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ORIGINAL ARTICLE

Comparison of two all-in-one adhesives bonded to non-carious cervical lesions—results at 3 years

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Abstract The aim of this study was to evaluate the clinical performance of S^3 Bond (Kuraray Corp., Japan) and G-Bond (GC Corp., Japan) all-in-one bonding agents, over 3 years in non-carious cervical lesions (NCCLs). Ethics Committee approval was obtained, and 60 restorations were placed in 11 patients aged 45–84 years (mean 60.5 years), using either Clearfil ST resin composite (Kuraray) and S^3 Bond or Gradia resin composite (GC) and G-Bond alternately, without phosphoric acid etch on the uncut enamel margins. Patients were recalled at 6 months, 1 year, 2 years and 3 years, and photographs were taken for assessment of colour match and marginal discoloration. One patient was not available at 3 years, resulting in 54 restorations being available for evaluation. One restoration of S^3/Clearfil ST was lost at 2 years, giving retention rates of 97% for S^3 and 100% for G-Bond. At 3 years, six restorations for S^3/Clearfil ST showed slight marginal discoloration and one restoration pronounced marginal staining. For G-Bond/Gradia at 3 years, 11 restorations exhibited slight marginal staining and one restoration pronounced marginal staining. Most restorations were bonded to sclerotic dentin. Statistical analysis of marginal staining showed no significant difference between the two restoration groups. The degree of marginal staining was almost identical for both materials and tended to be in larger restorations. Both S^3 and G-Bond all-in-one bonding systems appear to be good adhesives for the restoration of NCCL for the length of the current study. Restoration of NCCLs with the newer all-in-one adhesives appears to be a viable alternative technique to more complicated adhesive materials.

Keywords All-in-one adhesive · Non-carious cervical lesions · Clinical study · Resin-based adhesive · Dentine bonding

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Introduction

The use of resin-based adhesives for the restoration of teeth has been steadily increasing. Consequently, manufacturers have been developing bonding materials at a very rapid pace, making it difficult for the practitioner to keep track of which materials are clinically successful and ensure a long-lasting restoration. Much of this development in resin-based adhesives has been aimed at reducing the bonding steps and theoretically also reducing the technique sensitivity of the bonding process. The other so-called benefit of fewer steps is a shorter time for restoration placement; hence, it could be said that much of the change in bonding systems is market-led rather than evidence-driven. Due to the relatively short market life of many adhesive systems, few long-term clinical trial data are available, since by the time the clinical study results are published the material has either been withdrawn from the market or has been significantly modified. Nonetheless, it is important for clinical study data to be available to build the evidence base but also to inform practitioners that the modifications to adhesive systems may require changes in treatment practices to ensure durable restorations.

As the population ages, there is an associated increase in the incidence of non-carious cervical lesions (NCCLs) [1]. NCCLs can present in a very wide range of forms from the small lesion along an enamel margin to almost complete destruction of the tooth in its middle third [2, 3]. In addition, NCCLs can also be very sensitive to thermal stimuli or local pH change that can have a severe impact on the quality of life. This has led to numerous forms of treatments becoming available to manage the lesions [4, 5]. The most conservative form of management for sensitive lesions is the application of some type of surface modifying agent to occlude open dentinal tubules. At the other end of the scale is the placement of a restoration. Even if the lesion is not sensitive there may still be the necessity to place a restoration for aesthetics, in the case where a tooth may be a denture abutment requiring a clasp, or as a means to protect the tooth surface from further loss of tooth structure. As the tooth has already lost a substantial amount of tissue the aim of any restorative intervention should centre on a minimally invasive approach and rely on the adhesive qualities of the restorative material. The glass-ionomer cements (GICs) have been the best material for the restoration of NCCL [2]. However, the possible disadvantage of the GICs is their wear resistance, especially for denture abutments and to a lesser extent aesthetic qualities. When a wear-resistant material is needed, then the restorative alternative of choice has been the use of a resin-based adhesive and resin composite filling material. Clinical data have shown, however, that the longevity of bonded composite restorations can be somewhat unpredictable [6].

