The Highest Performing Zirconia for Patient's Health

An inclusive emphasis on Wear/Abrasion on the opposing natural tooth, Durability and Aesthetics

1. Introduction

The use of metal-ceramic restorations has been significantly declining in favor of zirconia ceramic prosthetics, mainly for esthetic and biocompatibility reasons. On the other hand, ceramics are fragile and brittle in nature. Compared to other ceramic materials, the use of monolithic zirconia often drastically reduces mechanical complications and requires a much less invasive preparation of the tooth structure, thereby allowing the patient to retain as much of the natural tooth structure as possible. Dental zirconia has traditionally been manufactured from tetragonal zirconia polycrystalline with a minor proportion of yttria as a stabilizer (3Y-TZP); this type of zirconia is extremely strong but presents relatively low translucency. After many years in the market, 3Y-TZP was followed by partially stabilized zirconia with a greater yttria concentration, such as 4 mol% (4Y-PSZ) or 5 mol% (5Y-PSZ). Newly developed monolithic zirconia ceramics have substantially enhanced esthetics and translucency. However, this material (4Y and/or 5Y) must be further studied in vitro and in vivo to determine its long-term ability to maintain its exceptional properties. The Cubic phase in 4Y and 5Y zirconia reduces the stress-induced transformation toughening of zirconia, resulting in reduced strength (from 1,200 MPa of 3Y to 600-750 MPa of 5Y) and toughness. Many zirconia materials are available today, and their properties are all different. The decision on what zirconia material to use should include consideration of 1) the wear/abrasion factor against the opposing natural tooth, 2) the durability (crack/fracture resistance) of the restoration, and 3) esthetic features.

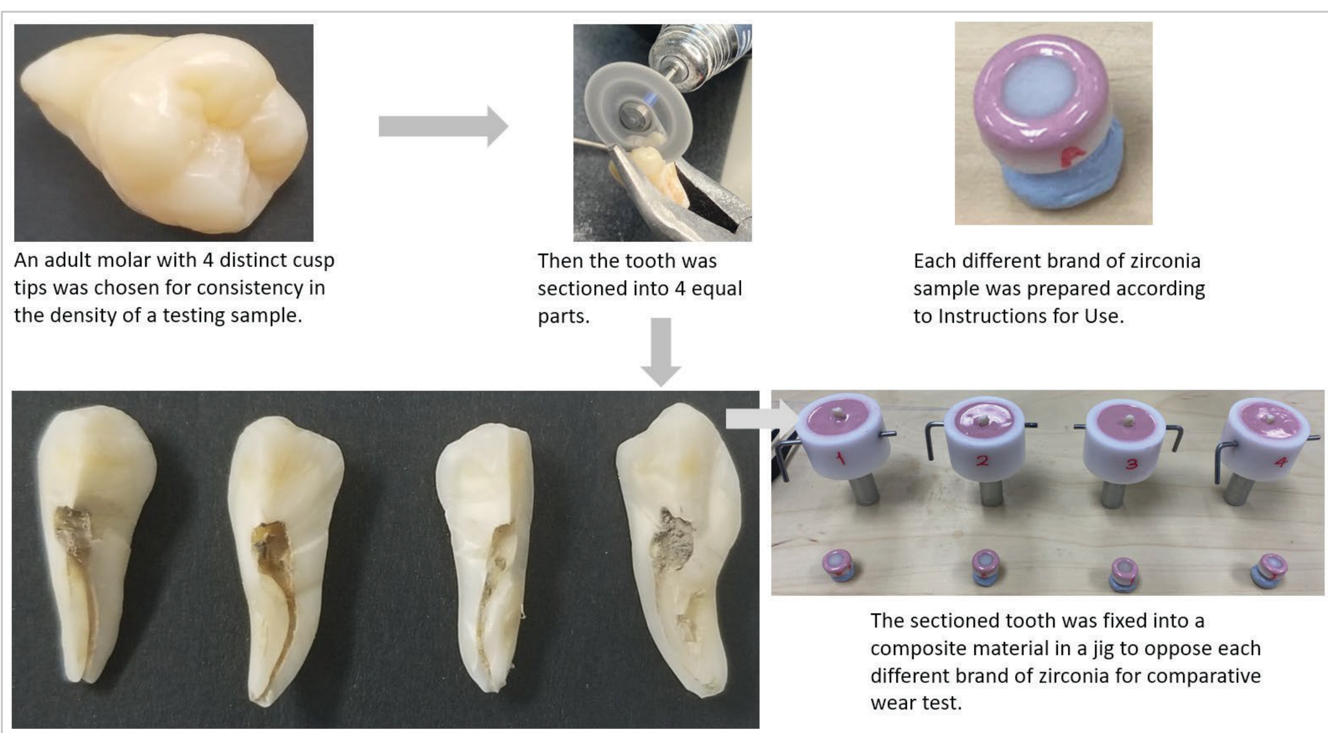

Figure 1. Sample preparation for wear/abrasion test (chewing simulation)

