Original Research

DENTAL MEDICINE

# Assessment of hardness and microroughness of injection-molded thermoplastic resins used for flexible removable partial dentures

Roxana Diana Vasiliu[1], Anamaria Matichescu[2], Sorin Daniel Porojan[3], Diana Uțu[4], Liliana Porojan[1]

1) Department of Dental Prostheses Technology, Center for Advanced Technologies in Dental Prosthodontics, Faculty of Dental Medicine, "Victor Babeș" University of Medicine and Pharmacy, Timișoara, Romania

2) Department of Preventive, Community Dentistry and Oral Health, Center for Advanced Technologies in Dental Prosthodontics, Faculty of Dental Medicine, "Victor Babeș" University of Medicine and Pharmacy, Timișoara, Romania

3) Department of Oral Rehabilitation, "Victor Babeș" University of Medicine and Pharmacy, Timișoara, Romania

4) Department of Pharmacology-Pharmacotherapy, Faculty of Pharmacy, "Victor Babeș" University of Medicine and Pharmacy, Timișoara, Romania

## Abstract

**Background and aim.** This study evaluates and compares three types of thermoplastic resins used for flexible, removable partial dentures, focusing on their microhardness and surface roughness.

**Methods.** Thirty samples with a thickness of 2 mm were obtained from thermoplastic resins and were tested after 24 hours of immersion in distilled water. The samples were obtained from injected resin cartridges of three thermoplastic resins with different degrees of flexibility. Two-way ANOVA and Tukey tests were performed to compare the samples. A Pearson correlation was calculated between the two parameters, surface roughness and Vickers microhardness.

**Results.** After statistical analysis, significant differences were found between the two resins' surface roughness. Regarding Vickers microhardness, one of the resins with the lowest flexibility range exhibited higher microhardness values.

**Conclusions.** Surface roughness values for the three resins were below 0.2 microns. Microhardness test revealed significant differences between Flaxiacryl and Flexifast samples (p<.05).

**Keywords:** thermoplastic resins, flexibility, surface roughness, Vickers microhardness

DOI: 10.15386/mpr-2849

Manuscript received: 14.01.2025
Received in revised form: 04.03.2025
Accepted: 29.03.2025

Address for correspondence:
Anamaria Matichescu
matichescu.anamaria@umft.ro



## Introduction

Injection-molded thermoplastic flexible resins, such as polyamide, polyester, and polycarbonate, are increasingly used to create removable partial dentures [1-4]. PMMA (polymethyl methacrylate) has traditionally been the preferred material for these dentures [5]. The microstructure of thermoplastic resins consists of fibers, a rubber phase, and crosslinking agents that enhance their mechanical properties. Specifically, polyamide resins are derived from nylon [6]. These flexible resins offer several advantages, including excellent aesthetics that closely match the color of gingival tissue and notable flexibility, making them suitable for dental surfaces with undercuts in both soft and hard tissues [7]. Furthermore, their structural properties can mitigate concerns such as metal and monomer allergies and fatigue failures of clasps [8-9]. The flexibility of these resins prevents them from fracturing due to high occlusal masticatory forces or accidents [10]. However, despite their flexibility and aesthetic appeal advantages, some drawbacks exist, including processing difficulties, a high water sorption rate, and susceptibility to staining [11]. Surface roughness is a critical factor in dental stomatitis, as very rough surfaces can lead to staining over time and promote microbial colonization [12-13]. The optimal surface roughness value is 0.2 microns; values exceeding this can enhance microbial colonization. In dental research studies, surface roughness is assessed using a digital profilometer, with key evaluation parameters Ra (average surface roughness) and Rz (maximum surface roughness). Microhardness refers to the resistance of dental materials to plastic deformation under a specific indentation load [14-15]. The microhardness test evaluates the mechanical behavior of various materials and is conducted with specialized equipment. Several studies have shown a correlation between microhardness, surface roughness, and wear resistance in injection-molded thermoplastic resins.

