Wear mechanisms of resin and porcelain denture teeth

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The aim of this investigation was to describe the wear mechanism in occlusal contact areas of porcelain and acrylic resin denture teeth opposing different dental materials. A 55-year-old man with earlier extensive wear was given two complete dentures, as identical as possible, in the upper jaw. One of the dentures had diatoric teeth in cross-linked resin and the other denture had diatoric teeth in porcelain. The dentures were antagonizing a new gold–acrylic fixed bridge from 46 to 36. Two contralateral segments of the bridge were made as removable double crowns. The removable segments were made in different materials: gold, porcelain, light-cured resin, and heat-cured resin. Wear of the denture teeth was studied by scanning electron microscopy on replica models made after 1 and 2 months of antagonizing contact with the various materials. Wear of both porcelain and modern cross-linked resin teeth was mainly a fatigue type of wear. Abrasion was observed when hard particles were assumed to be part of the wear debris. □ *Bruxism; dental materials; denture, complete*

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Wear of prosthodontic denture teeth has been discussed in several previous papers (1–9) in relation to clinical problems. A good wear resistance has been stated to be important, as rapid wear could cause loss of vertical dimension and loss of chewing efficiency (1, 2). Harrison (3) found in an in vivo study that the combination of porcelain to porcelain denture teeth showed the best wear resistance, compared with resin to resin denture teeth or other combinations. Similar observations have also been made in in vitro studies (4).

In spite of better color stability and better wear resistance there are some disadvantages with porcelain denture teeth, especially the clicking sound during chewing. Schultz (1) found that patients mostly preferred acrylic teeth. In vitro studies have shown that the wear resistance of acrylic resin teeth has been improved by new resin materials with highly cross-linked copolymers (5–7). For further improvements of wear resistance, a better understanding of the wear mechanism is necessary. The wear mechanism is a complex phenomenon involving various factors, among which the nature of the two opposing materials is of great importance. Most of our knowledge of the wear process comes from in vitro studies (8, 10–12). In such studies the wear resistance of dental materials might alter when one single variable is changed (10, 13). The in vivo situation is not standardized. All factors are constantly changing. The wear mechanism of denture teeth will therefore most certainly differ in in vitro and in vivo situations. Previous studies have also shown that the amount of wear will change when antagonizing teeth are made of different dental materials (14).

The aim of this investigation was to describe the wear mechanism in occlusal contact areas of porcelain and acrylic resin teeth opposing different dental materials. The wear process will be described in accordance with the definitions in the 'Standard of wear' DIN 50 320 (14, 15).

Materials and methods

A 55-year-old man with earlier extensive occlusal wear volunteered to participate in

Table 1. Materials used for production of removable segments

Occlusal materials	Brand	Manufacturer
Gold*	Sjödings Type III Sjödings Type IV	AB John Sjöding, Solna, Sweden
Porcelain†	Vita VMK	Vita Zahnfabrik, Säckingen, FRG
Light-cured resin‡	Dentacolor	Kulzer & Co. GmbH, Friedrichsdorf, FRG
Heat-cured resin‡	Biodent K + B 75	De Trey, Wiesbaden, FRG

* Combined in one segment.
† Metal substructure, V44 Metaux Precieux SA, Neuchatel, Switzerland.
‡ Metal substructure, Sjödings Type III, AB John Sjöding, Solna, Sweden.

this study. He had evident bruxism without symptoms of muscular dysfunction, but he was exposed to a somewhat dust-loaded working environment from time to time. His lower jaw was rehabilitated with a new gold–acrylic fixed bridge from 46 to 36. Two contralateral premolar segments of the bridge—crowns 44–45 and 34–35—were made as removable double crowns. A total of eight removable segments were made—that is, two of each combination of the materials listed in Table 1.

