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How to Strengthen Dental Ceramics

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Abstract Today's ceramic restoration application, despite its popularity gained through esthetical advantages and superior hygienically features, has a fragile structure due to its low tensile strength quality. In the long run, it can lose its endurance against shear and draw strengths that occur while chewing. Dental ceramics are sensitive to microcracks that show up on surfaces. Technical flaws like microcracks and porosity which appears during production and inappropriate thermal dilatation parameters cause mechanical failure in porcelain restoration. To improve mechanical strength of dental ceramics we should have a mechanism to prevent these micro cracks get generate and spread. Ceramic structure should be supported either by metal or substructures more durable which decrease effects of tension strength occurring on surface; either it must directly be strengthened structurally.

Keywords: *dental ceramics, strengthen methods, microcracks, ceramic substructure, glass ceramics*

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1. Introduction

Today's ceramic restoration application, despite its popularity gained through esthetical advantages and superior hygienically features, has a fragile structure due to its low tensile strength quality. In the long run, it can lose its endurance against shear and draw strengths that occur while chewing [1,2]. Crystal structure of ceramic material contains ionic and covalent type of strong bonds that gain stability and determination. However, because of those bonds, ceramic has a fragile structure. Ceramic has a high rigidity and pressure strength and low flexion performance [1,3]. Even the pressure strength of dental ceramics are between 350-550 MPa, the draw strength value is 20-60 MPa. Ceramic material used in dentistry is a glassy matrix that is produced via sintering and it contains leucite crystals; it can be identified as a sort of ceramic that is not totally transformed into glass phase. In other words, the material is basically made up of glass. Glass is sensitive to microcracks that show up on surfaces. This is a real handicap in dental ceramic practices [1,2,4] Technical flaws like microfractures and porosity which appears during production and inappropriate thermal dilatation parameters cause mechanical failure in porcelain restoration. For that reason, before making an assessment about oral mechanical features of dental ceramics, one should consider operations during production process of restoration. During the cooling process of material cooked in Owen to get room temperature, volumetrical shrinkage cause microcracks on surface of the material. These kinds of microcracks are called also "Griffith fractures" in memory of first researcher who has defined them. These microcracks can be spread through deeper layers due to failures which occur during preparation, modelling and cooking and cooling process of ceramic. It's a well-known fact that there is a direct relation between microcracks and mechanical strength of material [6,7]. Both superficial and internal microcracks make ceramic a fragile material. The number, depth, width and even the direction of microcracks have an important role on mechanical strength of material [2,3,6,7]. To improve mechanical strength of dental ceramics we should have a mechanism to prevent these microcracks get generate and spread. That's why, ceramic structure should be supported either by metal or substructures more durable which decrease effects of tension strength occurring on surface; either it must directly be strengthen structurally [3,8,9,10].

2. Methods for Strengthen Dental Ceramics

a) Strengthen with a metal substructure:

The restoration system which involves strengthening the ceramic material with metal is firstly invented by Weinstein in 1962. To obtain strong restorations, we attach ceramic materials to oxide layer which is situated out of metal compounds [1]. The resistance of dental ceramic to tension pressure is stronger than tension strength. In order to strengthen dental ceramic and to improve its strength against tension, shear and pressure forces, generally a metal substructure is used [11]. In a ceramic that sub-structurally improved by metal microfractures spread if only this strong substructure gets deformed. In addition to that, thanks to this structure, microcracks that appear on inner surface of crown are prevented [12]. However, for this system, it's important to use a metal substructure which has a thermal dilatation perimeter appropriate for porcelain. The perimeter of thermal dilatation of substructure material should be higher than porcelain's. Thanks to this difference, during cooling process, metal substructure shrinks more and more and it supports porcelain with pressure generated [10].

b) Thermal Strengthen

If you cool glasses at melting temperature down slowly, tension strengths generated in glasses break free. However, if you cool it down suddenly, internal structure in soft form turn into a hardened surface layer. Tensions generated in structure are trapped in. For example: If you repel cool air on melted surface, the whole structure shrivel equivalently, thus, tensions resulting from this shriveling generates a resistance against outer forces. Thermal strengthen is based on that principle [1,13,14]

