There have been significant technological advances in the field of dental ceramics over the last 10 years which have made a corresponding increase in the number of materials available. Improvements in strength, clinical performance, and longevity have made all ceramic restorations more popular and more predictable. Despite improvements these restorations are still time consuming, expensive and technique sensitive when compared to conventional porcelain fused to metal. There are however two principal reasons for all-ceramic restorations being favoured by the profession.

**Aesthetics**

With appropriate case selection, a good technician can produce a metal ceramic crown that is as aesthetically pleasing as an all-ceramic restoration. However, most technicians and clinicians will agree that all-ceramic crowns offer more predictable aesthetic results.

**Biocompatibility**

There is an increasing number of patients who require metal-free restorations because of allergy to metals. A true allergic reaction may appear over several years and manifest around the crown margins as gingival inflammation producing unsightly gingival tissues. There are also some patients who are metal phobic. Often influenced by non-dental health practitioners, these patients believe that metal causes systemic problems. Consequently, these patients will still demand the placement of non-metal restorations.

**Which system do I choose?**

The increased number of all-ceramic systems available can make it difficult to choose an appropriate restoration. The different ceramic systems have unique properties and applications that may or may not be suited to a particular clinical situation. Additionally the amount of tooth preparation and the choice of luting cement or bonding system need to be appropriate for the specific system used.

All-ceramic restorations are usually categorised depending on either the type of porcelain (feldspathic, leucite reinforced, low-fusing etc) or alternatively the method of fabrication (fired, cast, or pressed ceramic; or machined materials CAD-CAM etc). These classifications are often confusing. Thus, in the interests of simplicity, all-ceramic restorations may be listed in three groups:

1. The dentine bonded crown
2. Pressable ceramics
3. High alumina or zirconia cores veneered with conventional porcelain.

Generally speaking, as we progress down the list, the ceramic increases in thickness (and inherent strength) and so requires more tooth reduction. There is also an increase in opacity and ability to mask out dark underlying tooth structure. The clinical characteristics shift from that of a porcelain veneer towards that of a conventional metal ceramic restoration.

**The dentine/resin bonded crown/360° veneer**

The dentine bonded crown has been in use for over 15 years. It is defined as ‘a full coverage restoration in which an all-ceramic crown is bonded to the underlying dentine (and any available enamel) using a resin based luting material with the bond being mediated by the use of a dentine bonding system and a micromechanically retentive ceramic surface’ (Burke 1996).

It has a conservative tooth preparation that involves a 0.5mm axial reduction (1mm palatally) with a chamfered margin. The fitting surface of the crown is etched in the laboratory with hydrofluoric acid to provide micro-mechanical retention. A porcelain primer/dual cure resin cement and dentine bonding agent are then used at the cementation stage to complete the bonding process. The thin layer of porcelain is not inherently strong and full strength is not achieved until after cementation. Thus, with this type of crown there can be no trial cement phase. These crowns are only indicated for use in the anterior region and good moisture control is very important during cementation. Deep subgingival margins are, therefore, a contraindication their use.

Minimal tooth preparation is a distinct advantage of the dentine
bonded crown particularly when reshaping proclined or imbricated teeth, where often, the amount of tooth reduction necessary for a conventional crown could result in pulpal exposure. The small amount of tooth reduction means that care must be taken with provisional restorations. It is possible to use a bis-acryl resin (Integrity, Dentsply or Protemp 3M ESPE) which is placed over the prepared tooth in either a pre-op alginate impression or a vacuum formed template made from a diagnostic wax up. The resin can then be allowed to set and contract onto the preparation before any excess material is trimmed away. Usually no provisional cement is needed although a small amount of light cured adhesive resin may be used if necessary (see Figure 2).

Another advantage is that dentine bonded crowns are relatively inexpensive to manufacture. Porcelain is fired onto a refractory die with felspathic porcelain being the most commonly used, but depending on the clinical situation, other types of porcelain may be more appropriate. For example, low-fusing porcelain will potentially cause less wear of the opposing dentition and may be suitable in cases where tooth-wear is a
factor. On the other hand, Fortress (Chameleon Dental, www.miragecdp.com) is a leucite reinforced ceramic system that has the purported advantage of increased fracture resistance due to the leucite crystals. This type of porcelain is a slightly more opaque and may be used to mask very mild underlying discolouration (see Figures 3-6).