The patient was also given two complete dentures in the upper jaw, as identical as possible, except for the type of teeth. One of the dentures had diatoric teeth in cross-linked methyl methacrylat (SR Orthotyp, Ivoclar, Liechtenstein) and the other denture had diatoric teeth in porcelain (Vita Lumin, Vakuum Vita Zahnfabrik, FRG). The complete dentures were manufactured with ordinary clinical and laboratory procedures. The vertical relation was estimated with the use of an adequate free way space, and the horizontal relation of the set-up of denture teeth was in a retruded mandibular position. All segments of the above-mentioned materials were thereafter ground and polished to achieve, as nearly as possible, the same occlusal contact with both dentures. The occlusal contacts were tested with occlusal foil and photographed. Segments with porcelain in the occlusal surface were not refired but polished with a method shown to give smooth surfaces (16). The denture teeth were not polished between the periods of opposing different materials, to avoid changes in the occlusal contact.

The full upper dentures with either resin or porcelain teeth were exposed to the oral environment of an antagonizing contact to each of the various segments listed in Table 1 for 2 months each.

The patient was recalled every month. At the recalls impressions for replica models were made of the surfaces of premolars and molars of the full upper denture in accordance with a previously reported method (17). The dentures were kept wet during extraoral storage. The total time period covered by this study was 12 months. The replica models were studied and photographed in a scanning electron microscope (SEM) (Philips SEM 515 Philips, Eindhoven, The Netherlands). The analysis of the SEM observations was made by both authors together.

Results

Observation in SEM

Acrylic resin teeth. After 2 months in use opposing a gold alloy segment, wear facets in the material could be observed. Greater magnifications of the surface of the wear facet showed pits (Fig. 1) and, in the bottom of a pit, an irregular surface with multiple fractures (Fig. 2). Fig. 3 shows the same type of wear facet characterized by multiple pits in the surface after 2 months opposing light-cured resin.

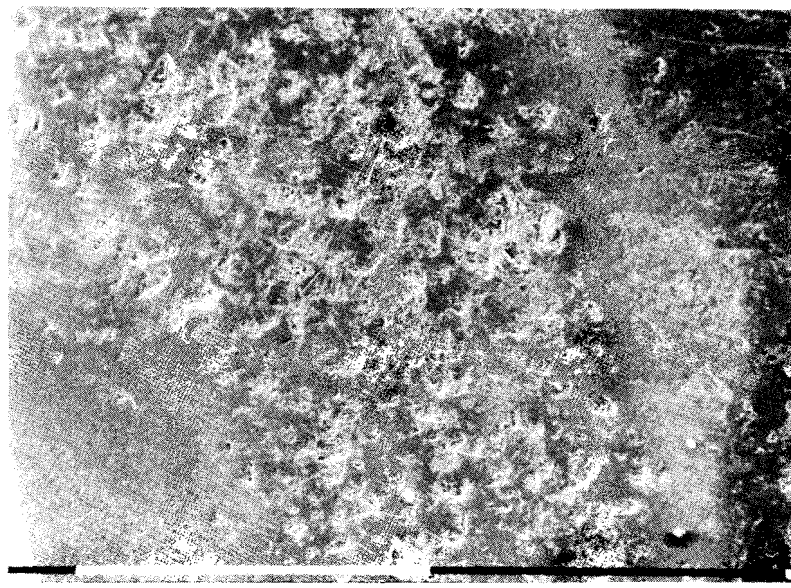

Fig. 1. Resin denture tooth antagonizing gold alloy for 2 months (white line = 1 mm).

After 2 months of antagonizing metal ceramic crowns the same denture tooth as seen in Fig. 3 showed a large increase of the contact areas, which now involved the lingual cusp (Fig. 4). Grooves, some pits, and flat areas can be seen on the surface in greater magnification (Fig. 5).

After 2 months of contact with heat-cured resin the surface of the resin denture teeth showed a marked wear facet but with a smoother appearance than after contacting metal ceramic crowns. A greater magnification of the surface showed a more complex situation, with a combination of smooth

