

# Wear resistance of some prosthodontic materials in vivo

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The purpose of this study was to compare a gravimetric method and an impression technique in the evaluation of occlusal substance loss. The wear of gold, porcelain, and microfilled resin was studied in vivo. The gravimetric method showed lower substance loss for porcelain than for gold, whereas the microfilled resin had the highest substance loss. To obtain a higher accuracy for the measurement of occlusal substance loss of restorative materials with an impression technique, the test area has to be restricted, the antagonizing occlusal contacts carefully recorded before the test period, and the number of cuts increased. The observed structure of wear facets (SEM) corroborated with previous findings of the wear mechanism of these materials; that is, gold has mainly abrasive wear in contact with porcelain, whereas porcelain has a fatigue type and microfilled resin a tribochemical type of wear. □ *Bruxism; dental materials; occlusal wear*

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The wear process of dental materials in the oral cavity has been shown to be very complex (1-3). It is important to study wear directly in the oral cavity, and a series of recent in vivo studies has shown large differences in resistance to wear between various types of prosthodontic materials.

Several difficulties are inherent in the study and measurement of wear in vivo, and different systems have been presented in an endeavor to resolve them (2, 3). Various impression techniques have been used to measure the vertical loss of material from the occlusal surface, and a precision of approximately 20 µm has been reported (4, 5).

The aim of this study was to compare two methods for assessing wear of dental materials: a gravimetric method and measurement of occlusal substance loss by an impression technique. Qualitative aspects of the wear process were also studied.

## Materials and methods

A 58-year-old man with a previous history of extensive wear of the natural teeth and

restorations received a new removable bridge from crowns 47 to 37 with telescopic crowns on the abutment teeth.

Two contralateral parts of the bridge, crowns 47-46 and 36-37, were made as removable segments (Fig. 1). The segments fitted well to the underlying bridge construction and were fixed with a horizontal screw (Fig. 1). In the upper jaw the patient had a fixed bridge with metal ceramic crowns from 17 to 27.

Two removable segments, one in each quadrant, were made of each of the three materials listed in Table 1. They were cast either as ordinary full crowns with a gold occlusal surface or as a metal substructure to be coated with microfilled light-cured resin or dental ceramic on the occlusal and buccal surfaces.

The contact between the opposing crowns or segments was, as in previous studies, adjusted clinically before the start of each test period, and the surfaces were polished to give conditions that were as similar as possible.

Segments with porcelain in the occlusal surface were not refired but polished with a method shown to give a smooth surface (6).

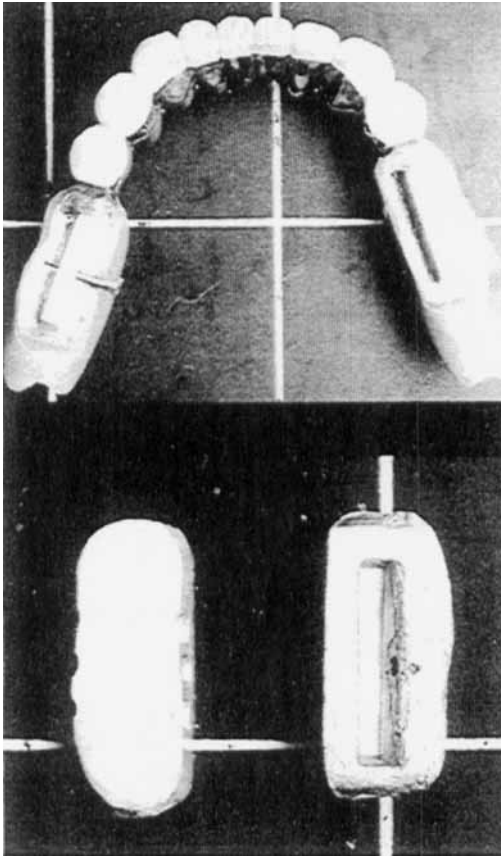


Fig. 1. Removable bridge (from 47 to 37) with telescopic crowns on the abutment teeth. Two contralateral parts of the bridge, crowns 47-46 and 36-37 were made as removable segments.

