Surface characteristics of composite resins comprising a porous reinforcing filler
An in vivo study

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The surface of composite restorations with filler particles comprising an ultrafine sintered glassfiber network were examined in vivo. The effect of different finishing methods and clinical wear was studied with SEM on replicas. Smooth and lustrous buccal surfaces were obtained with finishing discs. On occlusal surfaces a microfine finishing diamond gave a good surface finish. After wear (> 7 months) surface smoothness was favored by a close packing of the filler particles. The smoothest surfaces appeared when, in addition, the density of the sintered network was high. □ *Dental materials; fiberglass; finishing; sintered network; surface microstructure; wear*

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A porous filler comprising a sintered ultrafine glassfiber network has previously been suggested for composite resins (1). In such composites the inorganic and organic phases constitute interpenetrating networks and are thus mechanically interlocked. The porous filler may be used in a conventional manner, dispersed in a liquid resin to a mixture with a putty-like consistency. In addition, it is possible to use the filler particles in formulations in which they may be condensed to close interparticle contact (2).

The average density of the particles may be varied within wide limits. In high-density particles large solid sintered areas appear within the network structure. In an in vitro study the presence of such areas favored surface lustre after toothbrush–dentifrice abrasion (3). It could therefore be assumed that after in vivo wear surface characteristics are influenced both by the average density of the individual particles and by the amount of resin between them.

In a study of early surface changes due to clinical wear the finished surface should be as smooth as possible. It is also essential to be able to recognize the surface characteristics produced by the finishing instruments. The purpose was therefore 1) to study the surface appearance after finishing and 2) to examine a possible connection between inorganic structure and in vivo wear patterns of some experimental composite formulations.

Materials and methods

Composite resin restorations were placed in lower premolars and upper incisors. The patients were adults with intact or almost intact dentitions and with no crown and bridgework in contact with the teeth to be restored. They all had good oral hygiene and brushed their teeth one to three times a day with conventional types of abrasive dentifrices. The composite formulations used were, except for the average density of the sintered glassfiber network (SGN), approximately the same as previously given (experiment 10 in Ref. 2). Finishing procedures were studied on class II and class IV restorations (average SGN density, 1.4 g/cm^3), made by the use of a condensing technique (2) and a fairly high packing pressure (approximately 15 MPa). The finishing was made after approximately 1 week of clinical service. Surface characteristics after in vivo wear were studied on restorations in which the materials had been inserted by the use of various packing pressures. The studied restorations and their length of clinical ser-

Table I. Restorations studied after wear

Class	Clinical service (months)	Average SGN density (g/cm^3)
IV	20	1.4
II	12	1.4
II	24	1.0
II	7	1.5
I	29	1.0
I	29	*

* Adaptic® (batch 7F023, Johnson & Johnson Dental Products Co., East Windsor, N.J., USA).

vice are given in Table 1. A conventional composite served as control and was placed in the same premolar and adjacent to an experimental class I restoration.

Finished surfaces were studied after use of the following instruments: discs (Sof-Lex®; grits 360, 600, and 1200; 3M Dental Products, St. Paul, Minn., USA), finishing burs (Jet® La 7006, 12 fluted carbide bur, Beavers Dental Prod. Ltd., Ontario, Canada), a regular round diamond bur (DB 106, AB Dentatus, Hägersten, Sweden), and a round microfine finishing diamond bur (ComposhapeSet® CSR 5400, W. Hubschmid & Sohn, Lugano, Switzerland). The instruments were used at low speed (2000-3000 rpm) and with water spray, except for the discs, which were run dry. The finishing diamond bur was also used at a high speed (100,000–200,000 rpm). The restorations

