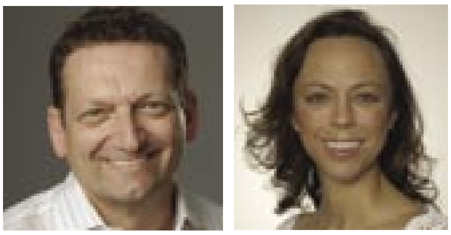
Ceramic veneers in general dental practice Part two: Choice of materials

Philip Newsome and Siobhan Owen explore the materials available for ceramic restoration and bonding the restoration to the underlying tooth



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Introduction

The first paper in this series explored the decision-making process behind the selection of ceramic veneers. Part two explores the materials available for a) the ceramic restoration itself and b) bonding that restoration to the underlying tooth.

Ceramic veneer materials

Compared to the time when veneers were introduced as a truly credible treatment option in the early 1980s there exists today a far wider choice of different ceramic systems. An understanding of the basic structure of the various dental ceramics is important because their physical properties are a result of their underlying composition and this, accordingly, dictates the most appropriate choice for any given clinical situation. There is considerable confusion amongst many dentists about ceramic choice and it often helps to think about any particular dental ceramic as a composite material sitting at some point on a spectrum comprising at one end an unfilled glassy matrix and, at the other, a virtually wholly crystalline structure with little or no matrix at all. Conceptually, this is very similar to the more familiar resin-based composite restorative materials but with a glass matrix as opposed to one composed of resin:

Predominantly glassy ceramics

At one end of this spectrum are purely vitreous, or glass, ceramics, three-dimensional networks of atoms having no regular pattern to the spacing and characterised by an amorphous structure. Dental ceramics in this category come from a group of mined minerals called feldspar and are based on silica (silicon oxide) and alumina (aluminium oxide) and hence belong to a family called aluminosilicate glasses. In appropriate situations, such feldspathic ceramics can create extremely aesthetic restorations with low opacity/high translucency. Conversely, they are unsuitable for masking dark teeth. Their main drawback though is their poor mechanical properties (Flexural strength of 56MPa) with the result that they are nowadays rarely used as the sole porcelain component of the restoration but as a veneer over a stronger underlying ceramic core.

Particle-filled glasses and glass-ceramics

1) Particle-filled glasses

As one moves along the continuum, filler particles are added in increasing amounts to the base glass matrix to improve mechanical properties and to control optical effects such as opalescence, colour and opacity. The first fillers to be used in dental ceramics contained particles of a crystalline mineral called leucite. This was added (between 17-25% mass) to create porcelains that are thermally compatible during firing with dental alloys and therefore can be fired successfully onto metal substructures. These systems, first developed in 1962 have been so successful that they still comprise over three quarters of all indirect restorations.

