RED bonding: Predictable cementation of indirect aesthetic restorations

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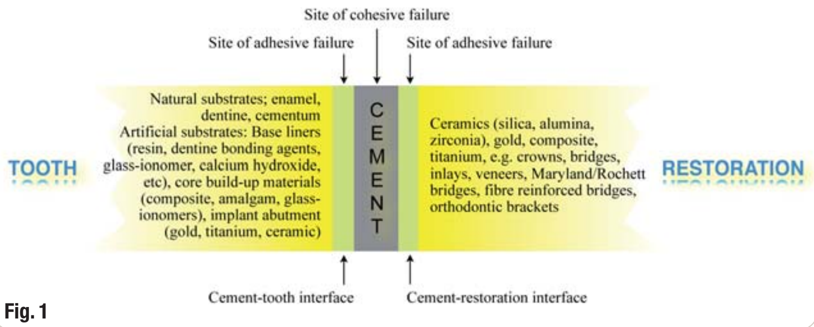


Fig. 1

Fig. 1_Cementation mechanism: two interfaces are created between the tooth and restoration—cement–tooth interface and cement–restoration interface.

_Most contemporary aesthetic dental treatment relies on resin-based aesthetic dentistry (RED). The essence of RED is achieving an efficacious bond to natural tooth substrate, be it enamel or dentine, for a long-lasting restoration. This is applicable to both direct and indirect aesthetic restorations.

Bonding to enamel is an established protocol, but bonding to dentine has proved more challenging and undergone considerable changes. However, the majority of current dentine bonding agents (DBA) is capable of efficacious bonding to dentine, but the method for achieving this goal is still debatable. Some authorities advocate self-etch DBA, while others prefer a total-etch approach, and further research will no doubt elucidate the validity of these methods.

Irrespective of the technique used, RED bonding is a quintessential requirement for success and durability of aesthetic dental restorations. It

	Formulation	Varieties	Advantages	Disadvantages	Cementation mechanism: Cement–tooth interface	Cementation mechanism: Cement–restoration interface
RMGI	Polyalkenoic acid with addition of a methacrylate component (e.g. HEMA) and fillers	Pre-capsulated, chemical and light-cured	Adhesion to dentine, thin film thickness, antimicrobial, fluoride releasing, low solubility, adheres to moist tooth substrate, reduced chemical trauma to pulp	Mechanically weaker than resins, significant post-cementation dimensional changes may fracture weak ceramics	Chemical adhesion	Mechanical interlocking
CR	Polymer infiltrated with filler particles	Chemical, light- and dual-cured, low and high viscosities, shade tints to modify colour	High compressive strength, superior optical properties	Technique sensitive, hydrolytic degradation, shade shift over time, possible post-op sensitivity with poor technique	Micromechanical adhesion and/or chemical adhesion	Chemical adhesion
AR	Polymer infiltrated with filler particles with the addition of an adhesive functional phosphate monomer (e.g. MPD)	Dual-cured, self-etch, self-adhesive, antibacterial, fluoride releasing	High compressive strength, superior optical properties, chemical bonding to cast-metal, alumina and zirconia substructures	Technique sensitive, hydrolytic degradation, shade shift over time, lower bond strength compared with CR, reduced post-op sensitivity compared with CR	Micromechanical adhesion and/or chemical adhesion	Chemical adhesion

Table I

Type of restoration	Restorative material	Ideal cement	Possible cement
Cast-metal crowns and inlays, intra-radicular posts, PFM crowns and FPDs (bridges)	High gold and semi-precious alloys	AR, RMGI	ZP, PC, CR
Maryland/Rochette bridges and splints	Semi-precious alloys	AR	CRD
Fibre-reinforced composite bridges and splints	Composite, fibre	AR	CRD
Light-transmitting intra-radicular posts	Fibre, zirconia	AR	CRD
Orthodontic fixed brackets	Metal alloy	AR	CRD
Inlays and onlays	Composite or silica-based ceramic	AR	CRD
PLVs (feldspathic)	Silica-based ceramics	CRL	AR
All-ceramic crowns, e.g. feldspathic, leucite-reinforced pressed glass, lithium disilicate	silica-based ceramics	AR, CRD	RMGI
All-ceramic crowns and FPDs of glass-infiltrated alumina, densely sintered alumina, zirconia substructures	Alumina- and zirconia-based ceramics	AR, RMGI	
Implant-supported crowns or FPDs	PFM, or alumina- and zirconia-based ceramics	AR, RMGI	ZOE

Key
AR: adhesive resin; CR: conventional resin; CRL: conventional resin, light-cured; CRD: conventional resin, dual-cured; FPD: fixed partial denture; PC: polycarboxylate; PLV: porcelain laminate veneer; RMGI: resin-modified glass ionomer; ZOE: zinc/oxide eugenol; ZP: zinc phosphate.

Table II

is worth noting that 50 % of clinical performance of dental cements is influenced by operator variables,[1] including an exacting clinical technique together with mixing, dispensing and loading the cement. The remaining risk factors are tooth preparation design (ideal 12° convergence angle for adequate resistance form), material properties, location of tooth in the mouth and patient factors, such as oral hygiene.

_Interfaces

The primary function of dental cement is retaining an indirect restoration on an intra-oral abutment, which can be natural tooth substrate or an artificial restorative material. The mechanisms by which cements achieve retention can broadly be termed "luting" or "bonding". Luting is non-adhesive retention, and bonding implies a closer attachment of the cement to the restoration and tooth, which includes micromechanical and chemical adhesion.

