3M Science. Applied to Life.™

3M™ Lava™ Esthetic

Esthetic Fluorescent Full-Contour Zirconia

Technical Product Profile

1. Introduction

Full-contour – or “one-piece” – all-ceramic crown and bridge restorations are gaining popularity fast. This trend is driven by the patients and dentists demand for metal-free, esthetic restorations that are also durable and affordable.

What fuels the trend are innovations in esthetic all-ceramic materials that can be manufactured efficiently via CAD/CAM processes.

The two leading material classes employed for full-contour all-ceramic restorations are glass ceramics and zirconia. While glass ceramics used to set the esthetic benchmark, zirconia materials offer the highest strength.

The basic idea behind 3M™ Lava™ Esthetic Fluorescent Full-Contour Zirconia was to develop a solution with excellent esthetics that offers a significant strength advantage versus glass ceramics and allows for a highly efficient CAD/CAM manufacturing. 3M – a leading company in ceramic solutions - is well equipped with the technologies it takes to make this vision a reality.

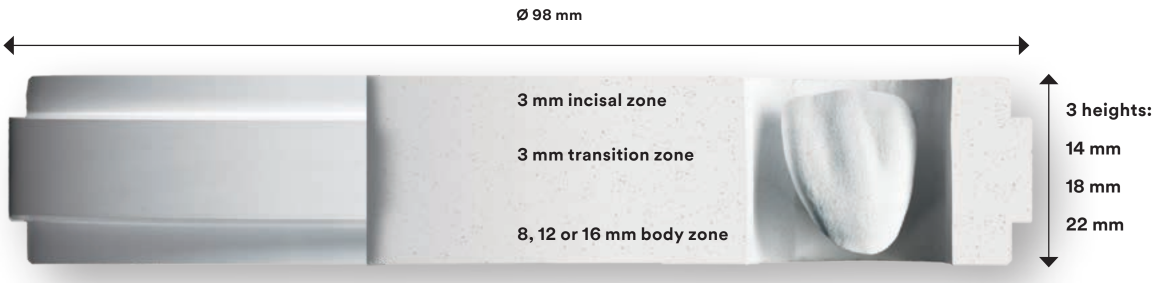
3M invented liquid shading of zirconia and pioneered the dental zirconia market with the introduction of 3M™ Lava™ Frame Zirconia in 2001. The next generation product 3M™ Lava™ Plus High Translucency Zirconia was the first zirconia system designed for matching all 16 VITA classical shades. With the introduction of Lava Esthetic Zirconia 3M sets another milestone in dental zirconia innovations by presenting the first pre-shaded zirconia with built-in fluorescence.

Now labs have a all-ceramic CAD/CAM solution at hand that offers high productivity processing and delivers all it takes for high full-contour esthetics: translucency, shade match and built-in fluorescence.

2. Product description

3M™ Lava™ Esthetic Fluorescent Full-Contour Zirconia discs are pre-sintered mill blanks used for the fabrication of esthetic, full-contour zirconia restorations. The restorations are designed using dental CAD software, and the data is converted into milling paths by CAM software. Subsequently the discs are processed in milling units suitable for pre-sintered zirconia. Milled restorations must be finally sintered in a furnace suitable for zirconia, using the cycle designated for Lava Esthetic Zirconia.

The discs are available in various heights and shades based on the VITA classical A1-D4® shade guide. All discs are pre-shaded with a shade gradient set vertically in the blank that becomes visible after sintering. The printed side of the blank marks the incisal area which is located in the upper 3 mm of the blank, followed by a 3 mm transition zone. The remaining height is the dentin-shaded body zone. After sintering, restorations display a shade gradient and all shades exhibit built-in fluorescence. Final esthetic finishing is performed by application of a glaze layer.



Features and Benefits

- High strength of 800 MPa*
- Optimized translucency for high esthetic full-contour restorations
- Designed for excellent shade match to VITA classical shades
- First zirconia with built-in toothlike fluorescence**
- Enhanced productivity: Streamlined "mill-sinter-glaze" process
- Available in all 16 VITA classical shades plus Bleach

* 3-point bending strength according to ISO 6872:2015; qualified for Type II, class 4; indications: crowns, bridges with a maximum of one pontic that must be supported on each side by a crown (prosthesis not to exceed three units), inlays, onlays and veneers.

** Fluorescence determined with light sources simulating natural UV light.

3M™ Lava™ Esthetic Fluorescent Full-Contour Zirconia enables dental labs to produce highly esthetic full-contour restorations in a simplified "mill-sinter-glaze" process with increased productivity:

Mill

98 mm disc format with step fitting open systems for dry milling of zirconia.

Save up to 3.5 hours vs. liquid shaded zirconia materials

No shading liquids.

No drying time.

Sinter at 1500°C

Total sinter cycle time: 5.2 hours

Save up to 2.2 hours vs. other zirconia materials

Glaze at < 900°C

Shades are designed for excellent shade match after glazing with a low fusing glaze material.

With 800 MPa* and a high translucency, Lava Esthetic Zirconia is ideal for esthetic full-contour restorations including 3-unit posterior bridges. Its indication range covers:

- Single crowns
- Bridges with a maximum of one pontic that must be supported on each side by a crown. Prosthesis not to exceed three units.
- Inlays, onlays, and veneers

The strength advantage over glass ceramic materials allows thinner wall thicknesses and connectors compared to materials such as IPS e.max Lithium disilicate. For cases with very limited space or parafunctional patients requiring ultimate strength, choose 3M™ Lava™ Plus Zirconia.

	Wall Thickness [mm]	Bridge Connector Cross-Sectional Area [mm²]
Anterior tooth	≥ 0.8	≥ 12
Posterior tooth	≥ 0.8	≥ 14

The high strength of Lava Esthetic Zirconia allows for conventional, self-adhesive or adhesive cementation. 3M recommends 3M™ RelyX™ Unicem 2 Cement – the world's most clinically proven self-adhesive resin cement, combining high bond strength with simple handling.

3. Background

3.1 Base material composition and translucency

Zirconia materials used for dental applications are polycrystalline materials. This means they consist of many small crystals or "grains" that can be visualized with electron microscopy.

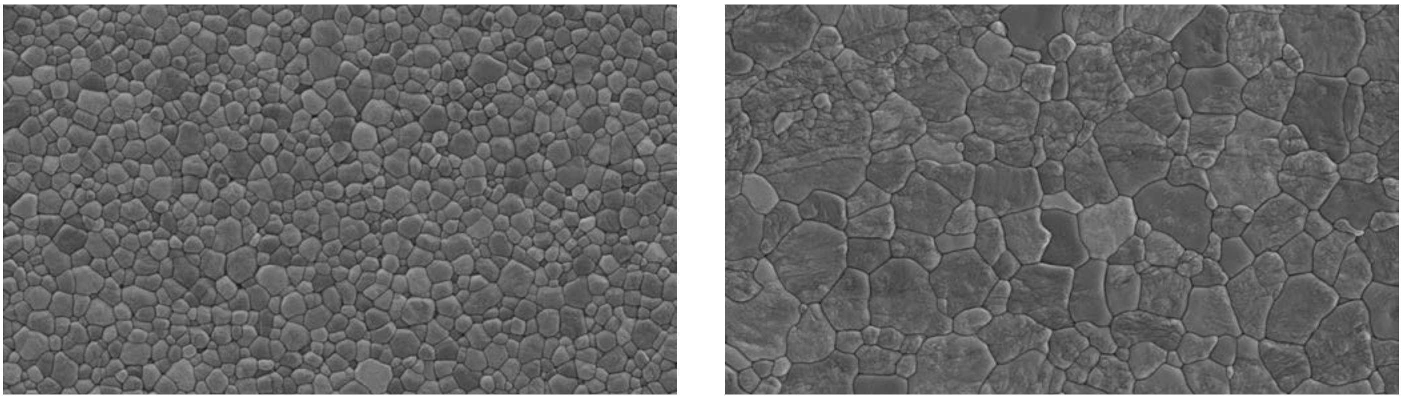


Fig. 1: SEM images of sintered 3M™ Lava™ Plus Zirconia (left) and 3M™ Lava™ Esthetic Zirconia (right) materials. Average grain size is approx. 0.4 µm for 3M™ Lava™ Plus Zirconia and approx. 1 µm for 3M™ Lava™ Esthetic Zirconia.

