

EVALUATION OF THERMOPLASTIC FLEXIBLE RESINS WEAR BEHAVIOR

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ABSTRACT

Aim of the study is to compare three different thermoplastic resins used for flexible removable dentures based on their wear behavior. **Materials and methods** 24 samples with a thickness of 2 mm were obtained using injected thermoplastic resins. The wear test was performed for half an hour with a force of 30 N using a stainless steel and a zirconia sphere. Two environments were selected for this study, a dry and a wet one with one lubricant that simulates the saliva. Statistical analysis was carried out using one one-way ANOVA test. Image J program was used to calculate the radius for every wear mark with an optical microscope. **Results** revealed changes for every material, the zirconia sphere in a dry environment and for the stainless steel sphere after applying lubricants. After half an hour there was no statistically significant weight loss among the samples ($p \leq 0.05$), but there were changes in their surface in the optical microscopy. **Conclusions:** Zirconia produced clearer wear marks on the resin samples compared to the stainless steel ball. The glycerine- lubricant increases the wear when using a stainless steel sphere.

Keywords: thermoplastic resins, wear test, abrasiveness, zirconia

INTRODUCTION

For years, thermoplastic injection-molded resins have been transforming the field of removable partial dentures. These innovative materials—polyamides, polyesters, and polycarbonates—are preferred for creating dentures without metal clasps for retention (1,2).

The term "thermoplastic resins" highlights a complex process where heat is applied to a fully polymerized base material, allowing it to be softened and injected under high pressure. This technique ensures durability and comfort, making thermoplastic resins an excellent solution for long-term dental prosthetics. Dental resins are injected from industrial-made cartridges to avoid dosage errors, and the equipment ensures high temperature and pressure during this

process. Injection-molded thermoplastic resins possess advantageous characteristics such as superior elasticity and impact strength compared to traditional heat-polymerized acrylic resin (PMMA) (3,4).

In the oral cavity, dental restorations face a variety of chewing forces, highlighting the importance of their durability and strength. Mechanical properties are a key factor when selecting a material because they indicate its long-term quality and behavior. Wear refers to the gradual loss of material from the surface of restorative materials caused by chemical and mechanical processes. The material wear rate depends on the material's microstructure, the applied force in time, and other clinical factors. A known method for studying wear in dental

materials is the ball-on-flat-tribotester. This test simulates intraoral conditions using a sliding sphere with or without artificial saliva. This device features a tetrahedral configuration with a rotating sphere, which creates circular wear scars on the surfaces of flat material specimens (5,6). The wear scars are examined using optical microscopy at varying magnifications. The ball can be made of different materials, but the frequently used ones are zirconia and stainless steel. The zirconia sphere represents the worst-case scenario due to its exceptional hardness. This test measures the wear of thermoplastic resins against a hard contact. Evaluating the wear resistance of these resins has clinical implications because the roughness of a surface influences microbial adhesion (7,8). A higher surface roughness can cause the restoration's failure, as well for the remaining teeth and gingiva where the resin clasps are.

Assessing the wear resistance of injection-molded thermoplastic resins is crucial, as existing literature lacks sufficient information on this subject.

MATERIALS AND METHODS

This study analyzed three types of injectable thermoplastic flexible resin denture base materials: one translucent monomer-free acrylic resin (FA - Flexiacryl, Sabilex, Argentina), a copolymer (FF - Flexyfast, Sabilex, Argentina), and thermoplastic polyolefin (PF - Premium Flex, Sabilex, Argentina), specifically formulated for dental use (see Table 1).

24 resin patterns with a thickness of 2 mm were printed using a digital light processing printer (Asiga, Australia) and a castable printed resin (Dental Cast, Harz Lab, Russia). The printed samples were then invested and prepared for the injection process. The injection was performed according to the manufacturer's instructions,

utilizing Sabilex (Buenos Aires, Argentina) equipment and adhering to the specified parameters for heat and pressure for the particular resin type (see Table 1).

The thermoplastic resin samples were injected from specific resin cartridges in a gypsum investment.

To ensure standardization, all prepared samples were manipulated by a single operator during the finishing and polishing stages. The top surfaces of the resin specimens were polished using sandpaper with grits of 600, 1000, 1500, and 2000, followed by polishing paste.

