INTRODUCTION

Dental enamel is a very translucent material, and as light passes through it, it is reflected off the dentin and back through the enamel, which produces the color that we see. Just as important, the light is transmitted into the root of the tooth, much like a fiber-optic cable. As the light passes into the root, it then reflects into the surrounding gum tissue, allowing for the pink of the gingiva to illuminate.

So, a primary objective of engineering and manufacturing dental restorative ceramic materials is to mimic the optical properties of natural dentition. Recent ceramics have been introduced with zirconia as an option, but its relevant opacity was a major problem, with the introduction of ultra-translucent zirconia such problem was slightly got over.

To achieve maximum esthetic demands, cementation is a crucial step, various cements have been used to adhere indirect restorations to tooth structure. As well as different curing modes, dual cured self-adhesive resin cements are chosen to accommodate variable restoration thicknesses with maximum translucency together with color stability of cured resin cement. The major problem associated with conventional dual cure resin cements is its color change especially in esthetic zone and reduced degree of conversion due to inadequate curing with thick restoration thicknesses.

Degree of conversion is important as it governs the physical and mechanical properties of luting cements such as compressive strength, tensile strength, hardness, toughness and biocompatibility; and is directly related to the monomer conversion during polymerization(1). Inadequate curing with reduced degree of conversion alters bond strength and dimensional stability and may result in possible allergic reactions compromising clinical performance of the luting cement(2).

Studying degree of conversion of adhesive cements under esthetic monolithic zirconia is important hoping to achieve maximum polymerization for maximum physical properties as we can.

There are few studies in the literature in this concern, so, the current study compares the color stability of two recent dual-cured resin cements whom manufacture claims that they have un altered esthetics and color stability under two thicknesses of ultra-translucent zirconia, hoping to achieve maximum natural tooth looking restoration as we can.

REVIEW OF LITERATURE

Achieving maximum esthetic restoration requires the presence of an esthetic material with minimal thickness directly cemented to tooth structure with cement that has high color stability.

A) Recent ceramic restorations:

The quest for a modern all ceramic material for tooth restoration started in the 1960s with **McClean's** porcelain jacket crown. Initially made of feldspathic porcelain, and later strengthened by an aluminous porcelain core, the material was limited to anterior crowns only due to a low compressive strength (3).

In 1963, **Weinstein, Katz, and Weinstein** (4) brought us the discovery of the metal oxide-ceramic bond that became the standard of strength in ceramic crowns, the Porcelain-Fused-to-Metal crown (PFM). In 1983 to overcome metal display, both Dicor and Cerestore were introduced as ceramic technology using the lost wax technique, which is still used in current pressed ceramics, such as Empress (Ivoclar).

The 1990s InCeram introduced "slip casting" where an all ceramic core was first fabricated(5), Empress2 followed using the same press casting to make a core out of a new ceramic, lithium disilicate(6). Later in the 1990s, Procera used a process of pressing an aluminum oxide core made on a computer generated enlarged die (to compensate for firing shrinkage) then sintered(7).

The central issue for all-ceramic restorations has been balancing esthetics (color and translucency) with strength or function with thin sections**(8)**.

Classification of modern ceramics

1. Glassy Phase Porcelains

Glassy phase veneering porcelains and pressable ceramics, feldspathic leucite-reinforced glassy materials consist mainly of an amorphous silica phase (approximately 40-60 weight percent amorphous silica) (9).

With the advantage of having the most esthetic optical properties in terms of: simulating the optical transmission and color of natural dentition. However, some of their disadvantage included low flexural strength (ranged between 60 and 80 MPa) limiting their indication to veneering layers, inlays and onlays (10).

2. Glass Ceramics:

Lithium disilicate glass-ceramics are approximately 30 weight percent amorphous silica and 70 weight percent crystalline lithium disilicate crystals. These glass-ceramics are typically used for pressable all-ceramic crowns and monolithic ceramic CAD/CAM crown restorations. Lithium disilicate is considered the benchmark for esthetic monolithic CAD/CAM ceramic crowns. On the other hand, the flexural strength and fracture (ranged from 472-299 MPa) limit their indication to single crown restorations (11).

