. (2010) evaluated the effect of two alkaline peroxide denture cleansers (Corega® Tabs and Bony Plus®) on the color stability of PMMA, although there is a statistically significant change, but it was clinically acceptable.

In the earlier years, several works were done comparing polyamide denture base and PMMA. The purpose of this study was to evaluate the effect of denture cleansers on the properties of polyamide. Durkan et al. (2013) did comparative effects of denture cleansers on physical properties (surface roughness, hardness and color stability) of two polyamides (Valpast®, Deflex®), a butadiene styrene copolymer PMMA (Rodex), and PMMA polymer as a control group (Paladent®). Polyamides showed low hardness and high roughness before and after immersion. A significant decrease in hardness was observed for all resins except Rodex after immersion ($p<0.05$). The denture cleansers changed the roughness, hardness and color of some resins.

In a more recent work by Polychronakis et al. (2015) where this study was to determine the effects of two denture cleansing methods on 3-D surface roughness, gloss and color of denture base materials. He compared nylon (Valplast®) and heatpolymerized acrylic denture base material (Paladon® 65). The samples were immersed in water (control), Val-Clean® (peroxide cleanser) and Corega® Extradent (peroxide cleanser) plus microwaving for a period simulating 30 days of daily cleansing. 3-D surface roughness, gloss and color parameters were measured before and after cleansing using an interferometric profilometer, a gloss meter and a colorimeter. Valplast® was found to have a significantly lower gloss and a higher roughness than Paladon® 65 before cleansing. After cleansing, ΔE* increased more in Valplast® than in Paladon® 65, gloss of both materials decreased and roughness only of Paladon® 65 increased within the Corega® extradent plus microwaving method.

Another similar study by Porwal et al. (2017), investigated the effect of different denture cleansers on the color stability, surface hardness, and roughness of different denture base resins. Color changes of all denture base resins were within the clinically accepted range for color difference. Surface roughness change of conventional heat cure resin was not within the clinically accepted range of surface roughness. The choice of denture cleanser for different denture base resins should be based on the chemistry of resin and cleanser, denture cleanser concentration, and duration of immersion.

On the other hand, significant color changes were observed, that exceeded the clinically accepted range when one polyamide (Deflex®) was immersed in a boiling solution of (Corega®) denture cleanser (Sagsoz et al., 2014).

2.3.3.2 EFFECT ON SURFACE ROUGHNESS

Released oxygen by sodium perborate containing denture cleanser is thought to have a high dissolving effect on plasticizers and loosens debris through mechanical means.

Hence, the use of this type of denture cleansers may result in hydrolysis and decomposition of denture base resin (Hong et al., 2009). Again, a high peroxide content and level of oxygenation in the strongly alkaline solution was found to be a damaging factor for denture base materials (Shah et al., 2015). In the same way, an effervescent denture cleanser, sodium perborate containing (Bony plus®), increased the surface roughness of the acrylic denture base resin (Peracini et al., 2010).

Similarly, after evaluating the effects of three sodium perborate-containing denture cleansers (Corega®, Protefix®, Valclean®) on the surface roughness of two polyamides (Valplast® and Deflex®), Surface roughness of the polyamide increased after 20 days of repeated immersion regardless of the type of the solution used (Durkan et al., 2013).

Once more, the surface roughness of a thermoinjection-molded polyamide (Deflex®) increased significantly after being subjected to daily cleansing with one of four denture cleansers (Corega®, Protefix®, Curaprox®, and Perlodent®) for 8 hours a day for 140 days (Ozyilmaz & Akin, 2019).

On the other hand, one polyamide denture base material (Valplast®) showed no statistically significant difference in the 3D-surface roughness before and after being soaked in two alkaline peroxide denture cleanser (Val-Clean® and Corega® Extradent) for a period simulating 30 days (Polychronakis et al., 2015).

Despite the oxygen dissociated from the hydrogen peroxide containing commercial denture cleansers, the surface roughness of a microwave-cured acrylic denture base can be smoother, as it may dislodge the pellicle formed on the surface (Dills et al., 1988), but this finding was not observed on thermoplastic resins.

2.3.3.3 EFFECT ON FLEXURAL PROPERTIES

Denture cleansing by immersion in the denture cleanser solution should not cause any changes in the mechanical flexural properties of the denture base material. However, Peracini et al. (2010) noted some alterations on the flexural properties of heat-polymerized acrylic resin after immersion in the denture cleanser.

Parlani et al. (2018) observed initial increase in the flexibility of nylon denture base after immersion in denture-cleansing tablet but started to decrease in the following month. There was not much effect after that. The best medium for storage of flexible denture was found to be artificial saliva.

On the other hand, a statistically significant reduction in the flexural strength of one polyamide (Valplast®) evaluated after immersion in three denture cleansers (Valclean®, Polident®, Clinsodent®) for six months (Shah et al., 2015).