The wear test used two spheres on a dry and wet surface. The wet lubricant was obtained from one-third glycerin and two parts distilled water to simulate the artificial saliva. The wear test was performed at room temperature. A zirconia and a stainless steel ball with a diameter of 6,35 mm were used to perform the test. The wear test was performed for half an hour for every specimen. The fixed frequency was 25 rotations/minute and the load was 30 N.

Weight loss was measured using an electronic analytical balance (ABT 100-5nm, Kern, Germany) with an accuracy of 0.00001 grams to observe the change in the sample's weight before and after the wear test with the two balls and under the two different conditions. Each sample was cleaned and well-dried with tissue paper before each weighing. The data was statistically analyzed.

Circular wear scars were examined using optical microscopy (Leica DM500, Wetzlar, Germany). The samples were cleaned with ethanol before the optical examination. The sliding distance (L) across each scar was calculated using tetragonal geometry: $L = 2\pi R f t \sin(\theta)$. The angle θ is 37°, measured between the rotation axis and the line from the sphere center to the contact point on the specimen.

Statistical analyses were calculated using a one-way ANOVA test. The study

was performed using a significance level of 0.05.

Table 1. Flexible resins were used in this study.

Name	Material	Flexibility	Manufacturer	Processing parameters
Premium Ultra (PU)	Thermoplastic polyolefin	High	Sabilex, Argentina	Injection molding technique: heat processed at 240 °C for 15 minutes
Flexiacryl (FA)	Resin copolymer	Medium	Sabilex, Argentina	Injection molding technique: heat processed at 280 °C for 25 minutes
Flexyfast (FF)	Monomer-free acrylic resin	Low	Sabilex, Argentina	Injection molding technique: heat processed at 230 °C for 15 minutes

RESULTS :

3.1.Specimen images:

Images from optical microscopy can be seen in **Fig 1-4**. The images were taken after the test ended t=30 minutes. Near circular-wear scars were examined using the optical microscope. The samples were analyzed using the same magnification of 40x on the optical microscope.

The normal load was 30 N for each sample in both phases, dry and wet. Specimens were washed and cleaned before examination.

Fig.1 and **2** show the effect of zirconia and stainless steel spheres without applying lubricants. Zirconia sphere produces clearer wear marks compared to stainless steel spheres for the same period. Significant differences can be seen in the shapes worn for PU material. The premium ultra (PU) material exhibits smaller marks, and the scars lack a defined shape. In contrast, the other

two materials display rounded shapes. Clear marks can be identified as the sliding direction of the sphere from right to left.

Additionally, the surface of the sphere was examined after the test, revealing some minor superficial scars. The scars on the sphere are less pronounced than those on the tested materials.

Fig. 3 and **4** illustrate how lubricants affect the surfaces of the samples. The presence of a wet environment significantly impacts surface wear. Notably, the application of a glycerine-based lubricant reduced the wear caused by the zirconia sphere on the resin samples but increased the wear of the stainless steel sphere. Fig 3 shows less clear wear scars compared to the dry environment, meaning that the lubricant that simulates the oral saliva has a significant role in wear behavior. Visible wear marks can be

seen in **Fig.4** for the three materials as the sliding direction of the sphere from right to left.



Figure 1. Optical microscope images of wear scars on resin samples with zirconia ball for half an hour in a dry environment. a)PU, b) FFC) FA



Figure 2. Optical microscope images of wear scars on resin samples with stainless steel ball for half an hour in a dry environment. a)PU, b) FFC) FA



Figure 3. Optical microscope images of wear scars on resin samples with zirconia for half an hour in a wet environment)PU, b) FFC) FA



Figure 4. Optical microscope images of wear scars on resin samples with stainless steel ball for half an hour in a wet environment. a)PU, b) FFC) FA

3.2. Weight measurements:

The mean values and standard deviation for weight measurements are illustrated in **Fig 5**. The weight was

registered for each sample before and after the wear test. Statistical analysis revealed some weight loss across all

samples(± 0.0002 g); however, it was not significant when comparing before and after measurements during this time interval ($p \leq 0.05$).

