The Deciding Factors
Since the initial supply to the dental field, Tosoh’s high purity and consistency of quality over many produced batches over many years has solidified the company’s position.

Relative to the raw zirconia disks and blocks, we have seen many imitations and false claims in the market. The zirconia powder produced by Tosoh is produced in ISO certified facilities, is free of unusual and potentially harmful elements, is produced according to a specification, is certified to that specification and has complete lot traceability. Every powder batch is also inspected, free of charge at third party facilities, for radioactivity with resulting reports available upon request. These are internally established protocols at the powder manufacture level that should be noted when choosing zirconia products.

Tosoh totally supports NADL’s What’s in Your Mouth (WIYM) campaign. The public needs to know there are questionable products in the marketplace. Essentially, cheaper products do not ensure peace of mind.

A dental laboratory needs to be scrupulous when it comes to selecting their disc supplier. Reputation and size are important. The large, established suppliers stand behind their products.

One should ensure the zirconia used to produce their restorations is certified and meets radioactivity requirements.

The Powder

Jay Thomas, Product Manager, Ceramics, Tosoh

From its initial role as a metal replacement in PFM crowns (circa 2005) to its present status as the material of choice for shaded and multilayer crowns, Tosoh’s zirconia powder has enjoyed worldwide market share in the 90th percentile.

By the 1980s, the first range of glass-ceramics was introduced.

The 1990s saw the introduction of Cerec, a milling machine that duplicated a resin inlay from a solid block of ceramic. Empress ceramics, In-Ceram and Procera alternatives were also introduced during this time. Procera consisted of a pressed alumina oxide core, which was sintered under pressure at a high temperature to create a more dense and stronger alumina oxide core. Veneering porcelain could be added to the core. Before the introduction of these materials, sintered alumina oxide was the strongest non-metal material used for crowns.

Ceramic restorations drastically changed in the 2000s with the introduction of CAD/CAM systems and the utilization of transformation-toughened zirconia.

This evolution has resulted in today’s zirconia-dominated market. While zirconia is now very familiar across the dental laboratory industry, not all products are created equal. Over the years and across the production timeline, offshoots have been created which have resulted in products that perhaps are more economically appealing, but may be questionable for use in the mouth. This has spurred doubts on exactly how the products of today came to be, and where the products of the future are headed. In addition, with the vast array of products available, deciding what to use and when can incite some hesitation on the part of both the lab and the doctor. In order to break these questions down, consider the timeline of zirconia’s production. If the powder is on the left and a finished placed crown is on the right, there’s a lot that happens in-between. Hear expert guidance and concerns narrowing down some deciding factors at each of those critical stops along the way.
The Production
Paul Cascone, Senior Vice-President of Research & Development, The Argen Corporation

It wasn’t so long ago (2004 to be exact) when there was only one zirconia available on the dental market. Now there are dozens! While this is a typical evolution for a material substitution, the number of options makes deciding which one to use difficult.

The original zirconia was chalky white and substituted for the alloy portion of a porcelain-fused-to-metal restoration. In 2009, the introduction of monolithic zirconia eliminated the need for porcelain. From there, the number of zirconia options just kept growing, offering different chemistries, different strengths, and different coloring schemes. This leads to questions on how to decide which supplier and which material to use.

To begin, as with any other critical supplier decision, the lab should work with a company that is reliable and can provide support for the products they sell. Unfortunately, the ISO standard for zirconia (ISO 6872:2015) is of no help in discriminating between sub-par and good materials. The ISO standard does not address Thoria radioactivity, which is present in the original zircon mineral. Also, the standard provides little guidance on the strength of zirconia restorations. The values published are seen by most reliable companies to be insufficient. This means that a manufacturer could have a zirconia product placed on the market with a 510k and the users would still not be certain as to its strength or radioactive properties.

Some of the incidents with zirconia materials that we are aware of include:

1. No radioactivity reports of the zirconia powder from some powder suppliers.
2. Inconsistent strength and/or translucency from lot to lot.
3. Poor compositional control.
4. Even insects in the powder!

But because of our tight supplier quality control, such materials have never been used by Argen.