The material formulation is a composition of "zirconia" (zirconiumdioxide, ZrO_2) with a small addition of "yttria" (diyttriumtrioxide, Y_2O_3). The yttria content determines the so-called "phase" of the crystals, i.e. how the Zr and O atoms are arranged. There are three distinct crystal phases for zirconia: monoclinic, tetragonal, and cubic.

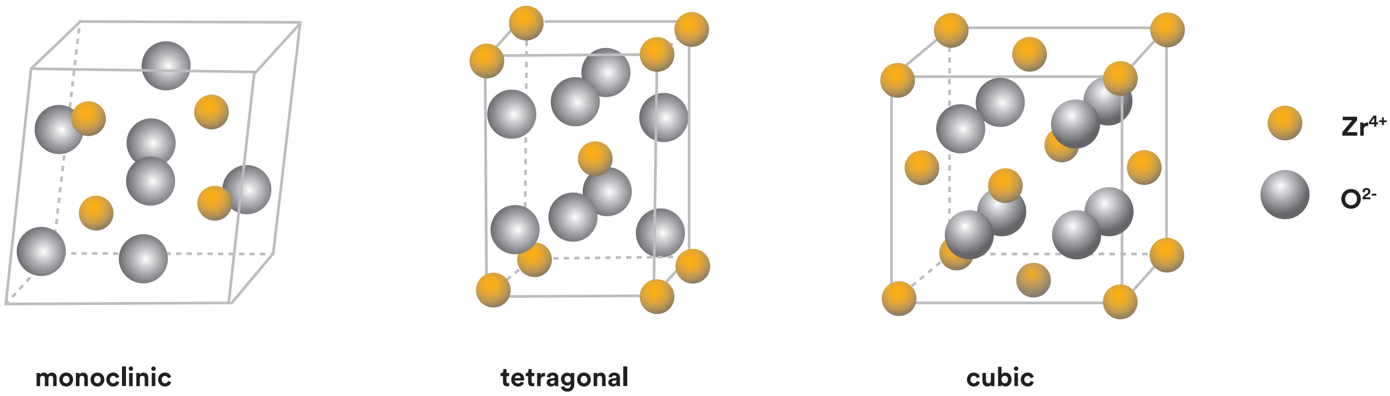


Fig. 2: Three zirconia crystal phases: monoclinic, tetragonal, and cubic.

In pure zirconia only the monoclinic phase is stable at temperatures below 1173°C. By adding yttria the tetragonal and cubic phases become stable at low temperatures. Adjusting the yttria content determines the ratio of crystals in the tetragonal and cubic phases and thus the material strength and translucency.

Previous generation zirconia materials such as 3M™ Lava™ Plus Zirconia contain 3 mol % yttria. This leads to a phase composition that is predominantly tetragonal with average grain sizes around 0.4 µm. These materials are referred to as "3Y-TZP" materials (3% yttria stabilized tetragonal zirconia polycrystalline materials). Under mechanical stress the tetragonal crystals can undergo phase transformation to monoclinic. This leads to a local volume increase that prevents crack propagation. This so-called "transformation toughening" makes this type of zirconia materials the strongest ceramic used in dental.

In 2014, zirconia materials with a higher yttria content (around 5 mol%) leading to a predominantly cubic phase composition came to the market. These materials are often referred to as "cubic" or "super-high translucency" zirconia. Cubic grains are larger leading to less grain boundaries for a given volume and have isotropic (same in all directions) light refractive indices – these effects decrease light scattering and therefore greatly enhance translucency.

Lava Esthetic Zirconia contains 5 mol% yttria. The crystal phase is predominantly cubic with an average grain size of approximately 1 µm. Due to the larger grain size and the predominantly cubic phase composition the translucency of Lava Esthetic Zirconia unshaded base material is higher than for the 3Y-TZP materials such as Lava Plus Zirconia.

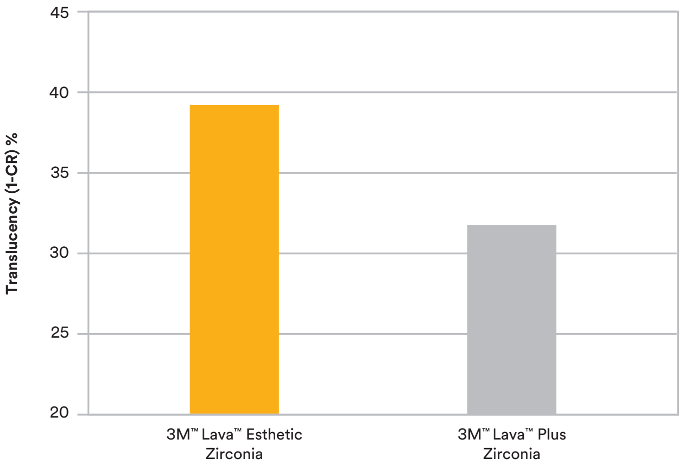


Fig. 3: Translucency (1-CR) of unshaded 1 mm thick zirconia samples measured with an X-Rite Color i7 Spectrophotometer in remission using the contrast ratio method. (3M Oral Care internal data. Data available upon request.)

The enhanced translucency is also clearly visible when comparing shaded full-contour restorations, e.g. under backlight conditions.

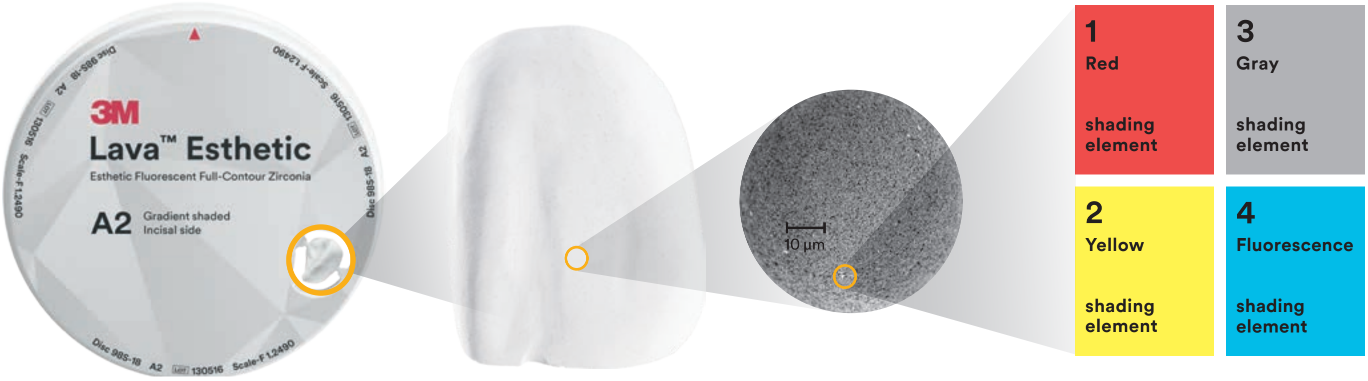
Fig. 4: Backlight images of same shape full-contour molar crowns made of 3M™ Lava™ Esthetic Zirconia (left) compared to 3M™ Lava™ Plus Zirconia (right).