3. Polycrystalline ceramics (Oxide Ceramics):

Zirconia and alumina dental ceramic materials are typically comprised of a nearly 100 weight percent crystalline phase, these ceramics have been used in dentistry for the last 15 years due to their high flexural strength and fracture toughness (ranged from 960 – 1500 MPa) (12).

Indications for partially stabilized tetragonal zirconia range from single crown restorations to full-arch frameworks. It can be provided with high opacity to cover discolored teeth and implant components.

However, zirconia tends to have a higher opacity, which would seem to contraindicate use in the esthetic zone and unlike the glass containing ceramics, the polycrystalline ceramics have high resistance to commonly used acid surface treatment **(13)**.

The survival rates of zirconia fixed dental prostheses (FDP) range from 73.9% to 100% **(14)**.

4. Resin-matrix ceramics:

Dental ceramics composed of an organic matrix combined with ceramic fillers. The hybrid ceramic is a new category of restorative material, with a dual structure: the ceramic network structure is reinforced with a polymer network structure.

Evolution of Zirconia

All ceramics eventually fail by catastrophic failure through a crack that propagates through the entire thickness of the ceramic. Different components are added to the glass matrix to require more energy to go around the particle and thus interfere with the crack propagation. When a crack is initiated in zirconia, the molecular structure of the zirconia changes from the tetragonal phase to the monoclinic phase. As this occurs, a 4% volume increase occurs that “squeezes” the cracks **(15)**.

Composition of Zirconia

The name zirconium comes from the Arabic “Zargun” (golden in color) which in turn comes from the two Persian words “Zar” (Gold) and “Gun” (Color). Zirconia is a crystalline dioxide of zirconium. The zircon mineral is purified to produce zirconia powder with controlled particle size and composition. Metal oxides are added to the powder; yttrium to stabilize the tetragonal phase of zirconium, aluminum to prevent water corrosion, and hafnium oxide to reduce pore development and coloring components. Both composition and powder particle size affect the ceramic microstructure, which dictates the mechanical and physical properties of the zirconia **(16)**.

Classification of zirconia:

1. According to polymorphism(17):

At ambient pressure, unalloyed zirconia can assume three crystallographic forms depending on the temperature. At room temperature and upon heating up to 1170 °C, the symmetry is monoclinic. The structure is tetragonal between 1170 and 2370 °C and cubic above 2370 °C and up to the melting point (18). The transformation from the tetragonal (t) phase to the monoclinic (m) phase upon cooling is accompanied by a substantial increase in volume (∼4.5%) enough to lead to catastrophic failure. This transformation is reversible and begins at ∼950 °C on cooling. Alloying pure zirconia with stabilizing oxides such as

CaO, MgO, Y_2O_3 or CeO_2 allows the retention of the tetragonal structure at room temperature and therefore the control of the stress induced. Tetragonal to monoclinic transformation, efficiently arresting crack propagation and leading to high toughness (19,20).

The tetragonal phase is stabilized at lower dopant concentrations than the cubic phase. Another way of stabilizing the tetragonal phase at room temperature is to decrease the crystal size (the critical average grain size is <0.3 μm) **(21).**

Zirconia-based ceramics used for biomedical purposes typically exist as a metastable tetragonal partially stabilized zirconia (PSZ) at room temperature. Metastable means that trapped energy still exists within the material to drive it back to the monoclinic phase. It turned out that the highly localized stress ahead of a propagating crack is enough to trigger zirconia grains to transform in the vicinity of the crack tip. In this case, the 4% volume increase becomes beneficial, essentially squeezing the crack to close and increasing toughness, known as transformation toughening **(21)**.