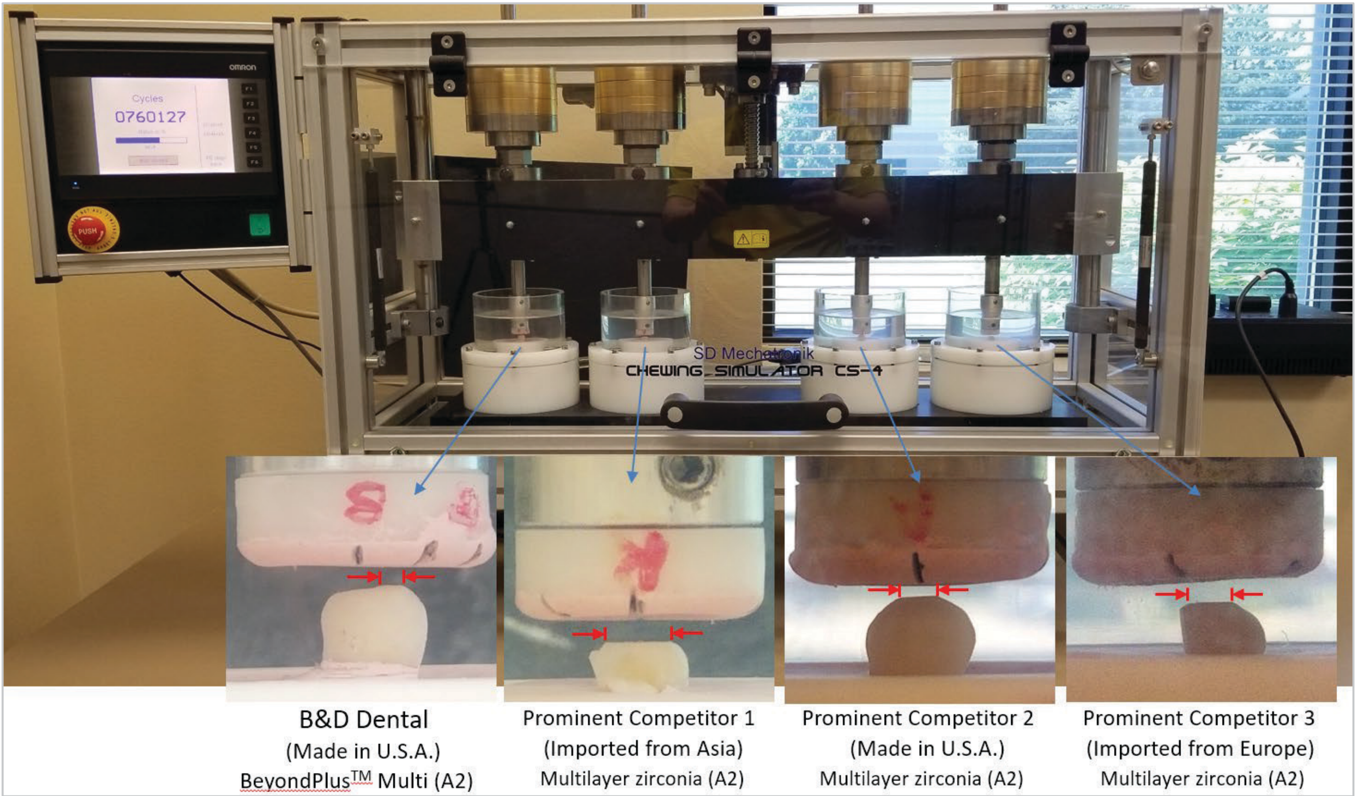

Figure 2. Chewing simulator test

Table 1. Testing sample information

Multilayer Zirconia Brand	Manufacturing method		Manufactured in
B&D Dental-BeyondPlus Multi-Y	Colloidal method	Wet process, particle reduction to nano size (200-300 nm)	USA
Brand K	Biaxial, Isostatic pressing	Dry compaction of powder	Asia
Brand A	Biaxial, Isostatic pressing	Dry compaction of powder	USA
Brand P	Biaxial, Isostatic pressing	Dry compaction of powder	Europe

