Compobond: Evolution of a new restorative dental material

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Fig. 1

Fig. 1_TE DBAs involve etching (red) both enamel and dentine followed by the primer (yellow) and adhesive (green).

_**Besides the physical and mechanical** properties of dental amalgam, one of the main reasons for its success is its clinical simplicity and forgiving technique. The derisory "drill and fill" slogan associated with dental treatment pertinently describes the provision of an amalgam restoration. The usual protocol for amalgam restorations is a single-stage procedure. Following decay excavation and tooth preparation, amalgam is placed directly into the cavity and anatomically curved and burnished. In addition, amalgam restorations are relatively technique insensitive, have favourable wear resistance and high strength, are 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 suitable alternatives for this iconic and ubiquitous restorative material—the candidate: resin-based composites. The last few decades have witnessed phenomenal research and improvement of composite technology, allaying concerns regarding wear resistance, retention of tooth structure, marginal adaptability and post-operative sensitivity. However, the unflagging Achilles' heel of composites is polymerisation shrinkage, which compromises the longevity of the restoration.[2] Nevertheless, newer materials have sought to overcome many of the 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 with resins. Numerous hybrid materials such as resin-modified glass-ionomers, compomers and giomers have sought 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 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 (FS) and modulus of elasticity (MOE) are higher, but their compressive strength and microhardness are lower compared with methacrylate-based composites.[5] Ormocer 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 the promising clinical outcomes of dentine bonding agent (DBAs) and resin-based composites.

_Dentine bonding agents

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) technique[7] in the late seventies (Fig. 1).

The first self-etching (SE) primer, combining an etchant and primer in a single step, was introduced in the early nineties.[8] The SE primers not only simplified bonding to dentine, but also eliminated the clinical errors associated with this exacting procedure. The result was a more predicable 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-nineties, combining all three constituents, etchant+primer+adhesive, in a single product and a one-step procedure (Fig. 2).

Contemporary DBAs can be divided into two varieties: TE or SE. To complicate matters further, the TE bonding systems are available as either three- or two-step systems, and SE as either two- or one-step systems, which are available as three-, two- or one-bottle components. Therefore, to resolve some of these dilemmas in 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 (approximately 22 MPa).[10]

The salient difference between the TE and SE agents is 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 SE agents, precursory etching is superfluous, since this is concurrently performed with the primer and adhesive.

Although SE agents expedite the bonding procedure, the major difference between TE and SE bonding agents concerns the smear layer. With TE agents, the etching and drying of dentine is susceptible to

Fig. 2_SE DBAs combine the etchant, primer and adhesive into a in a single product 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 an SE 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 an SE system.

Fig. 7_When using Vertise Flow, it is advisable to either bevel or etch aprismatic enamel of the cavity margins.
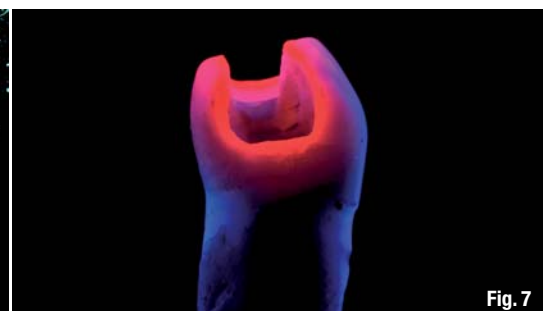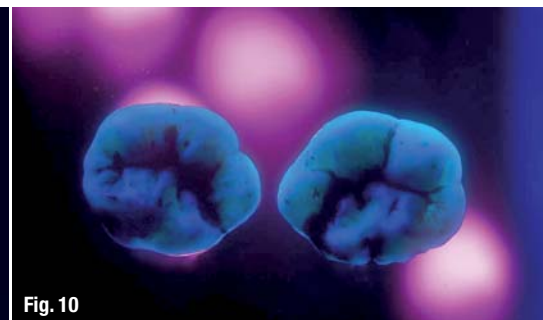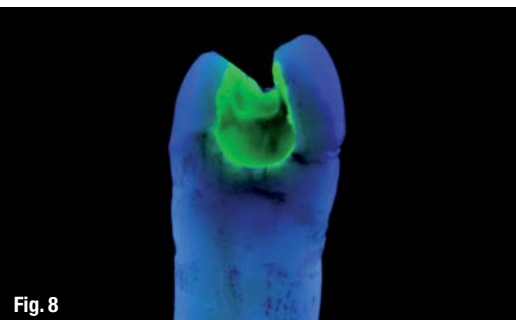
Fig. 8

Fig. 9

Fig. 10

Fig. 8_Vertise Flow is an excellent base lining, acting as a shock absorber due to its low MOE.
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.