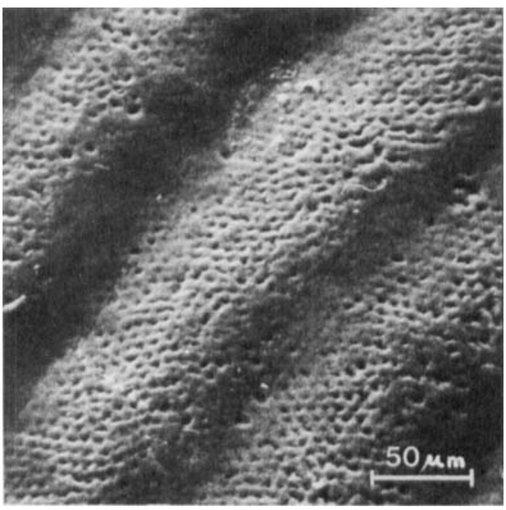

Fig. 1. Surface of enamel used as control.

studied after wear had been finished with the following instruments: class IV, finishing disc; class 1 and II, finishing bur or finishing diamond.

Clinically, the surfaces were compared with the surface of a piece of enamel (Fig. 1), by the use of a sharp explorer. The enamel was cut from central part of a buccal surface of a premolar. Finishing and wear patterns were studied with the scanning electron microscope (SEM) on replicas made with a two-stage replication technique (4). Impressions were taken with a silicone impression paste (Xantopren Blue®, Bayer Dental, Leverkusen, FRG). A primary impression was taken only to clean the surface. The second impression was cast with an epoxy resin (Orthobond®, Vernon Benshoff Co., Inc., Albany, N.Y., USA). The positive replicas were coated, by cold sputtering, with approximately 200 Å of gold before being studied in the SEM (Cambridge Stereoscan Mark IIa).

Results

The regular diamond bur produced a rough surface on both enamel and composite (Fig. 2a). This was the only finished surface that was ranked rougher than the test piece of enamel. The finishing diamond bur produced a fairly smooth surface with minor grooves of similar (and typical) appearance in enamel and composite (Fig. 2b). When used at high speed, a gouging out of the surface appeared. The discs produced a smooth and lustrous surface in both enamel and composite (Fig. 2c). The carbide bur produced a smooth surface in the enamel but a composite surface that seemed somewhat more irregular than that obtained with the finishing diamond burs and the discs (Fig. 2d).

The class IV restoration studied after wear (20 months) clinically appeared lustrous and was on probing ranked equal to the enamel. In the SEM fine irregularities appeared, alternating with smooth almost textureless areas (Fig. 3). The individual particles were not aligned by continuous crevice formations. In the class II restorations (after wear) occlusal areas resembling the class IV res-

