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Review Article

E Max Crowns in Dentistry

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Abstract

Introduction: In the recent era, the demand for esthetics has seen steep growth. The patients have been highly demanding of newer, more esthetically pleasing restoration for their teeth. This led to the development of ceramic restorations for direct and indirect use. Materials with high strength ceramic core have been developed, where the core is a high strength ceramic material. IPS E-Max is one such development which has been produced by Ivoclar Vivadent, Schaan in Liechtenstein.

Aim of Work: This review gives a detailed explanation of the microstructure, mechanical and optical properties of E-Max crowns. It explains the various clinical indications of E-max crowns and their performance.

Methodology: This review is a comprehensive research of PUBMED and Google Scholar from the year 1990 to 2019.

Conclusion: E-Max crowns have gained huge popularity in recent times because they combine the excellent esthetics and superior mechanical properties of all-ceramic and metal-ceramic restorations. The mechanical and optical properties of E-Max crowns are largely affected by the microstructure of the material, and hence a detailed study of the microstructure and phase transformation of the material is required. Due to the recent developments that keep taking place in E-max crowns and the recent advent of the material, there is a shortage of long-span studies for E-Max crowns, and hence more studies should be carried out to study the longevity and long term clinical success of E-Max crowns.

Keywords: *E-Max Crowns; Blue State; Microstructure; Translucency; Zirconia; Lithium Disilicate*

Introduction

In the recent era, the demand for esthetics has seen steep growth. The patients have been highly demanding of newer, more esthetically pleasing restoration for their teeth. This led to the development of ceramic restorations for direct and indirect use. Production of ceramics generally takes place by three means, the classic sintering technique, using pressure or casting technique, and with the help of the new direct milling machines. There is a huge pool of ceramic material available in the market which have excellent physical properties like good biocompatibility, stronger bonding properties, but the main disadvantage that has been associated with ceramics is the brittle nature that leads to recurrent failure of the restoration [1].

Initially, metal-ceramic materials had been developed where a metal lining attached to the ceramic provided strength to the restoration, but this was a huge compromise on the esthetics as the translucency of the material was compromised because of the opaqueness of metal. Several ceramic materials were later developed to overcome this, but they could not match their metal-ceramic counterpart in fracture resistance. With developing time, dental ceramics have also changed their course and a lot of new improvements have taken place in the form of material properties and the production of ceramics. Materials with high strength ceramic core have been developed, where the core is a high strength ceramic material that is made by sintering a slurry, which is densely packed consisting of aluminum trioxide and later infused with molten glass. IPS E-Max is one such development which has been produced by Ivoclar Vivadent, Schaan in Liechtenstein. It is produced in two forms, the first being a block form that can be used in CAD/CAM system, and the second is an ingot, which uses the lost wax technique and presents in the pressable form. In case any cracks or flaw is present in the material, the ceramic tends to fail under functional stress. In High strength, all ceramic material, glass, and alumina particles penetrate each other in the medium, thereby reducing the crack propagation, and producing higher strength up to four times the existing ceramic. This review explains in detail about the microstructure and the various mechanical and optical properties of the E-Max crowns [2].

History of E-max crowns

The earlier all-ceramic crown that was developed was IPS-Empress 2 in the year 1988, which had a heat pressed core. Empress 2 contained disilicate lithium fillers in the rage of 70 - 80%. The casting technique used was pressure-induced, reducing the overall defects and giving uniform distribution of the crystal. IPS E-Max Press was later produced by the year 2005, by the refinement of the crystals [3]. By the year 2006, digital dentistry took a major turn, and a lot of advances were seen in the field of diagnosis, impression making by CAD-CAM (Computer-aided design and mechanics), leading to the advent of E-Max CAD. The primary composition of the material is lithium metasilicate and comes in a blue state; this material is simpler in terms of milling and reports lower bur wear. Once the milling process completes, heat treatment and glazing are done, which forms the final lithium disilicate material. Due to the superior esthetics and strength comparable to conventional ceramics, CAD-CAM E-Max crowns have now gained a lot of popularity [4].

The microstructure of E-max crowns

Due to the various states in which E-max crowns are milled, there is a huge significance of the microstructure and phase transformation. Partially crystallized and fully crystalized, both the materials have a unique material form, and hence their microstructure study is of deep interest. The phase transformation process is also very important. The optical and mechanical properties of the material are dependent on the microstructure of the material and hence are of intense importance. An E-Max crown is delivered in a blue state; in this glass, materials in different forms are combined together using pressure procedure. The main component of the partially crystallized glass is 40% lithium metasilicate material; this is set in a glass phase and has a disilicate nucleus. The size of the particle is around 0.1 - 0.2 mm and is shaped like a platelet (Figure 1) [5].

Fully crystallized CAD consists 70% lithium disilicate which is dispersed in a glass matrix and once the glass is etched the glass matrix dissolves and lithium disilicate material is exposed (Figure 2).

