

IN BRIEF

- Dentine bonding agents can be used to protect eroded teeth.
- Bonding agents can infiltrate the dentine to protect against erosion.
- Seal and Protect appeared to be better than Optibond Solo.
- This *in situ* study supports the use of a minimally invasive method to protect teeth from acids.

The surface effects of erosion and abrasion on dentine with and without a protective layer

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Objective The aim of this *in situ* study was to investigate with four imaging modalities whether covering dentine with adhesive resins could protect against erosion from acids. The objectives were to observe and quantify the effects of acids and the soft tissues, especially the tongue, on dentine and the bonding agents using four assessment techniques: qualitative assessment with SEM, surface roughness and thickness of resin with the TSM and volume loss with the laser profilometer.

Design An *in situ* investigation using extracted dentine sections embedded in splints held on the palate of 10 volunteers. The dentine sections were protected by two resins and subjected to a tooth wear regime.

Results Both Seal and Protect and Optibond Solo protected the tooth surfaces from a tooth wear regime. There were no statistical differences between the control surfaces and those protected with dentine bonding agents for resin thickness, roughness and profilometry. The appearance of the slabs under both confocal and SEM showed that the material remained in place despite a vigorous wear regime and therefore protected the tooth surface.

Conclusions For patients with uncontrolled erosion or tooth wear, applying a dentine bonding agent to exposed dentine is a practical option to prevent further damage.

INTRODUCTION

Clinical experience tells us prevention of toothwear by eliminating the cause is not always practical or achievable. Therefore in some patients, early intervention is desirable, but restoring worn or eroded teeth with composites or crowns could be considered overly destructive especially when the damage is limited to early dentine exposure. If toothwear and particularly erosion is allowed to progress then the damage to dentine may be catastrophic, resulting in the potential for tooth loss.

Dentine bonding agents applied onto the surface of eroded dentine have the potential to prevent further demineralization by organic and inorganic acids.^{1,2} Dentine adhesive resins are known to infiltrate the top 1 – 10 µm of conditioned dentine, leaving a matrix composed of adhesive, collagen, and dentine that has the potential to bond to a composite resin.³ This complex, called the resin reinforced hybrid zone, may have the potential to protect dentine against acids for patients with erosion.⁴ Both materials selected for this study contain fillers; Solo (O.S., Kerr, USA) has relatively large fillers (7 µm) whilst Seal and Protect (S&P, Dentsply, Weybridge, UK) uses nano fillers (7 nm). Seal and Protect is derived from Prime and Bond NT, a dentine-bonding agent and is marketed as a desensitizing agent. It may also have antibacterial properties resulting from the incorporation of Triclosan™. Solo requires separate acid etching whereas S&P contains acidic monomers that are self-etching.

The use of dentine bonding agents to protect exposed dentine from acid was reported by the same authors.² The results from a laboratory study showed that the resins could protect tooth surfaces from acid and that O.S. provided better protection than S&P but a clinical study was needed to validate these findings.

The aim of this *in situ* study was to investigate if covering dentine with adhesive resins protects against erosion from acids. The objectives were to observe and quantify the effects of acids and the soft tissues, especially the tongue, on dentine and the bonding agents using four assessment techniques; qualitative assessment with SEM (Scanning Electron Microscope), surface roughness and thickness of resin using the TSM (Tandem Scanning Microscope) and volume loss with the laser profilometer.

MATERIALS AND METHODS

Dentine sections approximately 2 – 2.5 mm thick were cut with a water-cooled diamond saw (Labcut-1010, DR Bennett, Leicester, UK) from the mid-coronal region of 40 caries-free third molar teeth randomly selected from a pool of freshly extracted teeth stored in water at 4°C. The teeth were donated with consent from patients for dental research within the guidelines of the local ethics committee. Each disc was further sectioned with a wire saw (Diamond wire saw, DR Bennett, Leicester, UK) to produce dentine slabs approximately 6 mm by 8 mm. The prepared dentine slabs were further cleaned in a 5% solution of sodium dodecyl sulphate (SDS) for 24 hrs and sterilised by gamma irradiation in a Caesium 137 radiation unit (Gammacell 1000 Elite Nordion Int. Inc., Ontario).