3.2 Shading technology

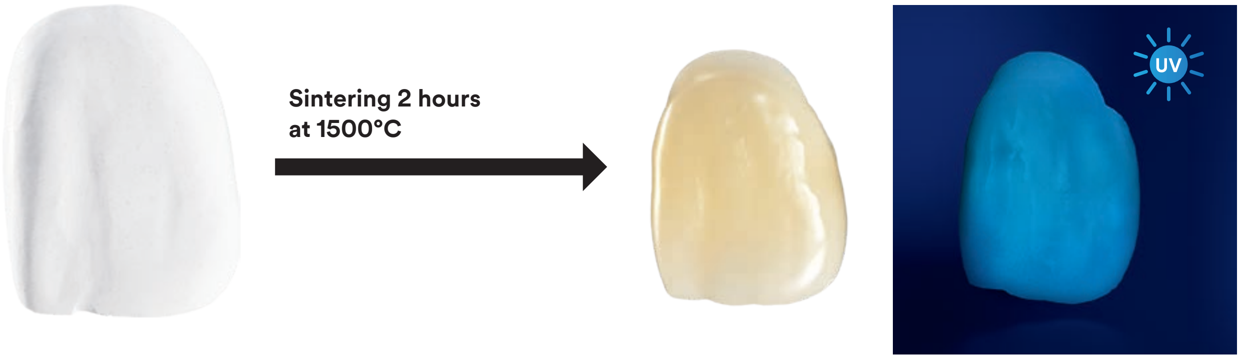
Shading of zirconia works by adding a small amount of shading elements like e.g. iron and rare earth elements etc. to the white zirconia base material. During sintering of the zirconia material these elements are built into the zirconia crystals and provide the desired shade effect.

For shading of 3M™ Lava™ Esthetic Zirconia a newly developed formula is utilized. Typical shading recipes for zirconia materials rely on two or three shading elements. For Lava Esthetic Zirconia three elements (red, yellow, gray) are employed to precisely adjust the color. In addition, a fourth element that enables fluorescence is added.
The 4-shading-element formulation is processed together with the cubic zirconia base material using 3M proprietary technologies to deliver the first gradient pre-shaded zirconia disc with built-in fluorescence.

Shading elements are carried by spherical microcrystalline clusters. These remain visible as small dots in the pre-sintered disc indicating the unique shading chemistry.



The cluster concentration increases from the top (printed side) to the bottom of the disc creating a shade gradient. For each color the shading element concentration is fine-tuned throughout the disc such that the fully sintered restoration matches the enamel and dentin shades of the corresponding VITA classical shade.



Final sintering at 1500°C for two hours produces a dense polycrystalline microstructure. The shading elements are distributed and built into the crystals to provide the desired shade gradient and toothlike fluorescence.

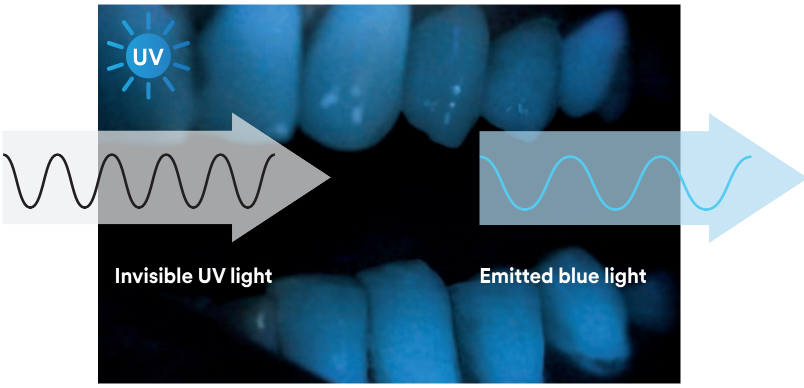
Besides the type and concentration of shading elements, the actual shade appearance is determined by the oxidation state of the shading elements. Zirconia is an oxygen conductor at elevated temperatures. Therefore the final oxidation state of the shading elements is determined by the sintering and the glazing conditions. Strictly following the sintering and glazing parameters described in the Lava Esthetic Zirconia instructions for use is key for a precise shade outcome.

3.3 Fluorescence

Fluorescence is a form of luminescence where a substance exposed to light or other electromagnetic radiation emits light with a longer wavelength than the absorbed radiation. If the fluorescence is initiated by invisible ultraviolet light, the emitted light can be in the visible region. This gives fluorescent substances a distinct color under UV light.

Teeth are fluorescent. They appear bluish under UV light, a phenomena that plays an important role under natural light conditions. Sunlight contains UV light, the resulting fluorescence makes teeth appear brighter.

Fig. 5: Clinical situation under daylight conditions ...



... and under UV light (Light source Benda NU-6 KL LW366nm).

To look more natural restorative materials have to mimic the fluorescence of teeth. Zirconia per se is not fluorescent. Due to its unique shading formulation, 3M™ Lava™ Esthetic Zirconia is the first inherently fluorescing pre-shaded zirconia, allowing for a more lifelike appearance.

Fig. 6: Images of monolithic zirconia crowns on fluorescent stump materials with a natural tooth reference in the middle. Left picture is under daylight conditions, right picture was taken under UV light (Light source Benda NU-6 KL LW366nm).

Fluorescent glazes are a common option to provide fluorescence for full-contour zirconia restorations. However, the resulting fluorescence can be speckled and uneven. Moreover, the glaze layer might be removed during adjustments and will wear off in clinical use. To allow a permanent and homogeneous fluorescent appearance even for unglazed areas a monolithic material should preferably be inherently fluorescent.

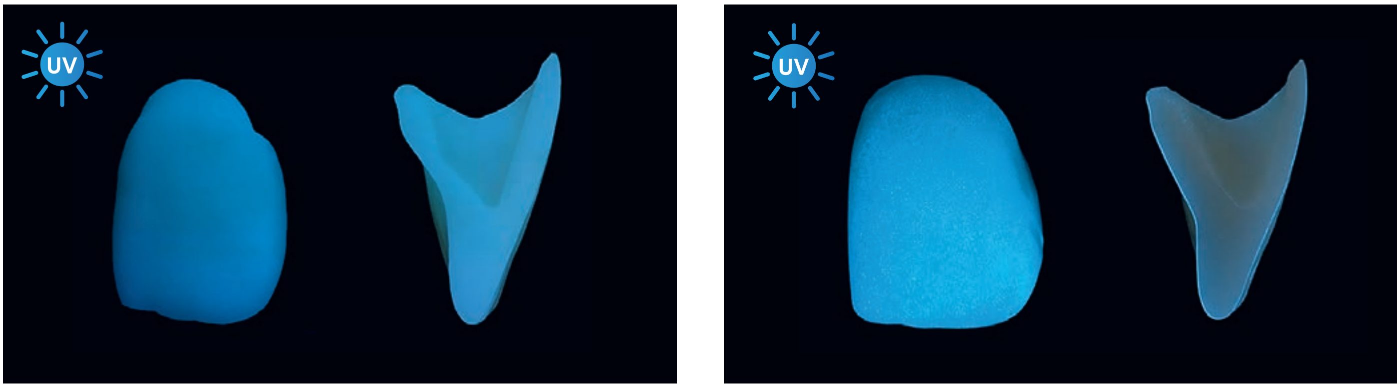


Fig. 7: Images of monolithic zirconia crowns and crown cross-sections under UV light (Light source Benda NU-6 KL LW366nm). Left picture shows the built-in homogeneous fluorescence of 3M™ Lava™ Esthetic Zirconia. On the right picture a non-fluorescent cubic zirconia crown is shown demonstrating the paint-on fluorescence effect achieved with a fluorescent glaze layer.