The most recent iteration of resin-based adhesives is the so-called 'all-in-one' system that combines the etching, priming and bonding steps into a single process.

The current research evidence from laboratory studies seems to indicate some all-in-one systems show a tendency to be more technique-sensitive than the two-step self-etching priming adhesives [7]. It has been shown some all-in-one systems have a propensity to phase-separation shortly after application onto a glass surface which is also likely to occur on the tooth surface, meaning that the bonding process may be compromised resulting in poorer bonding. Other laboratory studies also show the bond strengths of this group of materials frequently tends to be lower than most etch and rinse and self-etching adhesives [8–10]. However, the information from laboratory tests do not always correlate with the clinical performance of resin-based adhesives. Several short-term trials have shown some of the newer all-in-one systems are performing quite well, even when compared with the traditional three-step etch and rinse and two-step self-etching materials [11–13].

The objective of this clinical study was to compare over 3 years the retention and marginal staining of restorations placed in NCCL using two all-in-one resin-based adhesive systems with a resin composite from each respective manufacturer. The 1-year results were reported in 2008 [14]. The null hypothesis is that there is no difference in the clinical performance of the two adhesive systems.

Materials and methods

Sixty restorations were placed in NCCLs in 11 subjects (age range 45–84 years, mean 60.5 years). Patients presenting for treatment at the Royal Dental Hospital of Melbourne with NCCLs were referred for participation in the study. Voluntary participation and informed written consent from all subjects was obtained prior to commencement of treatment. Approval for the clinical trial was obtained from the Human Ethics Committee of the University of Melbourne as well as Dental Health Services Victoria. Subjects were excluded from the trial if they exhibited severe periodontal disease or chronic gingivitis, high caries risk, poor oral hygiene or were potentially unable to attend recall visits. Teeth with NCCLs were selected for restoration, and varying numbers of lesions were restored per patient. Each patient received at least two pairs of restorations of each of the adhesives being evaluated (Table 1). The size of restored lesions varied from shallow lesions (less than 1 mm deep) that tended to have an angular form, and occasionally exhibiting sensitivity to cold, to larger lesions approximately 5 mm occluso-gingivally in height and approximately 2 mm deep that more commonly exhibited smooth undulating surfaces (Fig. 1). In addition, the degree of dentine sclerosis was evaluated as either sclerotic or not. Where sensitivity was noted prior to insertion, these lesions were classified as not sclerotic.

Teeth were restored by one operator (MFB) with either Clearfil S^3 Bond and Clearfil ST hybrid resin composite (Kuraray Medical, Batch numbers 0042D, 0021C), or G-Bond and Gradia Direct Anterior resin composite (GC Corporation, Batch Numbers 0411101, 0411102). Restorations were placed using the following procedure: teeth were isolated by cotton rolls, and retraction chord if required, and high velocity evacuation, then dentine and enamel were cleaned with a slurry of pumice and water on a slowly rotating rubber cup in a slow-speed handpiece, washed and dried, but not desiccated. For Clearfil S^3 Bond, one drop was dispensed and applied to the tooth surface for 20 s, blown off with a strong blast of air for approximately 5 s, and light cured for 10 s using an LED curing light with a 1,000 mW/cm^2 output (Mini L.E.D., Acteon, Mount Laurel, NJ, USA). The Clearfil ST resin composite was applied in one increment for the smaller lesions and light-cured for at least 40 s. For larger lesions, resin composite was placed incrementally, each increment being cured for 40 s. In the case of G-Bond, it was dispensed, immediately applied to the NCCL with a brush, allowed to remain undisturbed for 10 s, blown off with a very strong air