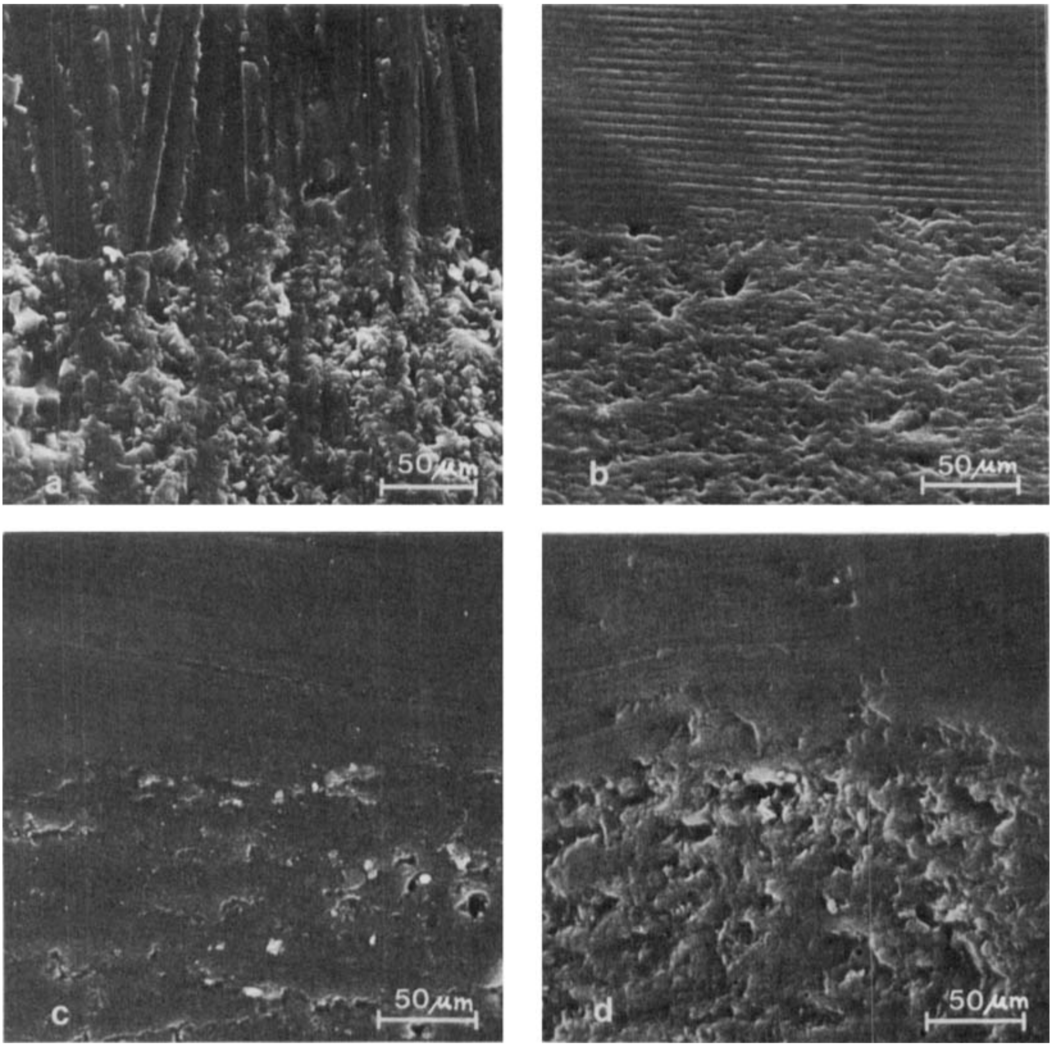

Fig. 2. Surfaces finished by: (a) regular diamond bur, (b) finishing diamond bur, (c) discs, and (d) 12 fluted carbide bur.

toration were found but also areas that only showed fine irregularities (Fig. 4). In the restorations with a low average density of the sintered network (SGN, 1.0 g/cm^3) the appearance of these fine irregularities was fairly equal on the entire occlusal surface. In the restorations with the higher average SGN densities the surface texture was more varied. On one of the class II restorations (2 years; SGN, 1.0 g/cm^3) a pronounced 'hilly' appearance was observed, comprising partly exposed particles surrounded by continuous crevices (Fig. 5). Exposed particles had a rounded-off profile and sometimes, as seen on the 7-month-old class II restoration (Fig. 6), showed a marked surface microstructure. In the SEM rather smooth areas were observed when the network seemed dense. This is illustrated in Fig. 6, which shows an exposed particle with a solid sintered area and another area where the density of the network appears to be high and the surface microstructure rather smooth. There was also on the microstructure level a smooth outline with no signs of gross fractures or 'plucking out' (Fig. 6). In Fig. 7

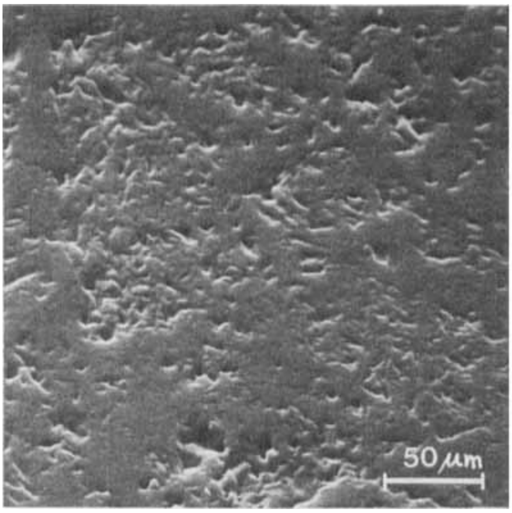

Fig. 3. Buccal surface of class IV restoration (after 20 months; SGN, 1.4 g/cm^3), showing smooth areas and areas with a fine surface texture.

