

Effect of denture cleaning on abrasion resistance and surface topography of polymerized CAD CAM acrylic resin denture base

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Abstract

Background: The application of computer-aided design computer-aided manufacturing (CAD CAM) technology in the fabrication of complete dentures, offers numerous advantages as it provides optimum fit and eliminates polymerization shrinkage of the acrylic base. Additionally, the porosity and surface roughness of CAD CAM resins is less compared to conventionally processed resins which leads to a decrease in the adhesion of bacteria on the denture base, which is associated with many conditions including halitosis and aspiration pneumonia in elderly denture wearers.

Aim: To evaluate the influence of tooth brushing with dentifrices on CAD CAM resin blocks in terms of abrasion resistance, surface roughness and scanning electron photomicrography.

Methods: This experimental study was carried out at the Faculty of Dentistry of King Abdulaziz University during 2016. A total of 40 rectangular shaped polymerized CAD CAM resin samples were subjected to 40,000 and 60,000 brushing strokes under a 200-gram vertical load simulating three years of tooth brushing strokes using commercially available denture cleaning dentifrice. Data were analyzed by SPSS version 20, using descriptive statistics and ANOVA.

Results: ANOVA test revealed a statistical significant weight loss of CAD CAM acrylic resin denture base specimens following 40,000 and 60,000 brushing strokes as well as a statistical significant change ($p=0.0.5$) in the surface roughness following brushing. The CAD CAM resin samples SEM baseline imaging revealed a relatively smooth homogenous surface, but following 40,000 and 60,000 brushing strokes, imaging displayed the presence of small scratches on the surface.

Conclusion: CAD CAM resin displayed a homogenous surface initially with low surface roughness that was significantly affected following simulating three years of manual brushing, but despite the significant weight loss, the findings are within the clinically acceptable limits.

Keywords: Denture cleansing, Denture base materials, CAD CAM, Abrasion resistance, Surface roughness

1. Introduction

The oral cavity environment promotes the formation, accumulation and deposition of biofilm on the surfaces of natural dentition and prostheses which is referred to as dental plaque and denture plaque respectively (1). Initially, the microflora of denture plaque was believed to be similar to that of dental plaque (2). However, recent reports suggest that although the matured biofilm accumulating on natural dentition and denture surfaces may have a similar bacterial count, the denture biofilms were found to have a higher content of *Streptococcus mutans*, *Streptococcus mitis* and *Streptococcus oralis*, whereas dental plaque displayed higher counts of *Neisseria mucosa*, *Selenomonas noxia* and *Tannerella forsythia*. Upon cleaning, the redevelopment of plaque was found to be more rapid and complex on natural dentition (3). Denture plaque is composed of a combination of microorganisms including bacteria and fungi as well as desquamated epithelial cells that are bound within a mucopolysaccharide matrix which