Table 1 Adhesives, components and manufacturers

Adhesive resin	Components	Batch number	Manufacturer
Clearfil[S3]	Bisphenol A diglycidylmethacrylate 10-methacryloxydecyl dihydrogen phosphate (10-MDP) Colloidal silica DL-Camphorquinone Water Initiators Accelerators	00026A	Kuraray Medical, Okayama, Japan
G-Bond	Acetone 4-Methacryloxyethyltrimellitate anhydride (4-MET) Urethane dimethacrylate Dimethacrylate component Phosphoric ester monomer	0501251	GC Corporation, Tokyo, Japan

blast for approximately 5 s to evaporate the solvent and thin the adhesive, then light-cured for 10 s. The resin composite, Gradia Direct Anterior was applied in the same manner as the Clearfil ST resin composite. When the adhesives were applied to the NCCL surfaces, it was ensured the tooth surface remained covered by the adhesive, this occasionally required re-application of adhesive during the 10 s. The NCCL surfaces were not scrubbed with the adhesives.

Fig. 1 Examples of NCCL prior to restoration. All teeth exhibit sclerotic dentine; however, it is noted that the incisors exhibit shallow, 'dished' out lesions compared with the deeper, angular lesions noted on the premolars

The restorations were contoured with fine composite finishing diamonds in an intermediate-speed handpiece under water spray and finished with Kerr Hawe Optidisc discs (Kerr Hawe, Bioggio, Switzerland). Teeth selected for restoration depended on the location of lesions per patient and each material was placed alternately. Where possible, restorations were paired but not necessarily in the same quadrant.

Subjects were recalled at 6 months and 1, 2 and 3 years after placement. The restorations were checked for presence or absence and for marginal staining. Photographs at 1:1 magnification were taken of the cavities prior to restoration, immediately after, then at 6 months and 1, 2 and 3 years. The photographs were also checked for restoration presence or absence, and colour match of the restoration with the surrounding tooth structure. Marginal discoloration was assessed by MJT from photographs, by comparing the test restoration against a standard set of photographs on a 9-point scale, where 0 represents no staining and 9 represents severe staining.

The retention of restorations was analyzed using one-way ANOVA and a *t*-test set at the 95% confidence level. Restoration survival was determined using a survival analysis equation.

Results

Thirty restorations of each adhesive and composite were placed in 11 patients. Table 2 shows the distribution of restorations to teeth, with the majority of restored teeth being premolars. Ninety-six percent of lesions were classified as sclerotic dentine NCCL. Most lesions exhibited a dentine surface that was smooth and semi-glossy to glossy in appearance, which was used as the main determinant for sclerosis (Fig. 1). The distribution of lesion

Table 2 Distribution of restorations in teeth

	Upper	Lower	Total
Molars	4	3	7
Premolars	13	15	28
Incisors/canines	14	11	25
Total	31	29	60

size was approximately 46% for the small, shallow more angular lesions and 56% for the larger and deep smooth lesions. All margins were located at or above the gingival crest. All patients were available at the 6-month, 1-year and 2-year recalls, and one patient with six restorations was unavailable at the 3-year recall. One restoration of S^3 adhesive was missing at the 3-year recall; otherwise all restorations remained intact. The overall 3-year cumulative survival rate was 98% for all restorations, 97.5% survival for S^3 adhesive and Clearfil ST composite and 100% survival for G-Bond adhesive and Gradia Direct composite.

At 3 years, six S^3 restorations showed slight marginal staining and one restoration showed quite pronounced marginal staining. For G-Bond, eleven restorations showed slight marginal staining and one restoration showed pronounced staining. In general, the larger lesion/restorations exhibited more marginal staining. Statistical comparison of the marginal staining scores showed no significant difference between the two materials ($p>0.05$). It was noted that marginal staining of both materials was more often located at the marginal extremities of the restorations or the disto-buccal corner of restorations in posterior teeth (Fig. 2). These locations often showed a slight excess of either adhesive or resin composite on the tooth extending beyond the margin of the NCCL. The roughened area is most likely the cause of the marginal staining. The majority of restorations did not exhibit marginal staining throughout the life of the study. No restoration exhibited the development of dental caries or sensitivity. It was noted, however, that about a quarter of the restorations evaluated showed some deterioration of the margins during the 3 years of the study.

