

Effect of Commercially Available Denture Adhesives on Microhardness of a Flexible Denture Base Material

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Abstract

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BACKGROUND: Various clinical cases of thermopress denture base materials necessitate the use of denture adhesives to achieve proper retention and stability of the removable prosthesis. Therefore; the microhardness of these flexible materials as surface property and its' alterations due to the application of various denture adhesives are still crucial issues to be discussed.

AIM: This study aimed to investigate the impact of two commercially available denture adhesives (DAs) on microhardness of a flexible denture base material.

METHODS: A total of 30 duplicate disc specimens (DS) were fabricated from a thermoplastic injection moulded resin (TR). The obtained 30-disc specimens (DS) were stored in distilled water for seven days, and then their microhardness was measured using Knoop Hardness Test (KHN) under a 10 g load for 10 seconds. The denture adhesives were prepared, and 15 DS were immersed in Corega Super Cream, while the other 15 DS were soaked in Fitty Dent Cream. All DS were stored in distilled water at 37°C. After 30 days of immersion in DAs, microhardness of DS was again measured. T-test for paired observation was used to investigate any alterations in microhardness between the baseline and after 30 days of immersion in the DAs. Statistical analysis was performed with SPSS 20®, Graph Pad Prism® and Microsoft Excel 2016 with a significant level set at $P \leq 0.05$.

RESULTS: Student's t-test had revealed a significant difference between both groups after application of denture adhesive as a P value < 0.05. The obtained results showed that DA material type, flexible denture base material and their surface interaction provoke a statistically significant outcome on the mean microhardness.

CONCLUSIONS: DAs were found to affect the microhardness of thermoplastic injection moulded resin (TR); which may jeopardise the durability and serviceability of complete denture and patients' acceptance and comfortability.

Introduction

Actually; removable dentures are remaining essential prostheses for many clinical conditions of oral rehabilitation, especially in cases that need restoration of the edentulous ridges; which are located posterior to the remaining anterior teeth [1]. Since its fortunate introduction in 1937, the polymethyl methacrylate (PMMA) persists as the most popular of all polymeric denture base materials used in removable prosthetic base [2]. Commonly, that acrylic resin consists of the powder form of polymethyl methacrylate (PMMA), and liquid form of methyl

methacrylate (MMA) proportioned mixture that is processed by a heat cured polymerisation technique [3], [4].

Moreover, PMMA has been the resin material of choice for fabrication of nonmetallic denture base prosthesis owing to many advantages including acceptable biocompatibility, the feasibility of manufacturing and manipulation, good aesthetics, favourable physicochemical properties as well as ease of construction, rebase, relining and repair. However, the inherent disadvantage of PMMA resin causes an allergic hypersensitivity reaction to some laboratory technicians and patients. This tissue reaction is provoked by the continuous leaching out of

the residual MMA monomer; therefore, also compromising the mechanical properties and surface hardness of the cured resin [5], [6]. Furthermore, PMMA denture base resin materials are characterized by low impact strength, weak strength properties, reasonable hardness and low fatigue resistance [7].

Currently, some thermoplastic resins like nylons and polyamides successfully became common alternatives to the PMMA resin materials due to the improvement of certain characteristics. The modified thermoplastic polymer characterised by improved physicochemical properties [8]. Thermoplastic resins show a smart, flexible nature which produces comfortable stress breaking a design to the removable partial and complete dentures [9]. Also, polyamide thermoplastic denture base materials offer a proper reflection of the oral tissue colour due to their high transparency (i.e. better esthetics). Also, flexible thermoplastic denture base materials present essential advantages to patients in terms of comfort (i.e. lightweight) [10].

Consequently, thermoplastic resins seem suitable denture base materials especially for patients with hypersensitivity to acrylic monomers (as there are almost no free monomers in this material) and for patients who are allergic to nickel. Ridges are having bilateral undercuts and patients having microstomia are also indicated for thermoplastic resins [11]. Recently, variable thermoplastic denture base materials are commercially available like flexible, flexplate, Proflex and Bio-dentaplastas [12].