The removable segments were designed with three buccal and two lingual grooves, to give a fixed orientation for an impression tray. An individual, silver impression tray was cast for each separate segment. To make the wax model for the impression tray, tin foil (0.5 mm) was used as a spacer on the occlusal surface of the segment to leave some space for the impression material at the initial impression. Impressions were made of the occlusal surface of the segments before insertion and after 1 month in the oral cavity with an Addition-cured silicone impression material (President, regular type, Coltene Inc., Altstaettern, Switzerland) (Fig. 2). After removal, the impression was filled with a heavy-body material (President), to stabilize the impression of the occlusal surface and for fixation of the thin occlusal layer before sectioning.

Each impression was then cut in three sections, A, B, and C, as shown in Fig. 3. The grooves of the silver tray were used for orientation. The thickness of the layer of impression material over the occlusal surface was then measured at three measuring points (I, II, and III) at a fixed distance from the outer margin (Fig. 2), using a Profile projector (Nippon, Koagu, Japan).

The difference in thickness of the layer of impression material before and after 1 month of use was calculated for each measuring point.

Before insertion in the mouth the removable segments were carefully cleaned in an

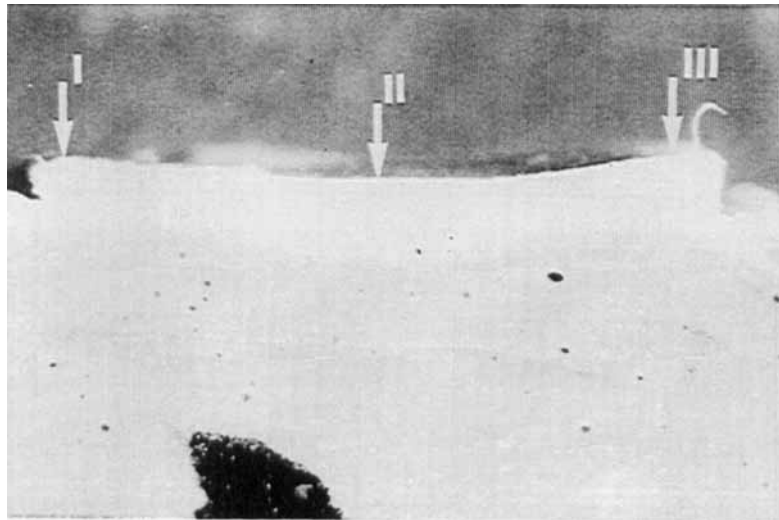
Table 1. Materials used for production of removable segments

Occlusal material	Brand	Manufacturer
Gold	Sjödings type III	AB John Sjöding, Solna, Sweden
Porcelain*	Willceram	Williams Gold Ltd, Buffalo, N.Y., USA
Microfilled light-cured resin†	Dentacolor	Kulzer & Co. GmbH, Friedrichsdorf, Germany

\* Metal substructure, Sjödings M3, AB John Sjöding.

† Metal substructure, Sjödings type IV, AB John Sjöding

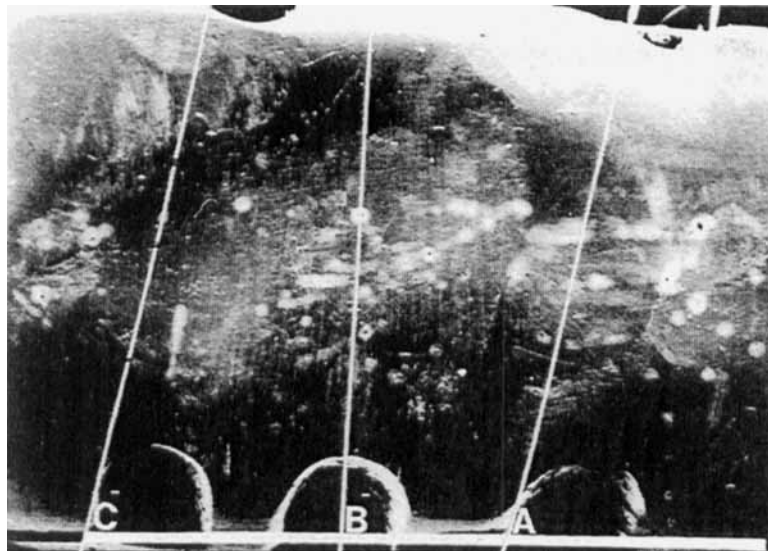
Fig. 2. Impression in an A-silicone material (white arrows) of the occlusal surface of the right segment. Heavy body material to stabilize the impression material. Measuring points indicated with white arrows, from left to the right of the photo.



ultrasonic bath and weighed in accordance with a method previously described (7). After 1 month in the mouth the segments were removed, cleaned in the same manner as reported above, and weighed. The weight change was converted to volume change by dividing it by the density of the material. The removable segments with microfilled resin were stored in distilled water before insertion in the mouth.

