EC DENTAL SCIENCE
Research Article

Lithium Disilicate Crowns Compared to Zirconia Crowns for the Restoration of Teeth

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Received: March 31, 2021; **Published:** April 26, 2021

Abstract

Objectives: The aim of this thesis is to determine whether lithium disilicate glass ceramic crowns or zirconium oxide crowns are more suitable choice for the restoration of anterior and posterior teeth. To that end the survival rate and mechanical properties of the two materials will be compared, and the options for restoration will be discussed.

Materials and Methods: An online search over PubMed was done for the mechanical properties of the lithium disilicate and zirconia crowns and FPD's for anterior and posterior region. The search included studies done in English from 2010 till 2019. A total of 51 papers were selected from 2544 papers found. The studies which included restorations like fully contoured, monolithic or bi-layered lithium disilicate or zirconia crowns and zirconia framework, partial coverage crowns, veneers, inlay/on-lay restorations were also used for this study. The articles about chairside restorations were excluded.

Results: In this study, the flexural strength of lithium disilicate material has been found to be on an average as 369.75 +/- 42 MPa with the fracture toughness of 2.044 MPa x m0.5 as compared to zirconia oxide which has an average of 1004 MPa flexural strength and Fracture strength of 6.9 MPa x m0.5.

Conclusion: It was concluded that Lithium disilicate crowns being aesthetically pleasing and possessing flexural and fatigue strength of over 290 - 460 MPa therefore, can be used to restore anterior teeth. On the other hand, Zirconia crowns consist of increased strength properties, over 1000 MPa, can withstand high stresses in load bearing areas, is a good option for the fabrication of the posterior restorations.

***Keywords:** Lithium Disilicate Crowns; Zirconium Dioxide Crowns; Monolithic Restorations; Layered Restorations*

Abbreviations

Y-TZP (HTZ): Yttrium Tetragonal Zirconia Poly Crystals (High Translucency Zirconia); Y-TZP (LTZ): Yttrium Tetragonal Zirconia Poly Crystals (Low Translucency Zirconia); ZrO_2: Zirconium Dioxide; Y_2O_3: Yttrium Oxide; HFO_2: Hafnium(IV) Oxide; FDP: Fixed Dental Prosthesis; FPD: Fixed Partial Denture; LDS: Lithium Disilicate; ZTA: Glass-Infiltrated Zirconia-Toughened Alumina; Mg-PSZ: Magnesia Partially Stabilized Zirconia; ZLs: Zirconia-Containing Lithium Silicate Ceramics; CaO: Calcium Oxide; La_2O_3: Lanthanum Oxide; MgO: Magnesium Oxide; PSZ: Partially Stabilized Zirconia

Introduction

The increase of awareness in patients has increase the demand over the years for the tooth colored restorations with better physical and aesthetic properties, made with ceramic material [5]. Improved aesthetics of restorations that mimic the natural appearance of the tooth is now requested for both anterior and posterior regions by the dentist and the patient equally [25,29]. To counter this demand the ceramics were launched in the market which would fulfill the need for both the aesthetics and strength of the material [20,41]. The options for the ceramic material out in the market are Lithium disilicate glass ceramics and zirconium dioxide, they are main materials due to their high modulus and fracture resistance along with aesthetics mimicking natural teeth [20,39].

Lithium disilicate was first introduced in the market by Ivocular Vivadent as Empress 2 back in 1988 as a heat pressed, lithium disilicate all ceramic material [34,37]. It was a glass ceramic material consisting of Lithium disilicate and lithium orthophosphate [36]. Later with the refinement of the material a new ceramic material was produced which is called IPS e.max by Ivocular Vivadent [17,37]. IPS e. max was brought in the market initially as a lost wax technique and then with the arrival of the CAD/CAM system it is now available for CAD/CAM application as well [11,17,37]. The IPS e. max consists of lithium dioxide, quartz, alumina, potassium oxide, phosphor oxide and other components [6]. IPS e. max consists of a wide variety of products for various preparations and techniques required by the dentist to provide the best of restorations to the liking of the patient without compromising on the material and retention [5].

Figure 1: *Lithium disilicate crown in the final state [6].*

Zirconia (Zr) is a transitional metal with an atomic number 40 and atomic weight 91.22g mol^{-1} the melting temperature of 1855°C to and boiling temperature of 3580 - 4409°C. It was first discovered by a chemist named Martin Heinrich Klaproth in Germany in 1789 [2,23,31]. Zirconia 3 mol% Yttria-stabilized tetragonal Zirconia polycrystals has excellent strength but poor translucency due to high whitish opacity [23,41]. It has been used increasingly for coping and frameworks of the dental prosthesis for its mechanical properties and biocompatibility and decrease bacterial adhesion in the mouth during regular use as compare to other materials [7]. Since zirconia has a high flexural strength, the demand for material with combined aesthetics urged the manufacturers develop a new zirconia with increased translucency and fully stabilized cubic/tetragonal material achieved by amalgamating other stabilizing oxides. This new zirconia can be used to fabricate the restorations of the anterior or posterior regions of the mouth [38].

