Balancing Esthetic Needs and Patient Outcomes

Dental Plus USA

Agenda

- Comparison of How Zirconia is Made
- Test Results
- Attributes & Benefits
- New Innovations
  - The Ultimate Balance of Esthetics & Function
  - How Fast is Fast Sintering?
  - How to Improve Shade Matching

Dental Plus Multi Zirconia

1. Has the lowest wear on opposing teeth of popular Zirconias tested

2. Highest translucency to strength ratio

3. Shade guides to match our material

4. Ultra Fast sinter opportunities with our zirconia.
   As fast as 22 minutes

The truth is that, not all zirconia is the same.

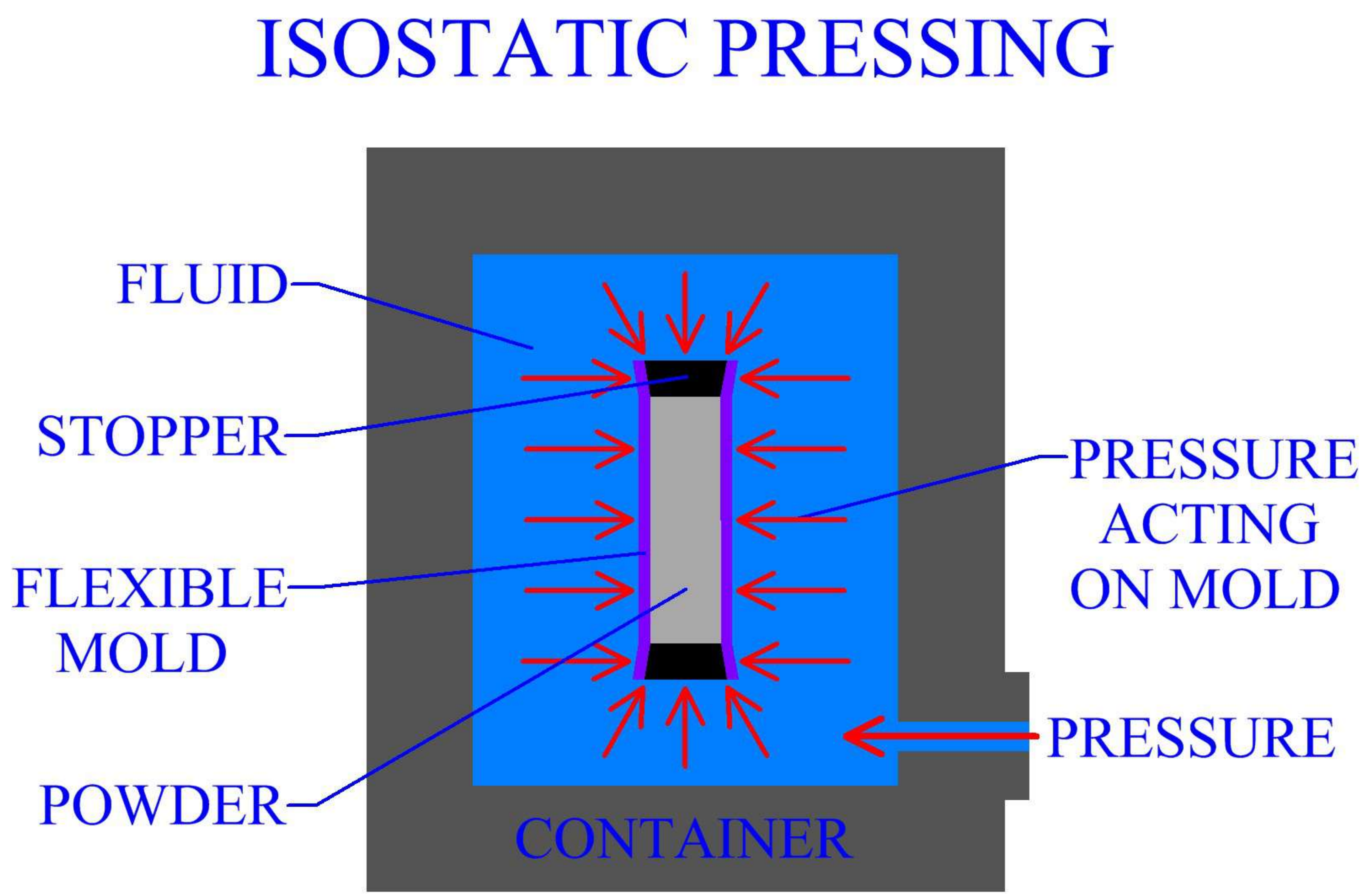
How zirconia is manufactured contributes to its inherent attributes such as translucency, strength, toughness, opposing wear and the stability of dental restorations.

- What differentiates one zirconia from another?
- What has improved with the newest generation of zirconia?
- What type of zirconia is best for a given restoration?

Production Method:

Colloidal Processing vs Dry Compaction

Dry Compaction vs. Colloidal Processing



Many zirconia manufacturers use isostatic pressing, requiring a binder to 'glue' the powder together.

This process relies on relatively larger particle sizes (40-60 µm).

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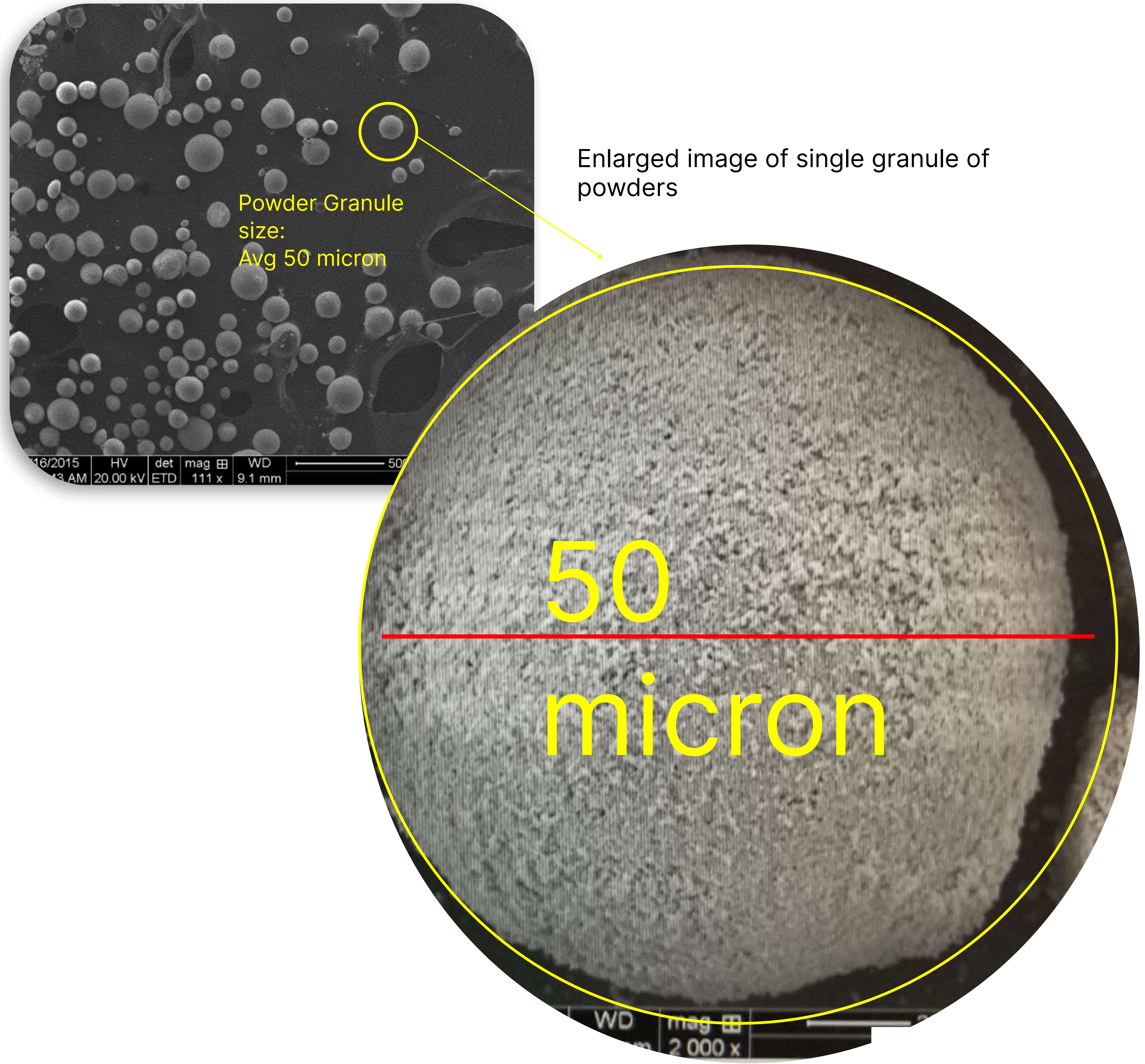


Enlarged image of single granule of powders

Downside of binders

- This is a magnified image of one granule. Each granule has hundreds of thousands of particles bound by chemical binders* to keep the disc in shape after compressing. Binders are burned out during the pre-sintering stage of green body disks (at about 900 °C) to leave a substantial volume of voids/pores in the disk.

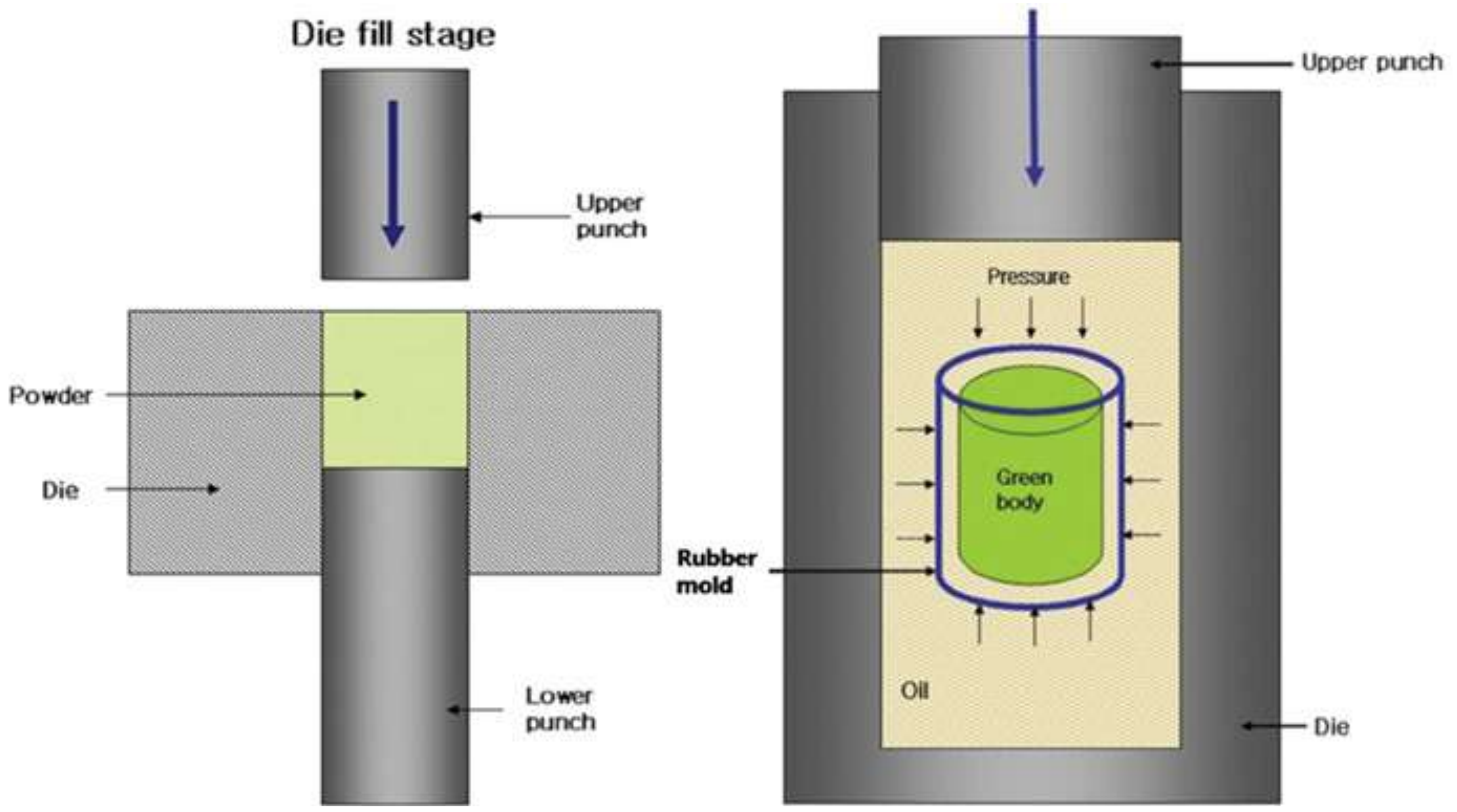
***The Downside of voids/pores** in the disk:*

Lowers the density of the disk, meaning you must mill restorations relatively larger
Lowers Accuracy More shrinkage has a higher margin of error
Lowers the translucency Even the small amounts of residual pores in the sintered zirconia significantly lowers translucency of a restoration.

