Restorative materials: clinical factors and decision pathways

Brenda Baker and **David Reaney** outline the applications and benefits of dental ceramics, and discuss a recent class of indirect nano-ceramic materials

When deciding upon a restorative material, an abundance of clinical factors are simultaneously all at play, each requiring careful consideration.

At times, putting the pieces together can feel like a bewildering and perplexing challenge, balancing patients' aesthetic desires and attitudes to treatment with financial and biomechanical constraints.

The following decision pathway may function as a helpful tool for treatment planning:

1. Key factors to consider
2. Material properties and indications (including implants)
3. Preparation and cementation guidelines.

KEY FACTORS TO CONSIDER

Abutment

The remaining tooth structure is critical when evaluating the material to be used. Irrespective of the shade or colour of a chosen ceramic material, the colour and shade of the restoration is profoundly affected by the shade of the abutment.

The need to mask what is underlying the tooth structure determines how thick or thin a restoration should be and will affect the strength of the material, which may have varying thicknesses and different degrees of translucency. This in turn will influence the colour and shade of the bonding agent, and the type of bonding agent suitable for the chosen material.

***Dr Brenda Baker BDS (Hons) MSc** graduated from Sydney University with honours and completed a masters degree in conservative dentistry from Eastman Dental College. She has taught in the prosthetic faculty at Sydney University and pursued a preventively-oriented career in private practice. Throughout her career, Dr Baker has had a commitment to continuing education in a variety of disciplines including prosthodontics, periodontics and pain management, and is currently director of clinical education for Southern Cross Dental.*

***Dr David Reaney BDS (Edin) DGDP(UK) MClinDent (Prosthodontics)** graduated with distinction from the University of Edinburgh. He has held the position of clinical lecturer at the School of Dentistry, Royal Victoria Hospital in Belfast and is currently in private practice in Moy, Northern Ireland. Dr Reaney is general manager of Southern Cross Dental.*

Figure 1: Patient demand for high aesthetics continues to drive the popularity of lithium disilicate, as seen in this lifelike e.max inlay

Preparation and load

Sharp angles can cause developmental stress in any restoration. This is exacerbated with ceramic restorations, for which rounded edges are necessary to decrease the incidence of fracture.

Masticatory forces can vary according to the location of the restoration and different stresses occur with bruxing.

The compressive strength of ceramic is 10 times higher than its tensile strength, so all-ceramic crowns should be placed primarily under compressive stresses.

Wear and longevity

Every dental material has its advantages and disadvantages, depending on the composition of the material. The longevity and wear resistance of a material is problematic to establish because it is multifactorial, including the type of restoration, the area in which the restoration will be placed, bond type, and masticatory forces.

By choosing a suitable material, clinicians guard against fractures, chipping, breakage and erosion of the restoration itself and the adjacent and opposing dentition.

Figure 2: Traditionally relied on for its strength, the optical properties of fully milled zirconia continue to improve

Figure 3: PFM crowns (shown here alongside its metal core) remain a reliable restoration, despite their lack of major recent advancements

Aesthetics

Aesthetics has become more important to patients worldwide. Manufacturers of dental materials have been compelled to develop materials with physical properties to enable the delivery of highly aesthetic restorative dentistry.

Aesthetics is complex and includes parameters such as hue, shape, tooth morphology and the position of the restoration relative to other teeth in the arch. Cultural and socioeconomic factors are involved in the decision-making process for both patient and dentist. Posterior aesthetics may or may not be a factor for some patients.

Some materials are available in different shades and colours. Other materials are

