Wear of Denture Teeth by Use of Metal Plates

Part 2 : Abrasive Wear of Posterior Teeth

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Abstract

An in vitro study was conducted to evaluate the abrasive wear resistance of high-strength denture teeth (HS teeth). Eight types of specimen were used in the experiments; 3 types of HS teeth, 3 types of conventional plastic denture teeth (PL teeth), porcelain teeth and metal teeth. Sliding-induced wear tests were conducted by sliding the samples on a metal plate. The abrasive wear resistance of the samples was evaluated in terms of wear depth, weight loss and SEM observation.

Comparison of wear depth showed that abrasive wear resistance of HS teeth was 4.7 times that of PL teeth, 0.7 times that of porcelain teeth and 8.3 times that of metal teeth. In terms of weight loss, the corresponding values were 3.3-fold, 0.2-fold and 11.4-fold, respectively.

Introduction

The purpose of removable partial dentures as a posterior prosthesis is reconstruction of normal occlusion using artificial teeth. That is, posterior artificial teeth are designed to maintain the form and function of the stomatognathic system including restoration of masticatory function, maintenance of the vertical dimension and prevention of temporomandibular joint dysfunction caused by occlusal disharmony.

Plastic and porcelain materials have been conventionally used for posterior artificial teeth. HS teeth retain some of the advantages of plastic teeth, such as easy occlusal adjustment and economical cost, while offering improved hardness and...
abrasive wear resistance\textsuperscript{1-3}.

Findings of basic studies on HS teeth have been reported, including impact resistance\textsuperscript{4}, bonding strength with denture base resin\textsuperscript{5,6}, and hardness\textsuperscript{1-3,5,6}. On the other hand, clinical findings have centered on the wear resistance of anterior artificial teeth\textsuperscript{7}. However, it seems there have been few studies on abrasive wear resistance of posterior HS teeth\textsuperscript{8,9}.

Therefore we conducted in vitro experiments in order to evaluate abrasive wear resistance of posterior HS denture teeth. We used a total of 8 types of specimen, which were made to slide on a metal plate made of Au-Pd-Ag alloy. The abrasive wear resistance of the specimens was evaluated in terms of wear depth, weight loss and SEM observation.

**Materials and Methods**

1. Materials

   A total of 8 types of specimen were used in our experiments as posterior artificial teeth; 3 types of HS teeth, 3 types of conventional plastic teeth (PL teeth), 1 type of porcelain teeth and 1 type of custom-made metal teeth made of Au-Pd-Ag alloy (Pallatop 12, Sankin), whose shape was comparable to that of porcelain teeth (Table 1).

   From each type, 5 upper right first premolars were chosen, totaling 40 artificial tooth specimens. Forty metal plates made of the Au-Pd-Ag alloy measuring 15×15×2 mm were made to match with the number of specimens and used to make contacts with the buccolingual cusps of the artificial teeth. The metal plates were heat-treated for aging and finished to reduce their surface roughness (Ra) to less than 0.1 μm with waterproof sandpaper and buff polishing.

<table>
<thead>
<tr>
<th>Brand</th>
<th>Material</th>
<th>Mold</th>
<th>Shade</th>
<th>Cusp Angle</th>
<th>Manufacturer</th>
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<td>0489</td>
<td>ED</td>
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<td>A3</td>
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<td>G-C</td>
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</tr>
<tr>
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<td>MN2</td>
<td>S1C</td>
<td>20°</td>
<td>IVOCLAR</td>
<td>SR</td>
<td></td>
</tr>
<tr>
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<td>SHOFU</td>
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<td>20°</td>
<td>G-C</td>
<td>150284</td>
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<td>30M</td>
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<td>SANKIN</td>
<td>A60016</td>
<td>MT</td>
</tr>
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</table>

2. Methods

1) A total of 30 teeth consisting of HS teeth and PL teeth were immersed in distilled water prior to the wear test. Water sorption was measured every 48 h for about 2 months according to JIS T-6508, and wear tests were conducted when each specimen reached a constant weight.

   The wear tests were conducted with a sliding-induced wear testing apparatus (Tokyo Giken), as shown in Fig. 1. Each metal plate was fixed with a jig (Fig. 1, b) on the upper specimen holder of the testing apparatus, while the specimen was
fixed to the lower holder so that both bucco-lingual cusps of the specimen could make contact with the metal plate. Both the upper and lower holders were immersed in distilled water, and the upper specimen holder to which the metal plate was fixed was moved in order to apply 200,000 strokes to the specimen in a mesio-distal direction at a rate of 300 stroke/min, with a stroke length of 3.0 mm and a constant loading of 1 kgf/tooth.

2) Measurement of specimen wear depth

Wear depth was measured before initiation of the wear test (at 0 stroke), and upon completion of 10,000 strokes, 50,000 strokes, 100,000 strokes and 200,000 strokes, respectively.

