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ORIGINAL ARTICLE

# Cigarette Smoking Effect on Microhardness and Flexural Properties of Denture Base Resins

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**ABSTRACT**
**Objective:** To identify the tobacco effect on flexural properties and the microhardness of three acrylic resins. **Material and Methods:** Three resins were tested: two thermo-polymerizable acrylic resins (RMB 20 and BMS 014) and one autopolymerized acrylic resin. The 3-point bending and microhardness tests were carried out with a universal tensile-compression machine and a micro-Vickers hardness tester. The acrylic resin specimens have been exposed for 21 days to cigarette smoke in a smoking room. Their mechanical strength was compared to unexposed samples. Statistical analysis was performed using the data processing software SPSS Statistics 21.0. **Results:** The flexural properties of the resins were affected by cigarette smoke only in the case of Major Base 20® (drop in strength with p= 0.02; 0.6; 0.7 and in elastic modulus with p= 0.86; 0.74 and 0.85 for Major Base 20®, BMS 014® and Major Repair®). The cigarette smoke affected significantly microhardness for all groups ($p<0.001$). **Conclusion:** Cigarette smoking does not affect the flexural properties of the acrylic resin (BMS 014® and Major Repair® unlike Major Base 20®), but it does reduce the microhardness.

**Keywords:** Tobacco Smoking; Dentures; Hardness; Flexural Strength.

## Introduction

The proportion of partially dentate adults is increasing, partly due to increased life expectancy and, therefore, a rise in the ratio of the elderly population [1]. There is an increased esthetic awareness among patients receiving dental treatment, especially prosthetic treatment. Removable partial dentures (RPDs) are a common solution for partially edentulous adults [2]. This conventional prosthetic therapy enhances patients' overall well-being [3].

Despite the constant evolution in removable denture base materials, polymethyl methacrylates (PMMA) remain commonly used since their introduction in 1937 [4]. These acrylic resins must meet the specifications defined by the ADA and are controlled [5] by the ISO 20795-1: 2013 standard, which establishes the classification of polymers and copolymers [6,7].

Aside from their low cost, their widespread use is due to their biocompatibility and acceptable aesthetics, ease of handling, good thermal conductivity, and low permeability to oral fluids [8]. The disadvantages of these materials are fractures due to intraoral forces because of their low impact strength, low fatigue resistance [9], and color instability [10,11].

Indeed, they are subjected to repeated mechanical, biological, and chemical stresses in the oral environment, which can alter these materials' longevity and accelerate their biodegradation. In the case of some patients, tobacco is added to this complex environment; it is undeniably one of the most ubiquitous consumer products.

Over nearly 20 years, the total number of tobacco consumers has globally declined by around 60 million, from 1.397 billion in 2000 to 1.337 billion in 2018, according to the third edition of the WHO Global Trends Report of smoking prevalence, 2000-2025 [12].

Still, this excessive consumption has a negative impact on oral health. Additionally, prosthetic rehabilitations are not exempted; they are exposed to aesthetic alterations following discolorations [13-15], significantly affecting the composite resin. Further studies interested in tobacco effect on roughness show that denture bases constructed from heat-cured acrylic resin material undergo a marked increase of surface roughness after exposure to cigarette smoke [4]. We are bound to seek the exact effect of tobacco smoke on flexural strength and microhardness.

Indeed, flexural strength is a variable that determines the resistance to fracture under flexural loading. The higher the flexural strength, the higher the resistance to fracture. When microhardness determines the ease of finishing dental material, the adhesion of dental plaque can increase at high roughness and low microhardness. Accordingly, *an in vitro* study was conducted to identify the tobacco effect on flexural strength and microhardness of 3 acrylic resins. We started from this null hypothesis: tobacco does not affect the flexural strength and the microhardness of the tested PMMA resins.

## Material and Methods

Samples Preparation

Three types of resins were used in this study, two of which are heat polymerized, frequently available for removable prostheses manufacture: Resin Major Base 20® (RMB 20), Resin BMS (RBMS), and another used both for repair and in mouth immediate relining: Resin Major Repair® (RMR). The characteristics of the acrylic resins used are grouped in Table 1.

Seventy-two acrylic resin samples were constructed from these materials measuring 65 mm × 10 mm × 3 mm and fabricated according to American Dental Association Specification No. 12 [16]. The specimens were randomly divided into lots: 24 for the Major Base 20 resin, 24 for the BMS resin, and 24 for the autopolymerized acrylic resin [17].