A second set of impressions with the same silicone material was made of each segment, one impression immediately after insertion in the mouth and another at the 1-month recall. These impressions were used for the production of replica models of the occlusal surface, in epoxy resin (8). The replica models were studied and photographed in a scanning electron microscope (SEM 515, Philips, Eindhoven, The Netherlands).

Fig. 3. Each impression was consequently cut into three sections, A, B, and C. Vertical white lines show the orientation of the cuts in the removable segments. Horizontal bar corresponds to 10 mm.



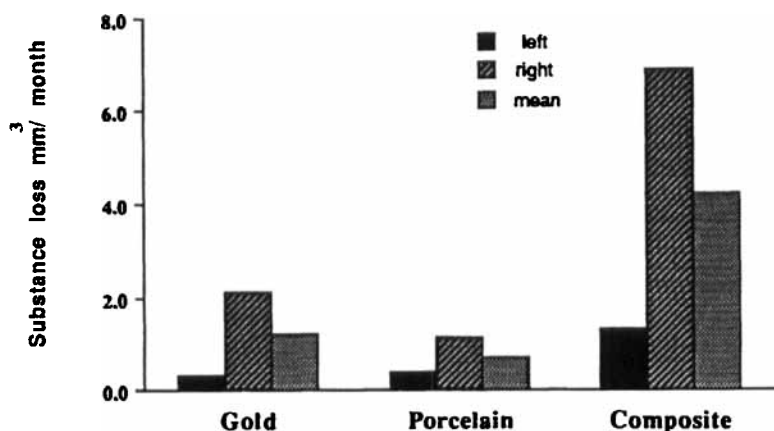


Fig. 4. Loss of substance ( $\text{mm}^3/\text{month}$ ) for various materials in contact with porcelain for the right side, the left side, and the mean values of both sides.

A methodologic study was carried out to estimate the error of the measurements of the thickness of the occlusal layer using profile-measuring microscopy. The measuring error was calculated on the basis of the standard deviation for five different measurements at each measuring point. The objective was replaced in the microscope between each measurement.

## Results

### Gravimetric method

Porcelain showed the lowest substance loss, and the microfilled resin material the greatest (Fig. 4). Notable also were the great differences in substance loss between the right and the left segments in this subject.

### Impression technique

A maximum mean difference was observed for the right gold alloy segment (C) (Table 2). For all materials tested the measured mean differences in thickness of the impression material were in general greater on the right side than on the left side.

The methodologic error of the measurements of impression thickness in the profile projector was calculated to be  $\pm 10 \mu\text{m}$ .

### Observations in SEM

The lingual wear facet observed in Fig. 5 (white arrow) could not be observed in the

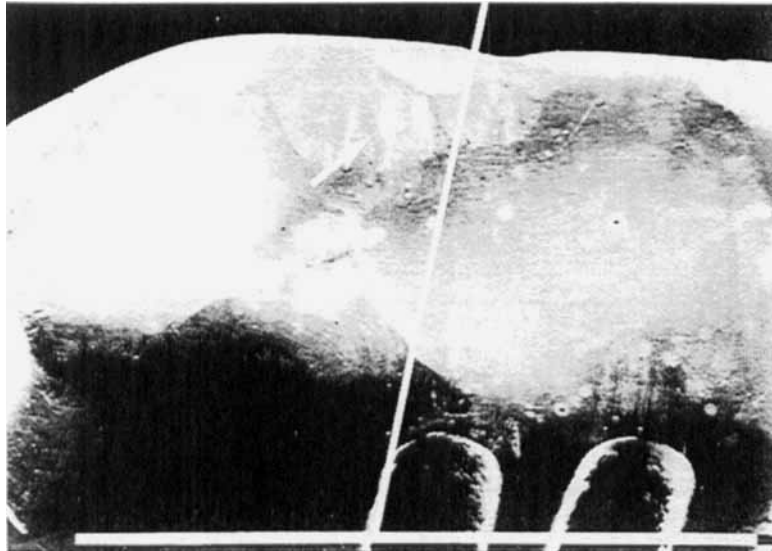
same segment before insertion in the mouth (Fig. 6). In the mesial part of the right-side segment with microfilled resin in the occlusal surface, an extended occlusal contact area could be observed after 1 month of exposure to the oral environment (Fig. 7) when compared with the contact area observed for the same segment before insertion (Fig. 8). It is important to note that this wear area is situated outside the surface, as was indicated with the use of the impression technique, cut A (white line). In the distal part of the left-side gold alloy segment the occlusal surface showed small changes in appearance before and after 1 month in use, and only one small wear facet could be observed. In the mesial part of the same segment no new wear facet could be observed in the occlusal surface after 1 month in use.