Whenever used properly, denture adhesives are considered as safe biomaterials that improve patient comfort, retention and stability of removable prosthesis and psychological security. Indeed, although the denture adhesives greatly enhance the removable denture performance and patient confidence, their use should not be aiming to compensate for the prosthetic denture deficiencies [13]. So, the patient should use the denture adhesive only on dentist advice and on the other hand, the dentist should give the patient full instructions about the proper use and precautions of denture adhesives [14].

Ideal requirements of a commercially available denture adhesive (gel powder, or cream form) should be: biocompatible, easily applied and adhere to the fitting surface of the denture, odorless and tasteless, being adhesive for long period (12 to 16 hours), retentive and stable during functions, comfortable and not favorable for microbial proliferation [15].

Surface microhardness may give an idea about material density; as dense materials usually have high resistance to superficial wear. Therefore, evaluating the microhardness of the thermopress acrylic resins indicates the material's ability to maintain the fine details recorded by the impression [16]. Few studies concerning thermoplastic acrylic

resin microhardness were conducted [17].

Flexible resin polymers were initially introduced for the construction of provisional and immediate prosthesis [18], [19]. Furthermore, the inherent flexibility of these polymeric materials protects this prosthesis from impact and fatigue fractures [20], [21], [22].

Therefore, the purpose of the presented in vitro study was to evaluate and to record any alteration in the mean microhardness value of a thermoplastic flexible base resin polymer when the denture adhesives are utilised.

This study aimed to investigate the impact of two commercially available denture adhesives (DAs) on microhardness of a flexible denture base material.

Material and Methods

Material

The studied two types of commercially available denture adhesives were: Super Corega Cream (Carboxymethyl cellulose-based, Stafford-Miller, Dungarvan Co. Waterford, Ireland) and Fittydent Cream (Sodium Carboxymethyl cellulose and polyvinyl acetate-based, Fittydent Int. GMBH, Pinkafeld, Austria). The investigated thermoplastic injection moulded resin flexible (TR) denture base material was TCS (Thermopress flexible partial and complete denture base resin, Signal Hill, California, USA).

Fabrication of Disc Specimens (DS)

A total of 30 identical disc specimens (10 mm in diameter and 5 mm in thickness) were fabricated from thermoplastic injection moulded resin (TR). Disc wax patterns were first prepared (Cavex set up regular modelling wax, Holland) in a metal split mould held in a metallic frame. After their solidification, the wax patterns were spread and inserted in a metallic flasks containing dental stone type III (Selenor Verde, Industria Zingardi SrL, Italy) to obtain molds for the processing of the tested thermoplastic materials by the injection molding technique, using the microinjection machine (Biostrong 400, Sabilex, Flexifoil S.A, Argentina).

After wax elimination, the thermopress material was manipulated according to the manufacturer's instructions to fill the moulds. After injection, the flasks were cooled down for 15 min. at room temperature. Then, the flasks were opened, and the discs were finished with very fine sandpaper and polished with polishing paste (Abrador-Star Glaze, Universal high-lustre polishing paste, Bredent, Germany). The prepared disc specimens were

visually inspected and checked for the clearance of voids or porosity. Moreover, the disc samples containing those defects were discarded. All the specimens were air dried and numbered.

All the test specimens were stored in distilled water at 37°C for 7 days. The 30-disc specimens were then divided into 2 principal groups (each group contains 15-disc specimens): group I: DS immersed in Corega Super Cream DA and subgroup II: DS immersed in Fitty Dent Cream DA. Then, each group was again considered as two subgroups: subgroup A before application of the Corega Super Cream DA, subgroup B after application of the Corega Super Cream DA, subgroup C before application of the Fitty Dent Cream DA and subgroup D after application of the Fitty Dent Cream.