The indentation method allows multiple indentations on a single specimen [16-17]. Despite the commercialization and extensive research on these materials, limited information remains regarding thermoplastic flexible resins' microhardness and surface roughness. This study compares three flexible resin dental materials for removable partial dentures, highlighting their mechanical and structural properties.

The first null hypothesis is that the materials will show differences in surface roughness after 24 hours of immersion.

The second hypothesis is that there will be significant differences between the microhardness values among the testes resins.

## Methods

This in vitro study analyzed three types of injectable thermoplastic flexible resin denture base materials: one translucent monomer-free acrylic monomer (FA) Flexiacryl, Sabilex, Argentina; a copolymer (FF) Flexyfast, Sabilex, Argentina; and a thermoplastic polyolefin (PF) Premium Flex, Sabilex, Argentina, formulated for dental use (Table I). These materials are indicated for flexible partial dentures with clasps.

**Obtaining the thermoplastic resin samples**

Thirty samples (n=10) with a thickness of 2 mm were printed using a digital light processing printer (Asiga, Australia) using castable printed resin (Dental Cast, Harz Lab, Rusia).

The printed samples were invested and prepared for the injection process. The injected samples were obtained according to the manufacturer's instructions using Sabilex equipment and observing the parameters for heat and pressure for the resin type (Table I). The thermoplastic resin samples were obtained from specific resin cartridges.

A single operator for standardization manipulated all the prepared samples during finishing and polishing.

The top surfaces of resin specimens were polished using 600, 1000, 1500, and 2000-grit sandpaper and polishing paste. The samples were stored for 24 hours in distilled water at 37 degrees Celsius.

**Testing the microroughness** was performed using a digital profilometer (Mitutoyo, Japan), and mean coordinates for Ra (average surface roughness) and Rz (maximum surface roughness) were evaluated after the samples were stored in 37 degrees Celsius bath for 24 hours.

**The Vickers microhardness** of the samples was tested after they were immersed in distilled water using a microhardness tester. Five micro indentations were made on each sample at an HVN=0.3 MPa.

Statistical analysis was performed using the two-way ANOVA and Tukey Kramer test to compare the statistical data. A Pearson correlation was also used to evaluate the correlation between the microhardness and surface micro roughness.

## Results

### Surface roughness measurements

The surface roughness of the resin samples was evaluated parallel to the injection direction for all the tested samples.

The results of the mean surface roughness and standard deviation values are presented in figure 1.

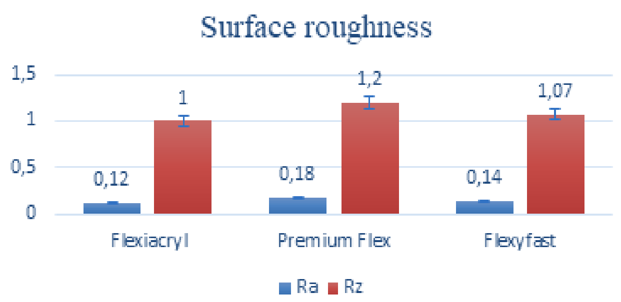


**Figure 1.** Mean values for surface microroughness and standard deviation (Ra, Rz parameters) for the tested samples after 24 hours of immersion.

**Table I.** Injectable thermoplastic flexible resin denture base materials included in this study.

| Name | Material | Flexibility | Manufacturer | Processing parameters |
|---|---|---|---|---|
| **Flexiacryl** | Resin copolymer | Medium | Sabilex, Argentina | Injection molding technique: heat processed at 280 ºC for 25 minutes |
| **Premium Flex** | Thermoplastic polyolefin | High | Sabilex, Argentina | Injection molding technique: heat processed at 240 ºC for 15 minutes |
| **Flexyfast** | Monomer-free acrylic resin | Low | Sabilex, Argentina | Injection molding technique: heat processed at 230 ºC for 15 minutes |

**Table II.** p-values (ANOVA test) for the microroughness values ($p \leq 0.05$).

| p value | Ra | Rz |
|---|---|---|
| Flexiacryl -Premium Flex | **<0.05** | **<0.05** |
| Premium Flex-Flexyfast | **>0.05** | **>0.05** |
| Flexiacryl-Flexyfast | **<0.05** | **<0.05** |

Statistically significant differences were found between the average surface roughness of Flexiacryl and Premium Flex samples ($p < 0.05$) and between Flexyfast and Flexiacryl samples. Between Premium Flex and Flexyfast, there were no significant differences ($p > 0.05$) (Table II).

