



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

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## 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

## 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

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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.

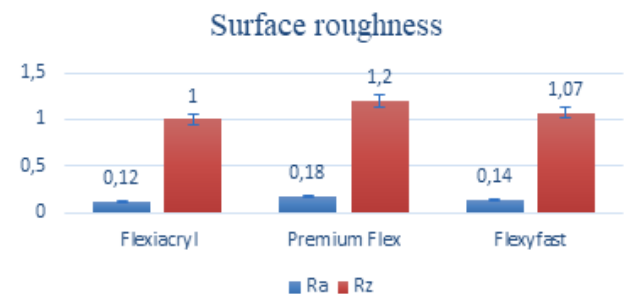
Statistical analysis was performed using the two-way ANOVA and Tukey Kramer test to compare the statistical data. A Pearson correlation was also used to evaluate the correlation between the microhardness and surface micro roughness.

**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
<b>Flexiacryl</b>	Resin copolymer	Medium	Sabilex, Argentina	Injection molding technique: heat processed at 280 °C for 25 minutes
<b>Premium Flex</b>	Thermoplastic polyolefin	High	Sabilex, Argentina	Injection molding technique: heat processed at 240 °C for 15 minutes
<b>Flexyfast</b>	Monomer-free acrylic resin	Low	Sabilex, Argentina	Injection molding technique: heat processed at 230 °C for 15 minutes

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

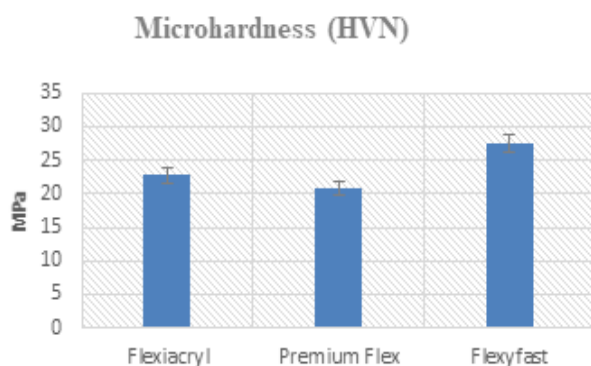
p value	Ra	Rz
Flexiacryl -Premium Flex	<0.05	<0.05
Premium Flex-Flexyfast	>0.05	>0.05
Flexiacryl-Flexyfast	<0.05	<0.05

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 ( $p < 0.05$ ). Significant differences were also registered between Flexiacryl and Flexyfast ( $p < 0.05$ ).

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 37°C, 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 Flexiacryl and Flexifast samples ( $p < .05$ ).
4. Microhardness values for Premium Flex and Flexiacryl values were statistically significant.

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