Dry Compaction vs. Colloidal Processing

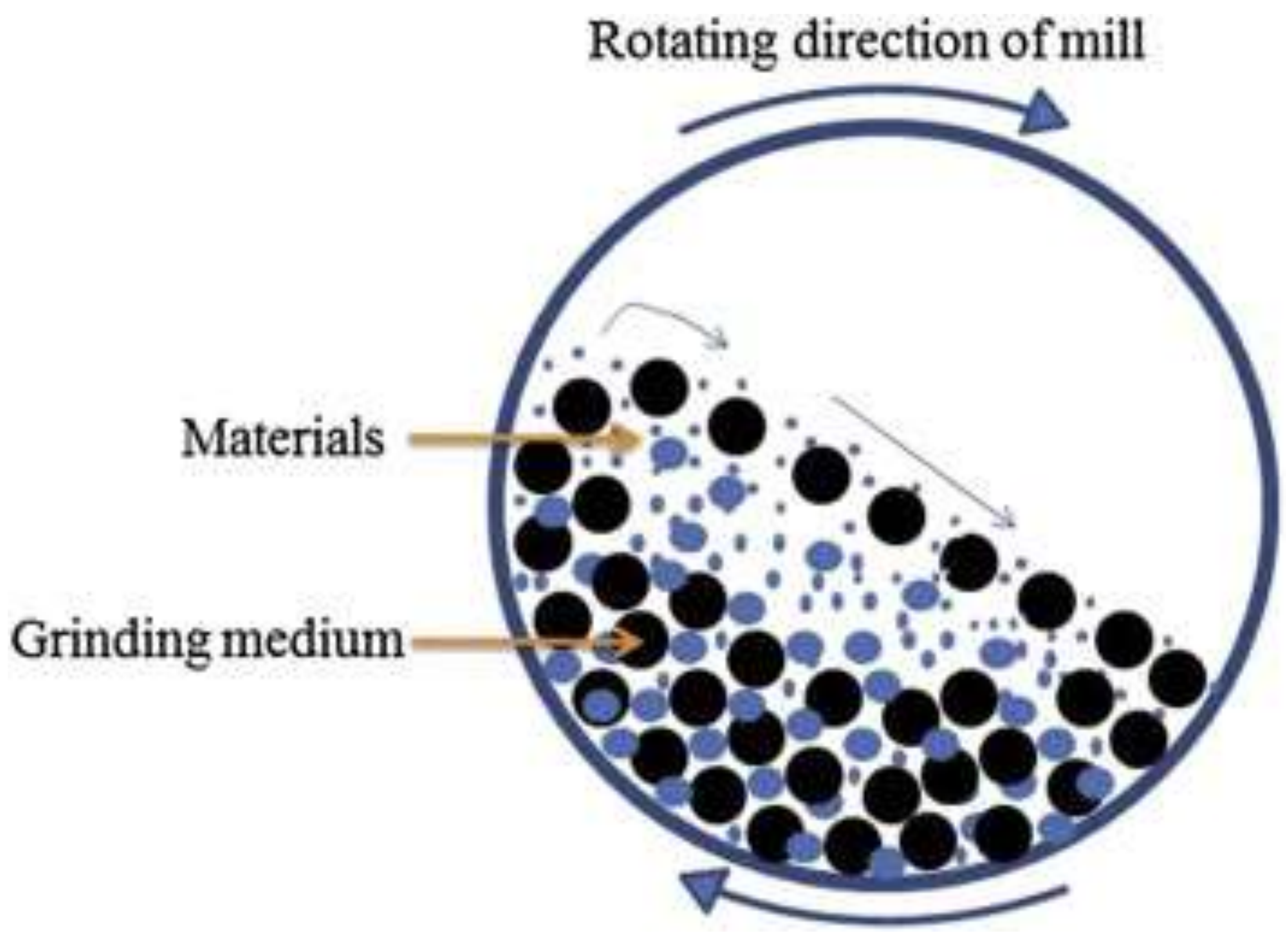
- In Cold Isostatic Pressing (CIP) the powders are contained in a flexible mold commonly made of polyurethane. The green body is then immersed in a liquid, usually water or oil, and then pumped to a high pressure. In CIP, the powder/green body is compacted with the same pressure from all directions for even density.

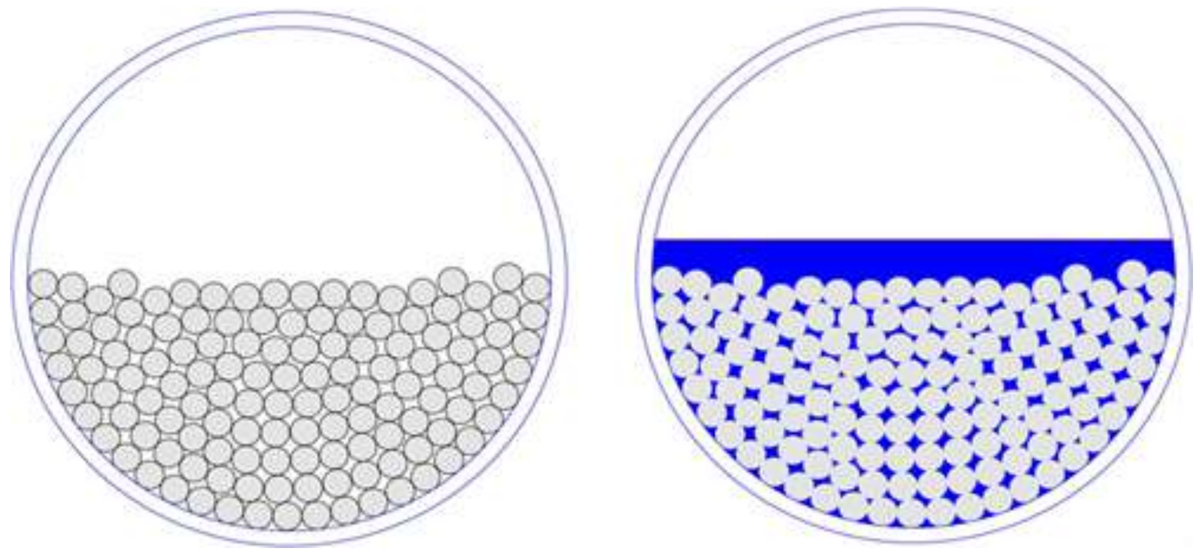
- But the pressing process shows a strong tendency of powders to agglomeration*, resulting in a less homogeneous product than what is created from the colloidal process.



* agglomeration: clumping of particles that are sticking together

Dry Compaction vs. Colloidal Processing





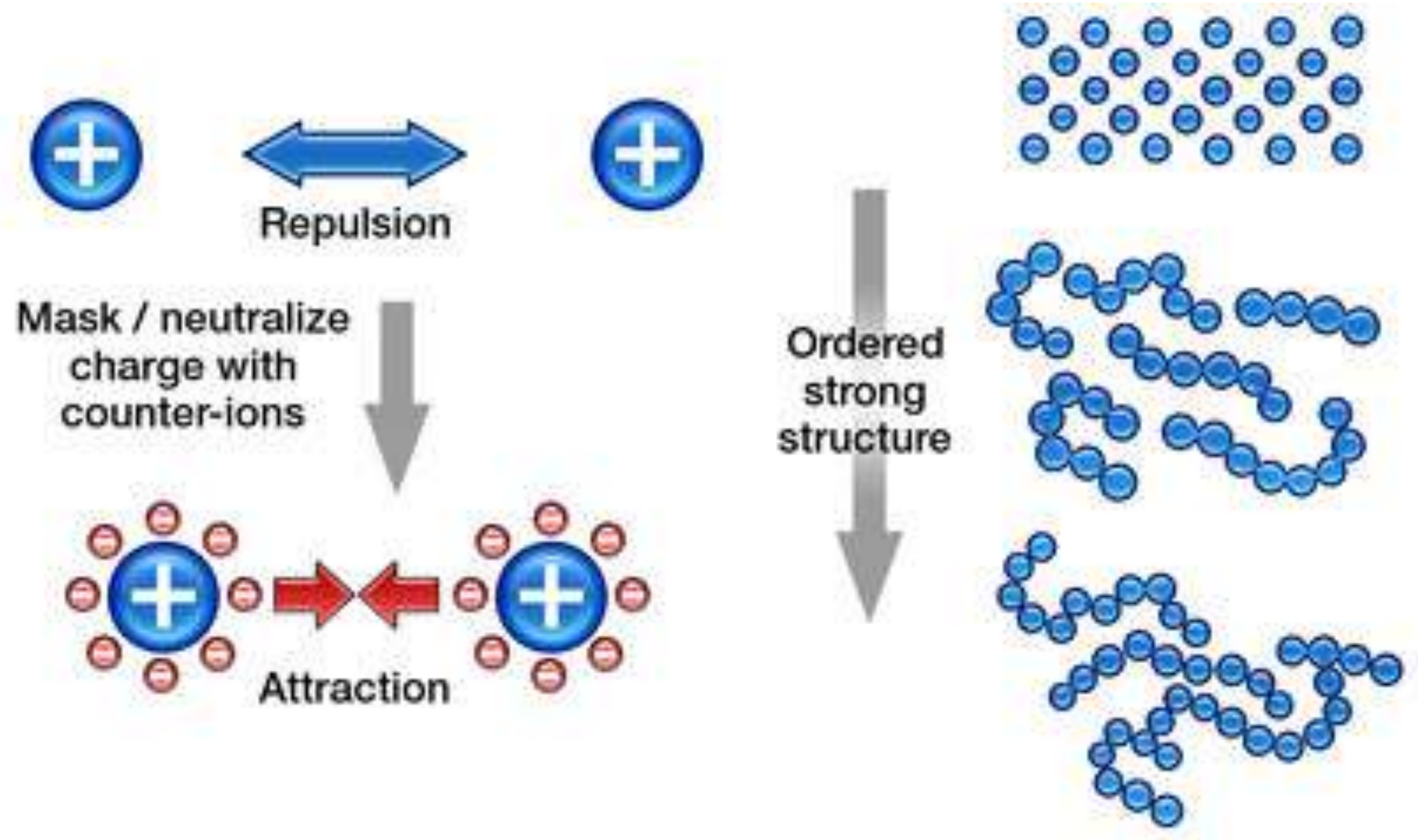
Reduction to Nano

Dental Plus reduces the binder-less version of zirconia granule down to 200 – 300 nano meters (*the size of smoke*).

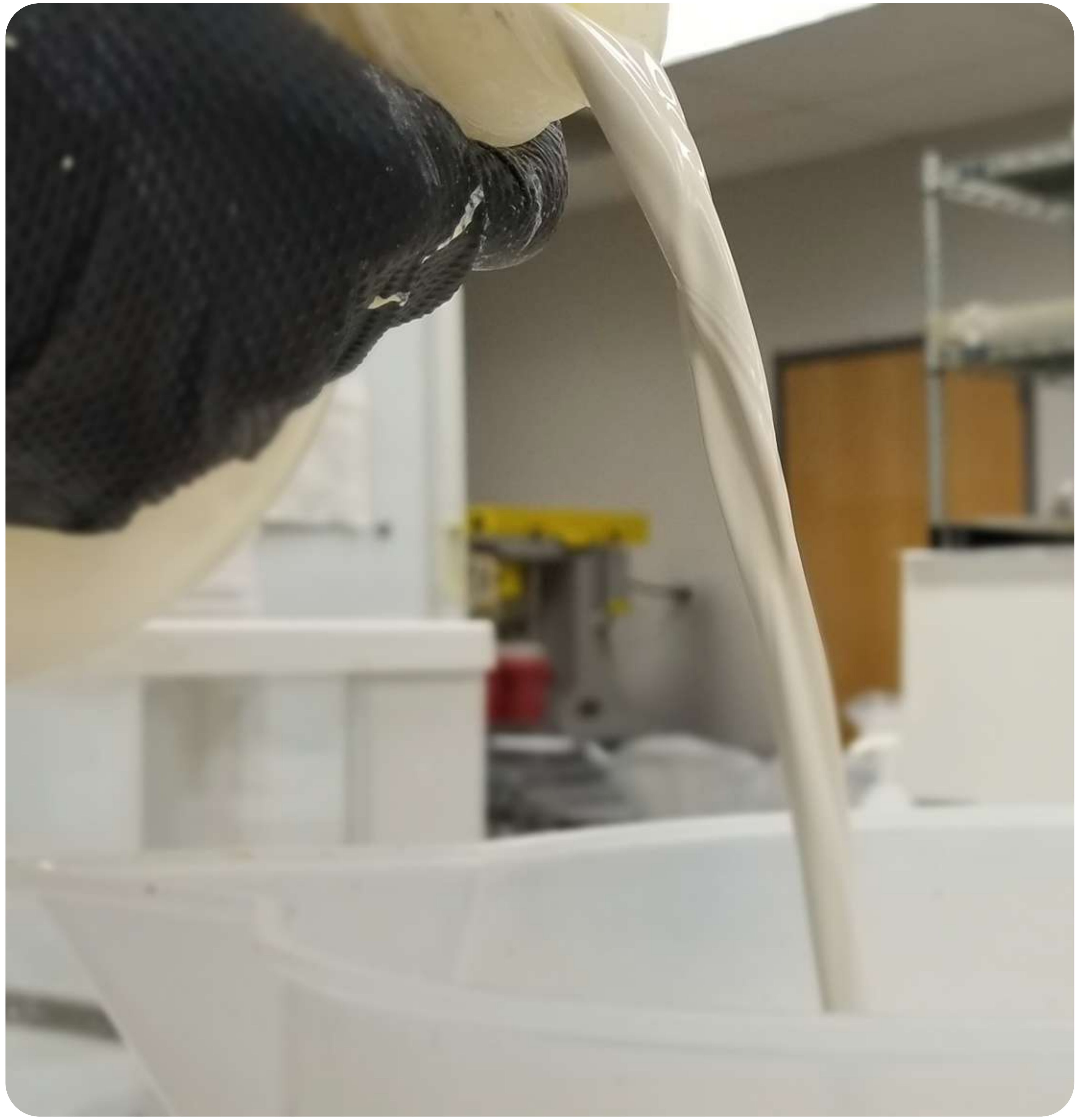
Dry Compaction vs. Colloidal Processing

Dry Compaction vs. Colloidal Processing

When the moisture content is over 50%, suspensions are formed in which particles are evenly dispersed in the liquid. The control of the interparticle forces allows us to produce stable suspensions. This stability is maintained even during consolidation.



This creates a **very homogeneous and dense green body** compared to conventional methods of dry compaction.



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Honey, I shrunk the zirconia

DENTAL PLUS USA zirconia is created using a patented process utilizing 300 nm particles (*without binders*), instead of settling for the 40–60 micron size.

That reduction, like comparing **14 feet to 1 inch**, results in a denser material with greater fracture toughness.

