Original Articles

Effects of Palaseal® Coating Agent on Surface Roughness of Heat-polymerized Denture Base Acrylic Resins

Duangjai Uraivichaikul[1], Issarawan Boonsiri[1], Kamolporn Wattanasirmkit[2]

[1]Department of Prosthodontics, College of Dental Medicine, Rangsit University, Pathum Thani, Thailand

[2]Department of Prosthodontics, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand

Abstract

The objective of this study was to evaluate effects of Palaseal® on surface roughness of acrylic resins which passed different polishing techniques. One hundred eighty heat-polymerized polymethymethacrylate specimens were fabricated and finished with abrasive sandpaper. Then they were randomly equally divided into six groups. A control group (N) was neither polished nor Palaseal® coated. The others were experimental groups as follows: No polishing with Palaseal® coating (NC), pumice and Tripoli polishing without coating (P), pumice and Tripoli polishing with coating (PC), silicone points polishing without coating (S), silicone points polishing with coating (SC). Changes in surface roughness were measured with a profilometer and calculated Ra of specimens. SEM was utilized for surface visualization and surface roughness confirmation. Two-way ANOVA and Tukey Honestly Significant Difference (HSD) were used for statistical analysis. Group (N) had the highest mean Ra value (670.5 nm.) whereas group (PC) had the lowest mean Ra value (241.9 nm.). Groups (N, NC) had the mean Ra value (670.5, 394.5 nm.) significantly (P<0.01) more than groups (S, SC) (300.1, 254.9 nm.) and groups (P, PC) (283.2, 241.9 nm.) respectively. Differences of the mean Ra values between Palaseal® uncoated groups (N, P, S) and coated groups (NC, PC, SC) were statistically significant (P<0.01). Lastly, there was interaction between surface polishing and Palaseal® coating. Palaseal® coating on heat polymerized acrylic resins enhanced surface smoothness of acrylic resins polished with pumice and Tripoli and silicone points, including finished with abrasive sandpaper.

Keywords: Acrylic resins, Coating agents, Palaseal®, Surface coating, Surface roughness

Received Date: May 8, 2019 **Revised Date:** Jun 11, 2019 **Accepted Date:** Sep 26, 2019

doi: 10.14456/jdat.2020.2

Correspondence to:

Duangjai Uraivichaikul, College of Dental Medicine, Rangsit University, 56/347 Muang-Ake, Phaholyothin Road, Lak-Hok, Muang Pathum Thani, 12000 Thailand. Tel/Fax: 02-997-2200 Ext 4486 or 080-0684400 E-mail: duangjai.j@rsu.ac.th or jo_chingching@yahoo.com

Introduction

Poly-methylmethacrylate (PMMA) resins have been the most common dental materials because of their excellent working characteristics, pleasant physical and esthetics properties, cost-effectiveness and ease of fabrication. However, there have been some limitations related to PMMA resins which make them different from an ideal denture base material.[1] For example, residual monomer content within the processed denture base increased due to the reduction of the processing temperature and time. In fact, the residual monomer leading to bubbles and porosities can diffuse rapidly into the oral cavity and body.[2] Moreover, some material properties resulted in disadvantages after long-term intraoral use. The disadvantages were discoloration, wear, surface adhesion and accumulation of microorganisms. The microorganisms which adhered and accumulated on the PMMA denture bases were associated with oral infections such as denture induced stomatitis.[3,4] Candida species were obviously found in the denture biofilm.[5] Denture-base irregularities were reservoirs for microorganism adhesion. Therefore, denture base acrylic resins should be properly finished and polished to gain smooth visible surfaces that promoted oral hygiene and reduced plaque accumulation. There were many studies about using chemical solutions to reduce accumulation of microorganism on denture base acrylic resins. For example, denture immersion in sodium hypochlorite was a recommended method of disinfection. Also, disinfection with 1 % sodium hypochlorite for 10 minutes seemed to be a very effective protocol.[6] Furthermore, *Candida albicans* adhesion was reduced by approximately 80 % after disinfection with 1 % sodium hypochlorite and without acquired saliva pellicle (ASP) formation. Also, it was decreased at the same level after disinfection with 4 % chlorhexidine gluconate and without the acquired saliva pellicle (ASP) formation. Whereas, being with ASP formation reduced the adhesion of *Candida albicans* by approximately 88 %.[7]

Tissue and occlusal adjustment was required during insertion of dentures although the dentures were highly polished from the laboratory. Therefore, many surfaces of the dentures such as the occlusal surface, the tissue surface and the polished surface were rough after the adjustment leading to plaque accumulation and microorganism adherence like *Candida albicans, Streptococcus oralis.*[8] The initial adhesion of microorganisms on surfaces depended on their physical and chemical properties along with those of the substrates and environmental solutions.[9] In fact, surface roughness (Ra) which was one of material properties affected initial adhesion. Restorative materials with enhanced surface roughness were vulnerable to be attached by microorganisms especially *Candida albicans.*[10] The surface roughness of 0.2 µm. was created as the threshold for the adhesion of bacteria, which the aggregation of bacteria considerably increased.[11,12]

Mechanical polishing was one method which reduced surface roughness of dentures. Mechanical polishing materials such as polishing wheels, felt cones, prophylactic pastes, rubber polishers, abrasive stones, aluminum oxide-based polishing pastes, silicone polishers, pumice, and lathe polishing.[13] According to a pervious study about mechanical polishing materials, polishing with polishing paste was more effective to enhance smoother surfaces than polishing with polishing cake and pumice and gold rouge respectively.[14] Moreover, mechanical polishing (conventional lathe polishing using pumice and chalk powder) produced lower surface roughness of denture base acrylic resins compared with chemical polishing (immersing in heated MMA monomer).[15] Similarly, mechanical polishing (universal polishing paste, aluminumoxide-Al_2O_3 in paste) produced smoother surface of CAD/CAM denture base resin compared to chemical polishing (immersing in heated MMA monomer).[16] Many studies presented that conventional laboratory polishing (with a lathe and polishing paste) produced the smoothest

