

# RED BONDING : PREDICTABLE CEMENTATION OF INDIRECT ESTHETIC RESTORATIONS

Irfan Ahmad, BDS  
The Ridgeway Dental Surgery  
173 The Ridgeway  
North Harrow  
Middlesex, HA2 7DF  
UK  
www.IrfanAhmadTRDS.co.uk  
E-mail: iahmadbds@aol.com

## **Abstract**

The literature regarding dental cements is compelling, and the choice of materials bewildering. The purpose of this article is to simplify the choice of dental cements for various indirect restorations based on current scientific thinking and clinical experience. The key feature of resin-based esthetic dentistry (RED) is achieving a predictable bond between the tooth substrate and the restoration for long lasting viability in the oral cavity. Specifically, cements should provide sufficient retention to prevent dislodgment, a lasting hermetic seal to prevent microleakage, mitigate post-operative sensitivity, and possess adequate strength to resist oral forces. This paper discusses the rationale for selecting dental cements based on the type of restoration, restorative material, and prevailing clinical scenarios. It also suggests guidelines, and presents case studies, for bonding esthetic indirect tooth coloured restorations using resin-based cements in combination with a newly launched dentine-bonding agent.

**Key word: resin-based esthetic dentistry (RED), interfaces, contemporary cements, bonding indirect esthetic restorations**

## **Introduction**

Most contemporary esthetic dental treatment relies on resin-based esthetic 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 esthetic 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) are capable of efficacious bonding to dentine, but the method for achieving this goal is still debatable. Some authorities advocate self-etching 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 esthetic dental restorations. It is worth noting that 50% of clinical performance of dental cements is influenced by operator variables<sup>1</sup>, including an exacting clinical technique together with mixing, dispensing & 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 onto 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, while bonding implies a closer intimation of the cement with 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 & restoration intaglio surface irregularities measuring 20-100 µm. This mechanism is applicable for all dental cements

2. Micromechanical 'adhesion' by engaging finer surface irregularities < 2 µm created by etching, air abrasion, and usually in combination with a dentine bonding agent by formation of a hybrid layer (0.5µm to 10µm)
3. Chemical (molecular) adhesion is the paragon of 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 is called the cement-tooth interface. On the opposing side is the artificial restoration, termed the cement-restoration interface. 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, accounting for adhesive failure, while cohesive failure is breakdown of the cement or fracture of the tooth or the restoration (Fig.1).

A tight and secure seal is essential for preventing microleakage between the concealed interfaces beneath the bulk of the restoration, as well as 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 resist these forces for maintaining 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 1). The latter are further subdivided into conventional resins (CR) and adhesive resins (AR).<sup>2</sup> True AR are only those that contain the monomers MDP (10-methacryloyloxydecyl dihydrogen phosphate) or 4-META (methacryloxyethyl trimellitate anhydride),<sup>3 4</sup> e.g. MaxCem Elite (Kerr Corp., USA), Rely X Unicem (3M ESPE, USA), or Panavia 21, Panavia F2, Clearfil SA (Kuraray Dental, Japan).

	Formulation	Varieties	Advantages	Disadvantages	Cementation mechanism: Cement-tooth interface	Cementation mechanism: Cement-restoration interface
Resin-modified glass ionomer (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
Conventional resins (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-operative sensitivity with poor technique	Micromechanical adhesion and/or chemical adhesion	Chemical adhesion
Adhesive resins (AR)	Polymer infiltrated with filler particles with the addition of an adhesive functional	Dual cured, self-etching, self-adhesive, antibacterial, fluoride releasing	High compressive strength, superior optical properties, chemical bonding to cast	Technique sensitive, hydrolytic degradation, shade shift over time, lower bond	Micromechanical adhesion and/or chemical adhesion	Chemical adhesion

	phosphate monomer e.g. MPD (10-Methacryloyloxydecyl dihydrogen phosphate)		metal , alumina and zirconia substructures	strength compared to CR, reduced post-operative sensitivity compared to CR		
--	---	--	--	--	--	--

Table 1: Properties of contemporary permanent dental cements and luting mechanisms at cement-tooth and cement-restoration interfaces

### Choosing 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.

#### Type of restoration

Indirect restorations are categorised as intra-coronal or extra-coronal. In addition, the restoration can be retentive or non-retentive (Table 2). 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) & inlays/onlays. This paradigm shift from retentive to non-retentive restorations has been possible due to advances in dental material technology and 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.

