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Wear resistance properties of the commercial acrylic based artificial teeth

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Abstract

Wear resistance properties of different brands of commercially available acrylic based artificial teeth were carried out in the presence of artificial saliva at the body normal temperature (37 oC) under the applied load of 64N by using pin-on-disc tribometer, fabricated in our laboratory. All the tested samples showed different values of the wear resistance property. Attempts were made to correlate wear resistance properties of these teeth with cost of the teeth. This study gave us some indication that the teeth with high price showed better performance, with the exception of the teeth brand 1 (brand name- Welbite), which showed good performance despite of their low price. The variation in wear resistance performance of these teeth was in fact attributed to the variation in quality of the teeth precursor material, properties of the filler particles, blending/ molding process of the finished product, etc.

Keywords: Wear, Artificial teeth, Acrylic resin, Tribometer.

INTRODUCTION

The commercially available teeth are generally composed of polymeric compounds or made up of porcelain. The polymer-based teeth are commonly used for making dentures due to the fact that various biocompatible properties of these types of teeth are controlled to the desired values during the manufacturing processes. For instance, bonding with denture, texture for cracks-free mechanical shaping, polishing, contact with other natural and artificial teeth, etc [1]. However, in comparison to porcelain-based teeth, the polymer-based teeth have low wear resistance and may not be recommended for longer use. In fact, wear results, at the contacting surfaces, wherever two bodies in relative motion are come in contact under the applied load. Such is the case with teeth where wear continues to be a major problem for patients with artificial teeth, since it creates a number of health related problems [2,3]. Following these concerns, a number of researchers have been focusing on developing wear resistant polymeric composites which could be employed for making artificial teeth.

Both dentists and patients prefer teeth having long life [4-7]. In order to fulfill demands of the dentists and patients, teeth making companies try to consider various measures for improving wear resistance properties of their products. These measures include development of good polymers, as well as polymer-based nanocomposite materials for making artificial teeth [8-12]. The researchers, who are involved in producing high quality and biocompatible materials for making artificial teeth, have made significant progress.

This study involves the evaluation of wear resistance properties of seven brands of commercial artificial teeth in the presence of artificial saliva. Attempts have been made to explain the observed differences in wear rate of these teeth.

EXPERIMENTAL

Materials

Artificial teeth of various brand names were purchased in the local market of Peshawar, Pakistan. Analytical grade essential chemicals were obtained from Merck and used as received. Distilled water (Millipore grade) was used for making stock and working solutions.

Artificial Saliva

1 dm^3 saliva was prepared [17,18] by making aqueous solution, containing 0.4, 0.4, 0.795, 0.78, 0.005, and 1.0 gdm^{-3} of NaCl, KCl, $CaCl_2.2H_2O$, $NaH_2PO_4.2H_2O$, $Na_2S.9H_2O$, and $(NH_2)_2CO$, respectively.

Wear Measurement

Modified Pin-on-disc Tribometer (Fig. 1) was employed for the evaluation of wear resistance properties of the commercial artificial teeth. The as-purchased artificial teeth were mechanically made into circular pins of equal diameters (3 mm) in order to fit them in the machine holder. Each pin was then subjected to wear tests, in which the pin of known weight was rubbed against the rotating stainless steel disc of known roughness. All the tests were performed under constant applied load (64 N) and sliding distance (1080 m) in the presence of 50 cm^3 of the synthetic saliva at the normal human body temperature (37 ^oC). The pin-on-disc assembly was housed in a thermostatically controlled 100 cm^3 double-walled stainless steel vessel. After the termination of each experiment, the tested pin was re-weighed.

Characterization

Scanning Electron Microscopy (SEM)

The wear debris as well as other desired solids were characterized by scanning electron microscopy (SEM, JEOL, JSM-5910). For this purpose, debris samples were mounted on standard aluminum stubs by means of a conducting double stick carbon tape and were sputtered with gold in an evacuated glass chamber of the auto fine coater (JEOL, JFC-1600) for 40 s. These stubs were then fixed in sample holder and shifted to the chamber of the scanning electron microscope. Following the standard procedure, first the observation chamber was evacuated and then distance between sample and tip of the electron gun was adjusted at 10 mm. Accelerating voltage was kept at 15 keV. Finally, morphological features of the test sample were inspected.