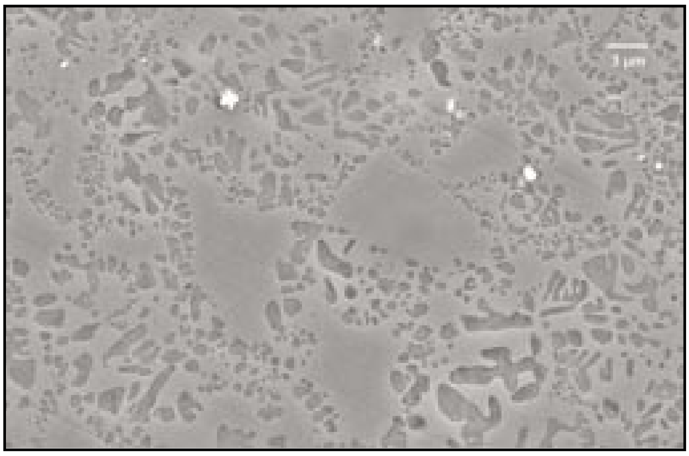

Figure 1: SEM view of Empress Esthetic ceramic

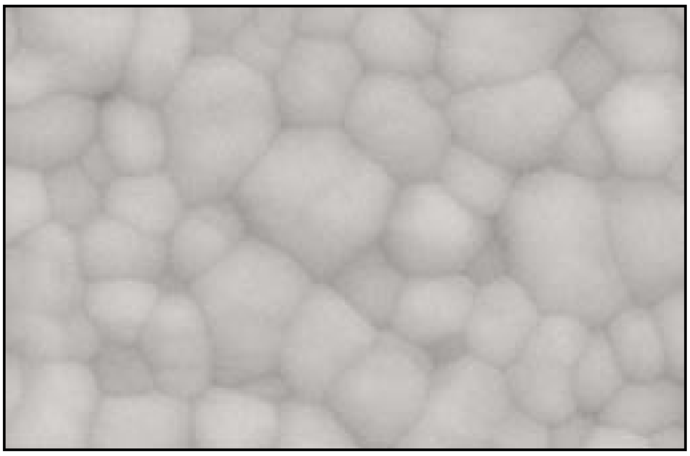

Figure 2: SEM view of Zirconium polycrystalline dental ceramic

Shortly after the development of leucite-filled porcelain the search was on for a ceramic core that could act as a more aesthetic alternative to metal, primarily as all ceramic substructures transmit some light, whereas metals do not. The first successful strengthened substructure ceramic was made of feldspathic glass filled with particles of aluminium oxide (McLean 1965).

Later on, leucite was used at much higher concentrations (40-55% mass) than those needed for metal-ceramics and in a system in which the ceramic is pressed into a mould at high temperatures resulting in reduced porosity and excellent fit e.g. Empress 1 and more recently Empress Esthetic (Ivoclar Vivadent) (Figure 1) and Finesse All-Ceramic (Dentsply). There are two major benefits to using leucite as a filler in dental ceramics (Kelly 2004). Firstly, leucite's index of refraction is close to that of feldspathic porcelain, thus maintaining some translucency and secondly, leucite etches at a much faster rate than the base glass, and it is this 'selective etching' that creates a multitude of tiny features for resin cements to enter and create a strong micro-mechanical bond. Restorations of this type exhibit much improved flexural strength as compared to basic feldspathic porcelain (160-300MPa) as a result of the almost perfect distribution of the leucite crystals within the glass matrix. This is achieved without any significant reduction in translucency.

2) Glass ceramics

The filler particles just described tend to be added mechanically to the glass, for example by mixing together with the glass powder before firing. More recently, an approach has been developed in which the filler particles are grown inside the basic glass restoration after it has been formed. In this approach the glass is given a special heat treatment (ceraming) causing the precipitation and growth of the crystals within the glass. The fillers are derived chemically from atoms of the glass itself. The first such glass-ceramics, as they are referred to, was Dicor (Dentsply) and this was followed by a glass-ceramic containing 70% crystalline lithium disilicate, Empress 2 and more recently Empress E-max (Ivoclar-Vivadent). The structure of these porcelains increases flexure resistance to 320-450 MPa as result of the densely distributed elongated crystals which increase in size after pressing. Such porcelains are used to make the restoration's inner coping which is then covered with a more aesthetic porcelain.

Polycrystalline ceramics

At the other end of the spectrum to the predominantly glassy ceramics are the polycrystalline ceramics that contain densely packed atoms with little or no vitreous glassy 'matrix' phase. This arrangement results in restorations which are more difficult to drive a crack through in comparison to the less dense and irregular linkages found in glass structures. As a consequence, polycrystalline ceramics are generally much tougher and stronger than glassy ceramics. They are however much more opaque and more difficult to process into complex shapes than are glass ceramics. It was only with the introduction of computer-aided manufacturing that well-fitting prostheses made from polycrystalline ceramics became possible. In general these systems use a 3D data set representing the prepared tooth or a wax model of the desired

Figure 3: The opacity and great strength of zirconium-based ceramics makes them ideal for use as internal copings in posterior crowns and bridges

substructure. There are two basic types of polycrystalline dental ceramics currently available based upon their component crystals:

1) Aluminium oxide

With aluminium oxide content as high as 99% these materials offer extremely high flexural strength – 680MPa in the case of Procera Alumina (Nobel Biocare). The Procera system was developed by Andersson and Oden (1993) and provides a solution when restorations need to exhibit high strength and aesthetic concerns are not paramount. The manufacture of these restorations uses a scanning process to machine the densely-sintered ceramics and demands very careful tooth preparation if errors in scanning are to be avoided.

2) Zirconium oxide

Zirconium oxide is a polycrystalline material with a tetragonal structure partially stabilized with yttrium oxide yielding an almost total absence of structural porosities (Figure 2). The result is great strength and fracture resistance (900MPa) and once again, as a consequence of its high opacity this material is used primarily as an internal coping for crowns and bridgework (Figure 3) Examples include Cercon (Dentsply), Lava (3M) and Procera Zirconia (Nobel Biocare).