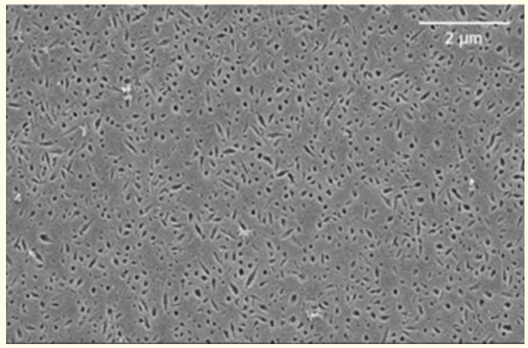

Figure 1: *Partially crystallized CAD, Lithium metasilicate with 0.2 mm particle size. (this picture is taken after etching with hydrofluoric acid for 10 seconds) [5].*

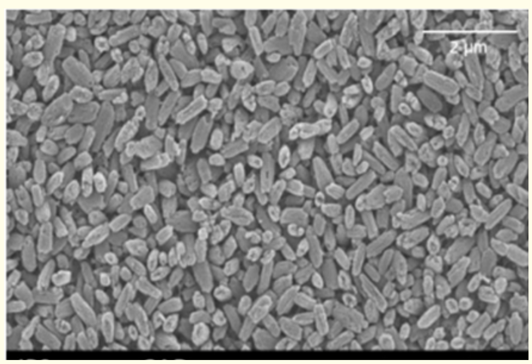

Figure 2: *Fully Crystalized CAD after acid etching with hydrofluoric acid for 30 seconds [5].*

X-ray diffraction revealed the presence of the glassy phase in various studies where the phases of the material were studied through different firing temperatures [6]. The partially crystallized material gave better mechanical properties in terms of edge stability and wear resistance after the usage of burs [5]. After the initial round of milling, the firing procedure is repeated, and once the material is tempered at 850 degrees in a vacuum, it is considered as fully crystallized. X-ray diffraction tests have also shown other phases apart in addition to lithium disilicate and metasilicates like lithium orthophosphate and cristobalite [7]. Nucleation and crystallization occur at two different levels, and the main mode of phase transformation is bulk crystallization. Condensation of the lithium disilicate materials is not seen when the temperature is low, and instead, lithium orthophosphate was noticed [6]. Another method to reduce the residual lithium metasilicate is to increase the pressure while firing; this led to an improved crystalline phase by overcoming the drawbacks of the crystalline phase. After all these procedures of heat treatment and phase, transformation is done. A fully crystallized 70% lithium disilicate material is achieved intermixed in the glass matrix. Porosity is also seen after firing, which is uniform in appearance. The particle distribution, size, and volume play an important role in the mechanical properties. The material character of E-Max crowns highly effects the properties of E-max like the fracture resistance, edge stability, optical properties, etc., and hence is an important field of study [8].

Bonding of ceramic

The bond strength of ceramic has been improved in the past decade because of the new and improved bonding techniques available. The dentin adhesive that is used these days contains a conditioner that is acidic in nature and a monomer, which is a combination of hydrophobic and hydrophilic solutions. Once the tooth is etched using the acid, the remaining acid is completely washed off from the surface, followed by the application of 2 - 3 layers of monomers. Single bottle adhesive has also been developed, which has the acid and monomer in the same bottle, thus reducing the time and effort of the clinician. It also reduces the chances of contamination of the finish line during cementation due to reduced working time. The usage of one bottle adhesive also has its own drawbacks like a reduces bond strength, although some studies have shown that the bond strength is less than conventional systems, others have shown no statistical difference between both [9].

Mechanical properties of E-max crowns

The main advancement in E-Max crowns was its superior mechanical properties compared to the predecessors. The Blue state of the material in which it is delivered is the main landmark where the characterization of ceramic is done informing about the inceptive properties. This section describes the properties of the materials in its partially crystallized form (Table 1) transformation during the firing of the material and the final properties in a fully crystallized form [10].

Mechanical Properties	Partially Crystallized	Fully Crystallized
Flexural Strength	~ 130MPa	260 - 400MPa
Fracture Resistance	0.9 to 1.25 MPa m $^{1/2}$	2 - 2.5MPa m$^{1/2}$
Hardness (Vickers)	~5000 MPa	~5000MPa

Table 1: *Mechanical properties of partially crystallized material and fully crystallized form after firing at 770 degrees for 5 minutes, followed by 850 degrees for 10 minutes [10].*

Linearly 2% shrinkage is seen in the partially crystallized form once tempering is done. Gaps around the margin of the restoration and compromised internal fit have been seen due to the shrinkage, but even after the shrinkage, the marginal gap is not significant and is less compared to other ceramic crowns. In a study conducted by Ji., *et al.* [11], they concluded that IPS E-Max crowns had a significantly lower marginal gap compared to CAD-CAM anatomic contour zirconia system. Another study conducted by Goujat., *et al*. [12], where they compared 4 CAD-CAM blocks for mechanical properties and internal fit, concluded that E-Max crown was superior to the other leucite reinforced restorations. The heating temperature and schedule of heating largely affect the mechanical properties of E-Max crowns and can be altered accordingly. The composition of IPS E-Max crowns largely affected their mechanical properties as opposed to the chemical formulation [12].