TABLE 1: RESTORATIVE CHART FOR ALL-CERAMIC RESTORATIONS

		MONOLITHIC RESTORATION				VENEERED RESTORATION		
		IPS Empress	IPS e.max (Press or CAD)	FMZir (Fully milled zirconia)	Zir-QUEST	Lava	PFZ (Porcelain-fused-to-zirconia)	e.max ZirPress
PROPERTIES	Supplier	Ivoclar Vivadent	Ivoclar Vivadent	SCDL	SCDL (Australian-made)	3M ESPE	SCDL	Ivoclar Vivadent
	Material	Leucite glass ceramic (able to be layered)	Lithium disilicate (able to be layered)	High translucency zirconia	Extra high translucency zirconia	Veneered zirconia	Veneered zirconia	Veneered zirconia
	Flexural strength	160mpa	360-400mpa	1,200mpa	>1,200mpa	1,200mpa	1,200mpa	1,200mpa
	Number of shades	12	20	16	Maximum	Eight framework shades	Eight framework shades	Eight framework shades
	Aesthetics/ translucency	+++++	+++++	+++	++++	++++	++++	++++
INDICATIONS	Crown	✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
	Inlay/onlay	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
	Inlay bridge/ Maryland	-	N/A	✓ (limited)	✓ (limited)	✓ (limited)	✓ (limited)	✓✓
	Veneer	✓✓✓	✓✓	-	-	-	-	-
	Thin veneer	-	✓✓✓	-	-	-	-	-
	Bridge	-	Three units (anterior/ premolar)	Four units (anterior) Three units (posterior)	Up to five units (no cantilever)	Up to six units	Full arch possible	
						Max. four pontics anterior or three pontics		

either monolithic, monochromatic or need to be veneered and or stained and glazed.

Finances

The cost of gold and other alloys is quite high and volatile. For some patients and hence some practitioners, this factor may have important consequences for material selection.

MATERIAL PROPERTIES AND INDICATIONS (INCLUDING IMPLANTS)

Dental ceramics are an inorganic structure consisting of metallic and semi-metallic elements and oxygen compounds. As a result of the varied composition, ceramics can be used in a variety of applications. By nature, ceramic materials are brittle, have high compressive strength and low tensile strength, which can make them more susceptible to fracture if used in the wrong clinical situation.

Dental ceramics have many advantages – dimensional stability, high wear resistance, biocompatibility and excellent aesthetic properties.

Ceramic compositions can show close similarities to the natural dentition when there is a high glass content and small amounts of filler particles. The filler particles function to control colour and opalescence, including degree of opacity. Dental ceramics have evolved and the previous major concern was the low fracture toughness. As a result of improvements in processing, mechanical properties, scientific advances with bonding of the restoration and clear restoration guidelines, the strength and fracture toughness of dental ceramics has improved greatly. Previously, there were limited indications for use of ceramics posteriorly but now restorative options exist for crowns and bridges, implant-supported restorations and also implant abutments, in addition to their traditional use for inlays/onlays.

Ceramics can be classified by microstructure and processing techniques, and can be divided into five groups:

1. Powder/liquid ceramics
2. Glass-based pressed and machinable materials
3. High strength crystalline ceramics
4. Metal ceramics
5. Resin nano-ceramics.

1. Powder/liquid ceramics

Before the introduction of pressed

TABLE 2: GUIDE TO RESTORATIVE OPTIONS FOR CEMENT-RETAINED (CR) VS SCREW-RETAINED (SR) IMPLANT CROWNS

PROPERTY	PFM		e.max		PFZ		FMZ	
	CR	SR	CR	SR	CR	SR	CR	SR
Strength	✓	✓	-	-	✓	✓	✓	✓
Retrievability	-	✓	-	✓	-	✓	-	✓
Aesthetics	✓	-	✓	-	✓	-	-	-

technology, ceramic restorations were most commonly produced by combining liquid and powder into a slurry and then stacking porcelain on the die. The ceramic is applied in layers and then fired. This process is still commonly used today for porcelain veneers. Ceramics fabricated in this way are typically feldspathic or leucite-reinforced glass, and used primarily for anterior restorations.

The fabrication process is challenging, time-consuming and requires a skilled ceramist who can layer material of varying colour and opacity.

This ceramic demonstrates less than 1% fracture rate when well-defined factors are followed. As dentine is flexible, a ceramic with low fracture resistance should not be used for restorations with less than 70% enamel. Preparations should stay within enamel. The optimal reduction is 0.75 mm cervically. Studies have shown 96% survival rate when incisal coverage preparations were used.

The flexural risk increases when powder/liquid materials are bonded to dentine. The material should not be used in cases with bruxing, overbite, overlapping, or bonding to composite or dentine substrates due to their flexibility and lack of ceramic support. Restorations can be made as thin as 0.3mm and therefore tooth preparation can be very conservative when utilising this material.

