Study of Two-body Wear Performance of Dental Materials

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Abstract: Introduction: The purpose of this study was to evaluate the two-body wear resistances of natural enamel and four dental materials in vitro.

Methods: The testing machine was modified to form a type of pin-on-disk wear test apparatus. Four dental material specimens (Au-Pd alloy, Ag-Pd alloy, FiltekTMP60 and FiltekTMZ350 composite resins) and enamel were used as the pins, and a steatite ceramic grinding wheel was used as the abrasive counter face. The wear volume loss and the rigidity value was measured. The worn surface and the element analysis of the debris were analyzed.

Result: The wear volume loss of Au-Pd alloy and its steatite antagonists were the nearest to those of the dental enamel. SEM microphotographs showed that, the main wear mechanism of the dental materials was abrasive and adhesive wear.

Conclusions: Au-Pd alloy had good wear resistance and was more suitable for dental applications than other three dental materials.

Keywords: Wear performance ■ Dental composite resin ■ Precious dental restorative alloys

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INTRODUCTION

Wear is an important consequence of occlusal interaction.[1] Wear can be defined as the progressive loss of substance resulting from mechanical interaction between two contacting surfaces existing relative motion. Depending on the structure and the interaction conditions of a tribosystem, both mechanical and environmental factors influence the material detachment. The usual classification of wear types include adhesive wear, abrasive wear, fatigue wear, and wear due primarily to chemical action of the environment.

Dental alloys are the major materials for dental restorations and widely used in prosthetic dentistry field due to their good physical and mechanical properties. Owing to their excellent aesthetic properties, dental composite materials gain steadily increasing importance and popularity for the restoration of class I and II defects. The wear behavior of dental composites has continuously been improved over the years; however, limited wear resistance is still regarded as one of the greatest problems of direct posterior resin restorations.[2] With regard to this aspect, clinical long-term studies have revealed that particularly in extensive posterior restorations[3] and in patients with abnormal occlusal habits such as clenching or bruxing composite materials may yield insufficient wear behaviour.[4–6]

Clinical tests are essential for estimating the complex wear performances of dental materials. However, these in vivo evaluations are often restricted by high investments and expenditures, and the results may vary largely amongst patients as the variables cannot be controlled sufficiently.[7] In contrast, in vitro studies allow for the investigation of single parameter of the wear process, but they cannot simulate the complex oral wear situation. In vitro results may, therefore, only partially reflect clinical wear, and it has to borne in mind that even in vitro wear simulations show considerable variability.[8,9]

The aim of this study was to investigate the two-body wear resistance of different light-cured composite resins and precious alloys versus steatite and the natural enamel as the controls. It was hypothesized that the wear of material and antagonist was influenced by the type of materials.

MATERIAL AND METHODS

Specimen preparation

Specimens (n = 9 per material; diameter 4 mm, thickness 11.2 mm) were prepared from different dental metal materials (Au-Pd alloy and Ag-Pd alloy) and light-cured composite resins (FiltekTMP60 and FiltekTMZ350). Specimens were smoothed under permanent water cooling using a polishing machine and silicon carbide grinding paper (grain 500). Plain human enamel specimens from the buccal faces of teeth were used as references for all materials.

Sliding wear tests were performed on a MMV-1 pin-on-disk vertical universal friction and wear testing machine. The testing machine was modified to form a type of pin-on-disk type apparatus. Dental metal materials (Au-Pd alloy and Ag-Pd alloy), light-cured composite resins (FiltekTMP60 and FiltekTMZ350) and natural enamel (used as control) were used as the pin, and a steatite ceramic grinding wheel was used as the abrasive counter face. A normal load of 41 N was applied to the specimens. The pin was rotated at a velocity of 150 rpm. The wear characteristics were evaluated by the volume loss of the specimens after sliding 50000 cycles. The artificial saliva was prepared according to International Organization for Standardization, ISO TR10271. The composition of the artificial saliva solution was 0.4 g L^{-1} NaCl, 0.4 g L^{-1} KCl, 0.78 g $L^{-1}$$Na_2HPO_4 \cdot 2H_2O$, 0.005 g L^{-1} $Na_2S \cdot 2H_2O$, 1 g L^{-1} Urea and 0.795 g L^{-1} $CaCl \cdot 2H_2O$.