In a test using a X-rite Color i7 photo spectrometer the fluorescence of both light (A1) and dark (A3.5) 3M™ Lava™ Esthetic Zirconia samples was found to be dentin-like. Samples were irradiated with artificial daylight with and without UV component. Fluorescence spectra were obtained by subtraction of spectra measured without UV from spectra measured with UV. Under these conditions Lava Esthetic zirconia samples show a broad fluorescence emission with a maximum at about 450nm (blue) that is similar to the spectrum of bovine dentin. IPS e.max® CAD sample shows fluorescence with a peak at 550nm (green/yellow) that deviates from dentin whereas the Katana™ Zirconia STML samples were found to not be fluorescent.

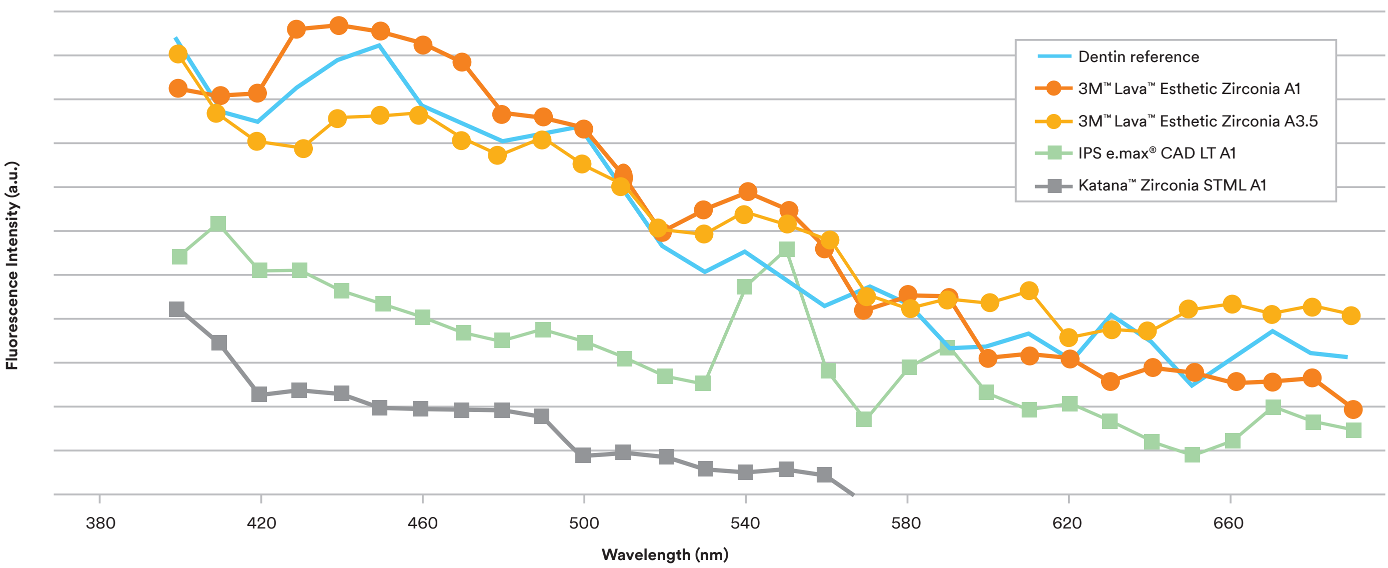


Fig. 8: UV fluorescence spectra of 3M™ Lava™ Esthetic Zirconia shades A1 and A3.5 compared to KATANA™ Zirconia STML A1, IPS e.max® CAD LT A1 and a bovine dentin reference.
Jahns et al., 3M Oral Care, J. Dent. Res. Vol #96 (Spec Iss A): 0098, 2017

3.4 Mechanical properties

Cubic zirconia crystals do not undergo phase transformation. The absence of transformation toughening leads to a decrease in strength and fracture toughness of cubic zirconia materials versus 3Y-TZP zirconia materials. However, cubic zirconia materials still offer a greatly improved strength and toughness compared to glass ceramic materials.

3.4.1 Flexural strength

With 800 MPa* 3M™ Lava™ Esthetic Zirconia provides a higher flexural strength than leading super-high translucent cubic zirconia and IPS e.max® CAD. Tetragonal 3M™ Lava™ Plus Zirconia provides even higher strength by transformation toughening.

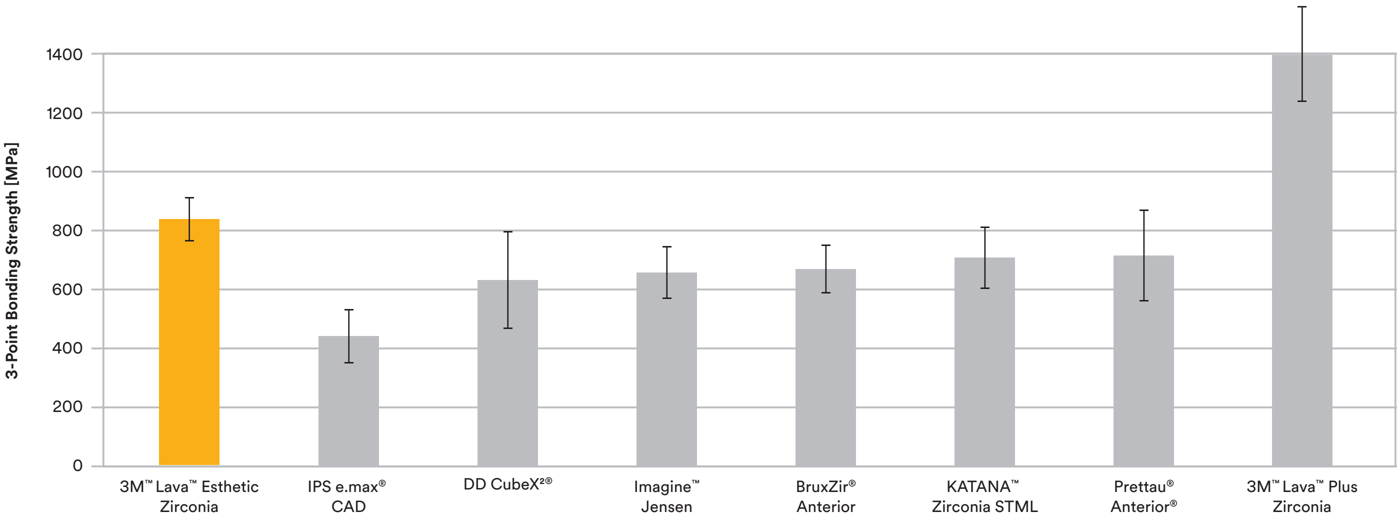


Fig. 9: 3-point bending strength according to ISO 6872:2015. (3M Oral Care internal data. Data available upon request.)

* 3-point bending strength according to ISO 6872:2015; qualified for Type II, class 4; indications: crowns, bridges with a maximum of one pontic that must be supported on each side by a crown (prosthesis not to exceed three units), inlays, onlays and veneers.