Optical properties of E-max crowns

For the success of any restoration, the esthetics in terms of color and translucency plays a huge role. The optical properties of the ceramic materials should match that of the natural tooth structure in order to mimic the natural tooth structure. The mechanical properties of metal-ceramic restoration had always been superior to all-ceramic materials, but the metal lining induced opacity in the restoration, thus compromising on the esthetics. The main advantage of IPS E-Max crowns is the vast range of shades and multiple radiolucencies that its available in. The color of the ceramic crown is dependent on the coloring ion that is present in it; the E-Max crown has a yellow, brown, and blue coloring ion dispersed in the matrix. During the firing procedure, the coloring ion undergoes oxidation resulting in a change of color from the "blue state" in which it was delivered [5]. The color is finally refined by glazing, polishing, and adding stains before the crown is tempered. The translucency of the material depends mainly on the ability of a material to absorb the light that has not been reflected and later scatters that light. E-Max crowns are present in variable translucencies, which are formed basically through the different microstructure of the material, namely, Low (LT), Medium (MO), and High (HT). The quantity of crystals is the same in all the variants, but they differ in the particle size of the crystal varying from 0.8 to 1.5 mm and 0.2 to 0.8 mm, respectively, for HT and LT. The matrix in which these crystals are dispersed is also different for both translucencies with HT having a glassy matrix and LT having a denser matrix [13]. To increase the translucency of E-Max crowns, the material chosen should have a similar refractive index of the glassy phase and lithium disilicate crystals. This combination of glassy and crystalline phases provides the light scattering property of E-Max crowns. If the percentage of crystals increases in the material without the glassy phase increasing proportionally, there is a positive increase in the mechanical property of the material decreasing the optical properties of the material [14]. Advancements are taking place at a high rate in E-Max crowns with increasing translucency, and novel materials classified as super translucent and ultra-translucent ceramic has also been developed. In a study conducted by Baldissara., *et al.* [15], they evaluated the optical properties of an ultra-translucent and a super translucent variant of crowns and compared it to LT. They used total transmission and contrast ratio as the parameter for comparison. The study concluded that the super translucent and ultra-translucent variant of ceramics possessed a high translucency even at the maximum thickness of the ceramic. Once the tetragonal phase of zirconia was removed from the matrix, it led to increased translucency, but that may lead to a compromise in the mechanical property, and hence, further studies are required to assess the difference in mechanical properties of zirconia after eliminating the tetragonal phase [15].

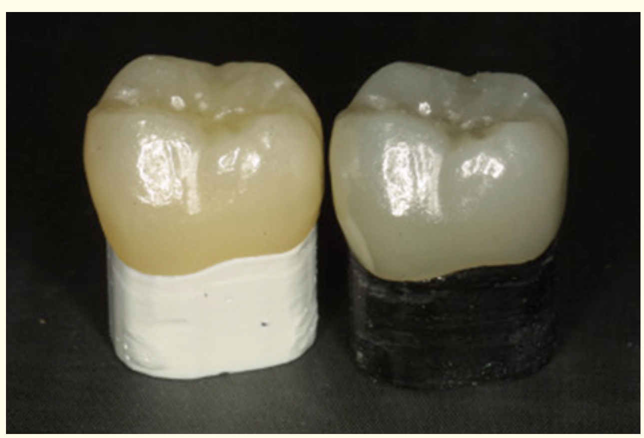

Figure 3: *High translucency of ultra-translucent ceramic seen placed on a black and white dye [15].*

