

COMPOBOND: EVOLUTION OF A NEW RESTORATIVE DENTAL MATERIAL

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Abstract

This paper discussed the background, evolution and clinical applications of a new dental restorative material, termed compobond. Compobonds are a new class of materials combining a resin-based composite with a bonding agent into a single formulation, forming self-adhering resin fillings. The advantage of these materials is obvious, the benefits of a composite resin filling material, but without the need to separately use bonding agents to affix the restorative to the tooth substrate. In essence, this unity eliminates onerous clinical protocols, saving time, eliminating procedural errors and reducing arduous patient endurance during dental treatment. However, any innovative material requires the test of time, combined with scientific assessment and in-vivo evaluation. This paper discusses the rationale for developing compobonds and proposes some uses in clinical practice.

Key word: resin-based composite, self-etching bonding agent, flowable composite, compobond, self-adhering resin filling

Introduction

Besides the physical and mechanical properties of dental amalgam, one of the main reasons for its success is the clinical simplicity and forgiving technique. The derisory 'drill & fill' slogan associated with dental treatment pertinently describes the provision of an amalgam restoration. The usually practiced protocol for amalgam restorations is a single stage procedure. Following decay excavation and tooth preparation, amalgam is directly placed into the cavity and anatomically curved & burnished. In addition, amalgam restorations are relatively technique insensitive, having favourable wear resistance, high strength, inexpensive and the post-operative expansion of the material helps 'seal' cavity margins.

Amalgam's demise started in the eighties, with questions being raised about excessive tooth removal for creating undercuts for retention, metal corrosion products, poor aesthetics, and possible mercury toxicity.¹ Since then, the profession has sought to find suitable alternatives for this iconic and ubiquitous restorative material. The candidate: resin-based composites. The last few decades have witness phenomenal research and improvement of composite technology, allaying concerns regarding wear resistance, retention to tooth structure, marginal adaptability, and post-operative sensitivity. However, the unflagging Achilles' heel of composites is polymerisation shrinkage that compromises the longevity of the restoration.² Nevertheless, newer materials have strived to overcome many of these negative effects associated with polymerisation shrinkage. The basis for improvement has been two-fold; firstly, a better understanding and efficacy of dentine bonding, and secondly, development of the chemical composition of resin-based composites to meet the challenges of polymerisation shrinkage, including superior physical and mechanical properties to meet the hostile demands of the oral cavity. In order to appreciate the rationale for the development of compobonds, it is important to chart the scientific breakthroughs of both dentine bonding and resin-based composites.

Historical

The ideal restorative material should be aesthetic, adhesive, abrasion-resistant, and bioactive to encourage regeneration, rather than repair, of the dental hard tissues. The last six decades have witnessed the introduction of many innovative materials as amalgam substitutes, and to fulfil the criteria of an ideal restorative dental material. These newer materials can be

categorised as resins and glass-ionomers with numerous hybrids, consisting of combinations of both materials. Resins yield a superior bond to enamel, but a less predictable bond to dentine.³ Conversely, glass-ionomers bond better to dentine by offering true chemical adhesion and releasing fluoride for bioactivity, but have inferior mechanical properties compared to resins. Numerous cross breed materials such as resin modified glass ionomers, compomers, and giomers have strived to exploit the beneficial properties of both materials with varying degrees of success. For example, in 2001 giomers were introduced, incorporating a pre-reacted glass (PRG) filler to facilitate fluoride release from a resin-based composite.⁴

Other classes of materials include siloranes and ormocers. Whilst the silorane-based composites have the lowest polymerisation shrinkage of any resin, they display mixed mechanical properties; flexural strength and modulus of elasticity (MOE) are higher, but their compressive strength & microhardness is lower compared to metacrylate-based composites.⁵ Orcemer technology is another addition to the dental restorative armamentarium, having excellent wear resistance, but poor polishability. The evolution of compobonds, launched in 2009, is based on the premise of promising clinical outcomes of dentine bonding agents (DBA) and resin-based composites.

Dentine Bonding Agents (DBA)

The acid-etch technique, introduced by Buonocore in 1955, was seminal and opened the doors to the possibilities of achieving a bond to natural tooth substrates with artificial acrylic-based restoratives.⁶ Whilst bonding to enamel has changed little since its inception more than half a century ago, bonding to dentine has proved far more elusive, undergoing enormous changes. A major advancement for achieving a sustainable bond to dentine was the introduction of the total-etch (TE) technique⁷ in the late seventies (Fig. 1).

The first self-etching primer, combining an etchant and primer into a single step, was introduced in the early nineties.⁸ The self-etching primers not only simplified bonding to dentine, but also eliminated the clinical errors associated with this exacting procedure. The result was a more predictable dentine bond and longevity of a composite resin filling. The next decade witnessed many formulations, including etchant+primer followed by adhesive, etchant followed by primer+adhesive, and more recently in the mid-noughties, combining all three constituents, etchant+primer+adhesive, into a single component and a one step procedure (Fig. 2).

Contemporary dentine bonding agents can be divided into two varieties, either the total-etch (TE) or the self-etch (SE). To complicate matters further, the TE bonding systems are available as either three or two-step systems, while SE as either two or one-step systems, which are available as one, two or three bottles components. Therefore to resolve some of these dilemmas for choosing a DBA, simplifying clinical techniques and minimising errors, the current trend is moving away from multi-component and multi-step bonding systems.⁹ Also, encouragingly, both TE and SE varieties have bond strengths to dentine that are comparable to that of enamel, i.e. approximately 22 MPa.¹⁰

The salient difference between the TE and SE agents is as that an initial etching stage is required with the former, but unnecessary with the latter. For TE, both enamel and dentine are simultaneously etched, usually with phosphoric acid, and followed by application of the primer and adhesive, or both components together in a single liquid. With the SE agents, precursory etching is superfluous, since this is concurrently performed together with the primer and adhesive.

