Understanding and selecting ceramics

This month, Chris Parker joins Philip Newsome, David Reaney and Siobhan Owen to look at one of the most common dilemmas facing dentists, namely ceramic selection.

The demand for aesthetic dental restorations continues to grow, and fewer patients are now content with ceramo-metal (porcelain-fused-to-metal – PFM) restorations and even less thrilled with all-metal ones, however much we talk about longevity and durability.

The aesthetic advantages of all-ceramic systems are obvious and yet many dentists experience difficulty knowing which ceramic to use in any given clinical situation. Ceramic systems have grown in complexity over the years and now offer an extremely wide range of options and choices. This is good in one sense as virtually every clinical scenario is catered for, but not so good in another that the ranges are so comprehensive that it can be somewhat daunting to the practitioner who has to select, prepare the tooth correctly, direct the laboratory and finally choose an appropriate luting cement. Long gone are the days when PFMs, cemented with zinc phosphate, were the only ‘aesthetic’ option.

The main goal of this article is not to overload you with scientific information but simply to explain currently available ceramic systems and hopefully make the task of selection less daunting.

Understanding ceramics

We find it helpful 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 a resin one.

Predominantly glassy ceramics

At one end of this spectrum are largely 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. Such feldspathic ceramics exhibit low opacity, high translucency and low heat conductivity, and are hard, chemically inert and biocompatible. While this high degree of translucency means they are unsuitable for masking dark teeth, their main drawbacks are their poor mechanical properties (flexural strength of 56MPa) and the high degree of shrinkage that occurs during firing. The result of all this is that they are nowadays never used as the sole porcelain component of the restoration but rather as a veneer over a stronger underlying core material.

Particle-filled glasses

As one moves further 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 introduction of the particles into the glass matrix can be achieved in a number of different ways, and the process used will affect the properties of the material and so influence material choice.

Polycrystalline ceramics

At the other end of the spectrum to the predominantly glassy ceramics are the polycrystalline ceramics, which contain densely packed atoms with little or no vitreous glassy ‘matrix’ phase.

This arrangement results in restorations that 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 glass ceramics.

It was only with the introduction of computer-aided manufacturing (CAM) that well-fitting prostheses made from polycrystalline ceramics became possible. In general, these systems use a three-dimensional data set representing the prepared tooth or a wax model of the desired substructure.

There are two basic types of polycrystalline dental ceramics currently available based upon their component crystals – namely aluminium oxide and zirconium oxide.
Clinical

Figure 1: This reflection electron microscope (REM) image of leucite-filled glass ceramic clearly shows the leucite crystals distributed among a glassy matrix. These are not so tightly packed and therefore allow light to pass through the structure.

Figures 2a and 2b: A leucite ceramic is the ideal choice of material when individual restorations, as with these four anterior veneers, require excellent aesthetics and where occlusal loading is not excessive.

Figure 3: Empress Esthetic is available in a wide range of translucencies as shown here – highly translucent ET, increased opacity EO and shaded TC.

Figure 4: Specially designed shade guides assist in determining the shade of the prepared tooth.
A quantum leap in ceramics

To understand where we are currently, we need to go back to the early 1980s. PFM s had been a dominant force for over 20 years and had changed dentistry forever. Patients and dentists alike, however, were growing increasingly concerned about the familiar shadowing or metal shine-through at the cervical margins and the general lack of translucency of anterior restorations. Dentistry was ready for another quantum leap.

Particle-filled glasses

Leucite reinforced glass ceramics

The IPS-Empress system was developed at the University of Zurich in the early 1980s and brought to market as IPS Empress 1 (subsequently renamed Empress Esthetic in 2004) by Ivoclar Vivadent in 1990. Other examples include Authentic (Jensen), Finesse (Dentsply) and OPC (Zahn).