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. Ensuring that the collagen fibres are hydrated necessitates leaving the dentine moist, which is difficult to assess clinically. Alternately, the DBA should contain a solvent to re-hydrate the collagen fibres, for example water or ethanol, so that the adhesive can impregnate the spaces once occupied by the inorganic phase and form a resin-collage complex, or a hybrid layer.

DBAs containing the solvent acetone are particularly likely to cause desiccated dentine, since acetone evaporates rapidly, leaving collapsed collagen fibres.[11] Therefore, if the adhesive bonding technique is incorrectly executed, the dentine bond will be 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 and 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 result.

On the other hand, SE DBAs dissolve, rather than remove the smear layer, which is incorporated within the collagen fibres and the resin monomer to form

Fig. 11_The lower first permanent molar is isolated with a rubber dam using a SoftClamp (KerrHawe SA). Notice the remnants of an old fissure sealant resin within the fissures.
Fig. 12_The tooth is air abraded with aluminium-oxide powder to remove plaque and decay, including remnants of old fissure sealants.
Fig. 13_A prophylaxis brush is used to clean the tooth with a slurry of pumice.

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 dentine tubules exposed.[13] Other studies have reported no difference in dentine hypersensitivity using either TE or SE systems, and poor clinical technique has been mentioned as the most significant factor, rather than the type of DBA, in causing post-operative symptoms.[14]

To summarise, the advantages of SE systems are:

1. less technique sensitive;
2. degree of dentine moisture not a concern; and
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 with traditional phosphoric acid with a pH ≈ 1, resulting in inferior bond strengths compared with TE systems.[15,16] However, other studies have failed to find significant differences between the two systems,[17] and current research is inconclusive. The SE agents are divided into strong or mild groups, the former having a pH of 1 and the latter a pH of 2.

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 that appears more significant to a viable dentine bond. Another possible drawback with the one-step SE agents is residual water that may remain in the
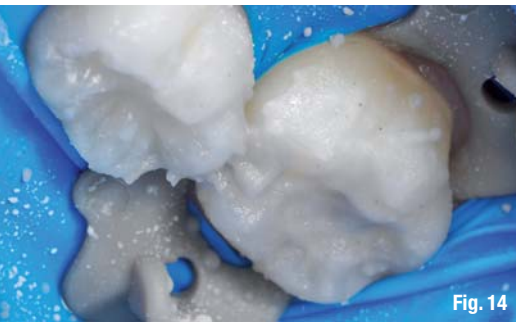

Fig. 11

Fig. 12

Fig. 13

dentine tubules, thereby leading to incomplete polymerisation of the adhesive, and ultimately compromising retention.[19] However, SE agents are innovative products in their infancy, and further *in vivo* medium and long-term trials are necessary to investigate these concerns.

The eighth and future generations of DBAs should improve on the seventh generation of SE bonding agents by incorporating substances for regenerating natural hard tissues, rather than limiting their functions to adhesion. These new so-called biomaterials should have anti-bacterial, bioactive and biofunctional properties, amongst other properties.

_Resin-based composites

The number of resin-based composites on the market is both impressive and overwhelming. Developments in composite technology over the last few decades has resulted in many novel products, and selecting the correct material for a specific clinical scenario is both daunting and perplexing. 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, for example posterior restorations, Class I and II.
_2. *Micro-filled:* More aesthetic than hybrids, retains surface polish/lustre over time, for example Class III, IV and V; highly filled (loaded) variants for extreme occlusal loads, for example Class I and II.

_3. *Nano-filled:* Similar to micro-filled, most aesthetic; aesthetically demanding regions of the mouth, high polishability, excellent optical properties (opalescence, fluorescence), for example Class III, IV and 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 increased polymerisation shrinkage. However, polymerisation stress is also lower owing to the reduced filler content. Ideal for small pits and fissures not exposed to occlusal loads, primary dentition restorations, blocking undercuts for indirect prostheses (for example, inlays and crowns) and stress-relieving liners for deep Class I, II, V and large cavities, preferably fluoride-releasing varieties, for example giomer.