Premium Flex samples reported higher values for the surface roughness Ra parameter after 24 hours of immersion in distilled water. Parameter Rz (maximum surface roughness) was registered and mirrored the values of the Ra parameter.

### Vickers microhardness evaluation

Vickers microhardness for the thermoplastic resins was determined. Figure 2 details mean values and standard deviation (SD).

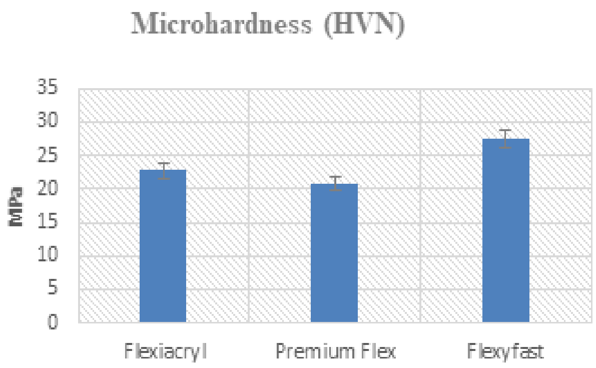


**Figure 2.** Mean values and standard deviation values for microhardness of the tested samples after 24 hours of immersion.

After microhardness testing, ANOVA calculated significant differences were found between Flexiacryl and Premium Flex samples ($p < .05$). Significant differences were also registered between Flexiacryl and Flexyfast ($p < .05$).

Samples obtained from Flexyfast resin registered greater microhardness values. Flexiacryl samples registered the lowest values.

A Pearson correlation was made between the surface roughness and microhardness, revealing a negative linear correlation (-0.44) between the surface microroughness and microhardness values.

## Discussion

The first and second hypotheses were accepted, indicating differences in the surface roughness and microhardness parameters among the tested samples. This study aimed to analyze the surface microroughness and Vickers microhardness of thermoplastic resin samples used for flexible partial dentures. Flexible dentures have gained popularity as prosthetic restorations over the years due to their favorable mechanical properties and excellent biocompatibility with surrounding tissues. They suit patients with monomer allergies, limited mouth openings, or severe ridge undercuts. Additionally, their aesthetic appearance makes them an ideal choice for cases where aesthetic considerations are important [18]. These resins are softened by heat and injected under pressure into flexible partial dentures using specialized machines [19]. The injection method used in this study offers several advantages [20]. The resin is supplied in cartridges that eliminate dosage errors, resulting in reduced contraction and greater mechanical resistance over time. In this study, the samples were stored for 24 hours in distilled water at 37ºC, after which all measurements were taken at room temperature. Some authors [21] suggest that these conditions can influence the mechanical properties of the materials, including hardness. The microstructure, microhardness modulus, and elasticity of materials significantly impact their surface quality. Surface roughness plays a crucial role in the durability of removable dental prostheses.