Although SE agents expedite the bonding procedure, the major difference between TE and SE bonding agents is concerning the smear layer. With TE agents, the etching and drying of dentine is susceptible to clinical errors. This is because the inorganic phase of dentine is dissolved, leaving the organic collagen matrix unsupported. If this organic matrix is not re-hydrated by the primer and adhesive, the dentine bond is severely compromised. In order to ensure that the collagen fibres are hydrated necessities leaving the dentine moist, which is difficult to assess clinically. Alternately, the DBA should contain a solvent to re-hydrate the collagen fibres, e.g. water or ethanol, in order that the adhesive can impregnate the spaces

once occupied by the inorganic phase, and form a resin-collage complex, or the hybrid layer. DBAs containing the solvent acetone are particularly vulnerable desiccated dentine, since acetone evaporates rapidly leaving collapsed collagen fibres.¹¹ Therefore, if the adhesive bonding technique is incorrectly executed, the dentine bond is inferior causing poor adhesion, marginal leakage & discolouration and post-operative sensitivity. One of the reasons for post-operative sensitivity is inadequate sealing of the dentine tubules following etching during the dentine bonding procedure.¹² The latter is due to inadequate clinical protocols cited above, and particularly plagues TE, multi-step bonding agents. After the etching phase, the dentine tubules are exposed and at risk after removal of the inorganic matrix plus the smear layer. If the next two stages, priming and introduction of the adhesive, are incompetently performed to seal the tubules by formation of an adequate hybrid layer, post-operative sensitivity is an inevitable symptom. On the other hand, SE DBAs dissolve, rather than removing the smear layer, which is incorporated within the collagen fibres and the resin monomer to form a viable hybrid layer. Therefore, the reduced post-operative sensitivity reported by some studies with SE agents could be attributed to incorporation of the smear layer into the hybrid layer, and therefore never leaving the exposed dentine tubules in a precarious situation.¹³ Other studies have reported no difference in dentine hypersensitivity using either the TE or SE systems, and poor clinical technique has quoted mentioned as the most significant factor, rather than the type of DBA, for mitigating post-operative symptoms.¹⁴

To summarise, the advantages of SE systems are:

1. Less technique sensitive
2. Degree of dentine moisture not a concern
3. Depth of etching and adhesive penetration are similar since both processes occur simultaneously

One of the drawbacks of the SE systems highlighted by some studies is the relatively high pH ≈ 2 , compared to traditional phosphoric acid with a pH ≈ 1 , resulting in inferior bond strengths compared to TE systems.^{15,16} However, other studies have failed to find significant differences between the two systems,¹⁷ and current research is inconclusive and ambivalent. The SE agents are divided into strong or mild groups, the former having a pH of 1, and the latter pH of 2, respectively. Although the milder versions are less aggressive and form thinner hybrid layers, a thinner hybridisation zone does not appear to compromise bond strength.¹⁸ It is the integrity (absence of voids, tears), rather than the thickness of the hybrid layer which seems more significant to a viable dentine bond. Another possible drawback with the one-step SE agents is residual water that may remain in the dentine tubules, thereby leading to incomplete polymerisation of the adhesive, and ultimately compromising retention.¹⁹ However, SE are innovate products in their infancy, and further in-vivo medium and long-term trials are necessary to validate these concerns.

Having achieved the 7th generation of SE bonding agents, the 8th and future generations of DBAs should incorporate ingredients for regenerating natural hard tissues, rather than limiting their functions to adhesion. The properties of these new, so called, biomaterials, should include antibacterial, bioactive and biofunctional performance.

Resin-based composites

The number of resin-based composites on the market is both impressive and overwhelming. Composite technology revolution over the last few decades has resulted in many novel products, and choosing the correct material for a specific clinical scenario is both daunting and perplexing. Unfortunately, revolution has led to confusion. The following generic classification categorises contemporary resin-based composites, together with their properties and uses:

1. Hybrids – Universal or general purpose. Low wear resistance, long term increase in surface roughness, e.g. posterior restorations, Class I, II
2. Micro-filled – More aesthetic than hybrids, retain surface polish/lustre over time, e.g. Class III, IV, V. Highly filled (loaded) variants for extreme occlusal loads, e.g. Class I, II

3. Nano-filled – Similar to micro-filled, most aesthetic. Aesthetically demanding regions of the mouth, high polishability, excellent optical properties (opalescence, fluorescence), e.g. Class III, IV, direct composite laminate veneers
4. Micro- and nano-hybrid varieties. Universal or general purpose
5. Flowables – low viscosity, low MOE, low filler content. Suited for areas of low occlusal loads due to poor wear resistance, low strength and increase polymerisation shrinkage. However, due to the reduced filler content, polymerisation stress is also lower. Ideal for small pits and fissures not exposed to occlusal loads, primary dentition restorations, blocking undercuts for indirect prostheses (e.g. inlays, crowns) and stress-relieving liners for deep Class I, II, V large cavities, preferably fluoride releasing varieties, e.g. giomer.

