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Original Article

Evaluation of the effect of denture adhesives on surface roughness of two chemically different denture base resins

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ABSTRACT

Objective: To evaluate the effect of four commercially available denture adhesives (DAs) on surface roughness of two chemically different denture base materials. **Materials and Methods:** Fifty specimens of heat-cured polymethyl methacrylate, and another fifty specimens of light-cured urethane dimethacrylate were divided into five groups (n = 10), each was immersed in four prepared DAs (Corega Super Cream, Corega Ultra Powder, Olivafix Cream, Protefix Cream) as well as distilled water (control group). The mean surface roughness (R_a) of the polished and unpolished surfaces of the specimens was recorded using profilometer device. *T*-test for paired observation was used to indicate any changes in surface roughness between the baseline and after 30 days of immersion in the DA. **Results:** Almost all the tested DAs had no significant effect on the roughness of polished and unpolished surfaces of both denture base materials. The Corega super cream DA produced significant increase in the roughness of the polished surfaces of both types of acrylic specimens ($P < 0.05$). **Conclusion:** The majority of the investigated DAs appears not to affect the surface roughness of denture base materials. Only Corega super cream DA produced detectable increase in the roughness of polished surfaces of denture base specimens.

Key words: Denture adhesives, denture base materials, surface roughness

INTRODUCTION

Commercial denture adhesives (DAs) are substances intended to improve the relationship between the denture base and underlying tissue. Some studies show that about 15–33% of the edentulous patients with complete removable prosthesis use complementary adhesive systems.[1,2] In spite of great advantages of using DAs for complete denture wearers, the earlier literature mentions unfavorable characteristics such as vertical dimension increase, mucosa hypersensitivity reactions, and altered oral flora.[2-4]

During use, the denture base materials have to retain their mechanical and physical properties, as well as surface smoothness and integrity, be impermeable to oral fluids and resist the bacterial action and growth.[5]

Surface roughness and degradation of the acrylic dentures contribute to the adherence, bonding, and colonization of microorganisms.[6-8] The consequences may be an increase in the prevalence of denture-related stomatitis,

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rate of staining, halitosis, as well as psychological discomfort, nausea, and social problems.[9-12]

In addition to the toxic effect of the leach out components of acrylic resin degradation, premature failure of acrylic denture base is highly expected as a consequence of the changes in physical and mechanical properties.[13]

The literature is lacking information about the influence of the DA on the surface integrity of denture base materials. This is despite the common use of DA among the edentulous patients. The aim of this study was to evaluate the effect of DAs on the surface roughness of two chemically different denture base resins; heat-cured polymethyl methacrylate (PMMA) resin and light-cured urethane dimethacrylate (UDMA) resin. The hypothesis to be tested is that the application of DA will have no impact on the surface roughness of both types of denture base resins.

MATERIALS AND METHODS

The types, chemical composition, and manufacturers of the DAs and denture base materials used in this study are listed in Table 1.

Sample fabrication

One hundred square samples of two types of denture base resins measuring (10 mm × 10 mm × 2 mm) were prepared. Fifty samples for PMMA resin and 50 samples for UDMA resin.

PMMA specimens were prepared by investing pieces of modeling wax (Cavex-Holand BV) in stone plaster (LabStone-Dentsply) by a conventional flasking procedure in metallic dental flask according to the manufacturer's instructions.

For UDMA (Eclipse) specimens, a silicon mold was created by investing wax into silicon material (Degoform plus-DeguDent GmbH, Germany). The silicon mold was lined with a separating agent (Al-Cote-Dentsply, USA) and warmed in the conditioning oven. Afterward, the prepacked resin was adapted into the silicon mold using finger pressure. The exposed surface of UDMA specimen was lined with air barrier coating (Eclipse, Air Barrier Coating, Dentsply, USA) and polymerization was carried out in a curing unit (Eclipse, Dentsply, USA) for 10 min.

All the specimens were visually inspected and checked for the absence of voids or porosity. Defected samples were discarded. The study specimens were prepared to the required dimensions by finishing discs and stones using a handpiece at low speed. Both surfaces were finished using 280, 360, and 400 grit abrasive papers (Middle East Factory - K.S.A, Riyadh, Saudi Arabia). One surface of each specimen was polished on wet rag wheel with slurry pumice and the other surface was left unpolished.

All the test specimens were stored in distilled water at 37°C for 48 h for residual monomer elimination. After that, all the specimens were dried with air and numbered and the initial surface roughness was measured for both sides of each specimen. Then, the specimens of both groups were randomly divided into five subgroups (n = 10). Four test groups for immersion in four different DA and one control group for immersion in distilled water.