Green Body

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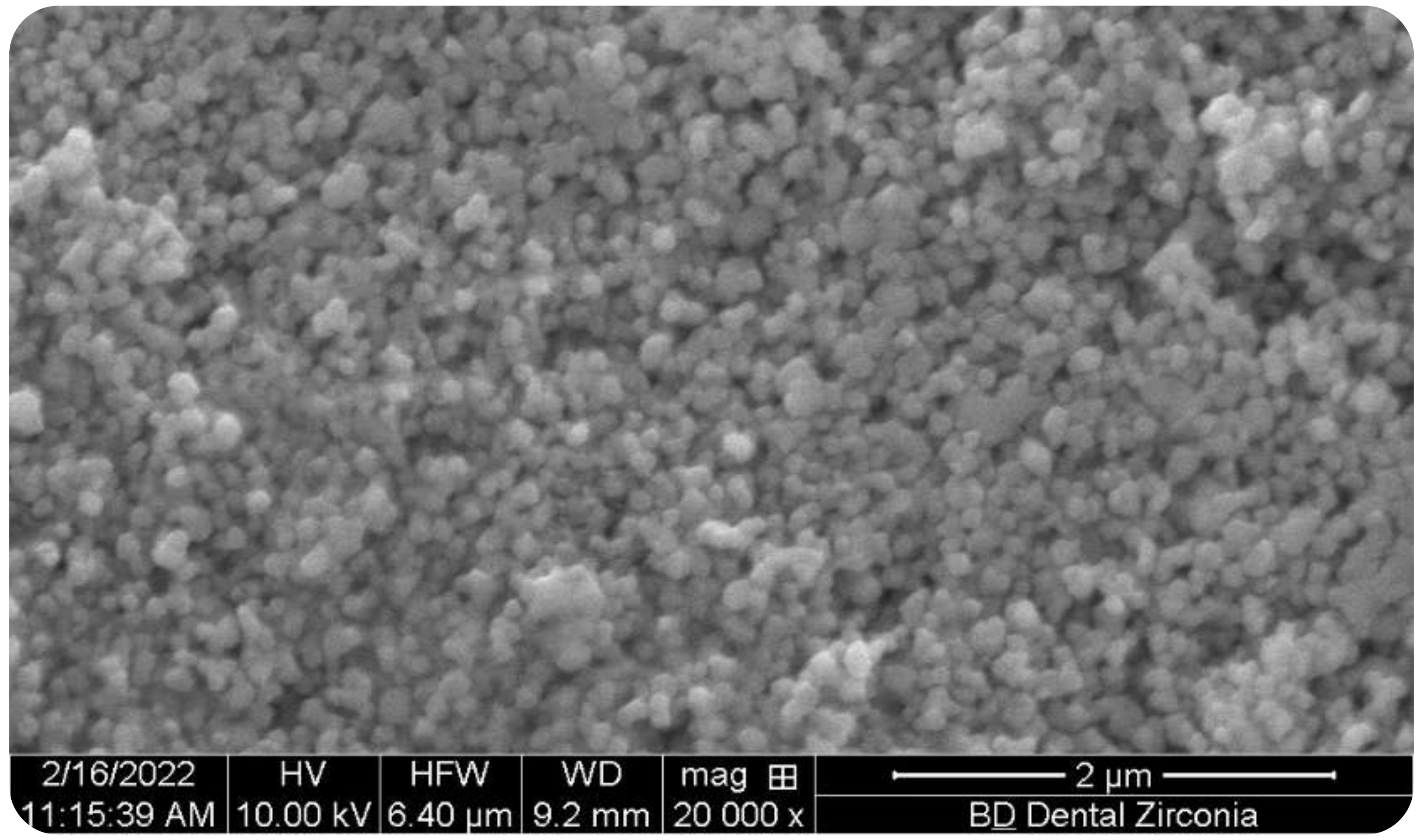
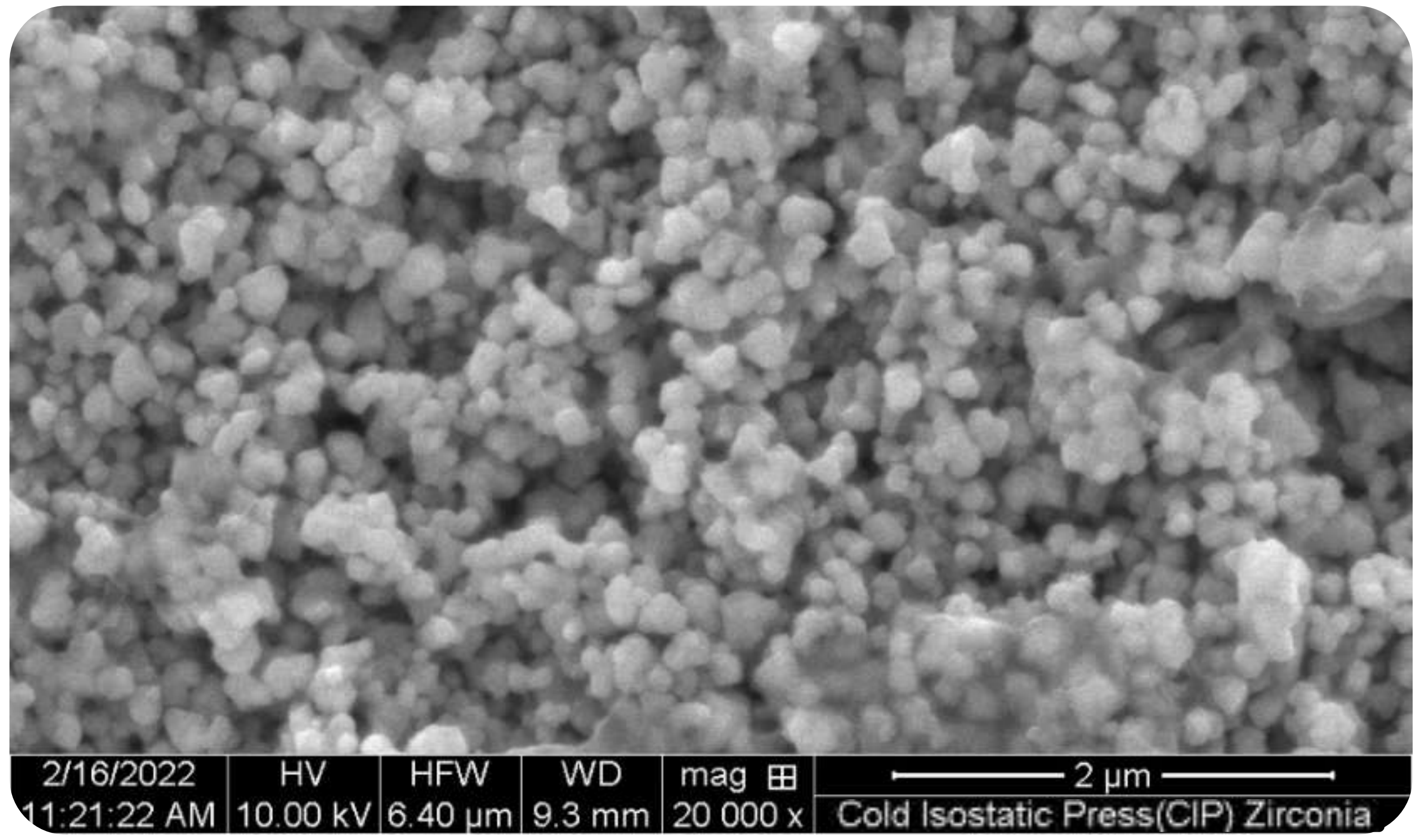
Colloidal		Dry Compaction
	Greater stability is achieved with the uniform, homogeneous grain packing with fewer and smaller voids in the disc.	
Smaller	**Particle Size**	**Larger**
More Dense	**Density**	Less Dense
Homogeneous particle packing	**Uniformity**	***Irregular*** particle packing

Colloidal Process

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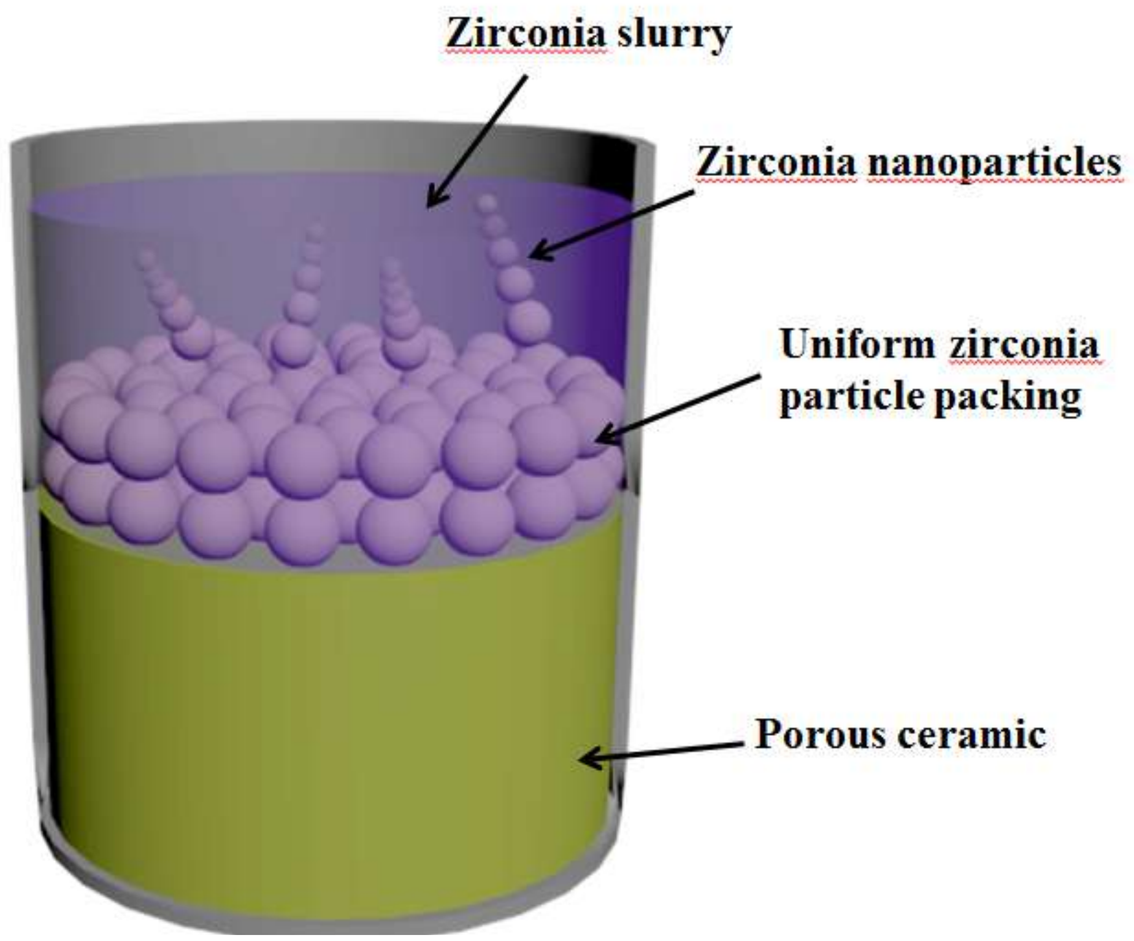

This unique production process consistently results in **far better TRANSLUCENCY at any given STRENGTH** than the dry compaction method.

Sintered Body

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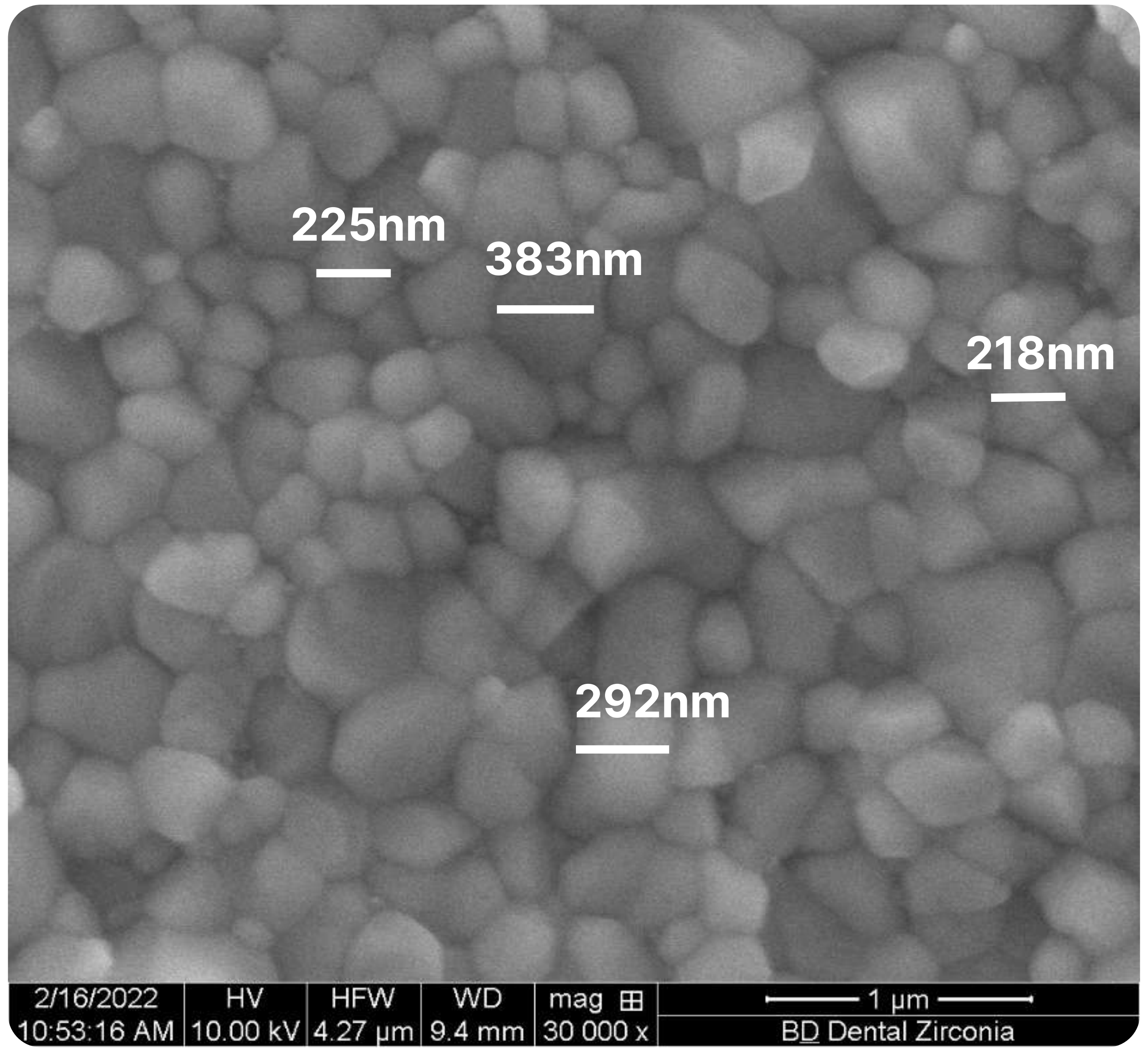
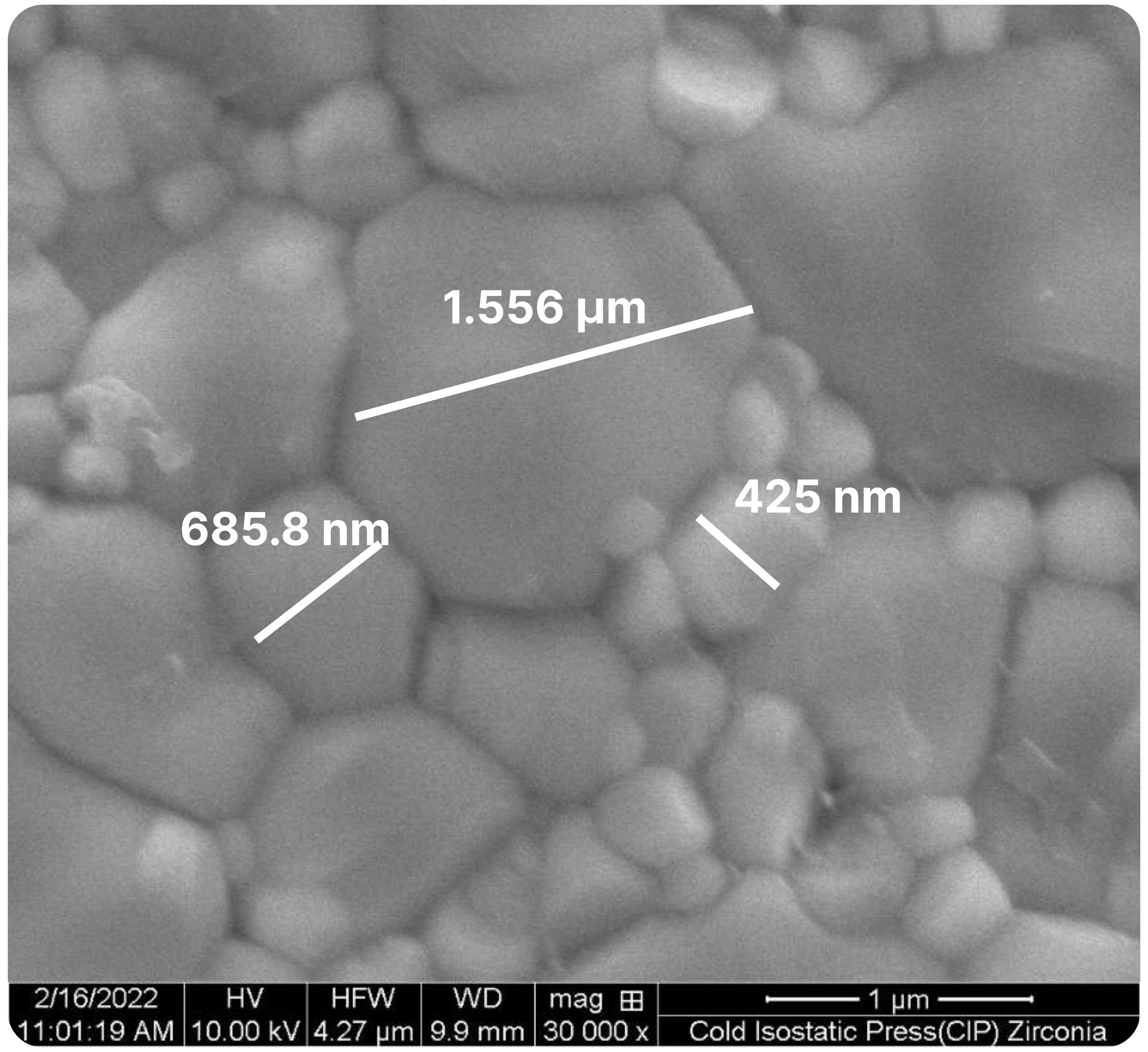
Engineered for Optimal Performance