In the wear facets of the gold alloy mainly

Table 2. Mean differences of the measured impression thickness ( $\mu\text{m}$ ) calculated in sections A, B, and C after 1 month in use and before insertion. Right- and left-side segments

Section	Occlusal material					
	Gold		Porcelain		Microfilled resin	
	R	L	R	L	R	L
A	20	10	10	10	20	0
B	70	60	20	20	20	10
C	120	10	10	-10	60	20

Fig. 5. Lingual wear facet (white arrow) in the right gold segment after 1 month in use, cut C (vertical white line). Horizontal bar corresponds to 10 mm.

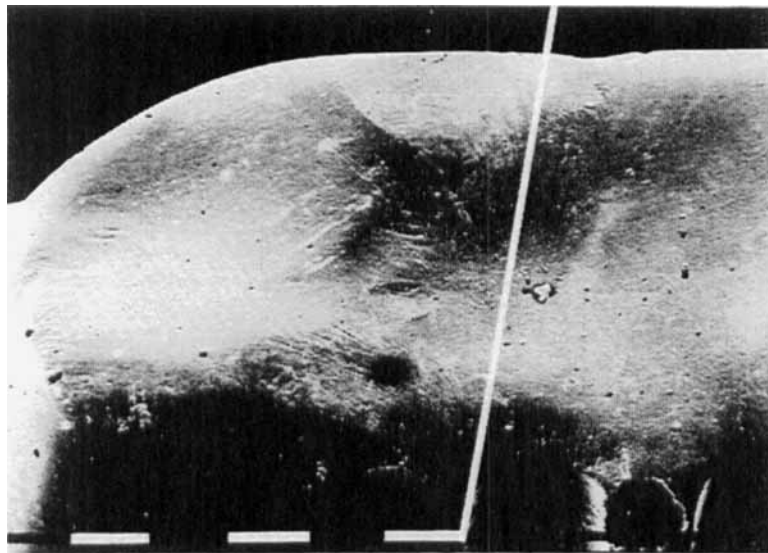


grooves (ploughing) were observed. Fracturing of the material was seldom observed.

The occlusal contact areas of porcelain showed loss of glaze and the presence of several pits with characteristic sharp edges (Fig. 9). After 1 month in use, small particles that appeared to have fractured off (white arrow) could also be observed.

The microfilled resin surface showed multiple small pits of various sizes in the occlusal contact areas after 1 month in use (Fig. 10). However, the edges had a more rounded appearance than the pits observed in the porcelain. In other occlusal contact areas loss of particles due to fracture could be observed (white arrow).

Fig. 6. Right gold segment before insertion in the mouth, white line indicating cut C. Horizontal bar corresponds to 1 mm.