Choosing the right porcelain

It should be clear by now that there is no single ceramic that is suitable for every clinical situation requiring ceramic veneer(s). In order to make a rational decision one needs to ask the following types of question:

- Does the veneer need to mask tooth discolouration? If so, how severe is this discolouration?
- What is the functional loading on the new restoration?
- Does the patient exhibit signs of tooth wear or parafunctional habits?

By balancing the requirements for aesthetics, strength and avoidance of further tooth wear, one can start to choose a porcelain that is most suitable for any given clinical scenario. Fundamentally, the rationale driving this choice is based on an assessment of the need for translucency versus opacity and on the demands on the strength of the restoration/tooth unit. A further consideration is the abrasiveness of the particular ceramic against natural tooth structure. Ideally, this should match that of natural tooth enamel. It is this interplay between light transmission, strength and clinical requirements which must be considered when choosing the type of porcelain to be used (Fons-Font et al 2006). For example, in many clinical situations, there is a need to mask deep discolourations and therefore a highly opaque porcelain is desirable as is the ability to deliver this level of opacity while still maintaining a thin cross-section and hence the porcelain should also be very strong. In this case an aluminium oxide ceramic such as Procera would be appropriate. In other clinical situations there is less need for such a high degree of opacity and, in fact, this can be highly undesirable when no change of tooth colour is required and a reinforced high-resistance feldspathic porcelain such as Empress Esthetic would be suitable. Where strength is the prime concern, as in cases where occlusal loading is high, then clearly a high-strength porcelain is required and the accompanying higher opacity means that aesthetics may have to compromised. Again an aluminium oxide ceramic would be appropriate although, as was discussed in Part One, the decision to use veneers in such cases in the first place should be thought through very carefully.

As far as abrasiveness is concerned, low-fusing ceramic (Empress 2, Finesse, Procera) has been shown to cause less wear of opposing teeth than conventional porcelain (Christenson 2000). It is also well documented that rough, abraded porcelain is extremely damaging to opposing unrestored teeth. One recent study compared various ceramic materials with gold (Elmaria 2006). While gold, unsurprisingly, proved to be the least abrasive, polished low-fusing porcelains also resulted in minimal tooth wear. This suggests that should intra-oral adjustment be required, thorough polishing will lead to an acceptably smooth surface.

What about the idea of using zirconium to make veneers? As was discussed earlier, they are very strong compared to more traditional ceramics and in theory at least, its opacity might be useful when trying to mask heavy discolouration. Unfortunately, as a material for laminate veneers, it has two major drawbacks. The first problem is that, while being very strong, it is also extremely opaque and is therefore only suitable for use in copings and substructures. The second problem is that the fitting surface of a zirconium restoration cannot be etched in the way that materials like Empress or Procera can be and so cannot rely on micro-mechanical

Figure 4: This patient had lost much enamel through over-exposure to soft drinks. Ceramic veneers were deemed inappropriate given the lack of sufficient enamel substrate for bonding, coupled with the need to increase vertical dimension. Empress dentine-bonded crowns were placed instead

retention. With these two factors in mind it becomes clear why zirconia veneers simply won't work. The restoration is far too thin to allow a core of zirconia plus a veneering, more aesthetic, translucent porcelain, and secondly there would be inadequate retention as a result of the inability to etch the fitting surface. In short they would look terrible and would probably fall off quite quickly!

Bonding materials

Although porcelain laminate veneers are fragile and require great care while being handled, once cemented the combined porcelain/luting composite/tooth unit is very strong (Stacey 1993). Stacey showed that the strength of this combined bond (63MPa) was significantly higher than the separate composite/etched enamel (31MPa) and luting composite/etched and silanised porcelain (33MPa) bond strengths. Other studies have confirmed this finding that adhesive cementation increases the strength and resistance of ceramics to fracture (Nathanson 1991 and Chen 1998).

Surface treatment of the ceramic

One of the main factors behind the successful bonding of porcelain veneers has been recognition that the way that the ceramic surface is treated is vital. Various techniques have been suggested including micro-etching with aluminium oxide particles and chemical preparation of the porcelain surface by etching with orthophosphoric or hydrofluoric acid (Oh 2003, Ozcan M 2003). Treatment with hydrofluoric acid has been shown to produce the best bond strengths, particularly when combined with the use of 3-methacryloyl oxypropyl trimethoxy silane coupling agent (Filho 2004). The etching process is carried out in the laboratory but silanisation is better postponed until just before bonding to the tooth. Single component systems (silane in alcohol or acetone) are the simplest to silanate. With the two-component systems the silane is mixed with an aqueous acid solution to hydrolyse the silane so that it can react directly with the porcelain surface. If it is not used within several hours the silane will polymerise to an unreactive polysiloxane thus reducing the bond strength (Suh 1991). With such two-component systems the coupling agent should therefore be applied immediately before cementing the veneer.