The cementation mechanism of cements is classified as:

1. non-adhesive or mechanical interlocking retention by engaging tooth surface and restoration intaglio surface irregularities, measuring 20 to 100 µm (this mechanism is applicable to all dental cements);
2. micromechanical "adhesion" by engaging finer surface irregularities <2 µm created by etching, air abrasion, and usually in combination with a DBA by formation of a hybrid layer (0.5 to 10 µm);
3. chemical (molecular) adhesion by bipolar, Van der Waals forces and chemical bonds, which is the ideal that contemporary cements strive to achieve.

In order to understand the cementation mechanism, two interfaces between the cement and the tooth/restoration complex require consideration. On the tooth side, the substrate is dentine, enamel or cementum, and this is called the "cement–tooth interface". On the opposing side is the artificial restoration, termed the "cement–restoration interface" (Fig. 1). Some cements of-

Table I_Properties of contemporary permanent dental cements and luting mechanisms at cement–tooth and cement–restoration interfaces.

Table II_Choice of cement depending on type of restoration and restorative material.

Table III_Retentive and non-retentive restorations.

Type of restoration	Intra-coronal	Extra-coronal
Inlay	Non-retentive	
Onlay		Non-retentive
PLV		Non-retentive
Maryland/Rochette bridges and splints		Non-retentive
Fibre-reinforced composite bridges and splints		Non-retentive
Orthodontic brackets		Non-retentive
Full-coverage crown		Retentive
FPD		Retentive
Implant-supported crowns and FPD		Retentive

Table III


Fig. 2


Fig. 3

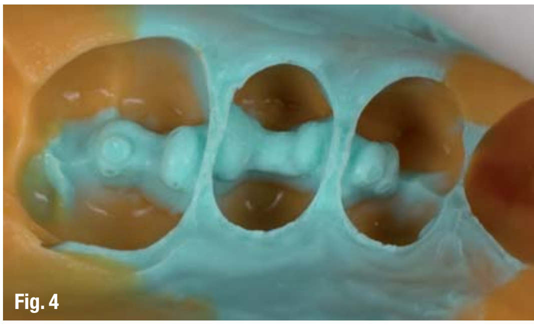


Fig. 4

Fig. 2_Defective amalgam restorations requiring replacement.
Fig. 3_After removing the amalgam fillings, no attempt is made to extend the cavity to create undercuts, thereby maintaining the structural integrity of the tooth. Also, soft carious dentine is excavated, but hard, discoloured infected dentine is left *in situ* to preserve tooth substrate.
Fig. 4_An impression is taken for fabricating indirect ceramic inlays.

fer chemical adhesion at both interfaces. However, a vast number of interfaces are possible depending on the substrate on the tooth and restoration sides. These interfaces are the weakest link and account for adhesive failure. Cohesive failure is the breakdown of the cement or fracture of the tooth or the restoration.

A tight and secure seal is essential for preventing micro-leakage between the concealed interfaces beneath the bulk of the restoration and at the "open" margins exposed to the oral cavity. Furthermore, exposed margins are also vulnerable to occlusal stresses transmitted from the coronal part of the restoration to the cervical aspect, and the cement should be resilient to these forces in order to maintain a long-lasting hermetic seal.

_Contemporary cements

At present, there is no single cement that can ubiquitously be used for all indirect restorations. The choice of cement depends on the type of restoration, the restorative material and prevailing clinical scenarios. Judicial selection is imperative for efficacious cementation and longevity of a prosthesis. Contemporary permanent cements for definitive restorations are broadly categorised as resin-modified glass ionomers (RMGI) and resins (Table I). The latter are further divided into conventional resins (CR) and adhesive resins (AR).[2] True AR are only those that contain the monomers MDP (10-methacryloyloxydecyl dihydrogen phosphate) or 4-META (methacryloxyethyl trimellitate anhydride),[3,4] e.g. Maxcem Elite (Kerr), RelyX Unicem (3M ESPE), and Panavia 21, Panavia F2.0, Clearfil SA (Kuraray Dental).

_Selecting a permanent cement

The choice of cement for an indirect prosthesis depends on the type of restoration, the restorative material from which the restoration is made, and the clinical situation. (Table II summarises the ideal choice of cement depending on the type of restoration and restorative material.)

Type of restoration

Indirect restorations are categorised as intracoronal or extra-coronal. In addition, the restoration can be retentive or non-retentive (Table III). Retentive restorations gain retention and resistance from of the geometry of the tooth preparation (e.g. crown preparation), and therefore adhesive cementation is not obligatory. Consequently, these restorations can be luted with traditional cements such as zinc phosphate or glass-ionomer varieties, which are less technique sensitive. Conversely, non-retentive restorations have limited retentive tooth preparation features and are predominantly, or totally reliant on RED bonding to the tooth substrate, e.g. Maryland/Rochette, fibre-reinforced fixed partial dentures (FPD), porcelain laminate veneers (PLV) and inlays/onlays.

This paradigm shift from retentive to non-retentive restorations has been possible owing to advances in dental material technology and adhesive clinical techniques, placing a greater

Fig. 5_Plaster cast showing undercuts in the cavity preparations, which will eventually be filled with the permanent resin-based cement.
Fig. 6_The cavity undercuts are blocked on the plaster cast to facilitate fabrication of the ceramic inlays.
Fig. 7_Post-cementation of ceramic inlays with a resin-based cement.