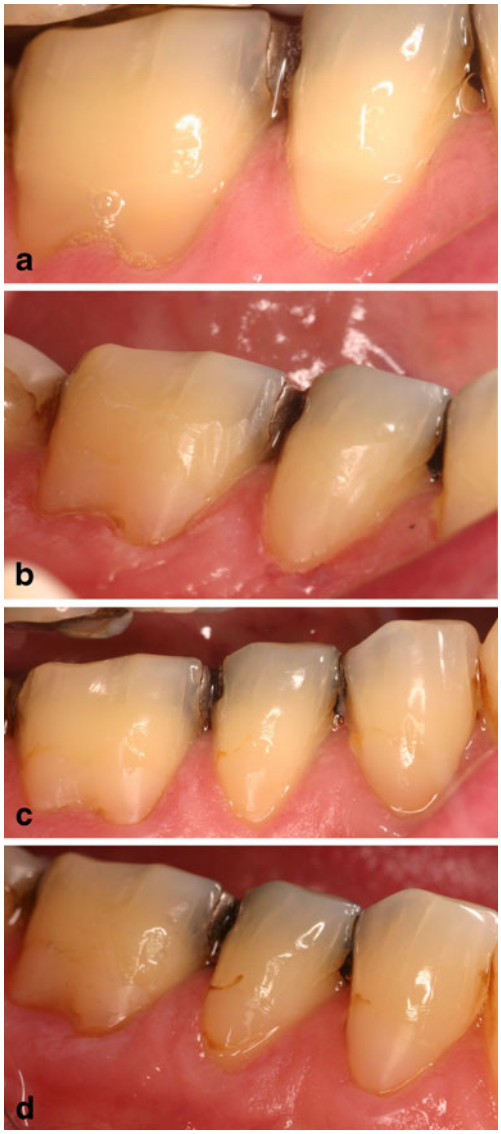

Fig. 2 Teeth 35, 36 (mirror image), NCCL before restoration showing shallow, smooth surfaced lesions (**a**). Baseline restorations 35 restored with G-Bond and Gradia Direct, 36 restored with Clearfil S^3 and Clearfil ST (**b**). Restorations at the 1-year recall showing marginal staining commencing at the disto-buccal corners of both restorations where a slight flash of resin composite appears to remain (**c**). The restorations at 3 years showing the staining has increased and the marginal defect seems more pronounced (**d**)

Discussion

This is one of the few clinical studies to report the 3-year performance of all-in-one systems used for the restoration of NCCL. The study uses a small sample of patients who also received multiple restorations, which removed the true randomization that can be achieved for studies with a much larger patient pool and number of restorations. Thus, the results and retention may not be representative for all variations and types of NCCLs that can occur. All of the restored teeth were in contact with opposing teeth. The placement of more than one pair of restorations per patient has some advantages and disadvantages. The advantage is that the influence of the oral environment is to some extent minimized. On the other hand, this can possibly be a disadvantage if several of the patients have an oral environment that affects the adhesion of the restorations, for example oral flora and dietary habits which may increase the chances of marginal staining, or functional habits such as bruxism or chewing of very hard food stuffs. It was noted that most of the stained restorations were seen