**Table 1. Materials and manufacturer information.**

| Characteristics | Major Base 20® | BMS 014® | Major Repair® |
|---|---|---|---|
| Polymerization Type | Thermopolymerizable | | Autopolymerized Acrylic Resin |
| Presentation | Powder (453g) and liquid (250ml) | Powder (500g) and liquid (250ml) | Powder and liquid |
| Manufacturer | Major Prodotti Dentari S.p.A., Italy | BMS Dental S. r.l., Italy | Major Prodotti Dentari S.p.A., Italy |
| Lot N° | 1502 KO | 10415 | 1302 TY |
| Standard | ISO 20795 Type 1 Class 1 | ISO 1567 Type 1 Class 1 | ISO 20795 Type 1 Class 1 |

These samples are prepared according to the press technique using a bronze muffle and respecting the manufacturers' recommended doses [18]. For the thermo polymerizable resins: The muffle was put under a gradually increased pressure until the maximum reduction of resin excess and complete closure of the muffle. The muffle was placed under a press at 1.4 bar for 20 minutes and then immersed in water. The temperature was gradually brought to 75 °C for 3 hours, followed by a one-hour boiling point at 100 °C. After gradual cooling of the muffle, deflating was carried out.

The specimens for the chemo-polymerized resin are prepared in a pressure cooker. The specimens were finished using a tungsten carbide bur. Polishing was carried out with 250 sandpaper, and grinders mounted on a polishing tower. Part of the specimens was thus eliminated for non-compliance with standards. After that, samples from each lot of resin were divided into 2 (n=12) subgroups as follows: The first subgroup is for specimens exposed to tobacco, and the second subgroup test is for specimens not exposed to tobacco.

Before exposure, samples were immersed in distilled water for 24 hours at 37 °C to remove residual monomer [4,19]. The unexposed subgroups were left in artificial saliva for 21 days [14].

Tobacco Smoke Exposure

The tobacco used contains 0.8 mg of nicotine and 10 mg of Tar (Cristal, Régie Nationale des Tabacs et des Allumettes, Tunis, Tunisie). A smoking chamber is made of insulating materials with a cover that hermetically seals the chamber. Three openings for the cigarette smoke entry have been designed to connect to a silicone tube, which three cigarettes fit perfectly. The chamber is connected to a suction system by creating negative pressure through a silicone tube. The pressure deployed by the vacuum pump has a maximum power of 8000Pa. Thus, an opening is created to relieve the pressure and approximate the standard conditions (approximately 20 mm hg; 1 mm hg = 133Pa) [14,20].

Concerning the number of cigarettes used per day, a heavy smoker attitude was followed [21-23], which means 20 or more cigarettes per day. For each subgroup, 20 * 3 = 60 cigarettes were smoked daily for 21 days [20]. Nine puff cycles were performed for each cigarette. Each cycle had a puff duration of 2 seconds and a puff frequency of 1 puff every 60 seconds. Each cigarette was smoked within a standard time of 10 minutes (Table 2). All cigarettes were smoked within 10mm of the filter paper [4,24]. The side not to be exposed has been marked with a marker. The specimens were placed at the back of the smoking chamber. Each sample was soaked in the same artificial saliva as a control subgroup before exposure to the smoke.

**Table 2. Recapitulation of tobacco exposure.**

| Groups | N | Number of Cigarettes Per Day | Total Exposure Days | Time for Each Cigarette |
|---|---|---|---|---|
| RMB 20 | 12 | 60 | 21 | 10 minutes |
| BMS 014 | 12 | 60 | 21 | 10 minutes |
| RMR | 12 | 60 | 21 | 10 minutes |

RMB 20: Resin Major Base 20; RBMS: Resin BMS; RMR: Resin Major Repair.

Flexural Strength Test and Elastic Modulus

Flexural strength was measured for each sample using the th4-H5KS Model HTN-5000N universal tensile machine equipped with a three-point flexion device. It is expressed in Newtons dependent on the maximum load applied. The specimen, placed on the two supports of the machine, was deformed through a force applied at an equal distance from these supports. The stress progression rate is constant and fixed at 1 mm/min. The two supports were spaced 50 mm apart. The stress value was progressive until the fracture of the specimen (Figures 1 and 2).