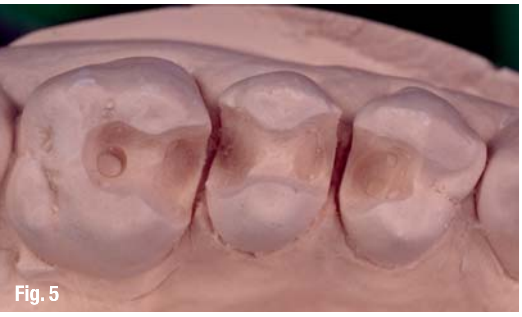


Fig. 5


Fig. 6


Fig. 7


Fig. 8


Fig. 9

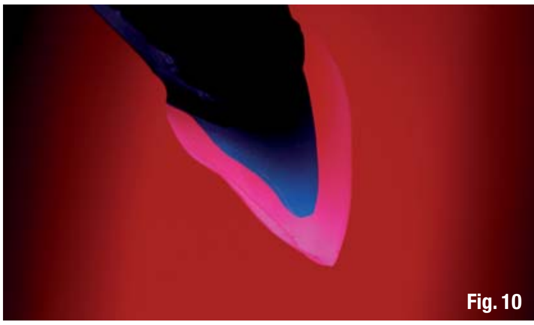


Fig. 10

emphasis on preserving natural tooth substrate. Whereas in the past, preparation design was geometric and extensive (dictated by the properties of the restorative material), it is now amorphous and minimalist (dictated by the extent of disease; Figs. 2–7).

Aesthetic restorations

Essentially, any restoration that achieves health and function can also be aesthetic. However, the term "aesthetic restorations" usually refers to tooth-coloured restorations or prostheses. Aesthetic restorations can be direct, using resin-based composites, or indirect, fabricated exclusively from a single ceramic material or with a strong substructure (ceramic or metal) that is subsequently veneered with a weaker overlying porcelain. This is the basis for the extremely successful porcelain-fused-to-metal (PFM) crowns and FPD.

The major disadvantage of PFM restorations is poor aesthetics at the cervical margins, presenting as greying owing to visibility of the metal substructure or "shine through" thin periodontal biotype gingivae. Therefore, a concerted effort has been made to seek alternatives, using dense, high strength ceramic cores to support aesthetic weaker porcelains. Although ceramics are capable of mimicking the appearance of natural teeth, they are plagued with fracturing in an aqueous and dynamic oral environment. Water imbibitions and occlusal stresses propagate crack formation of any exposed surface irregularities within the ceramic, leading to chipping or catastrophic fractures. Furthermore, even if the surface is highly polished or glazed, the tenet for using ceramics in the oral cavity is that they must be supported by either the natural tooth substrate or an underlying high strength substructure.

Ceramics are inherently brittle materials (high modulus of elasticity) and therefore susceptible to fractures. Microscopic imperfections within the material are termed "Griffith flaws", which grow into cracks and, if unimpeded, lead to catastrophic fracture of the ceramic. The cracks are propagated by the hostile oral environment: dynamics (occlusal forces) and humidity (stress corrosion). Furthermore, static fatigue is time dependent, which eventually results in breakage (Fig. 8).

Many strengthening mechanisms are used for halting fracture propagation, including reinforcement and infiltration with glasses, and phase transformation toughening. Preventing fractures also depends on the clinical scenario, method of fabrication of the restoration, and the manufacturing technique and strengthening process of the ceramic.

In order for ceramics to survive in the oral cavity, they must be supported by either the natural tooth substrate or a substructure. Two types of ceramic restorations are possible: first, a uni-layer restoration that is entirely composed of a single ceramic, gaining support through an adhesive bond to the underlying tooth substrate; and, second, a bi-layer restoration that has a supporting substructure for the aesthetic veneering

Fig. 8_Delamination of the veneering porcelain on the distal abutment of a FPD.
Fig. 9_Plaster cast of tooth preparations for a full-coverage crown.
Fig. 10_Uni-layer restorations are entirely fabricated of a single ceramic, and gain support from the underlying tooth.

Fig. 11_Bi-layer restorations are fabricated from a dense core (metal or ceramic), which supports an overlying aesthetic veneering porcelain.
Fig. 12_All-ceramic crowns fabricated from silica-based ceramics, which are the most aesthetic type of indirect restorations.
Fig. 13_Porcelain laminate veneers are delicate restorations requiring careful handling to prevent inadvertent breakage during the cementation procedure.