All materials will evolve over time and zirconia is no different. Although the majority of published clinical reports on dental zirconia are retrospective, the results have been extremely good on all fronts: esthetics, strength and biocompatibility. Zirconia

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Figure 1
A jewelry cleaner jar

Figure 2
A difficult case which is best handled by using dipping solutions
will continue to be the material of choice for dental prosthetics at least for the next decade, keeping in mind that more zirconia compositions will be introduced and our most difficult challenge will be to educate the dentist on the features and benefits of a chosen product.

Once the supplier has been decided, it is now time to consider the material selection. How you choose to color your zirconia plays a crucial role in determining what material you need to use for your application. We will discuss the coloring schemes since this decision impacts both the esthetics of the zirconia and the costs of carrying the inventory.

There are three basic ways of attaining the proper shade: 1) start with a white zirconia disc and use coloring liquids to attain the desired shade; 2) use pre-shaded zirconia discs; or 3) use multi-layer zirconia discs.

1. Water based coloring liquids provide the most control and the easiest way to individualize a case. The zirconia disc inventory costs are low but the results may be inconsistent. The shade will be dependent upon the amount of coloring liquid absorbed and the type of coloring liquids used. Also the quantity of yttria in the zirconia may require a different coloring solution. As the amount of yttria increases the amount of coloring elements must also increase. This is why there are different solutions for high translucency and super translucency zirconia. For a case that consists of several restorations using a jewelry cleaner jar (as shown in Figure 1) full immersion of the units in the coloring liquid ensures that the time in the liquid is the same for all units.

   Figure 2 shows a difficult case which is best handled by using dipping solutions.

   This is a custom shade with a modified incisal, longer 'enamel' layer and intrinsic characterization. The unit has been glazed only with no external stain.

2. Pre-shaded zirconia helps control chroma level across any unit thickness as shown in Figure 3.

   The major question with pre-shaded discs is “does the zirconia manufacturer have the same color understanding as you do?” Since we all see color differently, the concept of the shade A2 can vary.

   Using pre-shaded discs increases the inventory costs but this is more than compensated for by the consistent results.

3. Multilayer discs have different chroma levels increasing from the incisal to the gingival layer emulating the natural color transition found in teeth (Fig. 4). As with all zirconia, the color cannot be seen until the material is sintered so nesting becomes very important.

   Although the inventory costs are high compared to just the white discs, the results can be outstanding.

   So which type is right for your lab? The options will only keep increasing in the future.

Figure 3
(Above) Pre-shaded zirconia helps control chroma level across any unit thickness

Figure 4
(Below) Representation of a multi-layer zirconia disc
A minimum flexural strength value of 800 MPa is recommended for four or more unit bridges. In addition to low strength values, we have seen warping and large areas of porosity, (Fig. 1). There is one standard developed by the ADA specifically for dental zirconia (ANSI/ADA 131-2015 Dental CAD/CAM Machinable Zirconia Blanks) and another being developed on the international level. Companies are not required to meet these standards while in Europe, international and country standards must be followed. In my opinion, it is unfortunately too easy to get FDA 510K approval leading to many poor zirconia blocks available for purchase. While Tosoh is still a leading provider of powder, processing methodology is extremely important to produce a homogenous block with even density, uniform and well-documented shrinkage values. Also, there are now many providers of zirconia powders with varying quality, even to the point of having higher radioactive content.

A simple online search shows at least 30 suppliers of zirconia blocks from all over the world. In 2016 at Lab Day in Chicago, I photographed 55 booths selling zirconia; most with marketing claiming the standard 1200 MPa that is listed by Tosoh for a perfect, relatively long, sintering cycle. Some claim 1400 or even 1600 MPa — values that are rarely, if ever, recorded in independent tests. It is important to see independent verification of claims made by the block supplier particularly if they do not have a history of clinical success as the well-known suppliers do.

Even outside of gray or black market scenarios, adverse incidents still occur. Unexpected fracture and wear of the opposing dentition are the prime issues. With high translucency zirconia materials, it is important to recognize that higher thicknesses are required and these should not be used in high stress areas. High fracture rates can occur.

