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LITHIUM DISILICATE IN FIXED PROSTHESIS

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ABSTRACT

The introduction of new techniques combining digital workflow with dentistry has led to the development of new materials and new ways of producing and processing them. This is the case with lithium disilicate, a relatively new material in the history of dental prosthetics which for a long time was produced using the pressing technique and which today is gaining in popularity using the milling technique.

The aim of this study was to compare Pressed Lithium Disilicate and Milled Lithium Disilicate being monolithic or veneered among two parts.: flexural strength and marginal fit.

The method proposes a global transversal review of the different studies that have analyzed the different materials, comparing them among themselves when possible, by means of scientific literature analysis.

Many results are available today, often contradictory, not allowing to establish one technique superior to another but Regardless of this, the average variance between the Emax CAD or Emax press restorations assessed in this critical review was within the clinically acceptable range.

This investigation revealed similar mechanical properties between E.max CAD and E.max Press being both totally clinically acceptable. If one should choose between one and the other, one should base his choice on other aspects. A highlight that showed up of this investigation is more than the material itself, it is the workflow and the importance of the human influence during the process that matters. Regarding human influence, the more steps, the higher the

risk of variability in the result increase. Regarding workflow, the CAD CAM experience offer a simpler working procedure.

In the years to come, intraoral scanner will become more and more effective and widespread as they become more affordable. One can imagine that the CAD CAM procedure will overcome the use of Press system.

RESUMEN

La introducción de nuevas técnicas que combinan el flujo de trabajo digital con la odontología ha llevado al desarrollo de nuevos materiales y nuevas formas de producirlos y procesarlos. Este es el caso del disilicato de litio, un material relativamente nuevo en la historia de la prótesis dental que durante mucho tiempo se produjo mediante la técnica de prensado y que hoy en día está ganando en popularidad mediante la técnica de fresado.

El objetivo de este estudio fue de comparar el disilicato de litio prensado y el disilicato de litio fresado siendo monolítico o chapado entre dos partes: resistencia a la flexión y ajuste marginal.

El objetivo de este trabajo es proponer una revisión transversal global de los diferentes estudios que han analizado los diferentes materiales, comparándolos entre sí cuando sea posible, mediante el análisis de la literatura científica.

En la actualidad se dispone de muchos resultados, a menudo contradictorios, que no permiten establecer una técnica superior a otra, pero Independientemente de ello, la varianza media entre las restauraciones Emax CAD o Emax press evaluadas en esta revisión crítica se encontraba dentro del rango clínicamente aceptable.

Esta investigación reveló propiedades mecánicas similares entre E.max CAD y E.max Press siendo ambas totalmente aceptables desde el punto de vista clínico. Si hay que elegir entre uno y otro, hay que basar la elección en otros aspectos.

En los próximos años, los escáneres intraorales serán cada vez más eficaces y estarán más extendidos a medida que sean más asequibles. Cabe imaginar que el procedimiento CAD CAM superará el uso del sistema Press.

Table of Materials

1. INTRODUCTION

1.1. A bit of history

If dentistry is often associated with the use of the latest technologies in order to always have the optimum treatment. It is interesting to realize that some of these technologies have their roots in what is the most artisanal (1).

This is the case with ceramics; originally from the **Greek**, the term "***keramos***" means pot or pottery (1). If the use of ceramics in dentistry happens to be relatively new, the desire for a durable and beautiful material is much less so. Indeed, most cultures over the centuries have associated the integrity of the face and therefore also of the smile with health, youth, power and strength. Thus the loss of teeth especially anterior was already requiring at that time an aesthetic solution(2).

Figure 1 - First evidence of 4,000-year-old dental work found in Egyptian mummy

https://dental-polishers.com/dentistry-in-ancient-egypt/

Although traces of dental practice were already found in ancient **Egypt**, particularly in **Etruria**, most of these treatments were dentures from human or animal teeth(1). It was not until the **18th** century that the use of porcelain developed in dentistry. Democratized in Europe in the **1700s** by massive imports from China and Japan, Chinese imported porcelain represented a huge market, so much that China was dubbed *the "bleeding bowl of* Europe"(3).

As a result, many unsuccessful investments for almost 200 years were made by notably the **King of Poland** and the **Medici's family** in order to achieve the discovery of porcelain manufacturing. This period allowed an important development of alchemy, the roots of modern analytical chemistry that we know today. (3)

One of the major steps towards the discovery of porcelain was made by the **Conte Walther Von Tschirnhaus**, he discovered that lime and sand could merge when combined and presented at extreme temperatures, especially thanks to an ingenious process of focal lenses of more than 1 meter in diameter with which it reached temperatures above 1436 degrees Celsius. The material obtained at that time was close to porcelain. It was **Bottger**'s replacement of lime by feldspar in the 1710s that introduced feldsparic porcelain, which would be the major ingredient in dentistry cosmetic porcelain (2).

Figure 2 - Double lens burning apparatus of Walther Won Tschirnhaus https://commons.wikimedia.org/

But it was in **1774** that porcelain was first used in dentistry. **Alexis Duchateau**, a French apothecary, complaining about his stained ivory dentures and noticing that his enameled ceramic tools remained resistant and clean, had the idea of making a ceramic denture. With the help of a Parisian dentist called **Nicholas Dubois de Chémant** they managed to overcome the material firing contracting problem and made at the **Guehard's Porcelain Factory** the first porcelain prosthesis(4).

De Chémant continued to work on the formulation by increasing the share of feldspar thus increasing transparency to obtain today's feldspathic porcelain(3).

In 1808 an Italian dentist named **Giuseppangelo Fonzi** invented the first hybrid prosthesis "terrometallic" by successfully firing porcelain teeth on platinum pine to create teeth fixed on metals for the first time. This was possible due to the similar rate of thermal contraction between the two materials. This advance allowed more versatility in treatments as well as better aesthetics and better repairability (3).

Figure 3 - Group of prosthetic terrometallic teeth with platinum pin. Teeth were made by Giuseppangelo Fonzi, Italy, ca. 1808, and are from the collection of Vincenzo Guerini, Naples, Italy. https://temple.pastperfectonline.com/

This constant demand for aesthetics and resistance increasing over time, dental ceramics experienced many modifications from the **1950s** until today. Whether it was the addition of aluminum oxide by **McLean** to increase its resistance but which also increased its chipping (1) or in **1962** the discovery of a singularity in the expansion of a certain type of feldspar which through a process of fusion, crystallization and re-melting gave a new crystalline component not present at the origin, **Leucite**. It was later used to increase the dispersal of forces at the rate of 30 to 50% in ceramic powders and then in the first pressed ceramics (3).

All these modifications starting in 1710 with Bottger led to what we know today in ceramics: a vast field where there are a multitude of different dental ceramics each having its own specificities and indications (3).

1.2. Classification of dental ceramics.

Even though classifications are totally artificial, they remain valuable tools because they allow us to better organize our knowledge on a certain subject. However, there is not a single universal classification of dental ceramics, these classifications have evolved over time, becoming more and more complex with the arrival of new materials and while one can find in scientific journals and articles, both classification and author, it becomes difficult to make a classification as exhaustive as precise (5).

In this work, all ceramic systems will be group according to two criteria: chemical composition and manufacturing technique based on the most recent items.

1.2.1. Classification by chemical composition.

When looking at the classifications by composition, we find quite regularly the classification of **Kelly and Benetti** which describes ceramic materials according to their glass composition. It presents itself as follows, a predominance in glassy materials, particles filled glasses, polycrystalline ceramics(3). If this classification presents an obvious problem since it does not explicitly clarify how much glassy material it takes to be included or excluded from the category of predominantly glassy materials, it poses a deeper problem. Indeed Kelly and Benetti postulated and it has been postulate in other articles(5), that a direct correlation exists between the quantity of glassy materials and the aesthetic result as well as the physical characteristics of the restoration(3). In this case, the more glass materials were found in the restoration, the better the aesthetic result and, conversely, the resistance. Thus, polycrystalline ceramics such as zircone had to reside in a framework indication and could not be indicated for aesthetic cases. However, if this observation was true in the early days of zircone, it is now more complex. With the development of polycrystalline materials we are now able to obtain more translucent zircones allowing their use not only as a substructure but also for total reconstructions (6).

In the same way the particles filled glasses materials are becoming more and more popular. Therefore, a classification that tends to predict the indication of a specific material is confusing since over the years the materials gain in development quality and this will necessarily influence their indications (6).

Finally, the classification of Kelly and Benetti does not take into account the new arrival of highly filled with ceramics resin matrix materials that have just been added in the ceramics category by **the American American Association (ADA)**(6)**.**

According to the work of **Stefano Gracis,** the result is a more comprehensive and less exclusive classification that presents itself as:

1. **Glass-matrix ceramics:** non-metallic inorganic ceramic materials that contain a glass phase, in this family we can divide three groups: synthetic ceramics, felspathic ceramic and glass infiltrated ceramics.
2. **Polycrystalline ceramics:** non-metallic inorganic ceramic materials that do not contain any glass phase, then divided into four groups; alumina, stabilized zirconia, zirconia reinforced with alumina and alumina strengthen to zirconia.
3. **Resin-matrix ceramics:** polymer-matrices containing predominantly inorganic refractory compounds that may include porcelains, glasses, ceramics, and glass-ceramics(6).

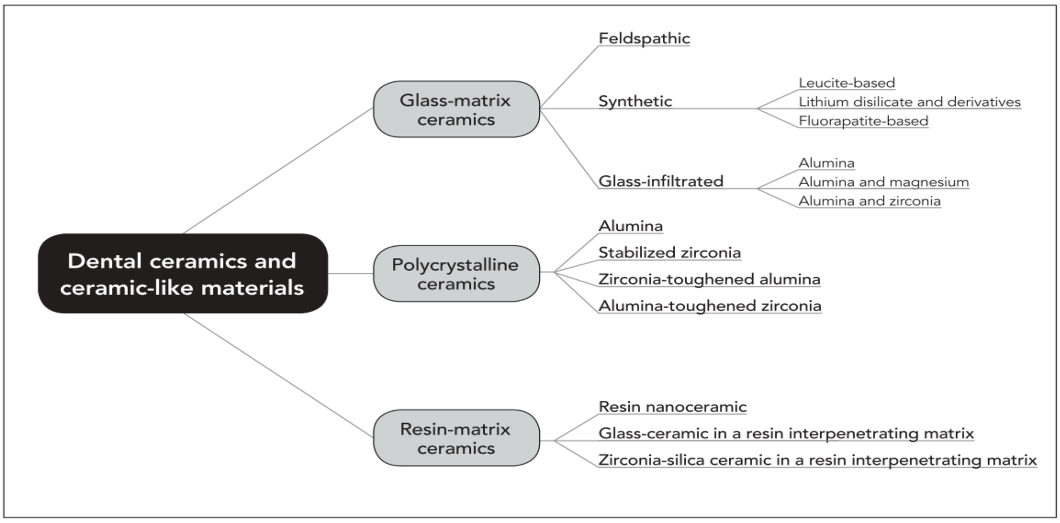


Figure 4 - Stefano Gracis classification of different ceramics, (6)

1.2.1.1. Glass-matrix Ceramics.

1.2.1.1.1. Feldspathic

The first porcelain used in dental and the one closest to what can be found naturally without modification. Only consisting of three basic elements: **natural feldspar** (which happens to be a mixture of sodium and potassium aluminosilicate), **quartz** (silica) and **kaolin** (5). Feldspar being the part responsible for the translucability of the material, quartz constitutes it the crystalline phase and the kaolin the elastic part (5). As explained previously thanks to a particular cooking process, appear leucite crystals which reinforce its physical characteristics that remain below other materials (60 to 70 MPa) but offering an aesthetic result as close to reality (7).

Among these we find the following brands: IPS Empress Esthetic, IPS Empress CAD, IPS Classic, Ivoclar Vivadent; Vitadur, Vita VMK 68, Vitablocs, Vident (6).

1.2.1.1.2. Synthetic leucite based

This is the first modification made to feldspathic porcelain, **leucite** has been used a lot to modify the thermal expansion coefficient which allows if one needs to fuse or cook at the same time porcelain with metal in the realization of ceramo-metallic crown for example (7).

But in this category of ceramics, leucite here allows to increase the flexural strength by artificially increasing the number of particles diffused in the material. The new generations have leucite crystals in the range of 10 to 20 microns allowing a homogeneous and more diffused distribution of forces as well as better behavior in terms of abrasion. They are then found naturally in the make-up of metal ceramic restorations (7).

Among them are the following brands: PS d.Sign, Ivoclar Vivadent; Vita VM7, VM9, VM13, Vident; Noritake EX-3, Cerabien, Cerabien ZR, Noritake (6).

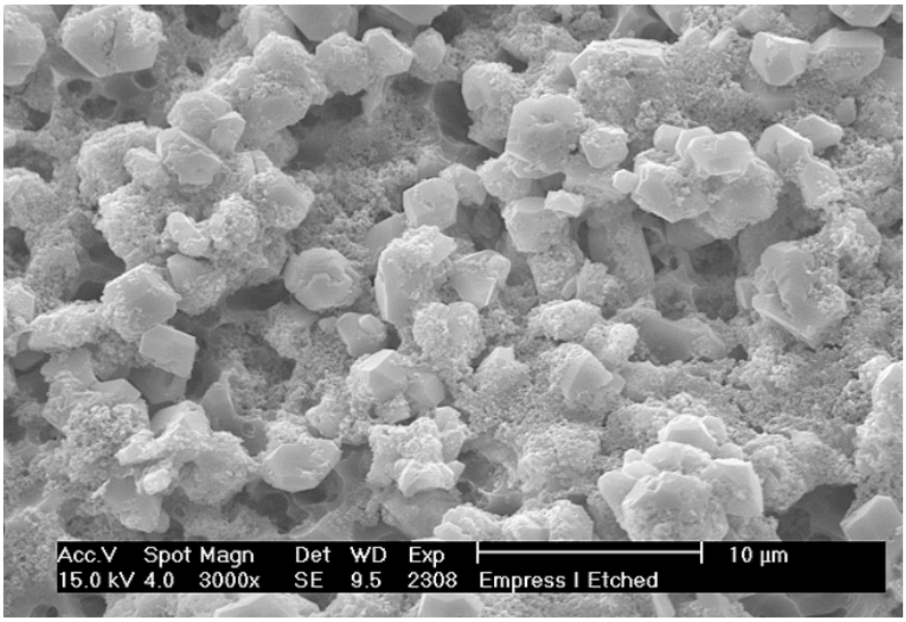


Figure 5 - Microscope image a Sweeping the internal structure of leucite crystals - (7)

1.2.1.1.3. Lithium disilicate

Consisting mainly of a crystalline structure to the tune of 70% Lithium disilicate ($Li_2Si_2O_5$) this ceramic has a much higher flexural strength than leucite glass ceramic, in the order of 350 - 450 Mpa and a fracture rate three times lower (7). This is due to the internal structure of lithium disilicate crystals which have a form of small, tangled plates oriented in a totally random manner. This orientation allows the deflection and stop the micro-cracks that could take place. There is also, but in a lesser amount, microcrystalline substructures of lithium ortho phosphate (Li_3PO_4) (7).

Unlike leucite lithium disilicate has a much higher expansion coefficient than the metal, not allowing it to be used in the manufacture of ceramic metal restoration. However, the versatility both by its aesthetic characteristics and its strength makes it a material that can be used for any type of restoration. (7)

Among them are the following brands; 3G HS, Pentron Ceramics; IPS e.max CAD, IPS e.max Press, Ivoclar Vivadent; Obsidian, Glidewell Laboratories; Suprinity, Vita; Celtra Duo, Dentsply (6).

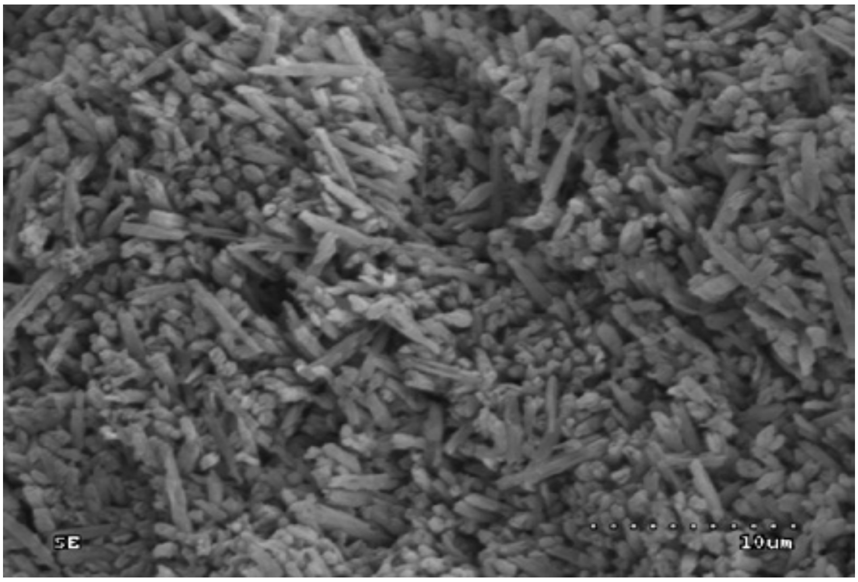


Figure 6 - Scanning microscope image of the internal structure of lithium disilicate crystals disilicate (7)

1.2.1.1.4. Fluorapatite based

This ceramic was the solution to the problem left by lithium disilicate which was not being able to be applied in layers on metal while offering a flexural strength superior to leucite. Its crystalline shape is made up of hydroxyapatite ($Ca10 (PO4)6OH2$) like the enamel, it offers similar characteristics in terms of resistance (7).

