A clinical and scanning electron microscopic study of a new restorative material for use in posterior teeth

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Eighty-two restorations with a new posterior restorative material showed good wear resistance on the occlusal surfaces after 2 years of service. The loss of substance averaged 30–50 μm, which is below the clinically detectable level. Inferior contact points were frequently registered, reflecting the problems with inadequate matrix systems. Clinically relevant problems were all related to the quality of the contact area. □ *Clinical performance; degradation of resin*

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Both clinical and in vitro evaluations of posterior composite restorations have shown lack of wear resistance and subsequent loss of anatomical form (1–9). The relatively soft resin phase around the filler particles is worn away, exposing the filler, which is then lost in the next instance. Thus more resin is exposed, and the advancing loss of the composite material takes place. The use of composite resin materials in the posterior region is therefore contraindicated. However, the materials are used fairly frequently, especially for esthetic reasons in premolars. The impact of the patients' desire to have tooth-colored restorations may also contribute heavily to the choice of material in such cases. Thus it is important to improve composite resin materials.

The purpose of the present investigation was to characterize the clinical behavior of a new restorative material for posterior use, P10 (3M Co., St. Paul, Minn., USA), after 2 years of service.

P10 is a composite material in which the quartz filler loading by weight is 85.5%. The average particle size is 3 μm, and the distribution of the filler particles is such that the resin part only fills the void volume between the filler particles (10).

Materials and methods

The material consisted of 78 class II and 4 class I restorations. Sixty were placed in the upper and 22 in the lower jaw, and a total of 77 were premolar restorations. All restorations had an antagonist; the dominant antagonizing contact was the cusp.

The restorative work was carried out in a private practice, and the treatment included both replacement of old restorations and primary caries, the latter being very few. In some of the cases the only reason for replacement was the patient's wish to have the amalgam restoration replaced with a tooth-colored material. The restorative work was carried out by two operators using the same technique (M. Rykke and T. I. Leidal). The cavities were prepared with a tungsten carbide bur (no. 1557, S. S. White, Philadelphia, Pa., USA) or with a cylindrical diamond (no. 3/2, Horico, Hopf, Ringleb and Co., Berlin, FRG) in an air turbine at ultra-high speed. A contra-angle handpiece at high speed was used when the final cavity design was made. No attempt was made to improve retention through placement of grooves within the cavity. The cavity margins were finished by means of hand instruments:

gingival margin trimmers and embrasure margin trimmers (L.M. Dental, Turku, Finland). Thus unsupported enamel was removed, leaving a smooth margin and a cavo-surface angle, as for amalgam or silicate. No bevel was placed anywhere to keep the cavity as small as possible. All the cavities were surrounded by enamel and the gingival wall placed as far from gingiva as possible. Moisture control was performed by means of rubber dam or with cotton wool rolls and saliva ejector. Micro-thin matrix bands (Starlite, Star Dental Mfg. Co. Inc., Conshohocken, Pa., USA) were used in combination with a Dentatus retainer (Dentatus, Hagersten, Sweden), in accordance with Nystrøm (11). The enamel was etched with an etchant liquid (3M Co.) applied in the cavity by means of soaked cotton pellets. After 60 sec the pellets were removed, and excess acid was removed with fresh cotton pellets. The cavity was rinsed thoroughly with water spray for 10 sec and dried with oil-free air through intermittent blasts, thus avoiding dehydration of the dentin. Next, lining of the dentinal walls was carried out with Procal (3M Co.) or Dycal® (L. D. Caulk Co., Milford, Del., USA). The matrix system was tightened, and wooden wedges were placed interproximally, to separate the teeth and to achieve a tight matrix system. P10 was mixed intensely for 30 sec on the provided pad, using a plastic spatula.

