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incise™ zirconia – taking a closer look

All-ceramic restorations are soaring in popularity amongst dentists and patients. Their aesthetic properties are ideal for anterior work, but discerning technicians have tended to avoid them for larger posterior restorations.

With progress of the materials and processing technology, these concerns have been dispelled. The primary improvement lies in the use of zirconia ceramic as a substructure material.

Restorations made using zirconia frameworks are the strongest and toughest all-ceramic units available. The benefits to the patient are obvious. The toughness and damage resistance during handling are major advantages for the laboratory.

Zirconia ceramics do not stimulate significant immune or rejection responses in patients. This is clearly of benefit to those people who are allergic to certain metals, and also instils confidence in patients who may have no existing restorative work or may not be aware of any allergies.

What is zirconia Y-TZP?

Zirconia (ZrO_2) is the oxide of the metal zirconium. The ceramic can be made in many different forms, with a correspondingly wide range of properties. Y-TZP (yttria-stabilised tetragonal zirconia polycrystal) is the strongest and toughest of the forms, and is used in Renishaw's incise™ CAD/CAM process. It is composed of a dense arrangement of sub-micron crystalline grains, each of which exhibits a tetragonal crystal structure.

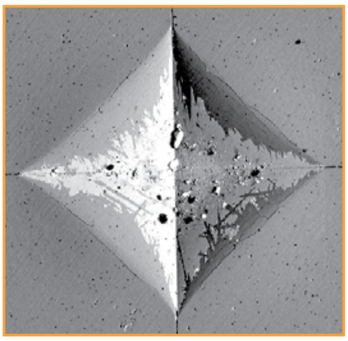

Figure 1a. SEM microscope image of an indentation in zirconia, created by pressing a pyramidal diamond into the surface.

Y-TZP possesses a toughening mechanism that is key to its high performance as a dental material. Any minute cracks that form in the ceramic cause the surrounding tetragonal material to transform into a monoclinic crystalline structure. This phase has a larger volume than the tetragonal bulk, so it compresses the crack faces together and drastically impedes crack growth.

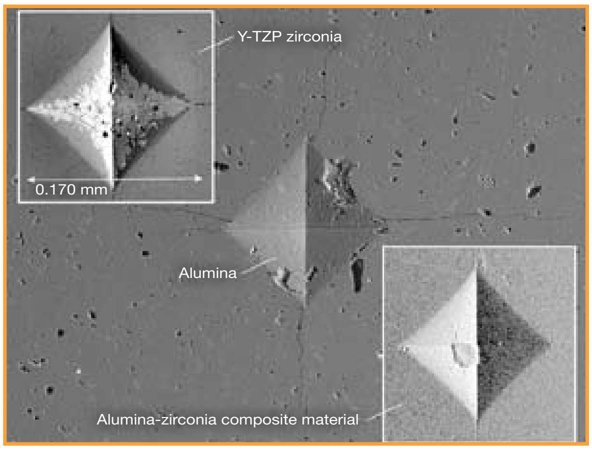

Figure 1b. A pyramid shaped diamond is pressed into each material under a 20 kg load. The size of the resulting impression is related to the hardness of the material, and toughness is demonstrated by the severity of corner cracks. Larger cracks are seen in those materials with lower fracture toughness.

This 'transformation toughening' is unique to zirconia and its effect is most marked in the TZP form. This explains why its strength and toughness are both over twice that of alumina ceramics.

The electron microscope images in Figure 1b show indentations that have been made in three different ceramic materials. In these examples, the alumina-zirconia composite material shows the smallest impression (it is the hardest), followed by the alumina and lastly Y-TZP. However, it is important not to confuse hardness with strength.

Hardness is not a desirable property for dental cores as it generally implies greater brittleness and can make the material more difficult to machine (needless to say, all of these ceramics are far harder than natural dental tissues).

The porosity of the alumina can be seen as well as the lack of toughness, with a considerable amount of inter-granular cracking that is not seen in the other materials.