Among these we find the following brands: IPSe.max Ceram, ZirPress, Ivoclar Vivadent (6).

1.2.1.1.5. Glass infiltrated: alumina, alumina and magnesium and alumina and zirconia

Nowadays they are much less used since the discovery of lithium disilicate and zirconia, they correspond to ceramics in which glassy matter is infiltrated into porous skeletal structures composed mainly of al2O3 alumina that can be hybridized with magnesium or zirconia (6).

Among these we find the following brands: : alumina(eg,In-Ceram Alumina, Vita); alumina and magnesium (eg, In-Ceram Spinell, Vita); alumina and zirconia (eg, In-Ceram Zirconia, Vita) (6).

1.2.1.2. Polycrystalline Ceramics

One of the main characteristics of polycrystalline ceramics is the presence within it of crystalline microstructures giving them high strength as well as high fracture resistance. Therefore making them difficult malleable and therefore usable mostly via computer-assisted tailoring (8). The high-quantity presence of these microstructures increases opacity, which has made this ceramic a preferred choice for framework manufacturing (5).

1.2.1.2.1. Alumina

Constituted in almost all (99.5%) of Al2O3 and inaugurated by Nobel BioCare as a core material, it is one of the hardest materials since it reaches 17 to 20 Gpa. However, with such high hardness it is associated with a too much rigid elasticity module, making alumina a highly fractured material. It falls into disuse as a result of the onset of stabilized zirconia. (6)

Among these we find the following brands: : Procera AllCeram, Nobel Biocare; In-Ceram AL(6).

1.2.1.2.2. Stabilized zirconia

Consisting of zirconium oxide also known as synthetic zirconia at the height of 95% partially stabilized by yttrium oxide The main characteristic of this material is its high tenacity due to the fact that its microstructure is totally crystalline (5). Above all, it has a reinforcement mechanism called "resistance transformation." This phenomenon discovered by Garvie in 1975 is the following: the partially stabilized zirconia facing an area of high mechanical stress undergoes a crystalline phase transformation. Moving from a tetragonal phase to a cubic phase it is accompanied by a 4% volume change to close the cracks (9). This property gives these ceramics a resistance to bending between 1000 and 1500 Mpa surpassing from a far the rest of the porcelain. These excellent features have made these systems ideal candidates for the realization of ceramic prostheses in areas with high mechanical compromise (5). But today processes to make up zirconia by infiltration allow to imitate the color variations of the dentin and enamel as well as the translucency (6).

Among these we find the following brands: NobelProcera Zirconia, Nobel Biocare; Lava/Lava Plus, 3M ESPE; In-Ceram YZ, Vita; Zirkon, DCS; Katana Zirconia ML, Noritake;; Cercon ht, Dentsply;; Zirconia Prettau , Zirkonzahn; IPS e.max ZirCAD, Ivoclar Vivadent;; Zenostar,Wieland (6).

1.2.1.2.3. Zirconia toughened alumina (ZTA) and alumina toughened zirconia (AZT)

It has been imagined materials that can benefit from both the properties of zirconia in its tetragonal form and the relative hardness of alumina. By adding unstable zirconia to alumina, we can increase its resistance to fracture. More than 50% of alumina is found in ZTA and conversely more than 50% zirconia in AZT. (6)

1.2.1.3. Resin Matrix Ceramics

Recently included in ceramic's classification because of the new ceramic definition given by the ADA in 2013 which is "pressed, fired, polished, or milled materials containing predominantly inorganic refractory compounds including porcelains, glasses, ceramics and glass-ceramics.” This category is about materials containing at least 50% of ceramics filling in an organic matrix. (6)

Among these we find the following brands: Lava Ultimate, 3M ESPE, Enamic, Vita (6)

1.2.2. Classification by manufacturing technique

This classification is more intuitive and a simple way to represent different materials according to the method of making. It makes sense because it directly connects the material to its manufacturing method as it is known that beyond the importance of the physical characteristics specific to the material itself, the way in which it will be manufactured will also have, and at the same level, an influence on the final characteristics of the product. (9)

1.2.2.1. Powder liquid

1.2.2.1.1. Conventional

They are veneering materials that can be all glass or a mixture of glass and crystal components. (9). They are mixed and applied by hand either on a metal or ceramic framework or used alone for anterior veneers. (9)

The work consists of different steps that begins with compaction; in which the powder is mixed with water and a binder to keep fragile particles between them during this pre-firing period called the "green state". In this stage we try to condense between them the different powders to obtain a high density of particles which will reduce the shrinkage at the time of firing. Vibrations are also used to help with water evacuation. (8)

The firing is done in a vacuum furnace to get rid of the air and the water during the process. First fired at low temperature to avoid crack when the water goes out, this first step of firing induces the porcelain fusing allowing a continuity at the contact points between the powder particles. In this stage the material is still porous, and it’s called low bisque stage. As the temperature goes high, the fusion of the particle increase permitting it to fill the gap between themselves, it goes with more contraction (around 20%) and compaction. At this final stage of firing, the sintering process will lead the particles to loss their form and will gave a highly glazed look.(8)

1.2.2.1.2. Casting Slip

Mainly used for alumina or zirconia handmade veneered crown, the slip technique consists in a homogenous dispersion of the ceramic particles in water. The pH (power of hydrogen) of the water is then modified to get charged dispersed ceramics particles. The slip is then applied by hand on a gypsum dye with a brush to form the underlying core, the water being absorbed by the gypsum porous surface by capillary action. This alumina core is then fired with very low shrinkage (0.2%) then veneered with lanthanum glass that will molten and get between the alumina’s particles building a complex network. The last step will be the veneering of the restoration itself. (9)

1.2.2.2. Pressable

We find there, monochromatic porcelain or glass ceramics ingots that are heated and then press via an injection system into a molding using a conventional lost-wax technique. The restoration is then stained and glazed to match the aesthetic. (9)

1.2.2.3. Computer-aided design and computer-aided manufacturing (CAD/CAM)

CAM is the use of a computer assisted milling machine to create by a subtractive method different prosthesis (inlay, onlay, crown, bridge, veneer) but also framework using blocks of different materials (can be ceramic or metal zirconia). It result to better properties in general regarding density and mechanical properties that the powder liquid or pressed system due to its standardization which lead to less human error (9).

In the CAD/CAM system we find glass material as glass crystal which was the first ceramic block material produced specifically for the CEREC system the glass/crystal block branded as VITABLOCKS Mark II are constituted of very fined grained powder resulting in a nearly pore free result. They are available as monochromatic but also with different type of shade stack one upon the other to form a bespoke color to match the patient tooth(9).

We find as well glass/leucite based materials, lithium disilicate and zirconia that can be used to form full contoured prosthesis work or framework(9).

1.3. Characteristics used to compare ceramics prothesis materials

1.3.1. Flexural Strength

The flexural strength is a physical force expressed in MPa (Megapascal). It characterizes the ability of a material to withstand plastic deformation. Indeed, beyond a certain applied force the material undergoes an irreversible deformation that results in the fracture. The 3 points bending test is therefore used to measure and calculate fracture resistance. The principle of the test is to place a 25mm long by 2mm wide and thickness material bar to be tested on two supports at each end and then apply increasing force to the center of the bar until the bar breaks. This applied force is calculated according to the following formula (10):

$$x = \frac{3\mathrm{Pl}}{2bd^2}$$

where:

P= the ultimate load at fracture,

l= the distance of the supports,

b= the width of the specimen,

d= the thickness of the specimen.

1.3.2. The marginal Fit

The external seal or marginal adaptation consists of the edge of the prosthesis, the limits of the prepared dental surface and the thickness of exposed cement. Ideally, the marginal area should be closed with a continuum between unprepared dental tissue and the prosthetic edge(11). Failing to get a complete closure, the marginal space will be as thin as possible. In 1970, the ADA set the threshold for clinically acceptable marginal adaptation at 40 µm. But, this order of magnitude is difficult to obtain in practice. It was then reassessed in 1971 at 120 µm (12). Starting at a marginal opening of 150 µm, the dissolution of the sealing cement creates a marginal hiatus that promotes the accumulation of bacterial plaque, responsible for periodontal and dentin-pulp pathologies(13). Therefore, the entire prosthetic chain, both clinically and in the laboratory, will focus on the lowest possible joint values in order to avoid these deleterious consequences. Hence, the interest of the evaluation of the dental-prosthetic joint of the prosthetic restorations fixed. To this end, several methods are described in the literature without real consensus around an ideal method(14). To assess the marginal discrepancy, the measurements established by Holmes are used (15).

In 1989, HOLMES proposed a standardization of terminology in order to make it possible to compare the results of various studies. He also described the different parameters of cervical adaptation (15).

1. **Internal space:** It is the distance measured perpendicularly from the inner surface of the prosthetic part to the wall of the dental surface (15).

2. **External or marginal space:** This is the smallest distance between the dental tissues and the prosthetic crown at the level of the marginal opening (15).
3. **Vertical marginal space:** The distance between the prosthetic margin and the preparation margin measured parallel to the abutment axis (15).
4. **Horizontal marginal space**: This is the marginal defect measured perpendicular to the abutment axis. It is the distance between the prosthetic restoration and the preparation measured perpendicular to the preparation axis (15).
5. **Absolute marginal space:** This is a combination of the marginal opening and the contour error. It is the hypotenuse of the vertical marginal space and the horizontal marginal space. It represents the distance between the cavo-superficial angle of the preparation and the prosthetic marginal margin. The absolute marginal space merges with the overcut or the undercut when there is no marginal opening. It merges with the marginal space when the contour is correct (15).
6. **The over-extension:** The over-extension is the distance from the marginal edge of the prosthesis to the marginal opening measured perpendicular to the axis of the preparation (15).
7. **Under-extension:** The under-extension is represented by the distance from the cavo-superficial angle of the cervical finish of the abutment to the marginal opening measured perpendicular to the axis of the preparation (15).

It should be taken into account that in vitro methods overestimate the quality of the joint compared to in vivo studies. Indeed, the clinical conditions of preparation, impression and cementation are far from the ideal conditions of in vitro studies (15).

1.3.3. Antagonist wear: Abrasiveness

Influenced by the hardness of the so-called materials, hardness can be defined as the resistance that a body opposed to local deformation, under load. This property will influence the finishing and polishing of the material and gives an indication of the resistance of the material to abrasion (16). At a microscopic scale, no surface is completely smooth, so the asperities of each meet. During movements, the surfaces will deform or fracture each other. If both surfaces are fragile, there will be a fracture of asperities. If there is a difference in hardness in the case of a ceramic crown occluding with a normal tooth for example, the hardest surface will dig, wear, the other, that is what is called antagonistic wear(17).

1.4. About Lithium Disilicate

1.4.1. Presentation and form

Developed in 1988 by the Ivoclar Vivadent industry under the brand name IPS Empress 2, lithium disilicate (2SiO2 - LiO2) is part of glass ceramics as previously explained(18). It is composed by Silicate Dioxide (minimum of 55% up to 71%) and Lithium Oxide (9% up to 17%) among other components that are quartz, phosphor oxide, alumina and potassium oxide soaked in a very low porosity glass matrix (1 %) (10).

The IPS Empress 2 offers enviable mechanical characteristics upon its release of a flexural strength of 350 Mpa and a fracture toughness of 3.33.3 MPa√m) (10). In comparison, physiologically, the enamel flexural strength is around 384 MPa and dentin around 297 MPa as the natural tooth fracture toughness are the following : molar = 305 MPa; premolar = 248 MPa which is around 1.5 MPa√m to 4.4 MPa√m (19)(20)(18).This is due to the internal structure of lithium disilicate crystals which have a form of small, tangled plates oriented in a totally random manner(18). This orientation allows the deflection and stopping of the micro-cracks that could take place (7).

Technological advances in this material led to its current form of commercialization under the brand name IPS e.Max Press and thus the stop of the Empress 2 in 2009. The connotation "Press" applies to its manufacturing technique since it is ingot by heat pressing technique similar to the lost wax technique at a 920° temperature. Existing in all the different colors, translucency and opacity it achieves a flexural strength up to 400 MPa and fracture toughness of 2,7 to 4.4 MPa/ m0,5(21).

With the technological advance of computer and computer-assisted dentistry, a new form of lithium disilicate has come out, still being marketed under the trademark name E.Max, the IPS E.Max CAD in 2006(21).

Block used along CAD-CAM device trough milling technique. Those are partially crystallized block containing lithium disilicate crystal nuclei with 40% lithium metasilicate(22). Initially in a so called “blue state” these blocks are characterized by a moderate flexural strength (130 MPa) resulting in higher cutting efficiency, easier and faster workability and lower wear of the milling tools as well as a higher edge stability. It needs after its milling a second round of heat treating to transform the metasilicate state in an around 70% lithium disilicate structure. It is considered fully crystallized after a 20-25 min under vacuum 850°C tempering process. This transformation will give a final flexural strength of 360 MPa and fracture toughness of 2,5 MPa/m0,5(21)(23). These mechanical characteristics make the E.Max the toughest glass matrix ceramics on the market on this day(21).

2. OBJECTIVES

The aim of this study was:

To compare Pressed Lithium Disilicate and Milled Lithium Disilicate being monolithic or veneered among two parts.

- Flexural strength
- Marginal Fit

3. METHODOLOGY

The search for studies followed the following methodology;

Based on the following databases: PubMed, Crochane, Medline plus, Biblioteca CRAI UEM, and the following journals: European Journal of Prosthodontics and Restorative Dentistry and Journal of Biomedical Materials Research, the articles were searched according to the following mesh words: lithium disilicate/lithia disilicate, marginal fit/adaptation, resistance, wear/tooth wear, press, CAD.

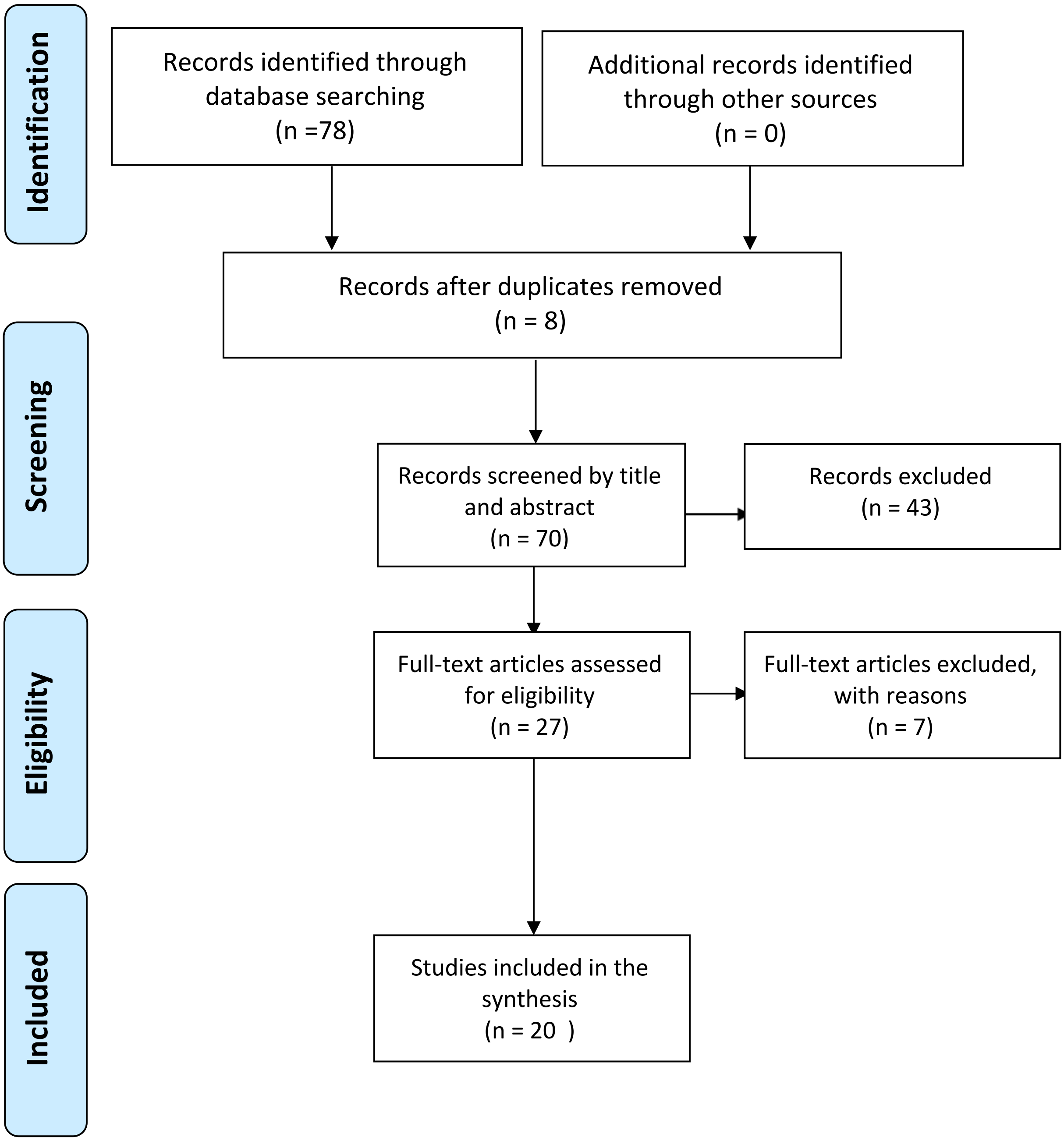
As a result, a very consequential number of articles were found, and we considered criteria of exclusion and inclusion in order of priority.