The volumetric wear rate was calculated from the weight change. The failure mode on the worn surface was analyzed using scanning electron microscope (SEM) and the elements of abrasive dust analysis were carried out by energy dispersive X-ray spectroscopy attached to SEM.

Determination of Vickers hardness

The Vickers hardness (HV) of each composite material was measured on six specimens (diameter 9 mm, height 2 mm) using a microhardness tester (MHV2000, Shanghai). A load of 0.49 N was applied for 15 s using a pyramid shaped die; the depth of the impression allows for the calculation of the hardness of the sample. HV was proportional to the quotient of the applied force and the impression surface, which was a part of a pyramid with square basement.

Statistical analysis

Data were analyzed using statistical software (SPSS 11.0 for Windows; SPSS Inc., Chicago, USA). The average value and standard deviations of HV and wear volume loss were calculated and analyzed using one-way analysis of variance (ANOVA). A P value less than 0.05 was considered statistically significant.

RESULTS

The wear volume loss and HV of the specimens were shown in Table 1. Volume wear loss followed by ascending was Au-Pd alloys, Ag-Pd alloy, FiltekTMZ350 and FiltekTMP60 ($P < 0.05$). Volume wear loss of steatite ceramics followed by ascending was FiltekTMP60, FiltekTMZ350, Ag-Pd alloy and Au-Pd alloys ($P < 0.05$). The volume wear loss of Au-Pd alloys and its wearing materials were the nearest to that of the dental enamel. Au-Pd alloys had the highest HV values and P60 resin had the lowest.

The typical worn surface of the Enamel samples after a sliding distance of 50000 m was showed in Figure 1. The wear track of the Enamel samples showed large plastic deformation and grooved scratches, and some materials pile up at the edge of the wear track. It show that the main wear mechanism underlying the dental enamel is abrasive wear accompanied with adhesive wear.

In contrast to the Enamel samples, the Au-Pd samples exhibited severe plastic deformation on the wear surface, as shown in Figure 1B. They showed adhesive wear and bulk wear marks pile up on the wear surface. Numerous grooved scratches with some abrasive particles could be seen on the wear surface of Ag-Pd samples, which belonged to abrasive wear obviously.

The SEM micrographs (Figure 1D and E) showed the typical morphology of light-cured composite resins formed during the wear experiments. A mass of wear marks and severe plastic deformation appeared on the wear surface of P60 composite resins. Relatively, Z350 composite resins samples showed a smooth surface with a little ploughing lines. During the experiment, two composite resins were producing a white debris, less amount of Z350 debris. It indicates that, the wear mechanism of light-cured composite resins is abrasive wear and adhesive wear.

The EDS spectra taken from the abrasive dusts were shown in Figure 2. The elements of Au-Pd alloy wear debris mainly included Au, Ag and Cu. The components of Ag-Pd debris were Ag, Zn and Pd. The components of Enamel wear dusts were Ca, P, C and O, which may construct characteristic hydroxyapatite. The elements of FiltekTMP60 and FiltekTMZ350 were mainly Si and O.

DISCUSSION

Wear is a developing phenomenon occurring in the oral cavity when surfaces move in contact. Both dental materials and opposing teeth may constitute various friction pairs when chewing. The influencing factors of wear

Table 1. Volume loss of samples and steatite ceramics and microhardness of samples.

Materials	Volume loss of samples (cm^3)	Volume loss of counter samples (cm^3)	HV
Au-Pd alloy	0.00547 ± 0.00013	0.00473 ± 0.00011	308 ± 25
Ag-Pd alloy	0.00646 ± 0.00045	0.00369 ± 0.00013	255 ± 19
Z350	0.00669 ± 0.00055	0.00458 ± 0.00067	119 ± 12
P60	0.00858 ± 0.00061	0.00201 ± 0.00064	89 ± 11
Enamel	0.00575 ± 0.00048	0.00536 ± 0.00025	336 ± 17