Dentistry studies [21,22] recommend using multiple surface roughness parameters for a comprehensive analysis. A contact profilometer is used to trace a stylus's movements across the material's surface for a specific distance. The stylus registers the peaks and valleys on the material surface, and the values obtained can be found on the micron scale [23]. Other authors suggested using more than one roughness parameter in determining the microroughness [24,25]. In this study, parameters Ra and Rz were determined, with the values for Ra closely mirroring those for Rz. The surface irregularities of these materials can contribute to an increase in microorganisms and bacterial accumulation on the flexible denture. Notably, all tested samples exhibited Ra values below 0.2 microns; an increase in plaque accumulation is expected above this threshold. Premium Flex demonstrated higher surface roughness values after immersion in distilled water, while Flexiacryl showed the lowest values. The findings of this research indicated slight changes in the surface roughness of the tested samples after immersion but below the accepted limit for the oral cavity. The slight increase in roughness can be attributed to tiny pores on the surface, resulting from hygroscopic moisture evaporation from the enclosed gypsum. Another study [26] on thermoplastic resins reached similar conclusions when evaluating the surface roughness parameters. Another key aspect explaining the differences in surface roughness among the three resins relates to their varying injection parameters: Flexiacryl is injected at the highest temperature of 280 degrees Celsius, while the other resins are injected at 230 and 240 degrees Celsius. Additionally, another study [27] found differences in measuring surface roughness based on whether the measurements were taken parallel or perpendicular to the injection lines, revealing smaller values for measurements made parallel to the injection site, which aligns with this study's results. Higher roughness parameters, such as microhardness and fracture strength, also influence the mechanical testing of dental materials. A material's surface hardness directly affects its wear resistance, as microhardness is defined by the plastic deformation of a material subjected to an indentation load [28]. The study's findings indicated that the microhardness values for Premium Flex were lower than those of the other tested materials. Flexyfast (a monomer-free acrylic resin) exhibited the lowest flexibility and the highest microhardness among the samples. Statistically significant differences were observed between the microhardness values of Premium Flex and Flexiacryl. A previous study [29] that evaluated the hardness of denture materials—specifically a PMMA and a thermoplastic polyamide resin—concluded that the hardness of the thermoplastic resin was the lowest.

There is currently a lack of research on the surface roughness and mechanical properties of these three types of flexible resins for removable partial dentures, indicating a need for further studies.

## Conclusions

Despite the limitations of this study, clear conclusions can be drawn:

1. Surface roughness values for the three resins were below 0.2 microns.

2. Pearson correlation test revealed a negative linear correlation between the surface microroughness and microhardness values.

3. Microhardness test revealed significant differences between Flaxiacryl and Flexifast samples ($p<.05$).

4. Microhardness values for Premium Flex and Flexiacryl values were statistically significant.

### References


1. Fueki K, Ohkubo C, Yatabe M, Arakawa I, Arita M, Ino S, et al. Clinical application of removable partial dentures using thermoplastic resin-part I: definition and indication of non-metal clasp dentures. J Prosthodont Res. 2014;58:3-10.
2. Fueki K, Ohkubo C, Yatabe M, Arakawa I, Arita M, Ino S, et al. Clinical application of removable partial dentures using thermoplastic resin. Part II: Material properties and clinical features of non-metal clasp dentures. J Prosthodont Res. 2014;58:71-84.
3. Katsumata Y, Hojo S, Hamano N, Watanabe T, Yamaguchi H, Okada S, et al. Bonding strength of autopolymerizing resin to nylon denture base polymer. Dent Mater J. 2009;28:409-418.
4. Takabayashi Y. Characteristics of denture thermoplastic resins for non-metal clasp dentures. Dent Mater J. 2010;29:353-361.
5. Ayaz EA, Bağış B, Turgut S. Effects of thermal cycling on surface roughness, hardness and flexural strength of polymethylmethacrylate and polyamide denture base resins. J Appl Biomater Funct Mater. 2015;13 :e280-6.
6. Parvizi A, Lindquist T, Schneider R, Williamson D, Boyer D, Dawson DV. Comparison of the dimensional accuracy of injection-molded denture base materials to that of conventional pressure-pack acrylic resin. J Prosthodont. 2004;13:83-89.
7. Takahashi Y, Hamanaka I, Shimizu H. Effect of thermal shock on mechanical properties of injection-molded thermoplastic denture base resins. Acta Odontol Scand. 2012;70:297-302.
8. Narde J, Ahmed N, Keskar V, Pandurangan KK. Evaluation of the Colour Stability and Surface Roughness of Polymethylmethacrylate and Indirect Composites With and Without Ageing: An In-Vitro Study. Cureus. 2024;16:e68073.
9. Vallittu PK. Fatigue resistance and stress of wrought-steel wire clasps. J Prosthodont. 1996;5:186-192.
10. Bacali C, Baldea I, Moldovan M, Carpa R, Olteanu DE, Filip GA, et al. Flexural strength, biocompatibility, and antimicrobial activity of a polymethyl methacrylate denture resin enhanced with graphene and silver nanoparticles. Clin Oral Investig. 2020;24:2713-2725.
11. Kanie T, Fujii K, Arikawa H, Inoue K. Flexural properties and impact strength of denture base polymer reinforced with woven glass fibers. Dent Mater. 2000;16:150-158.
12. Kawara M, Iwata Y, Iwasaki M, Komoda Y, Iida T, Asano T, et al. Scratch test of thermoplastic denture base resins for non-metal clasp dentures. J Prosthodont Res. 2014;58:35-40.
13. 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;7:201-211.
14. 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;13:258-269.
15. Tanner J, Carlén A, Söderling E, Vallittu PK. Adsorption of parotid saliva proteins and adhesion of Streptococcus mutans ATCC 21752 to dental fiber-reinforced composites. J Biomed Mater Res B Appl Biomater. 2003;66:391-398.
16. Powers J, Sakaguchi R. Craig's restorative dental materials. 12th ed. St. Louis (MO): Mosby Inc., 2006, pp. 60, 79, 151, 544–565.
17. Suwannaroop P, Chaijareenont P, Koottathape N, Takahashi H, Arksornnukit M. In vitro wear resistance, hardness and elastic modulus of artificial denture teeth. Dent Mater J. 2011;30:461-468.
18. Suzuki S. In vitro wear of nano-composite denture teeth. J Prosthodont. 2004;13:238-243.