Fourier Transform Infrared Spectrometry (FTIR)

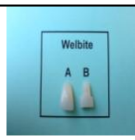
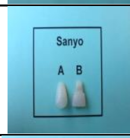
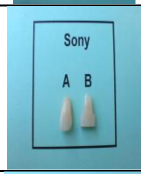
Infrared spectroscopic analysis of the test materials were performed with FTIR instrument (Schimadzu, IR Prestige-21, FTIR-8400S). In this process, small amount of the test powder and potassium bromide (KBr) were mixed in proper ratio and ground to finely powdered with the help of a specific mortar and pistol. Small amount from this powdered sample was shifted to a sample holder of the Diffuse Reflectance Accessory (DRS-8000A) of the FTIR instrument. The sample was then scanned at the scan rate of 10 in the region of 4000-400 cm^{-1}.

RESULTS AND DISCUSSION

Wear Resistance of Artificial Teeth

Acrylic based artificial teeth carrying different brand names were purchased in the local market from the reputed firm, involved in the teeth business. These teeth had different prices, close appearance and different densities. Details descriptions are describe in Table 1.The teeth presented in Table-1 were subjected to wear test in the presence of the artificial saliva under the applied load of 64 N for the sliding distance of 1080 m at the normal body temperature (37 ^oC), using the Pin-on-disc Tribometer, shown in Fig. 1. Wear of the test samples was assessed from the material loss during the wear experiments and the results are depicted in Fig. 2. As can be seen from this figure, considerable difference in wear resistance was observed among the commercial artificial teeth, measured under the same experimental conditions.

Table 1: Densities / costs / photos of various artificial teeth

Brand No.	Density g/cm^3	Cost/6 pieces set Pak. Rs	Teeth photo
[brand-1]	1.093	30	
[brand-2]	1.143	51	
[brand-3]	1.164	29	
[brand-4]	1.066	21	
[brand-5]	1.198	25	
[brand-6]	1.071	15	
[brand-7]	1.154	15	

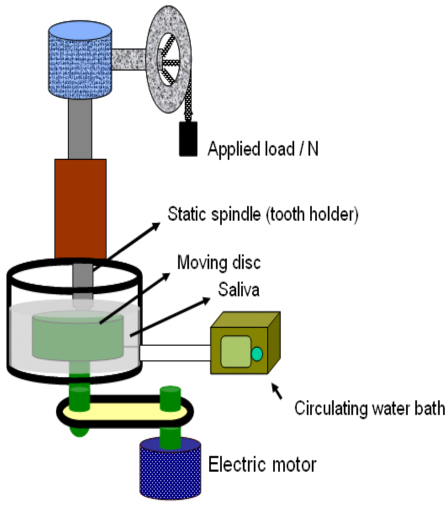


Figure 1: Schematic of Pin-On-Disc (POD) Tribometer, fabricated in this work at the Fine Particles and Tribology Research Laboratory, National Centre of Excellence in Physical Chemistry, University of Peshawar, Khyber Pukhtunkhwa, Pakistan

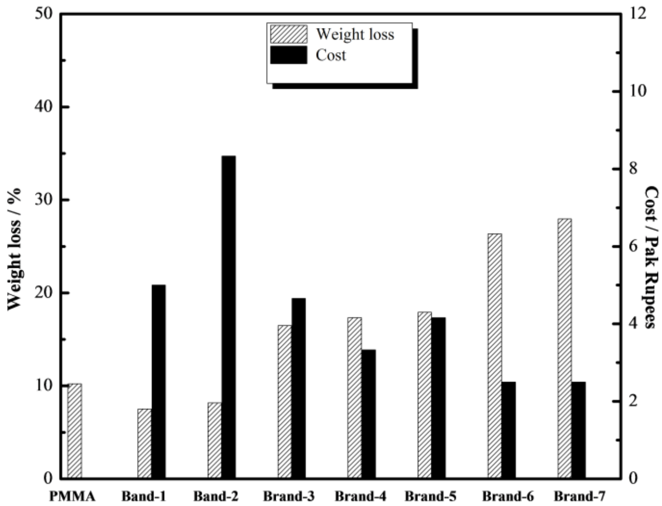


Figure 2: Loss in weights of different brands of artificial teeth during wear test, and their cost in Pakistani rupees. Wear test conditions: Applied load, 64N; Sliding distance, 1080 m; Temperature, 37 °C

