The effect of different finishing protocols on surface roughness and optical properties of Zirconia-Reinforced Lithium Silicate

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Dedication

My greatest supporters and the reason for who I am today

Mum and Dad

My Sister, my better half and number one cheerleader

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My dear friends who encouraged me and were there when I needed it the most.

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Introduction

Throughout the years, dentistry has evolved to meet both, patients and dentists' high esthetic expectations. In respect to that, a shift has occurred in material and technique of fabrication. Hence the development of a new era of metal- free ceramic restorations[1].

The success of all ceramic materials is due to their good mechanical properties, biocompatibility, low thermal conductivity and superior esthetics. The superior esthetics were in terms of both, color and optical properties, which were similar to that of the natural teeth[2]. Also, reproducing the appearance of natural teeth is a challenging process that require careful construction of the restoration in terms of shape, surface texture, color and translucency[3].

Celtra Duo, is a zirconia-reinforced lithium silicate ceramic material that has been recently introduced to the dental market. This material offers a variety of indications such as Crowns, Bridges, Partial crowns, Inlays, Onlays and Veneers. The manufacturer claims that the characteristic microstructure of the material gives it good optical and mechanical properties, along with good edge stability and polishability[4].

It's a monolithic crystalized ceramic block that the company states that it has two processing techniques in the dental lab. It can either be milled and polished having properties superior to glass ceramics , or milled and glazed offering properties similar to lithium disilicate ceramic materials[4].

Some monolithic restorations require glazing and staining while others require finishing and polishing to achieve good esthetics. Upon delivery of the restoration, its adjustment is inevitable and this would affect the surface characteristics of the ceramic material. Since there are variable polishing systems now available; the finishing protocol that would yield the best results should be evaluated[5].

Therefore, the main interest of this research was directed towards evaluating the color, translucency and surface-roughness of zirconia reinforced silicate ceramics after polishing and/or glazing.

Review of Literature

The word “ceramic” is derived from the Greek word “keramos” that means “burnt earth”. It’s derived from the ancient art of fabricating pottery where clay is fired to form a hard, brittle object. Another modern definition is “a material that contains metallic and non-metallic elements[6]**.**

With the growing demand for esthetics, dental ceramics have been the most commonly biocompatible materials used for dental restorations. Dental ceramics are known for their chemical stability, good optical properties (translucency and fluorescence) and their resemblance in the coefficient of thermal expansion to dental composition. The properties they offer, make them capable of perfectly matching the appearance of the natural teeth[7,8,9].

However, ceramics are limited by being brittle materials with inherent surface flaws. Tensile or complex stresses result in crack initiation and propagation that might eventually lead to fracture of the material[8,10].

During the past decade, the technological development in the dental field helped in the introduction of higher strength materials with different processing methods such as CAD/CAM technology. Such improvements achieved durable restorations with high success rates[11].

<u>Classifying dental ceramics</u>

The composition of dental ceramics falls into two main components: glass particles and crystals, with varying proportions. Generally, the ceramic material that is mainly composed of glass has superior esthetics and translucency. Unlike the crystalline material, its mechanical properties are higher on the expense of the optical, resulting in an opaque appearance[12].

In literature, there are several classifications for Dental ceramics including their composition, microstructure, processing method, fusing temperature, translucency, fracture resistance, and abrasiveness.[13] These classifications tend to be somehow inaccurate as they don’t permit the addition of the new materials easily[14].

Gracis et al in 2015 [14] recommended a new approach for classifying ceramic restorative materials into three big families depending on the phases in their chemical composition; **Glass-matrix ceramics, Polycrystalline ceramics and Resin-matrix ceramics**. And each family is further divided into 3 subgroups.

1) Glass-matrix ceramics: they are inorganic nonmetallic materials containing a glassy phase
    i. Feldspathic: eg IPS Empress
    ii. Synthetic: eg leucite based materials, Lithium disilicate and dervivtives such as IPS Emax, Celtra Duo and Vita Suprinity
    iii. Glass-infiltrated: alumina (In-Ceram alumina), alumina & magnesium (In-Ceram Spinell) and alumina & zirconia (In Ceram-Zirconia).
2) Polycrystalline ceramics: they are nonmetallic inorganic materials without any glass phase
    i. Alumina
    ii. Stabilized zirconia

iii. Zirconia-toughened alumina and alumina-toughened zirconia

3) Resin-matrix ceramics: materials with polymer matrices mainly containing inorganic refractory compounds such as porcelain, ceramics and/or glass ceramics.

i. Resin nanaoceramic

ii. Glass ceramic in a resin interpenetrating matrix.

iii. Zirconia-silica ceramic in a resin interpenetrating matrix.