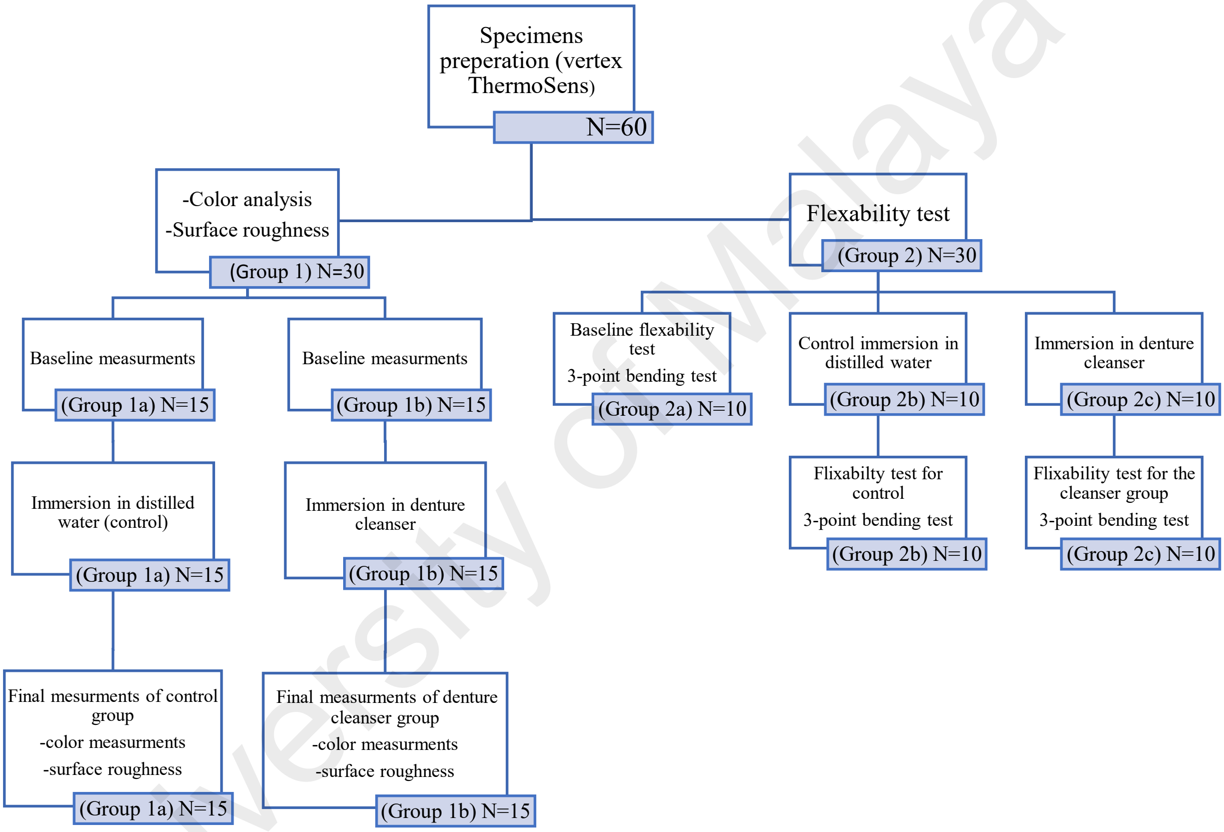

Figure 3.1: Sequence of the methodology

In this *in-vitro* experimental study, 60 rectangular specimens (64mm x 10mm x 3.3mm) of the thermoplastic resin Vertex™ ThermoSens (Vertex Dental B.V. 3705 HJ Zeist, Netherlands) (figure 3.2) were prepared. The sample was divided into two main groups:

- Group 1 (N=30) was subdivided into 2 subgroups:
  - Group 1a (N=15): as control group for color analysis and surface roughness test before and after immersion in distilled water.
  - Group 1b (N=15): color analysis and surface roughness test before and after immersion in the cleanser solution.
- Group 2 (N=30) was subdivided into 3 subgroups:
  - Group 2a (N=10): flexibility test baseline, without immersion in any solution.
  - Group 2b (N=10): as control group for flexibility test after immersion in distilled water.
  - Group 2c (N=10): flexibility test after immersion in the cleanser solution.

3.1 PREPARATION OF THE SPECIMENS

The specimens were prepared according to ISO specification 20795-1:2013 (ISO, 2013), using a wax rectangular shaped pattern with the dimensions (64 mm x 10mm x 3.3mm) was placed into a special metallic flask with posterior wax sprue for injection of the material inside the plaster molds. The flask contains major sprues 6-8 mm in diameter, which attached to mold, the top half of the flask is fixed to the lower by 4 screws after that dental stone is poured from the top (figure 3.3). Vertex™ ThermoSens (Vertex Dental B.V. 3705 HJ Zeist, Netherlands) is a thermo injectable material, so the flask is placed on a Vertex™ ThermoJect 22 injection machine (figure 3.4).

According to the manufacturer instructions, the cylinder of the machine is primarily preheated to 290°c in 8 minutes, then ThermoSens material cartridge was inserted in the cylinder and with the flask in position inside the machine. The machine starts the injection procedure under pressure of 6 bar at 290°c for 18 minutes, after the program is done, the flask removed from the machine and left for bench cooling for 20 minutes.

After opening the flask, the injection channels were removed. The edges were smoothed with the cross standard acrylic bur. According to the manufacturer instructions, the surface was polished with silicone polishers, and the finishing was done using Thermo-Gloss paste and a microfiber polishing brush. All the specimens were saved in 37° c distilled water for 24 hours before applying the measurements.

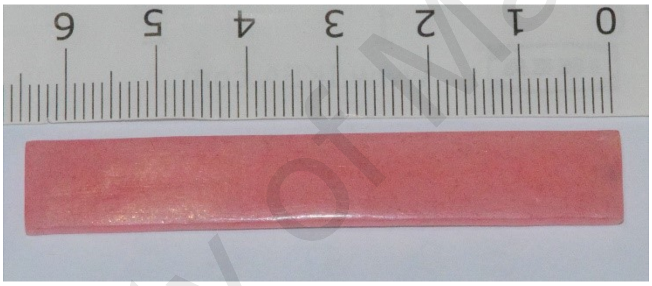

Figure 3.2: Vertex™ ThermoSens specimen

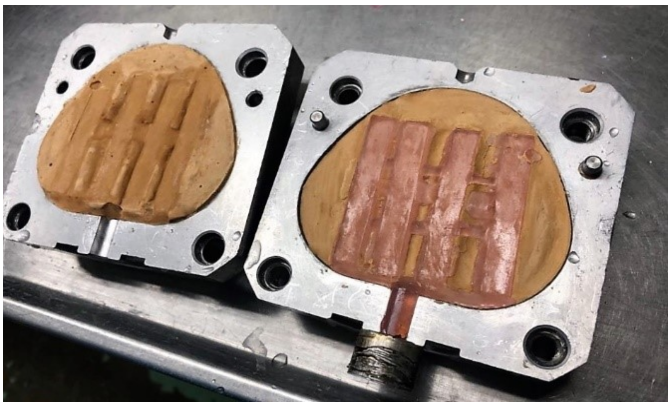

Figure 3.3: The metal flask after injecting the vertex™ material

Figure 3.4: Vertex™ ThermoJect 22 injection machine

3.2 IMMERSION PROCEDURE

After applying the baseline measurement of color analysis and surface roughness, group 1b and group 2c were immersed manually in a commercially available neutral peroxide enzymatic denture cleanser Polident 3 min™ (ingredients: Sodium bicarbonate, citric acid, potassium monopersulfate, sodium carbonate, sodium percarbonate, TAED, sodium benzoate, PEG-180, sodium lauryl sulfoacetate, VP/VA copolymer, aroma, blue 1 aluminum lake, blue 2, yellow 5 aluminum lake, yellow 5).

According to the manufacturer instruction, one tablet of Polident 3 min™ placed in 200ml of warm (40°c) tap water, and the specimens were immersed for 3 minutes. After immersion, the specimens were removed from the cleanser solution, thoroughly washed in running water, and then the procedure of immersion was repeated continuously for 180 times simulating 180 days of cleansing by the patient (Jin et al., 2003; Peracini et al., 2010). Similar procedure of immersion was performed for the groups 1a and 2b in room temperature (23±2 °C) distilled water, as the control groups.