Clinical presentation and usage of E-max crowns

E-Max crowns have been a recent development, and hence a lot of clinical and non-clinical studies have been conducted in the recent past. The initial use of E-Max crowns was only limited to esthetic frameworks, veneers in anterior teeth, inlays, and onlays. High-stress bearing areas were seldom given E-Max crowns. After a more elaborate understanding of the microstructure of the material, new developments were done in the mechanical properties, thereby increasing the field of use. The Manufacturers of E-Max crowns in 2016, released a new list of indications of E-Max crowns which included the usage of for single monolithic crowns, 3 unit Fixed partial dentures as opposed to just the framework, as veneers for inlays, onlays, and anterior teeth [16] (Figure 4). In a case report published in 2018, the anterior esthetic zone consisting of incisors, canine, and premolars, which initially had compromised esthetics due to old metal-ceramic restoration, was restored using E-Max crowns. The metal-ceramic restoration was opaque and hence did not mimic the natural appearance of a tooth, E-Max crowns provided better esthetics with a more natural tooth-like appearance (Figure 5) [17]. Schultheis., *et al.* [8] conducted a study where they evaluated the fatigue effect on the survival rate and fracture resistance of E-max monolithic 3-unit fixed partial denture and compared it to a conventional metal-ceramic prosthesis. They concluded that the strength and fracture resistance of the 3-unit E-max crown was comparable to the conventional metal-ceramic restorations. They also concluded that monolithic E-Max yielded higher strength compared to bi-layered Fixed partial dentures [8]. The manufacturers in 2016 stated that the E-max crown could be used for full coverage crowns when the finish line was kept at a minimum thickness of 1 mm overall. Such a thin finish line could cause fracture of the restoration and other forms of failures. The study conducted by Kelly., *et al.* [18] suggested that if the thickness of the crowns was increased from 1 mm to around 1.8 mm, it could increase the failure load to almost 2000N, which was earlier reported to be around 1400N [18]. Another study that tested cyclic fatigue on anterior monolithic veneers suggested that when cyclic loading was applied to anterior monolithic veneers, an increased failure rate was seen, thus contradicting the use of monolithic E-Max veneers in anterior teeth. Long-standing performance review of E-Max crowns is not available due to the reduced time span in which developments have been taking place. Sulaiman., *et al.* [20] conducted a study in which he evaluated the failure rate of the E-Max crown over a period of 4 years. He concluded that the failure rate of E-Max used for Monolithic Veneers was 1.3% and 1.53% for layered veneers. A failure rate of 1.01% was seen when E-Max crown material was used for inlay/onlay [20].

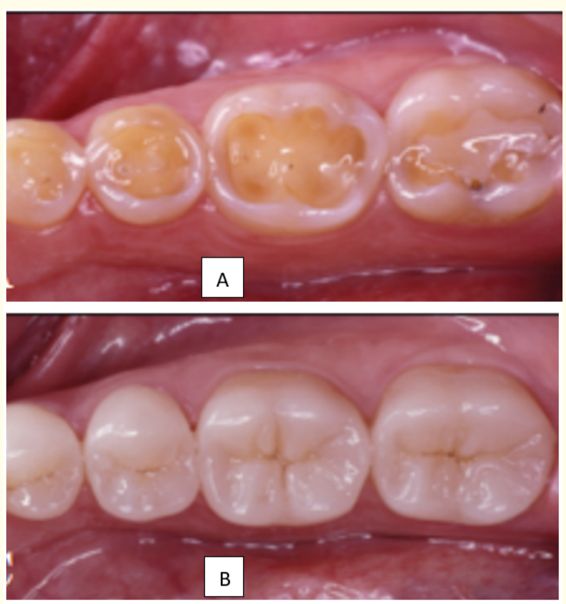

Figure 4: *A: Preoperative image of wear facets seen in posterior teeth; B: Post-operative image with E-max Crowns in the premolars and molars [19].*

Figure 5: *Replacement of metal-ceramic anterior restoration with all-ceramic E-Max restoration [17].*

In a study conducted by Guess., *et al.* [21], where they studied the 2-year outcome of all-ceramic crown placed on 80 molars in 25 patients, it was concluded that 100% success was seen in E-Max crowns at the end of 2 years. Another study that followed up for a span of 6 years concluded that 87.6% success was seen in cases where the monolithic ceramic single unit e-Max crown was placed. More studies are required to give a definite analysis of the longevity of E-Max crowns and restoration in the posterior stress-bearing area. The expanded horizons of usage of E-Max crowns like use in longer unit FPDs; multiple crowns need literature support.

Anterior teeth have shown more success and acceptability of E-max crown as the main concern for anterior teeth is esthetics, and the increased translucency of E-Max crowns makes it suitable for anterior restorations. The blending ability of E-Max crowns at the finish line of the crown for anterior teeth helps in mimicking the natural tooth structure more easily. Luting agent that is used for the cementation of the ceramic crowns also affects the final color of the restoration, and hence matching of the resin cement is also an important step during the cementation of E-Max crowns. All the studies related to E-Max crowns have a very short span of follow up, and hence more studies with longer follow up periods are required [21].

Conclusion

E-Max crowns have gained huge popularity in recent times because they combine the excellent esthetics and superior mechanical properties of all-ceramic and metal-ceramic restorations. The mechanical and optical properties of E-Max crowns are largely affected by the microstructure of the material and hence a detailed study of the microstructure and phase transformation of the material is required. Due to the recent developments that keep taking place in E-max crowns and the recent advent of the material, there is a shortage of long-span studies for E-Max crowns, and hence more studies should be carried out to study the longevity and long term clinical success of E-Max crowns.

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