Denture Adhesives Preparation

The prepared DAs (Corega Super Cream and Fitty Dent Cream) were obtained by weighing one gram of the DA and homogeneously mixed with 10 ml distilled water in a closed glass container. The disc specimens were individually immersed in the glass containers containing the prepared diluted DAs. The immersion time was 16 hours/day. The containers were covered and stored in an incubator at 37°C. Next, the specimens were removed out of the prepared DA, rinsed under running water and dried gently with air. After that, each sample was individually stored in distilled water for 8 hours at room temperature. The prepared diluted DA for each disc specimen was replaced and prepared daily, and the procedure was repeated for successive 30 days [23].

Microhardness Test (g/mm^2)

Microhardness was measured with Knoop microhardness tester (Microhardness HV-1000, China) that was calibrated with a load of 10 g for 10 seconds, by implementing Blue Hill Instron computer software program.

The Knoop hardness (KH) indenter was applying a load of 10g smoothly without impact, for 10 seconds and at four different points of each DS. An indentation was made on the block samples using diamond Knoop indenter which; is a pyramid in shape, giving a diamond or rhomboid indentation having a long and short diagonal. The ratio between the long diagonal to the short diagonal is 7:1.

When the indentation was made, the indenter was removed. Stresses were distributed in such a manner that the elastic recovery of the indentation occurs along the short diameter. The physical quality of the indenter and the accuracy of the applied load must be controlled to get the correct results. After the load was removed, the indentation was focused with the magnifying eyepiece and the two impression diagonals were measured, usually to the nearest 0.1

μm with a filar micrometre, and averaged (Figure 1). The KH mean of the four indentations for each DS was calculated in the four subgroups.

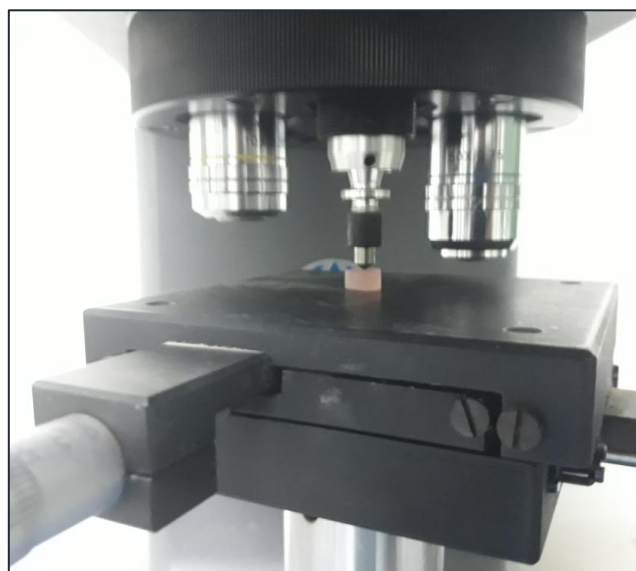


Figure 1: Knoop microhardness testing for TCS thermopress denture base material disc specimens

Statistics

Statistical analysis was performed with SPSS 20®, Graph Pad Prism® and Microsoft Excel 2016 with a significant level set at $P \leq 0.05$. The microhardness data were presented as means (M) and standard deviation (SD \pm) values. Furthermore; comparison between both 2 main groups before and after application of denture adhesive was performed using Student's t-test.

Results

The performed statistical analysis had revealed a significant difference in microhardness of the studied thermopress denture base material before and after exposure to the two denture adhesives. Evidently, for all evaluated disc specimens, the Knoop microhardness test values revealed an obvious reduction in the surface microhardness after the immersion in both types of denture adhesives (Table 1 and 2).

Table 1: Microhardness values in (g/mm^2) for TCS thermopress denture base material disc specimens after application of two denture adhesives

	Group I [Corega Super DA]		Group II [Fitty Dent DA]		P-Value
	M	SD \pm	M	SD \pm	
Before DA	17.20	0.62	17.33	0.50	0.52*
After DA	15.41	0.57	12.11	1.46	0.0001**

M; Mean, SD; Standard Deviation, P; Probability Level; *Insignificantly difference; ** Significantly difference.