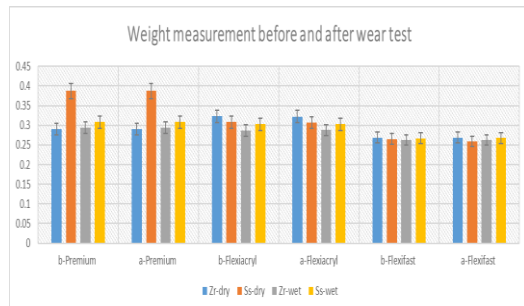


Figure 5. Mean values and standard deviation for the weight losses after wear test with stainless steel and zirconia sphere.

Image J program was used to calculate the radius for every wear area. The results are shown in **Fig.6**. The PU samples develop greater scars in a wet environment with a zirconia sphere. The FF samples are more influenced by the stainless steel sphere in a dry environment and the FA samples by a wet environment.

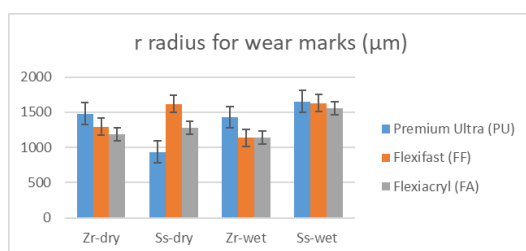


Figure 6. Mean values for the r parameter after wear test.

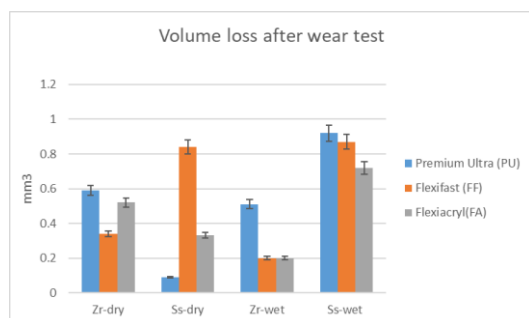


Figure 7. Volume loss for every sample after wear test.

The wear volume loss can be seen in **Fig 7** for every material. The three materials exhibited greater loss in the wet environment for the stainless steel sphere.

DISCUSSIONS:

PMMA has been the primary choice for removable partial denture bases for many years, but flexible resin materials are gaining popularity due to their excellent properties (9).

Abrasion occurs when a hard surface comes into contact with a softer material, such as thermoplastic resin. A significant contributor to abrasiveness is the debris particles created during the wear process (10). During mastication, food particles travel along the surfaces and cause abrasion (11,12). Another important factor to consider is the antagonist. The surfaces of removable partial dentures are vulnerable to indentation within the oral cavity, leading to heightened abrasiveness and accelerated wear. This susceptibility can compromise both their comfort and functionality, highlighting the importance of proper care and maintenance. A rougher surface increases the adherence of plaque and general diseases (13).

In this *in vitro* study samples were uniformly prepared for all three materials and adhered to the dimensions commonly used in clinical practice. The testing involved loading a sliding sphere in a wet environment, simulating conditions found in the oral cavity. The wear test quantifies the relative wear susceptibilities of resin restorative materials against hard contact. Another study in literature used also zirconia spheres to determine materials

wear over a period of time (14). This test however does not fully capture all the complex data present in the oral cavity. This study utilized two types of spheres: zirconia and stainless steel, with the zirconia sphere representing the worst-case antagonist.

The microscopic images revealed that the zirconia sphere produced clearer wear scars on all materials, especially for PU compared to the stainless steel sphere. Additionally, the environment affects the wear rate and depth, especially with different types of lubrication (15). This study confirmed similar findings, demonstrating that a wet environment influences the formation of wear scars. The

resin copolymers (FA) presented greater wear rates compared to the thermoplastic polyphenol (PU) samples. The monomer-free resin (FF) behaved similarly to the polyphenol material (PU). There were different findings for every material based on their microstructure. The weight was registered for each sample before and after the wear test. For half an hour time (1,500 cycles) there was a slight loss in weight but not significant for the tested materials. Further studies with a higher number of cycles must be made for a longer period of time.

CONCLUSIONS

Within the limitations of this study the following conclusions can be drawn:

1. The three materials responded differently in the wear test.
2. Zirconia sphere determined clearer wear marks without using lubricants compared

to stainless steel.

3. The stainless steel sphere produced clearer marks in a wet environment.
4. After a half an hour period of wear there were not significant weight losses for the samples.

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