Type of restoration	Intra-coronal	Extra-coronal
Inlay	Non-retentive	
Onlay		Non-retentive
PLV (porcelain laminate veneer)		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 (fixed partial denture)		Retentive
Implant supported crowns and FPD		Retentive

Table 2: Retentive and non-retentive restorations

#### Esthetics restorations

Essentially, any restoration that achieves health and function can also be esthetic. However, the term 'esthetic restorations' usually refers to tooth coloured restorations or prostheses. Esthetic 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 fixed partial dentures (FPD). The major disadvantage of PFM restorations is poor aesthetics at the cervical margins presenting as greying due 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 esthetic 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 tenant for using ceramics in the oral cavity is that they must be supported, either by 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's flaws, which grow into cracks, and if unimpeded, lead to catastrophic fracture of the ceramic. The cracks are propagated by the hostile oral environment; dynamic (occlusal forces) and humidity (stress corrosion). Furthermore, static fatigue is time dependant, which eventually results in breakage (Fig.8). Many strengthening mechanisms are used for halting fracture propagation including reinforcement and infiltration with glasses as well as phase transformation toughening. Preventing fractures also depends on the clinical scenario, method of fabrication of the restoration, and the manufacturing technique & strengthening process of the ceramic.

In order for ceramics to survive in the oral cavity, they must be supported, either by 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 and gains support by adhesive bonding to the underlying tooth substrate. The second, a bi-layer restoration, has a supporting substructure for the esthetic veneering porcelain (Figs.9-11). This substructure can either be metal, or a dense, high strength ceramic core, and these restorations can either be bonded with a resin cement, or luted with RMGI.<sup>5</sup>

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 esthetic type of ceramic, e.g. feldspathic, leucite-reinforced, lithium disilicate and synthetic porcelains (Fig.12). Alumina and zirconia have reduced glass content, reduced translucency & poorer light transmission making them less esthetic, but offering greater strength, e.g. alumina (flexural strength 700MPa) and zirconia (flexural strength >1000 MPa). But due to the 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 esthetic porcelains for both single and multiple unit FPDs. Table 3 summarises the ideal choice of cement depending on the type of restoration and restorative material.

Type of restoration	Restorative material	Ideal cement	Possible cement
Cast metal crowns & inlays, intra-radicular posts, porcelain fused to metal crowns & fixed partial dentures (bridges)	High gold & semi-precious alloys	AR, RMGI	ZP, PC, CR
Maryland/Rochette bridges & 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
Porcelain laminate veneers (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 fixed partial dentures of glass infiltrated alumina, densely sintered alumina, zirconia substructures	Alumina & zirconia based ceramics	AR, RMGI	-
Implant supported crowns or fixed partial dentures	Porcelain fused to metal, or alumina & zirconia based ceramics	AR, RMGI	ZOE

#### Key

ZOE - zinc/oxide eugenol, ZP - zinc phosphate, PC - polycarboxylate, RMGI - resin modified glass ionomer, CRL - conventional resin light-cured, CRD - conventional resin dual-cured, AR - adhesive resins

**Table 3: Choice of cement depending on type of restoration and restorative material**

#### Clinical scenario

The final aspect determining 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.<sup>6</sup> Similarly, a restoration with poor marginal integrity, when a remake is immediately not possible, it may be possible to 'seal' open margins using resin cements.

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

### **Bonding indirect esthetic restorations**

RED bonding indirect esthetic restoration is demanding and technique sensitive. Failure to follow meticulous clinical protocols, or using inappropriate materials, is a recipe for disaster. Furthermore, esthetic 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 esthetic restorations is either a RMGI or resin. Although RMGI offer chemical adhesion to dentine, they are unsuitable for esthetic restorations due to poor mechanical properties, inferior optical properties (profound opacity) making translucent silica-based ceramics appear dull, and a limited selection of shades makes accurate shade making difficult. Furthermore, RMGI suffer from significant post cementation dimensional changes that may fracture weaker uni-layer ceramic restorations.<sup>7</sup> Therefore, the ideal cement for esthetic restorations is a resin, which has superior mechanical, optical and physical properties (Table 1). In addition, newer resin cements also offer low film thickness of 8-21  $\mu\text{m}$ ,<sup>8</sup> comparable to that of RMGI, resulting in reduced microleakage.<sup>9</sup> The disadvantages of resins are hydrolytic degradation, chromatic instability over time, post-operative sensitivity and adherence to a stringent adhesive technique.