Decreasing order of importance	Inclusion	Exclusion
1) Publication date	From 2010 to 2020	Previous to 2000
2) Power of the article	Comparative study	Clinical case/report Conflict of interest
3) Nature of the article	Applicable to dentistry	Non-applicable to dentistry

Applying the inclusion and exclusion criteria, articles were first selected by mesh words after removing duplicate: 70.

Then, after reading the title and abstract 43 were discarded. The full text of the articles selected by the abstract was obtained and finally, 27 they were selected. 8 duplicate articles from different sources were discarded.

PRISMA 2020 Flow Diagram



4. DISCUSSION OF RESULTS

4.1. Flexural strength

The research is composed of 4 studies that met the inclusion criteria. Among these, 1 study showed that the Press technique showed better flexural strength, 2 studies showed that the CAD technique showed better flexural strength and 1 study did not find a significant difference in the flexural strength between both techniques. As all the studies did not use the same type of restauration, each thickness is different and consequently cannot be compare transversally as thickness is a major factor in flexural strength assessment (10).

Author (year)	Studied group	Flexural strength (MPa)	Methodology	Type of restoration	Size of sample
Ahmad et al. 2019 (23)	-Emax Press (mono, core) -Emax CAD (mono, core)	Press mono: 611 Press core: 411 CAD mono: 584 CAD core: 343	Aging: thermocycling, cyclic preload Measure: Three-point test	3 pieces bridge	40 40
Wang et al. 2020 (24)	IPS e.max Press IPS e.max CAD	IPS e.max Press: 270 IPS e.max CAD: 335	Measure: Biaxial flexural strength, SEM (scanning electron microscope)	Disk 13mmx1,2mm	1 1

Al-Thobity et al. 2020 (25)	IPS e.max Press GC LiSi Press IPS e.max CAD	IPS e;max Press:249,59 IPS e.max CAD: 364,64	Measure: Three points test	Polygone 16mmx4mmx1.2mm	15 15 15
Mohsen et al. 2011 (26)	IPS e-max Press IPS e-max CAD	IPS e-max Press: 318 IPS e-max CAD: 345	Measure: Biaxial Flexural Strength	Cylindrical 10mmx1,5mm	20 20
Fonzar et al. 2016 (27)	IPS e-max Press IPS e-max CAD	IPS e-max Press: 344,35 IPS e-max CAD: 345,74	Measure: Three points test, SEM	Ingots 16mmx4mmx1.2mm	15 15

Wang and colleagues did show a better result for the CAD/CAM restorations, but they used a sample of tool little quantities (n=1) too be considered relevant as a compared study (24).

Al-Thobity et al., Mohsen and al. and Fonzar et al. can be compared transversally as they used same dimension restauration with similar flexural test and similar sample size. All of them did find a better result in CAD/CAM restauration even if in the Fonzar et al. study, the discrepancy between CAD and Press flexural strength is not enough to be considered significant (25)(26)(27).

Ahmad et al. did work the closest to the real conditions found in the human body. It is the only study that worked on real restorations and with a process of aging by thermocycling and cyclic preload, that supposed to mimic the conditions of the mouth. However, it is the only study that found a better flexural property for IPS e-max Press (23).

In the end based on the few studies that were found in this review that directly compare both techniques, IPS e.max Press and IPS e.max CAD lithium disilicate formulations showed similar flexural resistance, being both totally clinically acceptable.

Consequently, the choice between them should be based on other aspects than this mechanical property.

4.2. Marginal fit

The research is composed of 9 studies that met the inclusion criteria. Among these, 3 studies showed that the Press technique showed smaller marginal discrepancies, 2 studies showed that the CAD technique showed smaller marginal discrepancies and 4 studies did not find a significant difference in the marginal discrepancies between both techniques. As all the studies did not use the same device to record and evaluate the marginal fit, the results may be closely related to methodology of assessment.

Author (year)	Studied group	Marginal Fit (μm)	Methodology	Type of restoration	Size of sample
Neves et al. 2014 (28)	E.max CAD (CEREC 3D)	39.2±8.7	Scanned with micro-computed tomography	Crown	5
	E.max CAD (E4D)	66.9±31.9			5
	E.max press	36.8±13.9			5
Leneena Gudugunta et al. 2019 (29)	CAD/CAM lithium disilicate	41,46 SD 15,94	Stereomicroscope with Image Analysis software	Onlay	15
	Pressable lithium disilicate	55,95 SD 26,68			15
Mously et al. 2014 (30)	E.max CAD (E4D)	46.65 (30.55–58.15)	X-ray microtomography	Crown	10
	E.max press				

		30.80 (24.35–41.75)			10
Alajaji et al. 2017 (31)	Group-1 three-axis milling system	67,67±14.04	X-ray microtomography	Inlay	15
	Group-2, five-axis milling system	56,19±12,32			15
	Group-3, conventional heat-press technique	35,48±8.12			15
Anadioti et al. 2014 (32)	E.max CAD+conventional impression (PVS)	76±23	Triple scan Protocol	Crown	15
	E.max CAD+Digital impression (LavaTM C.O.S.)	74±26			15
	E.max Press+conventional impression (PVS)	40±9			15
	E.max Press+Digital impression (LavaTM C.O.S.)	75±15			15
Guachetá et al. 2020 (33)	Group 1: E.max CAD + Digital impression (LavaTM)	40.37 ± 11.75	Stereomicroscope	Veneer	21
	Group 2: E.max Press + conventional impression (PVS)	50.63± 16.99			21
B.Azar et al. 2018 (34)	E.max CAD + Digital impression (LavaTM)	45 ± 12	Optical microscope at 200× magnification	Crowns	20

	E.max Press + conventional impression (PVS)	38 ± 12			20
Guess et al. 2014 (35)	E.max press E.max CAD (CEREC 3D)	51.78–65.41 48.63–52.46	Optical microscope at 200× magnification	Onlay	24 24
Ng et al. 2014 (36)	E.max CAD +Digital impression (LavaTM) E.max press+conventional impression (PVS)	48±25 74±47	Stereomicroscope with Image Analysis software	Crown	15 15

Mously and colleagues and Alajaji and colleagues are part of the authors that highlight that restorations made of E.max engineered with the press technique had better result by having significantly smaller marginal fit than those engineered with the CAD technique (30) (31).

What we found in common is those studies is the methodology used to evaluate the marginal fit, both used Micro-CT. This method has a major disadvantage, a low capacity of discrimination compared to optical or electron microscope (37). It is mainly caused by radiation artifacts which are produced by the different radiation absorption coefficient of the different materials used (37). We can then suspect that the choice of using this method of assessment can have affected the reliability of the results.

Neves and colleagues (38) showed for both Emax CAD CEREC 3D and Press technique very similar marginal discrepancy. However, the sample size is by comparison to the other studies, very small (n=5 per group) which could be considered inadequate to give proper significant result. Moreover, a silicon key of silicone was used to fix the crowns on to the model since no cementation was done to assess the marginal fit, this could have affected the accuracy of the final result (38).

Regarding cementation, the marginal gap should not be measured after its used or at least before and after cementation. As it has been reported that marginal gap increases by 13 to 22 μm when the restoration is being luted by cement (35). In this review, it has been found that in all the studies that showed before and after cementation, the marginal gap was significantly augmented. (33) (35)

Anadioti and colleagues (37) found that Emax Press technique showed better result only when being associated with conventional impression. When using digital impression, we end having the same marginal discrepancy for both material techniques. Taking in account that the study has been done in 2014 and consequently the precision of scanner impression is not, at that time, as precise as conventional impression, it leads to highlight the fact that impression technique influences at least with the same importance that the choice of material technique (37).

The results of all the studies show a large variability in terms of marginal fit between all the different restauration but also within the same restauration using the same impression technique or not. The reason can be found in the different cement used, or otherwise no cement used but also the material of the model which can be human, bovine, acrylic or zircon. In the same way, the type of scanner, the impression technique or the thickness of the die spacer can influence the final marginal fit result.

Regardless of this, the average variance between the Emax CAD or Emax press restorations assessed in this critical review was within the clinically acceptable range.

5. CONCLUSION

In the end, this investigation revealed similar mechanical properties between IPS E.max CAD and IPS E.max Press being both totally clinically acceptable. If one should choose between one and the other, one should base his choice on other aspects. A highlight that showed up from this investigation is more than the material itself, it is the workflow and the importance of the human influence during the process that matters. Regarding human influence, the more steps that require human manual ability we need, the higher the risk of variability in the result increase. Regarding workflow, the CAD CAM experience offer a simpler working procedure that is less time consuming with a better cost-effective technique (38).

In the years to come, intraoral scanner will become more and more effective and widespread as they become more affordable. One can imagine that the CAD CAM procedure, by its simplicity of using chairside, reducing the cost of transportation and assuring impression stability will overcome the use of Press system that is a more traditional approach (39).

As for today, if we consider the investment cost required for a complete CAD CAM chairside procedure in our office which is constituted by the cost of acquiring and maintaining CAD/CAM hardware/software, material spill/waste using milling blocks and axes the mill will be using and the existing technological limitation in the field of digital impression, working under a more traditional Press procedure can still be considered as relevant (39).

6. RESPONSIBILITY

Out of an economic point of view, lithium disilicate is far for being the most affordable material one can use when thinking of prosthesis or restorative option. It should be assessed the balance benefice/cost than can result from using such types of materials when esthetic is not considered important.

From an ecological point of view, it is important to understand that new techniques and technologies consumed more and more resources. The Press technique is being used for hundreds of years in other field that dentistry, making it a very common, easy of access and relatively poor pollutive procedure. However, the CAD technique imply using complex drilling machine combine with powerful computer that drag energy and rare resources around the globe. In the same way, the use of intraoral scanner in combination with the CAD technique also imply new resources, new technologies and more than that, asks the question of the senescence of those new technologies which become obsolete very quickly. This implies, therefore, an over consumption of dental equipment which has a harmful effect on the planet.

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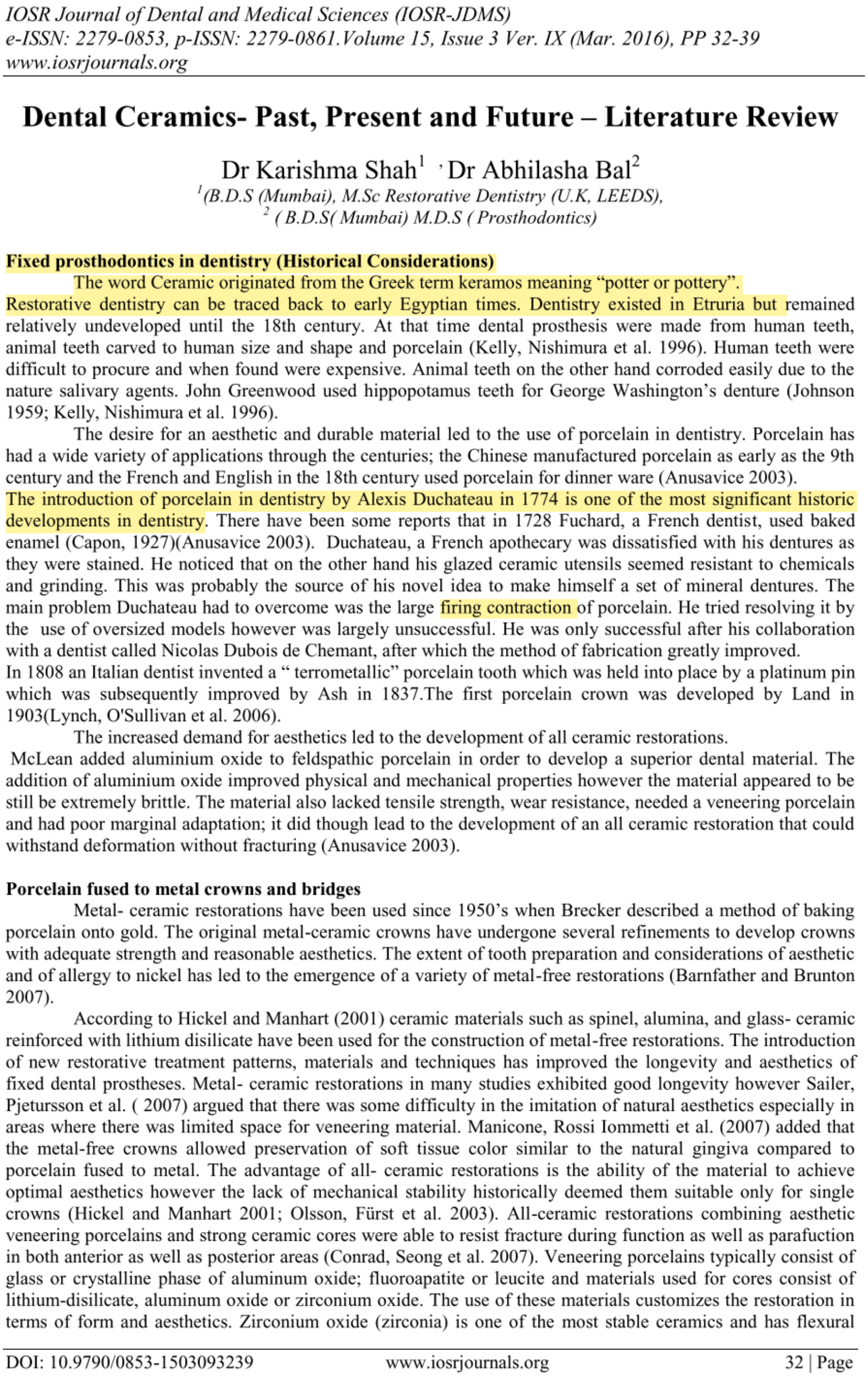
8. ANNEX



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Dental Ceramics- Past, Present and Future – Literature Review

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Fixed prosthodontics in dentistry (Historical Considerations)

The word Ceramic originated from the Greek term keramos meaning "potter or pottery".

Restorative dentistry can be traced back to early Egyptian times. Dentistry existed in Etruria but remained relatively undeveloped until the 18th century. At that time dental prosthesis were made from human teeth, animal teeth carved to human size and shape and porcelain (Kelly, Nishimura et al. 1996). Human teeth were difficult to procure and when found were expensive. Animal teeth on the other hand corroded easily due to the nature salivary agents. John Greenwood used hippopotamus teeth for George Washington's denture (Johnson 1959; Kelly, Nishimura et al. 1996).

The desire for an aesthetic and durable material led to the use of porcelain in dentistry. Porcelain has had a wide variety of applications through the centuries; the Chinese manufactured porcelain as early as the 9th century and the French and English in the 18th century used porcelain for dinner ware (Anusavice 2003).

The introduction of porcelain in dentistry by Alexis Duchateau in 1774 is one of the most significant historic developments in dentistry. There have been some reports that in 1728 Fuchard, a French dentist, used baked enamel (Capon, 1927)(Anusavice 2003). Duchateau, a French apothecary was dissatisfied with his dentures as they were stained. He noticed that on the other hand his glazed ceramic utensils seemed resistant to chemicals and grinding. This was probably the source of his novel idea to make himself a set of mineral dentures. The main problem Duchateau had to overcome was the large firing contraction of porcelain. He tried resolving it by the use of oversized models however was largely unsuccessful. He was only successful after his collaboration with a dentist called Nicolas Dubois de Chemant, after which the method of fabrication greatly improved.

In 1808 an Italian dentist invented a " terrometallic" porcelain tooth which was held into place by a platinum pin which was subsequently improved by Ash in 1837.The first porcelain crown was developed by Land in 1903(Lynch, O'Sullivan et al. 2006).

The increased demand for aesthetics led to the development of all ceramic restorations.

McLean added aluminium oxide to feldspathic porcelain in order to develop a superior dental material. The addition of aluminium oxide improved physical and mechanical properties however the material appeared to be still be extremely brittle. The material also lacked tensile strength, wear resistance, needed a veneering porcelain and had poor marginal adaptation; it did though lead to the development of an all ceramic restoration that could withstand deformation without fracturing (Anusavice 2003).

Porcelain fused to metal crowns and bridges

Metal- ceramic restorations have been used since 1950's when Brecker described a method of baking porcelain onto gold. The original metal-ceramic crowns have undergone several refinements to develop crowns with adequate strength and reasonable aesthetics. The extent of tooth preparation and considerations of aesthetic and of allergy to nickel has led to the emergence of a variety of metal-free restorations (Barnfather and Brunton 2007).