Several authors have reported that annealing at 900 °C for 1 h or relatively short heat treatments in the temperature range 900–1000 °C for 1min induce the reverse transformation from monoclinic to tetragonal. This phenomenon was accompanied by the relaxation of the compressive stresses at the surface and a decrease in strength (22,23).

2. **According to composition:**

The Open Biomaterials Journal (2014), mentioned types of zirconia used in dentistry these are:

- Yttrium cation-doped tetragonal zirconia polycrystals (3Y-TZP) most commonly used.
- Magnesium cation-doped partially stabilized zirconia (Mg-PSZ).
- And zirconia toughened alumina (ZTA).

3Y-TZP:

- Tetragonal zirconia (opaque zirconia) contains 3 mole % Y-TZP enhanced with 0.25% alumina to minimize the low temperature degradation. Flexural strength of 1,000 to 1,200 MPa and fracture toughness of 3.5 to 4.5 MPa·m$^{1/2}$ **(24)**.
- Cubic translucent Zirconia contains 4 mole % Y-TZP (e.g., KATANA™) has a flexural strength of 600 to 900 MPa and fracture toughness of 2.5 to 3.5 MPa·m$^{1/2}$ **(24)**.
- The third group is ultra-translucent zirconia contains 5 mole % Y-TZP (e.g., Lava Esthetic; BruxZir Anterior; KATANA™ UT/UTML; and Zpex Smile) with reduced mechanical properties. It has a flexural strength of 700 to 800 MPa and fracture toughness of 2.2 to 4 MPa·m$^{1/2}$ **(24)**.

Traditionally, dental zirconia is predominantly made of fine tetragonal zirconia crystals with small amounts of yttria stabilizer (i.e., 3Y-TZP). While exceptionally strong, 3Y-TZP ceramics have poor translucency. The current method to improve zirconia translucency is to introduce an optically isotropic cubic (c) phase into tetragonal (t) zirconia. This has been achieved by using a higher yttria content to produce partially stabilized zirconia, 4 mol% (4Y-PSZ) or 5 mol% (5Y-PSZ) (25).

The current changes in formulation that result in more esthetic appearance have not only lowered flexural strength from 1000 to 600 MPa, but also have eliminated the unique transformation toughening that gives zirconia its toughness and resistance to fracture. Therefore, the ultra-translucent 5Y-PSZ materials are somewhat restricted to single-unit crowns and short-span fixed dental prostheses in the anterior zone.

However, strength decrease, light transmission increased by 43% to 45% due to the increased cubic phase, less porosity, and increased size of the isotropic cubic grains (25).

Study by **Mao et al 2018 (26)** demonstrated that surface glass infiltration of 5Y-PSZ can effectively increase its strength, while retaining a high level of translucency. The strength of grade 5Y-PSZ is over 70% higher than their un-infiltrated counterpart**.**

3) According to method of fabrication:

The partially sintered zirconia blocks is milled into the final restoration shape and then fully sintered, producing approximately 20% shrinkage in the finished restoration. The computer design module contains algorithms that account for this shrinkage for the final coping to precisely fit the original die.

Fully sintered Zirconia block is a significantly harder material to mill. The machine must use a liquid cooled closed system with diamond cutting burs. The milling time is significantly longer –hours instead of minutes- although there is no additional sintering time. Milling the surface of the harder zirconia may lead to surface imperfections causing potential crack initiation.

Recently, rapid-firing zirconia blocks for chairside milling of zirconia restorations. Using the CEREC® Speed Fire oven (Dentsply Sirona) with a 30-minute sintering cycle **(18)** .

Monolithic (full-contour zirconia'' "translucent") restorations.

One of the most important reasons for introducing monolithic zirconia restorations is the significant rate of porcelain fracture from porcelain veneered zirconia-based restorations (6%–25% after three years), which is greater than the fracture rate reported for porcelain fused-to-metal (PFM) systems. Delamination (failure at porcelain-zirconia interface) and chipping (failure within the veneering porcelain) are the most common modes of failure (27)(28).