3.3 COLOR ANALYSIS

The color measurements were carried out using Spectrophotometer CM-5 (Konica Minolta, Japan) (figure 3.5), calibration was done according to the manufacturer instructions, using the provided white calibration plate. The aperture size used was 3mm, and each specimen was measured three times from three different places (every 16mm) on the same side. Color changes (ΔE) were calculated by measuring the values at several wavelengths in the visual spectrum with the use of Commission Internationale de l'Eclairage (CIE) L*a*b* uniform color scale (CIE, 1986). The CIE L*a*b* is a color system representing three-dimensional color space with components of lightness (L), red-green (a), and yellow-blue (b) (figure 3.6).

In order to find the color differences (ΔE) between the test group specimens (group 1: as baseline before the immersion and after immersion in the cleanser solution), in terms of L, a, and b, the calculations can be obtained from the following equation:

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

In which ΔL, Δ a, and Δb are the differences of L, a, and b values before and after immersion.

To transmit the color differences (ΔE) to a clinically understandable values, the color data were quantified by the National Bureau of Standards units, using the formula NBS units = ΔE × 0.92 (Lai et al., 2003; Polyzois et al., 1997).

Figure 3.5: Spectrophotometer CM-5

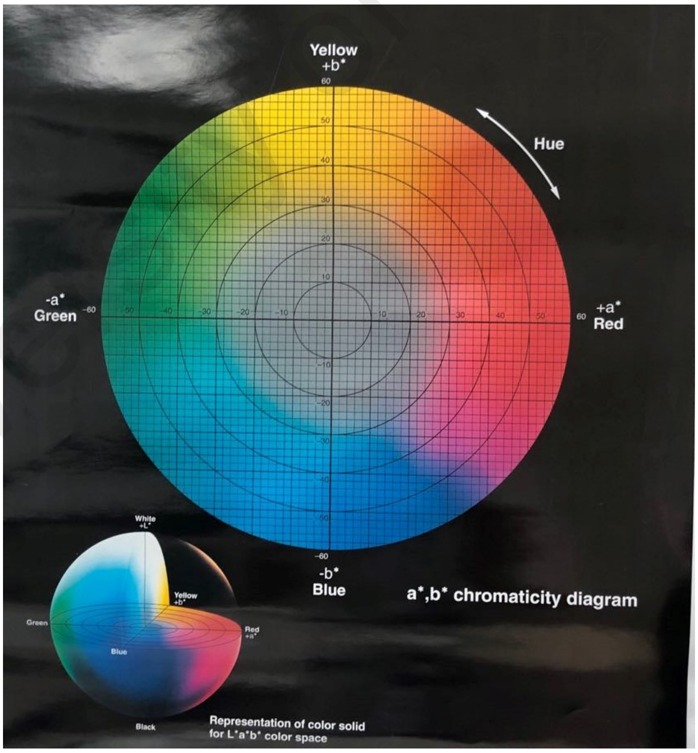

Figure 3.6: Color diagram

3.4 SURFACE ROUGHNESS ANALYSIS

An optical 3-dimensional (3D) surface analyzer (Infinite Focus Standard; Alicona Imaging, Graz, Austria) (figure 3.7) was used to obtain the surface roughness measurements. At 20X magnification, with 376nm vertical resolution and 2.93nm lateral resolution. The mean Ra value was computed using IFM software 5.1 Alicona Imaging (figure 3.8), from 5 (every 10.7mm) different spots (712.14µm x 540.25µm) on each specimen on the same side, and 5 lines on each spot, as the mean roughness value for the specimen. The line width is one point which equals to 438.51nm. In order to assess the surface roughness changes, Ra(µm) was used (Durkan et al., 2013). The roughness values before immersion of the specimens in the cleanser solution were measured and compared with the surface roughness values after immersion.

Figure 3.7: 3D surface analyser

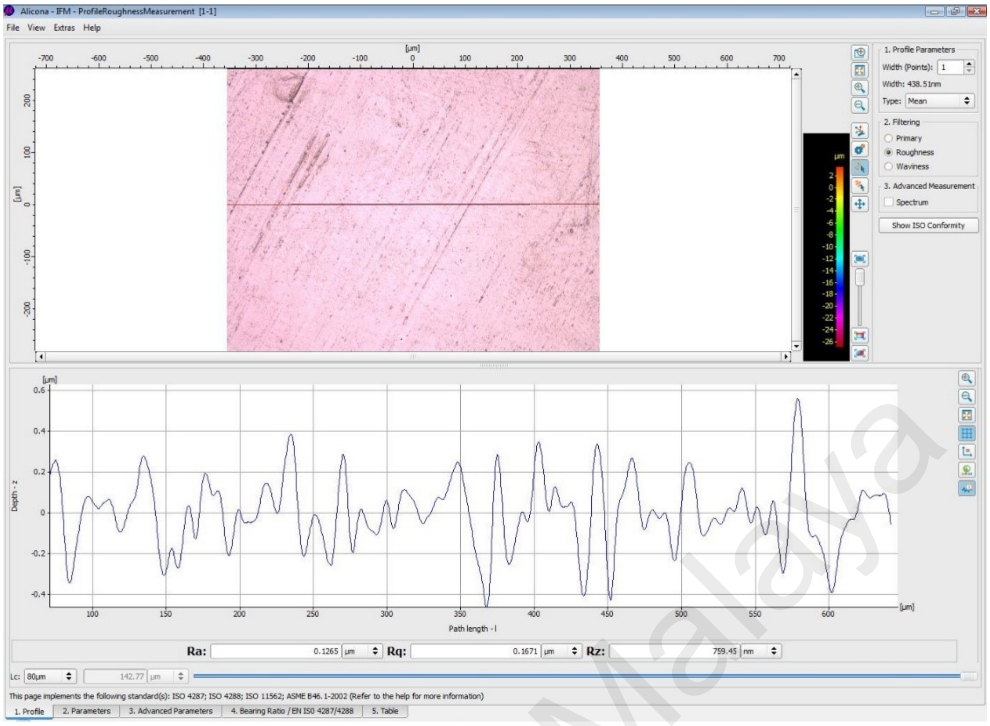

Figure 3.8: Reading of Ra(µm) using IFM software

3.5 FLEXURAL MODULUS TEST

Three-point bending test using universal testing machine (AG-X model, Shimadzu, Japan) (figure 3.9) was used for the flexural modulus tests. Each specimen exact dimensions were measured by a digital caliper, then inserted into the program for computation. After that, the distance between the two supporting heads was set at 50mm apart. Then the specimens were placed in position and the crosshead speed was set at 5 mm/min (Takabayashi, 2010; Yunus et al., 2005)

The flexural modulus (*E)* was determined after calibrating the machine, and the values automatically computed from the equation: $E = f1l^3/4\ bh^3d$

Where:

*f*1 is the load, in newtons, at a point in the straight-line portion (with the maximum slope) of the load/displacement curve.

l is the distance, in millimeters, between the supports, accurate to ± 0,01 mm.