Large multi-unit restorations based on frameworks or full contour zirconias require careful sintering. We learned that zirconia has a poor thermal conduction, making sintering strategy for large restorations very important. Thick areas like pontics will take much longer to fully sinter than the abutments; sintering must be extended. Sintering rates must be slowed and peak temperatures increased in order to fully densify thick zirconia restorations.

All zirconia restorations should be polished no matter if a glaze is applied or not. Although zirconia has a fine submicron structure and can be wear kind; it has a very high hardness. If the surface is left rough and then glazed, the glaze will wear off.

Figure 1

**Zirconia Microstructure**

- **Dense High Strength**
- **Porous Low Strength**
- **Warping after Sintering**
in 2-4 years and leave behind core structures that will wear away the opposing tooth at a rapid rate. Zirconia that is adjusted in the mouth should be carefully polished.

There are a large variety of ceramic restorations to choose from. These include feldspathic, leucite reinforced, glass ceramics, alumina, interpenetrating phase, and zirconia. The dental community often defaults to what is perceived to be the “highest strength” material — the cult of the MPa. I think there is a belief that strength will cover up the sins of improper preparation and occlusal development. The trend in zirconia has been to more translucent materials, but this sacrifices strength and fracture resistance properties that made the original “white” zirconia so useful. There are zirconia materials with higher yttria content that increase the cubic crystal type. The fracture resistance property is based on transformation from tetragonal to monoclinic but this is mostly lost in high translucency materials. In fact, high translucency zirconia materials are very susceptible to surface damage that might occur from occlusal adjustment or clinical use. With respect to translucency, in general with higher translucency mechanical properties decrease and minimum occlusal and wall thickness requirements increase (Fig. 2).

There are several clinical considerations for material selection: Esthetics/translucency, parafunctional habits, fracture resistance, wear kindness, and probably most important is the amount of tooth reduction. If we are looking at restoring function, tooth reduction should be the principle guiding factor. Low fracture resistant materials/low-strength materials can succeed as well as a high-strength zirconia if the material has adequate thickness. Machinable feldspathic materials like Vita MKII, when fabricated at 2.0 mm thickness and bonded into the tooth, have success rates over 95 percent 10 years plus out, certainly as good as any zirconia. As tooth reduction decreases, however, selection needs to turn to materials with higher fracture resistance. If translucency is the main objective for a given restoration, then zirconia probably should not be the first choice.

As far as the future evolution of zirconia, I believe that the basic mechanical properties of zirconia have already been achieved. There may be further refinement based on processing methodology and particle size and further variations in translucency may also be forthcoming based on composition and particle size. There are several graded blocks with respect to Chroma to help improve the overall esthetic value. Also, there are some that have gradations in translucency. Initial data has shown, however, that overall mechanical properties of these translucency graded materials do not match marketed values and in some cases are below those recommended by ISO standards.

There has also been initial research presented on rapid manufacturing of zirconia using printed suspensions of zirconia. The mechanical properties of the printed material are within those recommended and the accuracy of the single unit was also acceptable. The difficulty in printing ceramics relates back to the low density achieved. Therefore the full density sintering may result in differential shrinkage, stress, and inaccuracy for complex restorations. As advances occur in software modeling and printing techniques, however, these may be overcome in the future. JDT

### Table: Increasing Translucency Summary

<table>
<thead>
<tr>
<th>Yttria mol%</th>
<th>Translucency % 100</th>
<th>Approximate Mean Strength (MPa)</th>
<th>Damage Resistant</th>
<th>Minimum Occlusal Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>33%</td>
<td>900-1200</td>
<td>Yes</td>
<td>0.4 - 0.6</td>
</tr>
<tr>
<td>4</td>
<td>41%</td>
<td>750</td>
<td>Yes</td>
<td>0.5 - 0.8</td>
</tr>
<tr>
<td>5</td>
<td>49%</td>
<td>600</td>
<td>NO!</td>
<td>0.7 – 1.0</td>
</tr>
</tbody>
</table>

**Summary of Values From Manufacturers: Dentsply-Sirona, Vita, Ivoclar, Noritake, 3M/ESPE**

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**Figure 2**

As far as the future evolution of zirconia, I believe that the basic mechanical properties of zirconia have already been achieved.