Table 1: Materials used in this study

Product name	Material type	Composition	Manufacturer	Batch number
Corega super cream	Denture adhesive	Poly (methylvinylether/maleic acid) sodium-calcium mixed partial salt, petrolatum, cellulose gum, paraffinum liquidum	Stafford-Miller (Dungarvan, Irland)	V12353A
Corega ultra powder	Denture adhesive	Poly (methylvinylether/maleic acid) sodium-calcium mixed partial salt, cellulose gum, flavor	Stafford-Miller (Dungarvan, Irland)	N13032
Olivafix cream	Denture adhesive	Cellulose gum, Olea Europea (olive oil), calcium/ sodium, PVM/MA copolymer, hydrogenated soybean oil, trihydroxystearin, silica, mentol, lecithin, citrus limonum, menthyl lactate	Bonyf AG- (Liechtenstein. EU) - Swiss	41-27
Protefix cream	Denture adhesive	Poly (methylvinylether/maleic acid) sodium/calcium partial salt, carboxymethyl cellulose, paraffin, vaseline, silica, menthol, azorubin, p-hydroxy-benzoic acid methyl ester	Queisser Pharma (Flensburg, Germany)	088072
Eclipse	Denture base resin	Matrix: UDMA Filler: Silica, PMMA beads	Dentsply, New York, USA	120612
Ecocryl-Hot	Denture base resin	Powder: Methylmethacrylate-copolymer Liquid: Methylmethacrylate-monomer	Protechno, Girona, Spain	12-26964

UDMA: Urethane dimethacrylate, PMMA: Polymethyl methacrylate, PVM/MA: Poly (methylvinylether/maleic acid)

Denture adhesives preparation

One gram of the four used DAs [Table 1] was weighed and mixed with 10 ml distilled water in a plastic container. After dilution with water, the pH values of each DA were measured using pH meter (HANNA pH211-Woonsocket RI USA). Table 2 shows the measured pH values for the used DAs.

Four test groups of PMMA and UDMA specimens were completely immersed in the four prepared DAs, and the fifth group of specimens was immersed in a plastic container with 10 ml distilled water.

The immersion time was 16 h/day. The containers were covered and stored in an incubator at 37°C. Next, the specimens were removed out of the prepared DA and rinsed under running water. After that, each group of samples was stored in distilled water for 8 h at room temperature. The DA was replaced and prepared daily and the procedure was repeated for 30 days.

Measuring the surface roughness (R_a)

The R_a values were measured using a contact profilometer device (MarSurf PS1-MahrGmbH. GÖttingen-Germany). The instrument complied with DIN EN ISO 3274 standards. The profilometer can measure small surface variations by moving a diamond stylus across the specimen surface [Figure 1]. The tracing length of the instrument stylus was 5.6 mm and a cut-off of 0.8 mm at speed of 0.5 mm/s. The R_a value is the arithmetic average assigned to peaks and valleys of an area provided in μm.

The baseline R_a measurements were taken for both sides of each sample of the five study groups before immersion in the adhesives. The stylus moved across the specimen surface and three lines were recorded with a distance of 1 mm between each scanning line. The mean value for the three readings of the R_a was considered the surface roughness value for each specimen surface.

After 30 days of immersion, the specimens were removed, washed with running water for 10 s, and dried with compressed air. The final R_a of each test specimen was measured again as before immersion for both sides. The mean R_a was calculated and tabulated in a special form.

Statistical analysis

The collected data were analyzed using the SPSS statistical package (IBM SPSS Statistics for Windows, Version 20.0, Released 2011, IBM Corp., Armonk, New York, USA).

The mean and standard deviation of R_a for the study groups were calculated using descriptive data analysis.

T-test for paired observation was used to indicate any changes in R_a between the baseline and after 30 days of immersion in the DA.

RESULTS

Mean values and standard deviations of R_a for the PMMA and UDMA specimens at baseline and after 30 days of immersion in the DA are shown in Tables 3-6.

The *t*-test for paired observation indicated significant change in the roughness of the PMMA polished surfaces for the specimens that were immersed in the Corega cream adhesive ($P < 0.05$). No significant changes in surface roughness were noted with the other used DA [Table 3]. The same statistical test revealed that DA had no impact on surface roughness of the unpolished surfaces of the PMMA specimens [Table 5].