The next decision is choosing between adhesive or conventional resin cement. The AR variety of resin cements is inappropriate for esthetic restoration cementation due to their limited shade availability, and the uncontrollable working time of dual-cure setting causes difficulty cleaning excess set cement. Besides, many esthetic restorations require minimal preparation and are usually finished within enamel. Since self-etching AR 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.<sup>10</sup> For these reasons, a CR is therefore the ideal choice of cement for bonding tooth coloured esthetic restorations.

The CR cements are recommended for uni-layered, non-retentive, silica-based ceramics (lower flexural strength 100 MPa 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 (Fig.14a,b,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. CR have numerous shades and try-in pastes for precise shade matching. In addition, light-cured CR can be used for restorations that are 1.5 mm to 2 mm or thinner, while dual-cured CR for thicknesses of >2 mm or opaque cores, thereby increasing their versatility and clinical applications.

NX3 Nexus® (Kerr Corp., USA) is a CR cement, available in a large selection of tooth coloured shades, enabling accurate colour 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 7<sup>th</sup> generation DBA. A major concern with resin cements is ageing colour shift causing unsightly yellowing below translucent, esthetic restorations, especially associated with dual-cured resin cements. 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-etching DBA agents due to the residual acidic inhibition layer that retards or impedes setting of dual or dark-cured resin cements. NX3 has excellent bond compatibility with 7<sup>th</sup> generation self-etch and total-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 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 opacous (e.g. alumina or zirconia cores) to be predictably cemented.

### Dentine bonding agent (DBA)

Achieving RED bonding with CR cements requires use of a DBA. The adhesion mechanism of resins cements/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 25MPa.

OptiBond® XTR (Kerr Corp. USA) is the latest self-etching, universally compatible DBA for direct and indirect restorations. The XTR is a retro-step to the 6<sup>th</sup> generation bonding agents, eliminating many of the drawbacks of existing single component 7<sup>th</sup> generation DBA. Compared to 7<sup>th</sup> generation DBAs, XTR does not require selective etching of enamel margins due 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 a SBS greater than most self-etching systems of approximately 30 MPa. Another problem with SE BDA 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, and SBS to dentine of 37 MPa, and reduced post-operative sensitivity (Fig.17). Finally, XTR can be used with any CR cement for bonding indirect esthetic 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 hydrofluoric acid (HF 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.<sup>11</sup> 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. HF 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 for 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.<sup>12</sup> 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 (Fig.18a,b,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 starts 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 shear bond strengths are achieved when the temporary cement is removed with an effective dentine cleaner in conjunction with using a total-etch technique.<sup>13</sup> Alternately, immediate dentine sealing prior to taking an impression may also enhance bond strengths.<sup>14</sup>

The next stage is isolation, either with rubber dam or intra-sulcular gingival retraction cords. An arid environment is essential for resin-based cements. Rubber dam is the ideal choice for cementing inlays in posterior teeth, but may be unsuitable for anterior teeth since the retaining metal clamps can potentially traumatise the gingival margin, leading to recession, especially on anterior teeth with thin periodontal biotypes. 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, retraction cord may be inappropriate around implant abutments since the cord 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, irrespective if the abutment is dentine, enamel or artificial restorative material, e.g. a composite, amalgam, cast metal & ceramic core, or titanium, alumina & zirconia implant abutments. For conventional resin (CR) cements where the abutment is natural tooth substrate, pre-treatment involves application of a DBA, i.e. self-etching or total-etching. 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,<sup>15</sup> polymerisation shrinkage during the setting reaction, and disintegration of the cement due to fatigue and thermocycling. For this reason, auto-mixing dispensers and pre-capsulated cartridges are ideal for a smooth, reduced porosity mix.<sup>16</sup> Depending on the restoration, the cement is either dispensed onto 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 viscosity cements. Excess cement is immediately mopped, and floss is used to clear 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 & 10 seconds for LED lights of 800 mW/cm<sup>2</sup>). 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 chlorhexadine 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; cementation of a ceramic inlay (Figs.19-32) and PLVs (Figs.33-45).