Ideally, composites should possess similar physical, mechanical and optical properties as the natural hard tissues they are replacing. Therefore, for highly aesthetic restorations, where appearance and optical issues are of paramount concern, the ideal choice is a micro- or nanofilled composite. However, the later are unsuitable for high stress bearing posterior restorations due to poor wear characteristics, and in these circumstances a prudent choice is a universal composite, e.g. a hybrid or micro- or nano-hybrid.

Whilst resin-based composites have revolutionised restorative dentistry, they are not without their problems. The main reason for failure of composite fillings is marginal breakdown and secondary caries²⁰. However, it is not a fait accompli that secondary carious lesions will ensue in the presence of an open or discoloured cavosurface margin. The current thinking is that patient risk factors such as oral hygiene, dietary considerations and the attitude towards dental treatment, are pivotal in determining whether decay will follow.²¹

As previously stated, marginal breakdown is attributed to polymerisation shrinkage of a composite during its setting stage, ranging from 2% to 5%²² by volume, causing stresses that lead to bonding failure and gap formation (Figs. 3 & 4). Polymerisation stresses can be mitigated by the clinical technique, modulus of elasticity (MOE) of the material and cavity configuration or “C” factor. In an effort to circumvent polymerisation shrinkage, manufacturers have altered the chemical composition of composites to confer favourable properties. These include varying the size, shape and volume of the inorganic filler particles, as well as improving adhesion of the fillers to the organic resin matrix. Other factors that reduce stresses are the method of setting reaction, e.g. using pulse curing,²³ and incremental build-up of the composite filling during placement.²⁴ Another technique (discussed below) is using flowables, with a lower MOE, as the initial base-lining layer to absorb polymerisation stresses and counteract forces at the restoration-dentine interface.²⁵

Flowables

Flowable composites, introduced nearly two decades ago, have become ubiquitous for many applications. Flowables display greater fluidity & elasticity, offering better adaptation to internal cavity walls and are very user friendly. In addition, the radiopacity of these resins allows effortless detection of secondary caries, and revealing marginal integrity or open margins. A restorative material should possess radiopacity that is slightly greater than enamel to distinguish decay,²⁶ and greater than the ISO minimum standard of equal or greater to an equivalent thickness of aluminium. This is especially significant if flowables are used as intra-coronal initial lining layers below subsequent increments of universal composite. The ISO standard for minimum flexural strength (FS) for outer occlusal restorative materials is 80MPa, which is displayed by most of the current flowables on the market. The FS depends on the specific proprietary material, ranging from 70 MPa to approximately 100MPa, deteriorating over time, and is about 80% compared to nonflowables analogues. Although microleakage is a multifactorial phenomenon, MOE of the material is a crucial factor that determines its magnitude. Similar to FS, MOE shows is variable depending on the product, ranging from 3 GPa to over 11 GPa, and also decreasing over time. The viscoelastic properties of a flowable determine its flowability and clinical handling. The flow characteristics of flowable composites can be divided into low, medium and high flow.²⁷ Each variety is suitable for different clinical tasks. For example, a highly flowable material is desirable as a liner or fissure sealant, to intimately adapt to cavity walls or fissures crevices, respectively, while a less flowable variety is preferable for small cavities or repairs, where excessive slumping is a nuisance.

Currently, most of the flowable composites possess little bacterial inhibitory potential, especially against *Streptococcus mutans*, the main infective agent of dental caries. Whilst a few flowables on the market claim anti-bacterial activity, the effect is usually ephemeral, effective for only a few days.²⁸ Future composite developments should endeavour to incorporate both antibacterial and bioactivity in their formulations for enhanced therapeutic value.

In conclusion, flowables are useful for areas of reduced occlusal stresses, and contraindicated for bulk build-ups in stress bearing areas. Their popularity is due to ease of use and flexible adaptability, especially in areas of limited access. The clinical applications include fissure sealing, small cavities, base liners, repairing voids in defective restorations and blocking undercuts for subsequent indirect prostheses.

Evolution of a new resin-based restorative: Compobonds

As discussed above, the state-of-the-art of dentine bonding systems are the SE agents that obviate the need to perform an initial etching phase, while yielding bond strengths that are comparable to bonding to enamel. Also, the pinnacle of resin-based composites technology is the introduction of nano- and nano-hybrid composites. The advancements in both bonding agents and resins have now evolved by uniting these two materials to produce a new dental restorative: the compobonds. Compobonds exploit the benefits of SE DBAs and nanofilled resins, eliminating the precursory bonding stage necessary to adhere a resin to tooth substrate, and are termed self-adhering composites. In essence, an era is emerging when composites, similar to amalgam fillings, can be placed in a single step, eliminating errors, expatiating protocols, and improving predictability and longevity of restorations.

The first compobond was introduced in 2009 called Vertise™ Flow (Kerr Corp., USA), a self-adhering flowable combining a resin-based composite and a SE bonding agent based on the 7th generation DBA, OptiBond® All-in-One (Kerr Corp., USA). Vertise™ Flow is a light-cured composite with similar properties to conventional flowables but with the added advantage of eliminating the bonding stage that is prerequisite before using any resin-based restorative (Fig. 5).