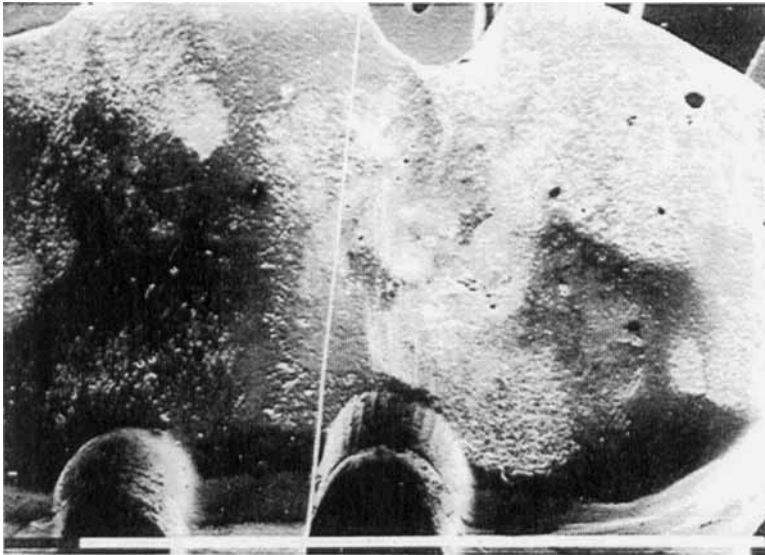


Fig. 7. Mesial part of the right-side segment with microfilled resin in the occlusal surface after 1 month in use, cut A (vertical white line). Horizontal bar corresponds to 10 mm.

## Discussion

The complexity of intraoral wear makes multiple clinical studies necessary to gain knowledge concerning this problem.

The subject in this study, like all four persons participating in the previous studies by the first author (A. Ekfeldt) (3, 7, 9, 10), had a history of extensive wear of nat-

ural teeth and/or restorative materials due to bruxing activities. Previous studies have shown that this is an acceptable 'accelerated' model for such studies (3).

The importance of the contact area has been thoroughly discussed in earlier studies (3, 7). The large difference in loss of substance found in this study (Fig. 4) between the right and left segment could probably be

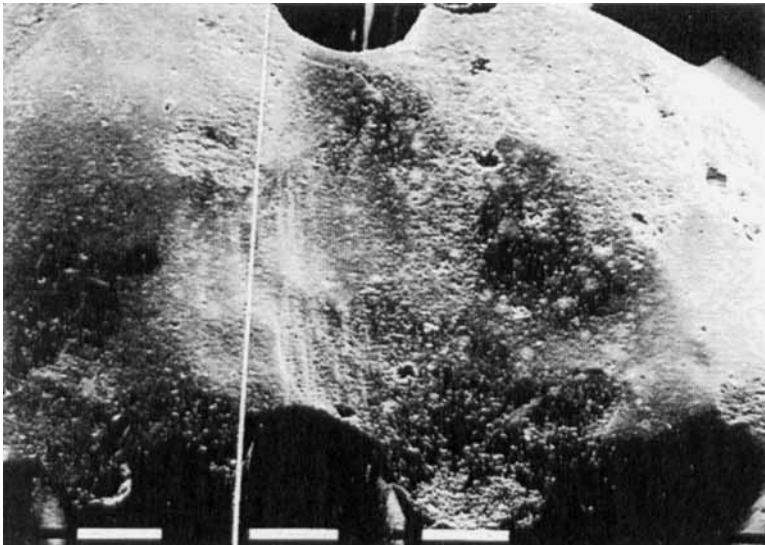


Fig. 8. The same segment before insertion in the mouth, cut A (vertical white line). Horizontal bar corresponds to 1 mm.

Fig. 9. Occlusal contact area of porcelain after 1 month's exposure to the oral environment, right-side segment. Horizontal bar corresponds to 10  $\mu$ m.

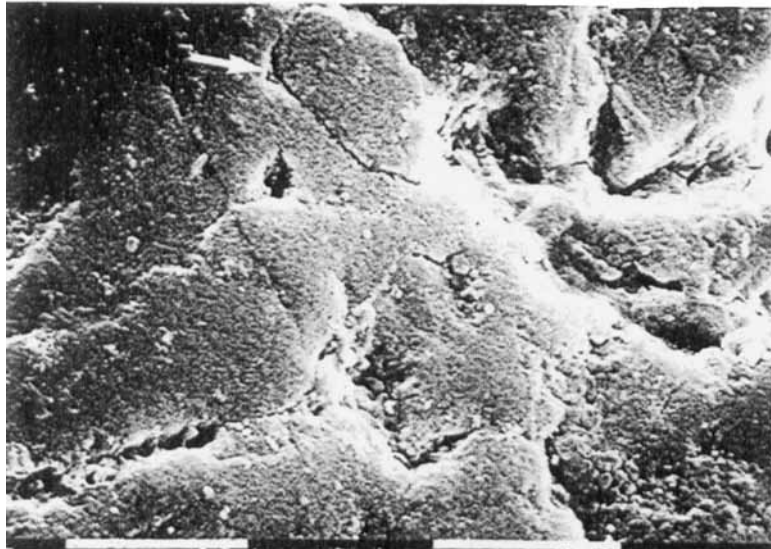


explained by the fact that this person mainly used his right chewing side when clenching and grinding. This difference between the right and left side was noticed for all segments and was also verified by observations in SEM. Such differences between the right and left sides were not noticed in the earlier studies by the first author (3), but persons having a preferred chewing side have been