### 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 choosing the most appropriate cement depending on the type of restoration, the restorative material and the prevailing clinical situation. For esthetic tooth coloured restorations, the ideal choice is RED bonding with conventional resin cements. It is often quoted 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, embarrassing, and while clinical judgement may be forgiven, the patient may not be so forgiving.

Figures

- Fig. 1 – *Cementation mechanism: two interfaces are created between the tooth and restoration – cement-tooth interface and cement restoration interface*
- 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 and 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*
- 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. 8 – *Delaminating of the veneering porcelain on the distal abutment of a fixed partial denture*
- 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 support an overlying esthetic veneering porcelain*
- Fig. 12 – *All-ceramic crowns fabricated from silica-based ceramics, which are the most esthetic type of indirect restorations*
- Fig. 13 – *Porcelain laminate veneers are delicate restorations requiring careful handling to prevent inadvertent breakage during the cementation procedure*
- Fig. 14 a, b & c – *Applying a silane-coupling agent onto the fitting surface of a silica-based ceramic restoration forms silane-silica bonds resulting in chemical adhesion at the cement-restoration interface*
- Fig. 15 – *Poor enamel etching pattern with a 7<sup>th</sup> generation DBA*
- Fig. 16 – *Profound enamel etching pattern with OptiBond® XTR*
- Fig. 17 – *OptiBond® XTR has deeper penetration into the dentine tubules with a reduced film thickness of only 5 µm, compared to 35 µm of other self-etching (SE) bonding agents*
- Fig. 18 a, b & c – *OptiBond® XTR incorporates an adhesive monomer and is copiously applied to the fitting surfaces of ceramic restorations or achieving chemical adhesion at the cement-restoration interface*

Inlay case study (Figs.19-32)

- Fig. 19 – *Cavity preparation for an inlay in maxillary first molar*
- Fig. 20 – *Impression of inlay cavity using an addition silicone impression material*
- Fig. 21 – *Temporary restoration in-situ*

- 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
- Fig. 25 – Pre-treatment of intaglio surface: etching with hydrofluoric acid
- Fig. 26 – Pre-treatment of intaglio surface: rinsing off hydrofluoric acid & 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 – 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 choosing 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 dringy 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 chosen shade of light cured NX3 is dispense onto the inlay, or directly into the prepared cavity avoiding introducing air blows
- Fig. 32 – Cementation technique: after mopping 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

#### PLV case study (Figs.33-45)

- Fig. 33 – Dento-facial view showing poor esthetics of the maxillary central incisors
- Fig. 34 – Pre-operative defective, discoloured and poorly contoured resin composite fillings on the maxillary central incisors
- Fig. 35 – The left central incisor is facially inclined and overlapping 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 esthetics, 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 – Chair-side fabricated acrylic temporary veneers using the vacuum stent of the wax-up
- 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 surround dentition and impeccable gingival health*

*Fig. 42 – Post-operative incisal view showing the pseudo-realignment of the left central incisor*

*Fig. 43 – Post-operative dento-facial view (compare with Fig.33)*

*Fig. 44 – Pre-operative facial view*

*Fig. 45 – Post-operative facial view. Notice elimination of the left central incisor imbrication over the left lateral incisor*