The material was inserted rapidly into the cavity by means of a double-ended plastic instrument in small increments to avoid trapping of air. The cavity was overfilled and covered with a plastic strip, and the material was pressed into the cavity by means of thumb or forefinger. Pressure was then released, so as not to disturb polymerization. After 5 min the matrix was removed, and surplus of material was removed through grinding with various round and flame-shaped diamonds and with stones and tungsten-carbide burs. Final correction of occlusion and articulation was carried out by the use of blue- and red-print paper and extra-fine grit diamond instruments (Fis, Finzler, Schrock and Kimmel, Bad Ems, FRG). The same instruments were used for the final finishing if additional finishing was deemed necessary at a later stage. When access was available, the approximal tooth filling interface was finished with Sof-Lex discs (3M Co.).

To investigate the restoration/tooth interface in the stereomicroscope and in the scanning electron microscope (SEM), the restorations and the neighboring teeth were replicated. A two-stage technique was used, involving a heavy-bodied and a light-bodied silicone product (Optosil Hard and Xantopren® Blue, Bayer, Leverkusen, FRG). Positive replications were produced in epoxy casting resin (Stycast®, Oeval, Brussels, Belgium). The replications were given an electrical conducting coat of gold and examined in a scanning electron microscope (J.M.S. 50A, Jeol, Tokyo, Japan), usually operated at 25 KV. Some of the replications were sectioned longitudinally to measure the exact possible loss of material through a microscope, using ocular and object micrometer with a measuring scale.

After approximately 1 and 2 years of service, the restorations were replicated again. Clinical evaluation was performed after 2 years. The examiner (H. Solem) used a new explorer (Ash, London, England) in combination with a surface reflecting mirror (Dental Mirror Co., Sligo, Ireland) and good clinical light. The quality of the margins was recorded by gently moving the explorer perpendicularly over the tooth/restoration interface in both directions. The criteria used were as follows: score 0: no catch of the explorer; score 1: catch against the restoration; score 2: catch against tooth substance; score 3: catch against both restoration and tooth substance; score 9: any other finding.

From each restoration the bucco-occlusal and the linguo-occlusal enamel/restoration interfaces were evaluated. If more than one score could be detected at the same margin, the highest score was recorded, indicating the least favorable result.

The quality of the contact area was determined by using a dental floss between the restoration and the neighboring tooth and was judged as no, weak, or good contact. The localization was also recorded—that is, whether the contact point had been placed

adequately. Secondary caries, overhangs at the gingival margins, and marginal discoloration indicating leakage were checked and recorded. No control fillings were placed in any patient.

To observe the ability of P10 to penetrate etched enamel, two restorations were made in premolars scheduled for extraction for orthodontic reasons. The teeth were extracted and demineralized, and the restorations subjected to SEM.

The reproducibility of the examiner evaluation was tested on the basis of independent double examinations on consecutive days on 51 restoration/tooth interfaces in vitro.

Results

Clinical assessments

The repeated examination showed good reproducibility of the examiner. Eighty-eight per cent of the restoration/tooth interfaces were assigned the same score on both occasions.

After 2 years no gross fractures or dislocation of any restorations could be seen. No secondary caries or marginal discoloration was detected in connection with any of the restorations. At the gingival margins 78% of the class I cavities were free from overhangs, whereas in 22% of the cases an overhang could be observed. Seventy-seven per cent of the restorations had a good contact point, 12% had a weak contact point, and 11% had no contact with the neighboring tooth.

The localization of the contacting point was judged adequate in only 51% of the cases, and 38% were judged to have been placed too far in the occlusal direction.

The quality of the occlusal margins was in general very good (Table 1). Of 164 margins, 117 were rated score 0 clinically, a finding that was confirmed by inspecting the replicas in the stereomicroscope. At 21 margins a catch of the explorer against the restoration was recorded, and 19 margins were assigned score 2, which means that the cavity enamel walls were exposed. Only two margins resulted in score 3. Both were in the same patient and situated mesiolingually in 15 and 25, respectively.

Table 1. Quality of the occlusal margins in accordance with the score of the interfaces (n = 164)

Score 0: no catch of the explorer, no.	117
Score 1: catch towards restoration, no.	21
Score 2: catch towards tooth substance, no.	19
Score 3: catch towards both restoration and tooth substance, no.	2
Score 9: any other finding, no.	5

Five margins were given score 9 because of porosities at the margin and covering of the cusp.