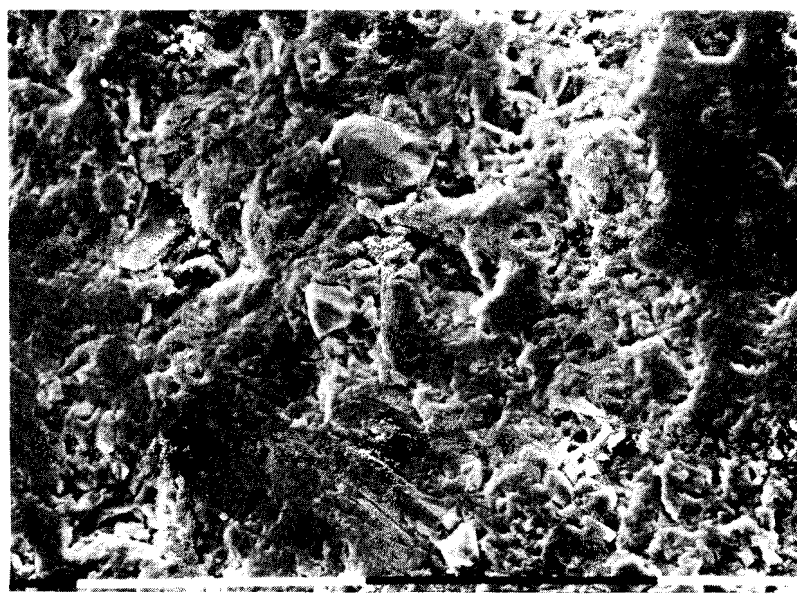

Fig. 2. Same resin denture tooth as in Fig. 1 (white line = 0.1 mm).

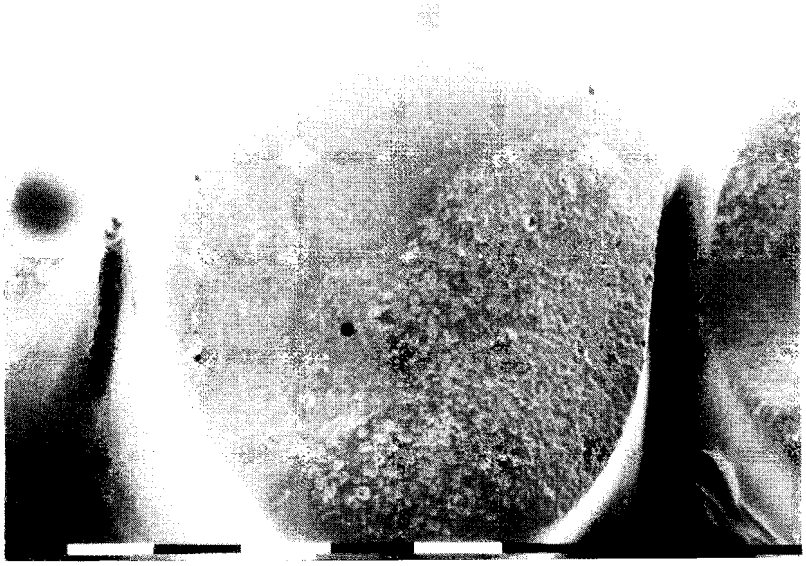

Fig. 3. Resin denture tooth antagonizing a light-cured resin for 2 months (white line = 1 mm).

and rough areas and some grooves (Fig. 6). Other parts of the contact area showed the same type of fracture as seen in Fig. 2.

Porcelain denture teeth. After 2 months of use opposing light-cured resin, the size of contact areas was, by clinical inspection, judged to be similar to those established at the first clinical adjustments. However, the surface had a distinctly rougher appearance, and a larger magnification showed multiple small fractures (Fig. 7).

Fig. 8 shows a porcelain denture tooth opposing a gold alloy crown for 2 months. The surface appearance was rough, with