19. Ucar Y, Akova T, Aysan I. Mechanical properties of polyamide versus different PMMA denture base materials. J Prosthodont. 2012;21:173-176.
20. Awad AN, Cho SH, Kesterke MJ, Chen JH. Comparison of tensile bond strength of denture reline materials on denture bases fabricated with CAD-CAM technology. J Prosthet Dent. 2023;129:616-622.
21. Chuchulska B, Dimitrova M, Dochev B. In Vitro Study of the Surface Roughness, Hardness, and Absorption of an Injection-Molded Denture Base Polymer, Manufactured under Insufficient Mold Solidification. Appl Sci. 2024;14:2906
22. Azpiazu-Flores FX, Schricker SR, Seghi RR, Johnston WM, Leyva Del Rio D. Adhesive strength of 3 long-term resilient liners to CAD-CAM denture base polymers and heat-polymerized polymethyl methacrylate with thermocycling. J Prosthet Dent. 2024;131:494-499.
23. Başeren M. Surface roughness of nanofill and nanohybrid composite resin and ormocer-based tooth-colored restorative materials after several finishing and polishing procedures. J Biomater Appl. 2004;19:121-134.
24. Jung M, Sehr K, Klimek J. Surface texture of four nanofilled and one hybrid composite after finishing. Oper Dent. 2007;32:45-52.
25. Darvell BW. Cutting, Abrasion and Polishing. In: Materials Science for Dentistry, 9th Edition, Woodhead Publishing in Ltd., Cambridge, 2009, p. 453.
26. Marchan SM, White D, Marchan QM, Dhuru V, Smith WA. Surface properties of dental nanocomposites after finishing with rigid rotary instruments. Oper Dent. 2013;38:519-527.
27. Somkuwar S, Mishra SK, Agrawal B, Choure R. Comparison of the flexural strength of polymethyl methacrylate resin reinforced with multiwalled carbon nanotubes and processed by conventional water bath technique and microwave polymerization. J Indian Prosthodont Soc. 2017;17:332-339.
28. Xu WP, Zhang LC, Li JP, Lu Y, Li HH, Ma YN, et al. Facile synthesis of silver@graphene oxide nanocomposites and their enhanced antibacterial properties. J Mater Chem. 2011;21:4593-4597.
29. Chwalibog A, Sawosz E, Hotowy A, Szeliga J, Mitura S, Mitura K, et al. Visualization of interaction between inorganic nanoparticles and bacteria or fungi. Int J Nanomedicine. 2010;5:1085-1094.