The mismatch in some mechanical and thermal properties such as fracture toughness, flexural strength, coefficient of thermal expansion, and elastic modulus affect the bonding between porcelain and zirconia. Significant differences on the coefficient of thermal expansion between the zirconia and porcelain influence in the residual stress distribution during the cooling process affecting the reliability of zirconia-based restorations (29).

So, monolithic zirconia came as an alternative to the failed veneered restorations with increased translucency and aesthetics compared to opaque zirconia and abbreviate the dental laboratory work on zirconia-based restorations **(30)** .

- **Strength:**

It was shown that the thickness of the restoration affects the light transmission through ceramics. By reducing the thickness of the restoration, the material would be more translucent and natural-looking, but less fracture resistant. So, recent translucent monolithic zirconia restorations fulfill this property, minimum thickness with sufficient strength and superior translucency. The flexural strength of all the monolithic TZP showed approximately 1,000 MPa indicate no requires for drastic increase in thickness compared with conventional crown restorations, and it may become a clinical benchmark for decreasing the amount of tooth to be removed. It can be stated that its flexural strength is higher than that of IPS e.max lithium disilicate which is 460 MPa, but it is lower than conventional zirconia (22).

The new translucency zirconia exhibits favorable mechanical properties and esthetic performance at 0.5-1mm (31).

In study performed by ***Nakamura et al (2015)*** **(32)**, he suggested that monolithic zirconia crowns with a minimal thickness of 0.5 mm possess enough strength for being applied to molar regions even after aging.

He also found that the fracture load of the zirconia crowns with the occlusal thickness of 0.5 mm (5558 ± 522 N) was significantly higher than that of lithium disilicate crowns with an occlusal thickness of 1.5 mm (3147 ± 409 N) **(33)**.

In study performed by **Al-Juaila et al 2018** (34), comparing e.max high translucent (EMHT) with ultra-translucent zirconia (UTZ) in 0.4 mm thickness, the results showed no significant difference between them. As the manufacturer instructions recommended that the minimum thickness of e.max to be 0.6 mm so using UTZ in esthetic cases are preferable than e.max to be more conservative to tooth structure.

- **Translucency of monolithic zirconia restorations:**

Translucency is the characteristic of allowing the passage of light while scattering it in such a way that the complete image can't be clearly seen. So, translucency stands somewhere between complete opacity and transparency (35). It can be adjusted by controlling the absorption, reflection, scattering and transmission of light through the material. Low reflectance and high scattering and transmission of light result in increasing translucency (36).

Zirconia crowns were less translucent than glass ceramic ones with the same thickness because the dense oxide ceramic structure of zirconia allowed more absorption and reflection rather than transmission of light. Yttria-stabilized tetragonal zirconia polycrystals (Y-TZPs) has excellent mechanical properties, but its intense white color and high opacity represent an esthetic limit. Cubic zirconia represents a new generation of dental ceramics with molecular structure and physical properties different from the conventional zirconia (37).

The different index of refraction of the materials compositing 3 Y-TZP zirconia (alumina, yttria, colorants) increases light reflection as incident light transmission is decreased. Furthermore, different index of refraction of enamel or dentin as well as pores in the zirconia produce light scattering and absorption, resulting in an opaque material**(38,39)**.

Harada et al. (2016) (40) found that ultra-translucent zirconia (UTZ) was significantly more translucent than all other types of zirconia, and e.max CAD high translucent (HT) showed translucency more than all studied materials.

In the literature, lowest transmittance values (0.065015 Å) were seen with conventional zirconia, however, the high translucency zirconia showed a significant increase in transmittance values (0.143969 Å) over that of conventional zirconia. But conventional lithium disilicate showed higher transmittance values (0.158738 Å) than the high translucency zirconia (0.143969 Å) (41).