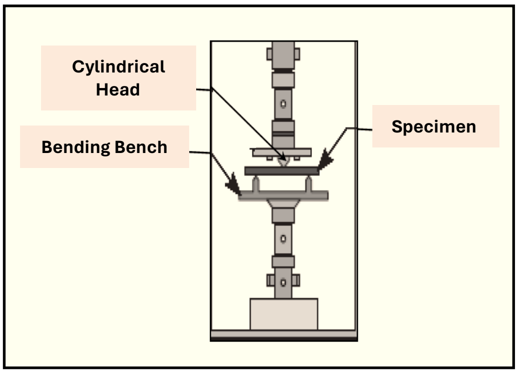


**Figure 1. Device ensuring the specimen bending by load application.**

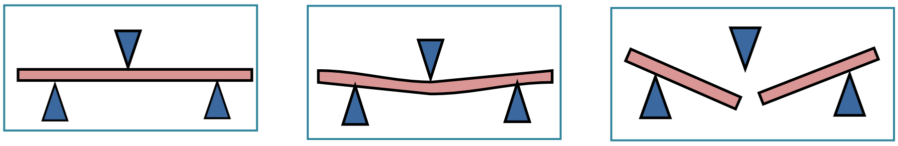

**Figure 2. Principle of the 3-point bending test: Samples were placed on the H5KS Model HTN-5000N tension-compression machine, which was ready for the 3-point bending test.**

The value of the flexural strength (R) expressed in mega-pascal was calculated according to the following formula $R = 3PL / 2bd^2$ where: R: is the flexural strength (MPa), P: is the maximum load applied to the specimen (N), L: distance between the two supports, b: is the width of the sample, d: is the thickness of the sample [25]. The results of the flexural strength test were used to calculate the modulus of elasticity using the following formula: E = FL3 / 4bh3d, where the variables are as follows: (E) modulus of elasticity (MPa), (F) load (N) at a suitable point (p) in a straight line of the tension/strain curve (elastic strain), (L) distance between the two supports, (b) width of the test piece, (h) thickness of the test piece, (d) deviation at this point (p).

Microhardness Test

The half specimens collected after the three-point bending test were used for this test. The machine used was a "micro-Vickers hardness tester digital auto turret" having the following characteristics: model 402 MVD and serial number V20614. The side of the half specimens exposed to tobacco smoke was placed on the apparatus tray. The microhardness measurement is the average of three measurements taken at three different locations under a load of 300 grams for 15 seconds [26]. The device gave the microhardness value directly after setting the magnification (X10) and delimiting the indentation by the operator. The value was calculated with software by measuring the depth and diagonals of the imprint left by the pyramid indenter.

Statistical Analysis

Statistical analysis was performed using the data processing software SPSS Statistics 21.0 (IBM Corp. Armonk, NY, USA). Normality was verified for the two quantitative variables, namely, flexural strength and Vickers microhardness, the distribution being Gaussian. The statistical tests used were the parametric one-way ANOVA tests to compare samples before and after exposure to tobacco. The level of significance adopted was $p<0.05$.

## Results

The RMB 20 significantly changes flexural strength ($p<0.05$). Indeed, the values drop after exposure to cigarette smoke (Table 3). There is a difference between the maximum and minimum values of the samples. The elastic modulus also decreases, but not significantly ($p>0.05$), showing no change in the stiffness of the samples (Table 4).

For the BMS 014 group, the mechanical behavior barely changes. Despite their decreases, the values of flexural strength and elastic modulus remain no significant ($p>0.05$). Equally, in the case of the BMS 014 and RMB 20, flexural strength and elastic modulus decrease but not significantly ($p>0.05$), showing again that tobacco does not affect this property (Tables 3 and 4).

**Table 3. Mean values, standard deviation, maximum, minimum, and p-value of flexural strength for exposed and unexposed samples.**

| Samples | N | Mean | SD | Minimum | Maximum | p-value |
|---|---|---|---|---|---|---|
| NES RMB 20 | 12 | 60.2333 | 11.06388 | 48.08 | 86.91 | 0.02 |
| ES RMB 20 | 12 | 48.8033 | 11.32575 | 30 | 66 | |
| NES BMS 014 | 12 | 61.2508 | 11.31763 | 42.75 | 76.91 | 0.6 |
| ES BMS 014 | 12 | 59.1617 | 14.00027 | 37.25 | 81.41 | |
| NES RMR | 12 | 48.6150 | 10.67425 | 35.41 | 69.58 | 0.7 |
| ES RMR | 12 | 46.6492 | 13.23137 | 27.33 | 69.33 | |

NES: Unexposed Samples; ES: Exposed Samples; RMB 20: Resin Major Base 20; BMS 014: Resin BMS 014; RMR: Resin Major Repair.