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allows the binding of plaque to the dentures' surfaces. (2). The accumulation of *Candida albicans*, which is a commonly found microorganism in the oral cavity, is associated with mucosal inflammation and halitosis (4). Denture related stomatitis is a prevalent condition often seen in denture wearers resulting from prolonged accumulation of denture plaque (5). Oral bacteria are associated with various other conditions including gastrointestinal infection, bacterial endocarditis and chronic obstructive pulmonary disease (1). Furthermore, swallowing and / or aspiration of microorganism accumulating on denture surfaces is linked to aspiration pneumonia in the elderly (6). It was reported that bacteria causing respiratory infection commonly colonized the denture surfaces of dependent elderly, which suggests that dentures may provide a reservoir of possible respiratory pathogens (7-9). Hence, maintaining good oral hygiene through routine denture cleaning is essential in the prevention of disease among denture wearers especially the frail elderly. Denture cleaning may be performed mechanically through manual brushing, or the use of ultrasonic water bath to remove denture-plaque and biofilms accumulation on the surfaces of dental prostheses (10). Brushing, the use of household bleach or vinegar solution and the immersion in commercially available effervescent products are all cleaning methods which minimize the accumulation of denture plaque (11). The utilization of denture cleansers was reported to significantly decrease the number of microorganisms on denture surfaces (12, 13). Mechanical cleaning with a toothbrush, dentifrice and water is an effective and simple method of removing denture plaque, but can result in wear of the denture base and relining materials due to the resin's low abrasion resistance. The resulting irregularities on the surface of the acrylic resin denture favors biofilm formation and pigmentation (4, 14, 15). Furthermore, brushing of acrylic resin denture bases may cause loss of mass, reduction of surface polish and surface detail as well as an increase in surface roughness which facilitates biofilm formation. It has been suggested that a surface roughness of 0.2 μm is the threshold for bacterial adhesion (16). Numerous factors can influence the degree of denture surface abrasion that results from cleaning. These include the abrasiveness of the dentifrice; the softness of the bristles; the technique used, the frequency of cleaning and force applied during brushing in addition to the mechanical properties of the denture base material including hardness and wear resistance (16-18). The composition of dentifrices is complex and varies among different brands. The main components are usually: water, detergent, thickening agent and specific coloring, flavoring and abrasive agents. The abrasiveness of such agents can also have a detrimental effect on the surface roughness of the denture prostheses. Most dentifrices contain silica and calcium carbonate as abrasive particles (19, 20). Classically and for a long time, heat cured Poly Methyl Methacrylate (PMMA) resin was the material of choice for the fabrication of removable prostheses due to its many attributes including aesthetic properties and ease of handling. However, and as a direct result of the heat curing processing technique, a continuous leaching of methyl methacrylate MMA monomer occurs and results in hypersensitivity to the material (21). The leaching of monomer subjects the resin to water sorption and adsorption thus affecting the dimensional stability. This weakens the mechanical strength of the resin Rahul Bhola (22). Such limitations have led to the development of new polymeric materials and processing techniques such as injection molding and the computer-aided design and computer-aided manufacturing CAD CAM milling of resin blocks for the fabrication of complete denture. CAD CAM technology for the fabrication of complete dentures allows the scanning and registration of the denture bearing area and relevant oral structures. The data is then transmitted to the software program where the teeth can be articulated and exported to a milling device for the fabrication of the complete dentures (23). Such technology offers numerous advantages, most importantly is the reduced chair time required for treatment as it replaces the clinical step of impression taking and all steps required for the setting of the artificial teeth with the advantage of patients' participation in denture design. Additionally, it has been suggested that the one-set alignment of the artificial teeth could increase the denture durability (24). Others have reported that CAD CAM technology can improve the accuracy of denture fit since the utilization of pre-polymerized acrylic resin eradicates the shrinkage issues related to the use of the heat cured acrylic resin base. Furthermore, pre-polymerized acrylic resin has lower porosity compared to the conventionally processed denture with a subsequent decrease in the accumulation of plaque and *Candida albicans* on the prostheses (25, 26). The disadvantages associated with the CAD CAM technology in the construction of complete dentures include the challenges associated with establishing the Maxillo-Mandibular relation and the occlusal vertical dimension (27), the high cost of the material and the increased laboratory costs compared with those for conventional method (28). Moreover, the CAD CAM procedure does not offer a trial denture, which is crucial for establishing comfort, aesthetics and phonetics prior to the fabrication of the prostheses (29). The CAD CAM technology employs the use of pre-polymerized resins that are reported to display good color stability and favorable mechanical properties (30). There is very little evidence however, on the effect of denture cleansers on such resins. The current report aims to evaluate the influence of brushing with dentifrices on polymerized CAD CAM resin used to fabricate dentures. This will be through measuring weight loss to evaluate abrasion resistance and the change in surface roughness both quantitatively and optically using the scanning electron photomicrography (SEM).

2. Material and Methods

This was an experimental study that was conducted at the Faculty of Dentistry of King Abdulaziz University during 2016. A total of 40 samples were prepared using polymerized CAD CAM acrylic resin discs (Polident d.o.o. Volčja Draga 42, SI-5293 Volčja Draga, Slovenia) were tested using a soft bristle brush (Oral-B. P&G manufacturing. Ireland Ltd. Green Road, Newbridge, Co. Kildare, Ireland) and a commercially available denture cleaning dentifrice (Colgate Palmolive, Guildford GU2 8JZ, UK).

2.1. Preparation of the specimens for abrasion resistance test

CAD CAM resin discs were cut using a diamond disk (Isomet, Buehler, USA) under water irrigation into rectangular shape, each measuring approximately 65 mm in length, 10 mm in width, and 3 mm in thickness. The specimens were finished and highly polished (1000 grit) under a water cooling system to obtain a mirror like surface. The polished specimens were stored in distilled water at 37 °C for 24 hrs. Each specimen was marked by drilling a small notch on one side using a round bur which was used to indicate the side used for testing.