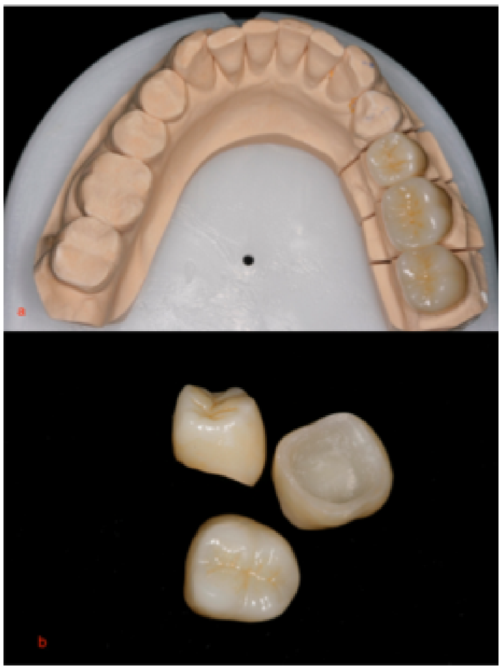

Figure 2a and 2b: *Final monolithic zirconia crowns with CAD/CAM technology [14].*

Aim of the Study

The aim of this review study is to analyze the two ceramic materials namely Lithium disilicate glass ceramics and Zirconium dioxide and compare their mechanical properties like flexural and fracture strength. This study also discusses the survival and failure rates in detail of both the material in order to distinguish the right choice of material for the anterior and posterior restorations of the teeth both in the maxillary or mandibular regions on the jaw. The type of restorations is explored and compared for both the materials along with the methods of fabrication of restoration which would give a better understanding of the materials to be used for the fabrication of aesthetically pleasing and mechanically stable restorations of teeth.

Thesis Objective

The aim of this thesis is to determine whether lithium disilicate glass ceramic crowns or zirconium oxide crowns are the more suitable choice for the restoration of anterior and posterior teeth. To that end the survival rate and mechanical properties of the two materials will be compared, and the options for restoration will be discussed.

Research questions

1 What are the mechanical properties of lithium disilicate and zirconium oxide material?

2 What is the survival rate of lithium disilicate and zirconium oxide crowns?

3 What are the reasons of failure of lithium disilicate crowns and zirconium oxide crowns?

4 What is the material of choice for the anterior and posterior teeth restoration?

Materials and Methods

An extensive online search was done over PubMed for *in vitro* and *in vivo* studies, clinical studies and reviews for the mechanical properties of the lithium disilicate and zirconia crowns and FPD's for anterior and posterior region. While selecting the papers, the focus was on flexural and fatigue strength of both restorations. The search included studies done in English for the past ten years, from period between 2010 till 2019. The studies selected were peer reviewed and full text was obtained from different journals. Vast terms were used to search for the papers and included terms like "lithium disilicate crown", zirconium oxide crowns, lithium disilicate mechanical properties, lithium disilicate crown survival rate, zirconia oxide crown Survival rate, Zirconia crowns failure, lithium disilicate crown failure complications, lithium disilicate crown fracture mode, monolithic lithium disilicate and monolithic zirconia. Around 2544 papers were found with the search terms used. A total of 51 papers were selected which discussed about the mechanical properties, failure rate, survival rate, Flexural strength and fracture resistance of both the concerned materials. The studies which included restorations like fully contoured, monolithic or bi-layered lithium disilicate or zirconia crowns and zirconia framework, partial coverage crowns, veneers, inlay/on-lay restorations were also used for this study. The articles about chairside restorations were excluded.

Search Terms	Search Results
Lithium disilicate crown	452
Zirconium oxide crowns	672
Lithium disilicate mechanical properties	163
Zirconia crowns failure	433
Lithium disilicate crown and survival rate	38
Zirconia oxide crown Survival rate	68
Lithium disilicate crown fracture mode	8
Lithium disilicate crown failure complications	16
Monolithic lithium disilicate	198
Lithium disilicate crowns and anterior failure	30
Lithium disilicate crown and anterior fracture	23
Monolithic zirconia	443

Table 1: *Overview of articles after first search.*

Result

Materials

Lithium disilicate

Due to the increase demand in the need for the all-ceramic restorations with strength, esthetics, biocompatibility and increased survival rate, a material with strong needle-like crystals meshed in a glassy matrix, called Lithium disilicate glass ceramic was developed [20,30]. The crystals are found in the interlocking manner which helps to stop the formation of cracks and chipping and enhances the overall flexural strength of the material. The lithium disilicate restorations require the surface treatment with hydrofluoric acids and silane coupling agents to bond the restoration adhesively with the abutment tooth structure [30]. It is esthetically pleasing with resemblance to enamel and can be used to fabricate the fixed restorations for the teeth in anterior region with great satisfaction to both patient and the dentist [20]. The IPS e. max (Ivoclar Vivadent, Ellwagen, Germany) is a lithium disilicate glass ceramic system consisting of wide range of material for various types of restoration [5].

Zirconium dioxide

Zirconia dental restorations are considerably very much preferred over the other dental ceramic when it comes to the mechanical properties and aesthetic especially for restorations in the posterior region [21,38].