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.

d is the deflection, in millimeters, at load $f1$.

Figure 3.9: Universal testing machine

3.6 STATISTICAL ANALYSIS

ΔE values were submitted to statistical analysis by means of One-sample test, then the Paired sample test was used to compare the color parameters (L*, a*, b*). The Ra values were analyzed using the Paired sample test. The flexural modulus values were submitted to One-way ANOVA test. All the statistics were done at a significant level of P=0.05 with the aid of the statistical program SPSS 20.0 (SPSS Inc., Chicago, IL,USA).

CHAPTER 4: RESULTS

4.1 COLOR STABILITY

One-sample test showed statistically significant difference (p=0.002) when comparing the colors changes (ΔE) on the thermoplastic resin after immersion in the denture cleanser with the control group. The color data (Appendix a: color changes data) were quantified by the National Bureau of Standards (NBS) units, using the formula NBS units = ΔE × 0.92. Table 4.1 shows the ΔE and the NBS values for the control and the test groups. The mean NBS value of the test group was classified as slight (0.5-1.5) (table 4.2).

Table 4.1: Means of ΔE and NBS units

Group	Mean ΔE (±SD)	Mean NBS (±SD)
Control (Distilled water)	**0.27(±0.21)**	**0.25(±0.20)**
Test group (Polident)	**0.75(±0.47)**	**0.68(±0.44)**

SD= standard deviation

Table 4.2: Classification unit by NBS

NBS unit	Critical observation of color change
0.0-0.5	Trace
0.5-1.5	Slight
1.5-3.0	Noticeable, perceivable
3.0-6.0	Appreciable, marked change
6.0-12.0	Much, extreme
12.0 or more	Change to another color

The baseline color measurements (L*, a*, and b*) of the denture base material are recorded in Table 4.3, before the specimens in this study were immersed in the denture cleanser solution. Paired sample test was used to compare the color parameters (L*, a*, b*) before and after immersion in the denture cleanser, it shows a statistically significant increase in the L* value after the immersion procedure. Table 4.4 shows the mean difference between the values (L*, a*, and b*) before and after the immersion in the denture cleanser, the standard deviation, and the significance.

Table 4.3: Mean (SD) baseline color measurement

	L*	a*	b*
Mean(±SD)	**37.5(±5.5)**	**5.8(±3.1)**	**-3.2(±2.1)**

Table 4.4: Mean values and standard deviations of ΔL*, Δa* and Δb*

	Mean(±SD)	Sig. (2-tailed)
ΔL*	**-.746(±.770)**	**.002**
Δa*	**.075(±.309)**	**.363**
Δb*	**.062(±.270)**	**.397**

Paired sample test shows statistical significance difference (p<0.05) in L values*

4.2 SURFACE ROUGHNESS

Paired sample test showed a statistically significant increase in the surface roughness of the thermoplastic resin after immersion in the denture cleanser ($P<0.05$).

Table 4.5 shows the mean and the standard deviation as well as the significance of Ra values of the thermoplastic resin before and after immersion in the denture cleanser and the control group.

Table 4.5: Ra(µm) mean (SD) and significance

		Mean (±SD)	Sig. (2-tailed)
Control group (Distilled water)	**Ra Before immersion**	**0.21(±0.02)**	**0.456**
	Ra After immersion	**0.21(±0.03)**	
Test group (Denture cleanser)	**Ra Before immersion**	**0.21(±0.03)**	***0.013**
	Ra After immersion	**0.24(±0.05)**	

SD= standard deviation
**Paired sample test significance, p<0.05*

4.3 FLEXURAL MODULUS

The one-way **ANOVA** data showed no statistically significant difference (*P>0.05)* in the flexural modulus of the thermoplastic resin, after the immersion in the denture cleanser for 180 times, nor in distilled water control group compared to the group without immersion.

Figure 4.1 shows the mean and the standard deviation of the flexural modulus for the three groups:2a (without immersion in the cleanser), 2b (after immersion in distilled water) and 2c (after immersion in the denture cleanser), and the significance are shown in Table 4.6.

Table 4.6: Flexural modulus of ThrmoSens (aMPa)

Group	Mean (±SD)	Sig. (2-tailed)
Without immersion(2a)	**1324(±91)**	
After immersion (control group, 2b)	**1337(±73)**	***.762**
After immersion (test group, 2c)	**1289(±125)**	***.436**

SD=standard deviation
**One-way ANOVA significance; p<0.05*

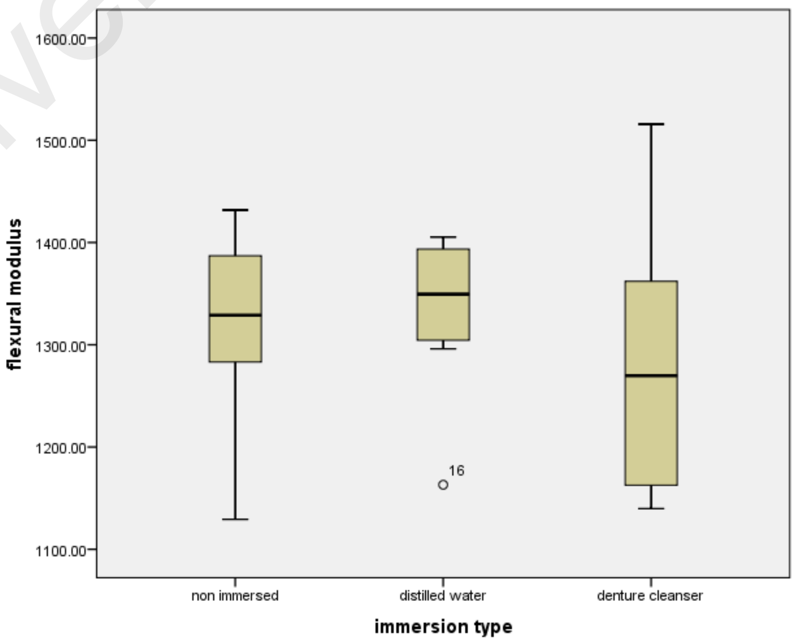

Figure 4.1: Means of flexural modulus for the three groups

CHAPTER 5: DISCUSSION

In the present study, protocol on the preparation of the Denture cleansers by the manufacturers' recommendations were followed. Warm tap water was suggested, and each denture cleanser tablet was utilized for the preparation of the denture cleanser solution. This procedure was repeated 180 times to simulate the normal immersion regime used by the patient for a period of 6 months of cleansing. This was implemented in previous work (Jin et al., 2003; Peracini et al., 2010; Porwal et al., 2017). The hypothesis that denture cleansers would influence the color stability, the surface roughness or the flexibility of denture base resins was partially rejected.