Characteristics and properties of Vertise™ Flow

Vertise™ Flow incorporates the properties of the DBA, OptiBond®, the first filled bonding agent introduced in 1992 (Fig. 6), that realised the potential of using a filled adhesive as a shock absorber beneath resin-based composite restorations. The bonding mechanism of OptiBond® to dentine is two-fold. Firstly, chemical adhesion is realised by the phosphate function group of the GPDM monomer (glycerol phosphate dimethacrylate) uniting with the calcium ions within the tooth, and secondly, micromechanical adhesion by formation of the hybrid layer composed of resin impregnation with the collagen fibres and the dentine smear layer. Initial SEMs and TEMs from the University of Leuven, Belgium show tight adaptation of Vertise™ Flow to both dentine and enamel. In addition, microleakage tests show that Vertise™ Flow's marginal integrity is comparable to other SE bonding agent in conjunction with non-adhering conventional flowable composites.²⁹

The shear bond strength (SBS) achievable with Vertise™ Flow and dentine is approximately 25 MPa, comparable to bonding to cut, prismatic enamel. However, the SBS is lower with uncut or aprismatic enamel, which is similar to using SE agents alone. For this reason, it is advisable to either bevel, or etch aprismatic enamel beforehand to ensure a sustainable and durable marginal seal (Fig. 7). Conversely, pre-etching dentine when using Vertise™ Flow reduces the SBS to dentine, and is therefore contraindicated. Another disadvantage of pre-etching dentine is opening dentine tubules that may not be sealed to the same depth by the subsequent use of Vertise™ Flow, and could contribute to post-operative sensitivity.

The chemical composition of Vertise™ Flow incorporates four types of fillers, with a total of 70% loading. The inclusion of nano-ytterbium fluoride confers excellent radiopacity & fluoride release [for bioactivity], the pre-polymerised fillers reduce microleakage, and nanoparticles improve polishability & thixotropic properties. The flexural strength is 120 MPa for mitigating

bulk fracture, and a low Modulus of Elasticity of around 7GPa for shock absorbing capability (Fig. 8).

Because Vertise™ Flow is functioning as both a dentine adhesive and a resin restorative material, a longer curing time is necessary to ensure that both constituents are fully polymerised. In addition, the light curing reaction also halts the etching process of the SE agent, increasing its pH from approximately 2 to 7, so that continual acidity does not erode the dentine bond.

A further advantage of Vertise™ Flow is inclusion of the acidic phosphate monomer, which provides chemical adhesion to a variety of intaglio surfaces of indirect prostheses, including non-precious alloys, gold, alumina, zirconia and silica ceramics, e.g. feldspathic, lithium disilicate or other pressed ceramic systems. This adhesive property is exceptionally useful for repairing intra-oral fractured porcelain, e.g. all-ceramic crowns, inlays or onlays, or patching up chipped porcelain defects without replacing the entire prosthesis (Fig. 9).

The handling properties of Vertise™ Flow are favourable for numerous applications. For example, its viscosity occupies a middle ground, neither too viscous nor too runny, and therefore satisfies a wider range of clinical applications, i.e. as a liner/sealant, as well as for entire small cavity restorations. Vertise™ Flow is available in a selection of shades for discerning aesthetic demands, ranging from XL for bleached teeth to Translucent for fissure sealing that allows visibility of any future decay (Fig. 10).

Similar to glass-ionomers and their variations, compobonds offer adhesion to natural tooth substrate. However, whilst both materials have similar indications, their properties and handling characteristics vary considerably. Glass-ionomers essentially adhere exclusively to dentine, have low mechanical strength, average aesthetics, low wear resistance but offer both fluoride release and recharge. In addition, the setting reaction is affected by the degree of moisture of dentine, and involves a two stage clinical procedure. On the other hand, compobonds offer dentine & enamel bonding, high strength, low wear, better aesthetics, a single stage clinical procedure and fluoride release, but not fluoride recharge.

Clinical applications of Vertise™ Flow

The clinical uses of Vertise™ Flow are not unlike those of conventional flowables, but with the added advantage of eliminating the bonding stage. Below are some suggested applications.

Fissure sealing

One of the fundamental treatments for preventative dentistry is fissure sealing posterior permanent teeth soon after their eruption into the oral cavity. Traditionally, this has been achieved solely with enamel etching, relying on micromechanical retention, and depending on diet, the fissure sealants require periodic replacement or repair. Using Vertise™ Flow instead of conventional fissure sealants offers not only micromechanical retention, but also chemical adhesion to the enamel via the SE agent that links with the calcium ions from the hydroxyapatite matrix.

The following case study depicts fissure sealing a first permanent molar tooth in a child of 14 years of age. Ideally the tooth should be isolated with rubber dam to ensure moisture control and a clear operating field (Fig. 1). Initially, the tooth is air abraded with aluminium oxide powder to clean the pits and fissures, remove the plaque biofilm, superficial incipient decay, and if present, remnants of old fissure sealants (Fig. 2). The cleansing is continued with slurry of pumice to eliminate residues of the aluminium powder (Figs. 3 & 4). After rinsing the pumice (Fig. 5), 37% phosphoric acid is dispensed to etch the pits and fissures (Fig. 6) and surrounding uncut, aprismatic enamel (Fig. 7). The classic frosty etched enamel appearance is clearly visible after rinsing off the etchant and drying the occlusal surface (Fig. 8).