SEM observations

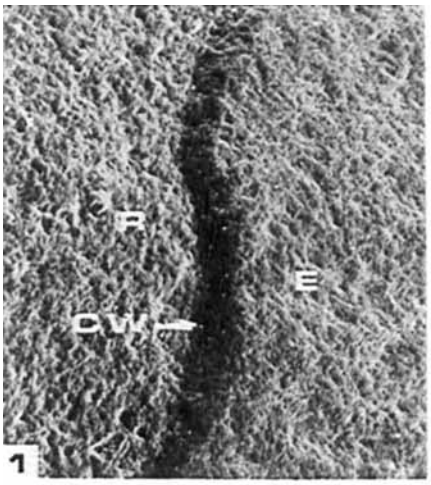
After 1 year a loss of substance could be detected at the occlusal margins. Exact measurements of this loss cannot be carried out with SEM. The height of the exposed enamel walls, however, could be estimated, and they were found to have an average of approximately 20 μm (Figs. 1, 3, and 5). After 2 years there was an increase in the loss of material, representing an approximate doubling of the 1-year value (Figs. 2, 4, and 6, compared with Figs. 1, 3, and 5). The penetration ability of P10 into etched enamel in vivo is visualized in Fig. 7, showing a replica of the etch pattern in enamel.

Transverse sections of casts made from the replica impressions after 2 years showed an average loss of material from the occlusal surface ranging between 30 and 50 μm when observed with ocular and object micrometer in the stereomicroscope (Fig. 8).

Discussion

An important aspect of a clinical study is that the working conditions are comparable to the routines in a practice. This is valid for the present study, since all cavities were placed in such a situation.

The quality of restorations was assessed by direct or indirect techniques. In accordance with Ryge & Snyder (12) all restorations were classified as 'alpha'—that is, indicating that all surfaces were perfect. The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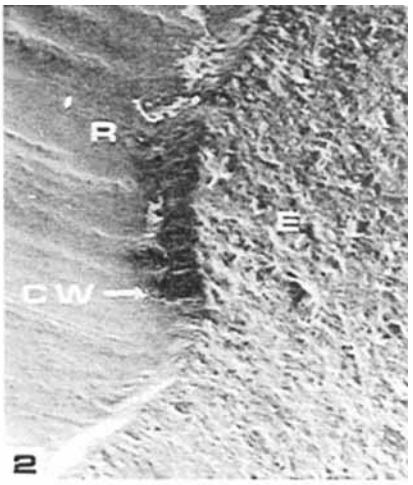
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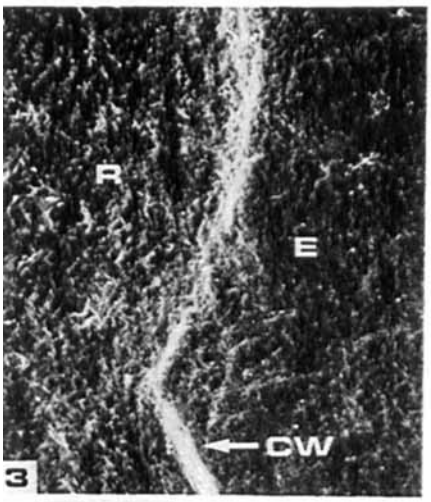
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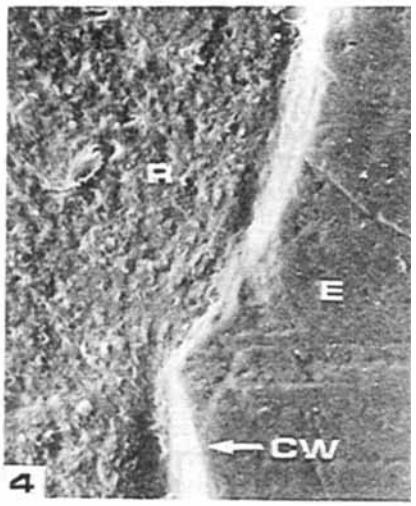
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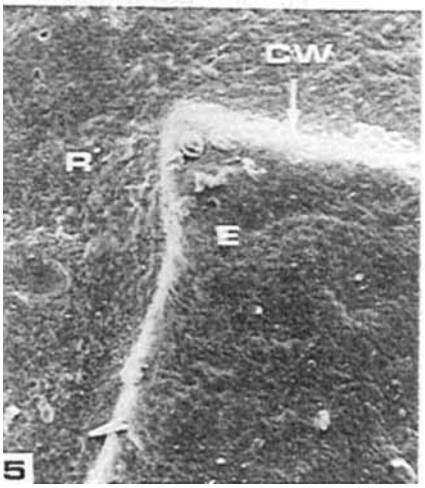
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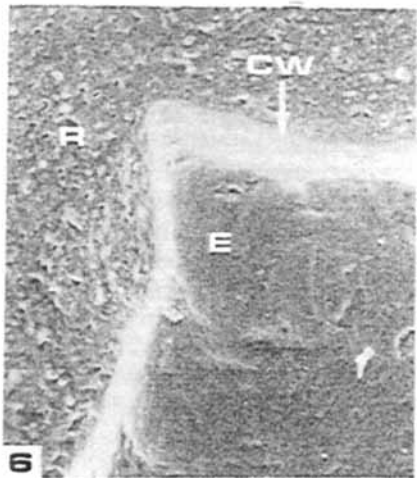
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SEM studies show that this conclusion is only partly true. Changes could be seen at most interfaces after 2 years, but only when the specimens were magnified. Most of the relevant findings could be observed in a stereomicroscope at low magnifications. The use of SEM was, however, valuable primarily because of its magnificent depth of field and secondly because of the possible production of excellent micrographs.