2.2. Brushing technique

The specimens were dried with absorbent paper until all visible moisture disappeared, and weighed immediately using an analytical digital electronic balance (Sciencetech ZS210 USA) prior to brushing. The initial weight in milligrams was obtained and expressed as (w_1), and subsequent weight loss measured following cleansing. The CAD CAM acrylic resin specimens were fixed and fitted in a slurry bath in the base of the testing brushing machine, while a movable part was equipped with four soft nylon bristled tooth brushes to perform mechanical brushing action on the specimens, similar to that of home cleaning by the patient (Figure 1). A denture cleaning dentifrice was used and all specimens were subjected to 40.000 and 60.000 brushing strokes each, equivalent to 3 years of manual brushing. The machine provides 200-gram vertical load.

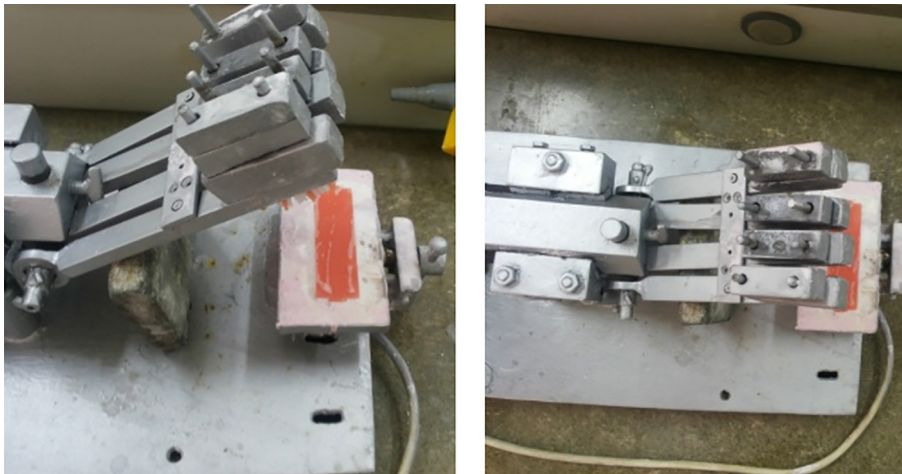


Figure 1. Acrylic resin specimen inside tooth brushing machine.

2.3. Calculation of weight loss (WL)

Following brushing, the specimens were removed and dried with soft absorbent paper. Each specimen was weighed to calculate weight loss as follows:

$$\text{Weight loss (WL)} = w_1 - w_2$$

$$\text{Weight loss (WL)} = w_1 - w_3$$

Where: w_1 : The initial weight, w_2 : The weight after 40.000 brush strokes, and w_3 : The weight after 60.000 brush strokes.

2.4. Surface roughness test (Ra)

Surface roughness was evaluated using surface Profilometer (Surftest SJ-201P, Mitutoyo America Corporation) following 40.000 and 60.000 brushing strokes. The stylus of the meter was passed across and perpendicular to the surface of the specimen. Three measurements were obtained from a different area of each specimen and the average of these readings was calculated (Ra) in micron. Surface roughness analysis was conducted by comparing the initial Ra values (Ra_1), after 40.000 (Ra_2) and 60.000 (Ra_3) brush strokes.

2.5. Scanning Electron Microscopy (SEM)

SEM was performed for investigation of the surface topography of the CAD CAM resin specimens before and after brushing, to provide details of surface abrasion. SEM (Zeiss EVO MA-10 Carl Zeiss U.K.) was used for imaging. To assure standardization, samples were mounted onto the SEM sample holder at the same orientation each time, to scan and image the same area. Imaging was performed at x350 and x700 magnification.

2.6. Statistical analysis

All statistical analysis was performed using the Statistical Package for Social Science (SPSS) version 20 (IBM Corp., Armonk, NY). Descriptive statistics as means and standard deviations were used. One -way analysis of variance (ANOVA) test for before and after brush was performed for significance at 5 percent level. ANOVA with repeated measures was used for comparison between them.