In the above scheme, these are particle-filled glasses, the particles being crystals of leucite (Figure 1). The introduction of these crystals create a castable glass ceramic using the familiar lost-wax process. The shape of the restoration is carved in wax, the pattern invested and heated in a furnace. A ceramic ingot is then heated to 1,200°C and forced under pressure into the mould. Using this technique it was possible to create either:
1. A monolithic restoration, i.e. made from one ingot that can

Figure 5: A selection of Empress CAD ingots

Figure 6: This REM image of a lithium disilicate ceramic clearly illustrates the tightly packed particles, which permit less light to pass through than is the case with leucite ceramics. The material is therefore less translucent but exhibits improved physical properties

Figure 7: In spite of the different shades and translucencies of the underlying preparations, lithium disilicate ceramic is capable of producing highly aesthetic final restorations
then be characterised by painting on its surface high chroma pigments, followed by glazing to seal the surface, or
2. A coping onto which a more translucent enamel veneering porcelain is pressed.

The introduction of leucite crystals in conjunction with the injection-moulding process reduced the risk of micro-crack formation and improved flexural strength (ranging from 95MPa to 180MPa, as compared with the 56MPa of feldspathic porcelain). The result is superb aesthetics, excellent marginal integrity and biocompatibility combined with ease of fabrication and an etchable fitting surface allowing bonding using silane/ adhesive resin. Indications are, however, rather limited – to inlays/onlays and anterior single-unit crowns and veneers (Figures 2a and 2b) – and great care must be exercised in case selection and treatment planning.

One notable feature of leucite-based ceramics is their high translucency, although this can be varied according to different clinical situations (Figure 3). The overall aesthetic result of an all-ceramic restoration is influenced by the following factors:

• Shade of the preparation
• Shade of the restoration (ingot/block, layering material)
• Shade of the cementation material.

Apart from restorations using zirconium frameworks (see later), which by their very nature are highly opaque, the final shade of a ceramic restoration is strongly influenced by the underlying preparation shade. Therefore, as well as recording the desired final shade, the shade of the prepared tooth should be recorded, especially when this is severely discoloured (Figure 4).

Leucite ceramic CAD/CAM systems

The discussion so far has focused on restorations made using traditional impressions sent to a laboratory and fabricated by skilled technicians. However, leucite ceramics are now available in CAD/CAM form, thus allowing aesthetic restorations to be milled chairside (using technology such as CEREC) and placed immediately (Figure 5).

This approach has the convenience of ‘one-stop’ restorations, albeit with the need for the prescribing dentist to carry out chairside polishing, staining and glazing.

In all other respects, these restorations are essentially the same as their laboratory-made counterparts in terms of mechanical properties, clinical indications, preparation requirements and luting protocols. Subsequent developments of the CAD theme include:

• Polychromatic blocks featuring a smooth transition between dentine and incisal areas, thus creating natural-looking results. This is aided by a combination of a high level of chroma in the cervical area and incisal translucency. These effects obviate the need for further characterisation in many cases
• Variable translucency blocks, which take the ability to customise chairside-made restorations even further by offering high translucency and lower brightness values, and vice versa.

The latter are especially useful in those cases where there is a likelihood of a dark underlying preparation ‘greying’ the final restoration.

Lithium disilicate ceramics

In 1989, a glass-ceramic (e.g. IPS Empress 2, subsequently renamed e.max) containing 70% crystalline lithium disilicate (Figure 6) was developed with the specific goal of improving upon the mechanical properties of leucite ceramics without compromising aesthetics, and as a result flexural strength rose to 360-400 MPa. The method of fabrication was essentially the same – i.e. pressed ceramic – and, again, restorations could be either monolithic or bi-layer, layered with a veneering ceramic specially designed for the lithium disilicate.

The improved physical properties saw these ceramics being recommended for short span anterior/premolar bridges in those cases with sufficient space present to house a 4mm by 4mm connector.

The high crystal density also permits greater masking of discoloured teeth than do the more translucent leucite ceramics (Figure 7). Indeed, more opaque ingots have been specifically developed to cope in such clinical situations.