In that comparative in vitro study, the mean and standard deviation for thermopress microhardness before denture adhesive application was (17.20 ± 0.62) and (17.33 ± 0.5) for subgroup A (Corega Super Cream DA) and subgroup C (Fitty Dent Cream DA) respectively. Also, the mean and standard deviation after denture adhesive application were (15.41 ± 0.57) and (12.11 ± 1.46) for subgroup B (Corega Super Cream DA) and subgroup D (Fitty Dent Cream DA) respectively; (Table: 1, Figure 2 and Figure 3).

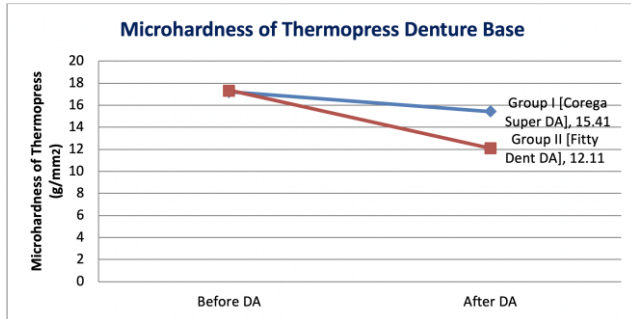


Figure 2: Line chart of reduced microhardness values for thermopress disc specimens after application of two denture adhesives for one month

Student's t-test was used to a comparison between the two denture adhesive groups before and after application of denture adhesive. That statistical test revealed an insignificant difference between A and C subgroups before application of denture adhesives; P value was > 0.05. However; Student's t-test revealed a significant difference between B and D subgroups after application of denture adhesives; P value was < 0.05; (Table 1).

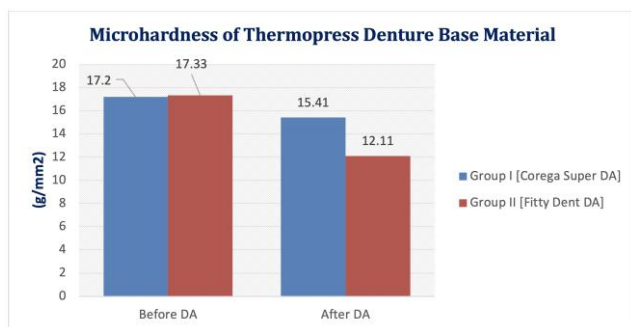


Figure 3: Bar chart of reduced microhardness values of TCS thermopress denture base material after application of two denture adhesives for one month

Moreover; paired t-test was performed to compare the mean microhardness values before and after application of denture adhesive within the same group (i.e. between subgroup A and B and between subgroup C and D); which revealed significant difference between before and after application of denture adhesive; P value was < 0.05 for both groups; (Table 2, Figure 2 and Figure 3). Furthermore; for both DA groups (group I and II), the percentage difference in microhardness before and after

application of denture adhesives was calculated according to the following formula:

$$\frac{(\text{Values Preoperative}) - (\text{Values Postoperative})}{(\text{Values Preoperative})} \times 100$$

That percentage difference of reduced microhardness after application of DA in both groups was (-10.41%) and (-30.12 %) for the group I (Corega Super Cream DA) and II (Fitty Dent Cream DA) respectively; (Table 2, and Figure 4).

Table 2: Percentage difference of reduced microhardness values in (g/mm²) of TCS thermopress denture base material disc specimens after application of two denture adhesives

	Before DA		After DA		P-value	Percentage % difference
	M	SD ±	M	SD ±		
Group I [Corega Super DA]	17.20	0.62	15.41	0.57	0.0003**	- 10.41
Group II [Fitty Dent DA]	17.33	0.50	12.11	1.46	0.0001**	-30.12

M: Mean, SD; Standard Deviation, P; Probability Level, %; Percentage; ** Significantly difference.

Discussion

Indeed; hardness tests are correlated to the surface resistance to indentation and are considered to assess the mechanical properties of dental polymers like tensile strength [17], [24]. After a long term of immersion of conventional denture base acrylics in disinfection solutions or water, Vickers microhardness test was used to investigate alterations in surface properties [25], [26], [27]. However; in that in vitro study, Knoop microhardness method had been implemented as an attempt to consider the elastic recovery and viscoelasticity of the studied flexible polyamide based denture materials [17], [18].