Zirconia is biocompatible material and shows less bacterial adhesion than the titanium that's why it is particularly of advantageous in the use of fabricating fixed dental prosthesis in the high stress bearing areas and in implant supported restorations [7,27,31]. Zirconium oxide is a metastable polymorphous ceramic material which exists in 3 crystal lattices: Monoclinic, Tetragonal and Cubic [2,15,16,28,38]. The Crystalline properties of the Zirconia can be altered by including different metal oxides like calcium oxide, Yttrium or magnesium [1]. The most stable form is the Monolithic form which can be stable at room temperature but has the lower mechanical properties than the tetragonal phase which is stable at between 1170°C to 2370°C. The few types of zirconia ceramic material available in the market for dental restorations are namely: Yttrium tetragonal zirconia polycrystals (3Y-TZP), Glass-infiltrated Zirconia-toughened alumina (ZTA), Magnesia partially stabilized zirconia (Mg-PSZ), Zirconia-containing lithium silicate ceramics (ZLs) and Resin nano-ceramic materials [2,28].

The zirconia used in dentistry is mainly tetragonal zirconia polycrystal (Y-TZP). Yttria is added with zirconia to stabilize the crystal structure of zirconia during the firing procedure of the restauration which helps in increase of the mechanical and physical properties of the material. The monoclinic phase of the zirconia transforms into tetragonal phase at 1206°C [4,23]. As per Bona., *et al*. 2015 the transformation of zirconia from tetragonal back to monoclinic form on cooling is called martensitic transformation. This transformation can change the unit cell volume of monoclinic phase, 4% more than the tetragonal phase, due to which the ceramic can encounter the cracks if the stabilizing oxides are not added in the zirconia. Hence, the mechanical properties of the ceramic can be altered by amalgamating the pure zirconia with lower valance oxides like Y_2O_3, CaO, La_2O_3 and MgO. By the addition of such oxides the Zirconia is stabilized at the room temperature [23]. The tetragonal phase can also be stabilized by decreasing the crystal grain size (average grain size is < 0.3 μm) which eventually creates a difference in surface energy and stabilizes the tetragonal phase. This material form is usually used in dentistry and called metastable tetragonal partially stabilized zirconia (PSZ) [4,28].

Restoration types

Structure of the restoration

Both Zirconia and lithium disilicate restorations are available as monolithic or layered restorations.

Monolithic restorations

Monolithic restorations are the type of restorations which are prepared with only one material without any layering with another material. It has no framework and is full anatomically contoured restoration for the replacement of the missing tooth structure. The glass ceramic monolithic restorations are further stained, glazed and fired in order to give it a natural appearance [26]. They have high flexural strength, increase fatigue strength and do not suffer with chipping of the veneered porcelain because of all-ceramic component. This type of restoration is recommended for restoration of posterior teeth with less space between the opposite dentition. Zirconia monolithic restorations are used in the load bearing areas while the monolithic lithium disilicate glass ceramic is proposed to be used in the anterior region [9]. Monolithic Lithium disilicate glass ceramic restorations have high translucency and aesthetic properties, due to the increased amount of glass content which makes it an ideal technique to fabricate crowns and bridges for the anterior segment [9]. This procedure is more cost effective and less time consuming as it does not involve the multiple layer build up and firing cycles for the restoration [12]. Zirconia is a whitish opaque in color and less translucent as monolithic restorations [13,23]. It has high strength and can bear the stress caused by the bruxism especially in the posterior region [12,13] but that is not the case with lithium disilicate material as its strength is comparatively lesser than zirconia [12].

Layered restoration

The second type of restoration is a layered restoration type which is prepared with a pressed or milled lithium disilicate core and veneering porcelain. This type of restoration has better aesthetics than the monolithic restoration since monolithic restorations has increased surface reflexivity and no internal coloration [33]. In this bilayer technique, the material is more susceptible to chipping in the core-veneer interface or can fracture due to a week core-veneer bonding. This technique has lower fracture resistance than monolithic restorations. This is one of the reasons monolithic restorations are much preferred over the bi-layered restoration [9,20].

Production methods for restorations

Press technique

Press technique is a procedure which uses lost wax technique or heat pressed technique where pre-fabricated ingots are simultaneously heated and pressed on to a previously formed mold to fabricate the dental restorations like single crowns and bridges [24].

Restorations fabricated with press lithium disilicate material are prepared in a lost-wax technique. The press ingots can either be used for framework or the full anatomical restorations with increased precision of fit. The 2 materials of choice are lithium disilicate glass-ceramic IPS e.max Press and IPS e. max ZirPress, which is a fluorapatite glass ceramic ingot for press-on technique on zirconium oxide frameworks [6].

Zirconia based restorations are available with zirconia coping veneered with porcelain that can be fabricated by either the layering technique or by hot pressing technique [4]. The types of Zirconia material available these days in the market are; 3% Y-TZP (LAVA All-Ceramic System - 3M ESPE, Seefeld, Germany), Glass- infiltrated zirconia- toughened alumina (In ceram Zirconia- VidentTM, Brea CA), Magnesia partially stabilized zirconia (Denzir-M- Dentronic AB), Zirconia-containing lithium disilicate (Cerec, Sirona, Bensheim, Germany; Artica, Kavo, Leutkirchen, Germany; Ceramill, Amann Girbach, Pforzheim, Germany) and for Resin nano-Ceramic material (Lava Ultimate CAD/CAM [2].