Similar results were observed with the UDMA specimens as DA had no impact on roughness of the polished and unpolished surfaces of the

Table 2: pH values of the denture adhesives

Denture adhesive	pH values (at 22.5°C)
Corega super cream	5.52
Corega powder	6.74
Olive fix cream	7.31
Protefix cream	6.13

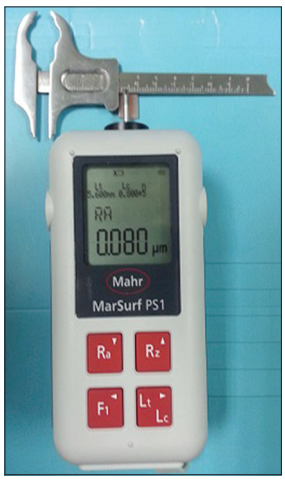

Figure 1: Surface roughness measurement using contact profilometer device

Table 3: Mean values and standard deviations of the R_a of the polished surface of polymethyl methacrylate specimens

Study groups	Polished surface/PMMA			
	Initial R_a value (μm)	Final R_a value (μm)	ΔR_a values (μm)	*P*
Corega cream group	0.129 (0.028)	0.139 (0.022)	0.01 (0.011)	0.023*
Corega powder group	0.109 (0.014)	0.117 (0.021)	0.008 (0.013)	0.079
Olivafix cream group	0.172 (0.046)	0.174 (0.042)	0.002 (0.055)	0.916
Protefix cream group	0.096 (0.018)	0.103 (0.018)	0.007 (0.016)	0.178
Distilled water (control group)	0.143 (0.025)	0.145 (0.024)	0.002 (0.004)	0.102

*Significant difference (P<0.05). PMMA: Polymethyl methacrylate

Table 4: Mean values and standard deviations of the $R_a$of the unpolished surface of urethane dimethacrylate specimens

Study groups	Unpolished surface/UDMA			
	Initial R_a value (μm)	Final R_a value (μm)	ΔR_a values (μm)	*P*
Corega cream group	0.640 (0.076)	0.667 (0.078)	0.027 (0.101)	0.419
Corega powder group	0.649 (0.071)	0.680 (0.046)	0.031 (0.058)	0.126
Olivafix cream group	0.730 (0.038)	0.711 (0.036)	−0.019 (0.056)	0.312
Protefix cream group	0.652 (0.073)	0.672 (0.057)	0.02 (0.089)	0.498
Distilled water (control group)	0.676 (0.072)	0.679 (0.072)	0.003 (0.006)	0.143

UDMA: Urethane dimethacrylate

Table 5: Mean values and standard deviations of the R_a of the unpolished surface of polymethyl methacrylate specimens

Study groups	Unpolished surface/PMMA			
	Initial R_a value (μm)	Final R_a value (μm)	ΔR_a values (μm)	*P*
Corega cream group	0.952 (0.143)	0.983 (0.140)	0.031 (0.142)	0.517
Corega powder group	0.754 (0.060)	0.726 (0.100)	−0.028 (0.115)	0.466
Olivafix cream group	0.967 (0.455)	0.958 (0.428)	−0.009 (0.698)	0.968
Protefix cream group	0.858 (0.101)	0.888 (0.109)	0.03 (0.084)	0.286
Distilled water (control group)	0.901 (0.259)	0.916 (0.262)	0.015 (0.023)	0.061

PMMA: Polymethyl methacrylate

Table 6: Mean values and standard deviations of the R_a of the polished surface of urethane dimethacrylate specimens

Study groups	Polished surface/UDMA			
	Initial R_a value (μm)	Final R_a value (μm)	ΔR_a values (μm)	*P*
Corega cream group	0.129 (0.015)	0.172 (0.042)	0.043 (0.037)	0.006*
Corega powder group	0.161 (0.024)	0.157 (0.024)	−0.004 (0.027)	0.625
Olivafix cream group	0.140 (0.022)	0.143 (0.022)	0.003 (0.035)	0.835
Protefix cream group	0.149 (0.034)	0.155 (0.038)	0.006 (0.011)	0.118
Distilled water (control group)	0.147 (0.019)	0.145 (0.018)	−0.002 (0.012)	0.705

*Significant difference (P<0.05). UDMA: Urethane dimethacrylate

specimens except for the polished surfaces of the specimens that were immersed in Corega cream adhesive [Tables 4 and 6].