3. Results

The mean difference of weight loss of CAD CAM acrylic resin denture base specimens following 40,000 and 60,000 brushing strokes was 0.22 mg and 0.4 mg respectively, which was significant ($P < 0.001$). An ANOVA test revealed a statistical significance at 5% level ($p_1 < 0.001$, $p_2 < 0.001$, $p_3 < 0.001$) as shown in Table 1. In Table 1, p_1 represents the significance of = $w_1 - w_2$, p_2 represents the significance of = $w_1 - w_3$, and p_3 represents the significance of = $w_2 - w_3$. The mean value of surface roughness of CAD CAM pre-polymerized resin base specimens before and after brushing strokes were $0.3 \pm 0.07 \mu\text{m}$, $0.4 \pm 0.10 \mu\text{m}$ and $0.4 \pm 0.09 \mu\text{m}$ respectively, which was statistically significant ($p = 0.004$). An ANOVA test revealed a statistical significance at 5% level as shown in Table 2. In Table 2, P_1 represents the significance of = $Ra_1 - Ra_2$, P_2 represents the significance of = $Ra_1 - Ra_3$, and P_3 represents the significance of = $Ra_2 - Ra_3$. The CAD CAM resin samples SEM baseline imaging revealed a relatively smooth homogenous surface at a lower magnification that was confirmed by higher magnification (Figures 2a, 2b). Following 40,000 brushing strokes, the CAD CAM resin samples presented with few fine small scratches on the surface which was confirmed by higher magnification (Figures 3a, 3b). After 60,000 brushing strokes, imaging of the CAD CAM resin displayed the presence of small scratches on the surface which was confirmed at a higher magnification (Figures 4a, 4b).

Table 1. The mean values of weight loss (mg) of CAD CAM resin

Parameter	Baseline	After 40.000	After 60.000
Mean \pm SD	8.87 \pm 0.09	8.65 \pm 0.07	8.47 \pm 0.09
Mean Difference		0.22	0.4
p-value	<0.001		
Significance	$p_1 < 0.001$, $p_2 < 0.001$, $p_3 < 0.001$		

Table 2. The mean values of surface roughness (Ra μm) of CAD CAM resin denture

Parameter	Baseline	After 40.000	After 60.000
Mean \pm SD	0.30 \pm 0.07	0.36 \pm 0.10	0.38 \pm 0.09
p-value	0.004		
Significance	$p_1 < 0.044$, $p_2 < 0.012$, $p_3 < 0.005$		

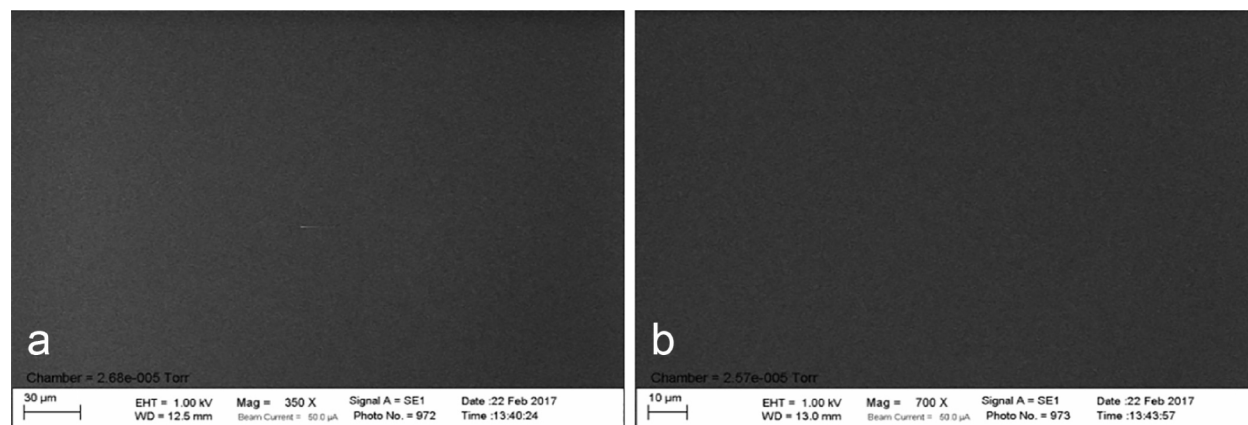


Figure 2. Surface of CAD CAM resin at baseline (a X350 and b X700 magnification).