Since Vertise™ Flow should be refrigerated to ensure extended shelf life and optimal performance, it is advisable to remove it beforehand to so that the material reaches room temperature. A translucent shade of Vertise™ Flow is copiously dispensed (Figs. 10 & 11)) and brushed onto the enamel to ensure intimate contact with its surface, and spread to a thin

layer of less than 0.5 mm (Figs. 11 & 12). The coated surface(s) are light cured with a curing light having an output of 800 MW/cm² for 20 seconds (Fig. 13). The rubber dam is then removed and articulation paper placed to check occlusal contacts (Fig. 14). All the articulation paper marks, except those on the supporting buccal cusps (palatal cusps for maxillary teeth), are adjusted and polished with Opti1Step Polishers (KerrHawe SA, Switzerland) - Fig. 15 & 16.

Small, non-stress bearing, non-contacting cavities

Small cavities in areas of minimum occlusal stress are ideal candidates for minimally invasive, microdentistry. Incipient carious lesions can be either monitored if the patient risk factors are low, or may require intervention for patients with a propensity for dental decay. The case study presented below is of a 13 years old girl who is an occasional attendee, and relatively indifferent to dental treatment. The pre-operative status shows the maxillary second pre-molar and first molar with occlusal cavitations, and an old defective composite occlusal restoration in the molar (Fig. 1). Cavity preparation is carried out using small diamond burs specifically designed to minimise removal of excessive tooth substrate (Fig. 2). Current research shows that it is unnecessary to remove all decayed dentine. Instead, the cavity margins are clearly defined for creating a hermetic seal for guarding against the negative effects of the dental biofilm, which perpetually colonises the tooth surface.³⁰ As previously mentioned, in order to improve bond strength to aprismatic enamel, the margins can be either etched, or bevelled (Fig. 3). The initial layer of Vertise™ Flow should be less than 0.5 mm thickness, and pressed into the recesses of the cavity floor & walls (Fig. 4 & 5). The initial layer of Vertise™ Flow is first light-cured (Fig. 6), before completing the cavity with additional layers. Finally, the restoration is polished with Opti1Step Polishers and OptiShine brush (KerrHawe SA, Switzerland) to yield a high lustre gloss (Fig. 7).

Class V cavities

Class V cavities have variable presentations. The exposed dentine in Class V cavities can be the result of enamel loss due to erosion, abrasion abfraction or infectious caries. The dentine reaction is highly erratic, often leading to formation of hypermineralized sclerotic dentine that is resistant and less receptive to dentine adhesion.³¹ Therefore, in the presence of sclerotic dentine, all DBAs are less efficacious and present a challenge for dentine bonding. For this reason, Vertise™ Flow is unsuitable for Class V lesions with blatant dentine hypermineralized sclerotic dentine. If sclerotic dentine is absent, dentine adhesion with bonding agents is superior (28 MPa), compared to a compomer (15 MPa) or a glass-ionomer (2.5 MPa).³² In the following case study, a freshly prepared buccal cavity without traces of sclerotic dentine was restored with Vertise™ Flow. Pre-operative articulation paper marks were created to verify that the buccal lesion was free of occlusal, stress-bearing contacts (Fig. 1). After placing the rubber dam, the tooth was cleaned with slurry of pumice (Fig. 2), and a cavity was prepared with bevelled enamel margins (Fig. 3). The final result shows restoration of the cavity with A3 Vertise™ Flow after polishing with Opti1Step Polishers (KerrHawe SA, Switzerland) – Fig. 4.

Stress-relieving linings

The rationale for using different composites for various increments of a restoration is that the materials should possess similar properties to the natural dentine and enamel they are replacing. Dentine has a lower MOE, and is therefore better suited for absorbing stresses than enamel. For this reason, in circumstances when the cavity extends into dentine, the initial layer of composite should have shock absorbing capabilities that are similar to dentine. OptiBond® (Kerr Corp, USA) was the first filled bonding agent introduced in 1992 that acted as a shock absorber underneath resin-based composite restorations.

The polymerisation contraction stresses of a resin-based composite is directly related to its filler volume, which also affects its mechanical properties such as wear resistance and modulus of elasticity (MOE). High filler content results in less contraction, which in turn influences the marginal integrity of the restoration.³³ Flowables have approximately 25% less filler than their nonflowable counterparts and therefore undergo increased volumetric shrinkage, However, since flowables have about 50% less MOE than nonflowables, they can absorb more stresses, and in theory, maintain superior marginal integrity.³⁴ The MOE of a

flowable ranges from as low as 1.4 GPa (low filler volume) to as high as 12.5GPa (high filler content).³⁵ In addition to filler content, other constituents such as the type and quantity of resin, photoinitiators and accelerators also influence the final MOE of the material. As a generalization, flowables with a lower MOE may act as shock absorbers when placed as pre-cured liners below subsequent increments of nonflowables. But current studies are inconclusive regarding this beneficial property,^{36 37} and further research is necessary to clarify the issue.

In the following case study, large Class I cavities in two mandibular molars were restored using Vertise™ Flow as an initial layer to act as a shock absorber, before completing the restoration with subsequent layers of a nonflowable composite. This case study shows the second and third mandibular molars with defective amalgam restorations requiring replacement. In addition, these teeth also exhibit bruxist activity with tooth wear resulting in occlusal enamel loss. Initial occlusal contacts were verified (Fig. 1) before placing a rubber dam, and removing the amalgam restorations. Notice the extensive decay in third molar (Fig. 2). Since molars are prone to high occlusal forces, placing bevels on enamel margins is unsuitable because the thin slice of composite resin periphery is likely to fracture during mastication. However, to achieve an efficacious bond to aprismatic enamel, it is prudent to etch the periphery while maintaining a 90° cavo-surface angle (Fig. 3). After thoroughly rinsing and drying, the etched enamel periphery of both cavities is clearly visible (Fig. 4 & 5). Vertise™ Flow is dispensed into the cavity, brushed to ensure that the material is evenly spread on the cavity walls and floor, and making sure that its thickness does not exceed 0.5 mm (Figs. 6 to 8). This initial layer of Vertise™ Flow is light cured for 20 seconds, and acts as the stress relieving lining (Fig. 9). Subsequent layers of the filling are built-up using increments of a regular composite, Herculite® XRV Ultra™ (Kerr Corp, USA), to replace dentine, and then successively building-up the buccal and lingual cups³⁸ separately without contacting the opposing sides (Fig. 10).