reported in other studies (11). Considering this observation and all other possible intra- and inter-individual variations, such as clenching and grinding habits, the obtained amount of loss of material from the gravimetric method should only be used as a guide for ranking the wear resistance of the various materials (3, 7, 10).

The advantage of a gravimetric method in

Fig. 10. Occlusal contact area of the microfilled resin after 1 month in use, left-side segment. Horizontal bar corresponds to 10  $\mu$ m.



measuring substance loss is its ability to give a value for the total substance loss. Most other *in vivo* methods only give a metric value for the vertical changes in the surface profile. However, absorption and evaporation of water, especially for resin-based materials, are possible sources of error. The methodologic error of this method has been discussed in earlier studies (3, 7, 10). In these studies the methodologic error recorded for gold, porcelain, and microfilled resin varied with the material tested. The corresponding coefficients of variation were 4%, 11%, and 26%, respectively, of the weight change recorded each month (7, 10).

The average loss of substance was lower for porcelain than for gold and the microfilled light-cured resin. A four to five times higher wear rate was observed for the resin (Fig. 4), which coincides with the findings in an earlier study (7).

The wear resistance of microfilled heat- or light-cured resin-based materials observed in this series of *in vivo* studies should contraindicate the use of such materials in the occlusal surface of prosthodontic restorations in an active bruxist.

The effect of the opposing material on the wear rate of the material tested has also been discussed earlier (3, 7, 10); porcelain seems to induce more substance loss in the opposing material than gold or acrylic resin. In this study, especially on the right side, gold alloy showed a greater substance loss than porcelain when opposing porcelain, but the difference between the two materials was small.

The difference in loss of substance observed with the gravimetric method in this study was supported by the findings on the SEM photos. The occlusal surface of the distal part of the right gold segment (Fig. 5) showed increased wear facets (white arrow) compared with the same occlusal surface before insertion (Fig. 6). When we compared the occlusal surface of the distal part of the left-side gold segment before insertion and after 1 month in use, only one new small wear facet could be observed. In the mesial part of the same segment no new wear facets could be identified. The extended wear facets seen on the surface of the right-side microfilled resin segment (Fig. 7) after 1

month of use corresponded with the recording of substance loss by the use of the gravimetric method for the same segment (Fig. 4).

Impression techniques presented for measuring vertical loss of material in the occlusal surface has earlier been described for class-I composites (4, 5). The limitation of this method is obvious when comparing the visual findings of extended wear facets on the occlusal surface of the right-side microfilled resin segment (Fig. 7) with the white line characterizing the cut for section A. Here the vertical loss of substance was predominantly outside the measuring area. This is also illustrated by the small difference (20  $\mu\text{m}$ , Table 2) in thickness of the impression material before and after insertion of the segment. However, for the right-side gold segment the cut for section C (white line, Fig. 5) was through the wear facets. The impression technique at this side produced a large mean difference (120  $\mu\text{m}$ , Table 2), expressing a high vertical substance loss in the occlusal surface.

To obtain a greater accuracy when measuring substance loss in the occlusal surface with an impression technique, the test area has to be restricted, the opposing occlusal contacts carefully recorded before the test period, and the number of cuts increased. Under such circumstances an impression technique might be used for an indication of wear resistance for restorative materials *in vivo*.

The observed structure of wear facets (SEM) confirmed previous findings of the wear mechanism of these materials; that is, gold has mainly abrasive wear in contact with porcelain, porcelain has mainly a fatigue type or wear, and microfilled resin a tribochemical type of wear (3).

General values for the amount of substance loss cannot be given. Large intra- and inter-individual variety is known for all important factors such as chewing pattern, bite force, diet, saliva, and parafunctions. However, the similarity in ranking of wear resistance, on the basis of results from the gravimetric method in this and previous studies (3, 7, 10), supports the assumption that the wear resistance for gold and por-

celain is almost equal and superior to that of the microfilled resin.

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