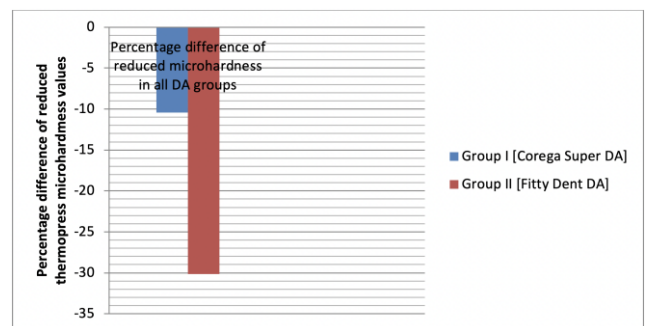


Figure 4: Bar chart for percentage difference of reduced microhardness for thermopress disc specimens after application of two denture adhesives for one month

Furthermore; surface properties of flexible denture base materials are of peculiar importance because they affect their durability, serviceability and longevity during function [28], [29]. Therefore; polymer surface roughness and microhardness had been investigated using different in vitro methods. However;

all those attempted techniques provided valuable information regarding the physico-mechanical properties for the tested dental materials, none of the *in vitro* testing could expose the investigated dental biomaterials in conditions simulating that of the oral environment (i.e. *in vivo*); such as pH and temperature fluctuations [30].

Generally; polymeric dental materials were characterised by water sorption phenomenon; which decreased their surface microhardness. That reduction was attributed to filler matrix debonding caused by excessive hydration [17], [30]. Also, the absence of cross-linked bifunctional resin in the acrylic-based denture materials could enhance the softening effect of acid solvents [31].

Furthermore; the presence of chemical constituents of DAs had adversely affected the mechanical properties of polyamide based resins. DAs components might produce a plasticising effect which; had attenuated the inter-chain polymer forces and had facilitated the polymer deformation with stress application [32]. Also, the specimens were daily stored in distilled water to simulate the patient saliva which; might have contributed to the reduction in the Knoop microhardness. This was in agreement with Xediek Consani et al., [33] who said that saliva affected similar to water that produced plasticising phenomenon, and thereby reduced the resin microhardness [33], [34].

Compared to heat cured acrylic polymethyl methacrylates, flexible polyamide-based denture base resins showed lower surface microhardness values. Moreover, thermopress flexible resins demonstrated a lesser amount of cross-linking agents, which might interpret the effect of the cross-linking on its surface microhardness. Therefore, those finding showed that thermopress polyamide based resin was much more flexible denture base materials than the conventional heat cure acrylic polymethyl methacrylate [19], [35], [36].

Denture adhesives were usually supplied in the form of powder, paste or cream. The mode of action of denture adhesive was as follow: They absorb too much water, swell, increase many times of its original volumes and consequently, the anions were formed to interact with the cations present in the proteins of the oral mucosa. Furthermore; the viscosity of the denture adhesive was increasing by the resulting thick salivary film, thereby improving the removable denture retention [36].

Recently; new denture adhesive materials were providing strong bio-adhesive as well as cohesive bonding forces. That promising denture adhesive bond was due to the free carboxyl groups produced from the hydration of denture adhesives (such as; sodium carboxyl-methyl cellulose, hydroxymethyl cellulose, methyl cellulose, or polymethyl vinyl ether-maleic anhydride, etc.). Those free carboxyl groups would form electrovalent bonds

that produced stickiness to oral mucosa and bio-adhesion. Also, the increased viscosity of the denture adhesive creams caused their lateral spread to exclude saliva and air thereby increasing the removable denture retention [36].

In that study, the decrease in microhardness values of TCS flexible denture base material after immersion for one month, in two different denture adhesives might be due to the enhancement of the degradation process of the polyamide base polymer. The accelerated polymer biodegradability might be because of the presence of addition polymerisation free radicals as well as partially cross-linked polyamide chains containing a large number of residual monomers [37], [38]. This evidence possesses an adverse effect certain physico-mechanical properties of the thermopress resin including surface hardness due to diffusion of the residual monomers from the polymer matrix with simultaneous water sorption into the resin microstructure. The consequence of this detrimental scenario is a plasticising phenomenon which; decreases the inter-chain bonding forces and therefore; significantly attenuated the polyamide microhardness facilitates the rapid deformation of polymer chains under load [39], [40].