surface details from the experimental composite (a) and a control (b) on the same premolar are illustrated. In contrast to the experimental resin the control shows particles with sharp angles. A gap, which may possibly have been caused by filler dislodgement, can also be seen. The surface of the control was, on probing, ranked as rougher than the enamel test piece. The occlusal surfaces of the experimental restorations showed parts that were ranked as equal to the enamel, but also some that were rougher.

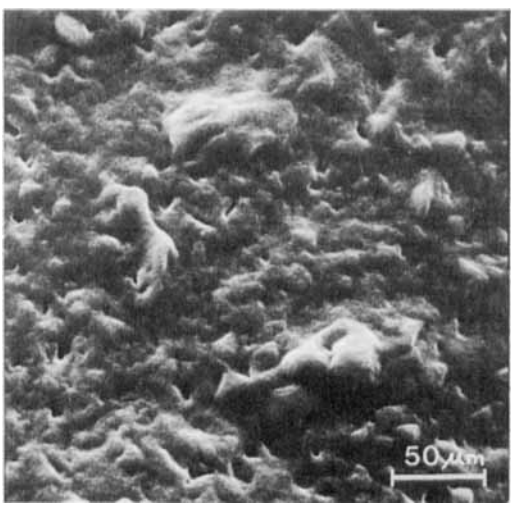

Fig. 4. Occlusal surface of class II restoration (after 12 months; SGN, 1.4 g/cm^3), showing fine irregularities.

Fig. 5. Occlusal surface of a class II restoration (after 24 months; SGN, 1.0 g/cm^3), showing partly exposed particle surrounded by a crevice (arrow).

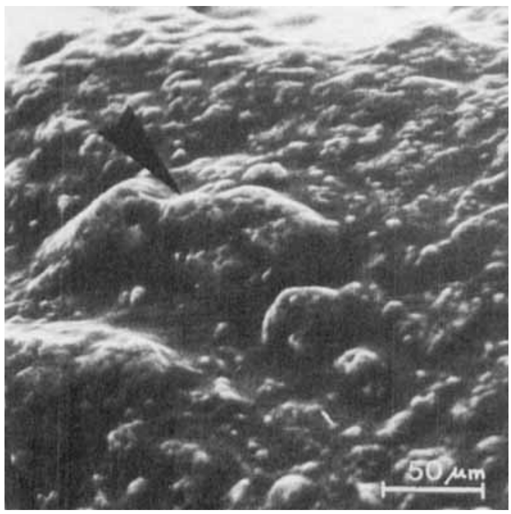

Fig. 6. Part of marginal ridge area of a class II restoration (after 7 months; SGN, 1.5 g/cm^3), showing the rounded-off surface microstructure of an SGN particle containing a small solid sintered area (arrow) and an area (upper right) where the density of the network appears high and the surface fairly smooth.

Discussion

After the finishing, the smoothest surfaces were obtained with the discs, in accordance with previous findings (5, 6). This smoothness may, however, to a certain extent be