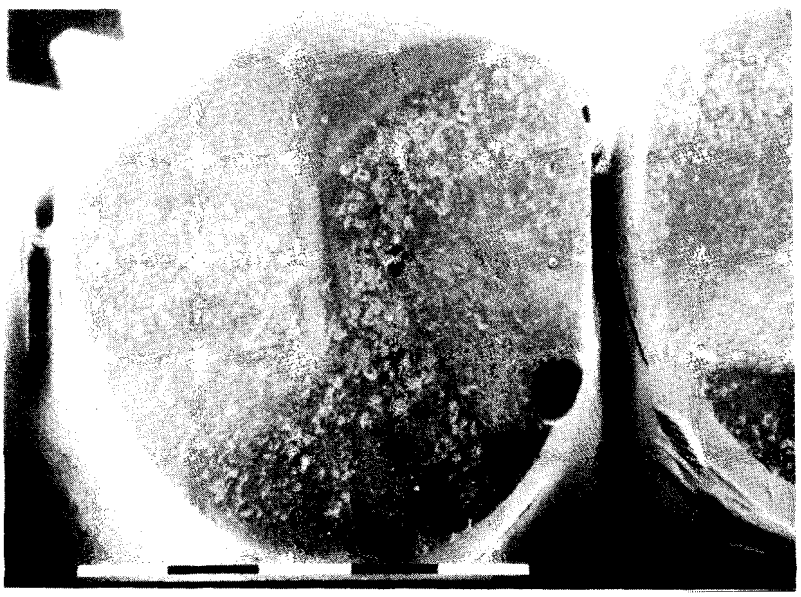

Fig. 4. Resin denture tooth antagonizing porcelain for 2 months (white line = 1 mm).

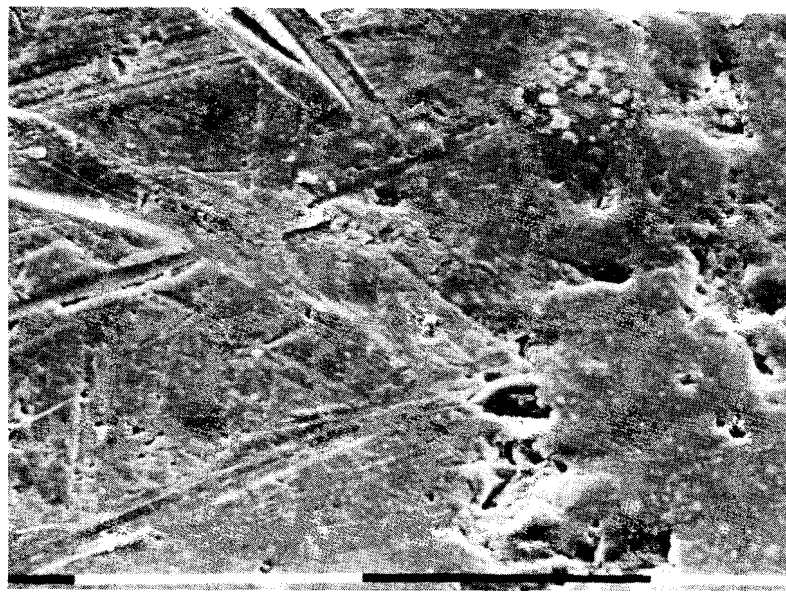

Fig. 5. Resin denture tooth antagonizing porcelain for 2 months (white line = 0.1 mm).

multiple pits and some scratches. A larger magnification showed multiple brittle fractures.

When porcelain denture teeth had been opposing dental ceramic crowns for 2 months, the size of the contact area did not seem to increase, but the surface appearance was somewhat changed to a smoother appearance, at least in parts of the wear facet, as shown in Fig. 9.

The porcelain denture teeth antagonizing heat-cured resin for 2 months also showed a smooth surface on the wear facet. A larger magnification of the surface indicated that

Fig. 6. Resin denture tooth antagonizing heat-cured resin for 2 months (white line = 0.1 mm).

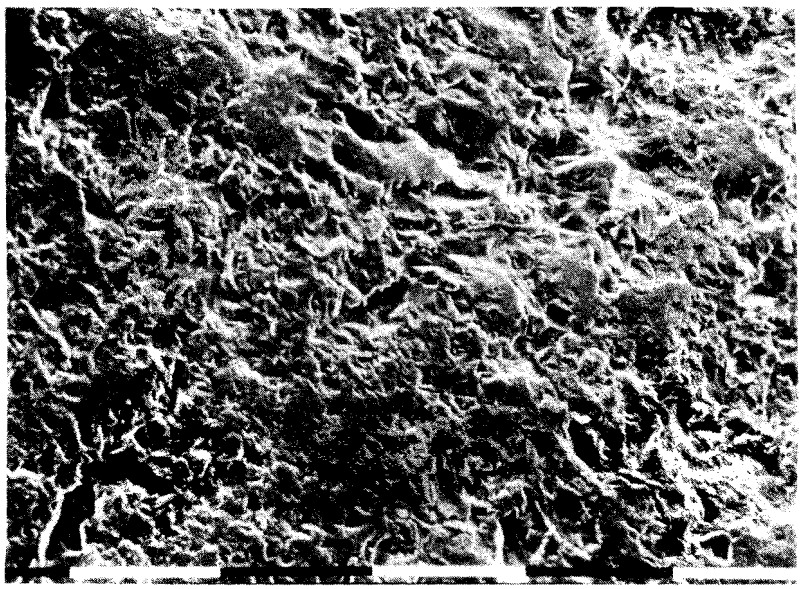

Fig. 7. Porcelain denture tooth antagonizing light-cured resin for 2 months (white line = 0.1 mm).

many small particles adhered to the surface, possibly as a smear layer (Fig. 10).