Sintered body from Colloidal Method
Dental Plus Multi Layer, A2

The grain sizes of zirconia from dry compaction processing are **significantly** larger than Dental Plus's Colloidal Zirconia



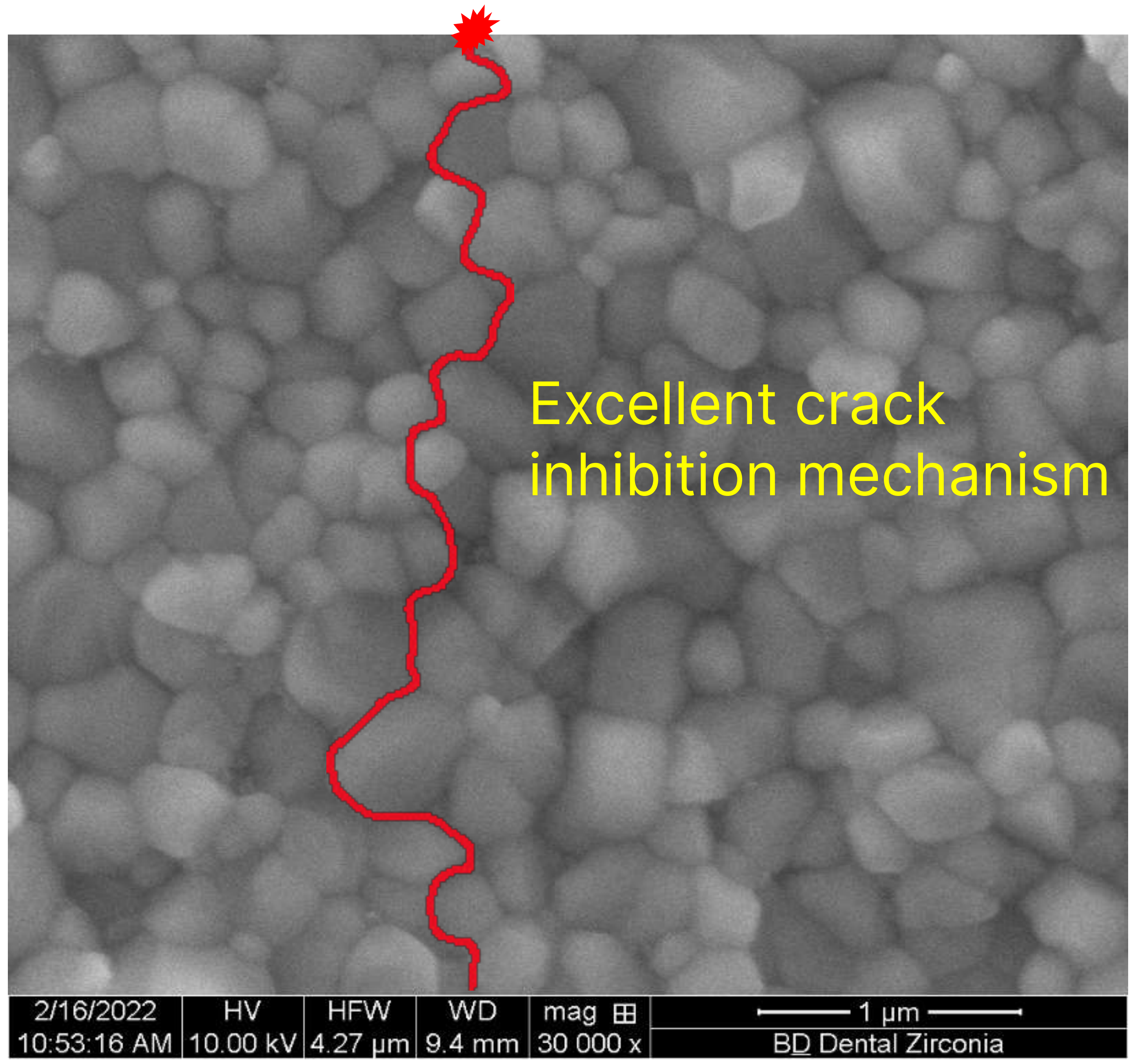
Sintered body from Common Method
Dry Compaction (Cold Isostatic Press, CIP)
Multi Layer, A2

Why does size matter?

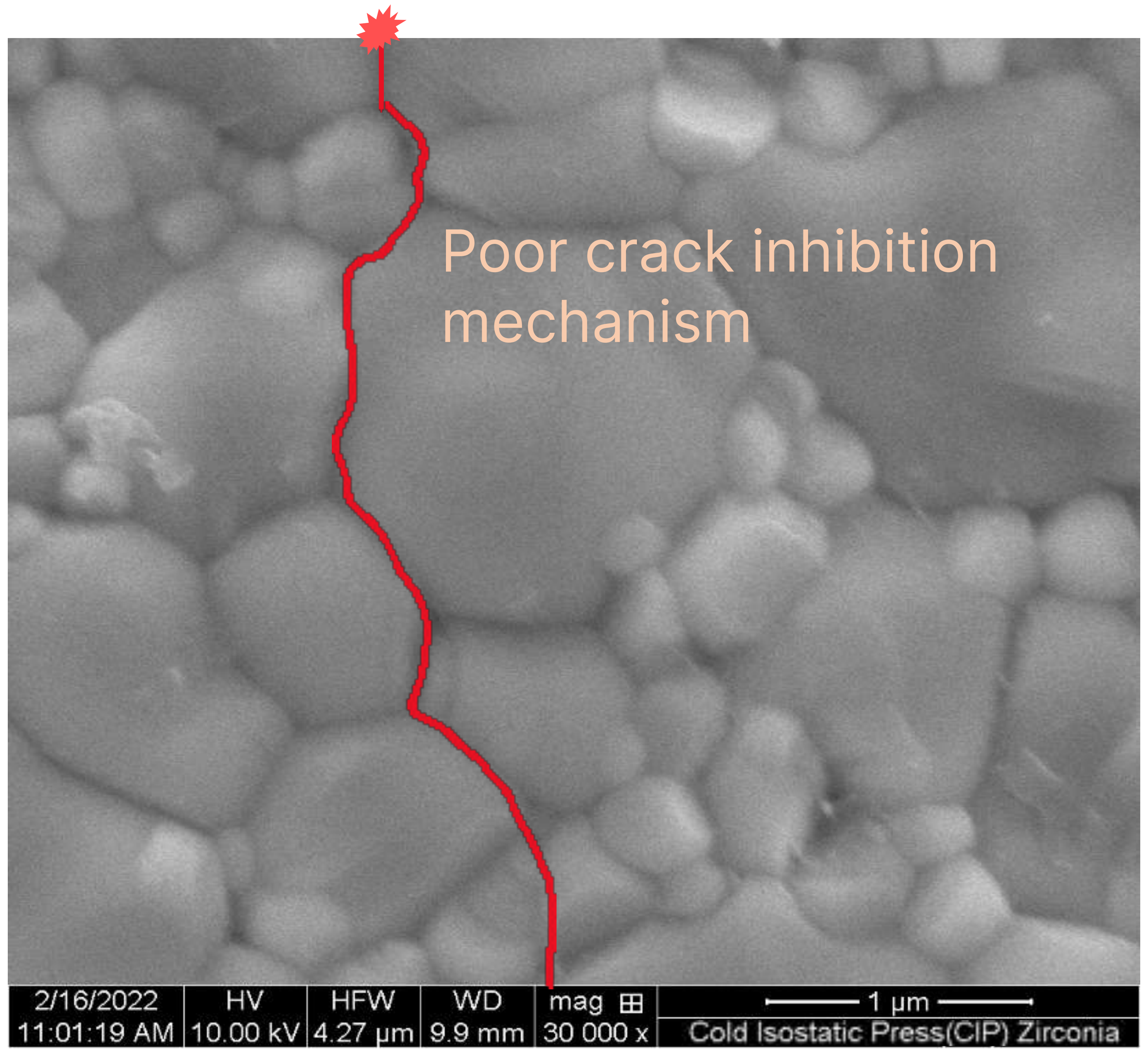
This extra process of ball milling requires more time, but it plays a vital role in creating the highest performance in:

- **Strength & Crack inhibition**
- **Translucency**
- **Surface roughness** (producing the lowest wear of the opposing dentition)
- **3-Dimensional Accuracy**

Crack initiation



Sintered body from Colloidal Method
Dental Plus Multi Layer, A2



Sintered body from Common Method
Dry Compaction (Cold Isostatic Press, CIP)
Multi Layer, A2

When an external force initiates a crack, smaller grain sizes significantly contributes to resisting crack propagation due to the large surface area created by smaller grains between boundaries.