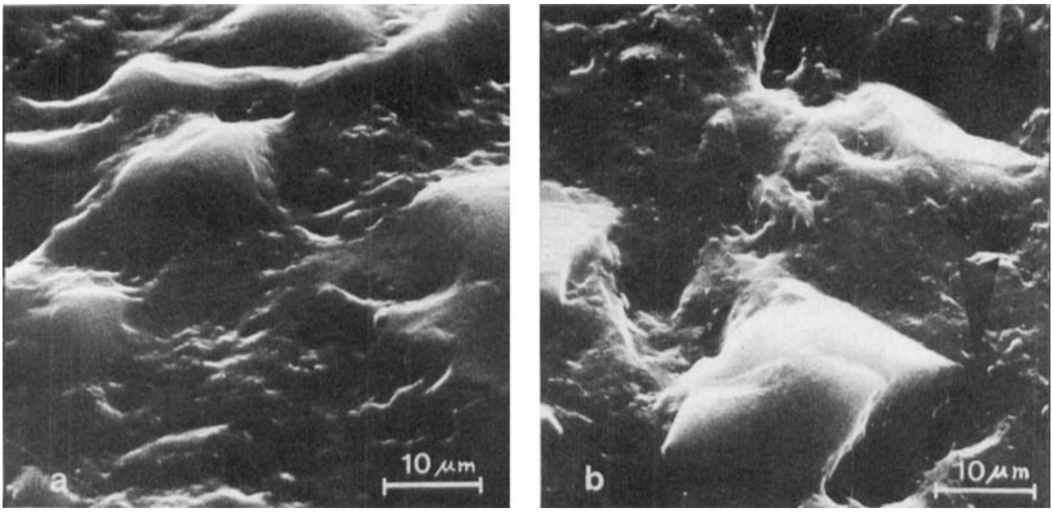

Fig. 7. Surface details from class I restorations (29 months) placed in the same premolar. Experimental composite (a) with glass exposed in the surface of a filler particle. Control (b) shows single filler particles with sharp angles and gap (arrow) possibly due to filler dislodgement.

produced by surface smearing on both enamel (7) and composite (8). On composites such smearing is produced by the resin, and the appearance of the surface may therefore change after a short period of toothbrush–dentifrice abrasion (8). The second best surface was obtained with the finishing diamond. This instrument has previously been shown to perform favorably in comparison with several other finishing methods (9). It therefore seems to be the instrument of choice for surfaces where the discs cannot be used. The ground surface has the advantage of a characteristic appearance with small grooves, which are easy to recognize in the replicas. In connection with gross excess, however, tungsten carbide burs may be preferable, since the risk of severe damage to the enamel then seems low (6).

Buccal surfaces of front teeth should not only have a low surface roughness to make them easy to clean but generally it is also considered desirable for them to give an 'enamel-like' lustre. In the class IV restoration a major part of the surface was still smooth and lustrous after 20 months of clinical service. This was probably because the particles were closely packed and because the density of the individual particles was fairly high. The smooth and almost textureless areas in the replicas have an appearance closely resembling areas previously observed (in the SEM) on specimens subjected to in vitro toothbrush–dentifrice abrasion (3). They were then identified as lustrous areas of solid sintered glass. It is, however, also possible that in the restoration there were parts that were not sintered to a solid but where the density of the glass network was sufficiently high to give a similar appearance.

On occlusal surfaces there is no need for surface lustre. Usually they are also easy to keep clean. To be comfortable to the patient the surface must, however, be such that it feels smooth to the tongue. The surface profile reflecting the individual particles should therefore be smooth, with no marked crevice formation between the particles. At this level the texture would be determined by both particle size distribution and how close the particles have been packed. The crevice formation illustrated in Fig. 5 thus indicates that the particles have been packed to an insufficient closeness. The surface of the individual particles seemed to increase in smoothness with increasing density of the glassfiber network. Apparently, at least some of the restorations comprised particles representing a wide distribution of densities.

No signs of fresh fractures or of

'plucking-out' were observed. Rather, the surface was characterized by its rounded microstructure, which indicated that glass had been worn away without dislodgement of gross particles. Considering the risks of crack formation (due to mechanical stress) at glass–resin interfaces and within interparticle resin, it is probably favorable if filler particles are both smooth (rounded-off) and mechanically interlocked with the resin.

It can be concluded that, clinically, the experimental composites could be given a high finish. After a period of clinical wear fairly smooth surfaces appear where the density of the network seems high. The particles should preferably be closely packed. The use of particle size distributions, including fairly big particles, may prove useful to minimize the border areas and thereby the risk of crevice formation.

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