Immersion in the denture cleanser tablets did influence flexural modulus of the flexible denture base. However, the changes were not significant ($p<0.05$). A significant ($p<0.05$) increase in the color changes and the surface roughness compared the control was observed.

The use of denture cleaning by immersion in chemical solution should not compromise any physical, mechanical or chemical properties of the denture base.

Asad et al. (1992) based on his work on acrylic resin base, suggested that the decontamination process during immersion in denture cleansers may result in alterations of the surface morphology and changes in the flexural properties.

5.1 COLOR CHANGES

Color stability is an important property of denture base. Previous reports have shown that color change in denture base materials is caused by changes in the matrix of the material and the staining effect of external colorants, and that solubility, water sorption, leakage, surface roughness, and chemical degradation may also be factors (Hersek et al., 1999; Shotwell et al., 1992).

The color changes measurements were carried out using Spectrophotometer. Digital or instrumental color analysis offers a clear advantage over visual color determination, since instrumental readings are objective, quantifiable, and are rapidly obtained (Okubo et al., 1998).

The standard Commission International de l'Eclairage CIE L*a*b* system, A uniform 3-dimensional system that has been widely used for the determination of chromatic differences by translating combinations of differences into mathematical data (CIE, 1986; Hersek et al., 1999).

NBS (National Bureau of Standards)-defined units were used to evaluate the color differences. NBS units were also used in this study, because the NBS parameter is important for color comparison and quality control functions (Nimeroff., 1968; Wyszecki & Stiles., 1982).

Vertex™ ThermoSens being the latest production compare to the polyamides predecessor, has shown superior results in color stability. The color changes exhibited in all specimens in this study. However, the change observed were less than 1.5 NBS-unit change. This present study indicated the mean NBS value classification as slight (0.5 - 1.5) (Table 4.2). NBS unit of greater than 3 was considered unacceptable. The results among the color parameters L*a*b*, the L* showed an increment. The color changes of the thermoplastic resin (Vertex™ ThermoSens) are derived mainly from an increase in L* parameter. This change may be due to the bleaching effect of the peroxide content in the denture cleanser, although this change did not cause clinical visible change. However, Polychronakis et al, 2015 found the main change in the polyamide (Valplast®) color parameters was chiefly from a* and b*.

Previous work on other groups of polyamides and various denture cleansers was done. No direct comparison can be made. It was noted that each denture cleanser with different constituent and mechanism showed different degree of color change. Shah et al. (2015)

findings showed more color changes on the polyamide (Valplast®) after immersion in three denture cleansers (Clinsodent®, Polident®, Valclean®) for three and six months. Based on the classification unit by NBS (Table 4.2), Clinsodent® had an appreciable effect on color change, while Polident® had a noticeable effect. Specimen immersed in Valclean® showed noticeable and appreciable color change for 3 and 6 months of immersion, respectively.

The manufacturer claimed that, the superior color integration in Vertex™ ThermoSens unlike most thermoplastic companies who introduce color after finishing creating their nylon beads (by pouring color over raw white nylon beads), ThermoSens integrates its color into each bead during the mixing process. This ensures an even color distribution that will ensure every injection is consistent. This method also eliminates any random color spots, flares or any other unnatural coloring that would not occur in a patient's mouth.

The results of this study are in harmony with studies carried out to evaluate the color changes after simulating 180 times of denture cleanser usage (Durkan et al., 2013; Polychronakis et al., 2015). The alkaline peroxide cleansing agents (Corega® Extradent and Val-Clean®) had no noticeable effect on the color stability of the thermoplastic denture base material (Valplast®), with period simulating 30 days of cleansing (Polychronakis et al., 2015).

Being a neutral cleanser, Polident 3 min™ has a lesser effect on color stability. It contains sodium perborate, other acidic ingredients like citric acid nullify its bleaching effect.

5.2 SURFACE ROUGHNESS

Surface roughness is an important factor, which affects the clinical life of materials and resistance to plaque formation. Surface roughness is related to the abrasion of materials.

For the purpose of the present study, an optical 3-dimensional (3D) surface analyzer (Infinite Focus Standard; Alicona Imaging, Graz, Austria) was used to measure the surface roughness of the thermoplastic polyamide resin (Vertex™ ThermoSens). In like manner, 3D non-contact optical interferometric profilometer was used to measure the surface roughness of a polyamide denture base material (Valplast®) (Polychronakis et al., 2015). 3D-surface roughness results are obtained by combining multiple traces, however, 2D or contact surface roughness measures are obtained along a single line, and thus, only a small sample of the surface is actually being inspected.

It was suggested that the surface roughness for the dental material that are acceptable in the oral cavity, should be Ra= 0.2µm, under that level no plaque reduction is expected (Quirynen & Bollen., 1995). This present study showed a significant increase in the surface roughness. The obtained mean Ra values exceeded the threshold level at baseline (0.20±0.03). Following immersion in Polident 3 min™ denture cleanser, an increment was observed to 0.24±0.05. One possible explanation for the increase in roughness observed from this study might be due to the elevated initial surface roughness. During the preparation, all the surface roughness of all specimens was previously standardized by smoothing and polishing procedures. The study specimens' size is small (64 mm x 10mm x 3.3 mm) and makes polishing difficult especially the operator grip while polishing. Apart from that polyamides have low melting point makes it difficult to achieve satisfactory polish. Excessive trimming by burs is not advised (Munns., 1962).

It was noted that (Valplast®) polyamide resin had a higher initial surface roughness. Polyamide-based resins have fibrous structure, semi-flexible structure and low surface hardness. Scanning electron microscope (SEM) images also confirmed that polyamide-based resins had a higher roughness when compared to PMMA groups (Durkan et al., 2013). The smoothing and polishing procedures were quite difficult with these materials.