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Clear acrylic orthodontic base plates were made for 10 male volunteers, age range 25–44 years old, each of whom had no clinical evidence of dental erosion. Orthodontic cribs were used to retain the appliance and fitted so as not to interfere with occlusion and to allow normal function to be as comfortable as possible. Four sterile dentine sections, taken from the mid-coronal plane of the extracted teeth (S1, S2, S3 and S4) were inserted symmetrically into the appliance. S2 and S3 were positioned either side of the midline in the anterior maxilla and S1 and S4 were placed in the premolar/molar regions of the base plate. A machined 2 mm diameter and 0.2 mm thick stainless steel disc (Exactoscale Ltd., Esher, Surrey, UK) was cemented at the edge of one corner of each dentine slab to act as a reference point for measuring the tooth wear using a similar protocol previously described by Bartlett *et al.*⁵ Seal & Protect (S&P) was applied to Slab 2 and Optibond Solo (O.S.) applied to Slab 3 using manufacturer's instructions. Seal and protect was applied without acid etching whilst Optibond had a 10 second acid etch.

The volunteers were asked to wear the base-plate for 8 hours daily for 20 consecutive days (excluding weekends) for a total of 160 hours. The eight hours were split into 4 hours in the morning and 4 hours in the afternoon and the periods chosen so as not to interfere with daily routines. The appliance was collected every day by the first author for immersion in acid and assessment. Three slabs were immersed for 24 minutes in a citric acid solution (0.05 M). The fourth slab (S4) was not immersed in the acid and acted as the control. Volunteers were asked not to eat or drink any beverages, except non-carbonated water or brush the surface with any oral hygiene methods during the period of the study. Cleaning of the appliance with a toothbrush without paste and immersion in 0.2% chlorhexidine for 1 minute was performed on alternate days by the first author. All volunteers complied fully with the study protocol.

Epoxy resin positive replicas of the sample surfaces were made from the baseline and subsequent follow-up impressions. These were gold coated and used for SEM (Scanning Electron Microscope) analysis. Base line images of the four slabs were taken with a tandem scanning confocal microscope (TSM - Noran Instruments, Middleton, Wisconsin, USA with a dry lens x 40/0.55). The peak-to-trough (Z height) measurements were taken with the confocal microscope using an extended focus image stage.⁶ The average roughness (R_a) of the area was calculated by drawing 10 lines across the extended focus (peak to trough) image obtained using the rugosity parameter on the Calcium Analyse part of Tempus package image analysis software used in the TSM (Tandem, Scanning Microscope, Kinetic Imaging Ltd, Liverpool, UK).

Impressions of the slabs and metal discs were taken at base line and all subsequent follow-up examinations with a silicone impression material (Panasil contact plus: Kettenbach, Germany). The measurement of tooth wear/erosion on the dentine slabs, using the metal discs as a reference point, was taken with non-contacting profilometer using previously published protocols.⁵

RESULTS

SEM

The SEM showed the surface detail but not depth of both the material and the tooth surfaces. The O.S. appeared smooth, but not as smooth as that seen with the S&P, and the O.S. progressively cracked over the study period (Fig. 1). The extent of this cracking was demonstrated by some low magnification SEM images (x 80). Images at higher magnifications of the cracks showed that they involved the full thickness of the resin coating. Resin tag formation was obvious, as seen at the base of some cracks but the tags appeared to be dislodged from the dentine surface. Cracks started becoming noticeable on the O.S. by the eighth day and continued to increase throughout the study period appearing as cracked or crazed surfaces.