**Pressed ceramics**

The hot-pressed leucite reinforced ceramics were introduced around 15 years ago, (Wohlwend and Scharer 1990), the leucite crystals serving to reinforce the glassy matrix and prevent crack propagation. The crystals strengthen the ceramic and make the core more opaque. The most popular systems currently include Empress (Ivoclar Vivadent, Cerpress (Leach and Dillon, www.leachdillon.com) and Matchmaker pressable (Schottlander). In one clinical study, a 97.4% success rate was reported for Empress crowns after three years (Sorensen et al 1998).

Pressable ceramic crowns are made using the lost wax technique; a ceramic ingot of the chosen shade is heated and then pressed into the mould. The final colour is stained (or veneered after cutting back) onto the surface. A particular
advantage of the Cerpress system, is that the core ceramic (Cerpress) and the veneering ceramic (Sensation SL, Leach and Dillon, www.leachdillon.com), have similar thermo mechanical properties. These allow a 360° ‘wrap’ of the veneering porcelain rather than just a surface stain or labial veneer (see Figures 7 and 8).

The fitting surface of the pressed ceramic is etched and it is bonded in situ with dual-curing resin cement. It is possible to mask out some degree of underlying discolouration. However, as this restoration is not completely opaque, it must be used with caution where there are severely discoloured teeth or metal posts and cores. In these situations it is useful to give some indication of the shade of the underlying tooth to the technician, and there are special shade guides available for dark underlying cores. If there is an existing metal post and core that are not to be replaced, it is possible to place a thin covering of very opaque composite resin over the post to mask it out. Alternatively, if a new cast post and core are to be made, then opaque porcelain can be fired onto the core to mask the underlying alloy (see Figures 9–12).

Alumina based systems

This category of restoration employs a high alumina content core which is then veneered with conventional porcelain. The strength and opacity of alumina means that these restorations are similar in nature to the metal ceramic crown. The high strength allows crowns to be placed on molar teeth and some manufacturers claim suitability for short span bridgework (although there is limited clinical evidence available to support this). The high opacity of the core allows dark teeth and metal post and cores to be masked out effectively. The inherent strength of the restoration also allows any type of luting cement to be used although resin based cements are usually recommended. The major disadvantage however, is the large amount of tooth reduction (1.5–2mm) that is required for these crowns. The various systems principally differ in the way the alumina core is made, which in turn influences the physical properties of the final crown.

In-Ceram

In-Ceram (Vita Zahnfabrik, www.vita-zahnfabrik.com) has been commercially available for around 15 years and the manufacturer claims that it is suitable for anterior and posterior crowns and short span bridgework. The system has a two-stage technique for fabricating the core for the crown. Firstly, a sintered porous alumina framework is slip cast onto a duplicate die and then the second stage involves infiltration with glass. Finally, the core is veneered with feldspathic porcelain for the final aesthetics. The In-Ceram core is so dense that conventional etching of the fitting surface with hydrofluoric acid is not possible as the latter does not increase the surface roughness or bond strength to the tooth (see Figure 13).

There are now three types of In-Ceram core based on either alumina, spinell (a mixture of alumina and magnesia) or zirconia. The alumina coping consists of 70% alumina for strength, the spinell coping is not as strong but offers twice the translucency for better aesthetics. The newer In-Ceram zirconia system uses a mixture of zirconia and alumina in order to achieve even more strength. This differs from other zirconia based systems that use zirconia exclusively for the core. A
prospective study of In-Ceram crowns placed in private practice showed a survival rate of 96% after three years with anterior crowns having a higher survival rate (98%) than molars or premolars (94%) (McLaren and White 2000).

Techceram
Techceram (Techceram) all-ceramic crowns rely on a base layer that is manufactured by a ‘flame spraying’ specialist grade alumina powder onto a refractory model before sintering. The base layer is usually 0.5mm thick for crowns and can be translucent or coloured, with eight different shades available. The final aesthetics are achieved with the application of Vita Alpha porcelain. This system is suitable for anterior and posterior single crowns and inlays and has a biaxial flexural strength (ISO 6872) of 300 MPa.