3.4.2 Flexural fatigue limit

Clinical use is accompanied by moisture and dynamic loading conditions. A material parameter that expresses resistance to a dynamic load in water is the so-called "flexural fatigue limit". For this test a 10 HZ sinusoidal load was applied in water and the flexural fatigue limit was determined according to the staircase method. 3M™ Lava™ Esthetic Zirconia exhibits a significantly higher flexural fatigue limit than IPS e.max® CAD and the cubic zirconia material Prettau® Anterior®.

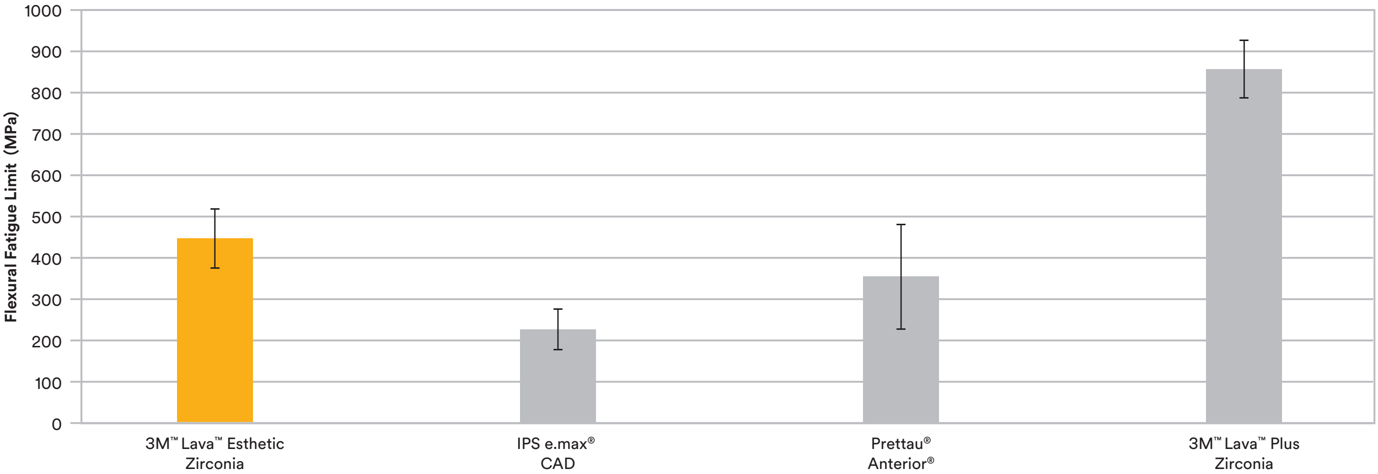


Fig. 10: Flexural fatigue limit at 10,000 cycles for a 10 HZ sinusoidal load applied in water in a 3-point bending geometry following ISO 6872:2015.
(3M Oral Care internal data. Data available upon request.)

3.4.3 Fracture toughness

Fracture toughness indicates how well a material can prevent crack propagation. Fracture toughness tests more closely replicate what occurs in the mouth, as test samples contain built-in defects. Here, the "Single-Edge V-Notch Beam" (SEVNB) method according to the ISO 6872:2008 was employed. For this test material bars prepared with a defined notch on the tension side are fractured in a 3-point bending geometry. Fracture toughness is calculated from fracture force, sample size, notch depth and support geometry.

The fracture toughness of Lava Esthetic Zirconia is significantly higher than that of IPS e.max® CAD. Fracture toughness of Lava Esthetic Zirconia is well above the recommended ISO 6872 limit for class 4 materials of 3.5 MPa $m^{0.5}$. This qualifies Lava Esthetic Zirconia for usage in 3-unit bridges also including the posterior area.

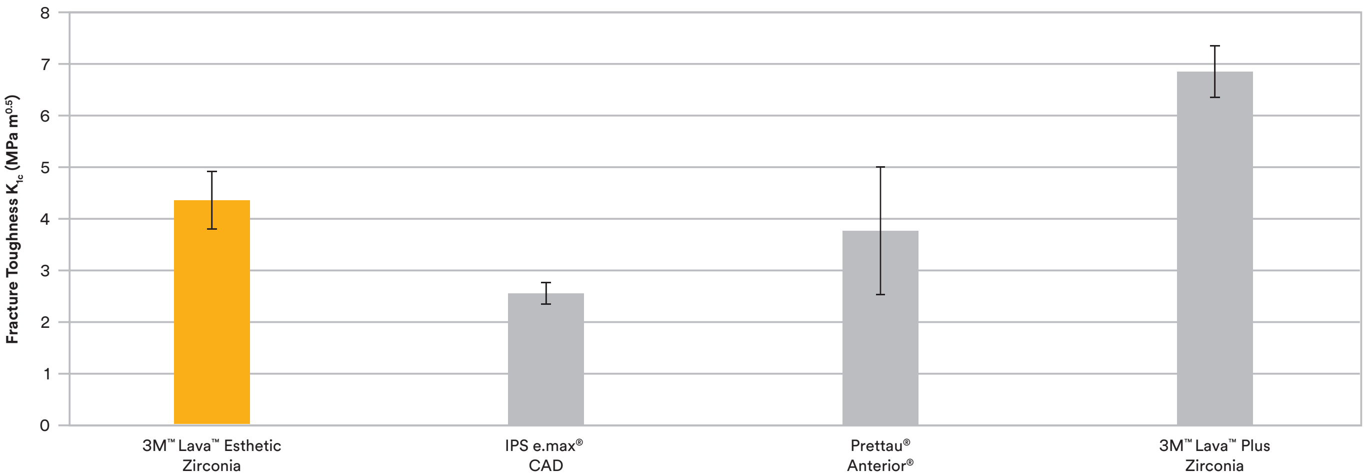


Fig. 11: Fracture toughness measured with the SEVNB method according to ISO 6872:2008. (3M Oral Care internal data. Data available upon request.)

3.5 Bonding

Depending on the indication and the clinical requirements, 3M™ Lava™ Esthetic Zirconia restorations can be cemented conventionally with glass ionomer cements such as 3M™ Ketac™ Cem Cement, or a resin-modified glass ionomer cement such as 3M™ RelyX™ Luting Plus Cement or adhesively e.g. with 3M™ RelyX™ Unicem 2 Self-Adhesive Resin Cement or 3M™ RelyX™ Ultimate Adhesive Resin Cement. Best esthetic results are achieved with resin cements – opaque conventional cements can shine through Lava Esthetic Zirconia restorations.

Highly efficient bonding to zirconia is achieved via phosphate functionalized monomers. RelyX Unicem Cement contains phosphate functionalized monomers which provide a strong self-adhesive bond to the zirconia surface. RelyX Ultimate Cement is used with 3M™ Scotchbond™ Universal Adhesive as the primer and adhesive. Scotchbond Universal Adhesive contains MDP monomers that provide chemical bonding through phosphate functional chemistry.

Regardless of the cement, the cementation area of the Lava Esthetic Zirconia restoration has to be sandblasted with aluminum oxide, grain size 30 to 50 µm and 2 bar pressure. The use of hydrofluoric acid does not have any effect whereas the use of phosphoric acid even leads to a negative impact on effectiveness of phosphate monomers.