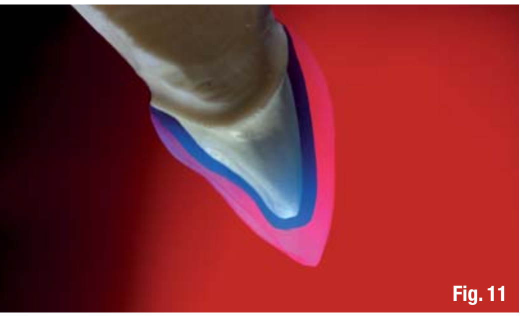


Fig. 11

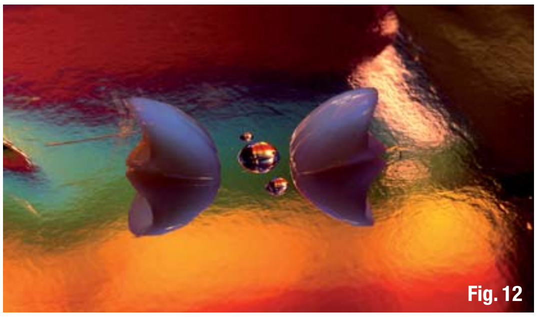


Fig. 12


Fig. 13


Fig. 14a

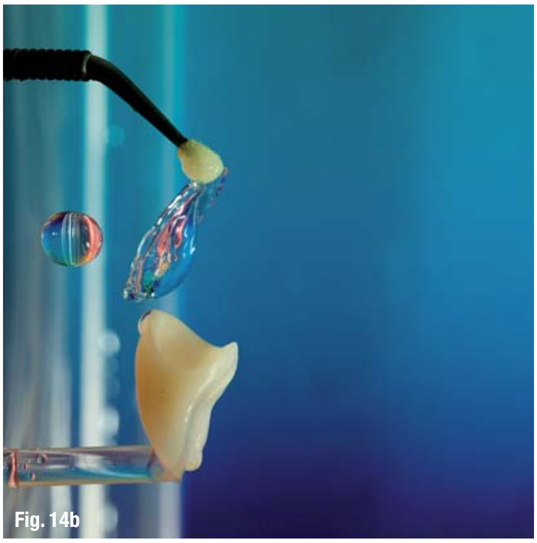


Fig. 14b

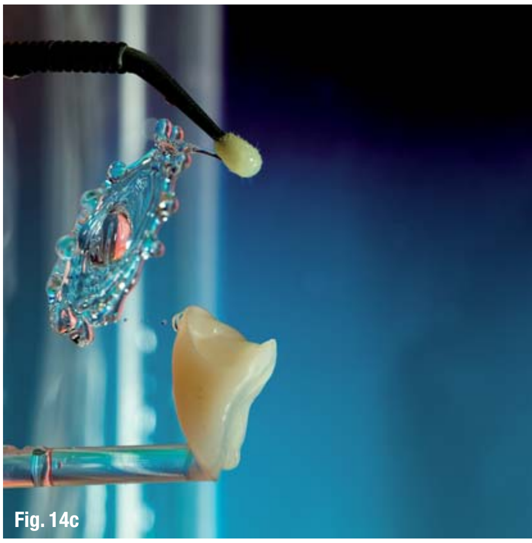


Fig. 14c

Figs. 14a–c_Applying a silane-coupling agent onto the fitting surface of a silica-based ceramic restoration forms silica–silane bonds, resulting in chemical adhesion at the cement–restoration interface.
Fig. 15_Poor enamel-etching pattern with a seventh-generation DBA.
Fig. 16_Profound enamel-etching pattern with OptiBond XTR.
Figs. 17a & b_OptiBond XTR has deeper penetration into the dentine tubules with a reduced film thickness of only 5 µm, compared with 35 µm of other self-etch bonding agents.

porcelain (Figs. 9–11). This substructure can be either metal or a dense, high strength ceramic core, and these restorations can be either bonded with a resin cement or luted with RMGI.[5]

Dental ceramics can arbitrarily be categorised as silica, alumina or zirconia based. Silica-based materials are weaker materials with a high glass content and excellent optical properties, making them the most aesthetic type of ceramic, e.g. feldspathic, leucite-reinforced, lithium disilicate and synthetic porcelains (Fig. 12). Alumina and zirconia have reduced glass content, reduced translucency and poorer light transmission, making them less aesthetic but offering greater strength, e.g. alumina (flexural strength of 700 MPa) and zirconia (flexural strength of >1000 MPa). However, owing to their hardness and inferior optical properties, uni-layered alumina and zirconia restorations are impractical. Hence, these high strength ceramics are ideal for bi-layer prostheses, acting as an underlying dense core for supporting weaker silica-based aesthetic porcelains for both single and multiple-unit FPDs.

Clinical scenario

The final aspect that determines the choice of cement is the clinical scenario. If the resistance and retention form of the tooth abutment is less than the ideal of 6° axial tapers (12° convergence angle), a resin cement is a prudent choice for reinforcing and improving the fracture strength of the abutment/cement/restoration complex.[6] Similarly, when a remake of a restoration with poor marginal integrity is not immediately possible, it may be possible to seal open margins using resin cements.

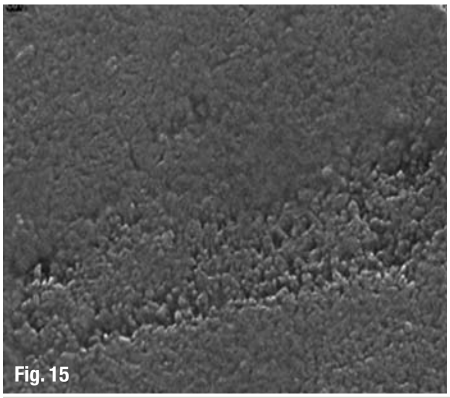


Fig. 15

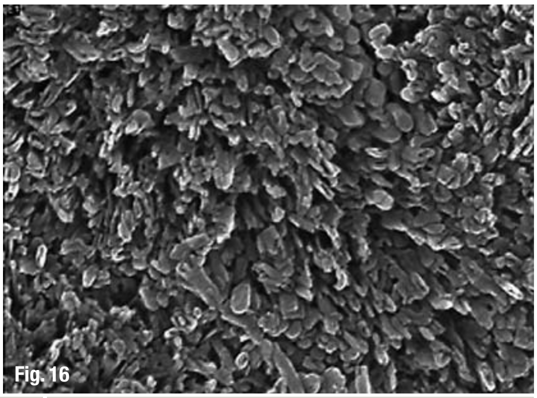


Fig. 16

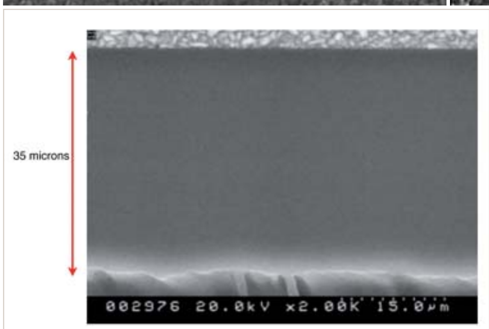


Fig. 17a Large film thickness of 35 microns, associated with SE DBA (SEM 2000X)

