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Flexural strength of Lithium Disilicate Based Glass Ceramic Blocks for CAD/CAM

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Flexural strength of Lithium Disilicate Based Glass Ceramic Blocks for CAD/CAM

A Master's Thesis
Submitted to the Department of Dentistry
And the Graduate School of Yonsei University
In partial fulfillment of the
Requirements for the degree of
Master of Dental Science

Seongwuk Kim

December 2023

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This certifies that the Master's Thesis of

Seongwuk Kim is approved.

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2023년 12월

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Abstract

Flexural Strength of Lithium Disilicate Based Glass Ceramics Blocks for CAD/CAM

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(Directed by Professor Byoung-Duck Roh, D.D.S., M.S.D., Ph.D.)

The purpose of this study is to evaluate flexural strength and other mechanical properties of CEREC Tessera ™, a new lithium disilicate CAD/CAM block and to compare it with IPS e.max® CAD which is widely used for dental restorations of CAD/CAM system.

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Fifteen specimens (length:15.0mm; width:4.0mm; thickness:3.0mm, ISO6872) each were fabricated from the two materials (IPS e.max® CAD, CEREC Tessera™). Every side of specimens was polished with wet silicon paper and sintered with Universal Glaze (Dentsply Sirona, Charlotte, NC, USA) as each manufacturer instruction.

To measure flexural strength, 3-point bending test was done with a universal Testing Machine (Instron 3366, Instron, MA, US), a support span of 10mm with a crosshead speed of 1.0mm/min. The Weibull modulus and Young's modulus were calculated from the test data.

Median value of flexural strength of e.max® was 225.3 MPa, and of Tessera™ was 214.0 MPa. There was no statistically significant difference between two groups according to Mann-Whitney test (p=0.852). The Weibull modulus for each group was 7.8167 and 5.2246, respectively. The Weibull characteristic strengths (σ_0), which is the strength at which 63.2% of specimen would fail, were 230.9MPa and 241.1MPa respectively. Likelihood ratio test was used, and there was no significant difference between two groups (p=0.1994). Young's modulus of each group was 9.69(± 0.95)GPa, 10.50(± 0.79)GPa respectively. Student's t-tsest was used and there was significant difference between two groups (p<0.05).

Within the limitation of our study, there is no difference in flexural strength and Weibull modulus between CEREC Tessera™ and IPS e.max® CAD. However, CEREC Tessera™

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has other advantages over IPS e.max® CAD. Therefore, it can be said that CEREC Tessera™ can be successfully used as IPS e.max® CAD.

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Keywords: Glass ceramic; CAD/CAM; 3-point bend test; Flexural strength; Weibull modulus; virgilite

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Flexural strength of Lithium Disilicate Based Glass Ceramic Blocks for CAD/CAM

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(Directed by Professor Byoung-Duck Roh)

I. Introduction

In these days, CAD/CAM (Computer Aided Design/Computer Aided Manufacturing) system is widely used in the production of dental restorations such as inlay or crown. It can be designed using a computer and is made by milling material block. Lithium disilicate is mainly used due to its aesthetics property and mechanical strength.

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Lithium disilicate is a type of glass ceramic. Glass ceramic consists of base glass and crystalline phase. Through crystallization, crystals grow from base glass, and be embedded uniformly in the glass matrix. Glass ceramic has similar properties with glass and ceramic, like esthetics, translucency, low thermal conductivity, adequate strength, biocompatibility, wear resistance, and chemical durability, so it is usefully used in dental area (Fu et al., 2020). But it is brittle like glass and ceramic, so fracture is one of the main causes of failure of glass ceramic restoration. In a retrospective study that evaluated 87,203 restorations made of IPS e.max® CAD (Ivoclar Vivadent, Schaan, Liechtenstein), fracture of restoration was the most frequent cause of failure (Abdulrahman et al., 2021).

To overcome this, CEREC Tessera™ (Dentsply Sirona, Charlotte, NC, USA), a new lithium disilicate block has been released. According to the manufacturer, Tessera™ is lithium disilicate with virgilite and has higher flexural strength than conventional ceramic blocks. The chemical formula of virgilite is γ-$LiAlSi_2O_6$, which is made by increasing the Al_2O_3 content in the base glass. According to previous study that compared Li_2O-SiO_2 based glass ceramic with different amount of Al_2O_3, appropriate amount of Al_2O_3 additive makes it denser and improves its mechanical properties (Hallmann et al., 2018).

To replace previously used material, Tessera™ must have better properties. Rosentritt et al.(2022) showed that Tessera™ wear less than e.max®. According to the study, virgilite crystals are approximately 200 nm in size, which is smaller than lithium disilicate crystals,

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which are 600 nm in size, and can be present between the lithium disilicate crystals to provide a smoother surface and stabilize the glass matrix.