Within the parameters of this *in vitro* study design and tested denture base materials, the following conclusions might be drawn:

- Knoop microhardness test was relevant for the assessment of surface microhardness of thermopress denture base material before and after exposure to the two denture adhesives.

- Flexible dentures may be highly indicated as provisional prostheses or space maintainers in certain patient's requiring replacement of missing teeth in the esthetic area and having some limitations; like allergy to heat cured acrylic resin or metal alloys, restricted jaw opening or severe soft or/and hard tissue undercuts.

- Commercially available denture adhesives (DAs) may have an impact on microhardness of flexible denture base materials.

- Corega Super Cream DA and Fitty Dent Cream DA have decreased the surface microhardness of TCS thermopress denture base material.

- Also; the microhardness of the thermopress denture base materials might be decreased with the use of one type of denture adhesive (Corega Super Cream DA) less than the other (Fitty Dent Cream DA).

- The percentage difference of reduced microhardness after one month of application of DA in both groups was critical and necessitates further evaluation of TCS microhardness after longer periods of DA exposure.

- Transverse strength of the studied

thermopress denture base material needs to be also assessed.

In spite of the innumerable advantages and multiple indications of the flexible thermoplastic polyamide base nylon resin, further in vitro and clinical studies are recommended as the flexible nonmetallic thermopress denture base materials are considered a crucial issue to be addressed.