surface of denture base acrylic resin.[17-19] Conventional laboratory polishing provided smoother surface of denture base acrylic resin than polishing with chairside silicone polishing kits.[17-19] Meanwhile, polishing with chairside silicone polishing kits produced a significantly smoother surface of acrylic resin than polishing with a tungsten carbide bur.[17] Denture base materials which were processed under ideal laboratory conditions after wax pattern investment still presented Ra measurements between 3.4 and 7.6 μm.[20] Thus, these fitting surfaces were prone to have microbial adherence. Many researchers tried to improve techniques and applied different coating materials such as titanium dioxide, monomers, oils or high polymerized glaze in order to overcome this situation.[21-23] For instance, titanium dioxide coatings on a denture base acrylic resin inhibited adhesion of *S. sanguinis* and *C. albicans*.[21] However, there were several drawbacks of these coating materials such as discoloration of the denture material after using, limitation of improvement of its mechanical properties or controversial longevity in the oral environment.[21-23] There were many studies about various brands of surface coating agents such as Biscover®LV, Surface Coat®, Optiglaze and Parylene®Coat. For example, the effectiveness and surface integrity of Biscover®LV-treated surfaces was more than that of Surface Coat®.[24] In addition, coating with 10-μm layer of Parylene® C decreased the surface roughness of PMMA although increasing the coating thickness leaded to higher surface roughness of PMMA.[25] Sulfobetaine methacrylate (S) and 3-hydroxypropyl methacrylate (HP) coatings considerably reduced the adhesion of *C. albicans* to the acrylic resin and could prevent the dentures from *C. albicans* accumulation.[22]

Each surface coating agent has different components as shown in table 1. However, some surface coating agents have the same components. For instance, Palaseal® is also composed of methylmethacrylate which was found in Optiglaze.[26]

Table 1 *Surface coating agents and their components*

Surface coating agents	Components	Manufacturer
Biscover® LV	Dipentaerythritolpentaacrylate, ethanol	Bisco, Inc Schaumburg, Illinois, USA
Optiglaze	Methyl methacrylate, multifunctional acrylate, silica filler and photo initiator	GC Corp
Parylene® coat	Organic polymers (polypara-xylylenes)	Penta Technology (Suzhou) Co., Ltd
Palaseal®	Methyl methacrylate 25-50 %, Tris(2-hydroxyethyl)-isocyanurat-triacrylate 25-50 %, Oligotriacrylate 5-10 % Propoxylated esters with acrylic acid 5-10 % Diphenyl(2,4,6- trimethylbenzoyl)phosphine oxide 0-5 % polyxyloxane hexaacrylate <1 %	Heraeus Kulzer GmbH

Properties of surface coating agents are similar to each other such as enhancing smoothness of the surface area which leads to reduce bacterial accumulation, helping abrasion resistance and reducing staining on the surface area.

According to KULZER MITSUI Chemical group (Heraeus Kulzer Gmbh), Palaseal® is the trade name of a product based on methacrylates. Its components are presented in table 1. It refers to a family of monomer used as sealing materials due to their ability to build a protective layer on various surfaces. According to manufacturer's instructions, it shows that Palaseal® can form a film of uniform thickness which is biocompatible and stable. Also, it is a light-cure lacquer that is used to apply to the surface of the denture materials and temporary crowns

and bridges made of PMMA acrylic resins. Besides, it has high surface hardness and abrasion resistance. With Palaseal® coat it is possible to achieve a smooth surface on newly finished and reworked PMMA-based prosthetic components. The smooth surface prevents mechanical irritation of the tongue and mucous membrane. The transparent lacquer does not alter the color of the prosthetic components. There has been studied about the capacity of Palaseal® glaze to make surface defects of composite resin.[27] Also, Palaseal® coating had a surface roughness higher than the plaque accumulation threshold (0.20 µm).[28,29] However, there were few studies about Palaseal® as a coating material for PMMA intraoral prostheses. Dentures and several dental prostheses can be fabricated from heat-cure or self-cure acrylic resin. However, heat-polymerized resin was mostly chosen for denture fabrication such as surface hardness, flexural strength, and bond strength to highly cross-linked tooth which were higher than auto-polymerized resin.[30,31] In addition, conventionally polished auto polymerized resin remained porous which promoted plaque formation and bacterial contamination compared to conventionally polished heat polymerized resin.[32] Therefore, heat polymerized acrylic resins were chosen to evaluate surface roughness in this study.

The purpose of this study was to evaluate effects of Palaseal® coating agent on the surface roughness of heat-polymerized denture base acrylic resins which passed two different polishing techniques. The null hypothesis was that different surface polishing and Palaseal® coating would have no effect on the surface roughness of heat- polymerized denture base acrylic resins.

Materials and methods

Fabrication of acrylic resin specimens

One hundred eighty rectangular (15*15*3 mm^3) PMMA specimens were fabricated from heat polymerization (ProBase Hot, Ivoclar Vivadent) and finished with 1,000 grit silicon abrasive sandpaper as standardization before an experiment. Then they were randomly divided into six groups. The six groups included one control group and five experimental groups. The control group (N) was neither polished nor Palaseal® coated (Heraeus Kulzer GmbH). The experimental groups were polished with different techniques such as a conventional polishing technique (pumice and Tripoli) (Whip Mix corporation, Kentucky, USA) and a chairside polishing technique (silicone points or Acrypoint) (Shofu Inc, Kyoto, Japan) as shown in table 2.

Table 2 *Surface polishing and Palaseal® coating in each experimental group.*

Groups	Abrasive sandpaper finishing	Pumice and Tripoli polishing	Silicone points polishing	Palaseal® coating	
				Coated	Uncoated
N	/	-	-	-	/
NC	/	-	-	/	-
P	/	/	-	-	/
PC	/	/	-	/	-
S	/	-	/	-	/
SC	/	-	/	/	-

The first group was unpolished and Palaseal® uncoated group (N). The second group was unpolished and Palaseal® coated group (NC). The third group was polished with pumice and Tripoli and Palaseal® uncoated (P). The fourth group was polished with pumice and Tripoli and Palaseal® coated (PC). The fifth group was polished with silicone points and Palaseal® uncoated (S). The last group was polished with silicone points and Palaseal® coated (SC).