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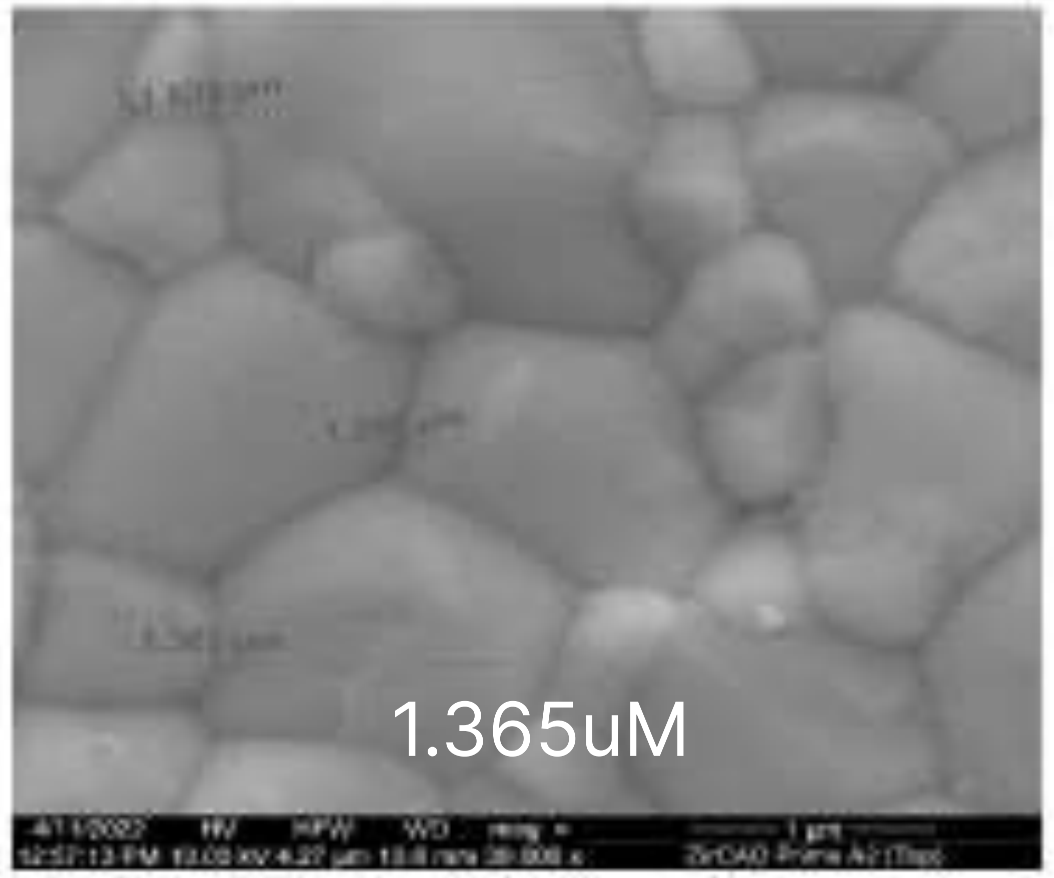
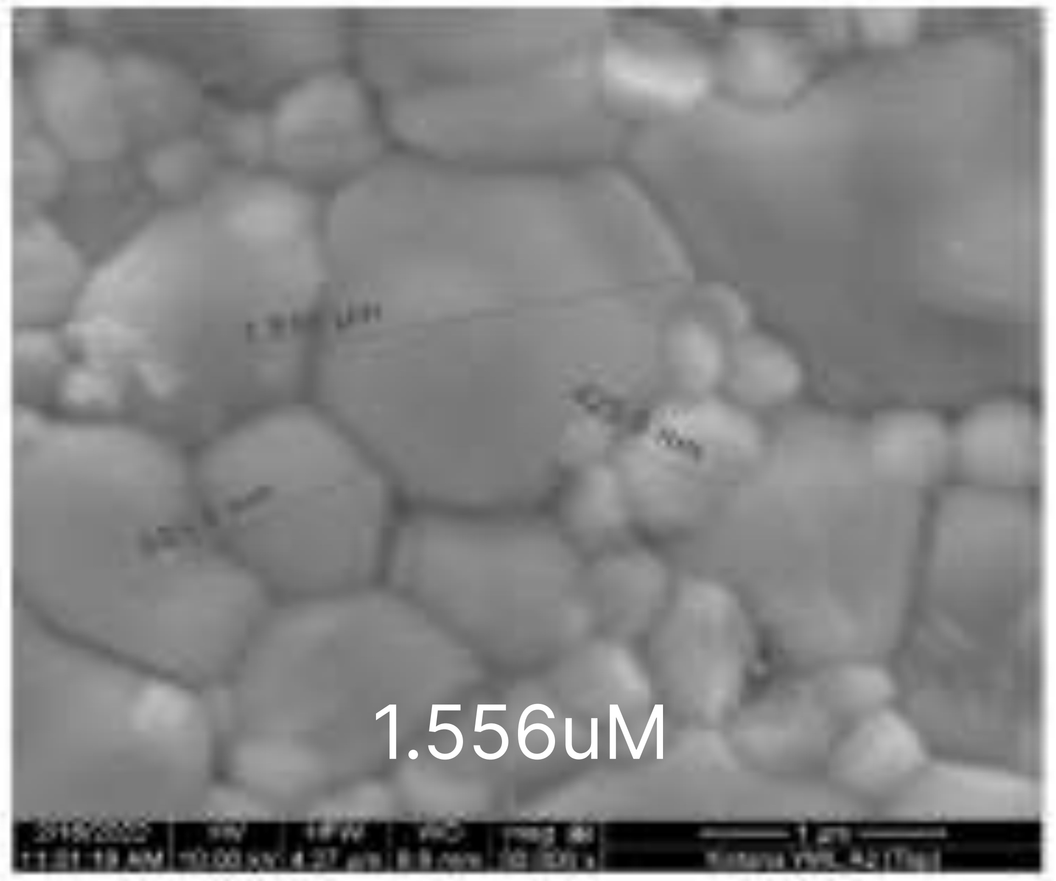
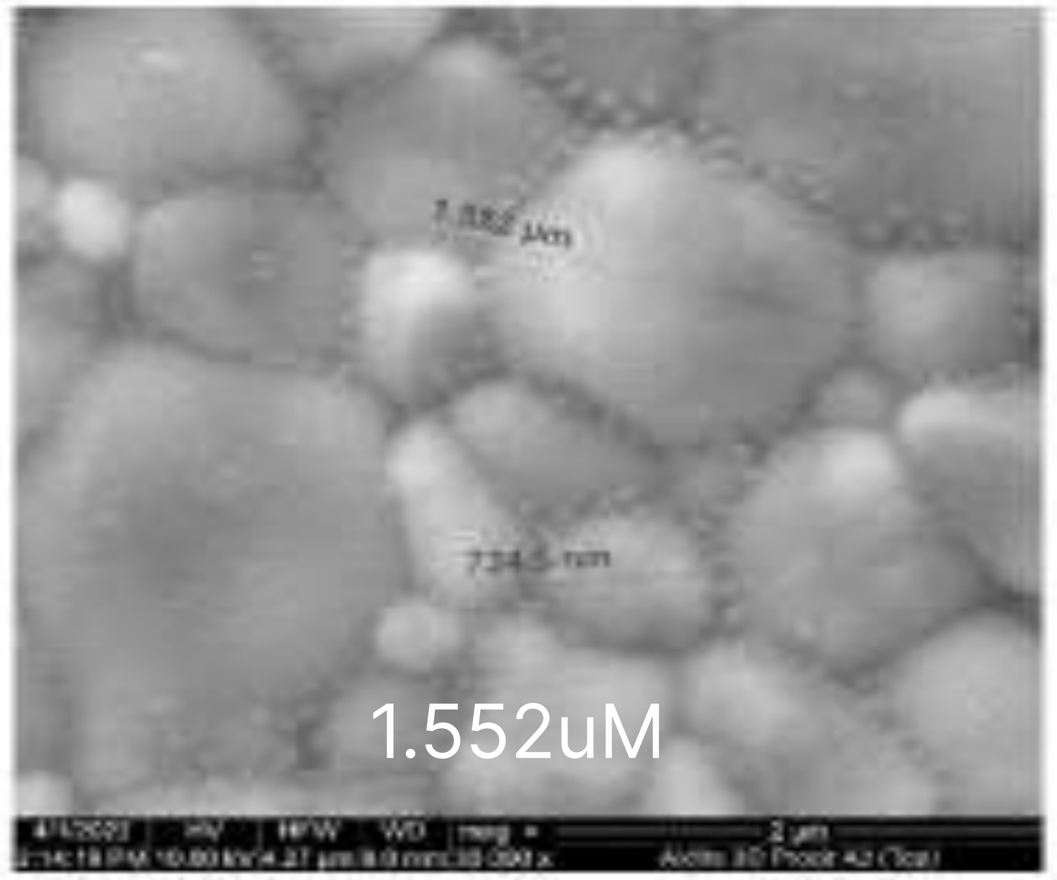
Zircad Prime



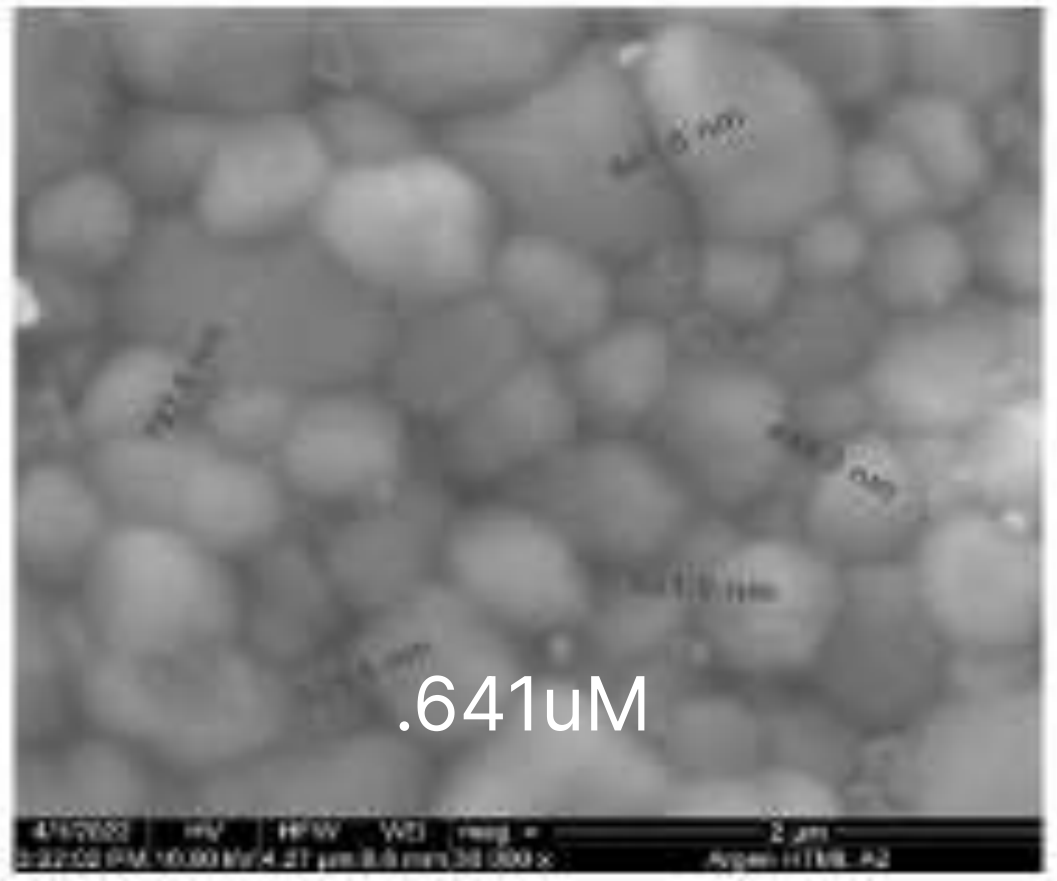
Katana

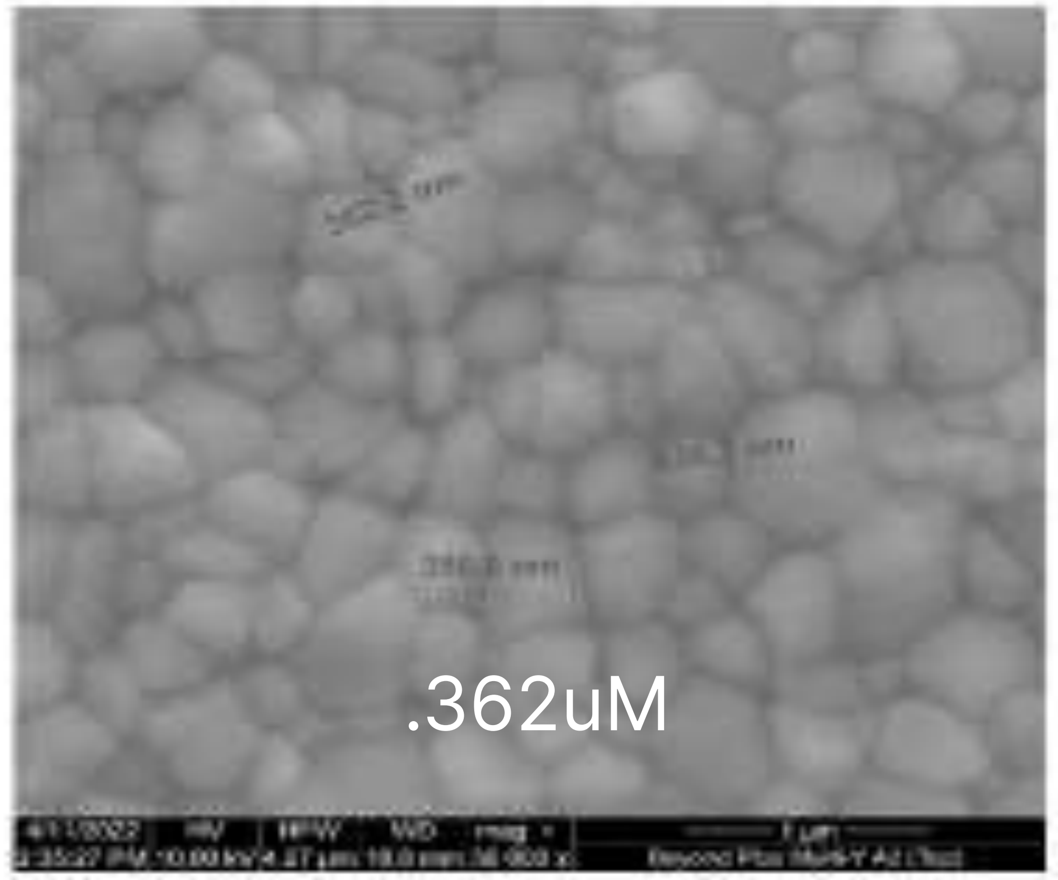


Aidite 3D Pro



Argen HTML





Dental Plus Multi

X 30,000 magnification

ORIGIN

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Pre-shaded Multi with Smart Incisal

Dental Plus Multi

1250 MPa cervical to 1100 MPa incisal


Photo Courtesy of Luke Khang, President, LSK 121 Laboratory

Success Formula for Adar Dental Network

Dental Plus USA

Photos courtesy of Pinhas Adar, Master Ceramist and founder of Adar Dental Network & Oral Design Center in Atlanta, GA

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Moreover, reducing the grainsize of 3Y-TZP ceramics is the most convenient way to enhance its translucency.

Materials containing particles in sizes less than about 0.1 μm appear more translucent due to less reflection and absorption when exposed to visible light wavelength than those containing large particles

Compared to the grain boundary, the presence of pores in the material and the amount of these pores are more important for translucency 64) In terms of high-density nano-crystalline ZrO_2, it is unlikely that pore diameter would be greater than the grain size and the usage of <50-nm grain zirconia declines the lights scattering problem. Employing 40-nm powder instead of 90-nm amplifies the sintering density and reduces pores and scattering.