only in a small number of patients, and it therefore seems that the oral environment, e.g., bacterial species and numbers, diet and oral hygiene habits, are important determinants of marginal staining. Another pertinent observation was the location of the marginal staining, which occurred most often in the regions where the resin composite filling material was thinnest. It is possible that the polymerization contraction of the composite towards its greatest volume affected the bond in these regions. In addition, the disto-buccal marginal zone is more difficult to access when finishing the restorations. The results may therefore have been influenced by operator variables with respect to marginal staining, such as leaving small flashes of adhesive or resin composite at the margins. The flash is a rough surface and can therefore be a site where stain can easily occur. The degree of marginal staining was not such that patients commented, and in a routine recall these small stains could easily be removed by careful polishing of the restoration margin. It was also observed that larger lesions/restorations seemed to exhibit more marginal staining. This may relate to the teeth with larger lesions possibly flexing more, hence leading to breakdown of restoration margins. This aspect of marginal staining needs further investigation as to whether it can be minimised by different methods of composite placement, different composites with varying stiffness, the thickness of the adhesive at the margins or even lesion size. The one restoration that was lost was from a large, shallow lesion. However, as the study NCCL were mostly sclerotic dentine, it seems that both systems are quite effective when bonding to sclerotic dentine which is in contrast to the study by van Dijken [15], who noted that more lesions tended to be lost in sclerotic lesions, although it was not a statistically different variation from non-sclerotic lesions. Lesion size did not seem to be a factor in retention or marginal staining is the current study.

The two adhesives used in this study are quite different in their chemistry, notably that G-Bond does not contain 2-hydroxyethyl methacrylate (HEMA) to aid the bonding process. However, it seems that the absence of HEMA has not had any adverse affect on restoration retention or marginal staining. The results of the current study are similar to another study showing loss of one restoration each for both of the adhesives at 2 years [12]. The other difference is the major functional monomers used. Both monomers, 10-MDP for S^3 and 4-MET for G-Bond, have shown salt formation with synthetic hydroxyapatite [16]. The 4-MET salt was reported to be less hydrolytically stable than 10-MDP, but this seems to not have affected the retention of the restorations in this study [16]. The only possible effect of the bond degradation might be related to the increased number of restorations of G-Bond showing marginal staining. Acid-etching was not used on the uncut enamel for either system.

Another study investigated over 2 years the use of S^3 and the two-step self-etching priming adhesive Clearfil SE Bond (Kuraray Medical) in which three pairs of restorations were placed per patient showed success rates of 81–84% in NCCL [12]. The authors stated that their retention rates were lower than those found in other trials of these materials [17], and concluded that this may be a result of the inexperience of the authors when using the newer self-etching systems in addition to the information provided in the manufacturers' instructions which they intimated may have been unclear with regard to the usage. They did not find a statistical difference between the two materials tested. A recent study compared the retention of Clearfil S^3 with Optibond FL (Kerr Corp,. Orange, CA, USA) and concluded both materials performed well [18]. The retention rate was almost identical to the outcomes of the current study. The 2-year study also noted that small enamel defects increased and occurred more frequently for the all-in-one material. The current study found similar observations.

Laboratory bond test data seem to indicate that the bond strengths of the all-in-one systems to enamel and dentine are not as high as other adhesive systems [7, 19]. Other studies observing the durability also demonstrate the all-in-one systems seem to show bond deterioration over time [20, 21] and probably do not perform as successfully as other types of adhesive, such as two step self-etching priming systems. However, the clinical results seem to contradict the laboratory data, as the current study shows close to 100% retention for all restorations. It is possible that the materials tested in this study do form a stable chemical bond to the highly mineralized surface of the NCCL. This may provide one explanation why laboratory data are poorly correlated with clinical performance, since laboratory studies are frequently performed on extracted third molars which have a lesser degree of dentine mineralization compared with NCCLs.

The results of this clinical study show that the two all-in-one adhesives used for restoring NCCLs provide an excellent result with only one restoration lost in a 3-year period. It seems that these materials, if placed in a meticulous manner, can be as successful for bonding to sclerotic dentine as two-step self-etching or etch and rinse systems.

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Conflict of interest The authors declare that they have no conflict of interest.

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