The clinical findings related to the scoring of the enamel/restoration interfaces showed good integrity. Out of 164 margins, 117 were assigned score 0. This finding is in accordance with Dogon et al. (13), who obtained fortunate results with the same restorative material after more than 5 years.

Score 1 was recorded at 21 margins, showing that surplus of material had not always been removed adequately. With a tooth-colored material it is definitely more difficult to finish the restoration in accordance with the cavity margin than when amalgam is used. Presumably, thin layers of P10 situated at and over the unprepared enamel have fractured away, leaving an edge of material that serves as a catch for the explorer. The same may be true of the findings at the gingival margins, where 22% of the restorations were found to have an overhang. It should be pointed out that these values must be regarded as failures in the clinical technique, representing the everyday clinical practice conditions and not a material shortcoming.

Score 2 was recorded at 19 margins, a finding indicating loss of material. This appearance may also occur initially, when the cavity is not overfilled, because the polymerization at the surface is inhibited by oxygen (14), and a subsequent catch of the probe towards the tooth substance will be the result. The 19 margins of this kind were probably not related to the above-mentioned phenomenon, since there was an obvious increase in the loss of substance when the 1-year and 2-year observations were compared in the SEM. Leinfelder et al. (4), using a conventional composite, demonstrated that occlusal wear was substantial after 2 years and that the loss of material was uniform rather than localized. Even exposure of dentin through wear could be observed in four cases in their study.

In the present series the pattern of wear gave the appearance of the restoration having submerged below the prepared cavity margins (Fig. 9). This could, however, not generally be recorded by the examiner through the clinical scorings. Only the stereomicroscope or SEM disclosed the phenomenon of uniform wear, which was found also at the margins scored as 'no catch of the explorer'. Fig. 10 visualizes how the clinical scoring situation appears in SEM. The new explorer is unable to detect the cavity/wall step. The new explorer is estimated to measure approximately 50 μm at the tip, and under this level no step will be felt clinically when the explorer is moved over the restoration/tooth interface. It is therefore evident that the tested material from this series is more resistant to wear than the conventional composites.