Ideally, composites should possess similar physical, mechanical and optical properties to 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 nano-filled composite. However, the later are unsuitable for high-stress-bearing posterior restorations owing to poor wear, and in these circumstances a prudent choice is a universal composite, for example 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 the failure of composite fillings is marginal breakdown and secondary caries.[20] However, it is not a *fait accompli*

Fig. 14_ The pumice removes residues of the aluminium-oxide power.
Fig. 15_ The rinsed tooth following cleaning with pumice.
Figs. 16a & b_ Etchant is dispensed into the fissures (a) and continued to the surrounding uncut, aprismatic enamel (b).

Fig. 17_ The classical frosty appearance of etched enamel is clearly evident (compare with Fig. 12).
Fig. 18a_ Vertise Flow is dispensed into the fissures.

Fig. 18b

Fig. 19a

Fig. 19b

Fig. 18b_Vertise Flow is dispensed onto the entire occlusal surface.
Figs. 19a & b_A brush is used to press Vertise Flow onto the enamel surface for 15–20 seconds (a) and to obtain a layer of < 0.5 mm thickness (b).

Fig. 20_The set Vertise Flow after appropriate light curing.
Fig. 21_Articulation paper is used to verify occlusal contacts. Notice extraneous flash material at the distal aspect of the permanent molar.
Fig. 22_For mandibular teeth, all occlusal contacts are removed, except those on the buccal supporting cusps. Notice that the distal flash material has been removed.

that secondary carious lesions will ensue in the presence of an open or discoloured cavo-surface margin. The current thinking is that patient risk factors, such as oral hygiene, dietary considerations and attitude towards dental treatment, are pivotal in determining whether decay will occur.[21]

As previously stated, marginal breakdown is attributed to polymerisation shrinkage of a composite during its setting stage, ranging from 2 to 5 % by volume,[22] causing stresses that lead to bonding failure and gap formation (Figs. 3 & 4). Polymerisation stresses can be mitigated by the clinical technique, MOE of the material and cavity configuration or the "C" factor. In an effort to circumvent polymerisation shrinkage, manufacturers have altered the chemical composition of composites to have 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, for example using pulse curing,[23] and incremental build-up of the composite filling during placement.[24] Another technique (discussed below) is using flowable composites with a lower MOE as the initial base-lining layer to absorb polymerisation stresses and counteract forces at the restoration-dentine interface.[25]

_Flowable composites

Flowables, introduced nearly two decades ago, have become ubiquitous for many applications. They exhibit greater fluidity and 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 reveals 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 or equal to or greater than 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 FS of outer occlusal restorative materials is 80 MPa, which is displayed by most of the current flowables on the market. The FS depends on the specific proprietary material, ranging from 70 to approximately 100 MPa, deteriorating over time, and is approximately 80 % compared with non-flowable analogues.

Although micro-leakage is a multifactorial phenomenon, MOE of the material is a crucial factor that determines its magnitude. Similar to FS, MOE is variable, depending on the product, ranging from 3 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 adhere to cavity walls or fissures crevices intricately, 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 *S. mutans*, the main infective agent of dental caries. Whilst a few flowables on the market claim anti-bacterial activity, the effect is usually

Fig. 20

Fig. 21

Fig. 22

Fig. 23

Fig. 24

Fig. 25

ephemeral, effective for only a few days.[28] Future composite developments should endeavour to incorporate both anti-bacterial and bioactivity in their formulations for enhanced therapeutic value.

In conclusion, flowables are useful for areas of reduced occlusal stresses, but are contra-indicated 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: Compobond

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 composite 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: compobond.

Compobonds exploit the benefits of SE DBAs and nano-filled 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 in which composites, similar to amalgam fillings, can be placed in a single step, eliminating errors, expediting protocols, and improving predictability and longevity of restorations.

The first compobond, called Vertise Flow (Kerr), was introduced in 2009, a self-adhering flowable combining a resin-based composite and an SE bonding agent based on the seventh-generation DBA OptiBond All-in-One (Kerr). 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 dimetharcrylate) 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 SEM and TEM images from the University of Leuven, Belgium, show tight adaptation of Vertise Flow to both dentine and enamel. In addition, micro-leakage tests show that Vertise Flow's marginal integrity is comparable to conventional (i.e. non-adhering) flowable composite when used in combination with an SE bonding agent.[29]

The shear bond strength (SBS) achievable with Vertise Flow and dentine is approximately 25 MPa,

Fig. 23_ The post-op view showing sealed fissures and the high lustre obtained after polishing with Opti1Step Polisher (compare with Fig. 11).
Fig. 24_ 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. 25_ Cavity preparation using micro-diamond burs for minimising excessive tooth removal.