The details of materials using in this study comprised of compositions and manufacturer as shown in table 3.

Table 3 *The details of materials using in the study.*

Materials	Use of materials	Compositions	Manufacturer
ProBase Hot Heat cured acrylic resins	Denture base processing	Powder: 95% PMMA, 4% plasticizer, 1% benzoylperoxide Liquid: 90% MMA, 10% dimethacrylate, catalyst	Ivoclar Vivadent
Pumice	Finishing and polishing	Silicon dioxide 76.2%, Aluminum oxide 13.5%, Ferric oxide 1.1%, Ferrous oxide 0.1%, water <0.1%	Whip Mix Corporation, Louisville, Kentucky, USA
AcryPoint	Finishing and polishing	Bonded abrasives (silicon carbide-SiC) in silicone matrix	Shofu Inc, Kyoto, Japan
Palaseal®	Coating	Methyl methacrylate 25-50 %, Tris(2-hydroxyethyl)-isocyanurat-triacrylate 25-50%, Oligotriacrylate 5-10% propoxylated esters with acrylic acid 5-10% Diphenyl (2,4,6- trimethylbenzoyl) phosphine oxide 0-5% polyxyloxane hexaacrylate <1%	Heraeus Kulzer GmbH

All specimens were prepared by using silicone molds made of rectangular custom-made plastic boxes. The plastic boxes were used to form the rectangular silicone molds. The rectangular patterns (15*15*3 mm^3) were made of heavy body condensation silicone material. Wax was melted and placed on the silicone molds. The glass slab was used to control the thickness of specimens. The molds were made by placing the rectangular wax in a metal flask with dental stone. The lower half with the flask was added up with mixed dental stone and was allowed to set for 1 hour. The stone surface was painted with a separating medium. The upper half of the flask was placed over the lower half and filled with mixed dental stone and allowed to set for 1 hour. The flask was placed into wax scalding unit for boiling out the wax (100°C, 5 minutes). The halves of the flask were separated. The stone surface was painted with separating medium. A heat cured denture base material was mixed according to the manufacturer's instructions and packed into the molds. The upper and lower flasks were closed and maintained under 200 lbs of compression for 30 minutes. The flasks were removed from the hydraulic press and cooled over the bench for 150 minutes. The curing procedure was processed by placing the flasks in the water bath at 71°C for 9 hours. The specimens were left in the flask overnight before removal. And then they were stored in water at room temperature for 24 hours.[33]

Finishing and polishing methods

Heat cured acrylic resin specimens were peripheral polished by a tungsten carbide bur. Then, they were finished with 1,000 grit size waterproof silicon abrasive paper by a polishing machine for 60 seconds as standardization. Finishing was achieved at 5000 rpm. under constant pressure and water irrigation. The abrasive paper also was cleaned under running tap water after each cycle. Group P and PC were then polished with pumice (Whip mix) and Tripoli on soft cloth wheels for 60 seconds using a polishing unit at 5,000 rpm. The polishing was controlled under constant pressure. Meanwhile, groups S and SC were then polished with silicone polishing points (Acrypoint, Shofu). Starting with dark grey polisher (coarse grit) and brown polisher (medium grit) and light grey polisher (fine grit) in the chairside micromotor at 5,000 rpm for 60 seconds each under constant pressure. Finishing and polishing were performed

by 1 operator to avoid operator variability. After polishing, the specimens were ultrasonically cleansed for 30 minutes to eliminate contamination of the surfaces. Then, they were immersed in distilled water for 48 hours at 37°C to promote release of residual monomer.[34] After that, they were dried and sterilized with ethylene oxide.[35]

Palaseal® coating methods

Groups NC, PC and SC were further coated with 1 layer of Palaseal® (Heraeus Kulzer) as shown in figure 1. To begin with, a measurable micropipette (10-1000 µl. size, Finn Pipette® F2) was set at 20 µl. to control coating thickness. Then, the micropipette tip was used to take Palaseal® and drop it on prepared PMMA specimens. Later, a cover slide sheet (22*22 mm.) was carefully put on the prepared specimens to avoid air bubble formation and promote surface smoothness. This procedure was done by one hand operator to avoid operator variability. Lastly, according to the manufacturer's instructions, the specimens were polymerized for 90 seconds in light curing HiLite® power unit (Dentacolor XS; HeraeusKulzer GmbH) after an exposure time approximately 20 seconds.

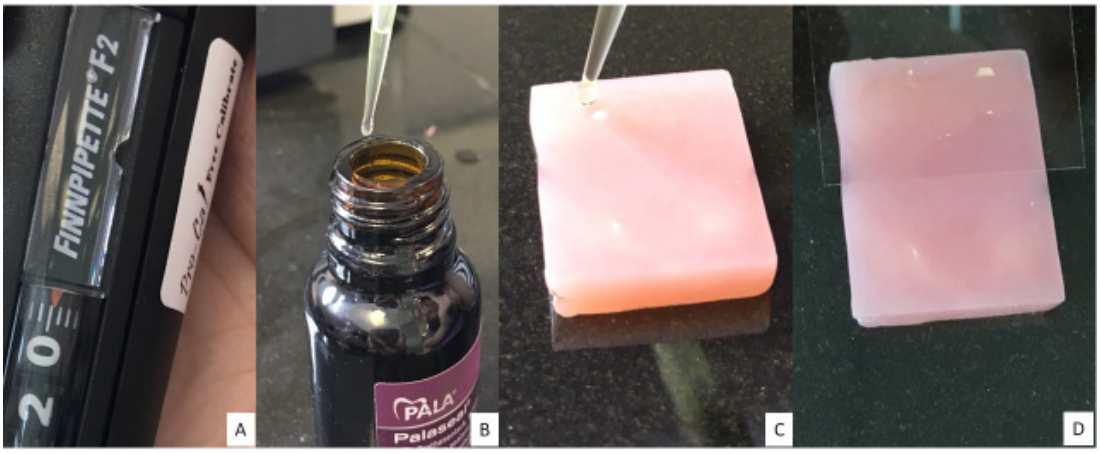

Figure 1 *Procedures of Palaseal® coating. A: set a measurable micropipette at 20 µl., B: take Palaseal® with the micropipette tip, C: drop it on prepared PMMA specimens, D: put a cover slide sheet on the specimens and polymerize the specimens with light curing HiLite® power unit for 90 seconds after an exposure time approximately 20 seconds.*

Palaseal® coating surface smoothness was controlled by using a cover slide sheet. After the complete coating procedure, the specimens were ultrasonically cleansed for 30 minutes to eliminate contamination of the surfaces. Then, they were immersed in distilled water for 48 hours at 37°C.[29] After that, they were dried and sterilized with ethylene oxide.[30] The specimens were kept into the vacuum sealed bags. Also, they were held with gloves to prevent them from contamination of the surfaces before during and after testing.