It was observed that, the result may vary in terms of the different dimensions of the samples and types of polyamides used. Abuzar et al. (2010) conventionally polished polyamide (Flexiplast®) with a bigger dimensions sample of (75mm x 22mm x 4mm), showed acceptable and below the threshold Ra 0.2 µm. The bigger the dimension made it easier handling during polishing procedure.

The effect of denture cleanser used in the current study is also consistent with the findings of Machado et al. (2009) who showed that sodium perborate solution increased surface roughness of acrylic resins. Similar observation of increase surface roughness on different group of polyamides with different type of denture cleanser by a recent work of Porwal et al. (2017). On other previous work comparable results were obtained after evaluating the effects of three sodium perborate-containing denture cleansers (Corega®, Protefix®, Valclean®) on the surface roughness of two polyamides (Valplast® and Deflex®), where the surface roughness of the polyamide increased after 20 days of repeated immersion regardless of the type of the solution used (Durkan et al., 2013). Furthermore, the surface roughness of a polyamide (DEFLEX, Nuxen SRL, Buenos Aires, Argentina; Dfl group) increased significantly after being subjected to daily cleansing with four denture cleansers (Corega®, Protefix®, Curaprox®, and Perlodent®) for 8 hours a day for 140 days (Ozyilmaz & Akin., 2019).

5.3 FLEXURAL MODULUS

Polyamide resins had higher fibrous content and lower modulus of elasticity. The manufacturers claimed Vertex™ ThermoSens is more rigid than nylon 6, but flexible enough to engage under heavy undercuts. Flexibility is desirable in clinical situations such as to engage under heavy undercuts. This provides stability and resistance during function. This study looked into the effect of Polident 3 min™ on the flexibility of Vertex™ ThermoSens. Three-point bending test was used, as it is valuable in comparing denture base materials because it simulates the type of stress to the denture during mastication (Craig et al., 1975). A flexural 3-point bending test was carried out by using an Instron universal testing machine. The dimensions of the tested sample were designed according to the ISO specification 20795-1:2013(ISO, 2013).

According to the International Organization for Standardization (ISO) 20795-1:2013 (ISO, 2013), the flexural modulus of the processed thermoplastic polymer should be at least 2000 MPa. At baseline before immersion flexural modulus was 1324 MPa. The lower flexural modulus exhibited by the thermoplastic material was because of its lesser rigidity. Following immersion, it reduced to 1289MPa. Although, there was a decrease in the values, none of the specimens broke during the test. Shah et al. (2015) had a similar experience, where none of the polyamide (Valplast®) specimens broke when subjected to the three-point bending test. Flexural modulus of polyamide denture base resin was reported to be lower than that of conventional PMMA (Stafford et al., 1986; Yunus et al., 2005), which means it is less rigid and more elastic than conventional PMMA polymers. Polyamide is promoted as a denture base material based on its flexibility, which allows engaging certain degree of undercuts for retention without these undercuts being blocked (MacGregor et al., 1984). Flexibility is desirable in clinical situations to engage under heavy undercuts. This ensures no unwanted movement while chewing.

Similar results were obtained when the elastic modulus was evaluated for different polyamides. Valplast® scored 800-1400 MPa when testing elastic modulus (Takahashi, 2009)

Results of the present study showed decrease in the modulus of elasticity of the tested polyamide denture base material (Vertex™ ThermoSens) after being immersed in the denture cleanser (Polident 3 min™) 180 times. However, that decrease was not significant ($p<0.05$).

This effect of decreasing the flexural modulus by Polident 3 min™ could be due to perborate content and the effervescent effect. The oxygen in its structure is decomposed to free oxygen radicals and thus water molecules are removed. Oxygen might cause a chemical softening of the resin surface by damaging interchain forces in the polymer (Durkan et al., 2013).

Parallel results were obtained when the flexural modulus of a thermoplastic denture base material (Lucitone FRS®) decreased after immersion in two denture-cleansing tablets (Parlani et al., 2018).

Polident 3 min™ can be safely used as denture cleanser for Vertex™ ThermoSens polyamide denture base materials as far as color stability and flexural strength both are concerned.

5.4 LIMITATIONS OF THE STUDY

1. The present study did not completely simulate clinical behavior. Where there was no actual use during function, combining the effect of mastication, saliva, and food.
2. The polishing protocol of the specimens, as recommended by the manufacturer was not carried in out in full due to the size of the test specimens. These specimens were too small unlike the normal denture; thus, handling was difficult. Achieving the finest surface at baseline could have effect on the data in the surface roughness test.
3. Direct comparison to other previous work was limited due to many variables and different materials used

CHAPTER 6: CONCLUSION

This study tested the effect of the immersion of one thermoplastic denture base material in a commercially available denture cleanser for a period simulating 180 days of usage. The effects were evaluated with respect to color changes, surface roughness, and flexural modulus. Within the limitations and based on the results of this study, it can be concluded that:

1. Color changes were observed on the thermoplastic denture base material after immersion in the denture cleanser. Classified by NBS as slight and clinically acceptable. Color change was not statistically significant ($p<0.05$)
2. The neutral peroxide enzymatic denture cleanser Polident 3 min™ significantly increased the surface roughness of the denture base material.
3. Although the immersion in the denture cleanser did not affect the flexural modulus significantly, the flexural modulus of the tested thermoplastic resin was lower than the ISO recommendations regardless of immersion in the denture cleanser.

CHAPTER 7: RECOMMENDATIONS

Future *in-vitro* studies on this material are recommended, where other conditions of the oral environment can be simulated, such as continuous cyclic loading. Also, the immersion period should be longer for the simulation of long-term use. The association with mechanical cleaning methods possibly will show potential changes, such as; increased surface roughness. Moreover, further clinical *in-vivo* studies are required to evaluate the daily use of the denture cleanser if it would cause any mucosal irritation, also the patient's oral health-related quality of life should be assessed when using this type of denture base and cleansing method. As well further studies can be carried out using different denture cleansing solutions.

REFERENCES

Abuzar, M. A., Bellur, S., Duong, N., Kim, B. B., Lu, P., Palfreyman, N., . . . Tran, V. T. (2010). Evaluating surface roughness of a polyamide denture base material in comparison with poly (methyl methacrylate). *Journal of oral science, 52*(4), 577-581.

Asad, T., Watkinson, A. C., & Huggett, R. (1992). The effect of disinfection procedures on flexural properties of denture base acrylic resins. *The Journal of prosthetic dentistry, 68*(1), 191-195.

Berger, J. C., Driscoll, C. F., Romberg, E., Luo, Q., & Thompson, G. (2006). Surface roughness of denture base acrylic resins after processing and after polishing. *Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry, 15*(3), 180-186.