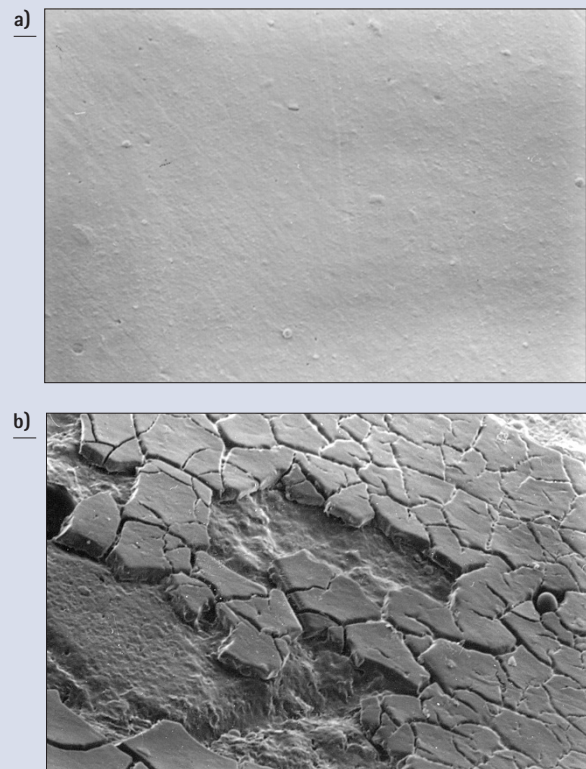


Fig. 1 A typical appearance of slab 3 coated with Optibond Solo (O.S.) imaged, using the SEM
Optibond Solo at baseline (a) x160 and (b) peeling and cracking of the O.S. coating after 20 days (x80)

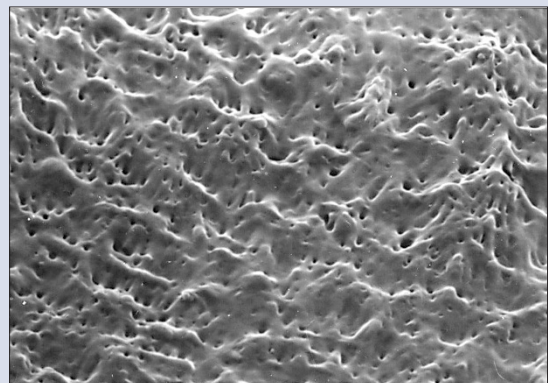


Fig. 2 A typical appearance of slab 1, after 20 days, immersed in acid but not protected, imaged using the SEM (x640)

Baseline images (no treatment) for slabs 1 and 4 showed a surface partially covered with a smear layer with patches of open dentinal tubules. Subsequent microscopic evaluation of the dentine slab immersed in acid and unprotected (slab 1) showed an overall rougher appearance with smoothing of the inter-tubular regions giving a characteristic undulating or rippled appearance of the dentine surface that increased throughout the experiment on some slabs, while others appeared smoother. At 20 days some pitting was noted on the surface of some of the slabs: this started becoming visible by the fourth and fifth week (Fig. 2).

The images of slab 4 unprotected and not immersed in acid (abrasion only) appeared generally smoother even though the rippled appearance on the surface was still visible but to a lesser extent than in slab 1 (Fig. 3). The surface smoothing was accompanied by a

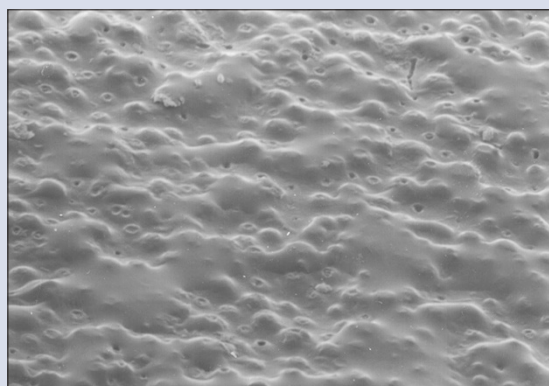


Fig. 3 A typical appearance of slab 4 unprotected and not immersed in acid after 20 days, imaged using the SEM (x640)

reduction in the number of visibly open tubules. The combination of these effects with the high reflectivity of these surfaces gave the appearance of a rippled or even a pitted surface on an otherwise smooth background. These changes in the appearance were confirmed by the SEM images that also revealed an increased rippling of the surface and sometimes near total obliteration of dentinal tubule orifices by the fifth week. On some slabs the rippled appearance was more evident by the fifth week with the trend for more destruction of the inter-tubular dentine being more evident on slab 1.

Confocal microscope

The Confocal microscope allows images through the depth of the material and tooth and provided measurements of the depth remaining of the dentine bonding agents. Locating the resin surfaces on the TSM was easily accomplished with Optibond Solo but this was much more difficult to achieve with Seal and Protect because this material was more translucent. The filler particles in S&P (7 nm) formed small clumps that appeared to sink within the resin layers and accumulate on the bottom of each layer. No cracking or crazing was observed with the S&P (Fig. 4) but peeling of the resin was observed at the periphery of the slabs on areas where some enamel was still present. The S&P at baseline appeared as a very smooth thin layer that appeared to adapt and follow the contours on the dentine surface. Progressively, as the material was worn, the resin surface appeared smoother with very few cracks noted on the resin surface (Fig. 1).