Measurement of surface roughness

A laser noncontact profilometer (Alicona, Infinite Focus SL, Austria) was used to measure the surface roughness of the specimens in each group. To explain, it calculated the arithmetic average height (Ra) of the specimens. A scan size was fixed by the magnification of the optical system. The magnification of the objective lens used in the measurement was *50 and scanning duration for each line was 5 minutes. The surface roughness was derived from computing the numeral values of the surface profile. The Ra value was able to indicate the overall surface roughness. Also, they could be defined as the mean value of absolute distance of the roughness profiles from the mean line within the measuring distance. For each specimen, a central area of 5*5 mm. was scanned by 3 lines with a profile length of 1.25 mm and a scan size of the area was Lc 250 µm.

Visual surface analysis

A Scanning Electron Microscope (SEM) was used to visualize the surface topography and verify the surface roughness of control and experimental samples. One sample from each group was visualized at 1000x, 3000x, and 5000x magnification. An effort was made to focus on a showing area and adjustment of the higher magnification while remaining on the same area was also done.

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) software (version 23, SPSS Inc., IBM Corp. Chicago, IL, USA) at 95% confidence of level was used to analyze the collected data. A *p*-value ≤ 0.05 was significantly considered. Mean surface roughness values were compared between various groups using two-way ANOVA. Also, Tukey Honestly Significant Difference (HSD) was chose to test for significant differences in the mean surface roughness values of each group.

Results

Two-way ANOVA test showed results in table 4. According to F values and *p*-value, they could be interpreted as following:

1) Surface roughness was significantly different across surface polishing.
2) Different Palaseal® coating had significantly difference in surface roughness.
3) There was significant interaction between surface polishing and Palaseal® coating in surface roughness.

Table 4 *The statistic results of Two-way ANOVA.*

Source	Type III Sum of Square	df	Mean Square	F	Sig.
Corrected Model	3960993.700	5	792198.740	1005.708	0.000
Intercept	23007205.700	1	23007205.700	29207.976	0.000
Surface Polishing	2762077.758	2	1381038.879	1753.249	0.000
Palaseal® Coating	656904.381	1	656904.381	833.950	0.000
Surface Polishing * Palaseal® Coating	542011.559	2	271005.780	344.046	0.000
Error	137060.292	174	787.703		
Total	27105259.690	180			
Corrected Total	4098053.990	179			

Next, pairwise comparison was conducted to test which pairs of surfaces polishing and Palaseal® coating were different in surface roughness. It was shown in table 5. Also, estimated marginal means of surface roughness (Ra) graph were plotted to analyze effect of interaction and presented in figure 2.

Table 5 *Multiple comparison and descriptive statistics (surface polishing)*

	Mean Difference	Std. Error of Difference	95% Confidence Interval of the Difference		*t*	df	Sig. (2-tailed)
			Lower	Upper			
Control - Pumice	269.920	18.864	232.248	307.591	14.309	65[b]	0.000[a]
Control - Silicone	254.999	18.959	217.151	292.848	13.450	66[b]	0.000[a]
Pumice - Silicone	-14.920	6.28348	-27.363	-2.477	-2.374	118	0.019[a]

**The letter "a" superscript meant significant difference at 0.05 between groups at 95% confidence level. The letter "b" superscript meant t-test came from unequal variances assumed.*

	Mean (nm.)	Standard Deviation
Control Non Coating	670.5	30.7
Control Coating	394.5	30.1
Pumice Non Coating	283.2	25.8
Pumice Coating	241.9	25.3
Silicone Non Coating	300.1	31.8
Silicone Coating	254.9	23.7

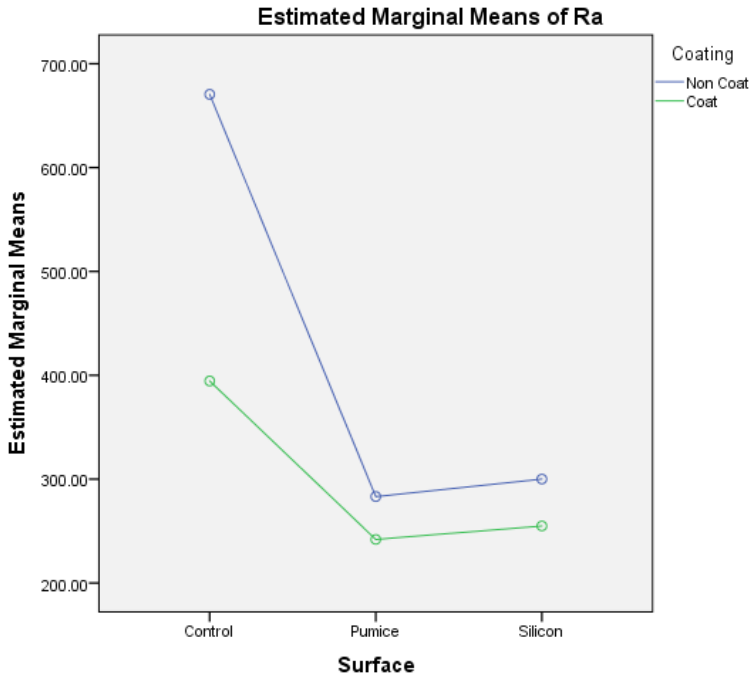

Figure 2 *Estimated marginal means of Ra (Surface Polishing * Palaseal® Coating)*

Starting with surface polishing, figure 2 illustrated means of each surface. It is clearly seen that control group had the highest mean, followed by silicone and pumice groups, respectively. Besides, table 5 showed pairwise comparison of each surface. Every pair had *p*-value less than significance level 0.05. Consequently, surface roughness could be ordered from maximum to minimum by control, pumice and silicone groups, respectively.