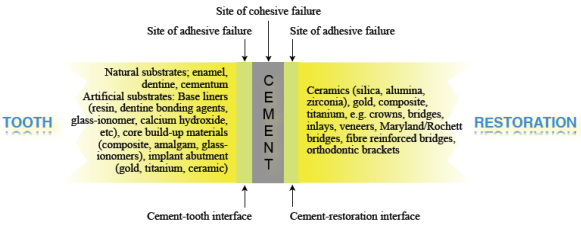


Fig. 1



Fig. 2



Fig. 3

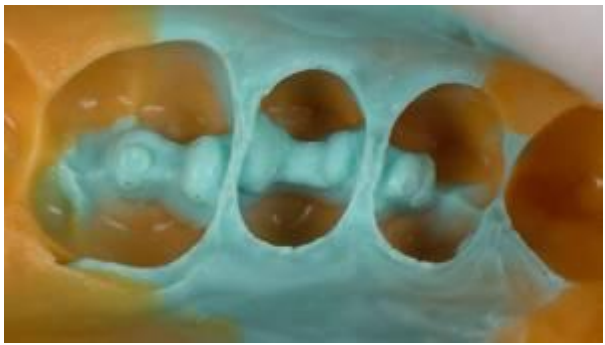


Fig. 4

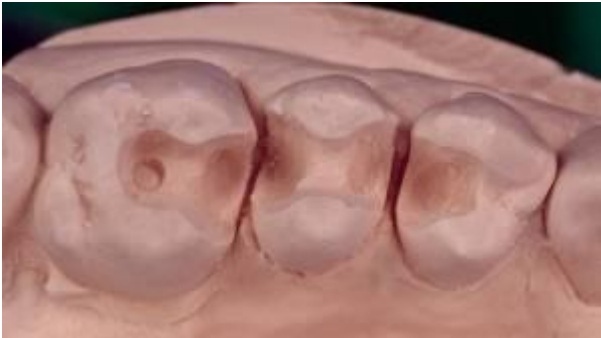


Fig. 5



Fig. 6



Fig. 7



Fig. 8



Fig. 9

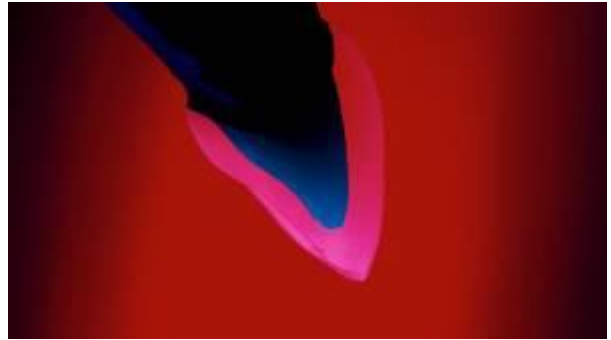


Fig. 10

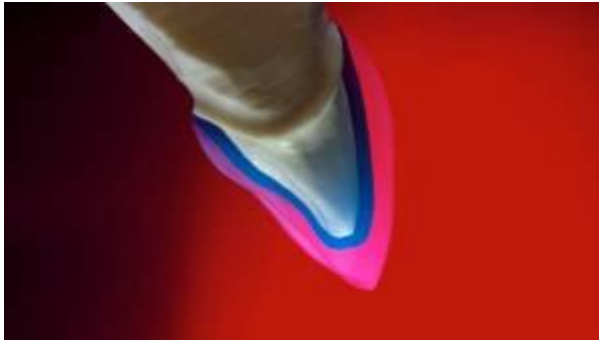


Fig. 11

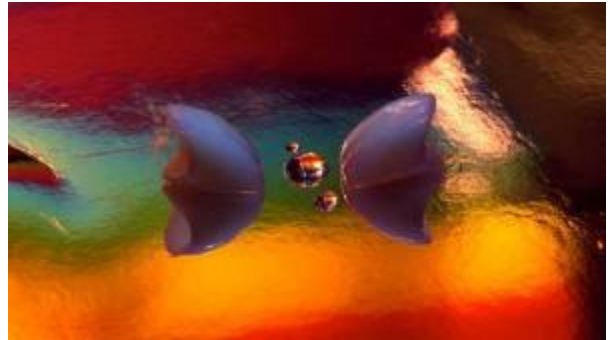


Fig. 12



Fig. 13



Fig. 14a