Layering technique

The layered technique is called a Lithography-based ceramic manufacturing technique in which the ceramic restoration is fabricated in layers using the CAD data. It is an additive technique where photosensitive resin coated ceramic particles are homogenously fused together and activated under the LED device layer by layer [35]. Another layering technique is the conventional method where the technician prepares the restoration by applying the veneering layers over the ceramic framework by applying the ceramic powder liquid mixture using a brush [32].

Lithium disilicate being a glass ceramic material has higher content of crystalline and therefore has higher mechanical properties than the feldspathic veneering ceramic and hence is used to prepare the veneering layer over the framework in layering technique [32].

Due to the inadequate translucency and poor exhibition of natural characteristics of the tooth by the metallic infrastructure, the zirconia veneered over the feldspathic porcelain, make the restoration sufficiently pleasing to the eye [40]. Since the invent of the Y-TZP material, the bi-layered restorations are fabricated using the Y-TZP infrastructure under the veneering layer by either of the conventional or new CAD-On layering techniques [32,35].

CAD/CAM

The monolithic restoration can be milled by CAD/CAM technique using blanks. This procedure is more cost effective and less time consuming as this procedure does not involve the multiple layer build up and firing cycles for the restoration [12].

For lithium metasilicate used in CAD/CAM technique, the material is available in a blue partially crystallized glass blocks form. It is then sent through the second heat treatment, where the initial phase dissolves and transforms in to lithium disilicate crystals and takes up its final color of the restoration [6].

The Y-TZP zirconia is usually used in dentistry as a framework, generally fabricated with CAD/CAM technology using either the soft matching or hard machining system. The restorations can be produced using either the milling of the fully sintered blanks with hard machining system, which causes no shrinkage in the restoration and the other is the soft machining system for a pre-sintered blanks which causes a shrinkage but can be fixed in the one of a designing stage of the CAD/CAM [4,19].

Mechanical properties

Lithium disilicate

The physical properties of lithium disilicate glass ceramic are better than those of the feldspathic porcelains. The flexural strength of Lithium disilicate is 365 MPa [3]. According to Rauch., *et al*. 2016 [25] the mechanical strength of lithium disilicate is up to 360 +/- 60 MPa and a fracture resistance between 2.0 and 2.5 MPa x $m^{0.5}$. The difference in composition of the material can cause the material to exhibit diverse characteristics as per the composition of the ceramic material like fracture toughness, hardness, fracture resistance, brittleness, flexural strength. The ceramic material has a high brittleness as compare to the other materials [37]. As per Willard., et al. in 2018 [37] the flexural strength and fracture toughness of the IPS e max CAD gets altered after the firing procedure. The partially crystallized material displays moderate flexural strength of 130 MPa and fracture toughness of 0.9 - 1.25 MPa x $m^{0.5}$ and the fully crystalized material exhibits the flexural strength of 262 - 360 MPa and a fracture toughness of 2.0 - 2.5 MPa. According to another study by Zadeh., et al. 2018 [38] the flexural strength and fracture toughness of Lithium disilicate is lesser as compare to the zirconia material. Zadeh., *et al*. 2018 [38] noted that the fracture toughness of lithium disilicate material is around 2.10 MPa.$m^{0.5}$ and the flexural strength showed mean value of 290 MPa with the help of Weibull modulus. Such low levels of strength can result in the failure of the restoration under stress in the mouth. Nishioka., *et al*. 2018 [20] took a staircase tests (1.2 +/- 7.5 MPa and flexural strength 295.2 MPa). In another study, the author evaluated 120 monolithic crowns of varying thickness and submitted them under the stress to measure the flexural strength and fracture toughness of lithium disilicate (LDS). All specimens were loaded in a static loading device and applied the load with a 2.5 mm stainless steel ball on the occlusal surface of the restorations mounted at a 10o and provided with the load to fracture. The fracture strength of 2.0 - 2.5 MPa x $m^{0.5}$ and a flexural strength of 360 +/- 60 MPa were recorded for LDS crowns.