Table 6 *Multiple Comparison and Descriptive Statistics (Palaseal® Coating)*

	Mean Difference	Std. Error of Difference	95% Confidence Interval of the Difference		*t*	df	Sig. (2-tailed)
			Lower	Upper			
Non-Coating - Coating	120.822	20.727	79.776	161.867	5.829	118[b]	0.000[a]

**The letter "a" superscript meant significant difference at 0.05 between groups at 95% confidence level. The letter "b" superscript meant t-test came from unequal variances assumed.*

	Mean (nm.)	Standard Deviation
Non-Coating	417.9	182.1
Coating	297.1	74.2

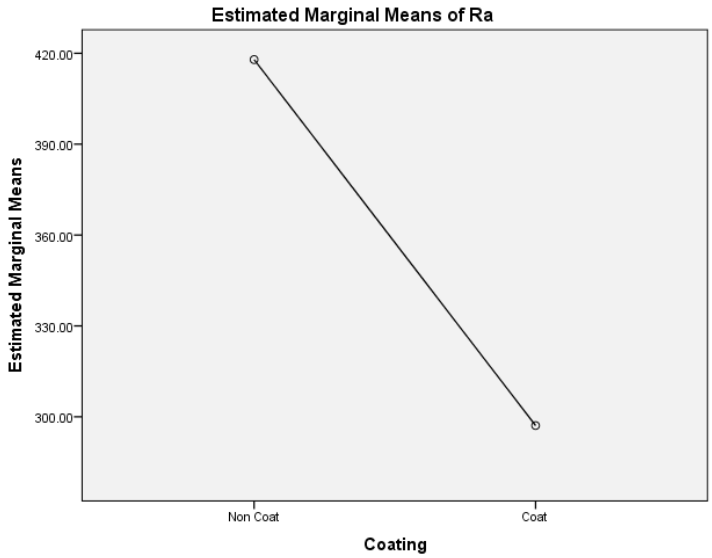

Figure 3 *Estimated marginal means of Ra (nm.) (Palaseal® Coating)*

Figure 3 illustrated clearly that mean of surface roughness for coating was dramatically lower than non-coating. Mean difference of non-coating groups was higher than coating groups. *P*-value shown in table 6 was less than significance level 0.05. Consequently, it was concluded that surface roughness of non-coating was higher than coating.

Lastly, the *t*-test results in table 7 presented that every combination was significant difference in surface roughness with other combinations. All *p*-values in the table were less than significance level 0.05.

Moreover, figure 4 depicted estimated marginal means of surface roughness by surface polishing and Palaseal® coating. A green line represented coating; whereas, a blue line referred to non-coating. Position of the green line was under the blue line, which meant that surface roughness of coating groups was lower than non-coating groups across three types of surface roughness. Also, surface roughness of control groups was the highest, followed by silicone and pumice groups, for both coating and non-coating groups.

In conclusion, there was significant difference in surface roughness across surface polishing, where pumice groups had the least roughness and control group had the most roughness. In addition, coating groups had less roughness on surface than non-coating groups. Finally, there was interaction between surface polishing and Palaseal® coating on surface roughness.

Scanning electron microscope images (5000x magnification) of poly-methylmethacrylate (PMMA) specimens (Fig. 5) revealed results which were similar to surface roughness measurements. To explain, (D) group PC had the smoothest surface while (A) group N had the roughest surface compared to the others. Furthermore, Palaseal® coated groups (group NC, PC, SC) had smoother surface than Palaseal® uncoated groups (N, P, S). In addition, group P has smoother surface than group S and group N respectively for coated and uncoated groups.

Table 7 Multiple Comparison and Descriptive Statistics (Surface Polishing * Palaseal® Coating)

	Mean Difference	Std. Error of Difference	95% Confidence Interval of the Difference		*t*	df	Sig. (2-tailed)
			Lower	Upper			
Control Non Coating – Control Coating	276.013	7.839	260.321	291.705	35.210	58	0.000[a]
Control Non Coating – Pumice Non Coating	387.286	7.317	372.630	401.943	52.926	56[b]	0.000[a]
Control Non Coating – Pumice Coating	428.565	7.259	414.025	443.107	59.041	56[b]	0.000[a]
Control Non Coating – Silicone Non Coating	370.420	8.069	354.267	386.572	45.904	58	0.000[a]
Control Non Coating – Silicone Coating	415.592	7.070	401.420	429.764	58.780	55[b]	0.000[a]
Control Coating – Pumice Non Coating	111.273	7.237	96.787	125.759	15.376	58	0.000[a]
Control Coating – Pumice Coating	152.553	7.177	138.1767	166.929	21.254	56[b]	0.000[a]
Control Coating – Silicone Non Coating	94.407	7.996	78.400	110.413	11.806	58	0.000[a]
Control Coating – Silicone Coating	139.579	6.987	125.577	153.581	19.978	55[b]	0.000[a]
Pumice Non Coating – Pumice Coating	41.279	6.603	29.060	53.498	6.251	58	0.000[a]
Pumice Non Coating – Silicone Non Coating	-16.867	7.486	-31.851	-1.882	-2.253	58	0.028[a]
Pumice Non Coating – Silicone Coating	28.306	6.396	15.503	41.109	4.426	58	0.000[a]
Pumice Coating – Silicone Non Coating	-58.146	7.428	-73.016	-43.276	-7.828	58	0.000[a]
Pumice Coating – Silicone Coating	-12.973	6.329	-25.642	-0.305	-2.050	58	0.045[a]
Silicone Non Coating – Silicone Coating	45.173	7.244	30.672	59.674	6.236	58	0.000[a]

**The letter "a" superscript meant significant difference at 0.05 between groups at 95% confidence level. The letter "b" superscript meant t-test came from unequal variances assumed.*