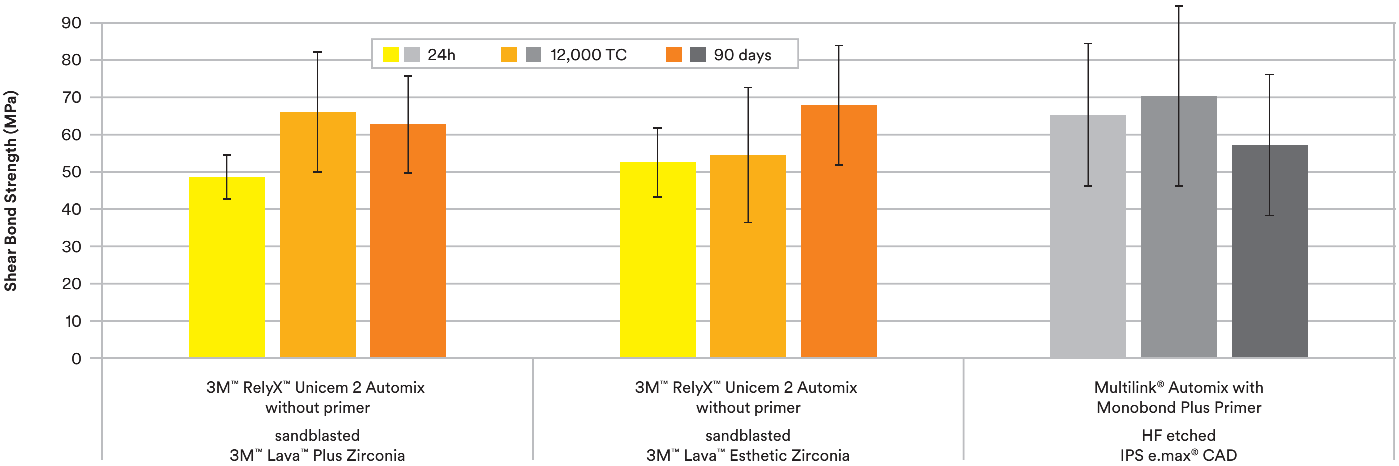


Fig. 12: Shear bond strength of 3M™ RelyX™ Unicem 2 Automix Cement to 3M™ Lava™ Esthetic Zirconia is on the same level as for 3M™ Lava™ Plus Zirconia. The self-adhesion of 3M™ RelyX™ Unicem 2 Cement to zirconia is equivalent to the adhesion of Multilink® to HF etched IPS e.max® CAD glass ceramic primed with Monobond Plus. Source: Rosentritt et al., Dentistry Journal 2017, 5, 32

Typically the sandblasting step is performed in the lab. In this case the bonding surface has to be carefully cleaned after try-in and before applying the cement. A highly efficient cleaning agent for Lava Esthetic Zirconia is sodium hypochlorite solution followed by a water rinse.

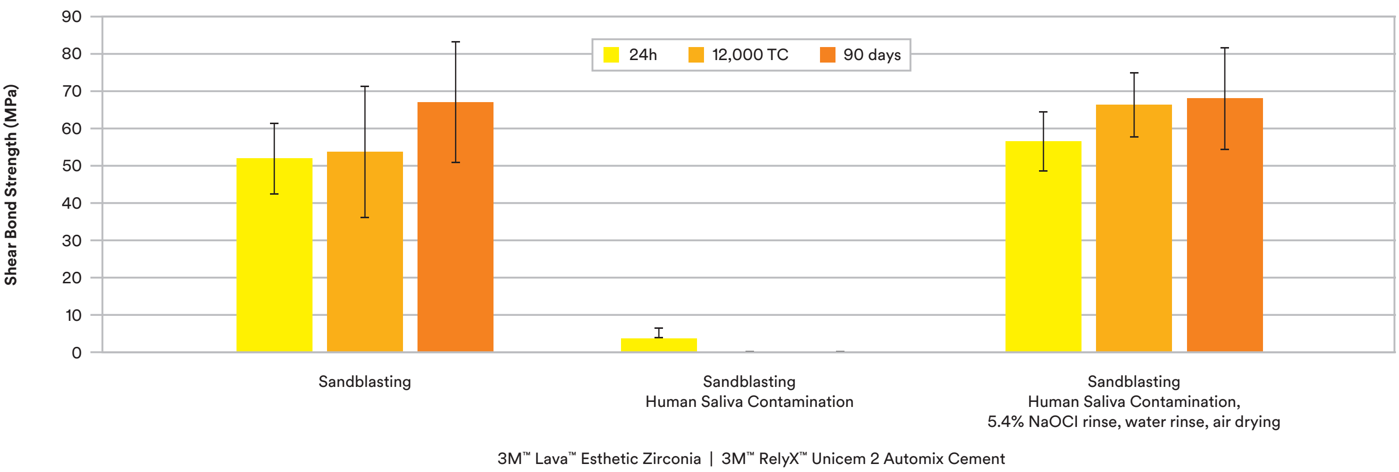


Fig. 13: Shear bond strength of 3M RelyX™ Unicem 2 Automix Cement to sandblasted 3M™ Lava™ Esthetic Zirconia after storage in 37°C water for 24 hours or 90 days and after 12,000 thermo cycles, respectively (left bars, control). Saliva contamination of the sandblasted surface inhibits bonding (middle bars). Bond strength is restored to the initial level by cleaning with 5.4% sodium hypochloride solution (right bars). Source: Rosentritt et al., Dentistry Journal 2017, 5, 32

3.6 Wear properties

Zirconia is a hard material – this is also true for cubic zirconia materials. 3M™ Lava™ Esthetic Zirconia has a hardness level similar to 3M™ Lava™ Plus Zirconia. One might intuitively expect that a hard material is not antagonist friendly because it is abrasive towards the opposing dentition.

However, abrasiveness is mainly determined by material smoothness and the ability of a material to stay smooth during function. A smooth surface will not lead to excessive antagonist abrasion because there will be little mechanical interlocking between the two wear bodies.

An in vitro study of wear of enamel antagonists on sintered, glazed and polished Lava Esthetic Zirconia, respectively, was conducted at University of Alabama, Birmingham, U.S.A. The values for glazed and sintered Lava Esthetic Zirconia samples are on the same level as on enamel (used as control). Polished Lava Esthetic Zirconia samples show a significantly lower wear.

In case adjustments are needed, Lava Esthetic Zirconia crowns are easier to adjust than conventional zirconia materials using a fine-grain diamond bur and water cooling. To maintain the antagonist friendly properties of Lava Esthetic Zirconia the adjusted areas need to be polished with e.g. rubber polishers suited for ceramics.