According to Hickel and Manhart (2001) ceramic materials such as spinel, alumina, and glass- ceramic reinforced with lithium disilicate have been used for the construction of metal-free restorations. The introduction of new restorative treatment patterns, materials and techniques has improved the longevity and aesthetics of fixed dental prostheses. Metal- ceramic restorations in many studies exhibited good longevity however Sailer, Pjetursson et al. (2007) argued that there was some difficulty in the imitation of natural aesthetics especially in areas where there was limited space for veneering material. Manicone, Rossi Iommetti et al. (2007) added that the metal-free crowns allowed preservation of soft tissue color similar to the natural gingiva compared to porcelain fused to metal. The advantage of all- ceramic restorations is the ability of the material to achieve optimal aesthetics however the lack of mechanical stability historically deemed them suitable only for single crowns (Hickel and Manhart 2001; Olsson, Fürst et al. 2003). All-ceramic restorations combining aesthetic veneering porcelains and strong ceramic cores were able to resist fracture during function as well as parafuction in both anterior as well as posterior areas (Conrad, Seong et al. 2007). Veneering porcelains typically consist of glass or crystalline phase of aluminum oxide; fluoroapatite or leucite and materials used for cores consist of lithium-disilicate, aluminum oxide or zirconium oxide. The use of these materials customizes the restoration in terms of form and aesthetics. Zirconium oxide (zirconia) is one of the most stable ceramics and has flexural

Ceramics in dentistry: Historical roots and current perspectives

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This article presents a brief history of dental ceramics and offers perspectives on recent research aimed at the further development of ceramics for clinical use, at their evaluation and selection, and very importantly, their clinical performance. Innovative ceramic materials and ceramics processing strategies that were introduced to restorative dentistry since the early 1980s are discussed. Notable research is highlighted regarding (1) wear of ceramics and opposing enamel, (2) polishability of porcelains, (3) influence of firing history on the thermal expansion of porcelains for metal ceramics, (4) machining and CAD/CAM as fabrication methods for clinical restorations, (5) fit of ceramic restorations, (6) clinical failure mechanisms of all-ceramic prostheses, (7) chemical and thermal strengthening of dental ceramics, (8) intraoral porcelain repair, and (9) criteria for selection of the various ceramics available. It is found that strong scientific and collaborative foundations exist for the continued understanding and improvement of dental ceramic systems. (J PROSTHET DENT 1996;75:18-32.)

The American Academy of Fixed Prosthodontics recently established the Ad Hoc Committee on Research in Fixed Prosthodontics. This Committee was assigned the responsibility of helping to sustain academic excellence and interest in fixed prosthodontics, which includes the related sciences, ethics, and social issues. The objective of the Committee was to disseminate knowledge and prepare perceptively for the future by making influential contributions to current literature that will have a significant bearing on the practice of fixed prosthodontics. Specifically, this involves defining an area of scientific investigation or clinical practice for review with an emphasis on vision and perspective. The Committee has selected ceramics as the focus of its first contribution.

OVERVIEW

Dental ceramics are known for their natural appearance and their durable chemical and optical properties. However, dentists have remained suspicious of the structural longevity, potential abrasivity, and fit of ceramic restorations. It was predictable that recent dental research in ceramics addressed issues of clinical survival, response during wear, and fit. These concerns have directly influenced the development of recently introduced ceramic materials and laboratory processing systems. After a brief historical perspective, this review focuses on recent improvements concerning the appropriate use of dental ceramics and, more importantly, how they perform clinically. Studies of clinical failure and damage mechanisms are crucial, because they provide data for substantial engineering improvements. This article concludes with a discussion of the esthetic versatility provided by current ceramic systems for fixed prosthodontics.

HISTORIC PERSPECTIVES

Ceramics as a restorative material

Although routine use of ceramics in restorative dentistry is a recent phenomenon, the desire for a durable and esthetic material is ancient. Most cultures through the centuries have acknowledged teeth as an integral facial structure for health, youth, beauty, and dignity. Teeth have routinely been designated with an equally powerful, if occasionally perverse, role in cultures where dentitions were purposely mutilated as inspired by vanity, fashion, and mystical and religious beliefs.[1, 2] Therefore, it has been almost universal that unexpected loss of tooth structure and, particularly, missing anterior teeth create physical and functional problems and often psychologic and social disturbances as well.

Although dental technology existed in Etruria as early as 700 BC and during the Roman first century BC, it remained virtually undeveloped until the eighteenth century. Candidate materials for artificial teeth during the 18th century were (1) human teeth, (2) animal teeth carved to the size and shape of human teeth, (3) ivory, and finally

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The opinions or assertions contained in this article are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Navy, Department of Defense, or the U.S. Government.

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Ceramic materials in dentistry: historical evolution and current practice

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ABSTRACT

Dental ceramics are presented within a simplifying framework allowing for facile understanding of their development, composition and indications. Engineering assessments of clinical function are dealt with and literature is reviewed on the clinical behaviour of all-ceramic systems. Practical aspects are presented regarding the choice and use of dental ceramics to maximize aesthetics and durability, emphasizing what we know and how we know it.

Keywords: Ceramics, particle-filled glasses, polycrystalline ceramics, CAD/CAM, all-ceramic restorations.

Abbreviation: LTD = low temperature degradation.

CERAMICS IN DENTISTRY – WHERE DID THIS STUFF COME FROM?

It is quite useful reviewing how and why ceramics came to be used in dentistry. This account serves three purposes: (1) to alert practitioners to the fact that the use of ceramics, since the very beginning, always represented the adoption of 'high technology' versus 'craft art'; (2) to reinforce the concept that ceramics and improved ceramics were introduced in order to solve specific problems or to increase restorative versatility; and (3) to provide a gentle background into the nature and science of ceramics. Astute readers are also provided with clues as to where to watch for the emergence of new ceramic technologies.

Since a distinction was drawn between 'high technology' and 'craft art' it is useful to provide some basic defining characteristics of each. Many would agree that 'high technology' should include: (1) dentistry borrowing materials/processes shortly after their being developed by an unrelated industry; (2) incorporation of new learning from recent scientific literature outside of dental medicine; and (3) the spread of outright new inventions within dentistry. 'Craft art', on the other hand, brings to mind materials and techniques borrowed from those involved in jewellery making, the arts and the manufacture of everyday goods. All audiences the senior author has spoken to before have chosen 'craft art' as the likely source of ceramics introduced into dentistry at any stage of development.

In the early 1700s many European rulers were spending enormous sums importing porcelain from China and Japan. Figure 1, from Schloss Charlottenburg in Berlin, is representative of just small portions of one of these collections. The collection of Augustus III of Saxony was perhaps the largest and is now on display at the Zwinger Museum in Dresden, his former palace. Such activity led China to be characterized as being 'the bleeding bowl of Europe'. Between 1604 and 1657 alone, over three million pieces of Chinese porcelain reached Europe.[1] In 1700, 'East Indiamen' ships unloaded 146 748 pieces in a European port in just one day as the market for porcelain grew insatiable.[1]

One response to this situation involved state sponsored research into 'porcelain discovery'. Notable European leaders including Augustus (III) the Strong, King of Poland and Elector of Saxony along with the Medici family of Florence, Italy were independently sponsoring research into the development of a European porcelain to match the hard, translucent and sonorous material developed in eastern Asia nearly 1100 years earlier. Europeans strived at 'porcelain discovery' without much success for about 200 years and this activity is credited with being largely responsible for the growth of modern analytical chemistry

REVIEW ARTICLE www.ijcmr.com Section: Dentistry

All Ceramic Materials in Dentistry: Past, Present and Future: A Review

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ABSTRACT

Fixed partial dentures (FPDs) with high-strength all-ceramic systems are necessary for replacing missing teeth. Wide range of materials and methods are available to fabricate a restoration outside the mouth and subsequently integrate with a tooth. The traditional methods of ceramic fabrication have been described to be time-consuming, technique sensitive, and rather unpredictable due to the many variables present which affect the outcome. All-ceramic restorations, has become a segment of dentistry which has experienced tremendous improvements in the recent years. The increasing use of polycrystalline alumina and zirconia as framework materials and the increasing popularity and variety of computer-aided design and computer-aided manufacturing (CAD-CAM) systems seem to be mutually accelerating trends over the last three decades. This article presents a review of the development of all-ceramic restorations, including the evolution and development of materials, technologies and how to improve the strength of all-ceramic restorations, with respect to survival, applications, strength, color, and aesthetics. The literature demonstrates that multiple all-ceramic materials and systems that are currently available for clinical use and concludes there is not a single universal material or, system available to suit for all clinical situations.

Keywords: All Ceramics, CAD/CAM System Zirconia, Aluminum Oxide, Nano-composite

INTRODUCTION

The word Ceramic is derived from the Greek word "keramos" which literally means "burnt stuff" but which has come to mean more specifically as a material produced by burning or firing.[1] Dental ceramics are materials that are part of systems designed with the purpose of producing dental prostheses that in turn are used to replace missing or damaged dental structures. The literature on this topic defines ceramics as inorganic, non-metallic materials made by man by the heating of raw minerals at high temperatures.

EVOLUTION OF DENTAL CERAMICS

In dentistry, ceramic was first introduced as restorative materials in the late 1700s, taking advantage that they can replicate the shape and color of the natural dentition. Later around 1710, Böttger introduced feldspar as the flux in Chinese porcelains. Since the first use of porcelain to make a complete denture by Alexis Duchateau in 1774, numerous dental porcelain compositions have been developed. French Dentist De Chemant patented the first porcelain tooth material in 1789. Pfaff from Germany developed a technique that allowed the porcelain teeth to be used effectively in denture base construction in 1839. Dr. Charles Land patented the first Ceramic crowns in 1903.[2] Ceramic materials are rapidly progressed for a wide range of applications. These porcelain crowns showed good aesthetic properties, but low flexural strength resulting in a higher incidence of clinical failures compared to metal ceramic system which were the first system developed in 1962 that used approximately 17–25 wt% of leucite-containing feldspathic porcelain to avoid poor matches in the coefficient of thermal expansion between the metal framework and veneering ceramic.

In 1965, McLean and Hughes used a glass matrix core comprising of 40 to 50 wt% Al_2O_3 to fabricate the first all-ceramic porcelain jacket crown (alumina-reinforced core ceramic). Castable ceramics (Dicor) were later developed by Grossman in 1972 at corning glass works with low flexural strength (150 MPa), which thus limits its application for a single crown restoration.[3] The traditional methods of ceramic fabrication have been described to be time-consuming, technique sensitive, and rather unpredictable due to the many variables present which affect the outcome.

The introduction of computer-aided design and computer-aided manufacturing (CAD/CAM) technology to restorative dentistry was carried out in the Cerec system (Sirona, Bensheim,Germany) and developed in 1982. might be a good alternative in field research and development of dental ceramics.[4] The advances in CAD/CAM technology are instrumental in the research and for the development of high-strength polycrystalline ceramics such as stabilized zirconium dioxide which could not have been practically processed by traditional laboratory methods. CAD-CAM systems are initially used in the fabrication of ceramic onlays, inlays, veneers, and crowns.

In-Ceram system was introduced for the first all-ceramic core materials for crowns and three-unit anterior fixed

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A New Classification System for All-Ceramic and Ceramic-like Restorative Materials

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Classification systems for all-ceramic materials are useful for communication and educational purposes and warrant continuous revisions and updates to incorporate new materials. This article proposes a classification system for ceramic and ceramic-like restorative materials in an attempt to systematize and include a new class of materials. This new classification system categorizes ceramic restorative materials into three families: *(1)* glass-matrix ceramics, *(2)* polycrystalline ceramics, and *(3)* resin-matrix ceramics. Subfamilies are described in each group along with their composition, allowing for newly developed materials to be placed into the already existing main families. The criteria used to differentiate ceramic materials are based on the phase or phases present in their chemical composition. Thus, an all-ceramic material is classified according to whether a glass-matrix phase is present (glass-matrix ceramics) or absent (polycrystalline ceramics) or whether the material contains an organic matrix highly filled with ceramic particles (resin-matrix ceramics). Also presented are the manufacturers' clinical indications for the different materials and an overview of the different fabrication methods and whether they are used as framework materials or monolithic solutions. Current developments in ceramic materials not yet available to the dental market are discussed. *Int J Prosthodont 2015;28:227–235. doi: 10.11607/ijp.4244*

Ceramics have been the mainstay of esthetic dentistry for more than 100 years. Originally in the naturally occurring feldspathic form, ceramics were used primarily for anterior teeth as high fusing porcelain jacket crowns, denture teeth, and partial coverage. Beginning with John McLean's introduction of aluminous porcelain in the mid-1960s,[1] there have been continuous improvements in strength, esthetics, and methods of fabrication, resulting in dozens of products for clinicians to choose from.

Due to the high number of products available and the speed at which new products are being introduced, today's clinician faces a complex decision process when choosing a ceramic restorative material for a particular indication. The selection is seldom made on the basis of a thorough understanding of the materials' characteristics. More often, it is based on criteria such as strength measured in vitro, degree of translucency, manufacturing techniques, the preference of the dental laboratory technician, and even advertising claims.

A classification system of the ceramic materials used in dentistry is useful for a variety of purposes, including communication and education. Ideally, a classification system should be helpful in providing clinically relevant information about where to use the material (anterior versus posterior), for what type of restoration (partial versus full, short versus long-span), and how to lute it (adhesively versus traditionally). Different classification systems have been proposed that focus on clinical indications, composition, ability to be etched, processing methods, firing temperatures, microstructure, translucency, fracture resistance, and antagonist wear.[2–6] These classifications, however, tend to be either vague or imprecise, and they do not easily allow for the inclusion of new restorative materials.

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Cerámicas dentales: clasificación y criterios de selección


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Dental ceramics: Classification and selection criteria

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Resumen : Hoy en día, hablar de restauraciones estéticas implica hablar de cerámica sin metal. Han sido tan importantes y revolucionarios los cambios y aportaciones en este campo en los últimos años que en la actualidad existen multitud de sistemas cerámicos. Todos ellos buscan el equilibrio entre los factores estéticos, biológicos, mecánicos y funcionales. Sin embargo, existen diferencias considerables entre ellos. Por lo tanto, para seleccionar la cerámica más adecuada en cada caso, es necesario conocer las principales características de estos materiales y de sus técnicas de confección. Esta elección no debe ser delegada al técnico de laboratorio, sino que debe ser responsabilidad del odontoestomatólogo porque él es quien conoce y controla las variables que condicionan el éxito de la restauración a largo plazo. En este artículo, se revisan los principales sistemas cerámicos disponibles actualmente y se analiza su comportamiento clínico. Por último, se exponen unas pautas para orientar al profesional en la toma de decisiónes.

Palabras clave: Cerámica, Composición química, Técnica de confección, Resistencia a la fractura, Ajuste marginal, Estética, Supervivencia clínica.

Abstract: At the present time, to speak about aesthetic restorations implies speaking about alloy free ceramics. This field has experienced important changes and revolutionary contributions. This has led to the introduction of a multitude of all-ceramic systems. All of these quest for a balance between the aesthetic, biological, mechanical and functional factors. However, considerable differences exist among them. Therefore, to select the most suitable ceramic in every case, it is necessary to know the main features of these materials and the laboratory procedures. Porcelain selection should not be left up to the laboratory technician. Material selection should be the responsibility of the clinician because he knows and controls the variables that determine the long-term success of the restoration. This article reviews the all-ceramic systems now available and its clinical performance. Lastly, decision making guidelines for the clinician are detailed.

Key words: Ceramics, chemical composition, laboratory procedure, fracture strength, marginal fit, aesthetics and clinical survival.

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materials

MDPI

Review

Glass–Ceramics in Dentistry: A Review

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Abstract: In this review, we first briefly introduce the general knowledge of glass–ceramics, including the discovery and development, the application, the microstructure, and the manufacturing of glass–ceramics. Second, the review presents a detailed description of glass–ceramics in dentistry. In this part, the history, property requirements, and manufacturing techniques of dental glass–ceramics are reviewed. The review provided a brief description of the most prevalent clinically used examples of dental glass–ceramics, namely, mica, leucite, and lithium disilicate glass–ceramics. In addition, we also introduce the newly developed ZrO_2–SiO_2 nanocrystalline glass–ceramics that show great potential as a new generation of dental glass–ceramics. Traditional strengthening mechanisms of glass–ceramics, including interlocking, ZrO_2–reinforced, and thermal residual stress effects, are discussed. Finally, a perspective and outlook for future directions in developing new dental glass–ceramics is provided to offer inspiration to the dental materials community.

Keywords: glass–ceramics; dental prostheses; strength; translucency; strengthening mechanisms

1. The History of Glass–Ceramics and Dental Glass–Ceramics

Synthetic glass–ceramics were serendipitously discovered by Stanley Donald Stookey in 1953. [1–4]. After the discovery of lithium disilicate glass–ceramic, Corning Inc. developed and commercialized two new glass–ceramics based on Li–aluminosilicates (LAS) and Mg–aluminosilicates (MAS) during 1953–1963 [5]. The LAS glass–ceramic was used as cookware because of its very low coefficient of thermal expansion (CTE). The development of MAS glass–ceramic was motivated by the need arose for a ceramic missile nosecone for a missile to be guided by an internal antenna [1]. Between 1963 and 1980, researchers tried to develop transparent and nano–crystalline glass–ceramics. For instance, nano–crystalline β–quartz glass–ceramic introduced by Schott has a crystalline size of about 50 nm [6].

In the last two decades, glass–ceramics have attracted great interests of people in scientific community. Figure 1 provides an idea of the scientific significance of glass–ceramics in terms of published papers. There are only 276 papers in 1999, however, the number keeps increasing over the last 20 years, reaching to approximately 1100 in 2018 (Figure 1). This indicates that more and more material scientists in research institutes and universities become interested in glass–ceramics.