Lithium disilicate CAD/CAM systems

As with leucite ceramics, lithium disilicate systems are available in CAD form, allowing the creation of restorations at the chairside. Again, the result is comparable with laboratory-made restorations in terms of mechanical properties, while final aesthetics largely depend on the dentist applying stain as and when necessary prior to cementation. It is worth noting that, for ease of milling, these CAD blocks are manufactured and supplied in their weaker lithium metasilicate state, therefore taking on a blue appearance. The milled blue blocks are then fully crystallised in a furnace, which transforms them to their full strength lithium disilicate state.

Polycrystalline ceramics

Aluminium oxide

With aluminium oxide content as high as 99%, these materials offer extremely high flexural strength – between 400MPa and 700 MPa in the case of Procera AllCeram (Nobel Biocare) and In-Ceram Alumina (Vident). These systems provide 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.

Zirconium oxide

Zirconium oxide-based restorations – e.g. Calypso (SCDL), Cercon (Dentsply), e.max ZirCAD (IPS Ivoclar Vivadent), Lava (3M) and Procera All Zircon (Nobel Biocare) – feature a wholly crystalline structure with no glassy matrix at all between the crystals (Figure 8). This makes for an extremely strong and tough structure (1200MPa), but one that is largely opaque and therefore largely only suitable for use as a framework on top of which a veneering ceramic is added.

This veneer can be added by means of either a pressable lithium disilicate ceramic or a highly aesthetic traditional veneering ceramic that, in addition to being used to veneer zirconium frameworks, can be used to veneer frameworks made of a variety of substrate ceramic materials. This is especially useful when different framework/coping materials are used in the same patient, enabling the creation of restorations of uniform aesthetic appearance with the same surface gloss and wear properties (Figure 9).
Clinical

Indications for zirconium-based restorations (which, by virtue of their physical properties and the technical complexity of production and handling, are only available through a dental laboratory) are primarily as individual crown copings and bridge frameworks including very long span bridges (up to 12 units), whereas in previous years only all-metal or PFM bridges were suitable.

Minimally invasive inlay-retained bridges can also be created using a zirconium framework in conjunction with either pressable ceramic veneer (Figure 10).

**Summary**

Using IPS Empress and e.max systems as an example, we have devised a simple decision tree to help you choose the most appropriate ceramic.

1. **Do you intend to use a CEREC machine to make the restoration?**
   If the answer to this is ‘No’, you can immediately rule out the following options (conversely if the answer to this question is ‘Yes’ then you will select one of these):
   - Empress CAD (including Empress CAD Multi and Empress CAD HT and LT)
   - e.max CAD.

2. **Is the restoration a single-unit where aesthetics are of the highest importance?**
   If the answer to this is ‘Yes’, you should select Empress Esthetic (or Empress CAD depending on your answer to Question 1).

3. **Is the restoration a single-unit where aesthetics and restoration strength are of similar importance?**
   Here you should consider using e.max Press (or e.max CAD, again depending on your answer to Question 1).

4. **Is the restoration a fixed bridge?**
   The choice here is between e.max Press (or e.max CAD if using chairside CAD/CAM) or e.max Zir CAD depending on the length of span, and aesthetic and functional requirements. When the span is short and the bridge located in the anterior or premolar region, consider using e.max Press (or e.max CAD if using chairside CAD/CAM). However, when the bridge is located in the molar region or is greater than three units, then e.max Zir CAD is the material of choice. The choice of material in which to veneer the zirconium substructure rests between e.max Zir Press or e.max Ceram. If the bridge has to match with other restorations, then probably the latter is preferable provided the other restorations are veneered using the same material.

**Figure 8:** Zirconium restorations comprise extremely densely packed crystals with no intervening matrix structure. This creates their characteristic strength and opacity

**Figure 9:** e.max Ceram has been used here on different substrates and yet the final appearance remains uniform

**Figure 10:** This three-unit inlay-retained bridge has an e.max ZrCAD substructure and an overlying veneer of e.max.Ceram

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