Fig. 26_ All aprismatic enamel margins are carefully bevelled.
Figs. 27a & b_ The initial layer of Vertise Flow should be < 0.5mm thickness (a) and spread with a brush to ensure intimate contact with the cavity walls and bevelled margins (b).

Fig. 26

Fig. 27a

Fig. 27b

Fig. 28

Fig. 29

Fig. 30

Fig. 28_The initial layer of Vertise Flow is light cured before adding further material.
Fig. 29_The finished restorations are polished with tips for a high lustre, ensuring impeccable integration with the surrounding enamel.
Fig. 30_Pre-op occlusal contacts to verify that the cavity is not in a stress-bearing area.

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 contra-indicated. 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 70 % loading. The inclusion of nano-ytterbium fluoride yields excellent radiopacity and fluoride release (for bio-activity), the pre-polymerised fillers reduce micro-leakage, and nanoparticles improve polishability and thixotropic properties. The FS is 120 MPa for mitigating bulk fracture, and the MOE is low, approximately 7 GPa, for shock absorbing capability (Fig. 8).

Because Vertise Flow functions 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, for example feldspathic, lithium-disilicate or other pressed ceramic systems. This adhesive property is exceptionally useful for repairing intra-oral fractured porcelain, for example 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, both as a liner/sealant and for entire small cavity restorations. Vertise Flow is available in a selection of shades for the subtlest of aesthetic requirements, 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 and low wear, 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 and enamel bonding, high mechanical strength, low wear, better aesthetics, a single-stage clinical procedure and fluoride release, but not fluoride recharge.

Fig. 31_After rubber dam isolation, pumice is used to cleanse the tooth.
Fig. 32_A cavity is prepared with bevelled enamel margins.
Fig. 33_Post-op view showing the cavity restored with A3 Vertise Flow.

Fig. 31

Fig. 32

Fig. 33

Fig. 34

Fig. 35

Fig. 36

_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 of 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 reports on fissure sealing of a first permanent molar tooth in a 14-year-old child. Ideally, the tooth should be isolated with a rubber dam to ensure moisture control and a clear operating field (Fig. 11). Initially, the tooth was 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. 12). The cleansing was continued with a slurry of pumice to eliminate residues of the aluminium powder (Figs. 13 & 14). After rinsing off the pumice (Fig. 15), 37 % phosphoric acid was dispensed to etch the pits and fissures (Fig. 16a) and surrounding uncut, aprismatic enamel (Fig. 16b). The classic frosty etched enamel appearance was clearly visible after

rinsing off the etchant and drying the occlusal surface (Fig. 17).

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. The Translucent shade of Vertise Flow was dispensed generously (Figs. 18a & b) 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. 19a & b). The coated surface(s) were light cured for 20 seconds with a curing light with an output of 800 MW/cm^2 (Fig. 20). The rubber dam was then removed and articulation paper placed to check occlusal contacts (Fig. 21). All the articulation paper marks, except those on the supporting buccal cusps (palatal cusps for maxillary teeth), were adjusted and polished with Opti1Step Polisher (KerrHawe SA; Figs. 22 & 23).

Small, non-stress-bearing, non-contacting cavities

Small cavities in areas of minimum occlusal stress are ideal candidates for minimally invasive, micro-dentistry. Incipient carious lesions either can be monitored if the patient risk factors are low or may require intervention for patients with a propensity for dental decay. In this case, a 13-year-old female patient, who is an occasional attendee and relatively indifferent to dental treatment, was treated.

The preoperative status shows the maxillary second pre-molar and first molar with occlusal cavitations, and an old defective composite occlusal restoration in the molar (Fig. 24). Cavity preparation was carried out using small diamond burs specifically

Fig. 34_Pre-op view showing defective amalgam fillings in two mandibular molars. Pre-op occlusal contacts are identified before placing the rubber dam.
Fig. 35_The old amalgam restorations are removed.
Fig. 36_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. 37_The etched enamel peripheries are clearly visible on the second mandibular molar.
Fig. 38_The etched enamel peripheries are clearly visible on the third mandibular molar.
Fig. 39_Vertise Flow is dispensed into the cavity.

Fig. 37

Fig. 38

Fig. 39

Fig. 40a

Fig. 40b

Fig. 41

Figs. 40a & b_A brush is used to spread the Vertise Flow on the cavity walls (a) and floor, ensuing that it is evenly spread with a thickness less than 0.5 mm (b).
Fig. 41_The initial Vertise Flow lining is light cured.