Staining fissures is a contentious issue; some patients are indifferent to this practice, while others adamantly refuse to have stained teeth. For those patients who are unconcerned, fissure staining and patterns imparts a realistic appearance to a composite filling. The technique involves using different stains, e.g. Kolor + Plus® (Kerr Corp, USA), that are dragged through the un-set composite resin using an endodontic reamer or file (Figs. 11 & 12). Once the desired fissure pattern is created, the composite is light cured (Figs. 13 & 14). After removing the rubber dam, articulation paper is used to check occlusal contacts (Fig. 15), and necessary adjustments made to ensure occlusal harmony. The final stage is achieving a high surface lustre and texture using Opti1Step Polishers (KerrHawe SA, Switzerland). The post-operative view shows composite fillings emulating natural cusps and fissure patterns, with imperceptible transition between the composite filling and surrounding enamel (Fig. 16).

Blocking undercuts

Another useful application of a flowable is blocking out undesirable undercuts prior to providing indirect restorations. Undercuts often complicate many clinical and laboratory procedures, e.g. impression making or restoration fabrication, respectively. Unwanted sharp line angles or deficiencies, such as voids, can readily be blocked and sealed with the easily adaptable flowable composites for both intra- and extra-coronal tooth preparations.

In the following case study a large amalgam restoration, with underlying profound decay, was scheduled for an indirect ceramic inlay. After isolation with rubber dam, the amalgam filling from the maxillary molar was removed revealing gross carious dentine (Fig. 1). All soft, carious dentine was exacted leaving blatant undercuts (Fig. 2). Due diligence was exercised not to remove all the hard, deeper decayed dentine to avoid possible pulpal exposure. In this instance, Vertise™ Flow has a dual function, firstly to block undercuts, and secondly to act as a stress absorbing liner for the subsequent indirect ceramic inlay (Fig. 3).

Repairing

Lastly, Vertise™ Flow can be used for minor repairs, for either chairside or laboratory made acrylic based temporary restorations, such as crowns with air blows or chips or fractures after

a period of use in the mouth. Once again, the repair protocol is simplified and predictable, involving a single step, with the added benefit of the SE bonding agent within Vertise™ Flow.

Another form of repair involves the increasingly problematic fractures associated with ceramic prostheses such as crowns or inlays. Since these types of all-ceramic indirect restorations are increasingly popular, the number of fractures is also becoming progressively more common, and replacement is costly and often clinically embarrassing. Traditionally, ceramic fracture repair involved several stages, i.e. etching with hydrofluoric acid, silination, and repairing with conventional resin-based composites, either a flowable or nonflowable variety. As previously mentioned, Vertise™ Flow incorporates an acidic phosphate monomer, which chemically links to many ceramic substrates such as silica, alumina and zirconia. Therefore, after roughening the fracture 'lesion' with a diamond bur, only a single step is necessary with Vertise™ Flow that combines both chemical bonding and a repairing composite to 'heal' the fracture. The following case study illustrates repair of a fractured, alumina core crown, veneered with silica (feldspathic) porcelain. The patient presents with a distal fracture of the all-ceramic crown on the maxillary left central incisor (Fig. 1). A shade analysis was performed with Vita Classic shade guide (Vita, Germany), and Vertise™ Flow A2 was chosen for the body of the crown, and a Translucent shade for the incisal edge translucency (Fig. 2). Initial cleansing was carried out with slurry of pumice to remove the plaque biofilm (Fig. 3).

To increase the surface area for bonding, the fractured porcelain requires pre-treatment roughening, which can be achieved either mechanically or chemically. The choice is mainly empirical, depending on the clinician's personal experience and penchant for either technique. Mechanical roughening involves using a rotary instrument followed by cleansing the site with phosphoric acid (Fig. 4), which does not etch porcelain, but removes any remaining debris. The chemical method involves etching the porcelain with hydrofluoric acid for 3 minutes. It is important to note that only silica based ceramics can be etched with hydrofluoric acid, and if the fracture extends deeper into an alumina or zirconia substructure, the latter will require mechanical roughening with a diamond bur. Customarily, the next stage is application of hydrofluoric acid and silane for creating a silica-silane bond. However, this is superfluous using Vertise™ Flow as the later incorporates an acidic phosphate monomer that bonds to silica, as well as alumina and zirconia ceramics. An A2 shade of Vertise™ Flow is dispensed directly onto the etched fracture site (Fig. 6), and spread intimately ensuring firm contact with the porcelain (Fig. 7). In order to mimic the incisal edge translucency, a Translucent shade of Vertise™ Flow is used at the incisal edge (Fig. 8), and slightly overbuilt to compensate for the polishing stage (Fig. 9). Finishing and polishing is carried out using sequentially finer grit discs (OptiDisc®, KerrHawe SA, Switzerland) – Fig. 10, creating a surface roughness (Ra) of approximately 0.2 µm, equal to or less than the threshold required for bacterial and plaque adhesion (Ra = 0.2 µm).³⁹ The post-operative result shows the polished repair harmoniously blending with the surrounding porcelain (Fig. 11).