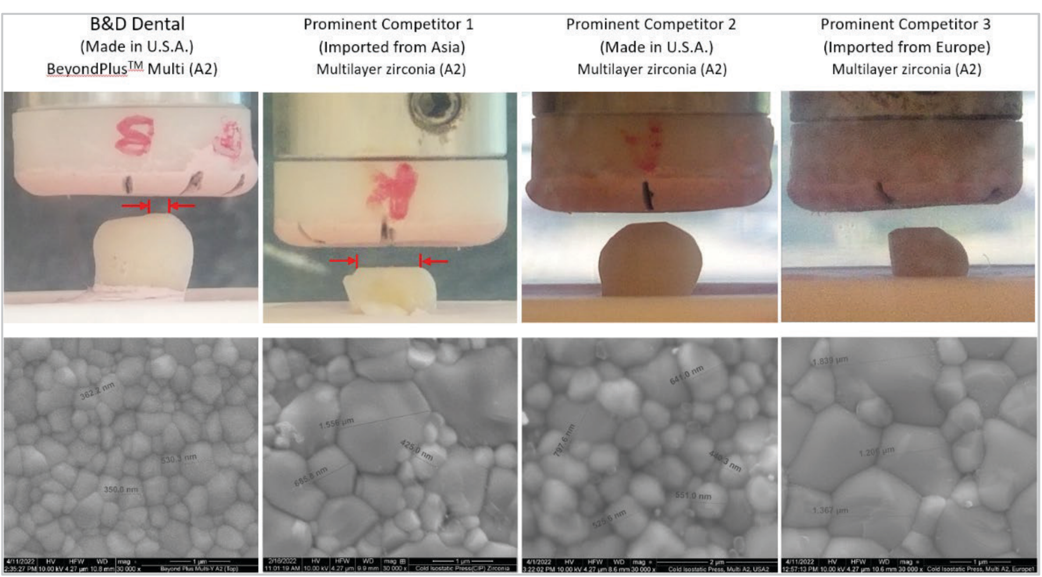

Figure 3. Chewing simulator test result with SEM image of each sample

2. Test of different zirconia materials for the wear/abrasion of opposing natural tooth

Four leading brands of multilayer zirconia (shade A2, incisal area) were prepared to measure the degree of wear/abrasion of the opposing natural dentition in a simulated in vitro test. The human molar tooth was cut into 4 pieces, as shown in figure 1, fixed in a device with die epoxy, and positioned to be a mandibular tooth opposing each of 4 different multilayer zirconia materials, as shown in table 1 that were sintered per manufacturer's Instructions for Use for each zirconia. A weight of 5kg (comparable to 49 N of chewing force) was exerted a total of 1,250,000 times to simulate chewing (SD Mechatronik, Dental Research Equipment, Germany). One simulated chewing cycle per second resulted in 2 weeks of accelerated mastication. 1,250,000 cycles equal 5 years of simulated chewing in this in vitro testing.

3. Wear/abrasion Test Result

Figures 3 and 4 show that the degree of wear/abrasion of opposing mandibular natural teeth increased substantially as the sintered grain size (especially the cubic grains) increased. And as the yttria content of the zirconia increased, the cubic grains correspondingly increased, as shown in the SEM images (scanning electron microscope, FEI Quanta 600 FE, USA). Specifically, the yttria content of Brand K and Brand P are substantially higher on the incisal/occlusal area, which was confirmed through an independent elemental analysis (EDS test, Energy-Dispersive X-Ray Spectroscopy).