Zirconia

Zirconia is a highly interesting polycrystalline ceramic material. It's a polymorphic material that has 3 crystalline forms: monoclinic, tetragonal, and cubic. The transformation from one form to another occurs with the increase in temperature. Owing to that transformation toughening, the material has superior mechanical properties (flexural strength up to 1000MPa) with an increased resistance to crack propagation when stress is induced[15,16]. It is a change of crystal structure (tetragonal to monoclinic) under stress area, when a crack occurs and propagates. After that transformation, volume increases in concerned area, this volume increment around the crack area creates compressive forces and stops the crack propagation[17]. Because of its opaque white color, it require veneering with a more esthetic material. However, cohesive failure of the veneering porcelain has been the major obstacle due to the frequent chipping of the veneering layer. Several attempts had been developed such as high strength CAD/CAM-fabrication of veneering porcelain, high strength heat-pressed ceramics and "double veneering" technique[18]. Owing to the

CAD/CAM technology, monolithic zirconia restorations were introduced to overcome such problem with better esthetic outcome[16,19]. Monolithic zirconia can be shaded before the sintering process, surface characterizations, glazing or polishing can be applied[17].

Lithium Disilicate

Lithium disilicate (LDS) is a glass ceramic material that is widely used in the dental field; IPS Emax introduced by Ivoclar Vivadent in 2005[20]. This material, with its 70% crystal phase and its characteristic spindle-shaped crystals, offers high flexural strength (360-400MPa) along with high fracture toughness. Also, the low refractive index of the lithium disilicate crystal, presented esthetically pleasing, translucent restorations. Hence, extending the range of indications of the material. The material was marketed first as Empress 2 and later as IPS e.max. It is a well-documented and successful long-term ceramic material that is currently in use [21]. The LDS is supplied in 2 different crystalline states depending on the application. The CAD form (emax CAD) is supplied in a pre-crystallized state that is more easily machined. This CAD form is primarily glassy with evidence of the presence of LMS and LOP crystals, which gives the e.max CAD milling blanks their characteristic “blue block” appearance. The milled restoration is subsequently heat treated to allow the crystallization process to be completed. In the final form the glass- ceramic contains primarily LDS crystals. The other form is the pressable ingot (e.max Press) which is supplied by the manufacturer in the fully crystallized state[21,22,23,24].

Zirconia Reinforced Lithium Silicate (ZLS)

As a part of the continuous technological innovation, new restorative materials are developed to offer a combination of improved strength, optimum esthetics and timesaving machining[25].

Among these, a new machinable group has recently been introduced in 2013 is zirconia-reinforced lithium silicate ceramics[26,27,21]. The inclusion of 10% zirconia particles, combined the esthetic properties of glass ceramics with the mechanical properties of zirconia particles[19,27].

Production ZLS ceramic blocks and restorations pass through three phases. At first, the melted material is molded resulting in a glassy block which is highly brittle. In the second phase, precrystallisation which is a thermal pretreatment where crystals start forming and growing, and the glass exhibits ceramic properties so it can be easily milled. The third phase is final crystallization cycle in the furnace to give the restoration its final color and physical properties[2].

Zirconia reinforced lithium silicate block is available in two forms; the soft partially crystalized state (PC) which can be easily milled that will require a further crystallization cycle or fully crystalized state (FC) with the final shade and properties of the material[27].

ZLS is commercially available in the market as Celtra Duo (Dentsply Sirona) and VITA Suprinity PC (VITA Zahnfabrik)[21].

Celtra Duo

Celtra Duo is a recent category of zirconia reinforced lithium silicate ceramics. This material is provided for CAD/CAM technology and popular for chair-side restorations. The material is available in LT (low translucency) and HT (high translucency) blocks[28]. Its composition by weight is: SiO_2 (56-64%), Li_2O (15-21%), K_2O (1-4%), P_2O_5 (3-8%), Al_2O_3(1-4%), ZrO_2 (10-12%), CeO_2 (0-4%) and pigments (6%)[14,10].

ZLS ceramic has a unique microstructure where it consists of high content of very fine lithium metasilicate and lithium disilicate crystals (average size: 0.5–0.7μm) with 10% zirconia particles that are completely diluted in the amorphous glassy matrix[25,21]. The formed crystals are 4 to 8 times smaller than lithium disilicate crystallites, which marks the difference from lithium disilicate ceramics[25]. The added zirconia particles are small and homogenously distributed that increases the material strength, yet can be easily machined with good esthetics and surface finish[26].

According to the manufacturer, the fully crystallized form of Celtra Duo offers two processing options; can be either hand-polished or glaze-fired in a ceramic furnace. Hand polishing of a Celtra Duo restoration has 210 MPa flexural strength. While glaze-firing results in a restoration of 370 MPa similar to Lithium Disilicate ceramics as IPS e.max CAD[28,29].

As for clinical evaluation of Celtra Duo restorations**, Zimmermann et al**[30] in 2017 performed a clinical study using CAD/CAM technology, describing preliminary clinical results for indirect ZLS restorations after 1 year. In this observational study, 67 indirect restorations were fabricated and divided into 2 groups according