**RED bonding: Predictable cementation of indirect aesthetic restorations**

**Author** Irfan Ahmad

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 is worth noting that 50 per cent of clinical performance of dental cements is influenced by operator variables, 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...
clinical technique _ Resin-based dentistry

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

“cement–restoration interface” (Fig 1). Some cements offer 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.

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 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
Hemostasis and Retraction?

No Problem.

Traxodent® from Premier® provides predictable hemostasis and soft tissue management in minutes.

Easy, effective hemostasis and retraction.
The sleek syringe with bendable tip permits easy application of Traxodent directly into the sulcus. After two minutes it is rinsed, leaving an open, retracted sulcus.

Traxodent is gentle, absorbent and fast.
The soft paste produces gentle pressure on the sulcus while it absorbs excess crevicular fluid. The aluminum chloride creates an astringent effect without irritating or discoloring surrounding tissue. Traxodent provides predictable hemostasis and retraction in less time and with greater comfort.

Try it – starter and value packs are available through your authorized dealer.

Available through: Ceramic Reconstructions • CTS Dental Supplies • DentalSky • Dental Directory • Dental Medical Ireland • Henry Schein/Mirerva • Karma • Myerson • Swallow Dental Supplies • Trycare

For more information, contact Scott Julian, UK Sales Manager: Tel: 07824442598 • Email: sjulian@premusa.com

Premier® Dental Products Company • 07824442598 • www.premusa.com • Cosmetic • Endo/Restorative • Hygiene/Perio • Instruments • Prosthetic

Survey of 313 dentists who have used Traxodent at least once in their practice. / Clinical images courtesy of Shalome Meibor DMD, Teaneck, NJ.
adhesive clinical techniques, placing a greater 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 unilayer 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 porcelain (Figs 9–11). This substructure can be either metal or a dense, high strength.
A ceramic core, and these restorations can be either bonded with a resin cement or luted with RMGI.\textsuperscript{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, eg 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, eg 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 bilayer 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.\textsuperscript{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.

Finally, if a dry environment is challenging, eg 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, 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. 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, comparable with that of RMGI, resulting in reduced micro-leakage. 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 per cent phosphoric acid, the higher pH primer in AR may not create an adequate enamel-etching pattern for efficacious bonding. For these reasons, a CR is therefore the ideal choice of cement for bonding tooth-coloured aesthetic restorations.

The CR cements are recommended for uni-layered, 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 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 2mm or thinner and dual-cured CR for thicknesses of >2mm or opaque cores, thereby increasing their versatil-
Today’s patient wants a beautiful smile with far less invasive dentistry. **Minimal** tooth reduction & clinically **Superior** outcomes transform smiles

That’s exactly what **LUMINEERS®** is all about.

Bring **LUMINEERS®** to your practice.... ....give your patients something to smile about!

Come and learn the **LUMINEERS®** technique at one of our one day courses.

You will:
Learn about the versatility of Ultra-thin Veneers
Realise minimally invasive options with prep vs no prep considerations for aesthetic dentistry.
Increase patient acceptance and gain practice growth.

**Objectives:**
Diagnosis and Case Selection
Treatment Planning & Smile Design
Case Presentations
Step-by-Step Procedure
Impression taking ‘Live’ Demo
Hands-On simulated step by step procedures.

Bring models or photos of prospective cases for discussion with our clinician.

**Bonus feature.....**
An introduction to the Ultimate provisional....

**Friday 15th February 2013**
Cardiff
**May 2013 tbc**
London

For information or to book your place

08451 301611
lumineers@dkap.co.uk  www.dkap.co.uk

A non-refundable deposit is required to reserve a place. Course content subject to change without notice. DKAP reserve the right to cancel.
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 dual-cured resin cements 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 DBAs 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 2mm 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 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 selfetch 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 5μm, 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: pretreatment 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 per cent for three minutes), followed by application of warm silane or DBA, which increases the SBS between ceramics and the dentine substrate at the cement–restoration interface. 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. 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.

2. Pre-treatment of intra-oral abutment

Pre-conditioning of the intra-oral abutment is begun by removing the temporary restorations and provisional cement, which is accomplished mechanically using hand instruments, air abrasion, pumice paste or ultrasonic devices. Complete removal of the provisional cement is 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. 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.
essential for avoiding compromising the bond strength between the natural tooth substrate (or artificial abutment, eg 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.\(^\text{13}\) Alternately, immediate dentine sealing prior to taking an impression may also enhance bond strength.\(^\text{14}\)

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, eg 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, ie self-etch or total-etch. If an artificial abutment is present, the conditioning depends on the restorative material of the abutment, eg 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, eg 10 per cent porosity can reduce strength by 55 per cent. Porosity is related to the method of mixing,\(^\text{15}\) 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.\(^\text{16}\)

Depending on the restoration, the cement is dispensed onto either the fitting surface or intraoral abutment, and the restoration correctly located and seated with pressure, with or without an ultrasonic insertion technique for high viscosity 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\(^2\)).
QuickWhite™ Whitening Kit

The latest must have ...

£19.50 + vat - 5 Large Syringes - Order your trial kit NOW

...AND MORE

4w Laser - 8w Laser - Cordless Laser - IntraOral Cameras

Call us 01227 780009 www.quicklase.com
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.*