Generally, teeth with high wear resistance and low cost is preferred by both the dentists and patients. As a general public concept, teeth with high price are expected to be of good quality in terms of material loss during use in mouth. In order to check this concept for the commercial teeth studied in this investigation, cost per single tooth has also been included in Fig. 2 along with material loss in the described commercial teeth. Inspection of this figure indicated that in general, costly teeth demonstrated high wear resistance. In addition, it can also be seen from this figure that except teeth of brand-1 and brand-2, all the other brands of teeth showed poor wear resistance as compared to the base material (PMMA). This observation indicated that in the later brands, the dispersed fillers apparently weakened the strength of the polymeric matrix and thus showed poor wear resistance as compared to the filler-free material. The following factors may be held responsible for the poor wear resistance of the brands -3 to 7:

- Poor adhesion of the matrix material with the dispersed filler particles.
- Agglomeration of the filler particles during the blending processes.
- Filler particles were softer than the matrix material
- Non-uniform distribution of the filler particles in the matrix material.
- Insufficient amount of fillers in the matrix material

Wear debris, generated during the wear experiments with these teeth, were analyzed with FT-IR and the results are displayed in Fig. 3. Inspection of this figure indicated that the materials of all brands of teeth showed identical spectra. All the spectra in these figures composed of absorption bands at different locations. The characteristics sharp intense peak at 1731 cm^{-1} corresponded to the stretching vibrations of the ester carbonyl group. The broad peak ranging from 1300-1000 cm^{-1} presented the stretching vibration of the C-O (ester bond) and the broad band from 970-700 cm^{-1} is corresponding to the C-H bending. The broad peak ranging from 3000-2760 cm^{-1} was considered to be stretching vibration of the –OH group. In addition, all the spectra in this figure matched well with the IR spectrum of pure PMMA (poly-methyl-methacrylate), described in the literature [13-15]. These findings revealed that,

(a) The base materials of all the commercial teeth were composed of PMMA (poly-methyl-methacrylate) and,

(b) The amount of fillers in the PMMA (poly-methyl-methacrylate) matrix in all the mentioned teeth was smaller enough to be detected with infrared spectrometry.

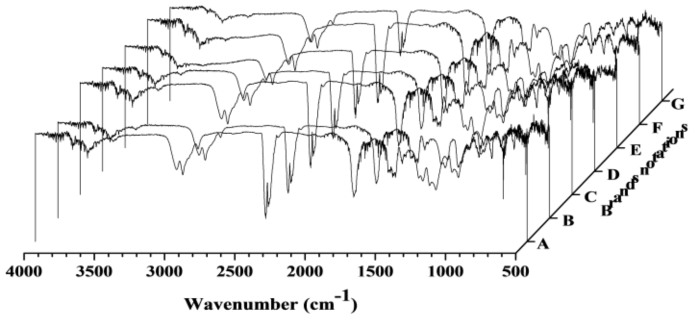


Figure 3: FT-IR spectra of the commercial polymeric artificial tooth of different brands, described in Table-1. A (brand-1); B (brand-2); C (brand-3); D (brand-4); E (brand-5); F (brand-6); G (brand-7)

Similarly, the debris obtained in the wear experiments with all the above-mentioned commercial artificial teeth were inspected with scanning electron microscope (SEM images, Fig. 4). These SEM images revealed the wear debris composed of particles with irregular shapes and sized in the size range of 1-7 µm. It can further be seen from these images that the debris did not show the presence of particles, which could be classified as filler material. Moreover, no significant difference was found in the particle morphologies of the obtained debris in all the teeth, except brand-1, which were relatively smaller in size. This observation pointed to the textural difference between brand-1 and other brands tested in this study. It was interesting to note that brand-1 showed higher wear resistance as compared to teeth of other brands, which indicated besides other factors, texture of the artificial teeth has obvious effect on their wear resistance properties.