Fig. 42_A regular composite, Herculite XRV Ultra, is used in increments for replacing dentine and building up individual buccal and lingual cusps.
Fig. 43_An endodontic file, loaded with brown Kolor + Plus stain, is dragged through the unset composite resin to create fissure patterns in the second molar restoration.
Fig. 44_An endodontic file, loaded with brown Kolor + Plus stain, is dragged through the unset composite resin to create fissure patterns in the third molar restoration.

designed to minimise removal of tooth substrate (Fig. 25). 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. 26). The initial layer of Vertise Flow should be less than 0.5 mm in thickness and pressed into the recesses of the cavity floor and walls (Figs. 27a & b). The initial layer of Vertise Flow was first light cured (Fig. 28) before completing the cavity with additional layers. Finally, the restoration was polished with Opti1Step Polisher and an OptiShine brush (KerrHawe SA) to yield a high lustre gloss (Fig. 29).

Class V and small buccal 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 hyper-mineralised 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 hyper-mineralised sclerotic dentine.

If sclerotic dentine is absent, adhesion with DBAs is superior (28 MPa) compared with compomers (15 MPa) or a glass-ionomer (2.5 MPa).[32] For small buccal cavities within enamel, Vertise Flow is the ideal material of choice, as shown in the following case.

Preoperative articulation paper marks verified that the buccal lesion was free of occlusal, stress-bearing contacts (Fig. 30). After isolation with a rubber dam, the tooth was cleaned with a slurry of pumice (Fig. 31) and a cavity was prepared with bevelled enamel margins (Fig. 32). The final result shows restoration of the cavity with A3 Vertise Flow after polishing with Opti1Step Polisher (Fig. 33).

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 able to absorb stresses than enamel. For this reason, in circumstances in which the cavity extends into dentine, the initial layer of composite should have shock-absorbing capabilities that are similar to dentine.

The polymerisation contraction stresses of a resin-based composite are directly related to its filler volume, which also affects its mechanical properties, such as wear resistance and 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 non-flowable counterparts and therefore undergo increased volumetric shrinkage. However, since flowables have about 50 % less MOE than non-flowables, they can absorb more stresses and, in theory, maintain superior marginal integrity.[34]

The MOE of flowables ranges from as low as 1.4 GPa (low filler volume) to as high as 12.5 GPa (high filler

Fig. 42

Fig. 43

Fig. 44

Fig. 45

Fig. 46

Fig. 47

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 generalisation, flowables with a lower MOE may act as shock absorbers when placed as pre-cured liners below subsequent increments of non-flowables. But current studies are inconclusive regarding this beneficial property,[36, 37] and further research is necessary to clarify the issue.

In the following case, 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 non-flowable composite. This case shows the second and third mandibular molars with defective amalgam restorations requiring replacement. In addition, these teeth also exhibit bruxism activity with tooth wear, resulting in occlusal enamel loss. Initial occlusal contacts were verified (Fig. 34) before placing a rubber dam and removing the amalgam restorations. Notice the extensive decay in the third molar (Fig. 35). Since molars are prone to high occlusal forces, placing bevels on enamel margins is unsuitable because the thin layer 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. 36).

After thoroughly rinsing and drying, the etched enamel periphery of both cavities was clearly visible (Figs. 37 & 38). Vertise Flow was dispensed into the cavity, brushed to ensure that the material was evenly spread along the cavity walls and floor, making sure that its thickness did not exceed 0.5 mm

(Figs. 39–40b). This initial layer of Vertise Flow was light cured for 20 seconds and acted as the stress-relieving lining (Fig. 41). Subsequent layers of the filling were built-up using increments of a regular composite, Herculite XRV Ultra (Kerr), to replace dentine, and then successively building-up the buccal and lingual cusps[38] separately without contacting the opposing sides (Fig. 42).

Staining fissures is a contentious issue; some patients are indifferent to this practice, while others adamantly refuse to have their teeth stained. For those patients who are unconcerned, fissure staining and patterns impart a realistic appearance to a composite filling. The technique involves using different stains, for example Kolor + Plus (Kerr), that are dragged through the unset composite resin using an endodontic reamer or file (Figs. 43 & 44). Once the desired fissure pattern had been created, the composite was light cured (Figs. 45 & 46). After removing the rubber dam, articulation paper was used to check occlusal contacts (Fig. 47), and necessary adjustments were made to ensure occlusal harmony. The final stage was achieving a high surface lustre and texture using Opti1Step Polisher. The post-operative view shows composite fillings emulating natural cusps and fissure patterns, with imperceptible transition between the composite filing and surrounding enamel (Fig. 48).