**Table 4. Mean values, standard deviation, maximum, minimum, and p-value of elastic modulus for exposed and unexposed samples.**

| Samples | N | Mean | SD | Minimum | Maximum | p-value |
|---|---|---|---|---|---|---|
| NES RMB 20 | 12 | 1267.7743 | 173.19914 | 940.97 | 1508.96 | 0.86 |
| ES RMB 20 | 12 | 1248.8125 | 333.32665 | 771.01 | 1833.32 | |
| NES BMS 014 | 12 | 1281.7593 | 255.79381 | 862.26 | 1653.15 | 0.74 |
| ES RBMS 014 | 12 | 1250.6845 | 184.82905 | 990.73 | 1566.34 | |
| NES RMR | 12 | 1138.6613 | 254.15113 | 843.62 | 1604.93 | 0.85 |
| ES RMR | 12 | 1120.0715 | 214.74618 | 737.84 | 1568.28 | |

NES: Unexposed Samples; ES: Exposed Samples; RMB 20: Resin Major Base 20; BMS 014: Resin BMS 014; RMR: Resin Major Repair.

With a $p<0.001$, the significant decrease in the hardness of the BMS 014 is confirmed (Table 5). As for RMB 20 and BMS 014 groups, a significant drop ($p<0.001$) in the hardness value for the specimens exposed to tobacco was recorded for the auto RMR (Table 5).

**Table 5. Mean values, standard deviation, maximum, minimum, and p-value of Vickers microhardness for exposed and unexposed samples.**

| Samples | N | Mean | SD | Minimum | Maximum | p-value |
|---|---|---|---|---|---|---|
| NES RMB 20 | 12 | 18.7458 | 1.16787 | 17.16 | 20.70 | <0.001 |
| ES RMB 20 | 12 | 13.3975 | 1.28585 | 10.80 | 15.83 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| NES BMS 014 | 12 | 17.9875 | 1.28348 | 16.00 | 20.50 | <0.001 |
| ES BMS 014 | 12 | 11.5942 | 1.18279 | 10.03 | 14.46 | |
| NES RMR | 12 | 16.4592 | 0.49283 | 15.36 | 17.00 | <0.001 |
| ES RMR | 12 | 12.3167 | 0.26200 | 11.90 | 12.73 | |

NES: Unexposed Samples; ES: Exposed Samples; RMB 20: Resin Major Base 20; BMS 014: Resin BMS 014; RMR: Resin Major Repair.

## Discussion

Our null hypothesis was partially rejected. Tobacco negatively affects microhardness, but the flexural strength was not altered for all tested resins except for Major Base 20 resin.

According to a review published in 2018 on the prevalence of smoking in the Maghreb, Tunisia appears to come first as a tobacco-consumer country [27]. This fact inspired us to conduct this *in vitro* study in order to investigate the effect of tobacco on flexural strength and the microhardness of denture base acrylic resins.

The specimens used in this study were prepared with plexiglass patterns. These plexiglass patterns have the advantage of being able to be reused repeatedly to produce conforming resin specimens. This technique prevents deformation and damage to the edges of the wax models during muffling. In addition to this technique, the partial muffling with heavy silicon in contact with the plexiglass (silicon molding) made it possible to minimize both the number of muffles and the roughing operations.

To accelerate tobacco's possible effect, the study adopted heavy smokers' attitudes (1 pack per day). And since the chosen enclosure contains 12 samples, the number of cigarettes has been increased three times to ensure the impregnation of all specimens; that is to say, three packages for each type of acrylic resin for 21 days [14,20]. Almost the same protocol as Patil et al. [14] has been followed in their previous studies. Any device permanently placed in the mouth should be meticulously polished. Indeed, according to Patil et al. [14], the surface condition is directly related to the degree of material polishing and finishing.

In this study, the smoking process takes place in a small enclosure, thus inducing an increase in temperature. This is partly responsible for surface deterioration [20]. According to Patil et al. [14], the thermal effect of the smoking process should be noticed. Indeed, one of the causes of material degradation in the oral cavity is the continual change in temperature. The rise and fall of temperature is involved in polymer chains' movement inside the polymer mass, according to Phoenix et al. [28]. This can induce stress on the material surface and the propagation of cracks [5]. Subsequently, material defects and surface deterioration are accentuated [20].

According to May et al. [11], overheating or insufficient curing temperature causes further porosity in the material. This is proportional to tobacco particle adhesion and microhardness decrease. Thus, this study showed that the effect of the combustion of tobacco accentuated the surface layer deterioration of the three acrylic resins used.