Macroscopic observations

The macroscopic inspection of the wear facets showed a relatively large and constant substance loss from the resin teeth in all contact situations. On porcelain teeth, however, the substance loss appeared macroscopically to be less, but an obvious change in surface structure was observed. However, the patient reported more comfort with the denture made with resin teeth.

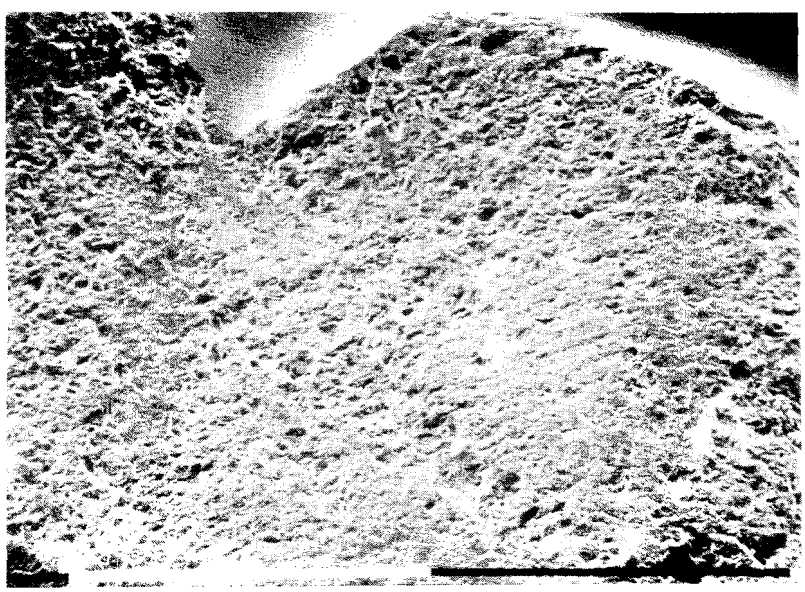

Fig. 8. Porcelain denture tooth antagonizing gold alloy for 2 months (white line = 1 mm).

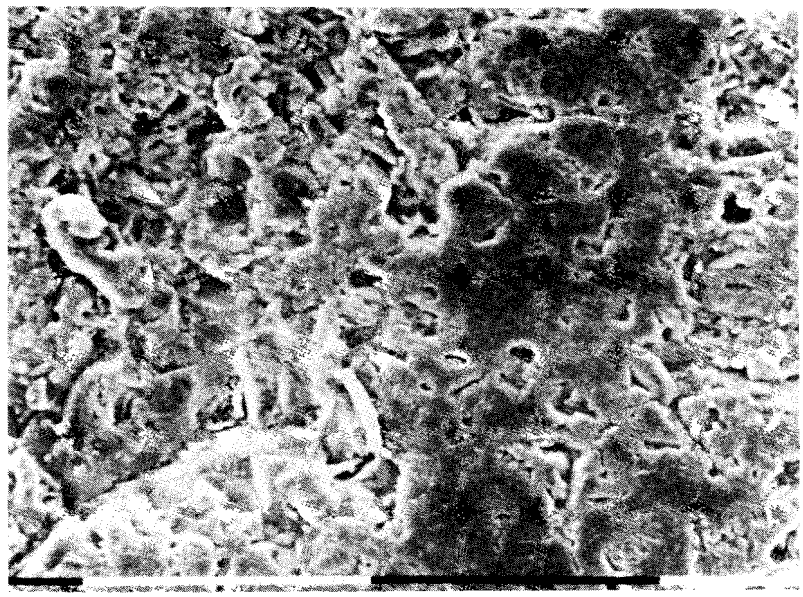

Fig. 9. Porcelain denture tooth antagonizing porcelain for 2 months (white line = 0.1 mm).