Author	Flexural Strength MPa	Fracture strength MPa x $m^{0.5}$
Baladhadayutham 2015	365	1.4 - 2.02
Willard., *et al*. in 2018	262 - 360	2.0 - 2.5
Zadeh., *et al*. 2018	290	2.10
Zhao., *et al*. 2017	376	N/G
Nishioka., *et al*. 2018	295.2	N/G
Kwon., *et al*. 2018	450 +/- 53	N/G
Zhang., *et al*. 2019	462 +/- 15	1.1
Nordahl 2015	360 +/- 60	2.0 - 2.5

Table 2: *Studies showing the flexural and fracture strength of lithium disilicate glass ceramic material.*
**: N/G: Value not given in the paper by the author.*

Zirconia

The Y-TZP ceramic is the most commonly used in the preparation of the dental restoration due to its higher flexural strength, aesthetics and biocompatibility [2,18]. In order to provide the dental restoration with higher mechanical properties, the Zirconia material is modified with the 3 mol% yttria (Y_2O_3) to control and sustain the tetragonal phase at room temperature, this also helps to prevent formation of cracks during transformation phase [15,40]. Chemically Y-TZP consists of ZrO_2, Y_2O_3, Y_2O_2, HFO_2, Aluminum oxide and other oxide [1]. The 3Y-TZP has flexural strength of up to 900 - 1200 MPa and a fracture strength of around 9 - 10 MPa x $m^{0.5}$ [2,19,40]. According to Zadeh., *et al*. 2018 a new zirconia material with cubic-tetragonal phase was introduced which has high translucency and high mechanical properties. This state is achieved by altering the composition and adding more stabilized oxides. The same study also reported the flexural strength values between 490 MPa to 557 MPa and fracture strength values 3.34 to 3.77 MPa x $m^{0.5}$ for cubic/tetragonal phase zirconia materials. Nishioka., *et al*. 2018 took a staircase tests (100,000 cycles Hz) approach in determining the fatigue strength and found the mean values for Y-TZP to be 370.2 +/- 38.7 MPa and flexural strength 635.0 MPa. According to Kwon., *et al*. 2018 the flexural strength of 3Y-TZP is 1194 +/- 111 MPa. Kwon., *et al*. 2018 performed the test by placing the specimens in the Universal testing machine and loading the specimens to failure for 1 mm/min. Miyazaki., *et al*. 2013 in his research explained that the Y-TZP has higher mechanical properties than other polycrystalline ceramics with fracture toughness from 5 - 10 MPa x $m^{1/2}$ and flexural strength of 900 to 1400 MPa. The fracture toughness of Y-TZP increase when the tetragonal crystal changes back to monoclinic crystal along with the change in volume up to 3 - 4% due to the stress concentration over the crack, at the time of crack initiation on the surface of Y-TZP, this transformation causes the stress induced to shield the crack tip from the applied forces [23]. Nordahl., *et al*. 2015 in his study evaluated 120 monolithic crowns of varying thickness and submitted them under the stress to measure the flexural strength and fracture toughness of Y-TZP High translucent zirconia (HTZ) and Y-TZP low translucent zirconia (LTZ) along with lithium disilicate. All specimens were loaded in a static loading device and applied the load with a 2.5 mm stainless steel ball on the occlusal surface of the restorations mounted at a 10° and provided with the load to fracture. The fracture strength of 5 - 10 MPa x $m^{0.5}$ and a flexural strength of > 1100 MPa was recorded for both Y-TZP (HTZ) and Y-TZP (LTZ).

Author	Flexural Strength MPa	Fracture strength MPa x $m^{0.5}$
Add El Ghany, 2016	900 - 1200	9 - 10
Miyazaki., *et al*. 2013	900 - 1400	5 - 10
Zadeh., *et al*. 2018	490 - 557	3.34 - 3.77
Nishioka., *et al*. 2018	635.0	N/G
Baladhadayutham 2015	1039	2.9 - 3.2
Kwon., *et al*. 2018	1194 +/- 111	N/G
Zhang., *et al*. 2019	908 +/- 44	5 +/- 0.3
Nordahl 2015	> 1100	5 - 10

Table 3: *Studies showing the flexural and fracture strength of zirconium dioxide material.*
**: N/G: Value not given in the paper by the author.*

According to the manufacturer the flexural strength of Zirconia-Containing Lithium Silicate ceramics reaches up to 370 to 420 MPa which is comparable to the lithium disilicate material and has mechanical properties 3 times that of Leucite-reinforced glass ceramics [27]. Nishioka., *et al*. 2018 took a staircase tests and found the flexural strength of 240.0 MPa and fatigue strength of 152.1 +/- 7.5 MPa for ZLS material. The restoration fabricated with this type of material has increased mechanical properties and is very cost effective in case of building up full contoured zirconia restorations [31]. This ceramic offers a great strength and optical properties therefore; it can be used for the fabrication of monolithic restorations [2]. This new material consists of 10 wt% zirconium oxide added to lithium silicate glass. A mixture of material containing a dual microstructure with very fine lithium metasilicate (Li_2SiO_3) and Lithium disilicate ($Li_2Si_2O_5$) crystals within a glassy matrix containing zirconium oxide is obtained in a solution [2,27].