Humans have long been aware of the medical and esthetic benefits of tooth replacements. Ancient Egyptians produced esthetic tooth replacements using bovine teeth. Ceramic materials for dental restorations were first invented in the 18th century [7]. Aesthetics (adequate translucency) and durability (adequate strength and chemical stability) are the two attributes of ceramics over other materials in terms of being used as dental materials.

In 1962, the first two US patents porcelain–fused–to–metal (PFM) restorations were awarded which consisted of gold alloy and feldspathic porcelain [8]. Since then PFM restorations have set the standard for multiple teeth restoration. In the past decades, dental bridges were mostly metal–porcelain

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Ceramics in Dentistry

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1. Introduction

It is quite usual in dentistry to adopt a material from engineers and adapt it to clinical conditions. A good example of such an instance is dental ceramics. In Dental science, ceramics are referred to as nonmetallic, inorganic structures primarily containing compounds of oxygen with one or more metallic or semi-metallic elements. They are usually sodium, potassium, calcium, magnesium, aluminum, silicon, phosphorus, zirconium & titanium.

As we peep into the dental history, a French dentist De Chemant patented the first porcelain tooth material in 1789. In 1808 Fonzi, an Italian dentist invented a "terrometallic" porcelain tooth that was held in place by a platinum pin or frame. Ash developed an improved version of the platinum tooth in 1837. Dr. Charles Land patented the first Ceramic crowns in 1903.Vita Zahnfabrik introduced the first commercial porcelain in 1963.

Structurally, dental ceramics contain a crystal phase and a glass phase based on the silica structure, characterized by a silica tetrahedra, containing central Si^{4+} ion with four O^- ions. It is not closely packed, having both covalent and ionic characteristics. The usual dental ceramic, is glassy in nature, with short range crystallinity. The only true crystalline ceramic used at present in restorative dentistry is Alumina (Al_2O_3), which is one of the hardest and strongest oxides known. Ceramics composed of single element are rare. Diamond is a major ceramic of this type, hardest natural material used to cut tooth enamel. Ceramics are widely used in dentistry due to its dual role – strength and esthetics.

Basically the inorganic composition of teeth and bones are ceramics – Hydroxyapatite. Hence ceramics like hydroxyapatite, wollastonite etc are used as bone graft materials. They have an entire plethora of synthetic techniques like wet chemical, sol-gel, hydrothermal methods etc. Also they are added as bioactive filler particles to other inert materials like polymers or coated over metallic implants. These ceramics are collectively called as bioceramics. There are basically two kinds of bioceramics-inert (e.g. Alumina) and bioactive (hydroxyapatite). They can be resorbable (Tricalciumphosphate) or non-resorbable (Zirconia).

Dental cements are basically glasses. Initially, silicate cements were introduced. They constitute the first dental cement to use glass as its component. The cement powder contains a glass of silica, alumina and fluorides. The liquid, is an aqueous solution of phosphoric acid with buffer salts. Fluoride ions leached out from the set cements are responsible for the anti-cariogenic property. But silicates are discontinued due to low pH during setting reaction that affects the dental pulp.

Ceramics overview: classification by microstructure and processing methods

Edward A. McLaren[1] and Russell Giordano[2]

Abstract

The plethora of ceramic systems available today for all types of indirect restorations can be confusing and overwhelming for the clinician. Having a better understanding of them is important. In this article, the authors use classification systems based on microstructural components of ceramics and the processing techniques to help illustrate the various properties.

Introduction

Many different types of ceramic systems have been introduced in recent years for all types of indirect restorations, from very conservative nonpreparation veneers, to multi-unit posterior fixed partial dentures and everything in between. Understanding all the different nuances of materials and material processing systems is overwhelming and can be confusing. This article will cover what types of ceramics are available based on a classification of the microstructural components of the ceramic. A second, simpler classification system based on how the ceramics are processed will give the main guidelines for their use.

The term "ceramic" derives from the Greek "keramos", which means "a potter or a pottery". This word is related to a Sanskrit term meaning "burned earth", since the basic components were clays from the earth heated to form pottery. Ceramics are non-metallic, inorganic materials. Ceramics refer to numerous materials, including metal oxides, borides, carbides, nitrides and complex mixtures of these materials.[1] The structure of these materials is crystalline, displaying a regular periodic arrangement of the component atoms, and may exhibit ionic or covalent bonding. Although ceramics can be very strong, they are also extremely brittle and will catastrophically fail after minor flexure. Thus, these materials are strong in compression but weak in tension.

Contrast that with metals: metals are non-brittle (display elastic behaviour) and ductile (display plastic behaviour). This is because of the nature of the interatomic bonding, which is called metallic bonds; a cloud of shared electrons that can easily move when energy is applied defines these bonds. This is what makes most metals excellent conductors. Ceramics can be very translucent to very opaque. In general, the more glassy the microstructure (i.e. non-crystalline), the more translucent; and the more crystalline, the more opaque. Many other factors contribute to translucency, for example, particle size, particle density, refractive index and porosity to name a few.

Different types of ceramics used in dentistry

The term "ceramic" technically refers to a crystalline material. Porcelain is a mixture of glass and crystal components. A non-crystalline containing material is simply a glass. However, dentistry typically refers to all three basic materials as dental ceramics. How ceramics are classified can be very confusing. Ceramics can be classified by their microstructure, (i.e. amount and type of crystalline phase and glass composition). They can also be classified by processing technique (powder/liquid, pressed or machined)

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MECHANICAL PROPERTIES OF DENTAL RESTORATIVE MATERIALS: RELATIVE CONTRIBUTION OF LABORATORY TESTS

PROPRIEDADES MECÂNICAS DOS MATERIAIS DENTÁRIOS RESTAURADORES: CONTRIBUIÇÃO RELATIVA DOS ENSAIOS LABORATORIAIS

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A wide variety of dental products that are launched on the market becomes the correct selection of these materials a difficult task. Although the mechanical properties do not necessarily represent their actual clinical performance, they are used to guide the effects of changes in their composition or processing on these properties. Also, these tests might help somehow the clinician to choose once comparisons between former formulations and new ones, as well as, with the leading brand, are highlighted by manufactures. This paper presents a review of the most important laboratory tests. In this manner, the knowledge of these tests will provide a critical opinion related to the properties of different dental materials.

UNITERMS: Dental materials, properties; Materials testing.

INTRODUCTION

In the current dental literature, several studies evaluate distinct properties of dental materials, which can influence and predict their performance[1,2,5,6,7,10,19]. Dental products have been developed very rapidily and, consequently, the number of studies designed to evaluate their characteristics is also increasing. Practitioners are aware of the importance of previous laboratory and clinical trials before putting the material into use in their practice. In this way, the knowledge of their mechanical properties is essential to support the correct indication of these materials and to expect a long-term performance[20].

Once in the oral cavity, a dynamic situation is established and then, adverse conditions to the material can be expected[8,13,17,20]. For different situations, each material would respond in a particular way. Several *in vitro* tests are proposed to evaluate different properties. Each test has its design and evaluates specific properties. Although there is a great number of studies that evaluate dental materials in the literature, in some cases it is somewhat difficult to compare the results. In order to seek for standardized testing protocols, an international organization was created to act in that direction. Table 1 presents the main guidance for dental materials laboratory testing recommended by International Organization for Standardization (ISO). A review of the usual tests that evaluate mechanical properties of dental materials is presented in an attempt to demonstrate their applicability and relevance.

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Case Report

Lithium Disilicate Restorations: Overview and A Case Report

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Abstract

To avoid the shortcoming of conventional metal-based materials and to provide natural-appearing dental restorations, manufacturers introduce different all-Ceram materials to the market, starting with feldspathic porcelain, Dicor material, pressable leucite-reinforced glass ceramic materials and ended with variable generations of zirconium and lithium disilicate. The multifunctional use of lithium disilicate, its translucent optical properties, and its availability as a mono-block, make it as a trending topic in dentistry.

In this overview article, *in-vitro* and clinical studies regarding lithium disilicate are discussed and one case of implant supported lithium disilicate crown manufactured by CAD/CAM technique is presented.

Keywords: Lithium disilicate; Press; CAD/CAM; Monolithic

Abbreviations

FDPs: Fixed Dental Prosthesis; CAD/CAM: Computer- Aided Design and Computer- Assisted Manufacturing; USPHS: United States Public Health Service; AIOP: Italian Academy of Prosthetic Dentistry

Introduction

The recent innovations in ceramic materials and CAD/CAM technologies are developed in order to enable the accomplishment of high aesthetic demands and to limit the shortcoming of conventional materials and methods; i.e., low tensile strength, sintering shrinkage, excessive brittleness, wear of antagonist, crack propagation [1] and marginal gaps [2].

Recently, lithium disilicate material had been widely marketed, because of the adhesive properties of this material [3] and its preservation of tooth structure [4]. Lithium disilicate restorations are manufactured by heat press-lost wax technique (IPS e.max Press) or by CAD/CAM technique (IPS e.max CAD). The former has a high survival rate based on short [5] and long term [6] survival evidence for each single crown restoration and 3-unit FDP. The latter (IPS e.max CAD) techniques, which produce different crystal characterization, lack enough clinical evaluations and trials thus are still not indicated for multiple units FDP [7,8]. The manufacturer (Ivoclar Vivadent) starting use lithium disilicate as a frame work to increase the strength of veneer such as IPS Empress2, where the veneer material was fluorapatite-based porcelain [9,10]. After that the monolithic blocks of lithium disilicate (IPS e.max CAD, IPS e.max Press) are presented. The second generation of these blocks is used for zirconium core veneering (Vita Suprinity; Vita Zahnfabrick, Bad Säckingen, Germany), while the third generation is used for implant-supported prosthesis due to its ability to be bonded with the titanium base and also to its presence in various shade blocks [7].

Recent literatures spotlight the properties of machinable lithium disilicate (IPS e.max CAD, Ivoclar Vivadent). This product, which is marketed as blue blocks, contains 40% of partially crystallized Lithium metasilicate, which transformed to lithium disilicate crystal after CAD-CAM milling and tempering. After this process, all crystal particles increased in size; so the flexural strength of material increased. The blue color of lithium disilicate blocks change to the tooth color during the oxidation phase in the tempering process [2,7,10]. Although the shrinkage of Lithium Disilicate during the crystallization process does not affect the margin fit [2], this kind of restoration is still not suggested for multi-unit FDP as conducted in AIOP closed meeting in 2013, due to the lower mechanical properties (fracture resistance and flexure strength) when compared with IPS e.max Press [8]. The lithium disilicate restorations cannot be applicable for all type of prosthesis; Table 1 represents the possible clinical uses of lithium disilicate restorations as conducted in AIOP closed meeting [11].

In-vitro studies

The mechanical properties of lithium disilicate restorations depend on the component of the block [12] and on the manufacturing process [7,13].

The zirconia reinforced lithium disilicate (Vita Suprinity; Vita Zahnfabrick, Bad Säckingen, Germany) that is manufactured by CAD-CAM has higher mechanical properties than machinable lithium disilicate (IPS e.max CAD) in terms of fracture toughness, flexure strength, hardness and elastic modulus. On the contrary, lithium disilicate glass ceramic (IPS e.max CAD) crown exhibits higher fatigue load to reach the failure value than the zirconium oxide crown (Y-TZP) [14]. In another study, which also compared the fatigue behavior of monolithic lithium disilicate versus veneered Y-TZP crown (IPS e.max ZirCAD), early veneer failure of IPS e.max ZirCAD was observed [15]. One of the most frequent failure cause of zirconium restoration; is chipping or fracturing of the veneering ceramic [16]. On the other hand, the lithium disilicate restoration may be fabricated as a single unit (monolithic) without a ceramic veneering need.

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Evaluation of marginal fit of 2 CAD-CAM anatomic contour zirconia crown systems and lithium disilicate glass-ceramic crown

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PURPOSE. This study was to evaluate the marginal fit of two CAD-CAM anatomic contour zirconia crown systems compared to lithium disilicate glass-ceramic crowns. **MATERIALS AND METHODS.** Shoulder and deep chamfer margin were formed on each acrylic resin tooth model of a maxillary first premolar. Two CAD-CAM systems (Prettau®Zirconia and ZENOSTAR®ZR translucent) and lithium disilicate glass ceramic (IPS e.max®press) crowns were made (n=16). Each crown was bonded to stone dies with resin cement (Rely X Unicem). Marginal gap and absolute marginal discrepancy of crowns were measured using a light microscope equipped with a digital camera (Leica DFC295) magnified by a factor of 100. Two-way analysis of variance (ANOVA) and post-hoc Tukey's HSD test were conducted to analyze the significance of crown marginal fit regarding the finish line configuration and the fabrication system. **RESULTS.** The mean marginal gap of lithium disilicate glass ceramic crowns (IPS e.max®press) was significantly lower than that of the CAD-CAM anatomic contour zirconia crown system (Prettau®Zirconia) ($P<.05$). Both fabrication systems and finish line configurations significantly influenced the absolute marginal discrepancy ($P<.05$). **CONCLUSION.** The lithium disilicate glass ceramic crown (IPS e.max®press) had significantly smaller marginal gap than the CAD-CAM anatomic contour zirconia crown system (Prettau®Zirconia). In terms of absolute marginal discrepancy, the CAD-CAM anatomic contour zirconia crown system (ZENOSTAR®ZR translucent) had under-extended margin, whereas the CAD-CAM anatomic contour zirconia crown system (Prettau®Zirconia) and lithium disilicate glass ceramic crowns (IPS e.max®press) had over-extended margins. ***[J Adv Prosthodont 2015;7:271-7]***

KEY WORDS: Anatomic contour zirconia crown; CAD-CAM; Lithium disilicate glass ceramic crown; Marginal gap; Absolute marginal discrepancy; Marginal fit

INTRODUCTION

Zirconia has excellent aesthetic quality, biocompatibility, and mechanical property. In addition, the price of zirconia is inexpensive compared to gold. Thus, zirconia is getting attention as a proper material for posterior teeth restoration to replace the existing ceramic.[1-3] Commercialization of zirconia is closely linked to the development of CAD/CAM introduced to the dental industry 20 years ago.[4-6] Recently, the introduction of new CAD/CAM milling technology and new zirconia made it possible to manufacture anatomic contour zirconia crown, enabling the forming of occlusal surface anatomically instead of in the form of porcelain veneer.[7,8] Anatomic contour zirconia crowns have excellent fracture resistance property because it does not have super-

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Review

The marginal fit of E.max Press and E.max CAD lithium disilicate restorations: A critical review

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This critical review aimed to assess the vertical marginal gap that was present when E.max lithium disilicate-based restoration (Press and CAD) are fabricated *in-vitro*. Published articles reporting vertical marginal gap measurements of *in-vitro* restorations that had been fabricated from E.Max lithium disilicate were sought with an electronic search of MEDLINE (PubMed) and hand search of selected dental journals. The outcomes were reviewed qualitatively. The majority of studies that compared the marginal fit of E.max press and E.max CAD restorations, found that the E.max lithium disilicate restorations fabricated with the press technique had significantly smaller marginal gaps than those fabricated with CAD technique. This research indicates that E.max lithium disilicate restorations fabricated with the press technique have measurably smaller marginal gaps when compared with those fabricated with CAD techniques within *in-vitro* environments. The marginal gaps achieved by the restorations across all groups were within a clinically acceptable range.

Keywords: Marginal fit, E.max, Press, CAD, Lithium disilicate

INTRODUCTION

Introduction of the acid etched ceramic protocol for bonding to enamel in 1980[1-3] and the dentin adhesives in the early 1990s[4,5], facilitated dental rehabilitation with all-ceramic prosthesis[6].

Lithium disilicate is a glassy ceramic that consists of quartz, lithium dioxide, phosphor oxide, alumina, potassium oxide and other components[7]. The material has high flexural strength up to 440 MPa[7]. IPS E.max lithium disilicate, introduced in 2005 by Ivoclar Vivadent (AG, Schaan, Liechtenstein), is a material where lithium disilicate crystals (SiO_2-Li_2O) are embedded into a matrix of glass to minimize microcrack propagation[8], thereby improving mechanical stability[9].

IPS E.max lithium disilicate restorations can be made using either lost-wax hot pressing techniques (IPS E.max Press) or computer-aided-designed/computer-aided manufactured (CAD/CAM) milling procedures (IPS E.max CAD) either in the dental office (chairside CAD/CAM systems) or in the dental laboratory[10].

CAD/CAM has been available for dental use since its development by Duret in France in the 1970s (System Duret CAD/CAM)[11]. Chairside CAD/CAM systems including Cerec (Sirona Dental Systems) are recognized as reliable chairside CAD/CAM systems[12-14] allowing the fabrication of restorations from monolithic blocks of lithium disilicate (IPS E.max CAD)[15]. Following design and milling, the precrystallized restorations undergo a heat crystallization process to achieve maximum strength[7,16]. The technology allows dental practitioners to fabricate restorations in a single visit by using intraoral optical impressions and in-office milling[17]. This workflow avoids use of provisional cements, and it has been argued that this results in improved dentine adhesion[18].

Dental laboratories can also use the lost-wax technique to fabricate pressable lithium disilicate restorations (IPS E.max Press). Ingots of lithium disilicate are heat-pressed within a porcelain furnace to mold the ceramic material into the desired shape[19,20]. This technique reduces processing errors that may be associated with conventional sintering and has been shown to improve mechanical stability[21,22].