The values for monomer to polymer conversion is generally poor for dental two-component composites (15, 16). It is assumed that P10 contains fine distributed air bubbles, which may be responsible for an incomplete polymerization of the material. It is antici-

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Fig. 1. Replica of enamel/restoration interface after 1 year. R = restoration; E = occlusal enamel surface; CW = cavity wall. (Original magnification, ×200.)

Fig. 2. Same area as in Fig. 1 after 2 years. (Original magnification, ×200.)

Fig. 3. Replica of enamel/restoration interface after 1 year. R = restoration; E = occlusal enamel surface; CW = cavity wall. (Original magnification, ×200.)

Fig. 4. Same area as in Fig. 3 after 2 years. (Original magnification, ×200.)

Fig. 5. Replica from part of a buccal covered cusp after 1 year. R = restoration; E = enamel *buccal* surface; CW = cavity wall in occlusal direction. Micrograph is mounted as in the clinical situation, where the horizontal cavity wall is perpendicular and the vertical cavity wall parallel to the axis of the tooth. Note the uniform loss of substance also along the vertical cavity wall. (Original magnification, ×200.)

Fig. 6. Same area as Fig. 5 after 2 years. Prism structure can be seen at the upper left top of enamel. (Original magnification, ×200.)

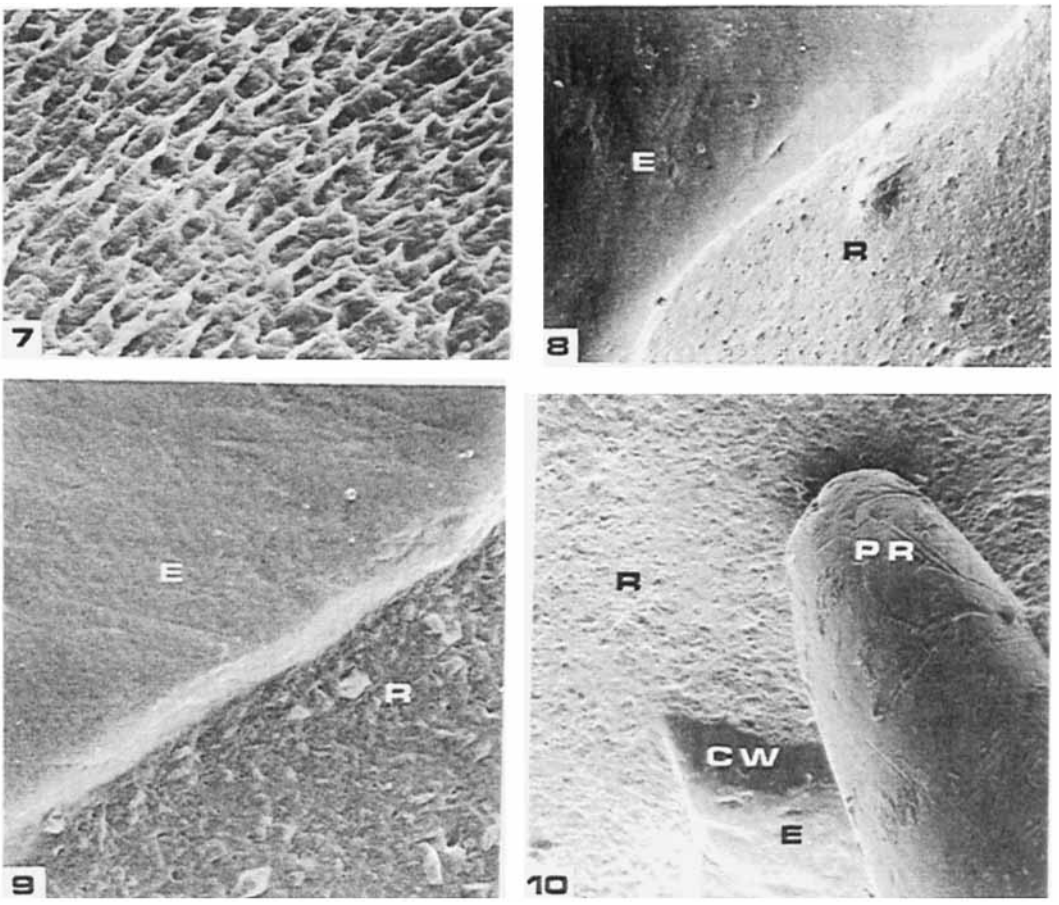

Fig. 7. Penetration of the restorative material into etched enamel in vivo. (Original magnification, ×600.)