For the dental technician, the principal advantage of this system compared to some of the others available, is that there is no expensive capital outlay for materials or equipment. Only the trimmed die (with shade) needs to be sent to the Techceram laboratory and then the base layer and die are returned to the technician for veneering with porcelain in the conventional manner (see Figures 14-17).

Procera AllCeram
This innovative ceramic was first described by Andersson and Ogen in 1993. Once again it is comprised of a high strength alumina core that is veneered with porcelain. The copy milling process allows the die for the core to be mechanically scanned at a UK lab and the data is sent via the internet to the factory in Sweden where a second (enlarged) die is milled. High purity/high density Al2O3 is then compacted onto the enlarged die and the external shape of the coping is milled before sintering at 1,600°C. The coping is then sent back to the UK lab for veneering with aluminous porcelain in the traditional way. The copings are of uniform thickness of either 0.4 or 0.6mm; the thicker coping having greater strength but requiring more tooth reduction if aesthetics are not to be compromised. The 0.4mm copings are generally used for smaller teeth, for example lower incisors, where extensive tooth preparation is not appropriate.

These crowns are suitable for anterior and posterior restorations and the manufacturers claim that they are suitable for short span bridgework. Compared to the previously mentioned systems, Procera (Nobel Biocare) exhibits the greatest strength in laboratory tests (see Figures 18-21).

Procera crowns may be used when restoring dental implants. However, the fit between the all-ceramic core and the implant abutment is such that permanent cement (as opposed to the usual soft cement) is required. This has implications should maintenance be required for the abutment and this could result in sacrificing the crown if it cannot be dislodged.

Zirconia based systems
The introduction of zirconia based systems brings a further increase in strength. The physical properties demonstrated in laboratory studies have shown them to be superior to the alumina based systems. It is claimed that the newest zirconia systems can be used for anterior and posterior crowns and multiple units.

Differences in construction of the zirconia core vary by brand. The two most popular brands at present both use ‘green state’
soft zirconia. This is either copy milled (Cercon, Dentsply Degudent, www.cercon-smart-ceramics.com), or digitally imaged (Lava, 3M ESPE), to create a core about 20% larger, before final sintering produces shrinkage to fit the die. A third method of manufacture involves milling very hard fully processed, pre-shrunk zirconia to fit the die (DCS Preci-fit, www.poppdental.com). With all three methods the final porcelain is hand layered onto the core.

The early zirconia based restorations suffered from poor aesthetics due to the white opaque nature of the core. In an attempt to address this problem, the Cercon system now has an ‘ivory’ coloured substructure available and the Lava system has eight Vita classic shades of core to choose from depending on the shade of the overlying restoration.

These new zirconia based systems show great promise and may ultimately be able to produce predictable all-ceramic fixed bridgework, however they are still at an early stage in their evolution and although preliminary research and clinical observations look promising, it is still advisable to closely follow the emerging research.

**Discussion/future trends**

The materials and methods for fabrication of all-ceramic restorations are changing rapidly and significantly. In an attempt to control quality and improve speed, dental laboratories are undergoing mechanisation with some outsourcing certain stages to other labs. The use of CAD/CAM and copy milling, particularly with regard to core material, is increasing. There is also an increase in the use of pressed ceramic rather than conventional hand layering techniques. The zirconia based systems are another exciting area of development which may finally mean that predictable metal-free bridges are to become a reality.

As the technology continues to evolve and improve at great pace, it is perhaps not surprising (although still frustrating) that clinical research is not keeping up with the changes. However, limitations aside, when selected and used correctly, all-ceramic restorations can have excellent aesthetic, biological and mechanical/physical properties. The end results can be both attractive to patients and rewarding to the clinician.

**References and acknowledgements**

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<tr>
<td>Procera 687 +/- 58 Mpa</td>
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<td>In-Ceram 352 +/- 113 Mpa</td>
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<td>Empress 1 135 +/- 22 Mpa</td>
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(Wagner and Chu 1996)