The 3-point bending test is evaluated according to the ISO 1567.1999 Standard. This test is widely used to assess the internal resistance of materials under different functional stresses. Our results showed a decrease in the flexural strength for Major resin but not in the elastic modulus. It could be due to a polymerization defect in some specimens or a localized defect in specimen thickness. In fact, a minor defect can lead to a big difference in value. Thus, cigarette smoke did not modify this parameter, a mixture of compression, tensile, and shear strength, directly reflecting material stiffness and breaking strength [27-29]. It was the case only for Major resin.

For BMS 014 resin and Major Repair®, there was no significant change in either flexural strength or elastic modulus. The tobacco smoke particles acted superficially and did not bury themselves inside the material at the deep layers. This smoke acted locally at the level of imperfections, irregularities, and surface porosities and could not reach the deeper defects of the PMMA layer.

Indeed, since their effect remained limited to the surface, these substances spared any porosities present at deep layers. So, their flexural strength and elastic modulus remained unharmed, owing to their rigidity and fracture resistance.

Thus, acrylic resin strength depends on several factors, such as the molecular weight of the polymer, polymer size marbles, the amount of residual monomer, plasticizer composition, amounts of cross-linking agents, the internal porosity of polymer matrix, the thickness of denture base, factors related to the patient, type of polishing and chemical agents action [21]. This smoking process, followed in this study, did not precisely reproduce that *in vivo*; the enclosure of tobacco exposure was more extensive than that in the oral cavity. In addition, within the mouth, there is the presence of saliva along with tongue movements with their cleaning effect on teeth and dentures.

The smoke was undoubtedly one of the causes of surface hardness deterioration, but the exact constituent to account for them remains unknown. Also, there is the effect of salivary enzymes, the variation in pH, and the absorption of water, which are all parameters intervening in the degradation of the restoration materials and must be taken into account [5].

In addition, the smoking process lasted only 21 days. This period did not alter the materials' strength. But in the long run, there could be an acceleration of degradation. Indeed, in the mouth, where several parameters interact, including tobacco in particular, dentures may have their rigidity reduced and thus become more vulnerable to fracture.

Hardness is a mechanical parameter used to characterize material surfaces. It can be defined as the resistance that material opposes to touch, pressure, impact, or wear. In the case of rigid polymers, the Vickers microhardness test is the most widely used method. The results showed a marked decrease in microhardness for the three acrylic resins used. Thus, tobacco-consumption smoke has an inevitable effect on the PMMA surface. The smoke caused an alteration of the material's surface layers.

After exposure, an excessive deposit of certain smoking components, including "tar" adhering to specimens' surfaces, was noted. Indeed, approximately 0.2% of tar composition is represented by brown pigments [19].

Apart from tar, upon combustion, the resulting smoke contains several other components, such as carbon monoxide, carbon dioxide, nicotine, ammonia, nickel, arsenic, and heavy metals such as lead and cadmium. This deposit, which causes a noticeable color change, is responsible for surface deterioration, reducing the hardness of the three acrylic resins [4].

The surface roughness is proportional to particle incrustation. In the case of tobacco smoke, these particles are released in substantial quantities, which are not without consequence in terms of defects and irregularities. It certainly alters the color but also the material's hardness [20,29]. The mechanical properties investigated in the present study were only a limited view of the materials. This *in vitro* study was limited in simulating the clinical condition.

Further studies investigating the effect of tobacco on the mechanical behavior of dentures in the oral environment are warranted. There is still a need for clinical studies with complete simulation of the oral environment and a longer time interval to assess tobacco's esthetic and mechanical impact.

## Conclusion

Cigarette smoking did not affect the elastic modulus of the tested resins. A decrease in flexural strength was noted for all samples, but it was statistically significant only for Major Base 20 resin. The microhardness of acrylic resins dropped significantly after cigarette smoking.

## Authors' Contributions


| | | |
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| SJ | https://orcid.org/0000-0001-9915-3637 | Methodology, Formal Analysis and Writing - Review and Editing. |
| SB | https://orcid.org/0000-0001-6576-5088 | Investigation, Data Curation and Visualization. |
| AL | https://orcid.org/0000-0003-4444-4271 | Validation. |
| MT | --- | Conceptualization and Supervision. |
| All authors declare that they contributed to a critical review of intellectual content and approval of the final version to be published. | | |


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None.

## Conflict of Interest

The authors declare no conflicts of interest.

## Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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