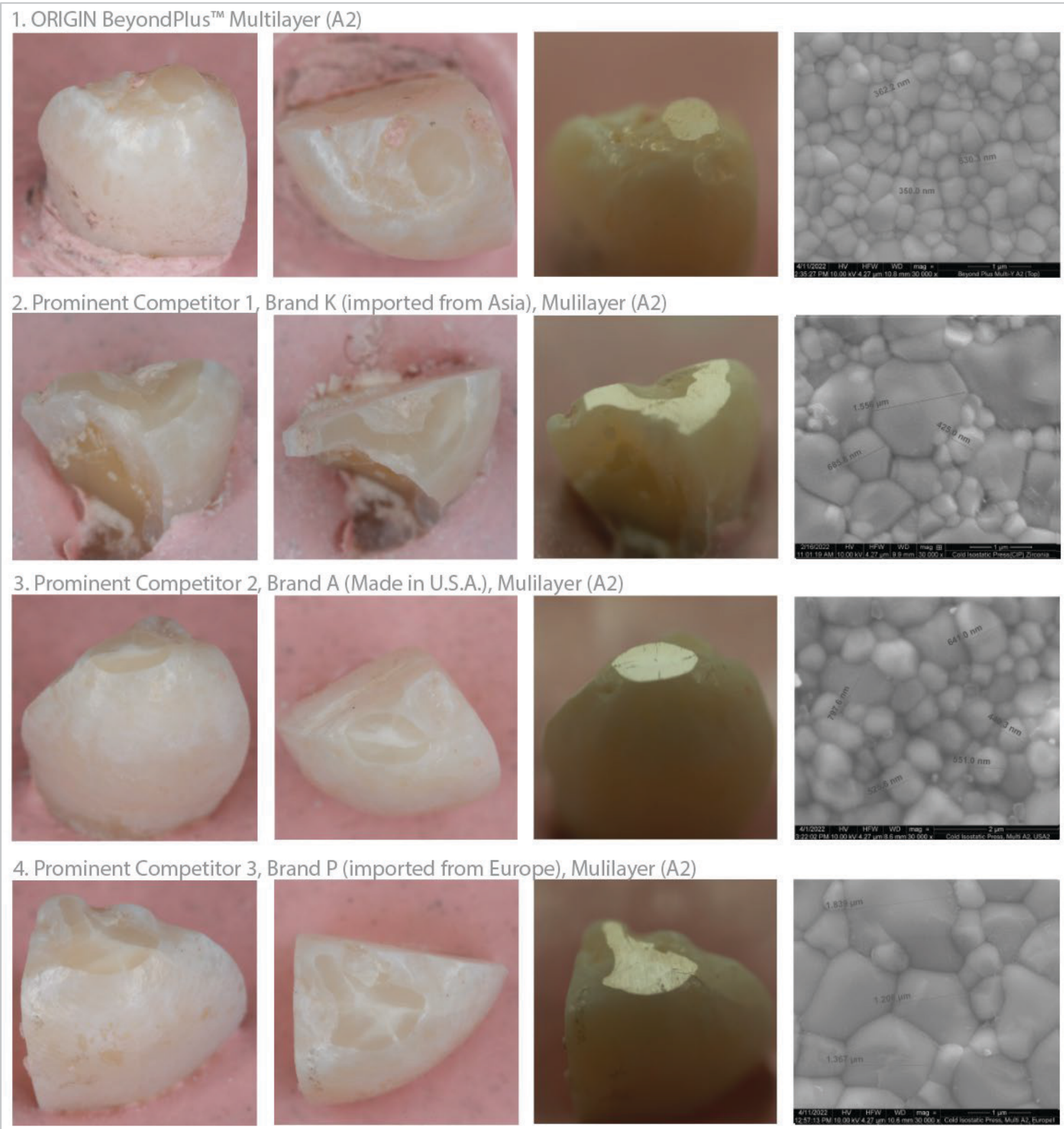

Figure 4. Photos and SEM images of each samples after Chewing simulator test.

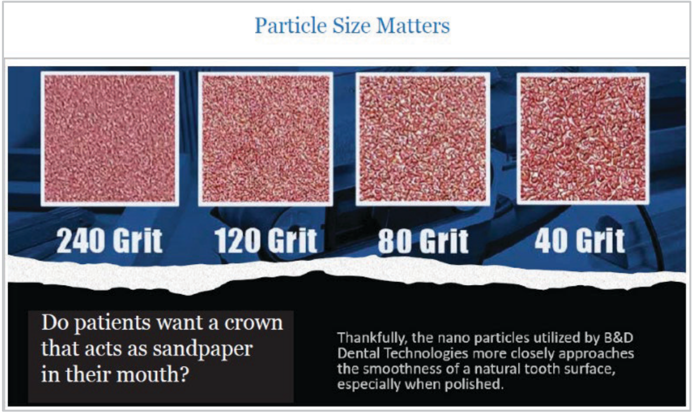

Figure 5. Abrasion factors by particle size

One noticeable characteristic is that Origin™ zirconia has smaller sintered grain sizes than Brand A even though it has higher yttria content than Brand A. This is due to the fact that the zirconia was manufactured using the Colloidal process in which zirconia powders (granules) were downsized to nanoparticles overnight in a liquid using a grinding medium. The average nanoparticle sizes were between 200-300 nanometers.

4. Durability (Crack and Flexure Resistance) and Esthetic Features

The first generation of zirconia contains a tetragonal crystalline structure. The tetragonal zirconia has high mechanical strength and resistance against crack propagation. The crack propagation is inhibited by the changing of the crystalline structure from tetragonal to monoclinic. At an early stage of crack initiation, the gaps between grain boundaries are filled by increased volume due to this transformation of the crystalline structure known as transformation toughening. The tetragonal (3Y) zirconia's strength and ability to inhibit crack propagation are not limited by the grain size or the uniformity of the grain size because most of the grains are tetragonal in structure. While tetragonal zirconia has significant strength benefits, the application is limited due to its opacity.