To decrease the repeat of oven drying is another option which thermally strengthens the ceramic material. Oven drying is necessary to get porcelain particles amalgamate with each other, thus form smooth surface. This practice generates leucite crystals and improves its concentrations. These crystals can cause a differentiation in perimeter of thermal dilatation and it can harm metal substructure. It can cause breaking and ruptures. Consequently, reducing oven drying process is useful to structure remain strong [10,15,16,17]

c) Strengthen By Controlled Crystallization Method

Under normal conditions, when a glass is heated up to a determined degree and then get cooled down, it does not crystallize. In this method, ceramic structure is heated up to first softening temperature. During this application, internal crystals generate and become larger. Then, via nucleation, little crystals spread equally. When the heat increases, crystallization increases. Number and dimension of crystals are depended on temperature and duration of application. It's not a preferred method due to its aesthetical disadvantages [12,18].

d) How to Decrease Tension Stress via an Optimum Restoration Design

Before designing a ceramic restoration which will cope with every negative condition, we should consider ceramic's weakness against low tensile strength, its fragility and sensitivity to microfractures. In this design, ceramic should be protected from high tension. You should avoid from restorations with sharp edges and apparent thicknesses [10,19,20]. Best way to decrease the tensile strength on bridges is to design connector zones that have intense stress with an appropriate thickness and shape [10,21]

e) Ion Exchange

In general, ceramic restorations fail because of larger and deeper microfractures caused by tensile strength. Ion exchange method is to generate at low temperature a compressive layer on ceramic's surface in order to microfractures becomes larger. This compressive layer on surface is created by exchange of some ions with bigger ions of glass matrix. Dental ceramic material is plunged into melted potassium nitrate salt tank cooler than glass transition temperature and Na+ ions found on dental ceramic's surface change place with K^+ ions of salt tank. By way of compressing on silicate system, Potassium ions which are bigger than sodium ions, generate a compression power [13,22]. On the other hand, a surface which is strengthened by use of the method of ion exchange, is not deep enough and having a 100 µm of depth erosion can make its strength' level return to original value [10,13].

f) Spread of Crystals inside the Glass Phase

Dental ceramics that contains glass phase can be strengthened by enhancing the content of crystals like leucite, lithium disilicate, alumina, magnesia-alumina, spinel, zirconia (10). When you add crystal materials in the glassy phase you get a strong glass-crystal composition, thus durability and fracture resistance increase. That way, it becomes impossible for any fracture to push on between crystal particles. Briefly, crystal particles prevent microfractures to push on forward and it provides a strong structure [10,23,24]. This kind of durability is related with the type, dimension, gaps between particles and heat expansion perimeter [23].

g) Transformation Saturation

Saturation is the amount of energy absorbed during microfracture push on [25]. Transformation saturation is a phenomenon, based on a phase transformation principal caused by tension strength. It decreases the pushing power of microfractures of any material [26]. In transformation saturation method we mostly use leucite and zirconium to strengthen the ceramic. In this method, changes of temperature in ceramic material play an important role. During thermal changes, volumes of leucite and zirconium found in glassy phase increases in glassy matrix and it creates pressure stresses inside the structure. This pressure stresses both prevent microfractures to push on and does decrease tension stresses situated at microfracture's peak [10,27].

Ceramic systems strengthened by metals are very useful in crown and bridge restorations. However, nowadays, in dental restorations, both doctors and patients have higher expectations. That's why, we go on to study for strengthened ceramic materials, and metal supported dental restorations and new alternatives [28].

In recent years, full ceramic systems have become more and more popular. Because, they generate a superior gingiva response, they have aesthetical features and they are inert, thus they transmit lesser heat and electrical energy by comparison to metal supported systems and decrease thermal sensitivities [30] and they are marginally compatible with traditional metal supported ceramic systems [31]. When using full ceramic systems, we make use of ceramic core structures obtained by strengthening labour.