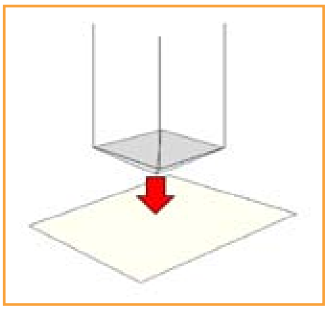

Figure 1c. The indentation process

Pressable and slip-cast ceramics differ from the structural materials shown in figure 1b. These have a glassy matrix binding ceramic particles, and do not possess the strength or fracture resistance of modern engineering ceramics.

Why not grind fully sintered zirconia directly?

Grinding zirconia in the 'hard' state means that no further sintering is necessary. However, this is more than offset by the slower grinding process. For bridges longer than 3 units, it is not possible to manufacture frameworks in the hard state to an adequate standard, and still meet the stringent delivery deadlines of modern dental laboratories. The incise™ system now supports up to 6-unit bridges and an increasingly diverse range of products are in development. These larger frameworks are not economical to make in the hard state. With years of research and development behind it, Renishaw's soft-state manufacturing methods have now reached a level where the accuracy and strength standards set by hard-state frameworks are being exceeded.

1. **Milling time.** Soft state machining takes a fraction of the time required for grinding. This makes the incise™ manufacturing facility more efficient enabling the rapid delivery times you expect, even on long span bridges.
2. **Range of frameworks is greater.** Bridges up to six units can be produced.
3. **Larger units.** Units up to 16 mm tall can be produced, increased by 5 mm over hard state machining.
4. **Less space required for tool access.** The tool size is much smaller, which allows the reproduction of finer details, and the production of sharp incisal edges with much reduced 'ballooning'.

What is soft-state zirconia?

Zirconia goes through a number of processing stages before it is suitable for use as a dental material. There are 4 main states through which the material goes in this processing route: powder, 'green state', pre-sintered, and the fully sintered (hard) state.

1. Zirconium oxide powder is mixed with the other powdered constituents of the billet. incise™ zirconia is yttria stabilised, so yttrium oxide is added at this point. This material stabilises the tetragonal crystalline structure to provide the high toughness required.
2. An organic-based binder is added and the powder is pressed into billets. The binder allows the pressed parts to retain their shape. Billets can be machined in this so-called 'green state'. However, the resulting frameworks release gas as the binder is burnt out which can introduce errors in the predicted shrinkage.
3. The green billets are pre-fired at relatively low temperature to burn out the binder. A small degree of sintering takes place, causing the zirconia powder particles to slightly fuse. This pre-sintered (often referred to as 'brown state') material is used in the incise™ system. The billets are strong enough to handle and mill, but are still highly porous and lacking in strength. The porosity also allows them to soak up staining agents, permitting colouring of the frameworks prior to firing, if necessary.
4. Pre-sintered material is fired at around 1500 °C for complete sintering to take place. All of the particles fuse to produce a strong and supremely tough material. Because the material shrinks when it is sintered, the frameworks machined from pre-sintered zirconia are automatically made over-size to compensate.

How do we ensure that the stages of manufacture do not weaken the framework?

Among its other products, Renishaw produces a range of Raman spectrometers - devices which are able to distinguish between zirconia's different microstructures. Damaged material will show an increased fraction of the monoclinic phase. Any material that may not be physically damaged but has weakened via phase transformation for other reasons will also be identified. Using this technology, Renishaw has been able to monitor the monoclinic phase content of frameworks after manufacture, manual adjustment and artificial ageing. No significant monoclinic content was observed.

To add to this, strength testing of completed restorations demonstrates the remarkable integrity of incise™ frameworks. incise™ crown and bridge frameworks are suitable for any location on the dental arch.

Renishaw's incise™ frameworks are machined using a CNC (computer numerically controlled) manufacturing process which incorporates many innovations, resulting in marked overall improvements in the accuracy, durability and aesthetics of the product received at the laboratory.

Take advantage of the latest materials and technology backed by cutting edge scientific research. Use incise™ to strengthen your restorations and your business.

For more information about Renishaw's dental products and software visit

www.renishaw.com/dental