Due to the inherent physical properties of the ceramic and the creation process, restorations made this way have a relatively low flexural strength of 60-110mpa and must be bonded to the tooth for strength and durability using an etching/adhesive process. The intaglio surface of the ceramic is etched with hydrofluoric acid and then porcelain conditioner is applied prior to the resin cement. In order to maintain aesthetics, shade changes need 0.2-0.3mm of space per shade.

As a result of CAD/CAM advancements, the powder/liquid forms are now frequently replaced by machinable blocks (eg Empress Esthetic CAD).

2. Glass-based ceramics – pressed and machinable

The most common glass-based ceramic is now IPS e.max (Ivoclar Vivadent), where 70% of the material is composed of lithium disilicate as a filler particle. IPS e.max shows enhanced strength and lower flexure, shear and tensile problems. IPS e.max Press has improved physical properties and translucency, while the flexural strength is 440mpa. The Press technique has two different types of ingots available: the IPS e.max Press and the IPS e.max Zirpress, which combines a CAD/CAM technique where glass-ceramic ingots are pressed onto Zircad frameworks. IPS e.max Press can be used in a monolithic application for inlays and onlays, posterior crowns, core for crowns and three-unit bridges anteriorly.

IPS e.max CAD is a lithium disilicate designed for CAD/CAM technology and can be used for anterior or posterior crowns, implant crowns and inlays, onlays and veneers. There is also a nano-fluroapatite ceramic called IPS e.max Ceram, which can veneer all IPS e.max components – either glass ceramic or zirconium oxide.

The stronger versions that are machined exhibit a recent innovation whereby pre-existing tri-shades (incisal, body, neck) are impregnated into the block. At least 0.2-0.3mm per shade change and at least 0.8mm of minimal working thickness is required in order to produce aesthetically attractive restorations. Both pressed and machinable glass ceramics are able to be etched and thus should be bonded with resin cement.

3. High strength crystalline ceramics

Zirconia is characterised by a dense, monocrystalline homogeneity, has low thermal conductivity, low corrosion potential and is radio-opaque.

Zirconia can be used for:

- Root canal posts
- Frameworks for posterior teeth
- Implant-supported crowns
- Multi-unit bridges
- Custom-made bars to support fixed and removable prostheses
- Implant abutments.

Some CAD/CAM systems machine fully sintered zirconia blocks, which have been processed by hot isostatic pressing. As fully sintered zirconia is hard and difficult to machine, a strong milling machine and extended milling periods are needed.

Most CAD/CAM systems shape blocks of partially sintered zirconia, which are then

TABLE 3: PREPARATION AND CEMENTATION GUIDELINES

		Reduction^	Finish line depth and configuration
Anterior crowns	**All-ceramic** (veneered or monolithic) e.max or Empress Esthetic	2.0mm incisally 1.0mm buccal/lingual	0.8-l.0mm shoulder
	Porcelain-fused-to-zirconia	2.0mm incisally 0.6 -l.0mm lingual aspect (Porcelain guidance requires greater clearance)	>0.4mm chamfer lingually >1.0mm labial
	Porcelain-fused-to-metal	2.0mm incisally 0.5-l.0mm lingual aspect (Porcelain guidance requires greater clearance)	1.5mm labial shoulder or heavy chamfer* 0.5mm lingual chamfer 1.5mm circumferentially for 360° ceramic margin
Posterior crowns	**Full contour crowns** (metal or zirconia)	1.0mm non-functional cusps 1.5mm functional cusps	0.3-0.5mm chamfer, knife-edge, shoulder or shoulder with bevel
	All-ceramic (veneered or monolithic) e.max or Empress Esthetic Porcelain-fused-to-zirconia	2.0mm non-functional cusps 2.5mm functional cusps	1.0mm shoulder or heavy chamfer
	Porcelain-fused-to-metal	If metal occlusal, as with FCC 2.0mm non-functional cusps 2.5mm functional cusps	1.5mm labial shoulder or chamfer* 0.5mm lingual chamfer (metal collar) 1.5mm circumferentially of 360° ceramic margin

^ Where the vertical dimension is to be increased, the amount of occlusal reduction required will be less or non-existent. Tilted posterior teeth may require less occlusal reduction
+ Reduction is too deep for diminutive teeth or long clinical crowns where metal collar is preferable. Lower incisors would be more suited to a heavy chamfer.

subsequently sintered. Examples of these systems are Lava and Procera.