References

1. Saad El-Din M, Gebreel A, Swedan M. Thermoplastic Distal Extension Removable Partial Dentures versus Vitallium ones Radiographic Evaluation. *Mansoura Journal of Dentistry*. 2014; 1(3):20-3.
2. Alhareb A, Akil H, Ahmad Z. Mechanical Properties of PMMA Denture Base Reinforced by Nitrile Rubber Particles with Al₂O₃/YSZ Fillers. *Procedia Manufacturing*. 2015; 2:301-6. <https://doi.org/10.1016/j.promfg.2015.07.053>
3. Jagger D, Jagger R, Allen S, Harrison A. An investigation into the transverse and impact strength of "high strength" denture base acrylic resins. *Journal of Oral Rehabilitation*. 2002; 29(3):263-7. <https://doi.org/10.1046/j.1365-2842.2002.00830.x> PMID:11896843
4. Powers J, Sakaguchi R. *Craig's restorative dental materials*, 13th ed. Mosby, Inc., an affiliate of Elsevier Inc, USA, 2012.
5. Lai C, Tsai M, Chen M, Chang H, Tay H. Morphology and properties of denture acrylic resins cured by microwave energy and conventional water bath. *Article in Dental Materials*. 2004; 20(2):133-41. [https://doi.org/10.1016/S0109-5641\(03\)00084-8](https://doi.org/10.1016/S0109-5641(03)00084-8)
6. Shinawi L. The Effect of Denture Cleansers on the Hardness of Denture Base Resins, Polyamides and Copolymers. *Review Article. EC Dental Science*. 2017; 10,4:110-9.
7. Rashid H, Sheikh Z, Vohra F. Allergic effects of the residual monomer used in denture base acrylic resins. *Eur J Dent*. 2015; 9:614-9. <https://doi.org/10.4103/1305-7456.172621> PMID:26929705 PMCid:PMC4745248
8. Sagsoz N, Yanikoglu N, Ulu H, Bayindir F. Color Changes of Polyamid and Polymethyl Methacrylate Denture Base Materials. *Open Journal of Stomatology*. 2014; 4:489-96. <https://doi.org/10.4236/ojst.2014.410066>
9. Al-Dharrab A, Shinawi L. Thermogravimetric Characterization of the Microstructure Composition of Polyamide Injection Molded Denture Base Material vs Conventional Compression Molded Heat-cured Denture Base Material. *J Contemp Dent Pract*. 2016; (2):99-104. <https://doi.org/10.5005/jp-journals-10024-1810> PMID:27206996
10. Anusavice K. *Phillip's Science of Dental Materials* 11.ed. Rio de Janeiro: Elsevier, 2005.
11. Ucar Y, Akova T, Aysan I. Mechanical properties of polyamide versus different PMMA denture base materials. *J Prosthodont*. 2012; 21(3):173-6. <https://doi.org/10.1111/j.1532-849X.2011.00804.x> PMID:22372855
12. Kohli S, Bhatia S. Polyamides in dentistry-A Review. *International Journal of Scientific Study*. 2013; 20-5.
13. Shankar Y. Denture Adhesives for Complete Denture: A Literature Review. *Indian Journal of Dental Sciences*. 2010; 11:1.
14. Kumar P, Shajahan P, Mathew J, Koruthu A, Aravind P, Ahammed M. Denture Adhesives in Prosthodontics: An Overview. *Journal of International Oral Health*. 2015; 1:93-5.
15. Yadav A, Yadav S. Denture Adhesives -Their Stand in Prosthodontics. *Review Article. The Journal of Indian Prosthodontic Society*. 2005; 5:62-4. <https://doi.org/10.4103/0972-4052.16871>
16. Jo L, Shenoy K, Shetty S. Flexural strength and hardness of resins for interim fixed partial dentures. *Indian J Dent Res*. 2011; 22:71-6. <https://doi.org/10.4103/0970-9290.79992> PMID:21525681
17. Nicodemo C, Rezende C, Moretti-Neto R, Rubo J. Microhardness of acrylic resin utilized for provisional crowns: Effect of different polymerization techniques and pH-Cycling. *Braz Dent Sci*. 2013; 16:44-50. <https://doi.org/10.14295/bds.2013.v16i2.896>
18. Abdel-Hamid D. Microhardness of Flexible Denture Base Materials: Effect of Microwave and Chemical Disinfection Methods. *Egyptian dental journal*. 2013; 59:1383-92.
19. Shah J, Bulbule N, Kulkarni S, Shah R, Kakade D. Comparative evaluation of sorption, solubility and microhardness of heat cure polymethylmethacrylate denture base resin & flexible denture base resin. *Journal of clinical and diagnostic research: JCDR*. 2014; 8(8):ZF01-ZF04. <https://doi.org/10.7860/JCDR/2014/8707.4770>
20. Goiato M, et al. Effect of accelerated aging on the microhardness and color stability of flexible resins for dentures. *Braz Oral Res*. 2010; 24:114-19. <https://doi.org/10.1590/S1806-83242010000100019> PMID:20339724
21. Kurtulmus H, et al. Effects of saliva and nasal secretion on some physical properties of four different resin materials. *Med Oral Patol Oral Cir Bucal*. 2010; 15:969-75. <https://doi.org/10.4317/medoral.15.e969>
22. Yavuz T, Aykent F. Temporary flexible removable partial denture: A clinical report. *Clinical Dentistry and Research*. 2012; 36:41-4.
23. Darwish M, Nassani M. Evaluation of the effect of denture adhesives on surface roughness of two chemically different denture base resins. *European Journal of Dentistry*. 2018; 197:133-156.
24. Lee H, Lee C, Asaoka K. Correlation in the mechanical properties of acrylic denture base resins. *Dental Material Journal*. 2012; 1:157-64. <https://doi.org/10.4012/dmj.2011-205>
25. Regis R, Soriani N, Azevedo A, Silva-Lovato C, Paranhos H, de Souza R. Effects of ethanol on the surface and bulk properties of a microwave-processed PMMA denture base resin. *J Prosthodont*. 2009; 18:489-95. <https://doi.org/10.1111/j.1532-849X.2009.00475.x> PMID:19500235
26. Neppelenbroek K, Pavarina A, Vergani C, Giampaolo E. Hardness of heat-polymerized acrylic resins after disinfection and long-term water immersion. *J Prosthet Dent*. 2005; 93:171-6. <https://doi.org/10.1016/j.prosdent.2004.10.020> PMID:15674229
27. Machado A, Breeding L, Vergani C, da Cruz Perez L. Hardness and surface roughness of relined and denture base acrylic resins after repeated disinfection procedures. *J Prosthet Dent*. 2009; 102:115-22. [https://doi.org/10.1016/S0022-3913\(09\)60120-7](https://doi.org/10.1016/S0022-3913(09)60120-7)
28. Shah J, Bulbule N, Kulkarni S, Shah R, Kakade D. Comparative Evaluation of Sorption, Solubility and Microhardness of Heat Cure Polymethylmethacrylate Denture Base Resin & Flexible Denture Base Resin. *Journal of Clinical and Diagnostic Research*. 2014; 8: 1-4. <https://doi.org/10.7860/JCDR/2014/8707.4770>
29. Moussa A, Dehis W, Elboraey A, Hisham, El-Gabry S. A Comparative Clinical Study of the Effect of Denture Cleansing on the Surface Roughness and Hardness of Two Denture Base Materials. *Open Access Maced J Med Sci*. 2016; 15(4):476-81. <https://doi.org/10.3889/oamjms.2016.089> PMID:27703578 PMCid:PMC5042638
30. Mekkawy M, Hussein L, Alsharawy M. Comparative study of surface roughness between polyamide, thermoplastic polymethyl methacrylate and acetal resins flexible denture base materials before and after polishing. *Life Science Journal*. 2015; 12:90-5.
31. Akova T, Ozkomur A, Uysal H. Effect of food-simulating liquids on the mechanical properties of provisional restorative materials. *Dent Mat*. 2006; 22:1130-4. <https://doi.org/10.1016/j.dental.2005.09.009> PMID:16386787
32. Yap A, Mah M, Lye C, Loh P. Influence of dietary simulating