3. Strengthened Ceramic Substructure Systems

This kind of ceramic is more durable than conventional ceramic. However, they lack esthetical because of their opacity. These ceramics are used for substructures and they are covered with ceramic materials to get esthetical efficiency [24].

3.1. Alluminosis Sub-Structured Ceramics

Feldspathic glass ceramic is produced by strengthening alumina particles. This ceramic is constituted of feldspathic glass that contains %40-50 alumina [32]. Hi-Ceram is a good example for this group.

3.2. Glass Infiltered Aluminosis Sub-Structured Ceramics

Substructure ceramic is prepared via slip-casting system by using the watery powder of alumina on heat proof stump. Plaster stump absorbs the water, and then we make sinterization at 1120°C degree along 10 hours to generate a porous structure. Then, we infilter lanthanum oxide glass on this porous structure and we repeat the sinterization process at 1100°C along 4-6 hours. Glassy porous fill the gaps in alumina structure and it raises flexion resistance [22,32,33]. In-Ceram is a good example for this group.

3.3. Pure Alumina Substructure Systems

CAD/CAM technology underlies this system. Models are analyzed via computer aided apparatus, and then metal stumps are prepared considering the sinterization shrinking of alumina. Then, aluminum oxide powder with a high level of purity is compressed on metal stumps. Substructures obtained get sinterized at 1550 °C along 1 hour. Then, we apply an appropriate superstructure ceramic on top of the substructure [34]. PrSocera is a good example to this group.

4. Glass Ceramics

In order to produce glass ceramics, we use controlled crystallization method. We apply heat on the glass material, thus crystals of the structure get nucleated, and they become larger and embedded in the glass matrix [35].

4.1. Feldspathic Glass Ceramics Strengthened with Leucite

This kind of ceramic is produced via controlled crystallization on glass matrix and enhancing leucite based glass ceramics. Lost candle and molding press method are used together. Glassy ceramic material tablets strengthened with leucite are baked in a special oven at 1150 C along 20 minutes. Under 0,3 - 0,4 MPa of pressure, glass material should be softened without melting away and it should be compress on to the gap obtained by lost candle method [22,36]. IPS-Empress is a good example to this group.

4.2. Glass Ceramics Containing Lithium Disilicate

In this system, glass ceramic material is strengthened via lithium discilate obtained by lost candle and hot press methods. Glassy matrix contains %65 lithium discilate in form of needles [22,37]. Empress 2 is a good example.

4.3. Fluoromica Glass Ceramics

Fluoromica Glass Ceramics are constituted of %45 glass, %55 tetracyclic mica crystals. Mica crystals provide a flexible material and easier surface penetrability. Also, they generate resistance to break accidents [38,39]. Dicor is a good example.

4.4. Apatite based Glass Ceramics

Synthetic hydroxyapatite is the best material which imitates natural dental structure. It is known as molding apatite too [36,39]. Hydroxyapatite-Cerapearl is a good example.

4.5. Substructure System Containing Zirconium Oxide

Zirconia is a material which cannot be found in nature. It contains zirconium silicate and zirconium oxide used in dentistry. Zirconium oxide ceramic is polycrystalline [22]. Zirconia is favored by dentist because of its durability, high break resistance and low flexible module. Also, its biocompatibility is very high. It's a low thermal conductor and it decreases pulp irritation [22,40]. Cerconve Zirkonzahn are good examples.

5. Conclusion

The extensive usage of porcelain material is mostly related with its positive chemical and physical features, its biocompatibility and aesthetical specialties. Because of its fragile structure it can be broke during restoration applications. This bad situation destroys completely any restoration and annoys doctors and patients. To prevent these clinical problems we must strengthen porcelain material using appropriate methods. If dental ceramics have strength structure, dental ceramics will become more indispensable material than amalgam and composite for all-round restorations. Also, use of dental ceramics increase more rapidly than previous, and both dentists and patients will become more peaceful and comfortable.

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