	Mean (nm.)	Standard Deviation
Control Non Coating	670.5	30.7
Control Coating	394.5	30.1
Pumice Non Coating	283.2	25.8
Pumice Coating	241.9	25.3
Silicone Non Coating	300.1	31.8
Silicone Coating	254.9	23.7

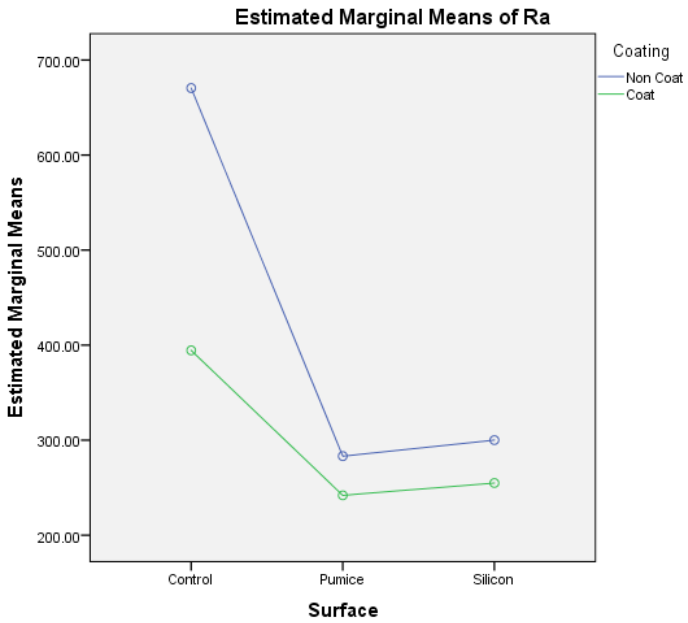

Figure 4 *Estimated marginal means of Ra (Surface Polishing * Palaseal® Coating)*

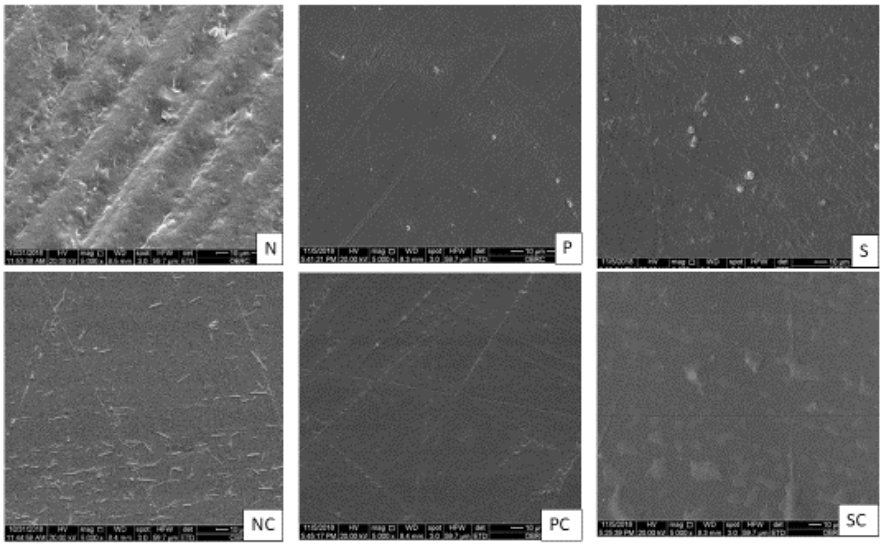

Figure 5 *Scanning electron microscope images (5000xmagnification) of poly-methylmethacrylate (PMMA) specimens. N: unpolished and uncoated group, NC: unpolished and coated group, P: polished with pumice and Tripoli and uncoated group, PC: polished with pumice and Tripoli and coated group, S: polished with silicone points and uncoated group, SC: polished with silicone points and coated group.*

Discussion

This study investigated how Palaseal® coating and different polishing techniques would affect surface roughness of heat polymerized denture base acrylic resins. Heat polymerized acrylic resin material was chosen to be the material of choices instead of auto polymerized acrylic resin material because of many reasons. Firstly, auto-polymerized acrylic resins has more residual monomer content than heat polymerized acrylic resins.[20] Secondly, surface hardness and flexural strength of heat-polymerized resin is higher than auto-polymerized resin.[30] Thirdly, using heat-polymerized denture base acrylic resin obtained higher bond strength to highly crosslinked tooth compared to auto-polymerized resin.[31] Finally, conventionally polished auto-polymerized resin remained porous which promoted plaque formation and bacterial contamination compared to conventionally polished heat polymerized resin.[32]

Conventional lathe polishing and chairside polishing was most common polishing systems used in process of polishing acrylic resins. Chairside polishing were preferred to use for tissue adjustment or occlusal adjustment on the surfaces of complete or partial dentures during delivery visit or post insertion visit.[17,20,28] However, chairside polishing technique provided higher surface roughness than conventional lathe polishing technique.[17] As a similar, the result showed that the mean Ra value of group S was higher than that of group P. This finding was as the same as the result of previous studies.[19-21] Pumice and Tripoli polishing technique was used as a conventional lathe polishing due to being a traditional technique utilizing pumice mixed with water to form a mud-like material for finishing and polishing denture base acrylic resins. Thus it was chosen to stand for a laboratory polishing technique in this study. In addition, there was a previous study found that polishing with pumice and gold rouge provided higher surface roughness of heat-cured acrylic resins materials than polishing with polishing paste and universal polishing paste respectively. However, pumice and gold rouge values were well within the threshold value of 0.2 mm.[14] As a consequence, pumice was used as one of polishing techniques instead of using universal polishing paste in this study. According to the manufacturer, the particle size of fine grain pumice (Whip mix) was 40 to 200 µm. which was moderate rough compared to that of abrasive particles in toothpaste which had a grain size 4-12 µm.[36] However, toothpaste which had the great abrasive effect to damage the surface of denture base material should be avoided while cleaning the denture.[37] Moreover, the result showed that the smoothest surfaces were produced when specimens were polished with pumice and Tripoli and then coated with Palaseal®. A reasonable explanation was that the smoother surface of specimens after the polishing was, the more chance of smoother surfaces of the specimens could be after Palaseal® coating. Furthermore, the consequences of this study showed that Palaseal® coating could lead to produce surfaces with Ra values within a range 0.241-0.254 µm which was close to Ra value 0.2 µm. as the threshold for microbial colonization.[20,28,29] In addition, it presented that a reduction of mean Ra values of all Palaseal® coated groups (NC, PC, SC) was statistically significant (P<0.01). It could be explained that Palaseal® coating was able to effectively seal rough surfaces of both acrylic resins polished with pumice and Tripoli and silicone points.