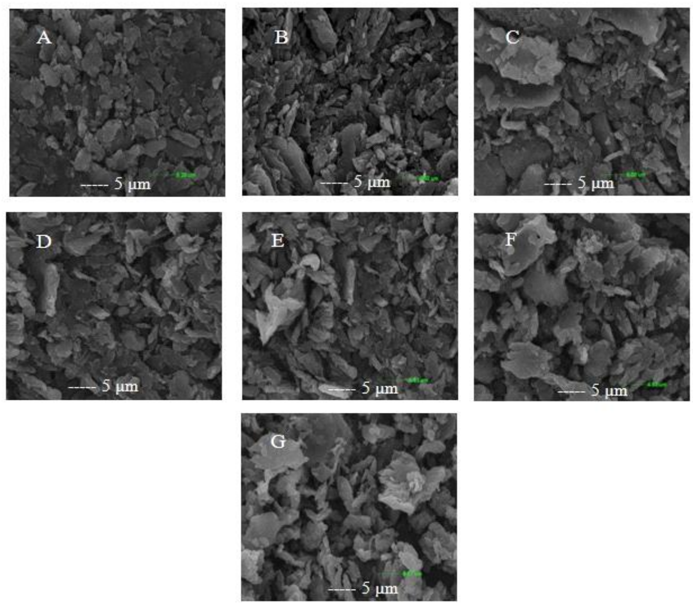


Figure 4: Scanning Electron Micrographs (SEM) of the wear debris, generated during the wear test with the commercial artificial teeth. A (brand-1); B (brand-2); C (brand-3); D (brand-4); E (brand-5); F (brand-6); G (brand-7)

It was also of interest to study the wear rate of the above-mentioned commercial artificial teeth. In this regard, wear experiments were conducted under the constant applied load of 64 N for various sliding distance in the presence of artificial saliva. The weight loss of the test tooth was recorded in all the wear experiments and from which the wear rate was estimated by using the following equation [16]:

$$W = m/LF \quad (1)$$

m = Weight loss (%)
W = wear rate (mm^3/Nm)
L = sliding distance (m)
F=force (N)

The values of wear rate obtained with all the commercial artificial teeth, studied in this work, have been plotted in Fig. 5. This figure demonstrated that significant difference was there in the wear rates, observed in different brands of the mentioned artificial teeth. Following the trend in wear rate variation, teeth of brand-1 (brand name, Welbite) could be classified the better one in terms of the wear resistance. This better performance of teeth of the mentioned brand with respect to others artificial teeth could be attributed to the use of good quality of filling material; uniform distribution of the filler particles in the polymeric matrix; the good adhesion of the matrix material with dispersed filler particles, and better curing methodology during the molding / processing of these teeth.

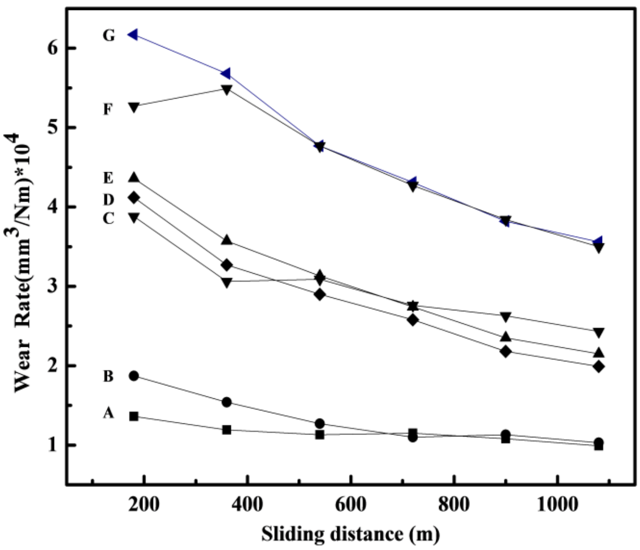


Figure 5: Wear rate of the commercial artificial teeth during the wear experiments in the presence of artificial saliva. A (brand-1); B (brand-2); C (brand-3); D (brand-4); E (brand-5); F (brand-6); G (brand-7).Wear test conditions: Applied load, 64N; temperature, 37 °C

CONCLUSIONS

Significant variation was found in wear resistance properties of the commercial artificial teeth. This was attributed to the quality of the precursor material and precision in the molding processing.

Artificial teeth with low price (brand name "Welbite") indicated better wear resistance performance as compared to other brands, investigated in this study.

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