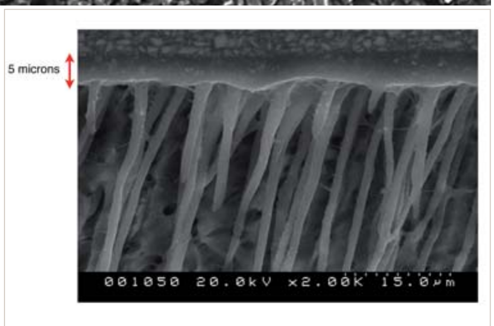


Fig. 17b OptiBond XTR- thiiner film thickness of 5 microns (SEM 2000X)

Finally, if a dry environment is challenging, e.g. deep sub-gingival margins, RMGI is a better choice since it is less sensitive to moisture.

_Bonding indirect aesthetic restorations

RED bonding indirect aesthetic restorations is demanding and technique sensitive. Failure to follow meticulous clinical protocols,

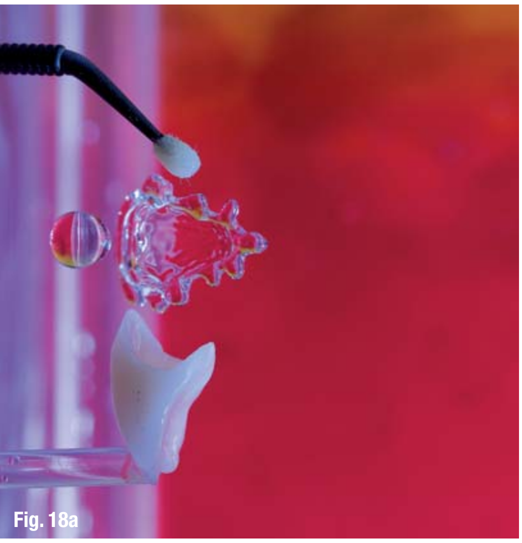


Fig. 18a


Fig. 18b

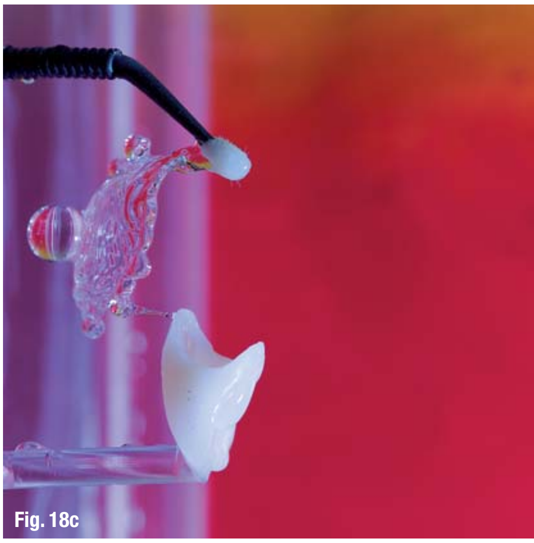


Fig. 18c

Figs. 18a–c_OptiBond XTR incorporates an adhesive monomer and is copiously applied to the fitting surfaces of ceramic restorations, achieving chemical adhesion at the cement–restoration interface.

or using inappropriate materials, is a recipe for disaster. Furthermore, aesthetic restorations are unique because they are often non-retentive, thin, delicate and fragile, requiring careful manipulation to prevent breakage during the cementation procedure (Fig. 13).

Choice of cement

The choice of permanent cement for definitive aesthetic restorations is either RMGI or resin. Although RMGIs offer chemical adhesion to dentine, they are unsuitable for aesthetic restorations owing to poor mechanical properties, inferior optical properties (profound opacity), making translucent silica-based ceramics appear dull, and a limited selection of shades, making accurate shade matching difficult. Furthermore, RMGIs undergo significant post-cementation dimensional changes that may fracture weaker uni-layer ceramic restorations.[7] Therefore, the ideal cement for aesthetic restorations is a resin, which has superior mechanical, optical and physical properties (Table I). In addition, newer resin cements also offer low film thicknesses of 8 to 21 µm,[8] comparable with that of RMGI, resulting in reduced micro-leakage.[9] The disadvantages of resins are hydrolytic degradation, chromatic instability over time, post-operative sensitivity and requiring adherence to a stringent adhesive technique.

The next decision is choosing between AR and CR cement. The AR variety of resin cements is inappropriate for aesthetic restoration cementation owing to their limited shade availability and because the uncontrollable working time of dual-cure setting causes difficulty cleaning excess set cement. Besides, many aesthetic restorations require minimal preparation and are usually finished within enamel. Since self-etch ARs do not require separate enamel etching with 37 % phosphoric acid, the higher pH primer in AR may not create an adequate enamel-etching pattern for efficacious bonding.[10] For these reasons, a CR is therefore the ideal choice of cement for bonding tooth-coloured aesthetic restorations.

The CR cements are recommended for unilayered, non-retentive, silica-based ceramics (lower flexural strength of 100 to 300 MPa), offering increased translucency, assuming the underlying tooth substrate is an acceptable colour. These ceramics are amenable to etching with hydrofluoric acid (HF) for enhanced mechanical retention, and when treated with silane (Figs. 14a–c) create silica–silane chemical bonds at the cement–restoration interface. However, CR must

Fig. 19_Cavity preparation for an inlay on the maxillary first molar.
Fig. 20_Impression of inlay cavity using an addition silicone impression material.
Fig. 21_Temporary restoration *in situ*.