Budtz-Jørgensen, E. (1979). Materials and methods for cleaning dentures. *The Journal of prosthetic dentistry, 42*(6), 619-623.

Budtz‐Jörgensen, E. (1974). The significance of Candida albicans in denture stomatitis. *European Journal of Oral Sciences, 82*(2), 151-190.

CIE, C. (1986). Official recommendations of the International Commission on illumination. *Publication CIE No. 15.2*.

Craig, R. G., Peyton, F. A., & Asgar, K. (1975). *Restorative dental materials*: Mosby.

de Freitas Fernandes, F. S., Pereira-Cenci, T., da Silva, W. J., Ricomini Filho, A. P., Straioto, F. G., & Cury, A. A. D. B. (2011). Efficacy of denture cleansers on Candida spp. biofilm formed on polyamide and polymethyl methacrylate resins. *The Journal of prosthetic dentistry, 105*(1), 51-58.

Dills, S. S., Olshan, A. M., Goldner, S., & Brogdon, C. (1988). Comparison of the antimicrobial capability of an abrasive paste and chemical-soak denture cleaners. *Journal of Prosthetic Dentistry, 60*(4), 467-470.

Durkan, R., AYAZ, E. A., Bagis, B., Gurbuz, A., Ozturk, N., & Korkmaz, F. M. (2013). Comparative effects of denture cleansers on physical properties of polyamide and polymethyl methacrylate base polymers. *Dental materials journal, 32*(3), 367-375.

Fueki, K., Ohkubo, C., Yatabe, M., Arakawa, I., Arita, M., Ino, S., . . . Komiyama, O. (2014a). Clinical application of removable partial dentures using thermoplastic resin—Part I: Definition and indication of non-metal clasp dentures. *Journal of prosthodontic research, 58*(1), 3-10.

Fueki, K., Ohkubo, C., Yatabe, M., Arakawa, I., Arita, M., Ino, S., . . . Komiyama, O. (2014b). Clinical application of removable partial dentures using thermoplastic resin. Part II: Material properties and clinical features of non-metal clasp dentures. *Journal of prosthodontic research, 58*(2), 71-84.

Gornitsky, M., Paradis, I., Landaverde, G., Malo, A.-M., & Velly, A. M. (2002). A clinical and microbiological evaluation of denture cleansers for geriatric patients in long-term care institutions. *Journal-Canadian Dental Association, 68*(1), 39-45.

Hamanaka, I., Iwamoto, M., Miyaguchi, T., Katumata, S., Ikeura, M., & Shimizu, H. (2012). Properties of denture base resins for nonclasp denture. *Annals of Japan Prosthodontic Society, 4*(Special Issue), 156.

Hamanaka, I., Takahashi, Y., & Shimizu, H. (2011). Mechanical properties of injection-molded thermoplastic denture base resins. *Acta Odontologica Scandinavica, 69*(2), 75-79.

Hargreaves, A. S. (1971). Nylon as a denture-base material. *The Dental practitioner and dental record, 22*, 122-128.

Hayran, Y., Sarikaya, I., Aydin, A., & Tekin, Y. H. (2018). Determination of the effective anticandidal concentration of denture cleanser tablets on some denture base resins. *Journal of Applied Oral Science, 26*.

Hersek, N., Uzun, G., & Yildiz, P. (1999). Color stability of denture base acrylic resins in three food colorants. *The Journal of prosthetic dentistry, 81*(4), 375-379.

Hishimoto, M., Katou, Y., Akita, Y., Murakami, Y., & Iida, S. (2008). Physical properties of polyester copolymer for denture materials. *Journal of Nippon Academy of Dental Technology, 29*, 196.

Hong, G., Murata, H., Li, Y., Sadamori, S., & Hamada, T. (2009). Influence of denture cleansers on the color stability of three types of denture base acrylic resin. *The Journal of prosthetic dentistry, 101*(3), 205-213.

Horn, D. J., Bulan-Brady, J., & Hicks, M. L. (1998). Sphere spectrophotometer versus human evaluation of tooth shade. *Journal of endodontics, 24*(12), 786-790.

Hussain, S., Jayesh, R., Nayar, S., Aruna, U., & Abraham, A. M. (2011). Prosthodontic management of a completely Edentulous patient with Bell's Palsy. *Indian Journal of multidisciplinary dentistry, 2*(1).

ISO specification of denture base polymers 20795-1:2013 (2013).

Jin, C., Nikawa, H., Makihira, S., Hamada, T., Furukawa, M., & Murata, H. (2003). Changes in surface roughness and colour stability of soft denture lining materials caused by denture cleansers. *Journal of oral rehabilitation, 30*(2), 125-130.

Johnson, W. W. (1959). The history of prosthetic dentistry. *The Journal of Prosthetic Dentistry*, *9*(5), 841-846.

Joiner, A. (2004). Tooth colour: a review of the literature. *Journal of dentistry, 32*, 3-12.

Kagermeier ‐ Callaway, A. S., Willershausen, B., Frank, T., & Stender, E. (2000). In vitro colonisation of acrylic resin denture base materials by Streptococcus oralis and Actinomyces viscosus. *International dental journal, 50*(2), 79-85.

Kawara, M., Iwata, Y., Iwasaki, M., Komoda, Y., Iida, T., Asano, T., & Komiyama, O. (2014). Scratch test of thermoplastic denture base resins for non-metal clasp dentures. *Journal of prosthodontic research, 58*(1), 35-40.

Keyf, F., & Güngör, T. (2003). Comparison of effects of bleach and cleansing tablet on reflectance and surface changes of a dental alloy used for removable partial dentures. *Journal of biomaterials applications, 18*(1), 5-14.

Koopmans, A., Kippuw, N., & De Graaff, J. (1988). Bacterial involvement in denture-induced stomatitis. *Journal of dental research, 67*(9), 1246-1250.

Kulak‐Ozkan, Y., Kazazoglu, E., & Arikan, A. (2002). Oral hygiene habits, denture cleanliness, presence of yeasts and stomatitis in elderly people. *Journal of oral rehabilitation, 29*(3), 300-304.

Lai, Y.-l., Lui, H.-f., & Lee, S.-y. (2003). In vitro color stability, stain resistance, and water sorption of four removable gingival flange materials. *The Journal of prosthetic dentistry, 90*(3), 293-300.

Lucena-Ferreira, S. C. d., Cavalcanti, I. M. G., & Cury, A. A. D. B. (2013). Efficacy of Denture Cleansers in Reducing Microbial Counts from Removable Partial Dentures: A Short-Term Clinical Evaluation. *Brazilian dental journal, 24*, 353-356.