Wear depth was measured in the following manner. The profile of the lingual cusp was traced at 20 times enlargement in the buccolingual direction using a surface roughness measuring apparatus (Surflyzer Surfcom 2000 A, Tokyo Seimitsu) with a probe diameter of 50 μm and a tracing head speed of 0.3 mm/s. Then each traced image was scanned with an image-analysis system (LA-500, PIAS) fitted with a CCD TV camera (PX-370, pixels H512 × V512, PIAS). The image of the specimen at each measurement point was subjected to binary picture analysis, and then the image of the specimen at 0 stroke and that at each measurement point was synthesized for each specimen.

Wear depth was measured based on the image synthesized from two images. For this, a line was drawn using an increment of 2 pixels from the lingual cusp tip at 0 stroke to the lingual cusp tip after a given number of strokes in the buccolingual direction (Fig. 2). Then the lengths of all these lines were measured to calculate the mean length. This mean length was divided by the enlargement ratio.
of 20 to obtain the measurement value.

3) Measurement of specimen weight loss

Measurement was made at 10,000 strokes, 50,000 strokes, 100,000 strokes and at completion of 200,000 strokes for each specimen. The weight loss was calculated for each specimen by dividing the difference in weight measurements made at 0 stroke and after a given number of strokes by the specific gravity.

4) SEM observation of the specimen wear surface

The wear surface of the lingual cusp of each specimen was photographed using a SEM (EMAX 8700, Horiba) after completion of 200,000 wear strokes.

Results

1. Wear depth of artificial teeth

Figure 3 shows the water sorption of specimens in distilled water. Table 2 and Fig. 4 show the wear depth of specimens at 10,000 strokes, 50,000 strokes, 100,000 strokes and 200,000 strokes.

2. Weight loss of artificial teeth

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<td>(6)</td>
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<td>(3)</td>
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<tr>
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<td>306</td>
<td>527</td>
<td>(28)</td>
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<tr>
<td></td>
<td></td>
<td>132</td>
<td>301</td>
<td>306</td>
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0 : Below 0.0 $\mu$m  Unit : $\mu$m  ( ) : SD

![Image-analysis system](a)  ![Measuring lines on the lingual cusp](b)  

Fig. 2  Measurement of wear depth
Fig. 3 Water sorption of artificial teeth in distilled water

Fig. 4 Wear depth of artificial teeth
Table 3 and Fig. 5 show the weight loss of each specimen upon completion of 10,000 strokes, 50,000 strokes, 100,000 strokes and 200,000 strokes, respectively.

Table 3  Weight loss of artificial teeth

<table>
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<th>Code</th>
<th>1 (×10⁵)</th>
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<td>AR</td>
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<td>(0.9)</td>
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<td>WL</td>
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<td>82.9</td>
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<td>(3.6)</td>
<td>(3.9)</td>
<td>(2.8)</td>
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</table>

0 : Below 1.0×10⁻⁵ cm³  Unit : ×10⁻⁵ cm³ ( ) : SD

Fig. 5  Weight loss of artificial teeth
3. SEM images of artificial teeth

Figures 6, 7 and 8 show the SEM images of the wear surface of the lingual cusp of each specimen upon completion of 200,000 strokes.

Fig. 6 Typical SEM images of HS tooth surface

Fig. 7 Typical SEM images of PL tooth surface
Discussion

Dentures with PL teeth show significant wear at an earlier time due to mastication and swallowing in comparison with dentures whose occlusal surface is restored with other materials. Porcelain teeth, on the other hand, show little wear themselves, but clinically they are often found to cause wear of opposing teeth.

Since clinical use of HS teeth has been increasing, we considered it significant to evaluate the abrasive wear resistance of HS teeth. Therefore experiments were conducted using plastic denture teeth, porcelain teeth and custom-made metal teeth as control materials. The cuspal inclination of these artificial teeth (Table 1) was specified based on the functional cusp angle which is usually used in partial dentures.

1. Method of weight loss measurement

Types of wear test apparatus used for evaluation of the abrasive wear resistance of artificial teeth differ according to the objectives of research and among researchers. As to anterior artificial teeth or restorative materials, test methods
using a toothbrush and toothpaste are widely employed for esthetic evaluation[7,11].

With regard to posterior artificial teeth, on the other hand, HIRASAWA et al. [12], Tsum[13] and JIBIKI et al. [14] reported the results of experiments with an abrasive wear testing apparatus, which simulated the impact and sliding motion occurring during mastication with reference to occlusal contact with opposing teeth.

However, the extent of abrasive wear found in the mouth is influenced by various factors including occlusal biting force[15,16], friction with food[17], individual masticatory efficiency, type of occlusion and type of retainer used[18]. Therefore SATOH[19] has asserted that there is still no in vitro test method which is easy to perform and highly reproducible.

Accordingly, in the present study we used a sliding-induced wear test apparatus which reproduces the sliding-induced wear that occurs in the mouth.

Previously employed wear test methods have included a two-body abrasion method in which no material is placed at the interface between two materials[20,21], and a three-body abrasion method in which an intermediary material is present at the interface[12,14,21]. In our experiments, the metal plate and the specimen maintained very close contact during the sliding motion, so that it was difficult to place the intermediary material between them. The two-body abrasion method was adopted for this reason, and also to eliminate any influence of the intermediary material on wear behavior.