Survival rate

Lithium disilicate crowns

For this review, three studies were analyzed for the evaluation of survival rate of lithium disilicate glass ceramic fabricated restorations. The analyzed studies were done with large number of restorations over the period of 2 - 5 years. The restorations were fabricated with IPS e. max material and were mostly done with single monolithic or bi-layered crowns, veneers, in-lay/on-lay and fixed partial dentures (FPD's) for both the anterior and posterior regions of maxilla and mandible. The average survival rates calculated is 97.81%, with highest survival rate for lithium disilicate restoration being 100% over the period of 2 years of follow ups and evaluation and the lowest being the 92.63% for 5 years. According to one of the studies done for the survival rate of the restorations fabricated with lithium disilicate glass ceramic material, the IPS e. max press, IPS e. max CAD/CAM and IPS e. max Ceram, the author evaluated total 811 restorations: single crowns (768) and FDP's (43) over the period of 5 years. The basis of the study was to evaluate the restoration made with lithium disilicate material under the normal daily life routine. The Kaplan-Meier analysis applied to find the survival rate for the crowns and FDP's was 94.69% and 90.58% respectively for lithium disilicate fabricated restorations [5]. Saleh., *et al*. 2016, studied the cases of 88 IPS e. max crowns placed in 47 patients, ranging from 18 to 64 years with 31 female patients (66%) and 16 male patients (34%). The 47 patients were given a total of 79 anterior teeth restorations and 9 posterior teeth restorations. The author applied the Kaplan-Meier statistical method to analyze the survival rate of the restorations over the period of 3 years. The observed survival rate of the 88 crowns was found to be 100% for 24 months and 97.7% for 35.9 months with minor chippings considered to be failures. Another clinical study done by Sulaiman., *et al*. 2015, explain the survival rate of the IPS e. max system of monolithic and layered restorations. The study conducted with 21340 restorations which included 15802 monolithic and 5538 layered restorations and follow up done over the period of 4 years showed the very high survival rate of 99.09% for monolithic single crowns and 98.17% layered single crowns and the combined survival rate of the restoration was 98.85%.The study clearly shows superiority of monolithic restorations over layered restorations for the fabrication of the restoration, either in anterior or posterior regions, along with the fracture resistance of the material.

Zirconium oxide crowns

According to Miyazaki., *et al*. 2013 the success rate of all ceramic restorations is in the range of 88% - 100% with 2 - 5 years and up to 97% after 5 - 15 years. In this review we have examined 4 case studies and found that the success and survival rate of zirconia is much higher than any other material available in the market. The restorations placed are single crowns and FDP's both in the anterior and posterior region of Maxilla and mandible. It was found that success rate of zirconia restorations is 96.1% on average for 5 year period. The highest success rate was calculated to be 100% over the period of 5 years and the lowest success rate came to be 62.1% for the time frame of 10 years. The survival rate evaluated for zirconia restoration is an average of 99.6% for 5 years. The highest survival being the 100% for 1 year to the lowest being 67.2% for the period of 10 years.

In one of the studies conducted by Konstantinidis., *et al*. 2018, the author did a test by providing 65 patients with the 65 posterior monolithic Zirconia crowns, with 29 (44.6%) maxillary restorations and 36 (55.4%) mandibular restorations were placed. He kept the patients on a 6 - 12 month after cementation follow ups. The UPSHS criteria and periodontal parameters were applied for the study and found the success rate to be 98.5% with no fractures, no loss of retention or tooth loss but only a minor marginal discoloration of only one of the restorations. This study concluded that the Monolithic Zirconia restorations are the best option for the posterior stress bearing restorations. Pihlaja., *et al*. 2016 in a study done over the period of 3 - 7 years concluded that the success rate of zirconia based partial FDP's after 4.9 years was 89% and survival rate was 100%. The total of 76 patients was given 88 zirconia FDP's in the anterior and posterior region. The restoration was deemed success as neither re-cementation of any of the 88 restorations was not needed nor any secondary caries was found. In line of one of the recent studies done, the author measured the survival and success rate of the 20 anterior zirconia crown of the maxillary teeth in 18 patients, on the basis of thickness of the framework, with 0.3 mm customized cervical third copings over a period of 5 years. The author in his study reported no fracture or loss of retention of the coping. The survival rate of 100% without any chipping was reported after 5 years of use [7]. In another retrospective Cohort study done by Miura., *et al*. 2017, the author performed a clinical evaluation of the 137 Y-TZP all ceramic crowns with a mean follow up of 7 years and using a Kaplan-Meier analysis, the survival and success rate were measured. The estimate success and survival rate over the 5 year period was found to be 96.9% and survival rate was 98.5%. The rate further decreased with the increase in years and was estimated to be 62.1% and 67.2% respectively for the period of 10 years.

Reasons for failure

Lithium disilicate crowns

The failure rate of Lithium disilicate is very less as compared to the other materials used for the restoration of teeth, be it in an anterior or posterior regions. For evaluating the failure rate of the restorations fabricated with lithium disilicate glass ceramic material, three studies are used here which explains the pattern of failure of the restorations. The major reason of failure is found to be chipping and fracture of the restoration which does not need replacement. The average failure rate calculated from the three studies evaluated is 2.45%. The highest failure rate recorded is 3.5% over the period of 10 years specifically for lithium disilicate restorations and 1.15% for the 45 months.