DISCUSSION

Most of the characteristics of DA was thoroughly evaluated by the previous investigations, regarding cytotoxic effect, reduction of the mucosal irritation beneath the denture, enhancement of the denture retention, bite force, chewing efficiency, and patient comfort as well as improvement in the oral health-related quality of life.[14] However, the extent to which DA may affect denture surface integrity in term of change in surface roughness is not yet clear. This study can be considered the first attempt to clarify the effect of four commercially available DAs on the surface roughness of two chemically different denture base materials. The heat-cured PMMA is conventional and most commonly used denture base material and the light-cured UDMA denture resin may be used in patient's allergic to MMA monomer.[15,16]

Surface roughness of denture base materials is considered one of the determinant factors in the clinical longevity of the dental prosthesis.[17,18]

Ideally, a surface with the lowest possible roughness is recommended to hinder microorganism retention, prevent local infections and early denture deterioration.[19]

In 1997, a clinical study by Bollen *et al*.[20] established that the threshold R_a for plaque retention of intraoral materials was 0.2 μm. Below this value, no further reduction in plaque accumulation can be expected. Above this value, a proportional increase in plaque accumulation may occur.[21]

In the present study, the changes in surface roughness of the acrylic resin specimens were measured by using a profilometer device as similar to previous investigations.[7,22,23] The main advantage of this method is that it is easy to conduct; accurate and the mean surface roughness of the acrylic specimens can be easily calculated. R_a is the arithmetic average height measurement, being frequently used as a universal roughness parameter for general quality control.[24]

The DAs tested in this study were dissolved in distilled water at percent solution consistent with expected conditions in the oral cavity as recommended by earlier studies.[3,25]

Overall, the findings of this study partially support the hypothesis of no change in surface roughness following the application of DA.

The Corega cream was the only DA that affected the roughness of the polished surface for both types of denture base materials. This finding may be related to the low pH value of the Corega cream (pH = 5.52) compared with other tested DAs as presented in Table 2. Under acidic conditions, the polymer surface may be softened by loss of structural ions.[24] Koda *et al*.[26] found that at lower pH conditions, there was an increase in the concentration of MMA monomer leached from the denture base acrylic resin. In addition, Jaeggi *et al*.[27] stated that under acidic condition, restorative materials including composite resin may suffer degradation which can be predicted by change in the surface topography and roughness.

In a study by Constantinescu *et al*.,[18] the denture base acrylic resins showed higher roughness when the pH was more acid. The authors related the changes in surface features and the increased surface roughness to factors leading to salivary acidity. Love and Biswas[3] recommended that DA with low pH values should not be used in an environment with natural teeth or remnants of natural teeth because the prolonged contact of DA with tooth substance may dissolve hydroxyapatite crystals.

The low pH can also change the UDMA resin matrix by acting as a catalyst for the ester groups that are present in dimethacrylate monomers. This process may cause degradation of the polymer network and lead to a phenomenon known as plasticization that may change the surface properties of the resin.[28,29]

Increase of the surface roughness of the Corega cream group may also be related to the presence of paraffinum liquidum. Among the studied DAs, the Corega cream is the only DA that contains the paraffinum liquidum in its composition. This mineral oil is added to the water-soluble polymer powder to give it the paste form. The liquid paraffin may have a plasticizing effect causing plasticization of polymer chains, leading to material degradation by increased water sorption and solubility.[30]

While the Corega cream affected the roughness of the polished surface of the used denture base materials, there was no apparent effect for this DA on the roughness of the unpolished surface. The relatively short exposure time to the DA may play a role in this finding. Another possible explanation may be due to the difficulty of complete removal of DA from rough surfaces of the samples by the used protocol of cleaning. This opinion may be supported by the clinical study done by Uysal *et al*., who reported that 20–30% of the patients found it difficult or extremely difficult to remove the adhesive from the denture base and oral tissues.[31] The valleys of the rough surface may be clogged by the adhesive remnants after drying with air. Clogging of the valleys may affect R_a value, resulting in nonsignificant effect, as it is known that R_a value is the arithmetic average assigned to peaks and valleys of an area.

The effect of other tested DAs on the surface roughness of both types of denture base materials was nonstatistically significant which is a desirable property for any DA not to alter or degrade the surface of the denture base material on which it is applied.[25,32] This finding may be the outcome of compatibility in the chemical composition between the used acrylic denture base materials and the DA as well as the suitability of its pH values.

The limitation of this *in vitro* study is that the DA was used in one concentration, which does not occur clinically because of the continuous dilution by saliva during denture wearing. However, this concentration could represent longer application time. In addition, the study is limited in simulating the intraoral condition of temperature and pH fluctuations combined with the mechanical loading during masticatory function. Further, the denture base surfaces used in the present study do not adequately represent the intaglio surface features of a denture *in vivo*. In this respect, the effect of DA on surface roughness of denture base materials under *in vivo* conditions may differ from this *in vitro* study. Additional clinical studies are also necessary to clarify the long term effect of different DA on the surface properties of denture base materials.

CONCLUSION

Within the limitations of this study, the majority of the investigated DAs appears not to affect the surface roughness of denture base materials.

Only Corega super cream DA produced detectable increase in the roughness of the polished surface of denture base specimens.

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Conflicts of interest
There are no conflicts of interest.

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