Composite luting cement

The composite luting cement is the weakest link in the tooth/cement/veneer chain for a number of reasons:

- Polymerisation shrinkage which may create a marginal gap with loss of marginal seal.
- Wear of the composite luting cement because the wear resistance is low and this is more pronounced when gaps are increased.
- Dissolution of the resin matrix in oral fluids.

Light-cured and dual-cured resin luting cements are available for use with veneers. Wholly light-cured materials are to be preferred because of greater control of the setting process and because dual-cure cements are susceptible to colour change over time. The aromatic tertiary amines used in dual cure resins are thought to readily oxidise to form colored oxidised products whereas the amines used in light-cured materials are more resistant to such oxidation (Lu and Powers 2004).

Bonding to enamel and dentine

The notion of etching enamel to accept resin luting cement is very well accepted and this will be familiar to all dentists. It has taken more time for the idea of dentine bonding to be accepted (Perdigao et al 1999). In principle, for dentine bonding to be effective the dentine surface must be conditioned and then primed to form a hybrid layer onto which an adhesive is placed and which copolymerises with the composite luting agent. The first bonding agents used a four-step process to etch enamel, etch dentine, prime the dentine followed by application of the adhesive. This evolved into the so-called ‘total-etch’ system in which the dentine and enamel are etched simultaneously while the prime and bond remain separate components. More recently ‘self-etch bonding’ systems have been introduced which combine all the steps. These have had a mixed reception (Tay 2005) despite the obvious convenience they represent, claims that they reduce post-operative sensitivity and despite manufacturers’ claims of bond strengths equivalent to those with enamel.

As far as ceramic veneers are concerned, the advent of dentinal adhesives has created the illusion that veneers bonded to dentine will be as successful as those bonded to enamel, thus encouraging dentists to use the technique in a wider range of clinical situations. Why is it that practitioners increasingly feel the need to extend veneer preparations into dentine and interproximally to the extent of breaking contacts with adjacent teeth? The main reasons would seem to be the ability of a thicker layer of porcelain to hide dark discolourations and mildly crowded teeth as well as greater ease of handling. Technicians also tend to find making thick ceramic veneers less challenging than very thin ones. As a result, tooth reduction into enamel alone can lead to bulky veneers and so in many cases the dentist will cut further into the tooth to prevent overbuilding of the final restoration. Unfortunately, in spite of the considerable advances made in the field of dentine bonding, the longevity of a veneer continues to be a direct function of the amount of enamel substrate supporting it (Friedman 2001). There is an almost complete lack of clinical evidence to support the technique of bonding veneers to dentine as opposed to enamel. As Swift (2006) has observed, recent reports of 50% failure at six years and 34% fracture is disturbing when compared with 93% to 100% success rates of 15 years observation in the 1980s i.e. at a time when veneers were universally bonded almost entirely to enamel.

Why is this the case when reported dentine bond strengths appear to match those achieved when bonding to enamel? Most longitudinal studies of dentine adhesives are performed using composite restorations directly-bonded onto non-carious Class V lesions where the strength and elastic modulus of the teeth are hardly affected (Peumans 2005). The difficulty of dentine bonding in the context of ceramic veneers is the disparity in flexibility between a rigid veneer and less rigid dentine. As Barghi and Overton (2007) have observed, removal of facial enamel or selection of teeth without facial enamel for veneer restorations is an attempt to match up high elastic modulus porcelain with lower elastic modulus dentine. It is predictable that functional loading of the veneered tooth will transfer this energy to the interface resulting in debonding or cracking in the porcelain. For this reason, the smaller the amount of enamel available for bonding and the greater the amount of dentine that is exposed during laminate veneer preparation the greater the likelihood that a full coverage restoration should be chosen. Such restorations rely far more on conventional retention form in addition to any retention gained through dentine bonding (Figure 4). The subject of the difficulties of bonding ceramic veneers to dentine will be explored further in the next paper in this series which looks at tooth preparation.

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