In one of his clinical studies, Saleh., *et al*. 2016, brought forward the clinical failures of the lithium disilicate, which involved the restoration of 88 crowns for 47 patients. The study showed lithium disilicate had only 3 crowns with fractures, one crown with minor chipping and 2 crowns with the major chipping. The failure rate was only 2.7% over the period of 3 years. Another clinical study done by Sulaiman., *et al*. 2015, explain the failure rate of the IPS e. max system of monolithic and layered restorations. The study was done with 21340 restorations which included 15802 monolithic and 5538 layered restorations. The combined failure rate of the two types of single crown restorations was 1.15% over the period of 4 years. As per the author, the cause of failure could be anything from the tooth preparation, type of material used and fabrication process of the restoration [33]. Malament., *et al*. 2019, in his study, he explained the difference in monolithic and bi-layered restorations by doing a clinical study in which he examined five hundred and fifty six patients with 1960 complete coverage lithium disilicate restorations, patients were given single crowns, 3 unit fixed partial dentures or cantilever anterior restorations. Study showed only 7 monolithic restoration failures over the period of 10 years which makes only 3.5% failure rates and a 0% failure of bi-layered restorations.

When preparing the teeth for restoration, certain parameters have to be kept in mind, in order to achieve the harmony and balance between the restoration and soft tissues. The accumulation of the plaque is one of the few challenges while providing the restoration. As per Saleh., *et al*. 2016, the crowns should be placed at least 0.5 mm subgingivally to maintain the biological width and to attain the desirable aesthetics and periodontal outcomes. A patient should always be given proper oral hygiene instructions and emphasize on maintaining the oral conditions. Otherwise, it would be appropriate to keep the crown margin levels above or at the gingival margins to avoid the restoration failures. The reason of failure was proved to be only the chipping and fractures in the restorations which could not be repaired and had to be replaced. The fracture trend usually differs from pressed to milled crowns restorations, but is definitely found in both types of processes. Due to the difference in the microstructure of the two types of restorations, the major fractures with the point of no repair are mostly encountered with the milled crown restorations [8].

Zirconium oxide crowns

Some of the studies observed for this review showed the failure rate of the Zirconia restorations to be the lowest. It was observed from the evaluated studies that zirconia crowns usually shows complications related to chipping of the veneers with no tooth loss or loss of retention of the restoration. Other problems reported by the authors are marginal discoloration, root fracture and abutment fractures, but the number of occurrence is rare. The failure rate found, as per the four studies evaluated for this review, is starting from 1.5% over the period of one year to the highest being 32.8% for 10 years with chipping being the major complication found in both anterior and posterior restorations.

As per Pihlaja., *et al*. 2016 and Miura., *et al*. 2017, the main reason for the failure of the zirconia restoration is the chipping of the veneering layer; significantly in the long span FDP's with 5 or more units. But the chipping usually is not much evident and can be over looked or found only on oral clinical examination. The chipping usually occurs on the occlusal surface because of wear of the surface due to constant pressure of stress bearing areas. Other authors also mentioned secondary caries, loss of abutment tooth vitality, root fracture, framework fracture, marginal discoloration and loss of retention as one of the reasons for the failure of zirconia restorations [7,22]. Other studies have reported chipping problems at the core-veneer surface as the reason for failure of zirconia material as well. There are various reasons that causes chipping like; insufficient bond strength of core-veneer, thickness of core-veneer, inadequate core material design or effects due to firing shrinkage [1].

Pihlaja., *et al*. 2016, in his study observed 88 zirconia FDP's given to 76 patients, over the period of 4.9 years. The author observed that only 13 units out of 387 units given to 11 patients suffered only chipping of veneering porcelain of FDP's. Out of these 13 units, 8 were placed in the anterior region and 5 were placed in posterior region. The chipping was very minor and did not require replacement of the restoration and hence was deemed not a failure of the restoration since there was no loss of function of restorations. In one of the studies conducted by Konstantinidis., *et al*. 2018, the author did a test by providing 65 patients with the 65 posterior monolithic Zirconia crowns, with 29 (44.6%) maxillary restorations and 36 (55.4%) mandibular restorations were placed. Patients were kept on a 6 - 12 month follow ups and found the success rate to be 98.5% with no fractures, no loss of retention or tooth loss but only a minor marginal discoloration of only one of the restorations and therefore, the failure rate is considered to be 0%. Dogan., *et al*. 2017, in his study proved the failure rate to be 0% by evaluating 20 anterior maxillary zirconia crowns in 18 patients, on the basis of thickness of the framework, with 0.3 mm customized cervical third copings over the period of 5 years. The author in his study reported no fracture or loss of retention of the coping and no chipping after 5 years of use. In another retrospective Cohort study done by Miura., *et al*. 2017, the author performed a clinical evaluation of the 137 Y-TZP all ceramic crowns with a mean follow up of 7 years and using a Kaplan-Meier analysis, the survival of the restorations were measured. The estimate failure rate over the 5 year period was found to be was 1.5%. The rate further decreased with the increase in years and was estimated to be 32.8% over the period of 10 years. A total of 21 crowns showed at least one complication with fracture of veneering ceramic being the most common complications. 16 crowns had major (5 crowns) or minor (11 crowns) chipping problems in which 10 crowns placed were in premolar region. 3 crowns showed root fractures, 1 crown had abutment fracture and 1 crown showed dislodgment.