Sintered zirconia can be immersed in specifically coloured dye, which minimises the high value of the material and will more closely match the colour of the abutment.

Porcelain-fused-to-zirconia (PFZ) is suitable for:

- Posterior multi-unit bridges
- Single posterior crowns
- Single anterior crowns (e.max can be pressed onto the zirconia or the crown can be veneered with porcelain)
- Implant-supported crowns and bridges
- Customised gingival flange areas in aesthetically critical zones
- Occlusally neutral environment (avoid the use of PFZ in bruxers).

Fully milled zirconia (FMZ) is a new generation of fully milled monolithic solid zirconia with no veneering ceramic. FMZ crowns or bridges are indicated for bruxers and grinders when PFM metal or full cast restorations are not desired by the patient and the opposing tooth is metallic, zirconia and no dentine is exposed. FMZ is best suited for posterior molar crowns when a tooth-coloured restoration is required but there is inadequate preparation space or a porcelain-fused-to-metal (PFM) crown has broken from grinding. When dentine is exposed on the antagonist preoperatively, FMZ should not be used and full gold or PFM is preferred.

4. Metal ceramics

Metal ceramics consist of a metal substructure usually veneered with a leucite-based feldspathic porcelain. There is an incompatibility of the coefficient of thermal expansion between the metal substructure and the traditional feldspathic glass ceramic, and so leucite is added to the feldspathic glass and adjusted until the coefficient of thermal expansion is similar or slightly lower than that of the metal substructure.

Metal ceramics, commonly referred to as PFMs, are indicated for all full-crown applications, particularly those with high risk factors. The structural core supporting the porcelain veneer is crucial to achieving a successful restoration. Microcracks can develop due to radial tensile and tangential compressive stresses.

In order to achieve aesthetics in the anterior region, which will be comparable to porcelain/zirconia crowns, an extra thickness of 0.3 mm is required for metal ceramic restorations. Despite its continued use, the material characteristics, technology, and complex aesthetics associated with metal ceramics can still present significant challenges.

5. Resin nano-ceramics

Lava Ultimate is a CAD/CAM material that is aesthetic, versatile and durable. Lava Ultimate contains three ceramic filler particles – silica particles of 20nm, zirconia particles of 4-11nm and agglomerated nanoparticles of silica and zirconia, which are all embedded in a highly cross-linked polymer matrix.

The flexural strength of Lava Ultimate is 200mpa, which provides excellent resiliency. This resin nano-ceramic has an elastic modulus comparable to dentine so it can better absorb chewing forces and thus less wear occurs to opposing enamel. Lava Ultimate is easy to adjust and indicated for implant-supported crowns and single unit restorations – crowns, onlays, inlays and veneers. Teeth should be prepared with a 5-6° taper with rounded edges and a shoulder margin. Resin nano-ceramic restorations require bonding with an adhesive resin cement.

PREPARATION AND CEMENTATION GUIDELINES

Bonding and cementation

The abutment and chosen restorative material will determine whether an adhesive or conventional cement should be employed.

Some ceramic materials can be etched with hydrofluoric acid and adhesively bonded using a resin cement. Zirconia can be bonded using a resin-modified glass ionomer cement when there is adequate retention.

When there is minimal or reduced retention with all-metal, PFM and zirconium-based crowns and bridges, the use of a resin cement with prior application of a separate self-etching bonding agent is appropriate. Optimal bonds minimise microleakage, which will subsequently improve the longevity of the restoration.

Dental ceramics have been in use for decades and there is a vast amount of information available with respect to their material characteristics, indications and contraindications. Every restorative ceramic material demonstrates advantages and disadvantages. Thus, it becomes time-consuming and challenging for dentists to research and know when to use the ideal material for individual restorations and/or combination cases.

The choices for clinicians nowadays can often be bewildering. Diagnosis of aesthetic requirements, functional loading, available tooth structure and an understanding of preparation and cementation protocols will enhance the success of the final restoration, irrespective of the chosen material. **ID**

Comments to *Irish Dentistry*
@IrishDentistry