In this study, a non-contact laser profilometer was used to measure surface roughness instead of using a contact stylus profilometer because of many advantages. First, a procedure of using a non-contact laser profilometer was less complicated than that of using a contact stylus type profilometer.[38] Second, there was no a diamond or ruby stylus related to potential damage of the specimen while moving on its surface in a non-contact laser. Lastly, the average gradient of the surface roughness was considered in measurement of the deviations in the vertical direction.[39] However, there were some limitations in using a non-contact laser profilometer. Too shiny specimens were

measured Ra values with difficulty because of their reflection of the light. Thus, the right angle should be found to measure them. Furthermore, a non-contact laser profilometer was less available than a stylus profilometer. In this study, arithmetic average height (Ra) was calculated in the profilometer because Ra was the most common amplitude parameter which was used to characterize surface roughness.[38] Ra was more preferable than the Rz and Rq because of sensitivity of Rz in case of high pecks and deep valleys and unsuitability for a small deviation from the mean line of Rq.[40]

In a polishing procedure with pumice and Tripoli and silicone points, one hand operator was used in the procedures instead of a polishing machine. As a consequence, human errors could be found. In a Palaseal® coating procedure, a measurable micropipette (20 µm.) was used to measure the volume of Palaseal® coating agent and to control coating thickness before applying. Then, a cover slide sheet (22*22 mm) was used to put on the coated surface of specimens to control surface smoothness of coating agents. According to Manufacturer's instructions, an applicator like a small brush was recommended to use for application. However, the applicator provided unexpected thickness and surface smoothness of the coating agent. Therefore, the cover slide sheet would prefer to the applicator.

Limitation in this study was that the surfaces of PMMA specimens were flat whereas any removable prosthesis had curve surfaces. Despite the limitation, Palaseal® coating agent could be effectively reduce surface roughness of acrylic resins specimens as presented by decrease in the mean Ra values and confirmed by SEM images.

Conclusions

In spite of the limitations of this study, and the conclusion based on the obtained results, it may be concluded as the following sentences.

1) Palaseal® coating on heat polymerized denture base acrylic resins produced reduction of surface roughness of acrylic resins both polished with pumice and Tripoli and silicone points.

2) Palaseal® coating on heat polymerized denture base acrylic resins even performed decrease in surface roughness of acrylic resins only finished with abrasive sandpaper.

3) Polishing with pumice and Tripoli was more effective to increase surface smoothness of heat-polymerized denture base acrylic resins than polishing with silicone points.

Therefore, denture base acrylic resins adjusted during delivery visit should be polished with a conventional laboratory technique (pumice and Tripoli) before Palaseal® coating because of obtaining the smoothest surface of acrylic resins. However, the laboratory technique after denture base adjustment may not be available in some dental clinics. Thus, a chairside polishing technique (silicone points) could be an acceptable option before Palaseal® coating based on this study.

However, further studies related to efficacy of Palaseal® coating agent should be supported such as tendency to reduce adherence of candida albicans on Palaseal® coated acrylic resin and longevity of Palaseal® coat after brushing or accelerated aging.

References

1. Salerno C, Pascale M, Contaldo M, Esposito V, Busciolano M, Milillo L, *et al.* Candida-associated denture stomatitis. ***Med Oral Pathol Oral Cir Bucal*** 2011;16(2):e139-43.

2. Zissis A, Yannikakis S, Polyzois G, Harrison A. A long term study on residual monomer release from denture materials. ***Eur J Prosthodont Restor Dent*** 2008;16(2):81-4.

3. Arendorf TM, Walker DM. Denture stomatitis: a review. ***J Oral Rehabil*** 1987;14(3):217-27.

4. Nikawa H, Hamada T, Yamamoto T. Denture plaque--past and recent concerns. ***J Dent*** 1998;26(4):299-304.

5. Ramage G, Tomsett K, Wickes BL, Lopez-Ribot JL, Redding SW. Denture stomatitis: a role for Candida biofilms. ***Oral Surg Oral Med Oral Pathol Oral Radiol Endod***2004;98(1):53-9.

6. Ramage G, Vandewalle K, Wickes BL, Lopez-Ribot JL. Characteristics of biofilm formation by Candida albicans. ***Rev Iberoam Micol*** 2001;18(4):163-70.