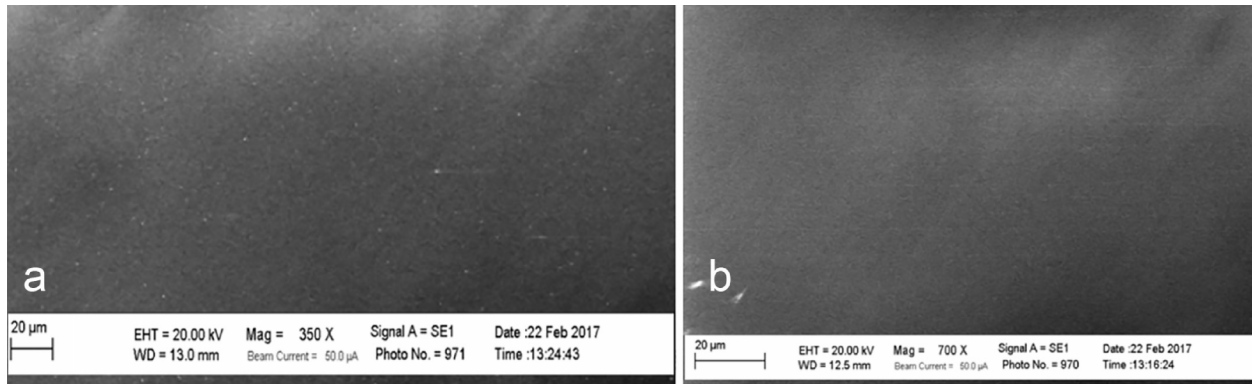


Figure 3. Surface of CAD CAM resin following 40000 brushing strokes (a X350 and b X700 magnification).

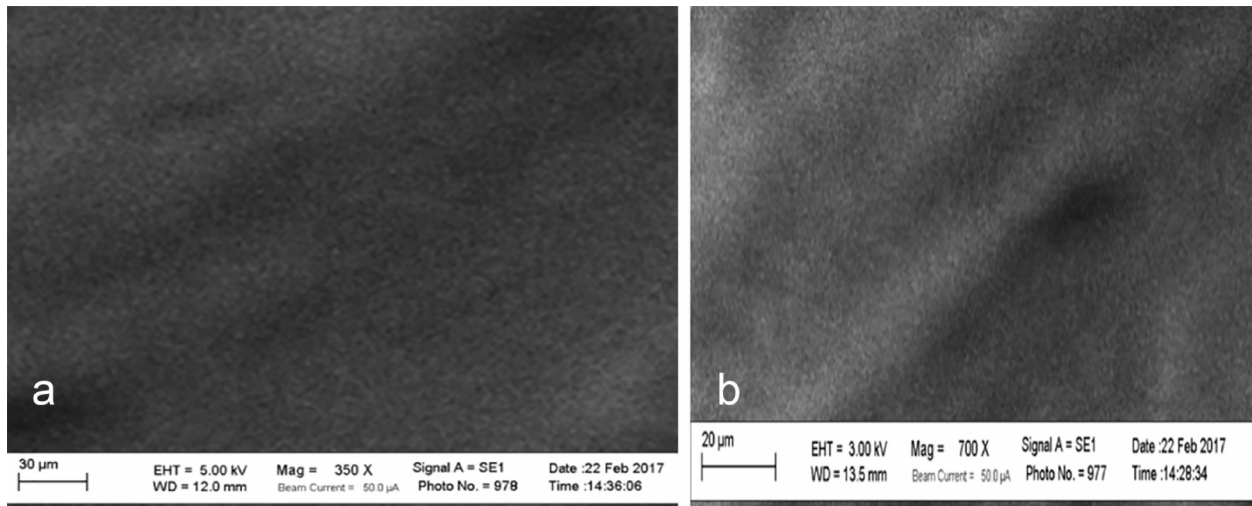


Figure 4. SEM of CAD CAM acrylic resin denture base specimen surface after 60000 brushing strokes (a X350 and b X700 magnification).