Resin thickness

For each time period the mean thickness over all observations was used as a summary statistic. Linear regression of thickness on time as the independent variable indicated a significant decrease of thickness with time: Seal and Protect slope = -0.52 (95% confidence interval -0.67 to -0.38) $p = 0.01$, Optibond Solo slope = -0.66 (95% confidence interval -0.83 to -0.48) $p = 0.18$. The variation in mean thickness and associated 95% confidence interval with time is shown in Figure 5. A t -test indicated that at each time period Optibond Solo was significantly thicker than Seal and Protect.

Resin roughness

Mean surface roughness R_a , over all subjects was used as a summary statistic to compare the effect of combined abrasion/erosion with abrasion only for a period of 20 days on control slabs. There was no significant difference between the erosion/abrasion and abrasion. The mean R_a for abrasion/erosion was 0.44, standard deviation 1.39, sample size of 10, and the mean R_a for abrasion only 0.10, standard deviation 1.30, sample size 10. The difference in the mean R_a was 0.34, with a 95% confidence interval from

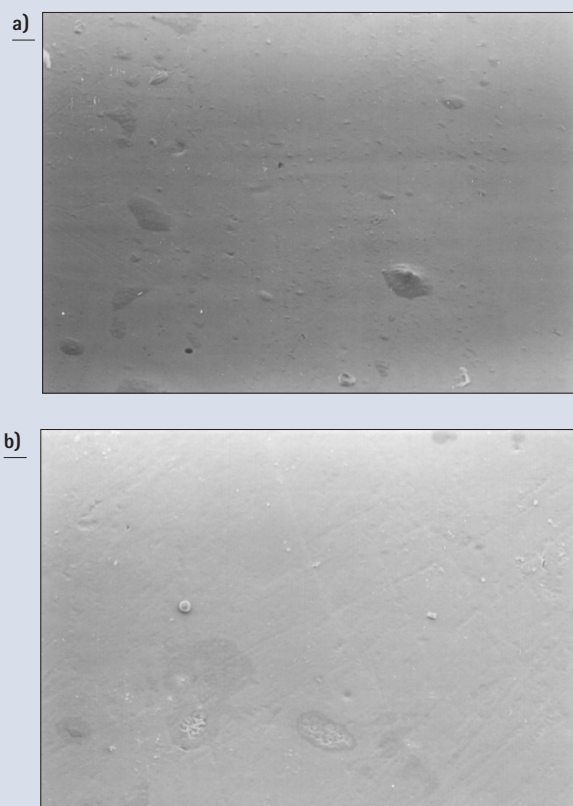


Fig. 4 A typical appearance of slab 2 coated with Seal and Protect, imaged using the SEM
SEM image of Seal and Protect coated dentine surface at baseline (a) and at 20 days (b) x160. There are no cracks or apparent damage to the surface

-0.93 to 1.60 ; the t test was 0.55, with 18 degrees of freedom and an associated p value of 0.58. The large standard deviations and confidence interval reflect the difficulty inherent in measuring R_a .

Non contacting laser profilometer

The initial and final steps height and the material lost are given in Table 1. Although the material lost for Optibond Solo was approximately three times that of Seal and Protect this difference was not statistically different, $p = 0.44$, again reflecting the scatter in data of this type. There was no significant difference between the controls, $p = 0.37$.