Blocking undercuts

Another useful application of flowables is blocking undesirable undercuts prior to providing indirect restorations. Undercuts often complicate many clinical and laboratory procedures, for example impres-

Fig. 45_Once the fissure pattern has been established, the composite is light cured in the second molar.
Fig. 46_Once the fissure pattern has been established, the composite is light cured in the third molar.
Fig. 47_After removing the rubber dam, occlusal contacts are checked using articulation paper.

Fig. 48_The filling is polished to a high lustre with Opti1Step Polisher, ensuring an indiscernible transition between the composite filling and surrounding natural tooth.
Fig. 49_Underlying decay is evident after removing an old amalgam filling from the maxillary molar.
Fig. 50_Undercuts are evident following excavation of soft, carious dentine.

Fig. 48

Fig. 49

Fig. 50

Fig. 51

Fig. 52

Fig. 53

Fig. 51_Vertise Flow is used to block the undercuts and acts as a stress-relieving lining.

Fig. 52_Pre-op view showing a distal fracture of the all-ceramic crown on the maxillary left central incisor.

Fig. 53_Shade analysis to ascertain colour of existing crown. Vertise Flow A2 and Translucent shades were selected to repair the fractured porcelain.

Fig. 54_Pumice is used to cleanse the crown and remove any plaque biofilm.

Fig. 55_The porcelain surface is mechanically roughened with a diamond bur and then cleansed with phosphoric acid.

Fig. 56_Prepared porcelain site.

sion making or restoration fabrication. 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, a large amalgam restoration with underlying profound decay was scheduled for an indirect ceramic inlay. After isolation with a rubber dam, the amalgam filling from the maxillary molar was removed, revealing gross carious dentine (Fig. 49). All soft, carious dentine was exacted, leaving blatant undercuts (Fig. 50). 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. 51).

Repair

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. Traditionally, ceramic fracture repair involved several stages, that is etching with hydrofluoric acid, silanation and repairing with conventional resin-based composites, either a flowable or non-flowable variety.

As previously mentioned, Vertise Flow incorporates an acidic phosphate monomer, which links chemically 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, which combines both chemical bonding and a repairing composite to "heal" the fracture.

The following case illustrates repair of a fractured, alumina core crown, veneered with silica (feldspathic) porcelain. The patient presented with a distal fracture of the all-ceramic crown on the maxillary left central incisor (Fig. 52). A shade analysis was performed with the Vita Classic shade guide (VITA). Vertise Flow A2 was chosen for the body of the crown, and the Translucent shade for the incisal edge translucency (Fig. 53). Initial cleansing was carried out with a slurry of pumice to remove the plaque biofilm (Fig. 54).

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. 55), which does not etch porcelain, but removes any remaining debris (Fig. 56).

Fig. 54

Fig. 55

Fig. 56

Fig. 57

Fig. 58

Fig. 59

The chemical method involves etching the porcelain with hydrofluoric acid for three 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 when using Vertise Flow, as the later incorporates an acidic phosphate monomer that bonds to silica, as well as alumina and zirconia ceramics. The A2 shade of Vertise Flow was dispensed directly onto the etched fracture site (Fig. 57), and spread intimately, ensuring firm contact with the porcelain (Fig. 58). In order to mimic the incisal edge translucency, the Translucent shade of Vertise Flow was used at the incisal edge (Fig. 59), and slightly overbuilt to compensate for the polishing stage (Fig. 60). Finishing and polishing were carried out using sequentially finer grit discs (OptiDisc, Kerr; Fig. 61), 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. 62).

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, quick and 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 focused on the rationale for the development of compobonds, citing technological advances in both DBAs and 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 an SE DBA with a composite-resin eliminate 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 trials will untimely judge the efficacy of compobonds and, if successful, will pave the way for non-flowable varieties to simplify direct composite restorations._

Editorial note: A complete list of references is available from the publisher.

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Fig. 57_The A2 shade of Vertise Flow is dispensed onto the site.
Fig. 58_A brush is used to spread the Vertise Flow to cover the fracture site.
Fig. 59_The Translucent shade of Vertise Flow is used to build the incisal edge.

Fig. 60_Palatal view showing the overbuilt repair before polishing.
Fig. 61_Polishing is carried out with various grits of OptiDisc to create a high lustre.
Fig. 62_Post-op view showing the "invisible" repair with a smooth texture and high lustre, impeccably blending with the surrounding porcelain.

Fig. 60

Fig. 61

Fig. 62