Fig. 19

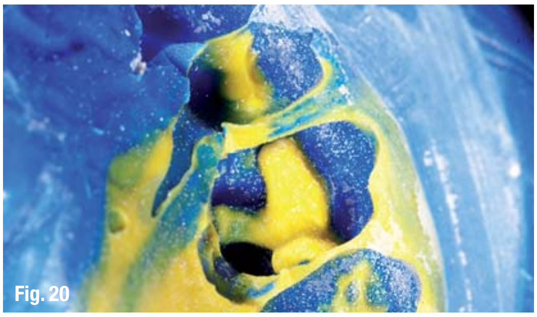


Fig. 20


Fig. 21

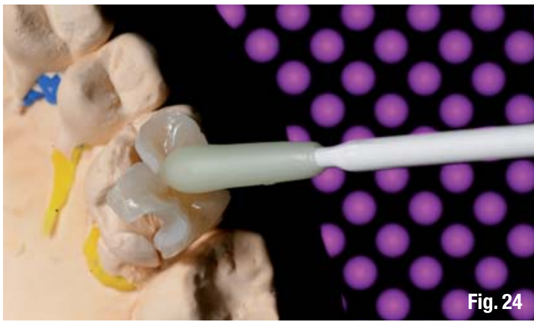


Fig. 22_Plaster cast of inlay cavity showing clearly defined margins.
Fig. 23_Completed silica-based ceramic inlay on plaster cast.
Fig. 24_Careful handling of the delicate inlay is essential during pre-treatment of the fitting (or intaglio) surface.

be used in combination with a separate DBA, either a total-etch or self-etch system. Conventional resins have numerous shades and try-in pastes for precise shade matching. In addition, light-cured CR can be used for restorations with thicknesses of 1.5 to 2 mm or thinner and dual-cured CR for thicknesses of >2 mm or opaque cores, thereby increasing their versatility and clinical applications.

NX3 Nexus (Kerr) is a CR cement available in a large selection of tooth-coloured shades, enabling accurate shade matching. Its try-in pastes precisely correspond to the definitive cement shades, allowing colour assessment and alteration before final cementation. The defining features of NX3 are chromatic stability over time and compatibility with most seventh-generation DBAs.

A major concern with resin cements, especially associated with dual-cured resin cements, is ageing colour shift causing unsightly yellowing below translucent, aesthetic restorations. This is attributed to the amine-initiated setting reaction of the luting agents. To mitigate the latter, NX3 Nexus incorporates an amine-free redox initiator system that guarantees chromatic stability over time.

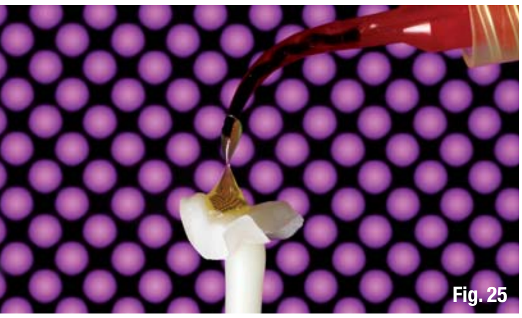
It is also essential that the CR and DBA be compatible with each other. Compatibility is particularly an issue with self-etch DBA agents owing to the residual acidic inhibition layer that retards or impedes setting of dual- or dark-cured resin cements. NX3 has excellent bond compatibility with seventh-generation total-etch and self-etch DBA without requiring an activator for dual-cured adhesives. This simplifies clinical protocols and ensures predictable bonding at the cement–tooth interface, and in combination with a DBA has a shear bond strength (SBS) of approximately 34 MPa for dentine and 30 MPa for enamel. At the cement–restoration interface, NX3 chemically adheres to most restorative materials, including resin-based composites, porcelain CAD/CAM blocks, alumina, zirconia and cast metal, achieving a maximum SBS of over 30 MPa. Finally, NX3 offers the choice of light or dual curing, allowing restorations with reduced light penetration, i.e. thicker than 2 mm or highly opaque (e.g. alumina or zirconia cores), to be predictably cemented.

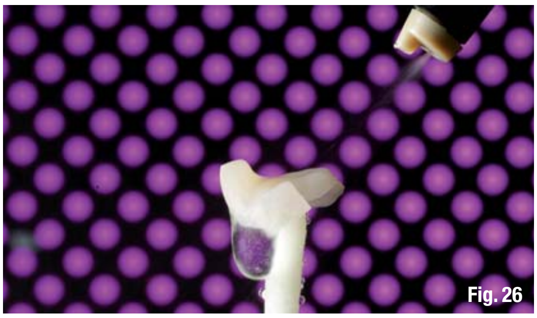
Dentine bonding agent

Achieving RED bonding with CR cements requires use of a DBA. The adhesion mechanism of resin cements and DBA at the cement–tooth interface is both micromechanical, by forming a hybrid layer, and chemical, by bonding with calcium ions from the hydroxyapatite of the tooth substrate. In order to resist the polymerisation stresses of the overlying resin cement, the bond strength of the DBA should be greater than 25 MPa.

OptiBond XTR (Kerr) is the latest self-etch, universally compatible DBA for direct and indirect restorations. The XTR is a retro-step to the sixth-generation bonding agents, eliminating many of the drawbacks of existing single-component

Fig. 25_Pre-treatment of intaglio surface: etching with HF acid.
Fig. 26_Pre-treatment of intaglio surface: rinsing off HF acid and drying with warm air until the surface appears frosty.
Fig. 27_Pre-treatment of intaglio surface: application of OptiBond XTR adhesive, dry, light-cure and store in a light-sealed container while the pre-treatment of the intra-oral abutment is carried out. NB: Application of silane onto the fitting surface of the porcelain is unnecessary when using OptiBond XTR.