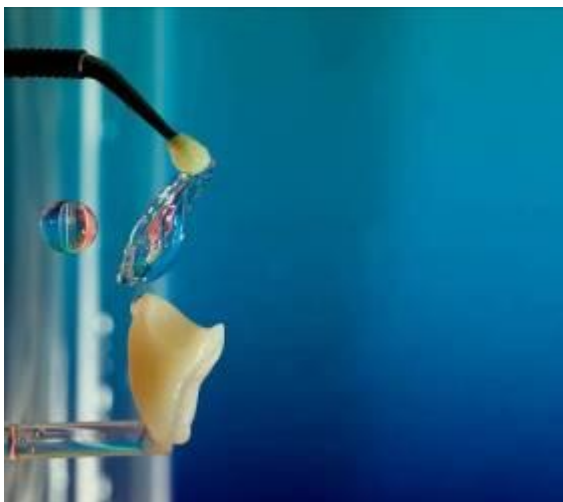


Fig. 14b

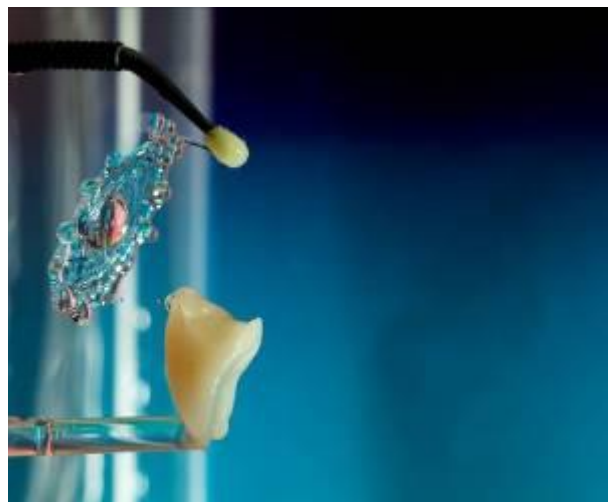


Fig. 14c

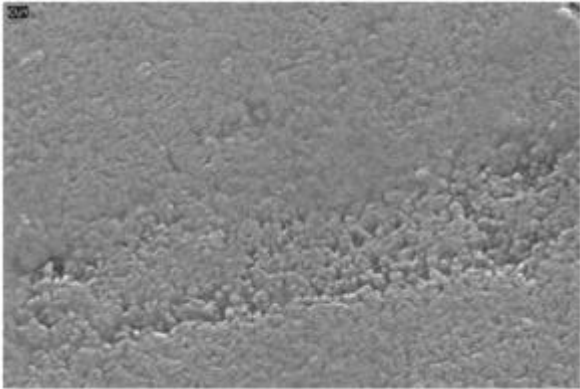


Fig. 15

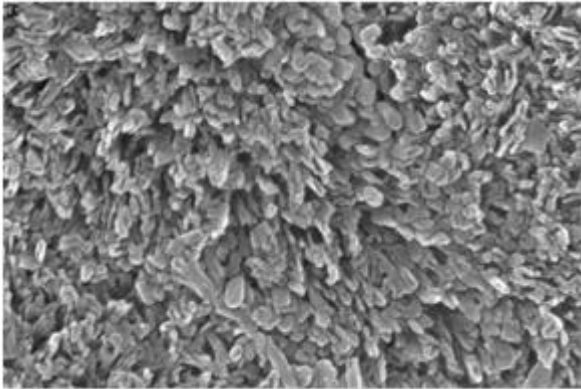
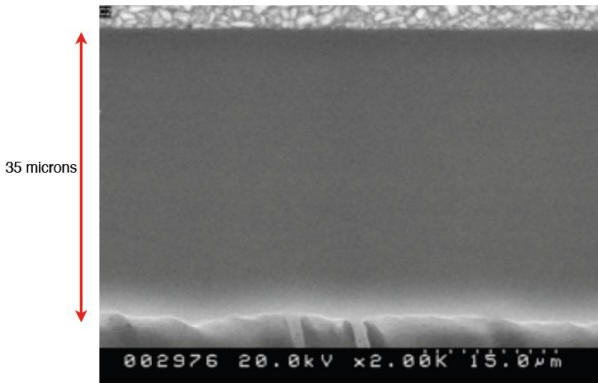


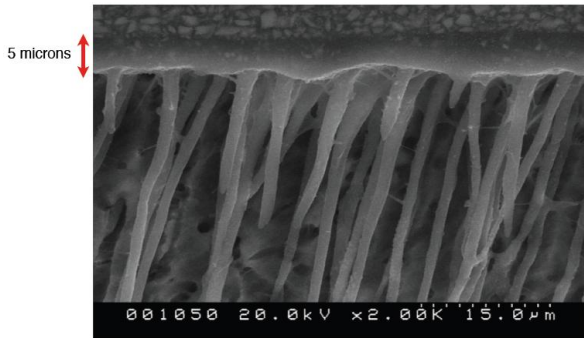
Fig. 16



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



Fig. 18a



OptiBond XTR- thinner film thickness of 5 microns (SEM 2000X)