Marginal fit is an important factor in the success of restorations[23,24]. Marginal fit is related to both vertical and horizontal discrepancies. The marginal gap has been defined as the vertical distance from the internal surface of the restoration to the finish line of the preparation[25]. Horizontal discrepancies, such as crown overhangs, can also occur and these result in serious misfit. Horizontal overhangs can be adjusted to some degree intraorally. Vertical marginal gaps can only be sealed with luting cement. Luting cements are rough, porous, and can dissolve[26]. The larger the marginal discrepancy, the faster will be the rate of cement dissolution[26]. Therefore, clinicians seek to minimize marginal gaps to decrease the incidence of tooth staining, gingival irritation and other dental and periodontal complications accompanied with the rough surfaces present after luting cement dissolution.

There is no clinical or evidence-based consensus regarding whether a specific marginal gap may be clinically acceptable for a given patient. Some studies indicate that a marginal fit <120 microns is clinically acceptable[27], but other authors showed that a marginal fit ≤100 microns is more suitable[28,29]. Others consider a fit ≤75 microns clinically acceptable[30]. However, in

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plane of preparation at a time. This technique accomplishes the tooth preparation more rapidly, with a reliable, predictable standard of excellence.

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Considerations in measurement of marginal fit

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The terminology describing "fit" and the techniques used for measuring fit vary considerably in the literature. Although fit can be most easily defined in terms of "misfit," there are many different locations between a tooth and a restoration where the measurements can be made. In this work, the measurements of misfit at different locations are geometrically related to each other and defined as internal gap, marginal gap, vertical marginal discrepancy, horizontal marginal discrepancy, overextended margin, underextended margin, absolute marginal discrepancy, and seating discrepancy. The significance and difference in magnitude of different locations are presented. The best alternative is perhaps the absolute marginal discrepancy, which would always be the largest measurement of error at the margin and would reflect the total misfit at that point. (J PROSTHET DENT 1989;62:405-8.)

The marginal "fit" of any dental restoration is vital to its long-term success. Lack of adequate fit is potentially detrimental to both the tooth and the supporting periodontal tissues. Unlike physical and mechanical properties of materials, the fit of a restoration has never been strictly defined. The reference points for measurements and the discriptive terminology defining *fit* vary considerably among investigators. Often the same term is used to refer to different measurements, or different terms are used to refer to the same measurement. This is a constant source of confusion in reporting and comparing studies.

Studies have reported measurement of fit relative to marginal adaptation,[1-3] internal adaptation,[4,5] vertical seating,[6-8] radiographic appearance,[9] and clinical adaptability as judged by experienced practitioners.[9,10] Two common techniques are measurement of embedded and sectioned specimens,[1,11,12] and measurement of specimens (or their replicas) by direct visualization.[7,13] Mechanical devices, such as the tracing jig[14] to measure relative distortion at the margin during porcelain firing cycles, have also been used frequently. Several studies[8,15] have evaluated fit

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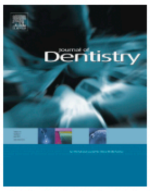

Wear of enamel opposing zirconia and lithium disilicate after adjustment, polishing and glazing[☆]

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ABSTRACT

Objectives: To compare the wear and opposing enamel wear of adjusted (A); adjusted and polished (AP); and adjusted and glazed (AG) zirconia and lithium disilicate.
Methods: Specimens ($n = 8$) were prepared of lithium disilicate (A, AP, and AG), zirconia (A, AP, and AG), veneering porcelain, and enamel (control). Surface roughness was measured for each ceramic. In vitro wear was conducted in the UAB-chewing simulator (10 N vertical load/2 mm slide/20 cycles/min) with lubricant (33% glycerin) for 400,000 cycles. Isolated cusps of extracted molars were used as antagonists.

Scans of the cusps and ceramics were taken at baseline and 400,000 cycles with a non-contact profilometer and super-imposed to determine wear. Data were analyzed with ANOVA and Tukey–Kramer post hoc tests (alpha = 0.05).
Results: A and AP zirconia showed no detectable signs of wear, and the veneering porcelain demonstrated the most wear. All other ceramics showed significantly less volumetric loss than the veneering porcelain, comparable to enamel–enamel wear. Veneering porcelain produced the most opposing enamel wear ($2.15 \pm 0.58\ \mathrm{mm}^3$). AP lithium disilicate and zirconia showed the least amount of enamel wear ($0.36 \pm 0.09\ \mathrm{mm}^3$ and $0.33 \pm 0.11\ \mathrm{mm}^3$ respectively). AG lithium disilicate had statistically similar enamel wear as AP lithium disilicate, but A lithium disilicate had more enamel wear. A and AG zirconia had more enamel wear than AP zirconia. No statistically significant difference was seen between the enamel–enamel group and any other group except the veneering porcelain.
Conclusions: Zirconia has less wear than lithium disilicate. Wear of enamel opposing adjusted lithium disilicate and zirconia decreased following polishing.
Clinical significance: Zirconia experiences less and lithium disilicate experiences equivalent occlusal wear as natural enamel. It is preferable to polish zirconia and lithium disilicate after adjustment to make them wear compatible with enamel. Veneering of zirconia and lithium disilicate should be avoided in areas of occlusal contact to prevent enamel wear.

[☆] Previously presented at the 2013 IADR meeting in Seattle, WA.

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Original

Wear characteristics of polished and glazed lithium disilicate ceramics opposed to three ceramic materials

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Abstract: This study compared the wear characteristics of a heat-pressed lithium disilicate ceramic material opposed to feldspathic porcelain, a lithium disilicate glass ceramic, and zirconia materials. Ceramic plate specimens were prepared from feldspathic porcelain (EX-3 nA1B), lithium disilicate glass ceramics (e.max CAD MO1/C14), and zirconia (Katana KT 10) and then ground or polished. Rounded rod specimens were fabricated from heat-pressed lithium disilicate glass ceramic (e.max press LT A3) and then glazed or polished. A sliding wear testing apparatus was used for wear testing. Wear of glazed rods was greater than that of polished rods when they were abraded with ground zirconia, ground porcelain, polished porcelain, or polished lithium disilicate ceramics. For both glazed and polished rods, wear was greater when the rods were abraded with ground plates. The findings indicate that application of a polished surface rather than a glazed surface is recommended for single restorations made of heat-pressed lithium disilicate material. In addition, care must be taken when polishing opposing materials, especially those used in occlusal contact areas. (J Oral Sci 58, 117-123, 2016)

Keywords: glazing; lithium; polishing; wear; XRD; zirconia.

Introduction

New ceramic materials continue to be introduced for restorations and fixed dental prostheses (1,2), probably because of the improved mechanical strength, biocompatibility, and esthetics of these materials (3). Occlusal adjustment of ceramic restorations involves polishing or glazing ceramic surfaces (4-6). Smoothed ceramic surfaces prevent excessive wear of opposing teeth and minimize plaque accumulation (7). The surface roughness of ceramic materials is a critical factor affecting wear (8-10). In addition, surface roughness of ceramic materials strongly correlates with wear of opposing materials (11).

Several studies reported that glazed and polished ceramic materials do not significantly differ in surface roughness (6). However, other studies found that wear of ceramics was greater for materials opposed to glazed ceramics than for those opposed to polished ones (12-16). Janyavula et al. reported that material and antagonist wear was greater for glazed zirconia than for polished zirconia (13). Lawson et al. reported that wear of opposing enamel was less for polished than for glazed lithium disilicate glass (LDG) ceramics (15). Thus, wear of antagonists appears to be greater for glazed ceramic materials than for polished ceramic materials.

Few studies have compared the wear characteristics of ceramic materials and zirconia. The purpose of the present study was to evaluate wear of a heat-pressed

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BMC Oral Health

RESEARCH ARTICLE **Open Access**

Current status on lithium disilicate and zirconia: a narrative review

Fernando Zarone, Maria Irene Di Mauro*, Pietro Ausiello, Gennaro Ruggiero and Roberto Sorrentino

Abstract

Background: The introduction of the new generation of particle-filled and high strength ceramics, hybrid composites and technopolymers in the last decade has offered an extensive palette of dental materials broadening the clinical indications in fixed prosthodontics, in the light of minimally invasive dentistry dictates. Moreover, last years have seen a dramatic increase in the patients' demand for non-metallic materials, sometimes induced by metal-phobia or alleged allergies. Therefore, the attention of scientific research has been progressively focusing on such materials, particularly on lithium disilicate and zirconia, in order to shed light on properties, indications and limitations of the new protagonists of the prosthetic scene.

Methods: This article is aimed at providing a narrative review regarding the state-of-the-art in the field of these popular ceramic materials, as to their physical-chemical, mechanical and optical properties, as well as to the proper dental applications, by means of scientific literature analysis and with reference to the authors' clinical experience.

Results: A huge amount of data, sometimes conflicting, is available today. Both in vitro and in vivo studies pointed out the outstanding peculiarities of lithium disilicate and zirconia: unparalleled optical and esthetic properties, together with high biocompatibility, high mechanical resistance, reduced thickness and favorable wear behavior have been increasingly orientating the clinicians' choice toward such ceramics.

Conclusions: The noticeable properties and versatility make lithium disilicate and zirconia materials of choice for modern prosthetic dentistry, requiring high esthetic and mechanical performances combined with a minimal invasive approach, so that the utilization of such metal-free ceramics has become more and more widespread over time.

Keywords: Lithium disilicate, Zirconia, ZLS, Ceramic, Minimally invasive, E.max, MDP, Aging, Translucent cubic zirconia

Background

At "The Digital Dentistry Society II Consensus Conference on Digital Technologies – Marrakech 2018" the main topics of digital interest were thoroughly discussed, in order to draw clinical recommendations based on scientific evidence and, when missing, on the clinical experience shared by the scientific community. The present narrative review is focused on the technical and clinical profile of the two most popular metal-free materials, lithium disilicate and zirconia, in order to briefly shed light on their different indications, advantages and shortcomings.

Methods

An extensive research has been carried out in the literature available on the subject, worldwide, limiting itself exclusively to articles in english, available on the main search engines (Pubmed, Embase, Scopus) and published in the most important indexed journals of the Materials and Dental sector, with and without impact factor. The results highlighted in this narrative review were extrapolated from this literature search, with reference to the authors' clinical experience.

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The Fracture Behaviour of Dental Enamel

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Abstract

Enamel is the hardest tissue in the human body covering the crowns of teeth. Whereas the underlying dental material dentin is very well characterised in terms of mechanical and fracture properties, available data for enamel are quite limited and are apart from the most recent investigation mainly based on indentation studies. Within the current study, stable crack-growth experiments in bovine enamel have been performed, to measure fracture resistance curves for enamel. Single edge notched bending specimens (SENB) prepared out of bovine incisors were tested in 3-point bending and subsequently analysed using optical and environmental scanning electron microscopy. Cracks propagated primarily within the protein-rich rod sheaths and crack propagation occurred under an inclined angle to initial notch direction not only due to enamel rod and hydroxyapatite crystallite orientation but potentially also due to protein shearing. Determined mode I fracture resistance curves ranged from 0,8 – 1,5 MPa*m$^{1/2}$ at the beginning of crack propagation up to 4,4 MPa*m$^{1/2}$ at 500 µm crack extension; corresponding mode II values ranged from 0,3 to 1,5 MPa*m$^{1/2}$.

Key words: *enamel, mechanical properties, fracture behaviour, resistance curves, toughening*

1. Introduction

Dental enamel (the outer hard tissue layer of tooth crowns) is a composite material that – comparable to other biological tissues like bone or dentin – exhibits a unique and complex hierarchical structure. It is composed of ~ 85 vol% hydroxyapatite crystals, ~ 12 vol% water and ~ 3 vol% organic matrix [1]. On the microstructural level enamel is composed of crystal rods (about 5 µm in diameter) that run from the dentin-enamel-junction (DEJ) to approximately 6-12 µm below the tooth surface [2]. Each single enamel rod consists of bundles of hydroxyapatite (HAP) crystallites of about 50 nm in diameter covered by an approximately 1 nm thick organic layer [3,4].

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Review Article

The science and application of IPS e.Max dental ceramic

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KEYWORDS
Computer-aided design;
Lithium disilicate;
Review

Abstract The aim of this paper is to report the state of current literature and recommendations for the lithium disilicate glass-ceramic IPS e.Max. The materials science, mechanical and optical properties were reviewed. Additionally an assessment was conducted of current implementation recommendations and clinical outcomes. This paper provides a brief historical overview, summary of the findings the findings of current literature, and clinical recommendation for the use of IPS e.Max CAD in dental applications.

Introduction

Over the last few decades the field of dental ceramics has evolved rapidly, both in material properties and manufacturing techniques. Among these advancements is the introduction of glass-ceramics, which are both highly esthetic and possess exceptional mechanical properties. One such material is the IPS e.Max line (Ivoclar Vivadent, Schaan, Liechtenstein), which comes in two forms, a block that can be milled in a CAD/CAM system (IPS™ e.Max CAD) and an ingot used for pressable crown fabrication following the lost wax technique (IPS™ e.Max Press). Due to the recent nature of these materials research into the material science, mechanical and optical properties, and clinical applications is still ongoing. By focusing on reviewing literature related IPS™ e.Max CAD, this paper aims to provide a background on the material, a brief review of current literature related to the materials science and mechanical properties of the material, a review of the optical and esthetic properties of the material, and an overview of clinical findings, recommendations, and applications.

Background and material history

Lithium disilicate ($2SiO_2{-}Li_2O$) dental ceramics were first introduced in 1988 for use as a heat-pressed core material marketed as IPS™ Empress 2 (Ivoclar Vivadent, Lichtenstein) [1]. Empress 2 was classified as a glass ceramic, a subgroup of particle-filled glasses, and contained

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Conflicts of interest: All authors declare no conflicts of interests.

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Case Report

Lithium Disilicate Restorations: Overview and A Case Report

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Abstract

To avoid the shortcoming of conventional metal-based materials and to provide natural-appearing dental restorations, manufacturers introduce different all-Ceram materials to the market, starting with feldspathic porcelain, Dicor material, pressable leucite-reinforced glass ceramic materials and ended with variable generations of zirconium and lithium disilicate. The multifunctional use of lithium disilicate, its translucent optical properties, and its availability as a mono-block, make it as a trending topic in dentistry.

In this overview article, *in-vitro* and clinical studies regarding lithium disilicate are discussed and one case of implant supported lithium disilicate crown manufactured by CAD/CAM technique is presented.

Keywords: Lithium disilicate; Press; CAD/CAM; Monolithic

Abbreviations

FDPs: Fixed Dental Prosthesis; CAD/CAM: Computer- Aided Design and Computer- Assisted Manufacturing; USPHS: United States Public Health Service; AIOP: Italian Academy of Prosthetic Dentistry

Introduction

The recent innovations in ceramic materials and CAD/CAM technologies are developed in order to enable the accomplishment of high aesthetic demands and to limit the shortcoming of conventional materials and methods; i.e., low tensile strength, sintering shrinkage, excessive brittleness, wear of antagonist, crack propagation [1] and marginal gaps [2].

Recently, lithium disilicate material had been widely marketed, because of the adhesive properties of this material [3] and its preservation of tooth structure [4]. Lithium disilicate restorations are manufactured by heat press-lost wax technique (IPS e.max Press) or by CAD/CAM technique (IPS e.max CAD). The former has a high survival rate based on short [5] and long term [6] survival evidence for each single crown restoration and 3-unit FDP. The latter (IPS e.max CAD) techniques, which produce different crystal characterization, lack enough clinical evaluations and trials thus are still not indicated for multiple units FDP [7,8]. The manufacturer (Ivoclar Vivadent) starting use lithium disilicate as a frame work to increase the strength of veneer such as IPS Empress2, where the veneer material was fluorapatite-based porcelain [9,10]. After that the monolithic blocks of lithium disilicate (IPS e.max CAD, IPS e.max Press) are presented. The second generation of these blocks is used for zirconium core veneering (Vita Suprinity; Vita Zahnfabrick, Bad Säckingen, Germany), while the third generation is used for implant-supported prosthesis due to its ability to be bonded with the titanium base and also to its presence in various shade blocks [7].

Recent literatures spotlight the properties of machinable lithium disilicate (IPS e.max CAD, Ivoclar Vivadent). This product, which is marketed as blue blocks, contains 40% of partially crystallized Lithium metasilicate, which transformed to lithium disilicate crystal after CAD-CAM milling and tempering. After this process, all crystal particles increased in size; so the flexural strength of material increased. The blue color of lithium disilicate blocks change to the tooth color during the oxidation phase in the tempering process [2,7,10]. Although the shrinkage of Lithium Disilicate during the crystallization process does not affect the margin fit [2], this kind of restoration is still not suggested for multi-unit FDP as conducted in AIOP closed meeting in 2013, due to the lower mechanical properties (fracture resistance and flexure strength) when compared with IPS e.max Press [8]. The lithium disilicate restorations cannot be applicable for all type of prosthesis; Table 1 represents the possible clinical uses of lithium disilicate restorations as conducted in AIOP closed meeting [11].

In-vitro studies

The mechanical properties of lithium disilicate restorations depend on the component of the block [12] and on the manufacturing process [7,13].