Discussion

The loss of vertical dimension of a full denture due to rapid wear of denture teeth is probably not a widespread, extensive clinical problem, and it is generally overshadowed by the greater bone resorption. The average vertical loss of denture teeth is estimated to be around 0.1 mm or less per year for resin denture teeth in clinical studies (3, 7, 9) and less for porcelain denture teeth opposing identical materials (3). In two of the studies mentioned (3, 7) at least one person showed an occlusal wear much above the average.

Fig. 10. Porcelain denture tooth antagonizing heat-cured resin for 2 months (white line = 0.1 mm).

Those persons reported clenching of their teeth and/or working in a dust-loaded environment.

The person in the present study had clenching and bruxing of his teeth probably outside the normal range, and he was also working in a somewhat dust-loaded environment from time to time. The model for analysis was chosen on the assumption that the increased load and contact time would not change the wear mechanism but only increase the amount of wear on the two different materials of denture tooth. These problems were examined in an earlier study (14).

In clinical studies the difficulties with regard to a standardization of the contact areas between the different opposing segments or teeth and other clinical factors make it necessary to use special techniques for a quantification of wear.

In a previous study a gravimetric method was used to obtain a ranking of wear resistance among various materials (14). A quantification of the wear was not possible in the present study. A gravimetric technique, as used in a previous study (14), was impossible because weight loss of the denture teeth would be far below the methodologic error of the weighting technique. This study was therefore limited to observations of the wear process.

The multiple pits and fractures on the surface of the resin teeth opposing gold and light-cured resin (Figs. 2 and 3) indicated that the wear mechanism was mainly a fatigue type of wear. In a previous study heat-cured resin crown veneering material was found to have a more tribochemical—that is, combined degradation and abrasion—wear mechanism (14). The difference is clearly a result of differences in physical and chemical properties, especially the higher resistance to disintegration due to cross-linking.

Against metal ceramic crowns a change in the surface appearance showing both pits and grooves indicated a more complex mechanism, including both fatigue and abrasive wear. The abrasion is likely a result of particles loosened from the porcelain surface acting as an abrasive agent on the resin. Both the present and the previous results show that fatigue fractures occur in the porcelain surface in contact with resins (14).

The surface of resin teeth antagonizing heat-cured resin was complex. Fig. 6 probably shows a smear layer that may be loose particles from the antagonizing heat-cured resin. This might explain the smooth areas. The grooves in the surface indicate an abrasive type of wear, and the irregular areas indicate multiple fractures. Most likely, a combined abrasive and fatigue type of wear occurred.

When porcelain denture teeth were opposing either light-cured resin or gold alloy crowns (Figs. 7 and 8), the surface was rough owing to multiple brittle fractures in the contact areas. These findings indicate a fatigue type of wear. However, on Fig. 8 scratches could also be observed on the wear surface, which might indicate an abrasive component when antagonizing gold alloy crowns. A reasonable speculation must be that loosened hard particles from the brittle porcelain had attached to the softer gold alloy surface and worked as an abrasive material. Wear tracks were also observed in the antagonizing alloy (14).

When opposing metal ceramic crowns, the surface of the porcelain denture teeth showed a smoother appearance (Fig. 9), but there were also areas with irregular structures with brittle fractures and loosened particles on the surface looking like wear debris. One might speculate that the debris is acting as a polishing agent on the porcelain surface. A self-polishing of antagonizing porcelain teeth has been noticed in a previous study (18) and was also observed on the antagonizing porcelain-covered crown (14). A rough surface on a porcelain denture tooth that opposes a softer material such as heat-cured resin will probably initially cause a heavy wear of the antagonizing material. But loosened particles from the softer material will probably also adhere to the rough surface, as shown in Fig. 10. If a smear layer is established in the contact surface, a decreased amount of wear between the two materials might be expected.

In conclusion, wear of both porcelain and modern cross-linked resin denture teeth is

mainly a fatigue type of wear with some abrasion where hard particles are part of the wear debris. A microscopic inspection of the wear facets indicates a larger wear in resin than porcelain in all contact situations.

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