Similar to porcelain repairs, existing chipped or marginally stained composites (both direct and indirect restorations), can be effortlessly repaired. The protocol is minimally invasive, economical, expedient, and also spares the patient protracted appointments to replace the entire restoration, which can instead be monitored at periodic recalls.

Conclusion

This article has introduced the evolution of a new dental restorative material, the compobonds. The discussion has focussed on the rationale for development of compobonds, citing technological advances in both dentine bonding agents & resin-based composite formulations. In addition, a proprietary product, Vertise™ Flow is described as the first generation of flowable compobonds with clinical applications similar to existing flowable composites, and some novel uses such as direct intra-oral porcelain fracture repairs. The benefits of combining a SE dentine bonding agent with a composite-resin eliminates the technique sensitive protocols associated with dentine bonding, making the entire process simpler and more predictable. However, as with any new material, scientific scrutiny and clinical trails will untimely judge the efficacy of compobonds, and if successful, will pave the way for nonflowable varieties to simplify direct composite restorations.

Figures



Fig. 1 – TE (total-etch) dentine bonding agents involve etching (red) both enamel and dentine followed by the primer (yellow) and adhesive (green).



Fig. 2 – SE (self-etch) dentine bonding agents combine the etchant, primer and adhesive into a single formation and a one-step clinical procedure.



Fig. 3 – One of the limitations of composite fillings is polymerisation shrinkage, leading to marginal breakdown.



Fig. 4 – Polymerisation shrinkage of resin-based composites results in marginal staining.

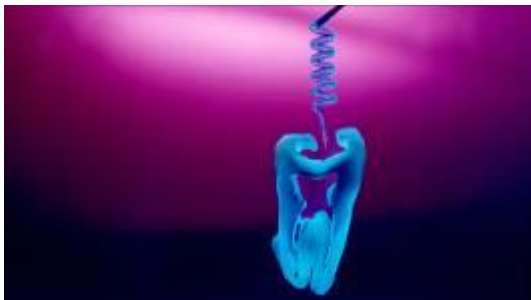


Fig. 5 – Vertise™ Flow is a self-adhering flowable composite, combining a self-etching bonding agent with a resin-based composite.

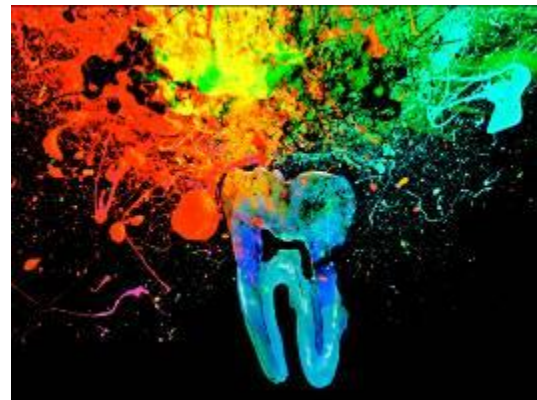


Fig. 6 – The bonding agent in Vertise™ Flow is based on the technological advances of OptiBond®, the first filled dentine-bonding agent introduced in 1992, which has now evolved into a self-etching system.



Fig. 7 – When using Vertise™ Flow, it is advisable to either bevel, or etch aprismatic enamel of the cavity margins.

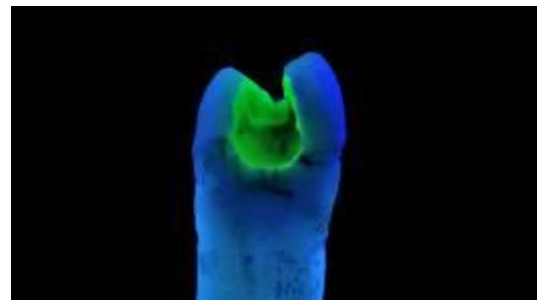


Fig. 8 – Vertise™ Flow is an excellent base lining, acting as a shock absorber due to its low modulus of elasticity.



Fig. 9 – Vertise™ Flow is ideal for intra-oral repairs of fractured porcelain.

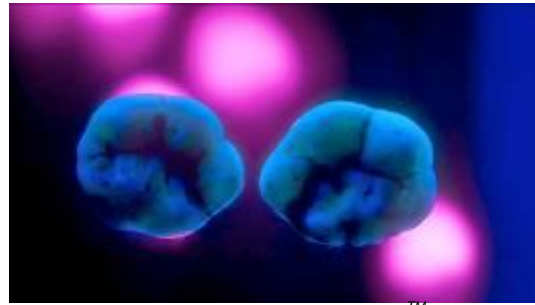


Fig. 10 – The translucent shade of Vertise™ Flow is invaluable for detecting future decay underneath fissure sealed teeth.

Fissure sealing



Fig. 1 – The lower first permanent molar is isolated with rubber dam using a SoftClamp™ (KerrHawe SA, Switzerland). Notice the remnants of an old fissure sealant resin within the fissures.



Fig. 2 – The tooth is air abraded with aluminium oxide powder to remove plaque and decay, including remnants of old fissure sealants.



Fig. 3 – A prophylaxis brush is used to clean the tooth with slurry of pumice.



Fig. 4 – The pumice removes residues of the aluminium oxide power.