The zirconia reinforced lithium disilicate (Vita Suprinity; Vita Zahnfabrick, Bad Säckingen, Germany) that is manufactured by CAD-CAM has higher mechanical properties than machinable lithium disilicate (IPS e.max CAD) in terms of fracture toughness, flexure strength, hardness and elastic modulus. On the contrary, lithium disilicate glass ceramic (IPS e.max CAD) crown exhibits higher fatigue load to reach the failure value than the zirconium oxide crown (Y-TZP) [14]. In another study, which also compared the fatigue behavior of monolithic lithium disilicate versus veneered Y-TZP crown (IPS e.max ZirCAD), early veneer failure of IPS e.max ZirCAD was observed [15]. One of the most frequent failure cause of zirconium restoration; is chipping or fracturing of the veneering ceramic [16]. On the other hand, the lithium disilicate restoration may be fabricated as a single unit (monolithic) without a ceramic veneering need.

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Fracture strength of three-unit fixed partial denture in lithium disilicate, press versus milled, *in-vitro study*

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Original article

Biaxial flexural strength and translucent characteristics of dental lithium disilicate glass ceramics with different translucencies

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ABSTRACT

Purpose: The aim of this study was to evaluate the biaxial flexural strength and translucent characteristics of dental lithium disilicate glass ceramics with different translucencies.
Methods: Two heat pressed lithium disilicate glass ceramics (IPS e.max Press and an experimental ceramic) and one computer aided design/ computer aided manufacture (CAD/CAM) lithium disilicate glass ceramic (IPS e.max CAD) with different translucencies were evaluated. Disk-shaped specimens of each group were subjected to a biaxial flexural strength (BFS) test. Translucent parameters (TP) were also tested at 0.5 mm and 1.0 mm thickness, respectively. X-ray diffraction (XRD) and SEM were used for crystalline and microstructural analysis.
Results: BFS values of two heat pressed lithium disilicate glass ceramics were significantly higher than the CAD/CAM counterpart. No difference in BFS between two heat pressed glass ceramic was found. There were significant differences in BFS and TP values among the tested subgroups with different translucencies for IPS e.max Press and IPS e.max CAD. No difference in crystalline composition was found among the tested glass ceramics, but microstructure with shorter and wider crystal was revealed for IPS e.max CAD ceramics.
Conclusions: Lithium disilicate glass ceramics with different translucencies demonstrated different BFS and TP values.

1. Introduction

As a result of the increased esthetical demand, lithium disilicate glass ceramics have been predominately advocated for dental prosthetic rehabilitation due to their excellent biocompatibility and esthetics [1,2]. Currently, there are two kinds of lithium disilicate glass ceramics are available in the market, heat pressed ceramic represented by a commercial product named IPS e.max Press and computer aided design/computer aided manufacture (CAD/CAM) ceramic named IPS e.max CAD, respectively [3]. Besides of those commercial products, previous studies also developed an experimental lithium disilicate glass ceramic for dental restorative application using heat pressing technique [4–6].

Heat pressed lithium disilicate glass ceramic ingots are fully crystallized and available in different translucency or opacity [7,8]. After heat pressing treatment, the ingots could be pressed into designed shape such as crowns or inlays [9]. Usually, CAD/CAM lithium disilicate glass ceramic blocks are partially crystallized to facilitate the milling controlled by computer. After milling, the restoration undergoes a post-milling heat treatment for final crystallization to achieve the designed strength and optical characteristic [10]. CAD/CAM technology enabled dental clinicians to finish the restoration in a single appointment [11].

There has been a debate on whether different processing techniques would lead to different strength of the final dental ceramic restoration. CAD/CAM glass-infiltrated zirconia-reinforced ceramics showed better mechanical properties then the traditional slip-cast material, attributed to the consistent processing [12]. However, other study showed that a CAD/CAM processing does not necessarily mean better mechanical properties [13]. As for lithium disilicate glass ceramics, controversial results were also reported in different research [3,14]. It seems that the effect of processing techniques of dental glass ceramics on the final strength remain unclear and need to be investigated.

In esthetic dentistry, an important parameter of the glass ceramic deserving better understanding is the translucency. The fabricated ceramic restoration should mimic the different

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ORIGINAL ARTICLE

Flexural properties of three lithium disilicate materials: An in vitro evaluation

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KEYWORDS

Lithium disilicate;
Ceramics;
CAD-CAM;
Heat press

Abstract *Objective:* The goal of this study was to investigate the flexural strength, Young's modulus and Weibull modulus of two heat-pressed and one CAD/CAM processed lithium disilicate (LD) ceramics.

Material and methods: A total of 45 specimens with dimensions 16 × 4 × 1.2 ± 0.2 mm were fabricated out of three LD ceramics. For heat-pressed LD specimens, acrylate polymer blocks were cut and divided into two groups ($n = 15$ per group); a GC LiSi Press LD group (LP) and an IPS e.max Press group (EP). Specimens for each group were pressed corresponding to the manufacturer's recommendations. For the CAD-CAM Group (EC), IPS e.max CAD blocks were cut to obtain specimens ($n = 15$) to the desired dimensions. Flexural strength and Young's modulus tests were executed using a universal testing machine. A one-way ANOVA and post-hoc Tuckey's tests were applied to analyze the results ($p \leq 0.05$).

Results: Regarding flexural strength, the EC group showed higher statistically substantial difference than the EP and LP groups ($p = 0.001$), while there was no pronounced difference between the EP and LP groups ($p = 0.065$). For Young's modulus test, all the three tested groups had no statistically substantial difference ($p = 0.798$).

Conclusion: The IPS e.max CAD group had higher mechanical performance than the IPS e.max Press and GC LiSi Press groups.

1. Introduction

Due to its esthetic appearance and favorable mechanical properties, dental ceramics have become the material of choice in restoring partial loss of the coronal tooth structure (Robert Kelly, 2004). Ceramics can be categorized based on their composition into polycrystalline, crystalline based with glass fillers, glass-based with crystalline fillers, and glass-based ceramics. Incorporation of crystals in ceramics is to enhance the mechan-

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Corrosion effect on the flexural strength & micro-hardness of ips e-max ceramics

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ABSTRACT

Objectives: The effect of ceramics construction (pressable, machinable) and corrosion on flexural strength and micro-hardness was studied. Materials & Methods: Two types of ceramics were tested: IPS e-max Press and IPS e-max CAD. Forty samples were constructed and divided into 2 groups according to the type of ceramics. Each group was then subdivided into 2 subgroups. Subgroups 1 were not subjected to corrosion while subgroups 2 were subjected to corrosion test. Finally each subgroup was divided into 2 classes according to the type of test: biaxial flexural strength, micro-hardness. Results: There was a significant difference between the two tested ceramics as regard weight loss as IPS e-max CAD recorded less weight loss than IPS e-max Press. As regard the flexural strength, IPS e-max CAD recorded significant higher strength than IPS e-max Press. Corroded samples recorded significant lower flexural strength than non-corroded samples for the two tested ceramics. As regard the Vickers micro-hardness test, the results showed significant difference between the two tested ceramics. IPS e-max CAD recorded higher micro-hardness values than IPS e-max Press. The results also showed that the corroded samples recorded no significant micro-hardness values than non- corroded samples for the two tested ceramics. Conclusions: IPS e-max CAD recorded less weight loss weight loss after being subjected to corrosion test than IPS e-max Press. The method of fabrication affected the flexural strength &micro-hardness of ceramic as machinable ceramic (e-max CAD) recorded significant higher data than pressable ceramic (e-mas Press). Corrosion decreased the flexural strength of both tested ceramics but had no effect on micro-hardness.

Keywords: IPS E-Max; Corrosion; Flexural Strength; Micro-Hardness

1. INTRODUCTION

Advanced progress in technology and research of new dental materials has resulted in an increased number of all-ceramic systems. Several processing techniques are available for fabricating all-ceramic restoration: sintering, heat pressing, infiltration, casting and machining. [1,2] Recently, IPS e-max is an innovative all-ceramic system which covers the entire all-ceramics indication range from thin veneers to 10 units FPDs. IPS e-max delivers high strength and high esthetic materials for the press and the CAD/CAM technologies [3].

IPs e-max Press (Ivoclar Vivadent) consists of a lithium-disilicate pressed glass ceramic, but its physical properties and translucency are improved through different firing processes compared to IPs Empress 2. E-max press is a pressed glass-ceramic ingot (lithium disilicate crystals). The lithium disilicate crystals prevent the propagation of microcracks and contribute to the esthetic translucency of the Ips e.max press restorations. [4].

IPs e.max CAD is a lithium disilicate glass-ceramic block for the CAD/CAM technique. It is fabricated using an innovative process which provides an impressive homogeneity of the material. The block can be processed very easily in a CAD/CAM unit in this crystalline intermediate stage. The typical and striking color of IPs e. max CAD ranges from whitish to blue and bluish-grey microstructure of the glass-ceramic. IPs e.max CAD combines uniqueness and high performance. The innovative lithium disilicate ceramic fulfills the highest esthetic demands and unites state of the art technology with exceptional user-friendliness [5].

The CEREC in-Lab system is an evolution from the dentist-based CERECIII system. CEREC in-Lab is based on the same technology as the chairside system, with the addition of laser measurement technology. The system is a self-contain scanning and milling unit designed to fabricate single copings and three-unit FPD frameworks. The die to be scanned is placed in the system and is op-

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Flexural resistance of heat-pressed and CAD-CAM lithium disilicate with different translucencies

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ABSTRACT

Objective. To compare flexural strength of CAD-CAM and heat-pressed lithium disilicate.
Methods. For Pressed specimens (Group A), acrylate polymer blocks were cut with a saw in bars shape. Sprueing, investing and preheating procedures were carried out following manufacturer's instructions. IPS e.max Press ingots (Ivoclar-Vivadent) were divided into subgroups (n = 15) according to translucency: A.1 = HT-A3; A.2 = MT-A3; A.3 = LT-A3; A.4 = MO2. Ingots were then pressed following manufacturer's instructions. For CAD-CAM specimens (Group B) blocks of IPS e.max CAD (Ivoclar-Vivadent) were divided into subgroups: B.1 = HT-A3; B.2 = MT-A3; B.3 = LT-A3; B.4 = MO2. Specimens (n = 15) were obtained by cutting the blocks with a saw. Final crystallization was performed following manufacturer's instructions. Both Press and CAD specimens were polished and finished with silica carbide papers of increasing grit. Final dimensions of the specimens were 4.0 ± 0.2 mm, 1.2 ± 0.2 mm, and 16.0 ± 0.2 mm. Specimens were tested using a three-point bending test. Flexural strength, Weibull modulus, and Weibull characteristic strength were calculated. Flexural strength data were statistically analyzed.
Results. The overall means of Press and CAD specimens did not differ significantly. Within the Press group different translucencies were found to have similar flexural strength. Within the CAD group, statistically significant differences emerged among the tested translucencies ($p < 0.001$). Specifically, MT had significantly higher flexural strength than HT and MO. Also, LT exhibited significantly higher flexural strength than MO.
Significance. The choice between IPS e.max Press and IPS e.max CAD formulations can be based on different criteria than flexural resistance. Within each formulation, for IPS e.max Press translucency does not affect the flexural strength while for IPS e.max CAD it is an influential factor.

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MICRO-COMPUTED TOMOGRAPHY EVALUATION OF MARGINAL FIT OF LITHIUM DISILICATE CROWNS FABRICATED BY USING CHAIRSIDE CAD/CAM SYSTEMS OR THE HEAT-PRESSING TECHNIQUE

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Statement of problem. No consensus exists concerning the acceptable ranges of marginal fit for lithium disilicate crowns fabricated with either heat-pressing techniques or computer-aided design and computer-aided manufacturing (CAD/CAM) systems.

Purpose. The purpose of the study was to evaluate with micro-computed tomography the marginal fit of lithium disilicate crowns fabricated with different chairside CAD/CAM systems (Cerec or E4D) or the heat-pressing technique.

Material and methods. Lithium disilicate crowns were fabricated to fit an in vitro cast of a single human premolar. Three fabrication techniques were used: digital impressions with Cerec 3D Bluecam scanner with titanium dioxide powder, followed by milling from IPS e.max CAD for Cerec; digital impressions with E4D Laser scanner without powder, followed by milling from IPS e.max CAD for E4D; and fabrication from IPS e.max Press by using the lost-wax and heat-pressing techniques. Each crown was fixed to the cast and scanned with micro-computed tomography to obtain 52 images for measuring the vertical and horizontal fit. Data were statistically analyzed by 1-way ANOVA, followed by the Tukey honestly significant difference test (α=.05).

Results. The mean values of vertical misfit were 36.8 ±13.9 µm for the heat-pressing group and 39.2 ±8.7 µm for the Cerec group, which were significantly smaller values than for the E4D group at 66.9 ±31.9 µm (P=.046). The percentage of crowns with a vertical misfit <75 µm was 83.8% for Cerec and heat-pressing, whereas this value was 65% for E4D. Both types of horizontal misfit (underextended and overextended) were 49.2% for heat-pressing, 50.8% for Cerec, and 58.8% for E4D.

Conclusions. Lithium disilicate crowns fabricated by using the Cerec 3D Bluecam scanner CAD/CAM system or the heat-pressing technique exhibited a significantly smaller vertical misfit than crowns fabricated by using an E4D Laser scanner CAD/CAM system. (J Prosthet Dent 2014;■:■-■)

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The marginal discrepancy of lithium disilicate onlays: Computer-aided design versus press

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Abstract

Aim:

The aim of the study was to evaluate and compare the vertical marginal discrepancy of computer-aided design (CAD)/computer-aided manufacturing (CAM) and pressable lithium disilicate onlays.

Materials and Methods:

A maxillary first premolar typodont tooth was prepared to receive lithium disilicate onlay. Mesio-occluso-distal cavity was prepared with palatal cusp reduction and collar preparation. In the proximal box, gingival seat was placed 1 mm coronal to the cementoenamel junction and mesiodistal width of the seat was kept to 1 mm. Thirty stone models were prepared from thirty rubber base impressions and divided into two groups, based on the technique of fabrication of onlays: (1) Group CL (CAD/CAM lithium disilicate) and (2) Group PL (Pressable lithium disilicate). Fifteen onlays per each group were fabricated by following the manufacturer instructions. Marginal fit of all the samples were analyzed by using stereomicroscope with Image Analysis software. Statistical analysis was done by *t*-test.

Results:

Statistical significant difference was found between both the groups. The lowest marginal discrepancy (41.46 μm) was measured for Group CL (CAD/CAM lithium disilicate) specimens, and the highest (55.95 μm) discrepancy was observed on the Group PL (Pressable lithium disilicate) specimens.

Conclusion:

Although there was a statistically significant difference between the two groups, marginal gap of both the groups were in clinically acceptable levels.

Keywords: All-ceramics, computer-aided design/computer-aided manufacturing, lithium disilicate, marginal gap, onlays

INTRODUCTION

The final goal of restorative dentistry is to fabricate the restorations similar to natural teeth. Ceramics are the best materials when esthetic restorations are demanded.[1] Esthetic and conservative treatment options for teeth weakened by caries or fractures are tooth-colored partial-coverage indirect restorations.[2] In particular, all-ceramic restorations have acquired popularity because of patient demands for highly esthetic restorations for severely compromised posterior teeth. As all-ceramic partial coverage restorations can be luted with adhesive-luting cement, these can be an alternative to the conventional traditional full-coverage crown in restoring weakened or missing tooth structure.[3] Exceptional esthetics and excellent biocompatibility are further advantages.[4] Especially, lithium disilicate has got utmost popularity in dental practice, presenting undebatable benefits.[5]

Lithium disilicate is a glassy ceramic that composed of quartz, lithium dioxide, oxides of phosphor and potassium, alumina, and other components. IPS e.max lithium disilicate is one of the all-ceramic materials where lithium disilicate crystals (SiO_2–LiO_2) are embedded into a glass matrix to minimize microcrack propagation, thereby enhancing mechanical stability. It was introduced in 2005 by Ivoclar Vivadent (AG, Schaan, Liechtenstein).[6]

MARGINAL AND INTERNAL ADAPTATION OF CERAMIC CROWN RESTORATIONS FABRICATED WITH CAD/CAM TECHNOLOGY AND THE HEAT-PRESS TECHNIQUE

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Statement of problem. The accuracy of chairside computer-aided design and computer-aided manufacturing (CAD/CAM) restorations is questionable, and the effect of the die spacer settings is not well stated in the literature.

Purpose. The purpose of the study was to evaluate the marginal and internal adaptation of E4D crowns fabricated with different spacer thicknesses and to compare these crowns with those fabricated with the heat-press technique.

Material and methods. The E4D system was used to fabricate 30 crowns for the first 3 groups, with different spacer thickness settings: 30 µm, 60 µm, and 100 µm. In the fourth group, 10 lithium disilicate crowns were fabricated with the heat-press technique. The occlusal gap, axial gap, vertical marginal gap, and absolute marginal discrepancy were evaluated by x-ray microtomography. Statistical significance was assessed with the Kruskal-Wallis test (α=.05). For post hoc analyses, the Mann-Whitney *U* test was used alongside the Bonferroni correction for multiple comparisons (α=.008).

Results. Within the CAD/CAM groups, the 30-µm spacer thickness resulted in the lowest median axial gap (90.04 µm), whereas the 60-µm spacer thickness resulted in the lowest median occlusal gap (152.39 µm). The median marginal gap values of the CAD/CAM-60 group (49.35 µm) and CAD/CAM-100 group (46.65 µm) were lower than those of the CAD/CAM-30 group (55.18 µm). No significant differences among the CAD/CAM groups were observed for absolute marginal discrepancy. The heat-press group had significantly different values than those of the CAD/CAM groups.