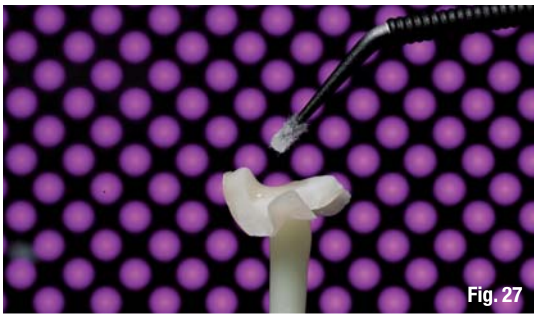


Fig. 28

Fig. 29

Fig. 30

Fig. 28_Pre-treatment of intra-oral abutment: isolation with rubber dam, removal of temporary dressing and thorough cleansing cavity with pumice, rinsing and drying. The inlay is seated using water-soluble NX3 try-in pastes for verifying colour and selecting the corresponding shade of the permanent cement.

Fig. 29_Pre-treatment of intra-oral abutment: OptiBond XTR primer is applied to both enamel and dentine, and continuously scrubbed for 20 seconds. This is followed by gentle drying for 5 seconds.

Fig. 30_Pre-treatment of intra-oral abutment: OptiBond XTR adhesive is lightly brushed for 15 seconds, air-dried for another 5 seconds and light-cured for 10 seconds.

Fig. 31_Cementation technique: the selected shade of light-cured NX3 is dispensed onto the inlay, or directly into the prepared cavity, avoiding introducing air.

Fig. 32_Cementation technique: after wiping away excess cement and ensuring patent contact points, NX3 is light-cured for 10 seconds from all aspects. All occlusal checks are carried out post-cementation to avoid damaging the ceramic beforehand. Any necessary adjustments, together with the margins are polished with OptiDiscs and Opti1Step polishing tips (both Kerr).

seventh-generation DBAs. Compared with seventh-generation DBAs, XTR does not require selective etching of enamel margins owing to its profound etching pattern on both cut (prismatic) and uncut (aprismatic) enamel (Figs. 15 & 16) and is fully compatible with all dual- and self-cured resin-based composites and cements. It has an SBS greater than most self-etch systems of approximately 30 MPa. Another problem with self-etch DBA is inadequate penetration of the adhesive into the dentine tubules following etching, which results in post-operative sensitivity and large film thicknesses. XTR overcomes this by penetrating deeper into dentine tubules, reducing the film thickness to less than 5 µm, SBS to dentine of 37 MPa, and post-operative sensitivity (Figs. 17a & b). Finally, XTR can be used with any CR cement for bonding indirect aesthetic restorations, and in combination with Nexus NX3 achieves dentine bond strengths of nearly of 42 MPa.

Cementation protocols

As mentioned previously, nearly half of all risk factors relating to successful cementation depends on operator factors, which leaves little latitude for errors. The cementation protocol can be divided into three distinct processes: pre-treatment of the intaglio or fitting surface of the restoration, pre-treatment of the intra-oral abutment, and clinical steps for cementation.

1. Pre-treatment of intaglio surface

The conditioning of the intaglio surface depends on the restorative material and the choice of cement (RMGI, CR, AR). The preferred method for silica-based restoration is chemical conditioning, using HF acid (4–10 % for 3 minutes), followed by application of warm silane or DBA, which increases the SBS between ceramics and the dentine substrate at the cement–restoration interface.[11] However, prolonged etching with HF acid can excessively dissolve the glass filler particles in the ceramic, making the surface smooth and negating the etching process. In addition, gross alteration to glass particles also compromises the strength of the ceramic.

Hydrofluoric and phosphoric acids cannot be used to etch metal, alumina or zirconia, but may be used for cleansing to ensure a contamination-free intaglio surface. The surface roughness or micro-irregularities of high strength dense ceramics must be created during the manufacturing process. Air abrasion of zirconia and alumina fitting surfaces prior to cementation is controversial. To date, there is no long-term data to verify this practice, and air abrasion of zirconia can cause transformation change from the tetragonal to the monoclinic phase, weakening and reducing the life expectancy of the restoration.[12] Other chemical agents include alloy primers or tin plating for some casting alloys.

Another benefit of using OptiBond XTR is that the adhesive liquid contains an adhesive monomer that provides true chemical adhesion for most restorative materials at the cement–restoration interface (Figs. 18a–c). Therefore, application of silane, or other alloy primers, to the fitting surface is superfluous.

Fig. 31

Fig. 32

Fig. 33


Fig. 34


Fig. 35


Fig. 36

2. Pre-treatment of intra-oral abutment

Pre-conditioning of the intra-oral abutment is begun by removing the temporary restoration and provisional cement, which is accomplished mechanically using hand instruments, air abrasion, pumice paste or ultrasonic devices. Complete removal of the provisional cement is essential for avoiding compromising the bond strength between the natural tooth substrate (or artificial abutment, e.g. intra-radicular post/cores or implant abutments) and the permanent cement. Higher SBSs are achieved when the temporary cement is removed with an effective dentine cleaner using a total-etch technique.[13] Alternately, immediate dentine sealing prior to taking an impression may also enhance bond strength.[14]

The next stage is isolation, either with a rubber dam or intra-sulcular gingival retraction cords. A dry environment is essential for resin-based cements. A rubber dam is the ideal choice for cementing inlays in posterior teeth but may be unsuitable for anterior teeth because the retaining metal clamps can potentially traumatise the gingival margin, leading to recession, especially for anterior teeth with thin periodontal biotypes. A gingival retraction cord, dry or impregnated with an astringent, not only allows visualisation of the abutment margins, but also acts as a physical barrier to avoid excess cement entering the delicate gingival sulcus. However, the use of a retraction cord may be inappropriate around implant abutments because it may lacerate the friable epithelial attachment.