As to the experimental conditions for the wear test, the stroke length was set at 3.0 mm in accordance with previous reports on mastication[22], and the number of strokes was set as 200,000, which is clinically comparable to the number of chewing strokes per year[23]. A constant load of 1.0 kgf/tooth was set with reference to a report by HARRISON et al.[24].

Previous methods for measurement of the amount of wear have included determination of weight loss[13,14,25] and tracing of cusp profile[19]. In consideration of the fact that wear of the upper lingual cusps of artificial teeth, i.e., working cusps, clinically results in a loss of the vertical dimension, we calculated the decrease in height of the cusp tips as the wear depth.

2. Wear depth and weight loss of artificial teeth

Wear depth (Table 2 and Fig. 4) of the three types of HS teeth and porcelain teeth was less than 0.0 μm after completion of 10,000, 30,000 and 100,000 strokes, respectively. As comparative evaluation could not be made among the different specimens, the mean values for each of the specimens after completion of 200,000 wear strokes were compared. The three types of HS teeth showed a wear depth of 50-73 μm. PL teeth, on the other hand, showed a wear depth of 220-364 μm, which was 4.7 times the wear resistance of HS teeth. The wear depth of porcelain teeth was 42 μm, which was 0.7 times the wear resistance of HS teeth, whereas the wear depth of metal teeth was 527 μm, which was 8.3 times the wear resistance of HS teeth. With regard to the weight loss of artificial teeth (Table 3 and Fig. 5), we compared the mean values of the specimens after completion of 200,000 wear strokes relative to the wear depth of artificial teeth.

Weight loss for the three types of HS teeth was in the range 22.2–26.4 × 10⁻⁵
cm³, whereas that of PL teeth, porcelain teeth and metal teeth was in the range 60.6–100.5 × 10⁻⁵ cm³, 6.0 × 10⁻⁵ cm³ and 291.9 × 10⁻⁵ cm³, respectively. HS teeth showed 3.3 times more abrasive wear resistance than PL teeth. This result was comparable to that for the abrasive wear resistance of anterior artificial teeth[71]. The abrasive wear resistance of HS teeth was 0.2 times that of porcelain teeth. This also matches the clinical report of YOKOYAMA, who indicated that HS tooth occlusal wear is slightly greater than that of porcelain teeth but significantly smaller than that of PL teeth[18], and another report indicating that porcelain material wears little when opposed with materials such as metal or resin with a low Vickers hardness[26]. HS teeth showed 11.4 times greater abrasive wear resistance than metal teeth. It has been reported that metal teeth show greater abrasive wear upon contact with the same type of metal[27]. Thus it is conceivable that significant cohesion between metals occurred in our experiment[21,27]. During the sliding-induced wear test in this study, the contaminating layer about 300 Å thick on the surface of the metal plate and the oxide layer of about 100-200 Å may have been removed during sliding, so that marked adhesive wear occurred between two metals[27].

In reality, however, upper and lower posterior teeth do not maintain close contact all the time, and saliva or oily food residue is usually present on the metal occlusal surface. These adhesive materials would act as lubricants between the two opposing surfaces[27], so that wear behavior could be different from that which was observed in this study.

3. SEM observations of wear surfaces of artificial teeth

Figures 6, 7 and 8 show SEM images of the wear surface of the lingual cusp of each artificial tooth. The findings suggest the same tendency as that observed for wear depth and weight loss; the roughness of the wear surfaces of the three types of HS teeth was lower than that of the three types of PL teeth and metal teeth, but slightly greater than the surface roughness of porcelain teeth. Linear defects were often observed on the wear surface of the three types of plastic denture teeth, apparently produced by wear strokes. Metal teeth showed the widest wear area among the specimens, apparently attributable to adhesive wear between two opposing metals of the same kind. Porcelain teeth had very little wear area, but obvious surface roughness was observed in comparison with the surrounding surface. It is considered that a greater number of strokes would enhance the surface roughness, resulting in further wear of the metal plate.

Conclusions

The present study was conducted to evaluate the abrasive wear resistance of HS teeth used as posterior artificial teeth. Three types of HS teeth, 3 types of PL teeth, 1 type of porcelain teeth and 1 type of custom-made metal teeth were used as specimens for sliding-induced tests, employing a metal plate made of Au-Pd-Ag alloy.

Wear depth and weight loss were measured for the 8 types of specimen, and the surface of each specimen was also observed by SEM.
The following conclusions were obtained from the findings of comprehensive evaluation of abrasive wear resistance of artificial teeth:

1. Comparison of wear depth showed that the abrasive wear resistance of HS teeth was 4.7 times that of PL teeth, 0.7 times that of porcelain teeth, and 8.3 times that of metal teeth. Comparison of weight loss showed that the abrasive wear resistance of HS teeth was 3.3 times that of PL teeth, 0.2 times that of porcelain teeth and 11.4 times that of metal teeth.

2. SEM observations of the wear surface showed that the extent of roughness was lowest in porcelain teeth and HS teeth followed by PL teeth and metal teeth. On the other hand, the metal teeth showed greater surface roughness than the other types.

References