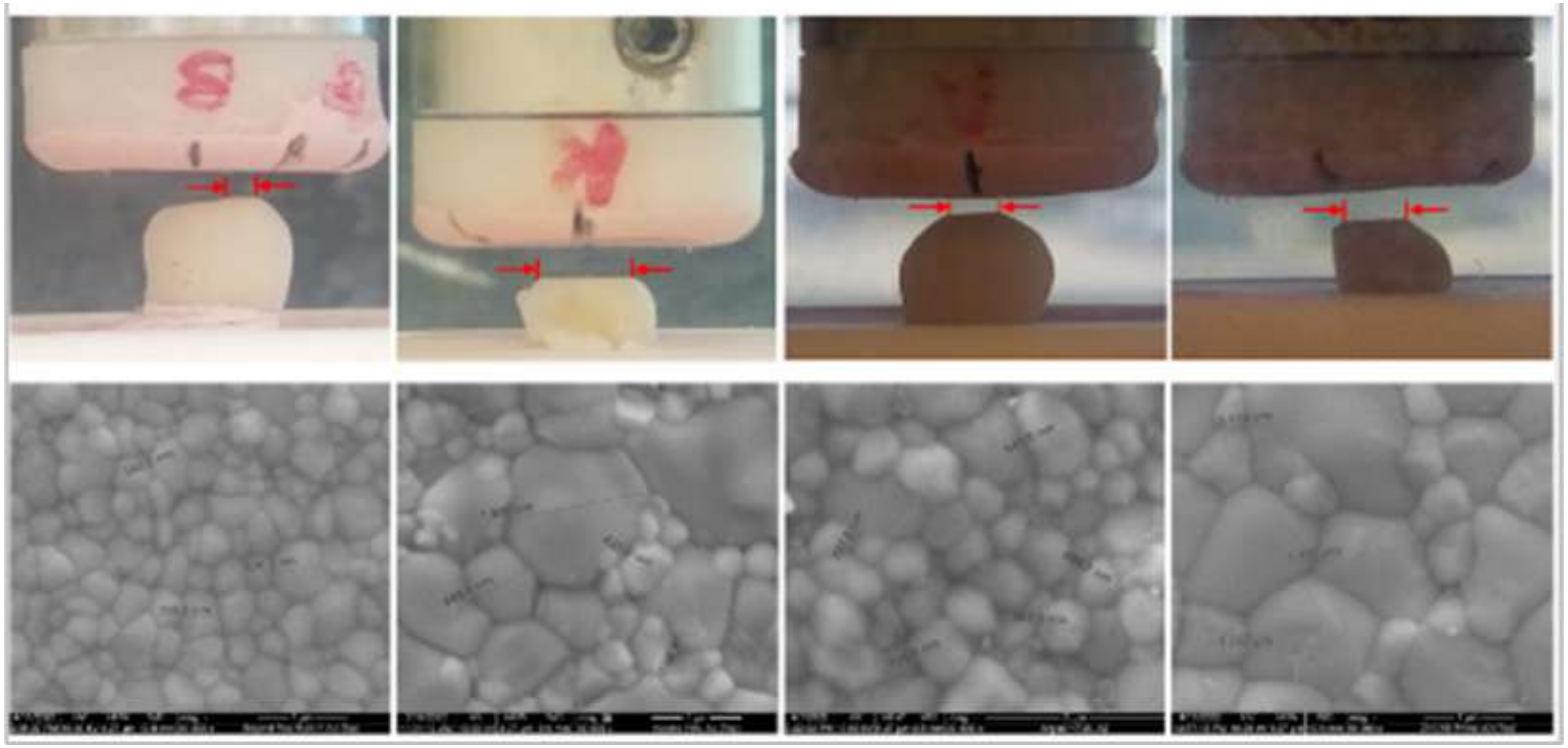
Porosity plays a significant role in the translucency of ZrO_2 material. Pores larger than 50 nm result in considerable scattering, thus reducing light transmission("pore scattering")5,64). The impurities affect the optical features of the material and lead to changes and variations in color. These changes may increase the difficulty of obtaining desired colors and achieving satisfactory color control, stability, and translucency

From; Dental materials 2022
Sintering temperature accuracy and its effect on translucent yttria-stabilized zirconia: Flexural strength, crystal structure, tetragonality and light transmission

Conclusions: Deviations of 5% from the sintering temperature recommended for YSZ materials with different yttria content influence material properties such as light transmittance, flexural strength, crystal phase fractions, tetragonality, and grain growth. Too low temperature results in decreased strength for some translucent zirconia materials, while others are less affected. Light transmittance varies depending on several factors such as grain size, crystal phase fractions and binder content in the start material prior to pre-sintering. Consequently, the use of high quality, well-calibrated furnaces is crucial when sintering YSZ materials to avoid unwanted material changes.

Chewing simulator test results

Dental Plus Multi (A2)	Katana Noritake STML, TML Multi (A2)	Argen HTML Multi (A2)	Ivoclar e.max ZirCAD Prime (multi A2)



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Sintering

Sintering affects everything;

- Grain size
- Resin bond strength
- Translucency
- Fracture toughness
- Shade

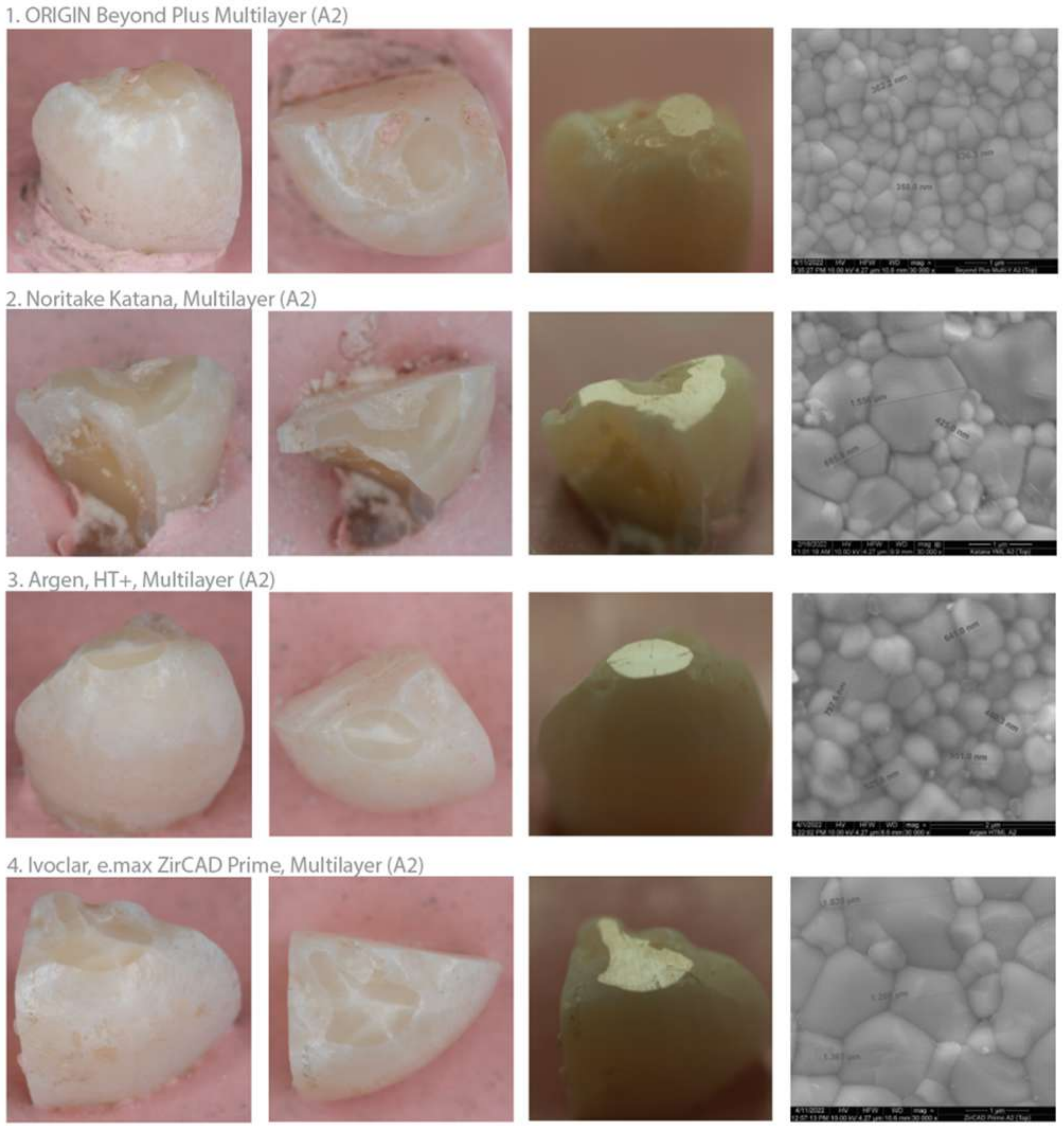
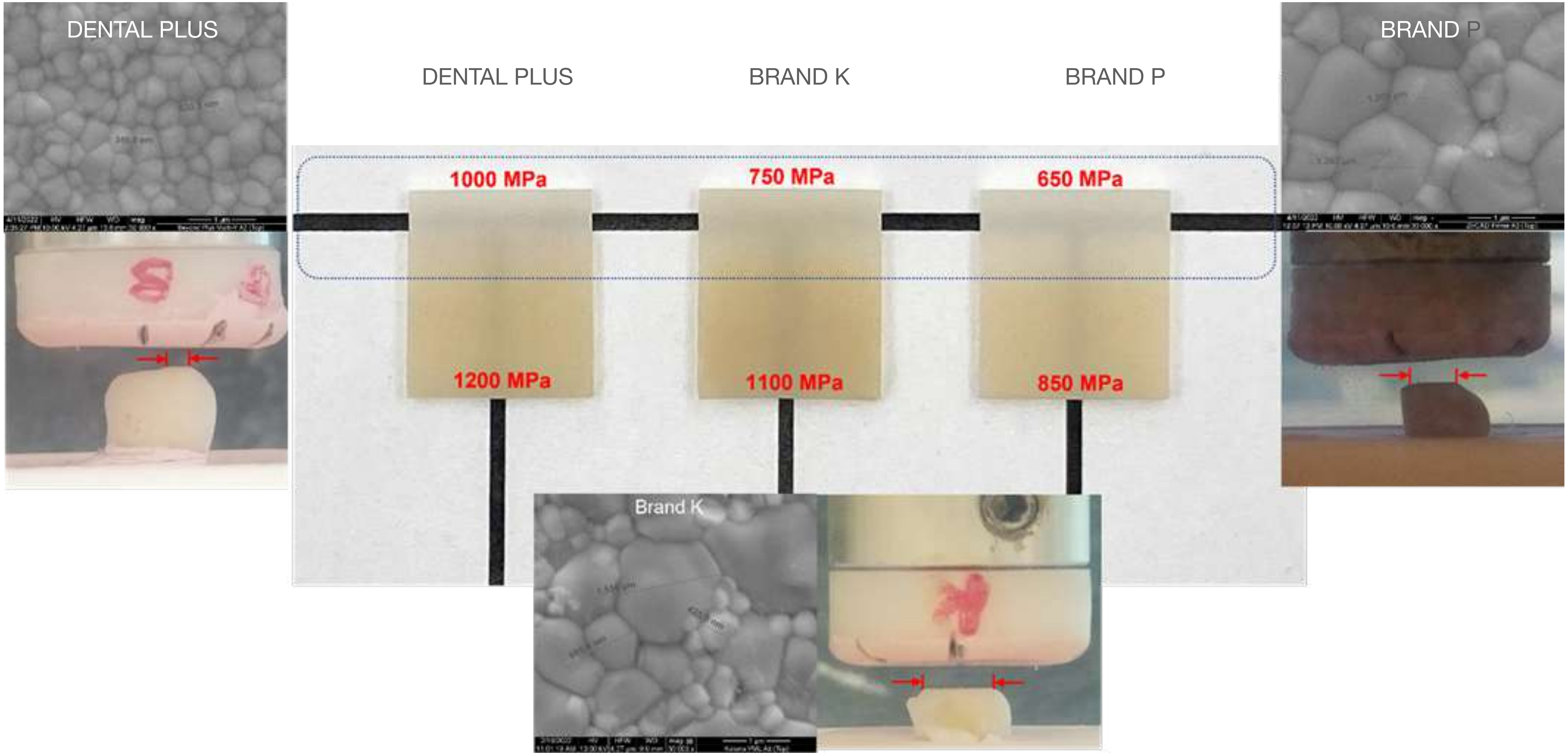


Figure 4. Photos and SEM images of each samples after Chewing simulator test.

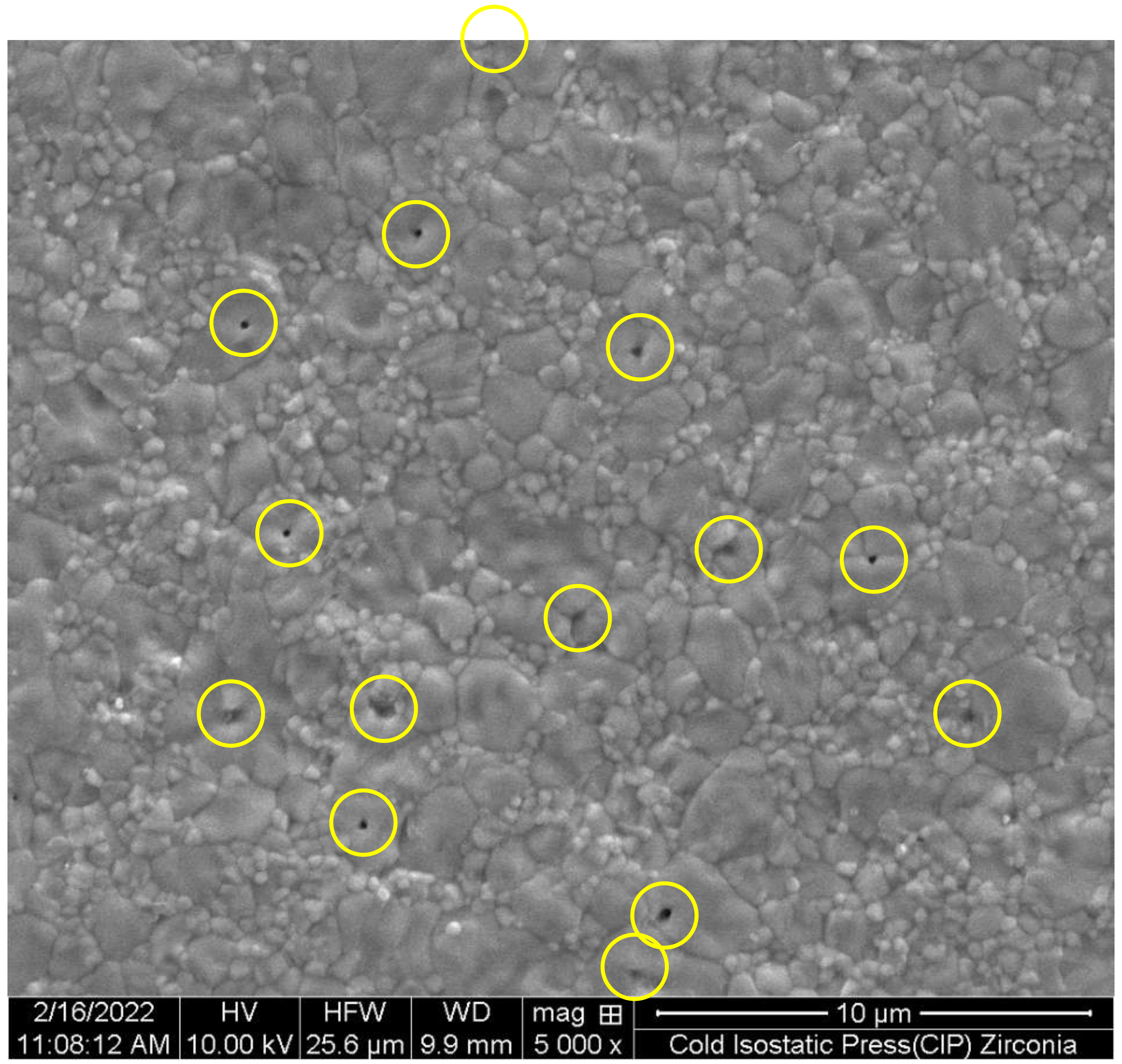
Figure 4 shows that the degree of wear/abrasion of opposing mandibular natural teeth substantially increased as the sintered grain size (especially the cubic grains) increased. And as the yttria contents of the zirconia increased, the cubic gains correspondingly increased, as shown in the SEM images (scanning electron microscope, FEI Quanta 600 FE, USA). Specifically, the yttria contents of Brand K and Brand P were substantially high, with 10.60 wt% and 10.72 wt%, respectively, which was confirmed through independent elemental analysis (EDS test, Energy-Dispersive X-Ray Spectroscopy).