Disadvantages of Traditionally Manufactured 4Y & 5Y

The new generation, cubic-containing zirconia (4Y, 5Y), contains a mixture of cubic and tetragonal grains in the zirconia facilitated by an increased amount of yttria. As the yttria content increases, the zirconia gains more translucency/esthetics from the cubic grains. This provides for a far superior esthetic. However, the mechanical strength, such as the flexural strength and fracture toughness, are compromised and the effects of transformational toughening are lost due to the increased amount of cubic structure when produced by conventional methods. As shown in figure 6, conventional cubic-containing zirconia has large cubic grains; these large grains reduce the grain boundaries' surface

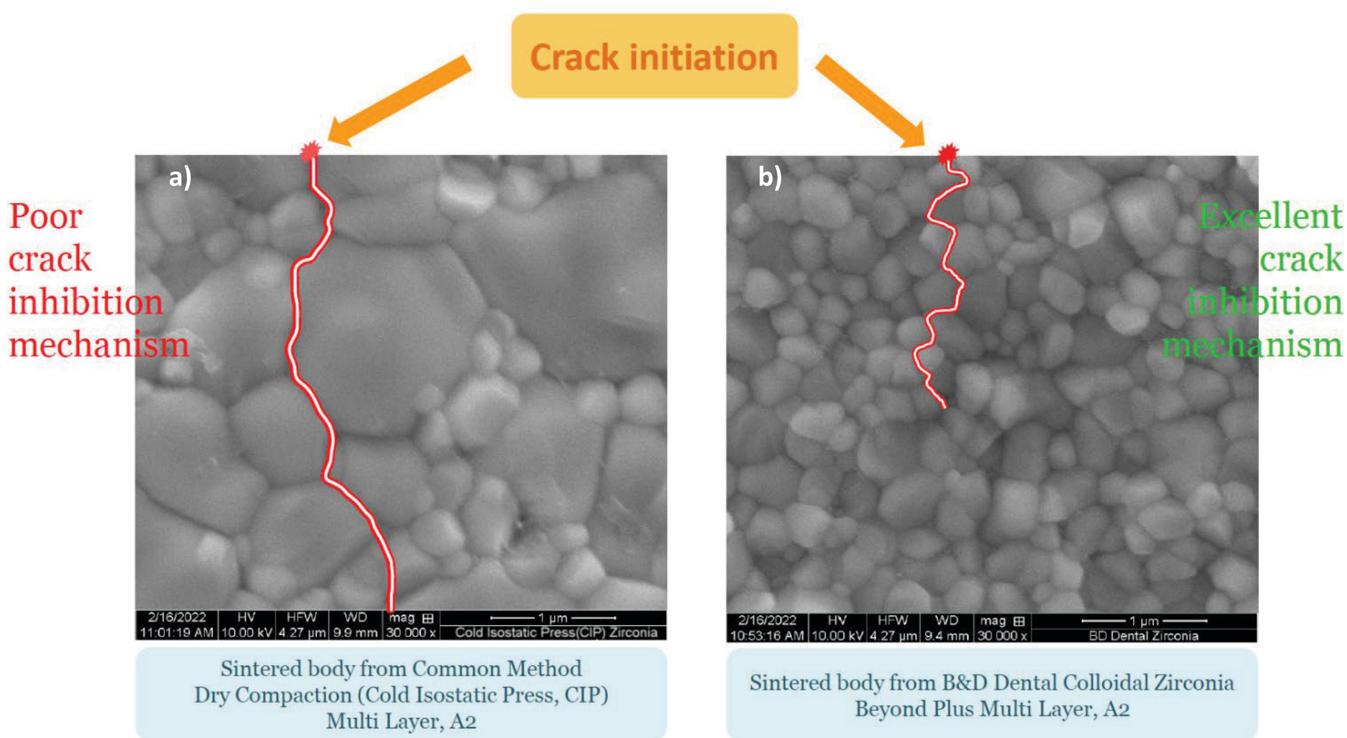

Figure 6. SEM Image of a) Conventional Cubic-Containing Zirconia, b) Origin™ zirconia