Fig. 17

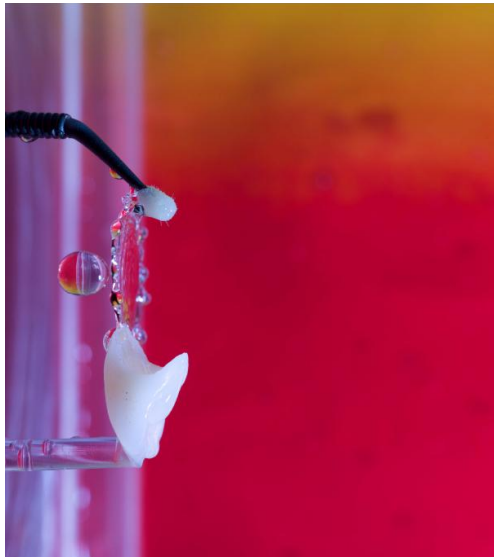


Fig. 18b

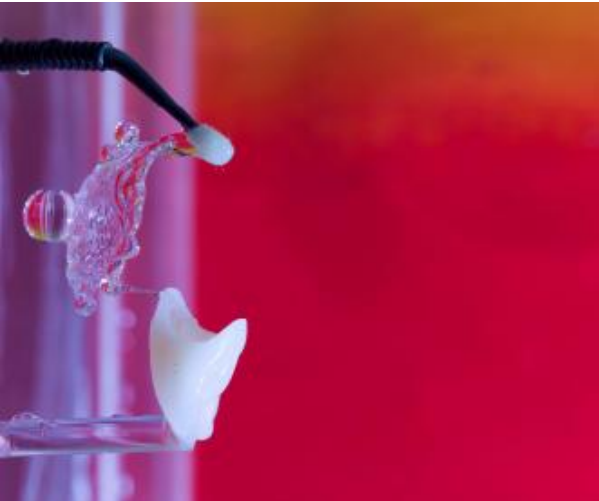


Fig. 18c



Fig. 19



Fig. 20



Fig. 21



Fig. 22

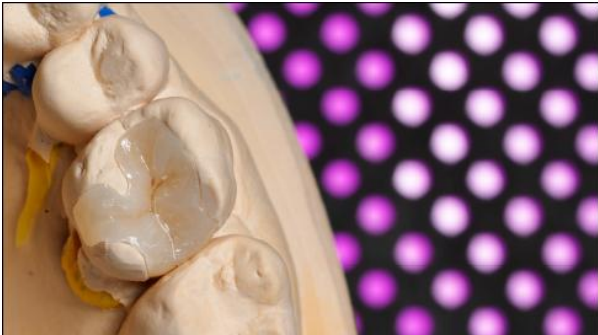


Fig. 23

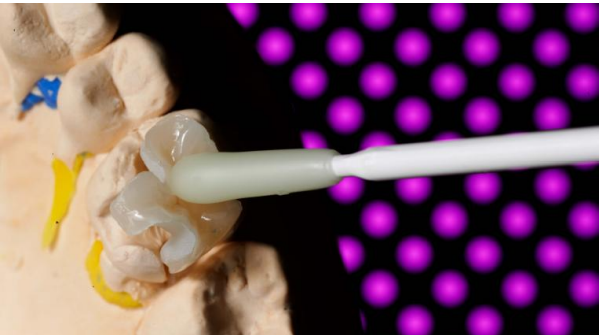


Fig. 24

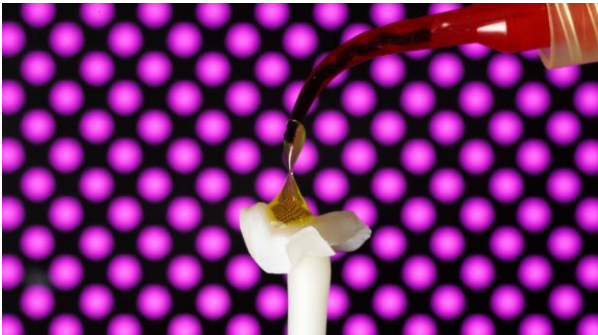


Fig. 25



Fig. 26



Fig. 27



Fig. 28



Fig. 29



Fig. 30



Fig. 31



Fig. 32



Fig. 33



Fig. 34



Fig. 35



Fig. 36

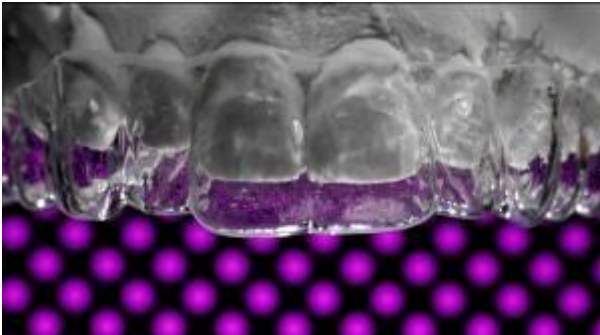


Fig. 37



Fig. 38



Fig. 39



Fig. 40



Fig. 41



Fig. 42



Fig. 43



Fig. 44



Fig. 45

- 
- <sup>1</sup> Bayne SC. Dental cements for luting and bonding. *Operative Dentistry* 2004
  - <sup>2</sup> Hill EE. Dental cements for definitive luting: a review and practical clinical considerations. *Dental Clin North Am* 2007;51(3):643-58,vi
  - <sup>3</sup> Blatz MB, Oppes S, Chiche G, Holst S, Sadan A. Influence of cementation technique on fracture strength and leakage of alumina all-ceramic crowns after cyclic loading. *Quintessence Int.* 2008;39(1):23-32
  - <sup>4</sup> Park JH, Duarte S Jr, Hernandez A, Blatz MB, Sadan A. In vitro shear bond strength of dual-curing resin cements to two different high-strength ceramic materials with different surface texture. *Acta Odontol Scand* 2009;Jul 4:1-10
  - <sup>5</sup> Al-Wahandni AM, Hussey DL, Grey N, Hatamleh MM. Fracture resistance of aluminium oxide and lithium disilicate-based crowns using different luting cements: an in vitro study. *J Contemp Dent Pract* 2009;10(2):51-8
  - <sup>6</sup> Baltzer A. All-ceramic single-tooth restorations: choosing the material to match the preparation-preparing the tooth to match the material. *Int J Comput Dent* 2008;11(3-4):241-56