Discussion

The aim of this thesis was to determine whether lithium disilicate glass ceramic crowns or zirconium oxide crowns are the more suitable choice for the restoration of anterior and posterior teeth. To that end the survival rate and mechanical properties of the two materials were compared.

Lithium disilicate glass ceramic is very frequently used in dentistry since its advent due to its immense aesthetic and mechanical properties. It has 3 times the strength of the porcelain and half the strength of the zirconia material [12]. In this study, the flexural strength of lithium disilicate material has been found to be on the average as 369.75 +/- 42 MPa with the fracture toughness of 2.044 MPa x $m^{0.5}$ as compared to zirconia which has an average 1004 MPa flexural strength and Fracture strength of 6.9 MPa x $m^{0.5}$. Lithium disilicate glass ceramics have lesser strength and toughness as compared to zirconia material due to which restorations fabricated with LDS cannot sustain the stresses of the load bearing areas in the mouth, this notion was also supported by Zadeh., *et al*. 2018 in his study.

Here in this study, it was found that the lithium disilicate material has a very high survival rate with an average of 97.81% for the period of 2 - 5 years. The restorations ranged from single monolithic and bi-layered crowns to FPD, placed both in mandibular and maxillary regions. The zirconia material on the other hand showed fabulous results with the average success rate of 96.1% and survival rate of 99.6% over the period of 5 years. It is very much evident from the rate of survival of both the materials under the constant natural stresses in the mouth that the zirconia restorations have higher strength than the lithium disilicate material and survive better in the stress bearing areas with minimum failure. The zirconium oxide has an increased mechanical strength, corrosion resistance, fracture toughness and high biocompatibility, therefore, the Y-TZP system is used as an all ceramic system for various restorations types; from Single crowns to bridges and fixed partial dentures. Such restoration due to its tremendous aesthetic and mechanical properties can be placed in both the anterior and posterior regions [19].

The failure rate for the lithium disilicate material in this study shows very low values of only 2.45% over the period of 10 years that also without any major complications. The restorations were placed in the anterior region of the mouth as monolithic or bi-layered single crowns and FPD's. The three studies evaluated, only shows the restorations faced minor or major chipping problems throughout the time of use without any replacement of the restorations due to the fracture. In cases such as bruxism, monolithic lithium disilicate glass ceramic material is advised to not to be used as it cannot withstand the stress caused by bruxism [12]. Zirconia restorations when compared to lithium disilicate glass ceramics have lower failure rate over the period of 5 years. It was noted that with the passage of time, there is increase in the failure of restorations. The restorations tend to go through complications like chipping but with no fracture of the crowns. The studies showed that the chipping usually occurred in the occlusal surface of the posterior veneering porcelain. Other reasons of failure were found to be root fracture, abutment fracture and dislodgment of the crown.

The criterion to select the best material to be used for the restoration is guided by the mechanical and optical properties, commonly flexural strength and translucency of the material [40]. Other important factors to keep in mind are biocompatibility, occlusion, tactile perceptions, fabrication process, affordability of patient and survival rate [17]. Lithium disilicate glass ceramic restorations are more aesthetic as compare to zirconia restorations and hence can be used in the anterior regions of the jaw but due to its lower flexural strength, compare to zirconia, it cannot withstand the load and is contraindicated for use in the posterior region of the jaw [10,38]. Zirconia (3Y-TZP) consisting of high strength properties, with 1000 MPa, can endure the stress applied in the load bearing areas, the posterior region in the occlusion from premolar to the molar region. It has been found that the ideal minimum core thickness for zirconia based crown for anterior restorations shall be 0.3 mm thick coping in the cervical region and for the posterior restorations shall be 0.5 mm [7]. Since the Zirconia has a lower translucency esthetically and cannot depict the natural characteristics of the tooth better than the lithium disilicate glass ceramics therefore, Zirconia is preferred to be placed in the posterior region which is also confirmed by Zhang., *et al*. in his study of 2019. Due to its high fracture resistance, monolithic Y-TZP prosthesis is advised to be used for restoration purposes, neglecting the poor aesthetics of the material [12].

This study was done on a short basis with a large database of samples analyzed from the clinical cases of different authors. This data clearly shows the types and material of restorations used with their clinical survival and failure rates when used under the normal daily life practical use. This study has its own limitations and the clinical use of the materials cannot be relied solely on this review as it only contains the data from the authors who performed the clinical study according to their perspective of the usage of materials. This is a vast and continuously changing field of dentistry which requires in depth and meticulous research with a larger number of samples with various aspects of clinical use.

Conclusion

Within the limitations of this study it can be concluded that Lithium disilicate crowns are aesthetically pleasing to the eye and can mimic the natural appearance of the tooth along with possessing high flexural and fatigue strength of over 290 - 460 MPa therefore, can be used to restore anterior teeth.

On the other hand, Zirconia crowns consist of increased strength properties, over 1000 MPa, can withstand high stresses in load bearing areas, is a good option for the fabrication of the posterior restorations.

Declaration of Academic Integrity

I declare that I independently completed this thesis and this thesis was not previously submitted to another academic institution. I also confirm that no other sources have been used than those indicated in this thesis and the thoughts taken directly or indirectly from external sources are properly marked as such.

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