- solvents on the hardness of provisional restorative materials. *Dent Mat.* 2004; 20:370-6. <https://doi.org/10.1016/j.dental.2003.06.001> PMID:15019452
33. Xediek R, Vieira M, Mesquita M, Sinhoreti M, Guiraldo R, Nóbilo M. Effect of polymerization cycles on the linear dimensional change, hardness and impact strength of denture base acrylic resins. *Minerva Stomatol.* 2012; 61:272-81.
34. Assunção W, Gomes E, Barão V, Barbosa D, Delben J, Tabata L. Effect of storage in artificial saliva and thermal cycling on Knoop hardness of resin denture teeth. *J Prosthodont Res.* 2010; 54:123–7. <https://doi.org/10.1016/j.jpor.2009.12.001> PMID:20083446
35. Shankar Y. Denture Adhesives for Complete Denture: A Literature Review. *Indian Journal of Dental Sciences.* 2010; 1(1):23-8.
36. Kumar P, Shajahan P, Mathew J, Koruthu A, Aravind P, Ahammed M. Denture Adhesives in Prosthodontics: An Overview. *Journal of International Oral Health.* 2015; 93-5. PMID:26225115 PMID:PMC4516076
37. Klironomos T, Katsimpali A, Polyzois G. The effect of microwave disinfection on denture base polymers, liners and teeth: A Basic overview. *Acta stomatologica Croatica.* 2015; 49(3):242-53. <https://doi.org/10.15644/asc49/3/7> PMID:27688409 PMID:PMC4993596
38. Schwindling F, Stober T. Effect of chemical disinfection on the surface roughness of hard denture base materials: a systematic literature review. *International Journal of Prosthodontics.* 2014; 27(3): 215-25. <https://doi.org/10.11607/ijp.3759> PMID:24905261
39. Shinawi L. The Effect of Denture Cleansers on the Hardness of Denture Base Resins, Polyamides and Copolymers: Review Article. *EC Dental Science.* 2017; 10(4):110-9.
40. Porwal A, et al. Effect of denture cleansers on color stability, surface roughness, and hardness of different denture base resins. *Journal of Indian Prosthodontic Society.* 2017; 17(1): 61-7. PMID:28216847 PMID:PMC5308072