7. Rodriguez Acosta EJ, da Silva PM, Jacobina M, Lara VS, Neppelenbroek KH, Porto VC. *Candida albicans* adherence to denture base material: chemical disinfection and the effect of acquired salivary pellicle formation. ***J Prosthodont*** 2015;24(3):200-6.
8. Srividya S, Nair C, Shetty J. Effect of different polishing agents on surface finish and hardness of denture base acrylic resins: a comparative study. ***Int J Prosth and Res Dent*** 2011;1:7-11.
9. Liu Y, Zhao Q. Influence of surface energy of modified surfaces on bacterial adhesion. ***Biophys Chem*** 2005;117(1):39-45.
10. Bollen CM, Lambrechts P, Quirynen M. Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: a review of the literature. ***Dent Mater*** 1997;13(4):258-69.
11. Teughels W, Van Assche N, Sliepen I, Quirynen M. Effect of material characteristics and/or surface topography on biofilm development. ***Clin Oral Implants Res*** 2006;17 Suppl 2:68-81.
12. Bollen CM, Papaioanno W, Van Eldere J, Schepers E, Quirynen M, van Steenberghe D. The influence of abutment surface roughness on plaque accumulation and peri-implant mucositis. ***Clin Oral Implants Res*** 1996;7(3):201-11.
13. Sofou A, Emmanouil J, Peutzfeldt A, Owall B. The effect of different polishing techniques on the surface roughness of acrylic resin materials. ***Eur J Prosthodont Restor Dent*** 2001;9(3-4):117-22.
14. Rao DC, Kalavathy N, Mohammad HS, Hariprasad A, Kumar CR. Evaluation of the surface roughness of three heat-cured acrylic denture base resins with different conventional lathe polishing techniques: A comparative study. ***J Indian Prosthodont Soc*** 2015; 15(4):374-80.
15. Al-Rifaiy MQ. The effect of mechanical and chemical polishing techniques on the surface roughness of denture base acrylic resins. ***Saudi Dent J*** 2010;22(1):13-7.
16. Alammari MR. The influence of polishing techniques on pre-polymerized CAD\CAM acrylic resin denture bases. ***Electronic physician*** 2017;9(10):5452-8.
17. Kuhar M, Funduk N. Effects of polishing techniques on the surface roughness of acrylic denture base resins. ***J Prosthet Dent*** 2005;93(1):76-85.
18. Gungor H, Gundogdu M, Yesil Duymus Z. Investigation of the effect of different polishing techniques on the surface roughness of denture base and repair materials. ***J Prosthet Dent*** 2014;112(5):1271-7.
19. Chatzivasileiou K, Emmanouil I, Kotsiomiti E, Pissiotis A. Polishing of denture base acrylic resin with chairside polishing kits: an SEM and surface roughness study. ***Int J Prosthodont*** 2013;26(1):79-81.
20. Zissis AJ, Polyzois GL, Yannikakis SA, Harrison A. Roughness of denture materials: a comparative study. ***Int J Prosthodont*** 2000;13(2):136-40.
21. Arai T, Ueda T, Sugiyama T, Sakurai K. Inhibiting microbial adhesion to denture base acrylic resin by titanium dioxide coating. ***J Oral Rehabil*** 2009;36(12):902-8.
22. Lazarin AA, Machado AL, Zamperini CA, Wady AF, Spolidorio DM, Vergani CE. Effect of experimental photopolymerized coatings on the hydrophobicity of a denture base acrylic resin and on Candida albicans adhesion. ***Arch Oral Biol*** 2013;58(1):1-9.
23. Szabo G, Valderhaug J, Ruyter IE. Some properties of a denture acrylic coating. ***Acto Odontol Scand*** 1985;43(4):249-56.
24. Silva MJ, de Oliveira DG, Marcillo OO, Neppelenbroek KH, Lara VS, Porto VC. Effect of denture-coating composite on Candida albicans biofilm and surface degradation after disinfection protocol. ***Int Dent J*** 2016;66(2):86-92.
25. Bourlidi S, Qureshi J, Soo S, Petridis H. Effect of different initial finishes and Parylene coating thickness on the surface properties of coated PMMA. ***J Prosthet Dent*** 2016;115(3):363-70.
26. Sahin O, Koroglu A, Dede DO, Yilmaz B. Effect of surface sealant agents on the surface roughness and color stability of denture base materials. ***J Prosthet Dent*** 2016;116(4):610-6.
27. Isma Bertrand MF, Leforestier E, Muller M, Lupi-Pegurier L, Bolla M. Effect of surface penetrating sealant on surface texture and microhardness of composite resins. ***J Biomed Mater Res*** 2000;53(6):658-63.
28. Koroglu A, Sahin O, Dede DO, Yilmaz B. Effect of different surface treatment methods on the surface roughness and color stability of interim prosthodontic materials. ***J Prosthet Dent*** 2016;115(4):447-55.
29. Sahin O, Koroglu A, Dede DO, Yilmaz B. Effect of surface sealant agents on the surface roughness and color stability of denture base materials. ***J Prosthet Dent*** 2016;116(4):610-616.
30. Isma Liza Ali, Norsiah Yunus, Mohamed Ibrahim. Abu-Hassan. Hardness, flexural strength, and flexural modulus comparisons of three differently cured denture base systems. ***J Prosthodont*** 2008;17(7):545-549.
31. Korkmaz T, Dogan A, Dogan OM, Demir H. The bond strength of a highly cross-linked denture tooth to denture base polymers: a comparative study. ***J Adhes Dent*** 2011;13(1):85-92.
32. Julie C. Berger Dds MS, F. Driscoll Dmd C, Romberg PhD E, Luo PhD Q, Thompson G. Surface roughness of denture base acrylic resins after processing and after polishing. ***J Prosthet Dent*** 2006;15(3):180-6.
33. Oliveira LV, Mesquita MF, Henriques GE, Consani RL, Fragoso WS. Effect of polishing technique and brushing on surface roughness of acrylic resins. ***J Prosthodont*** 2008;17(4):308-11.
34. Neppelenbroek KH, Pavarina AC, Vergani CE, Giampaolo ET. Hardness of heat-polymerized acrylic resins after disinfection and

long-term water immersion. ***J Prosthet Dent*** 2005;93(2):171-6.
35. Mima EG, Pavarina AC, Neppelenbroek KH, Vergani CE, Spolidorio DM, Machado AL. Effect of different exposure times on microwave irradiation on the disinfection of a hard chairside reline resin. ***J Prosthodont*** 2008;17(4):312-7.
36. Planinsic G. Explore your toothpaste Phys. Educ., 2006, 41, p. 311-6.
37. Zilinskas J, Junevicius J, Cesaitis K, Juneviciute G. The effect of cleaning substances on the surface of denture base material. ***Med Sci Monit*** 2013;19:1142-5.
38. Sherrington I, Smith EH. Modern measurement techniques in surface metrology: part I; stylus instruments, electron microscopy and non-optical comparators. ***Wear*** 1988;125(3):271-88.
39. Poon CY, Bhushan B. Comparison of surface roughness measurements by stylus profiler, AFM and non-contact optical profiler. ***Wear*** 1995;190(1):76-88.
40 Gadelmawla ES, Koura MM, Maksoud T, Elewa I, Soliman H. Roughness parameters. ***J Mater Process Technol*** 2002;123(1):133-45.