4. Discussion

Polymerized CAD CAM acrylic resin denture base has many attributes over conventional acrylic resins mainly due to the method of fabrication that is executed under high pressure and high temperature. This results in low levels of residual monomer and thus, no polymerization shrinkage, making it more hydrophobic and more dimensionally stable than conventionally processed resins. Furthermore, this fabrication method produces a clinically esthetical smooth surface (23, 30). However, there is little evidence relating to the performance of such materials following the daily denture cleansing routine recommended for denture wearers which relies on the use of soft bristle brushes and commercially available dentifrices. A classical review of more than 20 articles was conducted to evaluate the efficacy of various denture cleansers and methods including their advantages and disadvantages of each method (31). The authors stated that chemical denture cleansers are not as effective when used clinically compared to the in vitro assay and advocated the standardization of denture cleansing methods. Since then, many reports on the subject have been published, and the universal practice of denture cleaning through manual brushing or by immersion in denture cleansing solutions has become widely established. The current study employed commercially soft flexible nylon bristled toothbrush with a commercially available denture cleaning paste due to ease of availability to all as well as wide use among complete denture wearers as reported in literature. The use of denture cleaning dentifrices is recommended since brushing using water alone does not remove organic deposits and stains from dentures (4). However, cleaning complete dentures using a soft bristled toothbrush combined with dentifrices was also associated with adverse effects on acrylic resin (32). The results of the present study revealed significant weight loss at 40,000 brushing strokes and at 60,000 strokes and the presence of small scratches following 60,000 strokes which may be due to the abrasive properties of the dentifrice used. The results in weight loss, although significant, are still considered trivial and insufficient to affect the clinical fit of denture bases, as the supporting tissues could compensate a discrepancy of such minor degree (15, 33). In a report to examine the effect of bristle type on the

abrasion of acrylic, profilometry was used to measure the effect of 5000, 10000, 15000 and 20000 brushing strokes (linear vs. rotary actions), and concluded that abrasion was progressive and significantly greater with linear action (14). A report on the abrasion resistance of five various types of acrylic resin artificial teeth was conducted, using a tooth brushing device with soft toothbrushes under a 200 g load and testing three brands of dentifrices. The report concluded that all acrylic teeth presented similar abrasion resistance and that specific dentifrices for dentures tend to cause less damage to acrylic resin (15). The current investigation employed a quantitative analysis of surface roughness (Ra) using a profilometer to measure the irregularities present on this surface before and after two brushing cycles, and to provide information of the abrasive effect on the surface characteristics of the material. The morphology of surface, including description of the surface pattern, porosity and changes in the surface texture were evaluated using scanning electron microscope (SEM) at two magnification powers, which is similar to other test methodologies in the literature (34). The results of the current investigation indicate that CAD CAM resins display initial surface roughness values of $0.3\pm 0.07\ \mu\text{m}$, and values of $0.4\pm 0.10\ \mu\text{m}$ and $0.4\pm 0.09\ \mu\text{m}$ following 40000 and 60000 brushing strokes respectively. These values highlight the importance of a daily denture cleaning routine as it was reported that a surface roughness of $0.2\ \mu\text{m}$ is the threshold for bacterial adhesion (16). These reports studied the abrasion resistance and surface roughness of injection-molded PMMA compared to the compression-molded PMMA by calculating the weight-loss following 100,000 brush strokes as well as measuring surface roughness. They reported no statistical significance in terms of percentage weight-loss between injection-molded and compression-molded specimens, or with regard to surface texture. However, there was a statistically significant difference ($p<0.017$) between injection-molded (producing the highest roughness) and compression-molded PMMA. Alternative denture cleansing routine include immersion in chemical denture cleansers which is reported to result in less abrasion than paste, and combining denture brushing with water alone which is less effective than brushing with dentifrices (4, 12). A smooth scratch free surface of the dental prosthesis is important both esthetically and for oral hygiene, since surface roughness of denture base promotes the adhesion of microorganisms which is present on the surfaces of complete denture even in people with clinically healthy mucosa (35, 36). In a recent study evaluating the abrasiveness of toothbrushes compared to denture brushes on heat cured PMMA vs. microwave-processed resins, five brands of brushes were used in a tooth brushing machine at 17,800 strokes and an additional 35,600 strokes at a load of 200 g. The results indicated an increase in weight loss with time but no change in the surface roughness. Additionally, no statistically significant differences were recorded between toothbrushes and denture brushes weight loss or surface roughness, and concluded that the type of brush and the polymerization method did not influence resin wear after brushing (17). Within the limitations of the current study, the results suggest that the physical properties (in terms of abrasion resistance and surface roughness) of CAD CAM resins used for the fabrication of complete dentures are within the clinically acceptable range.

5. Conclusions

Smooth prosthetic surfaces are crucial to maintain durability as well as plaque resistance of the prostheses surface. The current findings suggest that CAD CAM denture base resins exhibit favorable abrasion resistance characteristics and have low baseline surface roughness values that are not adversely affected by three-years simulated manual brushing. Further investigation is needed to assess the effect of denture cleansing on the other physical properties of CAD CAM resin as well as to compare the effect of other denture cleansing techniques.

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Conflict of Interest:

There is no conflict of interest to be declared.

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