Tooth abutment pre-treatment depends on the type of cement being used. If RMGI is employed, no further conditioning is usually necessary, whether the abutment is dentine, enamel or artificial restorative material, e.g. a composite, amalgam, cast-metal and ceramic core or titanium, alumina or zirconia implant abutments. For CR cements, where the abutment is natural tooth substrate, pre-treatment involves application of a DBA, i.e. self-etch or total-etch. If an artificial abutment is present, the conditioning depends on the restorative material of the abutment, e.g. for composite and amalgam core build-ups, the pre-treatment is air abrasion followed by etching with phosphoric acid.

3. Clinical procedure

After pre-treatment of the intaglio surfaces and intra-oral abutments, the next stage is dispensing the chosen cement. One of the major factors that reduces cement strength is introduction of air into the cement, e.g. 10 % porosity can reduce strength by 55 %. Porosity is related to the method of mixing,[15] polymerisation shrinkage during the setting reaction, and disintegration of the cement owing to fatigue and thermo-cycling. For this reason, auto-mixing dispensers and pre-capsulated cartridges are ideal for a smooth, reduced porosity mix.[16]

Depending on the restoration, the cement is dispensed onto either the fitting surface or intra-oral abutment, and the restoration correctly located and seated with pressure, with or without an ultrasonic insertion technique for high vis-

Fig. 33_Dento-facial view showing poor aesthetics of the maxillary central incisors.
Fig. 34_Pre-op defective, discoloured and poorly contoured resin composite fillings on the maxillary central incisors.
Fig. 35_The left central incisor is facially inclined and overlapping the lateral incisor.
Fig. 36_Diagnostic wax-up to simulate pseudo-realignment of the left central incisor so that it is in line with the maxillary arch.

Fig. 37_Transparent vacuum stent fabricated from a plaster cast of the diagnostic wax-up for intra-oral composite mock-up for gaining patient acceptance of the proposed aesthetics, and for making chairside temporary acrylic restorations.
Fig. 38_Minimally invasive PLV preparations on the central incisors finished within enamel with distinct finish lines, by a healthy periodontium.
Fig. 39_Chairside-fabricated acrylic temporary veneers using the vacuum stent of the wax-up.

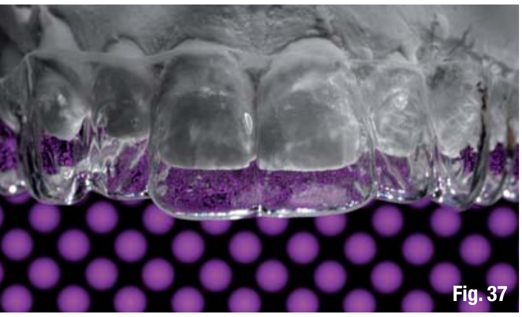


Fig. 37


Fig. 38


Fig. 39


Fig. 40


Fig. 41


Fig. 42

Fig. 40_Two silica-based ceramic PLV for the central incisors.
Fig. 41_PLV cemented with a resin-based cement, showing harmonious integration with the surrounding dentition and impeccable gingival health.
Fig. 42_Post-op incisal view showing the pseudo-realignment of the left central incisor.

cosity cements. Excess cement is immediately wiped off, and floss is used to clear the interproximal areas. If a retraction cord is placed beforehand, this is now removed together with excess cement and the restoration firmly held in place during light-curing from all aspects with an appropriate light intensity and duration (20 second for halogen lights and 10 seconds for LED lights of 800 mW/cm^2).

After setting, a #12 blade is used to trim set excess cement. The occlusion is checked and adjusted accordingly. Finally, minor adjustments and margins are polished with silicone tips, interproximal diamond strips, and the sulcus irrigated with chlorhexidine solution to wash out remnants of set cement and to promote gingival health.

To illustrate the above three processes of cementation, two case studies are presented in Figures 19 to 32 (cementation of a ceramic inlay) and Figures 33 to 45 (PLVs).

_Conclusion

Cementation is the penultimate clinical procedure, besides review and maintenance, for the provision of indirect restorations. Fitting indirect restorations requires adherence to stringent clinical procedures for ensuring success and longevity. Achieving these objectives involves understanding the mechanism of adhesion, the benefits and limitations of contemporary cements, and selecting the most appropriate cement depending on the type of restoration, the restorative material and the prevailing clinical situation. For aesthetic tooth-coloured restorations, the ideal choice is RED bonding with CR cements.

It is observed in the dental literature that all-ceramic restoration survival rates are now approaching those of metal-ceramic prostheses. However, providing metal-ceramic units is relatively technique insensitive, unlike all-ceramic prostheses, which are highly technique sensitive. Forgetting this basic difference in clinical practice is costly, frustrating and embarrassing, and although clinical judgement may be forgiven, the patient may not be so forgiving._

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

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Fig. 43_Post-op dento-facial view (compare with Fig. 33).
Fig. 44_Pre-op facial view.
Fig. 45_Post-op facial view. Notice elimination of the left central incisor imbrication over the left lateral incisor.


Fig. 43


Fig. 44


Fig. 45