One of the methods of increasing zirconia translucency concerned decreasing the alumina content below 0.05%. Another approach of improving zirconia translucency was increasing the lanthanum oxide content to 0.2% mol. For Y-TZP zirconia, the grains have irregular boundaries that limit light transmission (anisotropic), so, a new approach to increase the translucency of zirconia was to develop an isotropic cubic zirconia material, which decreases light scattering from birefringent grain boundaries. This was achieved by using an increased percentage of yttria to stabilize zirconia composition, resulting in a 10 to 15% cubic crystalline zirconia phase interposed with the tetragonal phase (42,43)

An opaque polycrystalline ceramic can be made translucent when reducing the grain sizes to sub-micron or nanoscale ideally under 100 nm, the grain size of translucent zirconia should be less than the visible wavelength, which is in the range of (400-700 nm) to decrease the scattering of the light and to gain translucency (44,45).

However, extremely small grain sizes (in range of 200 nm) can affect the transformation toughening mechanism of zirconia. this would produce a decrease in strength and resistance to fracture of translucent zirconia (46)

Kim et al. 2013 **(47)** reported that the sintering time affects the grain size of zirconia ceramic. He concluded that a short sintering time yields small grain size and increases the light transmittance values of translucent zirconia ceramic.

Pores and pore density have a great influence on light scattering in zirconia ceramics, mainly when they are comparable in size with the wavelengths of visible light (400-700nm). Due to the typical pore size (in the range of 200-400nm) and pore density (0.05%). The translucent zirconia shows a minimal nanosized porosity (48).

Two methods have been used for studying the translucency of all-ceramic crowns. The absolute translucency was measured by a spectrophotometer or a spectroradiometer, which detected the whole light transmitted through the ceramic crown. The relative translucency measuring method was used to compare the relative translucency of various all-ceramic crowns by the contrast ratio or translucency parameter that was measured on a black and white background (49).

Translucency and thickness of monolithic zirconia

The translucency decreases as ceramic thickness increases**,** study performed by **Baldissara et al 2016** **(50)**, **he found that** the translucency of super translucent (ST)cubic zirconia 1.0-mm was significantly higher (91.2%) than that of ultra-translucent (UT) cubic zirconia 1.5-mm (87%). Although UT is more translucent than ST. He also found both the UT 1.0mm and UT 1.5mm showed greater translucency than IPS e.max CAD low translucency (LT) 1.5mm (this the thickness that is recommended by the manufacture) showed (47%).

According to BruxZir, at the 0.5 mm thickness, the translucency parameter is 10.7 (0.1), but, at the 1.0 mm thickness, the translucency parameter is 7.8 (0.1)[c.] Translucency parameter a function of wavelength when measured between 360-750 nm in reflection. So, zirconia having similar optical properties can be a better substitute for glass ceramic restorations because of its superior mechanical properties (51).

Bonding to Zirconia

According to bonding of ceramic materials can be divided into etchable ceramics (containing silica particles and leucite-reinforced feldspathic ceramic) and non-etchable ceramics (silica-based material, including zirconium oxide and aluminum oxide). The most commonly used cements to bond ceramic restorations are glass ionomer (GIC) and resin-based cements to the remaining tooth structure. GIC and resin-modified GIC (RMGIC) are used to cement acid-resistant ceramics, because these cements are very easy to use. However, the most popular and effective cements for all types of ceramic restorations are the resin-based composites, including the systems containing the 10-methacryloyloxydecyl-dihydrogen-phosphate (MDP) monomer **(30)**. (MDP) is the hydrophilic phosphate monomer that is reported to be most promising monomer for chemical bonding to hydroxyapatite of enamel and dentin due to being stable against hydrolysis and forming strong ionic bonds with calcium. It is one of the most successful materials in the market for chemical bonding and do not require conditioning the dentin or ceramic surfaces (52).

The clinical success of resin bonding procedures for cementing ceramic restorations and repairing fractured ceramic restorations depends