Conclusion. The spacer thickness and fabrication technique affected the adaptation of ceramic crowns. The heat-press group yielded the best marginal and internal crown adaptation results. The 30- or 60-µm spacer settings are recommended for the E4D CAD/CAM system. (J Prosthet Dent 2014;■:■-■)

CLINICAL IMPLICATIONS

The results of this study may aid in the clinical determination of the most accurate spacer thickness settings for the optimal adaptation of CAD/CAM crown restorations, thereby improving clinical success and longevity.

Crown adaptation along with esthetic value and fracture resistance are important to the clinical success and longevity of crown restorations.[1-7] Crown adaptation is defined by the measurements of the marginal and internal gaps of crown restorations. Holmes et al[8] stated that the internal gap is the perpendicular distance from

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Micro-CT Evaluation of Ceramic Inlays: Comparison of the Marginal and Internal Fit of Five and Three Axis CAM Systems with a Heat Press Technique

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ABSTRACT

Objectives: To evaluate the marginal and internal adaptation of CAD/CAM lithium-disilicate inlay restorations fabricated by two milling systems (Five and Three-axis), and a traditional heat-press technique.
Methods: Fifteen premolar teeth with an MOD cavity preparation were fabricated. Lithium-disilicate inlay restorations were obtained by three fabrication techniques and fitted to their dies ($n = 15$/gp) as follows: *Group-1*, three-axis milling system, *Group-2*, five-axis milling system, *Group-3*, conventional heat-press technique. Gaps were evaluated by X-ray microtomography. Marginal gap (MG), occlusal-marginal gap (OMG), proximal-marginal gap (PMG), gingival-marginal gap (GMG), absolute marginal discrepancy (AMD), axial-internal gap (AIG), and occlusal-internal gap (OIG) were evaluated at 120 different points per inlay. Data were analyzed using repeated measures ANOVA. Pairwise comparisons were conducted for post-hoc testes and the Bonferroni correction was used to adjust for multiple comparisons ($\alpha = 0.007$).
Results: The heat-press group demonstrated significantly smaller mean-values amongst all outcomes compared with CAD/CAM groups except for GMG, where there was no statistically significant difference between groups in the ANOVA ($p = 0.042$). Within the CAD/CAM groups, the five-axis group showed significantly lower OMG mean-value compared with the three-axis group $p < 0.001$, and lower AIG mean-value compared with the three-axis group $p < 0.001$. There was no significant difference between the five-axis and the three-axis groups' AMD, MG, PMG, and OIG locations.
Conclusion: Different fabrication techniques affected the marginal and internal adaptation of ceramic inlay restorations. The heat-press group showed the best marginal and internal adaptation results; however, in every group, all samples were within the clinically acceptable MG limit (100 μm).

CLINICAL SIGNIFICANCE

The marginal fit and internal adaptation of inlay ceramic restorations fabricated by a five-axis milling system have not been tested or compared with those fabricated by three-axis machines and the conventional heat-press method. The preferred method of inlay fabrication, whether in the lab or chair side, may be influenced by the results of this study and could affect future clinical decision-making.

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3D and 2D Marginal Fit of Pressed and CAD/CAM Lithium Disilicate Crowns Made from Digital and Conventional Impressions

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Keywords
All-ceramic restoration; CAD/CAM; digital impression; marginal fit; technology; triple-scan protocol.

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Abstract

Purpose: This in vitro study evaluated the 3D and 2D marginal fit of pressed and computer-aided-designed/computer-aided-manufactured (CAD/CAM) all-ceramic crowns made from digital and conventional impressions.
Materials and Methods: A dentoform tooth (#30) was prepared for an all-ceramic crown (master die). Thirty type IV definitive casts were made from 30 polyvinyl siloxane (PVS) impressions. Thirty resin models were produced from thirty Lava Chairside Oral Scanner impressions. Thirty crowns were pressed in lithium disilicate (IPS e.max Press; 15/impression technique). Thirty crowns were milled from lithium disilicate blocks (IPS e.max CAD; 15/impression technique) using the E4D scanner and milling engine. The master die and the intaglio of the crowns were digitized using a 3D laser coordinate measurement machine with accuracy of ±0.00898 mm. For each specimen a separate data set was created for the Qualify 2012 software. The digital master die and the digital intaglio of each crown were merged using best-fitting alignment. An area above the margin with 0.75 mm occlusal-gingival width circumferentially was defined. The 3D marginal fit of each specimen was an average of all 3D gap values on that area. For the 2D measurements, the marginal gap was measured at two standardized points (on the margin and at 0.75 mm above the margin), from standardized facial-lingual and mesial-distal digitized sections. One-way ANOVA with post hoc Tukey's honestly significant difference and two-way ANOVA tests were used, separately, for statistical analysis of the 3D and 2D marginal data (alpha = 0.05).
Results: One-way ANOVA revealed that both 3D and 2D mean marginal gap for group A: PVS impression/IPS e.max Press (0.048 mm ± 0.009 and 0.040 mm ± 0.009) were significantly smaller than those obtained from the other three groups ($p < 0.0001$), while no significant differences were found among groups B: PVS impression/IPS e.max CAD (0.088 mm ± 0.024 and 0.076 mm ± 0.023), C: digital impression/IPS e.max Press (0.089 mm ± 0.020 and 0.075 mm ± 0.015) and D: digital impression/IPS e.max CAD (0.084 mm ± 0.021 and 0.074 mm ± 0.026). The results of two-way ANOVA revealed a significant interaction between impression techniques and crown fabrication methods for both 3D and 2D measurements.
Conclusions: The combination of PVS impression method and press fabrication technique produced the most accurate 3D and 2D marginal fits.

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RESEARCH ARTICLE

WILEY

Comparison of marginal and internal fit of pressed lithium disilicate veneers fabricated via a manual waxing technique versus a 3D printed technique

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Abstract

Objective: The purpose of this in vitro study was to compare the marginal and internal fit of pressed lithium disilicate veneers fabricated from a 3D printed castable wax resin versus a manual waxing technique.

Materials and Methods: A typodont model central incisor was prepared for a porcelain veneer. Following stone model fabrication from a polyvinyl siloxane impression, the model was digitized using a laboratory scanner. Group 1 veneers were designed digitally and 3D printed with a castable wax resin, then pressed. Group 2 veneers were fabricated using a manual wax and press approach. Veneers from both groups were bonded to printed dies. Following measurements of marginal adaptation under a stereo microscope, the dies were sectioned and measurements were made for internal adaption. Statistical analysis included a Kolmogorov test and a Mann–Whitney U test.

Results: Average marginal gap (μm) for Group 1 was 40.37 ± 11.75 and 50.63 ± 16.99 for Group 2 (p = 0.51). Average internal gap (μm) for Group 1 was 61.21 ± 18.20 and 68.03 ± 14.07 for Group 2 (p = 0.178).

Conclusion: There was no difference in marginal fit or internal fit between pressed lithium disilicate veneers fabricated with a 3D printed castable resin and those fabricated with a manual waxing technique. The use of digital technologies and 3D printing provide significant advantages in the fabrication of pressed glass ceramic veneers, with marginal and internal adaptation comparable to manual wax and press techniques.

KEYWORDS
CAD/CAM, ceramics, dental materials, digital dentistry, laboratory technology

1 | INTRODUCTION

Conventionally fabricated porcelain veneers, whether pressed or stacked, have an excellent track record of success for the management of esthetic and functional problems in anterior teeth.[1-5] The introduction of digital technology has expanded the number of methods available for the fabrication of porcelain veneers. Today, there are four possible methods to fabricate ceramic veneers: (a) The stacking of feldspathic ceramic on platinum foil-covered refractory dies; (b) Waxing on stone dies and subsequent vacuum pressing using a lost wax technique; (c) Computer-aided design (CAD) followed by milling from a ceramic block via subtractive computer-aided manufacturing

The marginal fit of lithium disilicate crowns: Press vs. CAD/CAM

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Abstract: This study aimed to compare the vertical marginal gap of teeth restored with lithium disilicate crowns fabricated using CAD/CAM or by pressed ceramic approach. Twenty mandibular third molar teeth were collected after surgical extractions and prepared to receive full veneer crowns. Teeth were optically scanned and lithium disilicate blocks were used to fabricate crowns using CAD/CAM technique. Polyvinyl siloxane impressions of the prepared teeth were made and monolithic pressed lithium disilicate crowns were fabricated. The marginal gap was measured using optical microscope at 200× magnification (Keyence VHX-5000, Japan). Statistical analysis was performed using Wilcoxon test. The lithium disilicate pressed crowns had significantly smaller ($p = 0.006$) marginal gaps (38 ± 12 µm) than the lithium disilicate CAD/CAM crowns (45 ± 12 µm). This research indicates that lithium disilicate crowns fabricated with the press technique have measurably smaller marginal gaps compared with those fabricated with CAD/CAM technique within in vitro environments. The marginal gaps achieved by the crowns across all groups were within a clinically acceptable range.

Keywords: Crowns; Marginal Fit, Press, CAD/CAM, Lithium Disilicate

Declaration of Interest: The authors certify that they have no commercial or associative interest that represents a conflict of interest in connection with the manuscript.

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Introduction

Lithium disilicate is a ceramic material that is recommended for the fabrication of dental restorations including single crowns and short span fixed dental prostheses. The material is available in pre-sintered blocks for chairside milling using CAD/CAM systems.[1] With this method, clinicians can fabricate restorations during a single visit by using intraoral digital impressions and in-office milling.[2] Following the initial stages of fabrication, crowns must be heat-treated to allow the crystallization process to take place and to achieve maximum strength.[3,4] Lithium disilicate restorations can also be fabricated using the lost-wax, pressed ceramic technique. Ingots of lithium disilicate are heat-pressed into a mold within the ceramic furnace to obtain the desired shape after the wax burn-out.[5,6] Regarding the strength of the material, pressed lithium disilicate is 11% stronger than the CAD/CAM lithium disilicate according to Ivoclar's 2011scientific report.

The recent FDI document on oral health states that modern dentistry should provide oral care that allow patients to achieve an improved oral health status.[7] One factor that should be considered is the fit of the prosthesis to the tooth.[8]

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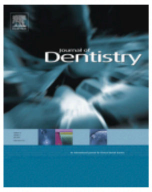

Marginal and internal fit of heat pressed versus CAD/CAM fabricated all-ceramic onlays after exposure to thermo-mechanical fatigue

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ABSTRACT

Objectives: The aim of the study was to evaluate the marginal and internal fit of heat-pressed and CAD/CAM fabricated all-ceramic onlays before and after luting as well as after thermo-mechanical fatigue.

Materials and methods: Seventy-two caries-free, extracted human mandibular molars were randomly divided into three groups ($n = 24$/group). All teeth received an onlay preparation with a mesio-occlusal–distal inlay cavity and an occlusal reduction of all cusps. Teeth were restored with heat-pressed IPS-e.max-Press* (IP, *Ivoclar-Vivadent) and Vita-PM9 (VP, Vita-Zahnfabrik) as well as CAD/CAM fabricated IPS-e.max-CAD* (IC, Cerec 3D/InLab/Sirona) all-ceramic materials. After cementation with a dual-polymerising resin cement (VariolinkII*), all restorations were subjected to mouth-motion fatigue (98 N, 1.2 million cycles; 5 °C/55 °C). Marginal fit discrepancies were examined on epoxy replicas before and after luting as well as after fatigue at 200× magnification. Internal fit was evaluated by multiple sectioning technique. For the statistical analysis, a linear model was fitted with accounting for repeated measurements.

Results: Adhesive cementation of onlays resulted in significantly increased marginal gap values in all groups, whereas thermo-mechanical fatigue had no effect. Marginal gap values of all test groups were equal after fatigue exposure. Internal discrepancies of CAD/CAM fabricated restorations were significantly higher than both press manufactured onlays.

Conclusions: Mean marginal gap values of the investigated onlays before and after luting as well as after fatigue were within the clinically acceptable range. Marginal fit was not affected by the investigated heat-press versus CAD/CAM fabrication technique. Press fabrication resulted in a superior internal fit of onlays as compared to the CAD/CAM technique.

Clinical relevance: Clinical requirements of 100 μm for marginal fit were fulfilled by the heat-press as well as by the CAD/CAM fabricated all-ceramic onlays. Superior internal fit was observed with the heat-press manufacturing method. The impact of present findings on the clinical long-term behaviour of differently fabricated all-ceramic onlays warrants further investigation.

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A COMPARISON OF THE MARGINAL FIT OF CROWNS FABRICATED WITH DIGITAL AND CONVENTIONAL METHODS

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Statement of problem. Little evidence is available with regard to the marginal fit of crowns fabricated with digital impressions and computer-aided design/computer-aided manufacturing technology in comparison with crowns fabricated from conventional techniques.

Purpose. The purpose of this study was to determine and compare the marginal fit of crowns fabricated with digital and conventional methods.

Material and methods. The maxillary right second premolar was prepared for a ceramic crown in a typodont. The typodont was then digitized with a laboratory scanner, and the digital file was used to mill a replica of the maxillary arch from a monolithic block of yttria-stabilized zirconia to serve as the master model. Digital impressions of the prepared maxillary right second premolar were recorded with a scanning unit. Scan files were exported as .STL files and sent by e-mail to a dental laboratory. The files were input into a digital design workflow for digital articulation, digital waxing, and design of the definitive crown. Fifteen crowns were produced by milling computer-aided designed lithium disilicate glass ceramic blocks with a 5-axis milling. Fifteen lithium disilicate glass ceramic crowns were produced with a conventional impression and a laboratory fabrication method. The original zirconia die was removed from the zirconia master model to evaluate the crown margins. Circumferential marginal gap measurements were made at 8 measurement locations: mescal, distal, buccal, palatal and associated line angles (mesiobuccal, mesiolingual, distobuccal, and distolingual). Measurements were made to determine the vertical component of the marginal gap according to the definition of marginal fit.

Results. A total of 240 images (2 groups, 15 crowns per group, 8 sites per crown) were recorded and measured. The overall mean ±SD vertical gap measurement for the digitally made crowns was 48 ±25 µm, which was significantly smaller than that for the conventionally made crowns (74 ±47 µm).

Conclusion. The fully digital fabrication method provided better margin fit than the conventional method. (J Prosthet Dent 2014;■:■-■)

CLINICAL IMPLICATIONS

Ceramic crowns fabricated by using digital impressions and computer-aided design/computer-aided manufacturing technology had a better marginal fit than those created from conventional techniques.

Computer-aided design/computer-aided manufacturing (CAD/CAM) is increasingly being used by dental laboratories to fabricate dental prostheses.[1] The implementation of this digital method has decreased manufacturing costs by reducing technician time and material costs while increasing productivity.[2] More recently, the use of intraoral digital scanners to create virtual impressions has allowed dentists to eliminate the use of impression materials, identify preparation margins, evaluate interocclusal space, and design prostheses. Francois Duret envisioned the use of digital technology in dentistry in 1973; specifically the use of an intraoral optical image to create a definitive prosthesis.[3,4] The integration of digital imaging, digital design, and digitally controlled machining was

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Internal and marginal fit Of pressed and cad lithium disilicate crowns made from digital and conventional impressions

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Micro-computed tomography evaluation of marginal fit of lithium disilicate crowns fabricated by using chairside CAD/CAM systems or the heat-pressing technique

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Statement of problem. No consensus exists concerning the acceptable ranges of marginal fit for lithium disilicate crowns fabricated with either heat-pressing techniques or computer-aided design and computer-aided manufacturing (CAD/CAM) systems.

Purpose. The purpose of the study was to evaluate with micro-computed tomography the marginal fit of lithium disilicate crowns fabricated with different chairside CAD/CAM systems (Cerec or E4D) or the heat-pressing technique.

Material and methods. Lithium disilicate crowns were fabricated to fit an in vitro cast of a single human premolar. Three fabrication techniques were used: digital impressions with Cerec 3D Bluecam scanner with titanium dioxide powder, followed by milling from IPS e.max CAD for Cerec; digital impressions with E4D Laser scanner without powder, followed by milling from IPS e.max CAD for E4D; and fabrication from IPS e.max Press by using the lost-wax and heat-pressing techniques. Each crown was fixed to the cast and scanned with micro-computed tomography to obtain 52 images for measuring the vertical and horizontal fit. Data were statistically analyzed by 1-way ANOVA, followed by the Tukey honestly significant difference test (α=.05).

Results. The mean values of vertical misfit were 36.8 ±13.9 µm for the heat-pressing group and 39.2 ±8.7 µm for the Cerec group, which were significantly smaller values than for the E4D group at 66.9 ±31.9 µm (P=.046). The percentage of crowns with a vertical misfit <75 µm was 83.8% for Cerec and heat-pressing, whereas this value was 65% for E4D. Both types of horizontal misfit (underextended and overextended) were 49.2% for heat-pressing, 50.8% for Cerec, and 58.8% for E4D.

Conclusions. Lithium disilicate crowns fabricated by using the Cerec 3D Bluecam scanner CAD/CAM system or the heat-pressing technique exhibited a significantly smaller vertical misfit than crowns fabricated by using an E4D Laser scanner CAD/CAM system. (J Prosthet Dent 2014;■:■-■)

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