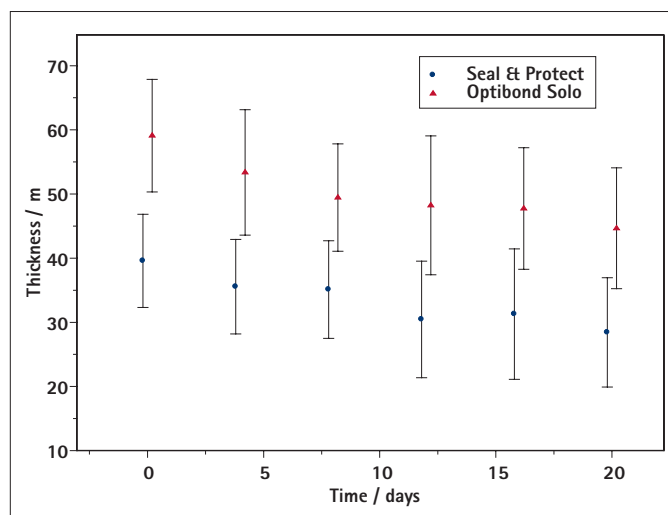


Fig. 5 Mean resin thickness and associated 95% confidence intervals for Seal & Protect and Optibond Solo as a function of time

Table 1 Material lost in μm over a 20 day period as measured by laser profilometry.

	Erosion / abrasion Seal and Protect	Optibond Solo	Control	Abrasion Control
Initial	444.2	371.7	233.9	429.4
Final	482.8	485.0	310.5	489.4
Difference	38.6	113.3	76.63	60.0

DISCUSSION

The aim of this study was to assess whether dentine bonding agents could protect teeth from acid commonly associated with erosion. In addition, the behaviour of two proprietary dentine-bonding agents were compared for their ability to protect the dentine. The position of the dentine slabs protected with the bonding agents was chosen to mimic, as far as practically possible, the location where the technique is most likely to be used clinically. Individual variations in oral anatomy, such as a high palatal vault, made the assessment procedures more demanding in some volunteers.

The results from the *in situ* investigation showed that over this time period the dentine bonding agents remained attached, for the most part, to the tooth surface. Provided they were in place, the dentine bonding agents protected the tooth from acid. The measuring systems did not show any statistical difference between the controls and the coated slabs and probably reflected the relatively short study period. There were also relatively few study patients, and with greater numbers the effects of the dentine bonding agents might have been greater, especially on the profilometry. Although the visual images of the dentine bonding agents suggested that Optibond Solo deteriorated more quickly, it was the thicker and therefore more could be lost for the same effect.

The use of a citric acid solution with the same titratable acidity as a commercially available orange juice eliminated a number of potential problems that may have been encountered using commercial orange juice. The immersion time was based on the estimated time it might take to drink a glass of orange juice. This time was also judged to be sufficient to create enough erosion so that the various measuring techniques could distinguish between eroded and non eroded surfaces. The subjects were asked to avoid cleaning the dentine slabs to eliminate the potential for inter-subject differences in the application of toothbrush pressure and timing.

Cracks started appearing on the Optibond Solo by the eighth day and continued to increase throughout the experiment on both direct visual and microscopic observation. This may have been the result of dimensional changes as the material absorbed water. No cracking or crazing was observed with the Seal and Protect but peeling of the resin was observed at the periphery of the slabs on areas where some enamel was still present and may reflect material

breakdown at the periphery, since S&P was applied without etching.⁷ The resins failed completely at various stages in the experiment in two volunteers and it is difficult to identify reasons for this apart from both volunteers were observed to dislodge and play around with the appliance with their tongue.

The tooth wear on the protected and unprotected dentine highlighted the action that the tongue may have on any material in the mouth on which it has direct contact. Erosion exacerbated this effect on the unprotected dentine slabs. More material loss was recorded with Optibond Solo and this is probably due to it being less abrasion resistant than Seal & Protect. The effect of the dentine bonding agents appeared to result in a similar amount of wear that would result purely from the abrasive action of the tongue. In other words the dentine bonding agents counteracted the effect of the acid.

The use of dentine bonding agents as protective agents against erosion and abrasion has been reported a number of times.^{1,2} Not all of the dentine bonding systems will be appropriate for this application, either because of complexity of use or inappropriate constituents. As a self-etching system S&P has clear advantages in placement over the O.S. system which requires a separate etching stage, but the O.S. was not originally designed for this role. It is interesting to note that in the laboratory investigation, the O.S. provided better protection. This may reflect that this material is better suited for a role of protection in dryer conditions.

CONCLUSION

This study showed that Optibond Solo and Seal and Protect protected dentine against a vigorous wear regime. Optibond Solo deteriorated faster than Seal and Protect but was applied in a thicker layer. Both materials could potentially be used to protect dentine but it appears from this study that Seal and Protect is the more useful.

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