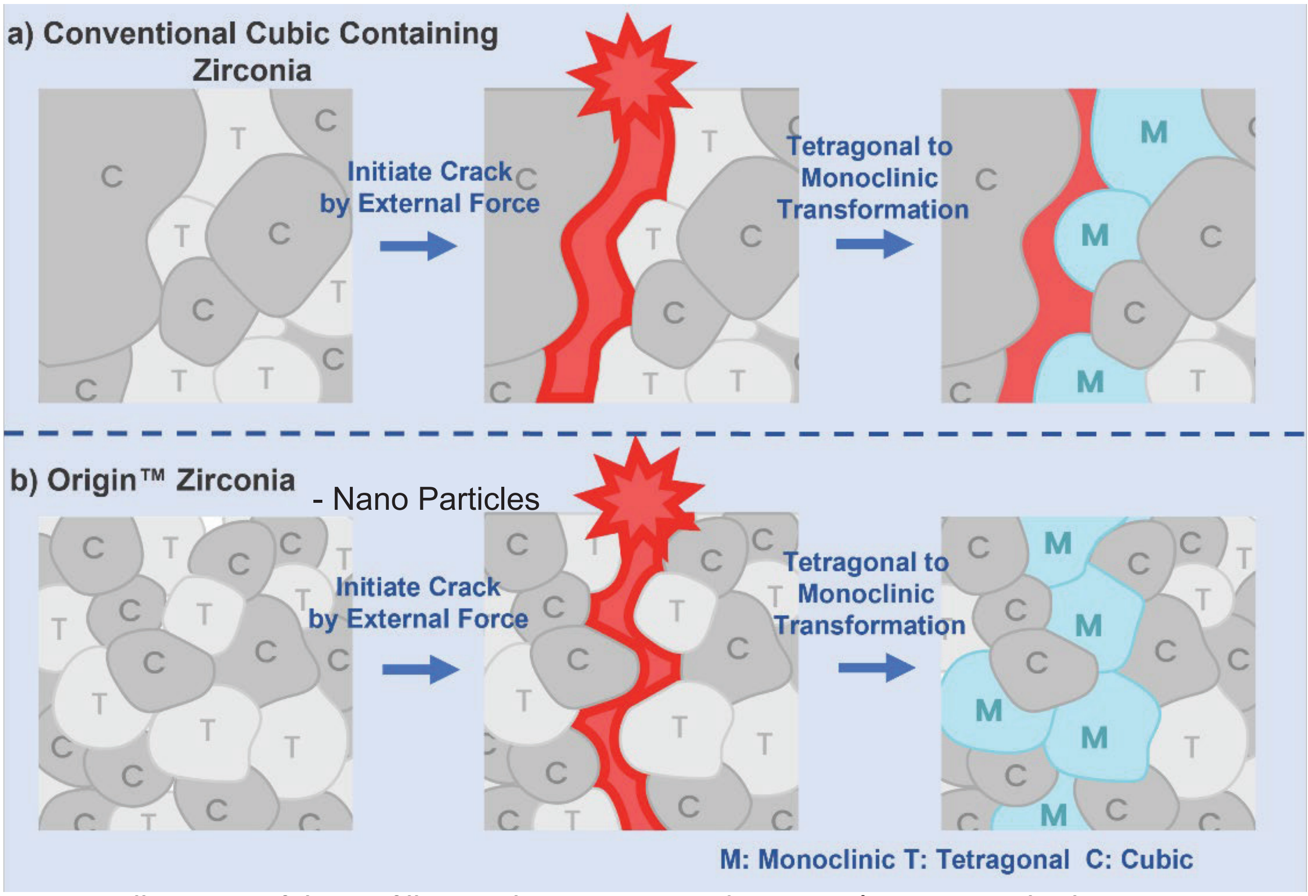

Figure 7. Illustration of the gap filling mechanism in sintered zirconia, a) Conventional Cubic-Containing Zirconia vs b) Origin® zirconia

area. Crack propagation occurs at the grain boundaries because the grain boundaries do not have a covalent bond. So, the more surface area the grain boundaries have (smaller grains have increased surface area), the greater the resistance to crack propagation. In summary, while conventional cubic containing zirconia tends to be more translucent due to the increased size of the cubic grains, it has substantially compromised mechanical properties, such as diminished crack inhibition capabilities, due to the decreased surface area of the grain boundaries.

Figure 6 a) shows the SEM image of cubic containing zirconia manufactured from conventional methods. The grain size of the sintered body has become bigger by adding yttria; as the grain size increases, the grain boundaries' surface area is decreased, resulting in poor mechanical strength.