  - <sup>7</sup> Federlin M, Schmidt S, Hiller KA, Thonemann B, Schmalz G. Partial ceramic crowns: influence of preparation design and luting material on internal adaptation. *Oper Dent* 2004;29(5):560-70
  - <sup>8</sup> Kramer N, Lohbauer U, Frankenberger R. Adhesive luting of indirect restorations. *AM J Dent* 2000;13:60D-76D
  - <sup>9</sup> Albert FE, El-Mowafy OM. Marginal adaptation and microleakage of Procera ALLCeram crowns with four cements. *Int J Prosthodont* 2004;17(5):529-35
  - <sup>10</sup> Ibarra G, Johnson GH, Geursten W, Vargas MA. Microleakage of porcelain veneer restorations bonded to enamel and dentine with a new self-adhesive resin-based dental cement. *Dent Mater* 2007;23(2):218-25
  - <sup>11</sup> Graiff L, Piovan C, Vigolo P, Mason PN. Shear bond strength between feldspathic CAD/CAM ceramic and human dentine for two adhesive systems. *J Prosthodont* 2008;17:294-9
  - <sup>12</sup> Donovan TE. Factors essential for successful all-ceramic restorations. *JADA* 2008;139:14S-18S
  - <sup>13</sup> Sarac D, Bulucu B, Sarac S, Kulunk S. The effect of dentine-cleaning agents on resin cement bond strength to dentine. *JADA* 2008;139:751-758
  - <sup>14</sup> Paul SJ, Schärer P. The dual bonding technique: a modified method to improve adhesive luting procedures. *Int J Prosthodontics Restorative Dent* 1997;17(6):536-545
  - <sup>15</sup> Nomoto R, Komoriyama M, McCabe JF, Hirano S. Effect of mixing method on the porosity of encapsulated glass ionomer cement. *Dent Mater* 2004;20(10):972-8
  - <sup>16</sup> Alexandra D, Vesna B, Zorica M. Porosity of different luting cements. *Dent Mater* 2007;23(6):674-678