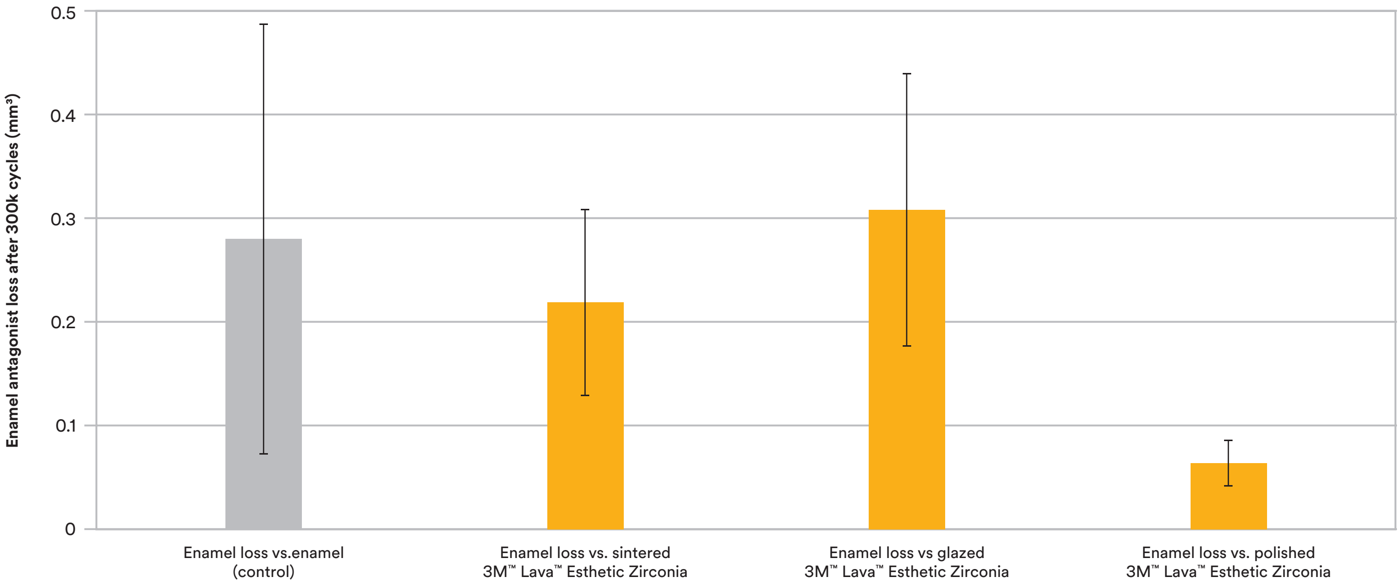


Fig. 14: Wear of enamel antagonist vs. 3M™ Lava™ Esthetic Zirconia with different surface finishing (as sintered, glazed, polished) and vs. enamel (control).
Burgess et al., J. Dent. Res. Vol #96 (Spec Iss A): 0096, 2017.

4. Technical data summary

Comparison of material parameters of 3M™ Lava™ Esthetic Zirconia and 3M™ Lava™ Plus Zirconia

	3M™ Lava™ Esthetic Esthetic Fluorescent Full-Contour Zirconia	3M™ Lava™ Plus High Translucency Zirconia
Composition	ZrO_2 with approx. 5 mol% Yttria	ZrO_2 with approx. 3 mol% Yttria
Mean grain size	approx. 1 µm	approx. 0.4 µm
Phase composition	approx. 53% cubic, 47% tetragonal	approx. 82% tetragonal, 18% cubic
Radioactivity	< 0.1 Bq/g ^{238}U	< 0.1 Bq/g ^{238}U
Flexural strength (3-point bending ISO 6872:2015)	800 MPa	> 1100 MPa
Young's modulus	216 GPa	210 GPa
Fracture toughness (SEVNB ISO 6872:2008)	3 – 5 MPa $m^{0.5}$	5 – 10 MPa $m^{0.5}$
Thermal expansion coefficient	10.1 +/- 0.5 1/K	10.5 +/- 0.2 1/K
Vickers Hardness	> 1200	> 1200
Density	> 6.05 g/cm³	> 6.05 g/cm³
Translucency (1-Cr) (unshaded material, 1 mm thickness)	40%	32%
ISO 6872:2015 material class	Type II, class 4	Type II, class 5
Dyeing procedure	Gradient pre-shaded	21 shading liquids, 2 color markers, 8 effect shades

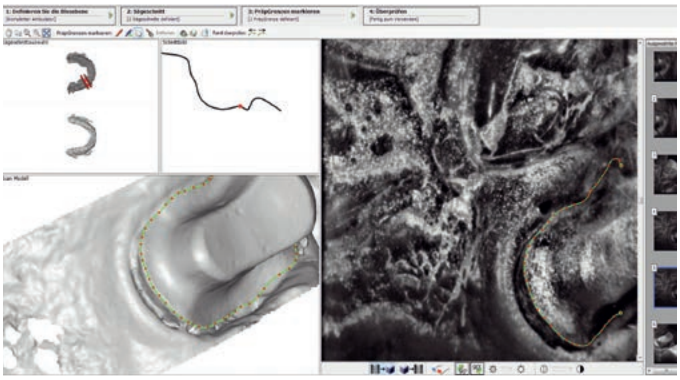
5. Clinical case step by step

Preparation and shade selection

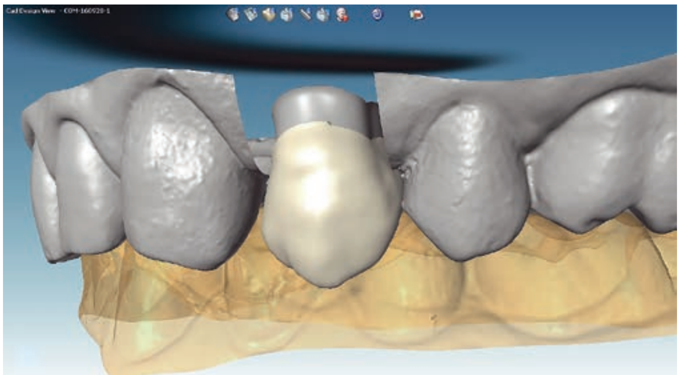
Crown preparation on tooth 24.

Shade selection VITA classical A3 shade.

Lab processing



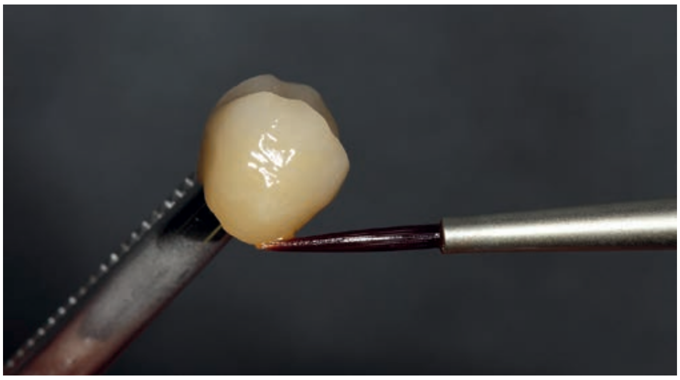
Data processing of 3M™ True Definition Scanner scan data.



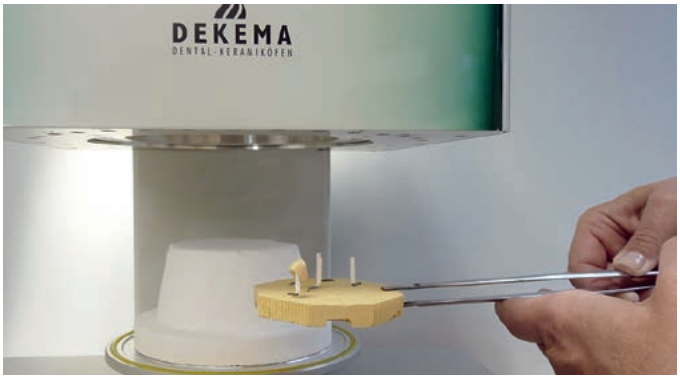
CAD design of full-contour crown.

Milling of crown out of a 3M™ Lava™ Esthetic Zirconia A3 disc.

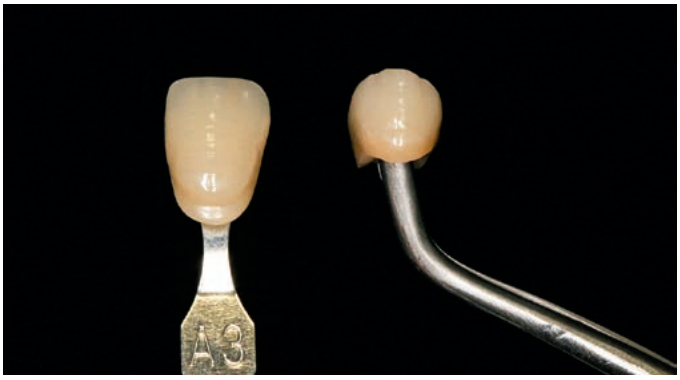
Sintering at 1500°C for 2 hours.