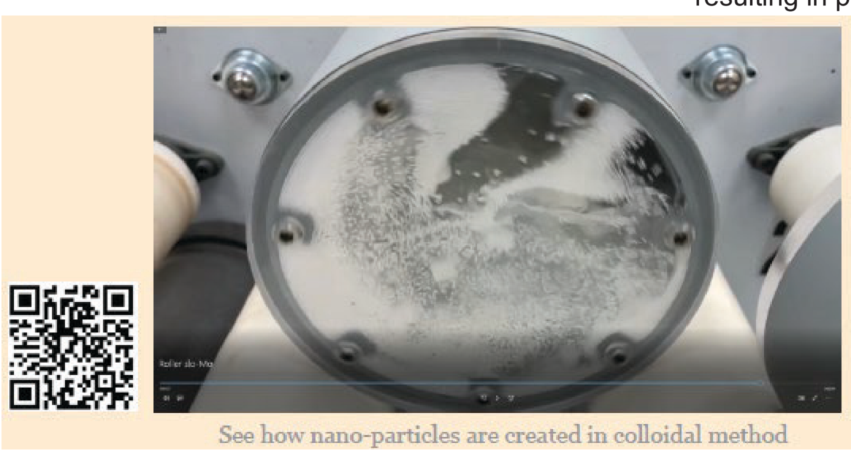

Figure 8. Particle Size Reduction Process

Benefits of Small Grain Size

Figure 6 b) is the SEM image of the cubic containing Origin® zirconia. The grain size is much smaller than cubic containing zirconia manufactured from conventional methods (figure 6 a) even though the same amount of yttria was added to the zirconia.

Origin® zirconia has much smaller cubic grain sizes than conventionally

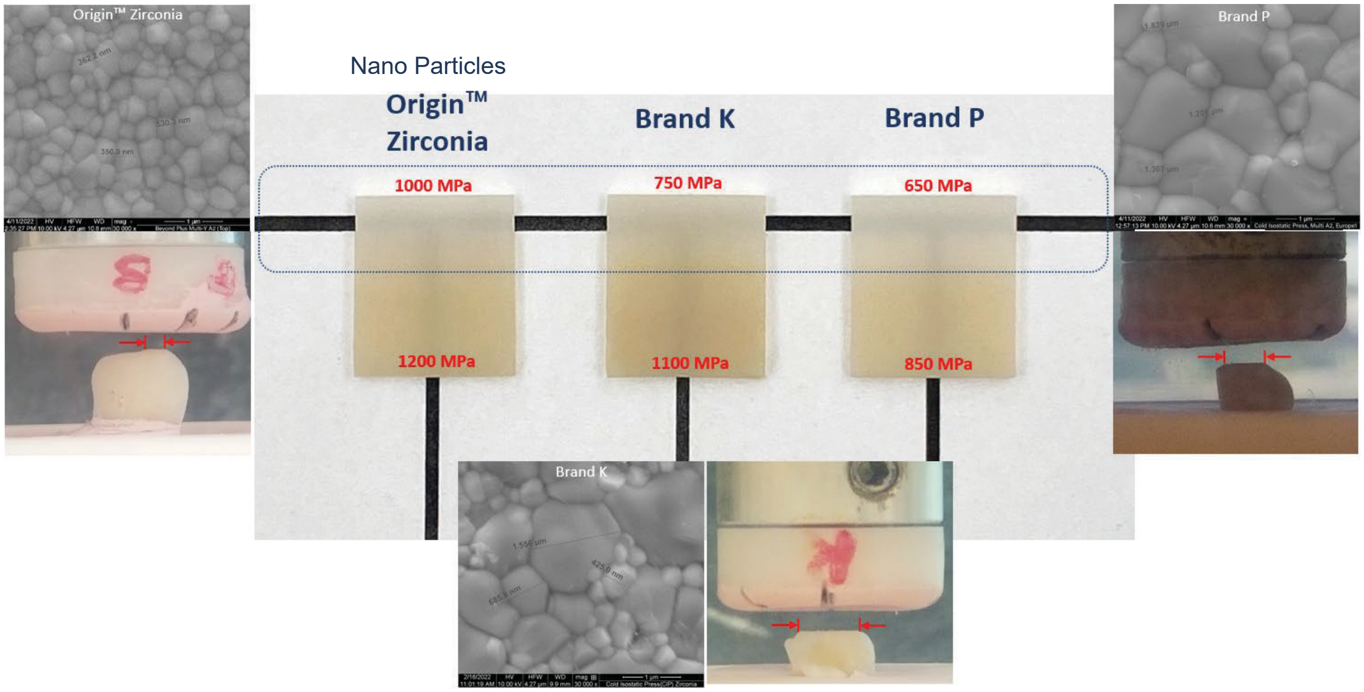

Figure 9. Inclusive Comparison of Strength, Translucency, Grain Size by SEM, and Opposing Natural Tooth Wear (After 5 Years) in In-vivo Test

manufactured cubic containing zirconia because it is produced by a unique colloidal wet process (as opposed to the conventional dry compaction done by the vast majority of manufacturers). In this process, the zirconia particles are mixed into a suspension that then allows for ball grinding into extremely fine nano-size particles (200-300nm, Figure 9) with uniform distribution. As a result, the starting point (pre-sinter) particle size from Origin® zirconia is much smaller and more uniform.