Fig. 8. Replica of enamel/restoration interface after 2 years of service at low (×60) magnification. E = enamel; R = restoration.

Fig. 9. Replica of enamel/restoration interface from area where antagonist has not been in contact with the region. E = enamel surface; R = restoration. (Original magnification, ×200.)

Fig. 10. Replica of the clinical situation where the tip of a new probe (PR) has been 'frozen' when the scoring of the restoration/enamel interface was performed. The exposed cavity wall (CW) was not detected by the evaluator, giving score 0. R = restoration; E = enamel surface. The region is the same as in Figs. 5 and 6. (Original magnification, ×200.)

pated that this fact, at least in part, may be responsible for the small but consistent loss of material in the present study. It is therefore believed that light-induced polymerization systems may improve the degree of conversion and thus reduce wear. Because of inferior polymerization, the loss of material may primarily be a chemical degradation process that predisposes to mechanical wear (15). The appearance is uniform, exposing the cavity wall in a characteristic manner (Figs. 8–10).

No intermediate resin layer was used before P10 was inserted. If it is true that the resin is the weakest component when polymerizing restorative materials are con-

sidered, we wanted to test the high-filled composite without any additional resin. The penetration of resin into etched enamel is probably related more to the resin viscosity than to the viscosity of the material as a whole. The present findings indicate sufficient tag formation, creating a good sealing (Fig. 7). In this connection it is important to emphasize that P10 was *pressed* into the cavity. If for some reason no pressure can be applied, the use of an intermediate resin should be considered. The literature on the use of an intermediate resin layer is controversial. Dogon (17) and Forsten (18) favor the use of it, in contrast to Jørgensen & Shimokobe (19) and Ulvestad (20).

The lining of the dentinal cavity walls *after* the etching procedure may be open to question. The 'normal' procedure is that etching is performed after lining. Acids tend to dissolve liners based on calcium hydroxide, and with the 'normal' procedure, the dentin will, after the lining is washed away, be partly exposed to the restorative material, causing pulpal irritation (21). It is anticipated that postoperative pains in connection with the use of composites and the acid etch technique are more frequently related to the removal of the liner and the exposure of dentin than to the leakage phenomenon. When the smeared layer is removed and etching performed at the enamel margin, leakage will not take place (22). In addition, the therapeutic effect of liners based on calcium hydroxide will have an enhanced effect on the pulp when the smeared layer is removed from the dentin before lining is performed. Normal pulpal conditions were found after both short and long postoperative periods when this procedure was tested (23).

No beveling of any cavity margin was performed. It does not seem to be in accordance with good dentistry to remove sound enamel and have it replaced by any material weaker than enamel. The cavities in this series were therefore kept as small as possible and prepared as for amalgam. Degradation of a material is difficult to observe in a long, beveled cavity, where the localization of the prepared margin is difficult to detect. Removal of the thin coat of enamel at the gingival margin when beveling is carried out will make leakage possible and therefore appears highly contraindicated.

The relatively discouraging findings related to the quality of the contact points should not be regarded as material failures but illustrates a clinical pattern in connection with the use of such materials.

There is therefore obviously a need for a matrix system otherwise designed than the ones constructed for amalgam, as the use of the latter did not meet the demands for an appropriate matrix system in this series. The bad contact conditions observed after 2 years could also be seen in the replicas produced shortly after the restorations were made. Non-adequate results must therefore be compared with the results of the clinical procedure at the start.

P10 has no radiopacity. This fact may cause diagnostic problems in relation to secondary caries. The material may serve as the material of choice in selected cases of class II and for the general use in class I.

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