Translucency, strength, particle size, wear comparison

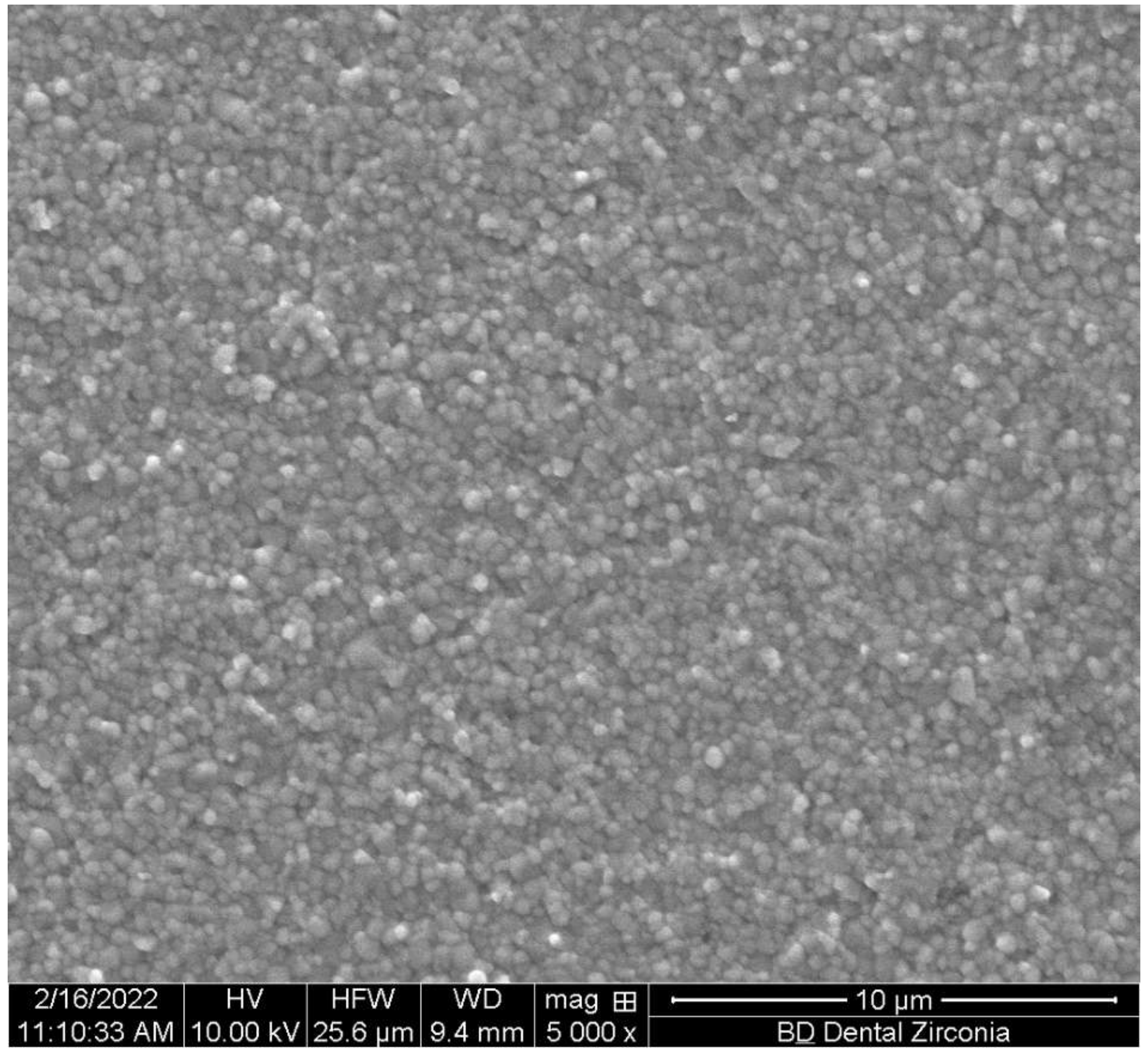


Comparison of Particle Structure of Sintered Body

- Scanning Electron Microscope (SEM)



Sintered body from Common Method
Dry Compaction (Cold Isostatic Press, CIP)
Multi Layer, A2



Sintered body from Colloidal Method
Dental Plus Multi Layer, A2

Dental Plus Zirconia (on the right) has a dispersion of uniform and homogeneous grains.

The CIP zirconia from overseas on the left (well-known brand) has irregularly dispersed and heterogeneous grains. The CIP zirconia has **voids in the cubic grains**. These voids cause decreased translucency in the zirconia.

How can I improve shade matching?

This is an image showing the structure of a tooth. The strands which are visible are both dentin rods and enamel rods.

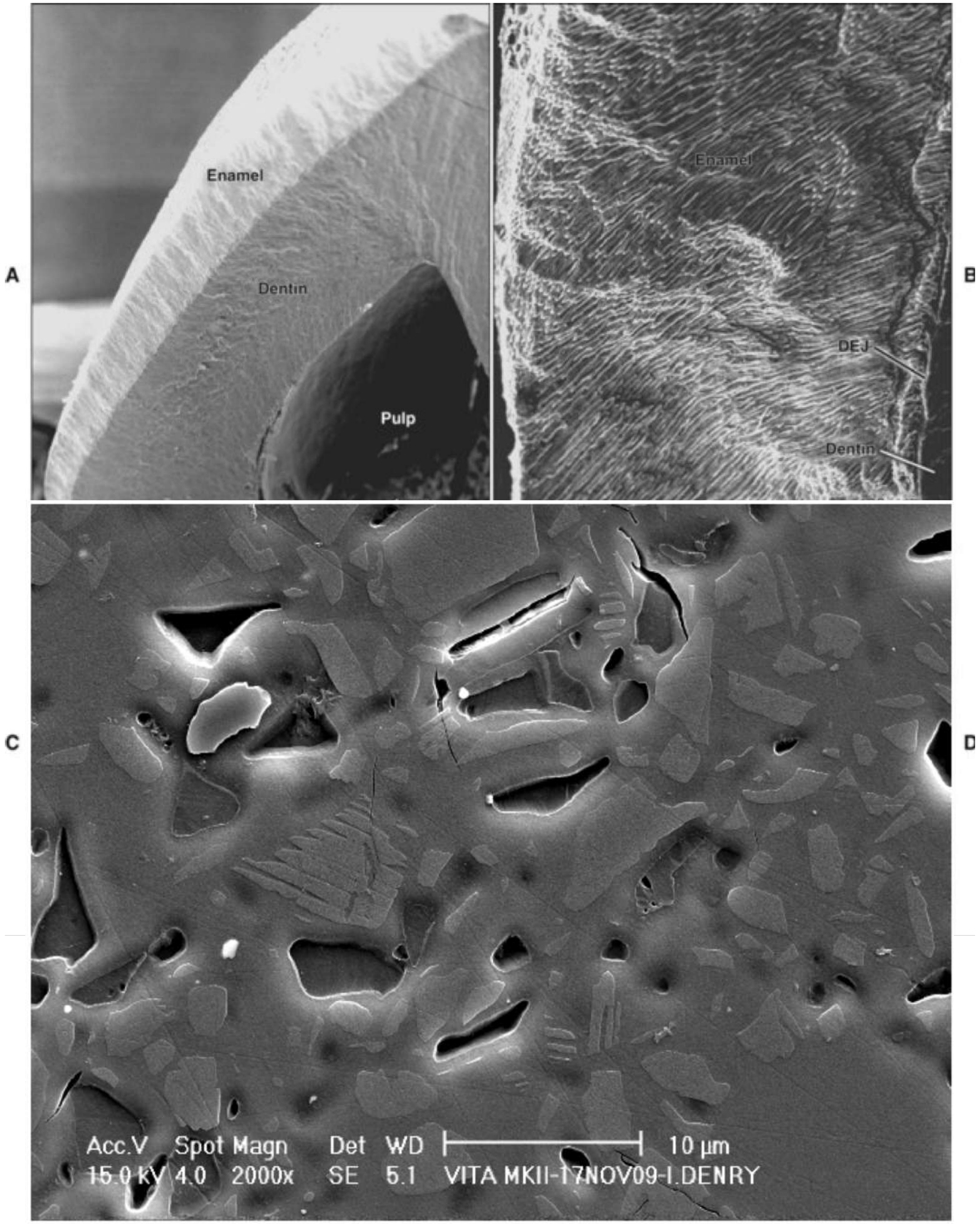


Image of zirconia structure

This is the structure of feldspathic porcelain

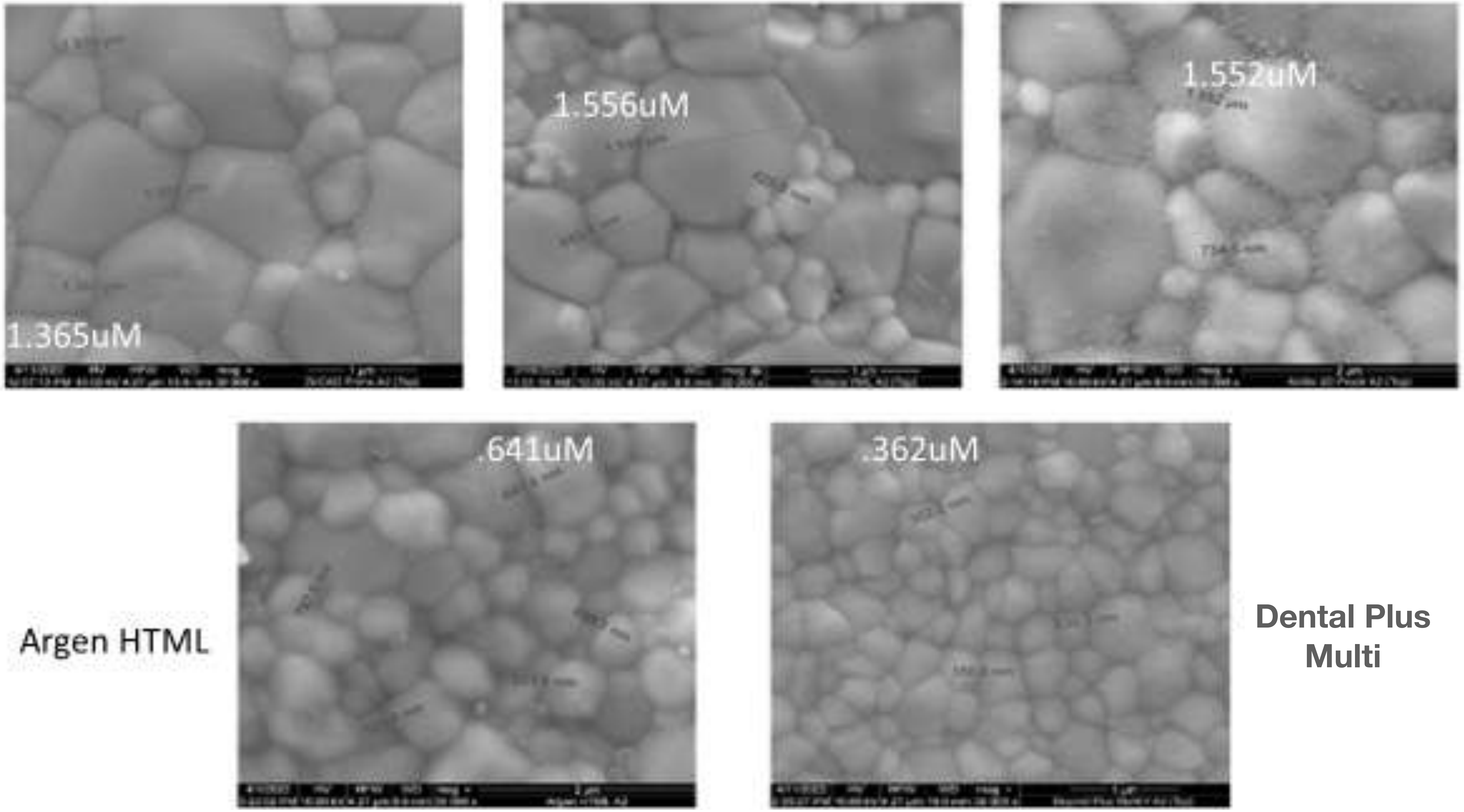
Zircad Prime

Katana

Aidite 3D

Argen HTML

Dental Plus Multi



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Stuff others may not have told you

Sintering is the **second most important** thing you need to know about the zirconia you use

- Grain size matters
- Fracture resistance
- Bond strength to cementing resins

Table 1. Sintering parameters

Sintering Type	T1 (°C)	Ramp (°C/min)	Holding (°C)	T2 (°C)	Ramp (°C/min)	Holding (°C)	T3 (°C)	Ramp (°C/min)	Holding (°C)	T4 (°C)	Ramp (°C/min)	Holding (°C)	Total time
Fast Sintering	980	999	0	1450	180	0	1530	25	7	1060	999	0	**22.4 min**
Regular Sintering	1050	20	60	1250	10	30	1480	5	150	250	20	0	**7 hrs**