Fig. 5 – The rinsed tooth following cleaning with pumice.



Fig. 6 – Etchant is dispensed into the fissures and ...



Fig. 7 – ... continued to the surrounding uncut, aprismatic enamel.



Fig. 8 – The classical frosty appearance of etched enamel is clearly evident (compare with Fig. 2)



Fig. 9 – Vertise™ Flow is dispensed into the fissures...



Fig. 10 – ... and then to the entire occlusal surface.



Fig. 11 – A brush is used to press Vertise™ Flow onto the enamel surface for 15-20 seconds ...



Fig. 12 – ...and to obtain a layer of < 0.5 mm thickness.



Fig. 13 – The set Vertise™ Flow after appropriate light curing.



Fig. 14 – Articulation paper is used to verify occlusal contacts. Notice extraneous flash material at the distal aspect of the permanent molar.



Fig. 15 – For mandibular teeth, all occlusal contacts are removed, except those on the buccal supporting cusps. Notice that the distal flash material has been removed.



Fig. 16 – The post-operative view showing sealed fissures and the high lustre obtained after polishing with Opti1Step Polishers (compare with Fig. 1).

Small Class I cavity



Fig. 1 – Pre-op view showing cavitation in the occlusal surfaces of a maxillary molar and pre-molar. The molar also requires replacement of an occlusal defective composite filling.



Fig. 2 - Cavity preparation using micro-diamond burs for minimising excessive tooth removal.



Fig. 3 – All aprismatic enamel margins are carefully bevelled.



Fig. 4 – The initial layer of Vertise™ Flow should be <0.5mm thickness...



Fig. 5 – ... and spread with a brush to ensure intimate contact with the cavity walls and bevelled margins.



Fig. 6 – The initial layer of Vertise™ Flow is light cured before adding further material.



Fig. 7 – The finished restorations are polished with tips for a high lustre, ensuring impeccable integration with the surrounding enamel.

Small buccal cavity



Fig. 1 – Pre-operative occlusal contacts to verify that cavity is not in a stress bearing area.



Fig. 2 – After rubber dam isolation, pumice is used to cleanse the tooth.



Fig. 3 – A cavity is prepared with bevelled enamel margins.



Fig. 4 – Post-operative view showing the cavity restored with A3 Vertise™ Flow.

Stress-relieving linings



Fig. 1 – Pre-op view showing defective amalgam fillings in two mandibular molars. Pre-operative occlusal contacts are identified before placing the rubber dam.



Fig. 2 – The old amalgam restorations are removed.



Fig. 3 – After removing soft decayed dentine, the enamel margins are finished with a 90° cavo-surface angle and etched with phosphoric acid for 15 seconds.



Fig. 4 – The etched enamel peripheries are clearly visible on the second mandibular molar.



Fig. 5 – The etched enamel peripheries are clearly visible on the third mandibular molar.



Fig. 6 – Vertise™ Flow is dispensed into the cavity.



Fig. 7 – A brush is used to spread the Vertise™ Flow against the cavity walls and...



Fig. 8 – ...floor, ensuring that it is evenly spread with a thickness less than 0.5 mm.



Fig. 9 – The initial Vertise™ Flow lining is light cured.



Fig. 10 – A regular composite, Herculite® XRV Ultra™, is used in increments for replacing dentine and building up individual buccal and lingual cups.



Fig. 11 – An endodontic file, loaded with brown Kolor + Plus® stain is dragged through the un-set composite resin to create fissure patterns in the second molar restoration.



Fig. 12 – An endodontic file, loaded with brown Kolor + Plus® stain is dragged through the un-set composite resin to create fissure patterns in the third molar restoration.



Fig. 13 – Once the fissure patterns are established, the composite is light cured in the second molar.



Fig. 14 – Once the fissure patterns are established, the composite is light cured in the third molar.



Fig. 15 – After removing the rubber dam, occlusal contacts are checked using articulation paper.



Fig. 16 – The filling is polished to a high lustre with Opti1Step Polishers, ensuring an indiscernible transition between the composite filling and surrounding natural tooth.

Blocking undercuts



Fig. 1 – Underlying decay is clearing evident after removing an old amalgam filling from the maxillary molar.



Fig. 2 – Undercuts are evident following excavation of soft, carious dentine.



Fig. 3 – Vertise™ Flow is used to block the undercuts and act as a stress relieving lining.

Repairing fractured porcelain



Fig. 1 – Pre-operative view showing a distal fracture of the all-ceramic crown on the maxillary left central incisor.



Fig. 2 – Shade analysis to ascertain colour of existing crown. Vertise™ Flow A2, and translucent shades were selected to repair the fractured porcelain.



Fig. 3 – Pumice is used to cleanse the crown and remove any plaque biofilm.



Fig. 4 – The porcelain surface is mechanically roughened with a diamond bur and then cleansed with phosphoric acid.



Fig. 5 – Prepared porcelain site



Fig. 6 – An A2 shade of Vertise™ Flow is dispensed onto the site.



Fig. 7 – A brush is used to spread the Vertise™ Flow to cover the fracture site.



Fig. 8 – A translucent shade of Vertise™ Flow is used to build the incisal edge.



Fig. 9 – Palatal view showing the overbuilt repair before polishing.



Fig. 10 – Polishing is carried out with various grits of OptiDisc® to create a high lustre.



Fig. 11 – Post-operative view showing the 'invisible' repair, with a smooth texture and high lustre, impeccably blending with the surrounding porcelain.

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