These smaller grain sizes provide two distinct benefits that overcome the disadvantages associated with the conventional manufacturing method. These benefits are; 1) increased surface area of the grain boundaries and 2) effective utilization of transformation toughening.

As can be seen in figure 7, the smaller grain structures in 7 b) have increased surface area in the grain boundaries and create a much harder path for the crack to propagate once initiated. Additionally, Once the crack has started, tetragonal grains turn to monoclinic, which have a much larger volume. This change works to stop the crack propagation through its expansion (transformation toughening). The cubic grain has a stable crystalline structure and does not change (or "grow') based on the external force. This means that the transformation toughening only occurs through the tetragonal grains.

The conventional cubic-containing zirconia cannot perform effective transformation toughening compared to Origin® zirconia (BeyondPlus™ Multi-Y) because the grain size of the cubic and tetragonal grains are significantly different. In other words, the transformation toughening is impractical and ineffective because the tetragonal grain size is much smaller compared to the cubic grain and cannot fill the gap appropriately even though it changes volume (t -> m) in the monoclinic phase.

5. Comparison of Attributes

Figure 9 compares Origin® zirconia (BeyondPlus™ Multi-Y) and two other prominent brands of cubic-containing zirconia in regard to; opposing natural tooth wear after 5 years (in Vitro), each zirconia's sintered grain size, esthetic/translucency effect, and flexural strength. Origin® zirconia performed significantly better than Brand K and Brand P in all areas due to its unique production method. While maintaining all the benefits of tetragonal zirconia (3Y and/or 4Y), Origin® zirconia has the translucency of cubic-containing zirconia (5Y). The strength of the incisal area is much higher (1000 MPa vs. 750, 650 MPa) than the other two zirconia materials yet, contrary to the conventional method, the translucency is not decreased compared to the lower strength brands. In summary, the unique manufacturing process involving the colloidal method contributes to the superior mechanical, clinical, and esthetic properties.

6. Case Applications

Origin® zirconia is indicated for single crowns to full mouth bridge cases. The uniform particle size distribution and solid mechanical properties contribute to consistent and reliable results for all-purpose dental restorations. (Figures 10-12). The denser greenbody from the colloidal processing results in less shrinkage during the sintering process, which increases 3-dimensional accuracy.

Figure 10.

Figure 11.

Figure 12. Origin® zirconia in patient's mouth

7. Conclusion

The consideration when choosing a dental zirconia must include the overall aspects of 1) the wear/abrasion against the opposing natural tooth, 2) the durability/crack resistance, and finally 3) the esthetic features. The traditional manufacturing method of cubic-containing multi-layered zirconia (4Y and/or 5Y) has an esthetic effect (translucency) but results in larger cubic grain sizes that compromise mechanical strength and increase opposing natural tooth abrasion, causing potential problems for patient's health. Increased amounts of yttria in the Origin® BeyondPlus™ Multi-Y (Figure 13) also result in some reduced mechanical properties but they are substantially less significant as other conventional cubic-containing zirconia because of its unique manufacturing process. The grain size remains small and uniform through the material, which minimizes reduced mechanical properties and abrasion of the opposing natural tooth.

Figure 13. Origin Beyond Plus Multi-Y ™

Why is Origin™ the only true **High Performance Zirconia?**

B&D Dental Technologies has been driving innovation for more than a decade as validated with over a dozen patents for zirconia.

The Recognized Zirconia Experts

Our unique production process:

- Particle size reduction to 300 nm for performance optimization *(100 times smaller than any competitor)* = **Highest Translucency and Strength** in the industry
- Homogeneous particle size and no binder **= Far less chipping during milling**
- Lowest shrinkage in the industry **= More crowns per disk** **= Larger crowns fit in thinner disk**

What does this mean for *your lab?*

"**I've never seen better looking zirconia.** *Beyond Plus™* mills with less flaking and chipping which ***drastically reduces remakes***. The enhanced esthetics from the natural light transmission along with the translucent incisal is fantastic. For **chroma accuracy,** the value and shades are **spot on!** Post processing is ***fast***. *Beyond Plus™* has the strength I need so that I don't have to sacrifice the esthetics. My doctors really do notice the difference."

Brian Heaslip , Digital Dental Laboratory

We're not content with compromise, **you shouldn't be either!** *Rely on our Experts.*

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