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Test No	Force @ Peak (N)	Stress @ Peak (N/mm²)	Def. @ Peak (mm)	Width (mm)	Thickness (mm)
1	883.1	1078.156	0.698	3.98	2.95
2	931.4	1134.274	0.846	3.99	2.94
3	873.2	1049.075	0.749	3.99	2.96
4	642.8	791.398	0.628	3.92	2.95
5	925.7	1114.944	0.791	3.98	2.96
6	769.4	943.395	0.734	3.99	2.93
7	898.6	1086.923	0.851	3.99	2.95
8	710.9	855.597	0.681	4.01	2.95
9	889.7	1073.467	0.8	4.0	2.95
10	618.5	755.112	0.673	4.03	2.94
11	638.1	779.041	0.716	3.99	2.92
12	646.3	789.052	0.602	3.99	2.94
13	542.6	872.560	0.628	3.99	2.9
14	609.9	766.747	0.694	4.0	2.89
Min	609.9	755.11	0.578	3.92	2.89
Mean	768.02	**934.98**	0.72	3.989	2.938
Max	931.4	1134.274	0.851	4.03	2.96
S.D.	126.66	148.07	0.09	0.024	0.021
C. of V.	16.49	15.84	11.54	0.594	0.721
L.C.L.	641.36	786.91	0.62	3.976	2.926
U.C.L.	894.68	1083.06	0.80	4.003	2.95

Table 2. Flexural strength of the fast-sintered of nano zirconia

Independent Studies Comparing Slip Casting (Colloidal) vs Dry Compaction (CIP)

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Independent Studies Comparing the Slip Casting (Colloidal) Method over The Dry Compaction (Cold Isostatic Pressing) Method

Google

slip casting process vs isostatic pressing zirconia

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About 80,100 results (0.67 seconds)

https://www.scientific.net › AMR.896.335

Comparison between Slip Casting and Cold Isostatic Pressing ...

by NF Amat · 2014 · Cited by 6 — In the present work, the performances of the two methods are compared in the fabrication of nanostructured zirconia compacts for dental crown applications.

https://www.semanticscholar.org › paper › Comparison-be...

Comparison between Slip Casting and ... - Semantic Scholar

Feb 1, 2014 — First, a zirconia suspension suitable for slip casting was prepared. ... of zirconia pellets were fabricated using uniaxial pressing and ...

You visited this page on 1/30/22.

https://www.semanticscholar.org › paper › Comparison-be...

Comparison between slip-casting and uniaxial pressing for the ...

Slip casting and uniaxial pressing were compared as first consolidation stages prior to cold isostatic pressing (CIP) to produce translucent yttria ceramics ...

https://www.researchgate.net › ... › Ceramics

Comparison between slip-casting and uniaxial pressing for ...

Slip casting and uniaxial pressing were compared as first consolidation stages prior to cold isostatic pressing (CIP) to produce translucent yttria ceramics ...

http://dx.doi.org › mjas-2016-2003-25 PDF

FABRICATION OF Y-TZP FOR DENTAL CROWNS ...

Cold isostatic pressing (CIP) and slip casting are among several ... Tetragonal zirconia polycrystalline partially stabilized by 3 mol% of yttria (3Y-TZP) ...

https://www.osti.gov › biblio

Processing zirconia by sintering/hot isostatic pressing (Journal ...

Here, the effects of green density, time, temperature, and pressure on sintered density, grain size, and pore size of slip-cast ZrO{sub 2}-3 mol% Y{sub ...

https://www.idexlab.com › openisme › topic-cold-isosta...

Cold Isostatic Pressing - Explore the Science & Experts | ideXlab

Zirconia slurries were then slip-cast into a pellet. Second, another group of zirconia pellets were fabricated using uniaxial Pressing and were then ...

https://pubmed.ncbi.nlm.nih.gov › ...

Effect of Powder Characteristics on Slip Casting Fabrication of ...

by WC Kim · 2020 · Cited by 1 — Dense zirconia compacts were fabricated by slip casting and sintering of nanoscale zirconia powders, and the effect of the powder ...

https://dl.asminternational.org › book › chapter › Formin...

Forming and Predensification of Ceramics

CERAMIC-FORMING PROCESSES usually start with a powder and consist of ... wet or dry bag techniques), hot uniaxial pressing, slip casting, tape casting, ...

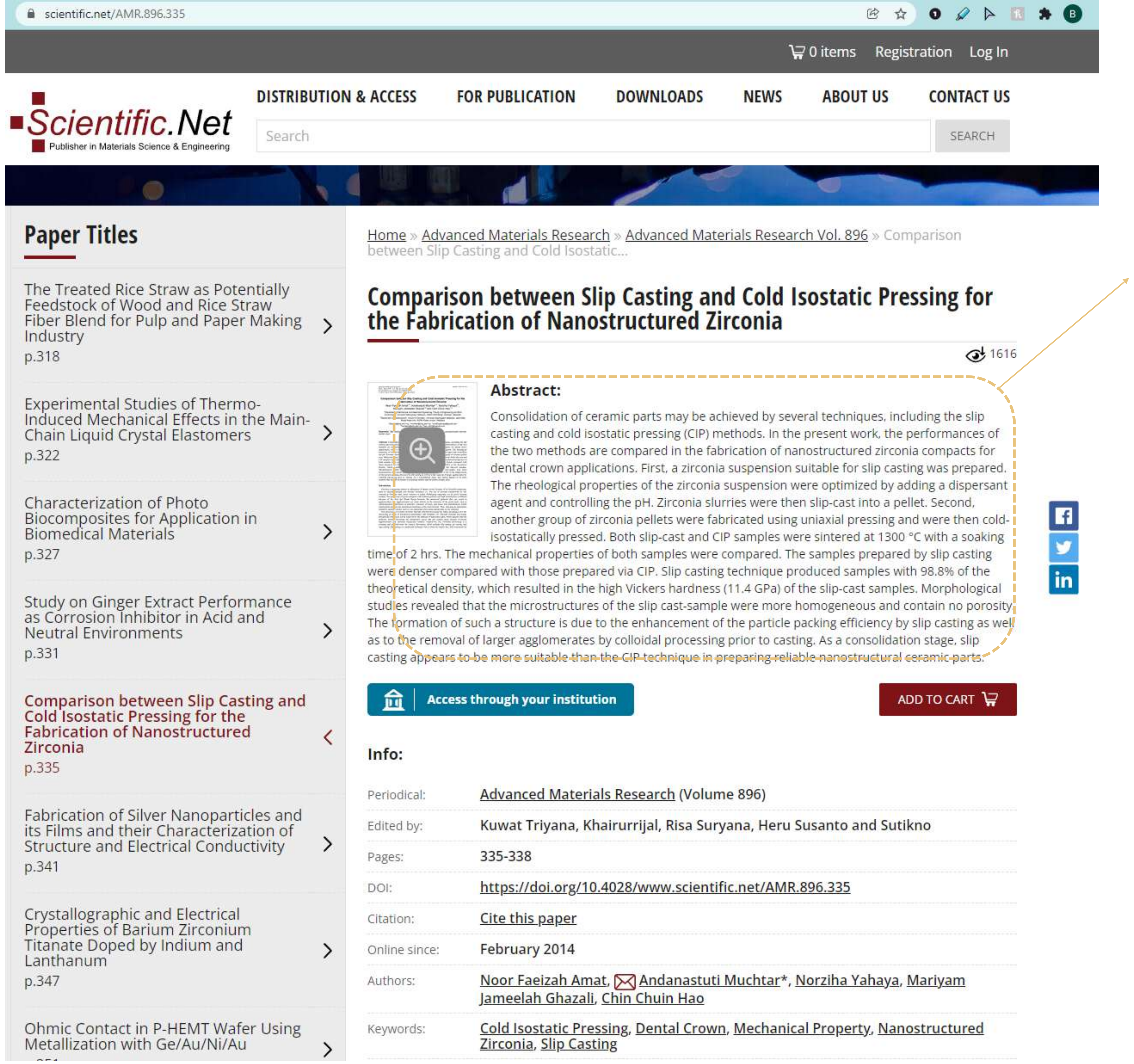
https://www.mdpi.com › htm

Methods Used for the Compaction and Molding of Ceramic ...

by VP Meshalkin · 2020 · Cited by 6 — The static methods of dry pressing include uniaxial pressing in sealed steel molds, cold isostatic pressing, and quasi-isostatic pressing, which ar...

- A Google search of slip casting process vs isostatic pressing (dry compaction) of zirconia will pull a good number of scientific papers comparing the two methods. They conclude that slip casting (colloidal) method is a better method for creating high quality of zirconia.

Independent Studies Comparing the Slip Casting (Colloidal) Method over The Dry Compaction (Isostatic Pressing) Method



- In this referenced work, the performance of the two methods are compared in the fabrication of nanostructured zirconia compacts for dental crown applications.
- The mechanical properties of both samples were compared. The samples prepared by slip casting were denser compared with those prepared via CIP. The slip casting technique produced samples with 98.8% of the theoretical density, which resulted in the high Vickers hardness (11.4 GPa) of the slip-cast samples. Morphological studies revealed that the microstructures of the slip cast-sample were more homogeneous and contain no porosity.
- The formation of such a structure is due to the enhancement of the particle packing efficiency by slip casting as well as to the removal of larger agglomerates by colloidal processing prior to casting. As a consolidation stage, slip casting appears to be more suitable than the CIP technique in preparing reliable nanostructural ceramic parts.

Independent Studies Comparing the Slip Casting (Colloidal) Method over The Dry Compaction (Isostatic Pressing) Method

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J Mech Behav Biomed Mater. 2021 Feb;114:104180. doi: 10.1016/j.jmbbm.2020.104180.
Epub 2020 Oct 31.

Biaxial flexural strength, crystalline structure, and grain size of new commercially available zirconia-based ceramics for dental appliances produced using a new slip-casting method

Jean-François Roulet[1], Kristy Lee Schepker[2], Andres Truco[2], Hans-Christoph Schwarz[3], Mateus Garcia Rocha[4]

Affiliations + expand

PMID: 33158788 DOI: 10.1016/j.jmbbm.2020.104180

Abstract

Objective: The aim of this study was to evaluate the biaxial flexural strength, the crystalline structure, and the grain size of zirconia-based ceramics produced using a new slip-casting method.

Materials and methods: Yttria-stabilized Tetragonal Zirconia Polycrystal (Y-TZP) and Alumina Toughened Zirconia (ATZ) ceramics were purchased from different manufactures. For the experimental group, ceramics produced using a patent pending slip-casting method (Slurry, Decema GmbH) was used. Slurry ceramics (n = 42) with a diameter of 14 ± 0.2 mm were produced by a proprietary colloidal shaping process, sintered, and subsequently polished with a lapping process using 15 μm diamond particles to a thickness of 1.2 ± 0.2 mm. For the control group, ceramics produced using the hot isostatic pressure method (HIP, Metoxit AG) were used. HIP ceramics discs (n = 42) with a diameter of 15.5 ± 0.02 mm were produced by classical HIP method and subsequently machined to a thickness of 1.99 ± 0.04 mm 32 discs of each ceramic were submitted to a biaxial flexural strength test using an universal testing machine at a crosshead speed of 0.5 mm/min. Statistical analyses using two-way ANOVA and Weibull distribution were performed. 2 discs of each ceramic were analyzed using X-ray diffraction for grain crystalline phase quantification. 2 discs of each ceramic were thermally etched and scanning electron microscopy images were obtained for grain size analysis (ISO 13383-1:2012). 6 discs of each ceramic were used for density measurement using the Archimedes' method.

Results: For both ATZ and Y-TZP ceramics, the biaxial flexural strength and the characteristic strength of ceramics produced using the Slurry method were significantly higher than ones of the ceramic produced using HIP. The structure analysis confirmed the superiority of the Slurry ceramics which had only 1.2% tetragonal phase compared to 11-16% for the HIP ceramics. Grain size distributions covered a wide range 50-800 nm; the ZrO_2 grains of the Slurry ceramics were significantly smaller than the ones of the control ceramics, while the Al_2O_3 grain distributions were not affected by the manufacturing process. The manufacturing process had no influence on the density of both materials.

Conclusions: The Slurry method using a new proprietary slip-casting method to produce Y-TZP and ATZ dental ceramics presented higher biaxial flexural strength, less monoclinic phase and smaller ZrO_2 grains.

Keywords: Biaxial strength; Density; Hybrid ceramic; Manufacturing process; Structure; XRD; Y-TZP ceramic.

- **Results:** For both ATZ (Alumina toughened zirconia) and Y-TZP ceramics, the biaxial flexural strength and the characteristic strength of ceramics produced using the Slurry method were significantly higher than ones of the ceramic produced using HIP (Hot Isostatic Pressing).
- the ZrO_2 grains of the Slurry ceramics were significantly smaller than the ones of the control ceramics.
- **Conclusions:** The Slurry method using a new proprietary slip-casting method to produce Y-TZP and ATZ dental ceramics presented higher biaxial flexural strength, less monoclinic phase and smaller ZrO_2 grains.

Independent Studies Comparing the Slip Casting (Colloidal) Method over The Dry Compaction (Cold Isostatic Pressing) Method

Dental Plus USA

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Comparison between slip-casting and uniaxial pressing for the fabrication of translucent yttria ceramics

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Abstract

Slip casting and uniaxial pressing were compared as first consolidation stages prior to cold isostatic pressing (CIP) to produce translucent yttria ceramics. In the first step, yttria slurries suitable for slip casting were prepared. The viscosity was optimized with respect to the starting agglomeration state, amount of dispersant, milling time, and number of milling balls. Secondly, pellets were prepared either by slip casting or uniaxial pressing and then cold-isostatically pressed. Finally, the pellets were made translucent by a combination of pre-sintering and hot isostatic pressing (HIP). Although slip-cast and pressed samples exhibited similar green-body densities after CIP and pre-sintering, the samples prepared by slip casting were more homogeneous in terms of translucency and microstructure throughout their bodies. This was attributed to the ability of slip casting to minimize density gradients during packing, and to the beneficial effect of ball-milling to remove larger agglomerates before casting. Therefore, slip casting as a first consolidation stage prior to CIP appears to be more suitable than uniaxial pressing in order to prepare homogeneous optical ceramics.

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- Therefore, slip casting as a first consolidation stage prior to CIP appears to be more suitable than uniaxial pressing in order to prepare homogeneous optical ceramics.

Article

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