MacGregor, A., Graham, J., Stafford, G., & Huggett, R. (1984). Recent experiences with denture polymers. *Journal of dentistry, 12*(2), 146-157.

Machado, A. L., Breeding, L. C., Vergani, C. E., & da Cruz Perez, L. E. (2009). Hardness and surface roughness of reline and denture base acrylic resins after repeated disinfection procedures. *The Journal of prosthetic dentistry, 102*(2), 115-122.

Mahmoud Nabil Helaly, A. M. A.-E., and Ali, & El-Sheikh. (2018). Effect of Two Cleansing Agents on Color Stability of Two Thermoplastic Denture Base materials. . *JSM Dentistry, 6*(2), 1-6.

McCabe, J. (1976). Tissue sensitivity to acrylic resin. *British Dental Journal, 140*, 347-350.

Mohsin H.A, A.-H. N. F., Mustafa Mahdi Jassim. (2017). Evaluating some Mechanical and Physical Properties of Vertex Thermosens Denture base material in Comparison with Heat Cure Acrylicdenture Base Material. *International Journal of Science and Research, 6*(5), 394-397.

Munns, D. (1962). Nylon as a denture base material. *The Journal of Contemporary Dental Practice, 13*, 142.

Neill, D. (1968). A study of materials and methods employed in cleaning dentures. *British Dental Journal, 124*(3), 107-115.

Nikawa, H., Yamamoto, T., Harnada, T., Rahardjo, M. B., & Murata, H. (1995). Commercial Denture Cleansers-Cleansing efficacy Against Candida albicans Biofilm and Compatibility With Soft Denture-lining Materials. *International Journal of Prosthodontics, 8*(5).

Nimeroff, I. (1968). Colorimetry. *Natl Bureau Stand Monogr, 104*, 4-32.

Ödman, P. A. (1992). The effectiveness of an enzyme-containing denture cleanser. *Quintessence international, 23*(3).

Okubo, S. R., Kanawati, A., Richards, M. W., & Childressd, S. (1998). Evaluation of visual and instrument shade matching. *The Journal of prosthetic dentistry, 80*(6), 642-648.

Ozyilmaz, O. Y., & Akin, C. (2019). Effect of cleansers on denture base resins' structural properties. *Journal of applied biomaterials & functional materials, 17*(1), 2280800019827797.

Parlani, S., Agarwal, B., Malaiya, A., Singh, S., & Mishra, S. (2018). Evaluation of Flexural Modulus of Flexible Denture Base Material kept in Water, Denture Cleanser, Artificial Saliva, and Open Air for Different Time Intervals: An in vitro Study. *International Journal of Prosthodontics and Restorative Dentistry, 8*, 54-58.

Peracini, A., Davi, L. R., de Queiroz Ribeiro, N., de Souza, R. F., da Silva, C. H. L., & Paranhos, H. d. F. O. (2010). Effect of denture cleansers on physical properties of heat-polymerized acrylic resin. *Journal of prosthodontic research, 54*(2), 78-83.

Polychronakis, N. C., Polyzois, G. L., Lagouvardos, P. E., & Papadopoulos, T. D. (2015). Effects of cleansing methods on 3-D surface roughness, gloss and color of a polyamide denture base material. *Acta Odontologica Scandinavica, 73*(5), 353-363.

Polyzois, G. L., Yannikakis, S. A., Zissis, A. J., & Demetriou, P. P. (1997). Color changes of denture base materials after disinfection and sterilization immersion. *International Journal of Prosthodontics, 10*(1).

Porwal, A., Khandelwal, M., Punia, V., & Sharma, V. (2017). Effect of denture cleansers on color stability, surface roughness, and hardness of different denture base resins. *The Journal of the Indian Prosthodontic Society, 17*(1), 61.

Quirynen, M., & Bollen, C. (1995). The influence of surface roughness and surface‐free energy on supra‐and subgingival plaque formation in man: A review of the literature. *Journal of clinical periodontology, 22*(1), 1-14.

Quirynen, M., Marechal, M., Busscher, H., Weerkamp, A., Darius, P., & van Steenberghe, D. (1990). The influence of surface free energy and surface roughness on early plaque formation: an in vivo study in man. *Journal of clinical periodontology, 17*(3), 138-144.

Roberts, G. (1956). Nylon in orthodontics: an experiment. *Br Dent J, 100*, 13.

Sagsoz, N. P., Yanıkoglu, N., Ulu, H., & Bayındır, F. (2014). Color changes of polyamid and polymetyhl methacrylate denture base materials. *Open Journal of Stomatology, 4*(10), 489.

Shah, V. R., Shah, D. N., Chauhan, C. J., Doshi, P. J., & Kumar, A. (2015). Evaluation of flexural strength and color stability of different denture base materials including flexible material after using different denture cleansers. *Journal of Indian Prosthodontic Society, 15*(4), 367-373.

Shotwell, J., Razzoog, M., & Koran, A. (1992). Color stability of long-term soft denture liners. *The Journal of prosthetic dentistry, 68*(5), 836-838.

Stafford, G., Huggett, R., MacGregor, A., & Graham, J. (1986). The use of nylon as a denture-base material. *Journal of dentistry, 14*(1), 18-22.

Takabayashi, Y. (2010). Characteristics of denture thermoplastic resins for non-metal clasp dentures. *Dental materials journal, 29*(4), 353-361.

Takahashi, H. (2009). Basic properties of thermoplastic resin for denture base materials referred to" non clasp denture". *JDental Materials Journal, 28*, 161-167.

Verran, J., & Maryan, C. J. (1997). Retention of Candida albicans on acrylic resin and silicone of different surface topography. *The Journal of prosthetic dentistry, 77*(5), 535-539.

Watt, D. (1955). Clinical assessment of nylon as a partial denture base material. *British Dental Journal, 98*, 238-244.

Wiskott, H. W., Nicholls, J. I., Belser, U. C., Wiskott, H., Nicholls, J., & Belser, U. (1995). Stress fatigue: Basic principles and prosthodontic implications. *International Journal of Prosthodontics, 8*(2).

Wyszecki, G. 牖. t., & Stiles, W. S. (1982). *Color science: concepts and methods, quantitative data and formulae*: John Wiley & Sons New York, NY.

Yunus, N., Rashid, A., Azmi, L., & Abu‐Hassan, M. (2005). Some flexural properties of a nylon denture base polymer. *Journal of oral rehabilitation, 32*(1), 65-71.