Individualization with low-fuzing (< 900°C) stains and glaze.



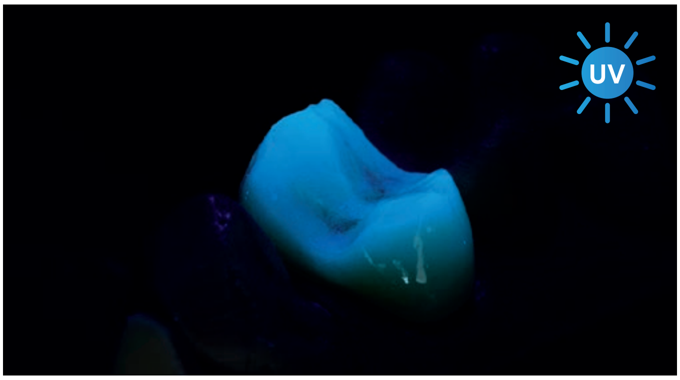
Firing of glaze.



Shade match of final crown to VITA classical A3 shade.

Sandblasting with 50 µm alumina at 2 bars (30 PSI).

Final restoration on 3D printed model.

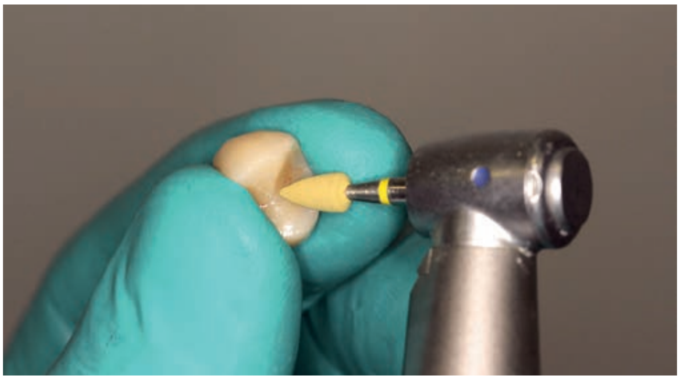


Final restoration under UV light (Light source Benda NU-6 KL LW366nm).

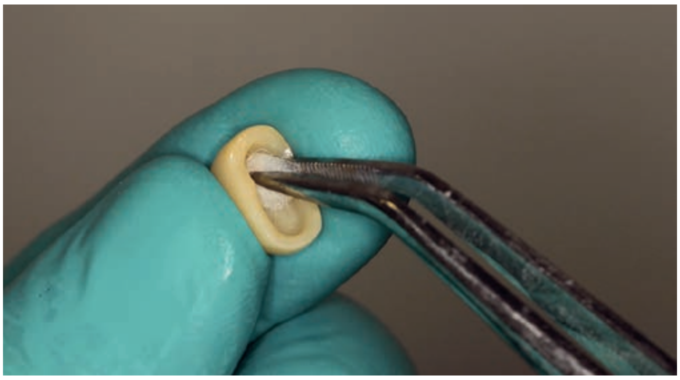
Seating

Try-in of restoration.

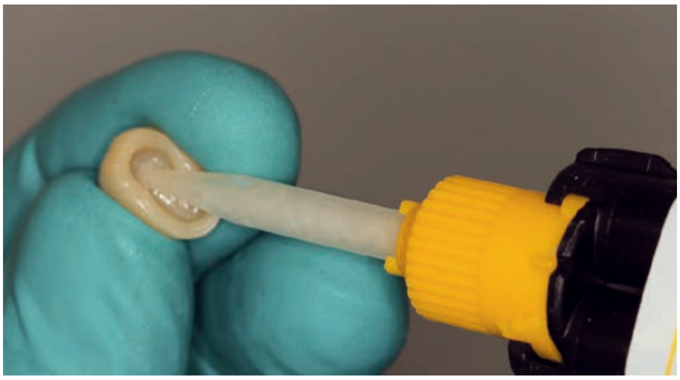
Adjustment with fine-grain diamond bur and water cooling.



Re-polishing of adjusted area with rubber polishers for ceramics.

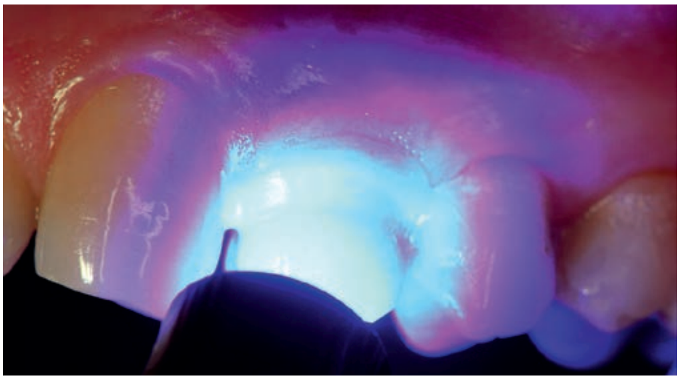


Cleaning of bonding surface after final try-in with 5% sodium hypochlorite (NaOCl), rinse and dry.



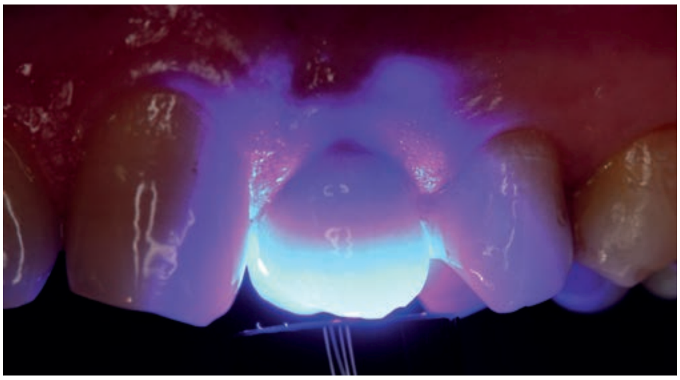
Application of 3M™ RelyX™ Unicem 2 Automix Self-Adhesive Resin Cement.

Seating of final restoration.



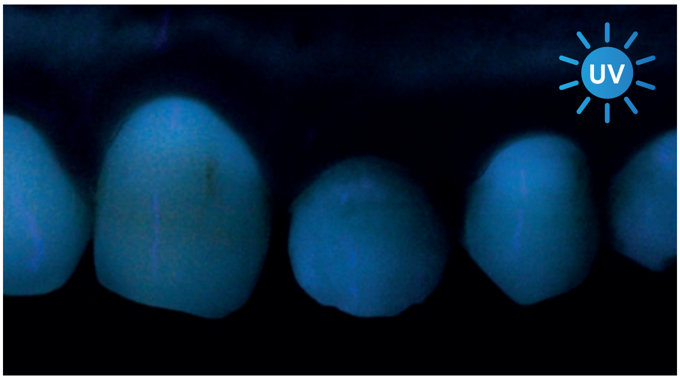
Tack cure of excess cement with 3M™ Elipar™ Deep Cure Curing Light for 2 seconds.

Removal of excess cement.



Final curing for 20 seconds per surface.

Final outcome showing natural appearance of full-contour restoration.



Final situation under UV light demonstrating toothlike fluorescence (Light source Benda NU-6 KL LW366nm).

3M.com/Dental

3M Oral Care
2510 Conway Avenue
St. Paul, MN 55144-1000
USA
1-800-634-2249

3M Canada
Post Office Box 5757
London, Ontario N6A 4T1
Canada
1-888-363-3685