Tessera™ takes less time for firing than e.max® (Table 1). According to the manufacturer, it is already crystalized and only an additional glaze firing is required. In a previous study that analyzed SEM images of it, it is observed that there is no change in the size and number of crystals between before and after firing (Phark and Duarte, 2022).

There are some positive clinical case reports about dental restoration made by Tessera™. Holken et al (Hölken and Dietrich, 2022), reported 7 indirect restoration cases with Tessera™, and there was no failure until 1 year follow up, but there is limitation that its sample size is too small and there is no long-term data.

However, one of the most important properties is ability to resist tensile forces. Because ceramics are brittle material, it is vulnerable to tensile force, so flexural strength is meaningful mechanical property to assess it. Contrary to the manufacturer's claims, previous studies didn't show that Tessera™ has higher flexural strength than e.max®. In the previous study, Tessera™ had lower or similar flexural strength compared to e.max®. Mean flexural strength were e.max®=384.14, Tessera™=243.61MPa (p<0.05) (Reid et al., 2023), e.max®= 424.3, Tessera™= 463.22MPa (p=0.41) (Demirel et al., 2023) respectively.

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To find out whether CEREC Tessera™, a new lithium disilicate CAD/CAM block can be successfully used as IPS e.max® CAD which is widely used for dental restorations with CAD/CAM system or not, present study was conducted.

In the present study, flexural strength which is meaningful mechanical property for glass ceramic was evaluated. Also, in brittle material, fracture can be occurred by small flaw, so measured strength has big deviation between specimens and some specimens can fail well below the mean strength So, its reliability is important factor. In this case, Weibull distribution may be more useful to analyze the data than normal distribution (McCabe and Carrick, 1986). To measure its reliability, Weibull modulus can be used.

Therefore, purpose of this study is to measure flexural strength and Weibull modulus of CEREC Tessera™, a new lithium disilicate CAD/CAM block and to compare it with IPS e.max® CAD which conventionally used for dental restorations of CAD/CAM system. Young's modulus which indicates resistance to bending action also calculated from the experiment data. Scanning electron microscope was used to observe microstructure of two materials.

The null hypothesis of this study was that there would be no difference in (1) flexural strength, (2) Weibull modulus, (3) Young's modulus between CEREC Tessera™ and IPS e.max® CAD.

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II. Materials and methods

1. Specimen preparation

Two kinds of ceramic blocks (IPS e.max® CAD, CEREC Tessera™) were sectioned to 15x4x3mm size using a low-speed diamond cutter (TOPMET METSAW-LS, R&B, Daejeon, Korea) under constant water cooling and 15 specimens of each kind of ceramics were made. The sectioned specimens were manually trimmed under 0.01 mm error with digital vernier caliper and bur. The specimens were polished with wet silicon papers up to 1200-grit. The specimens were fired in a furnace (Austromat 624, Dekema, Bavaria, German) with Universal glaze (Dentsply Sirona, Charlotte, NC, USA) as instructed by the manufactures (Table 1).

Material	Starting temperature	Pre-heating time	Heating rate	Firing temperature	Firing Time	Holding time with vaccum
IPS e.max® CAD	500°C	0 min	1st: 60°C/min 2nd: 30°C/min	770°C 850°C	5 min 10 min	10 min
CEREC Tessera™	400°C	2 min	55°C/min	760°C	2 min	0 min

Table 1. Firing instruction by each manufacturer

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2. 3 point bending test

To measure flexural strength, Weibull modulus, and Young's modulus, 3 point bending test was done using Instron Universal Testing Machine (Instron 3366, Instron, MA, US) with crosshead speed of 1.0mm/min. Fixture for three-point bending, consisting of support rollers positioned with their centers 10 mm apart. The load was applied at the midpoint between the supports until specimen fracture.

3. Flexural strength

Flexural strength, σ can be calculated with equation below.

$$\sigma = \frac{3Pl}{2wb^2}$$

where

P is the breaking load, in newtons;

l is the test span (center-to-center distance between support rollers), in millimeters;

w is the width of the specimen, i.e. the dimension of the side at right angles to the direction of the applied load, in millimeters;

b is the thickness of the specimen, i.e. the dimension of the side parallel to the direction of the applied load, in millimeters (ISO, 2015)

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4. Weibull modulus & Characteristic strength

To determine the reliability of brittle materials, Weibull modulus of each material was measured from experimental data. The smaller the Weibull modulus, the larger the scatter of the data.

Data that follow Weibull distribution satisfy the equation below.

$$P(\sigma) = 1 - e^{-(\sigma / \sigma_0)^m},$$

where $P(\sigma)$ is the failure probability, σ is the fracture strength, σ_0 is the characteristic strength, and m is the Weibull modulus.

Using a plot with $\ln\ln[1/(1 - P(\sigma)]$ on y-axis and a corresponding $\ln\sigma$ on x-axis and linear regression fit on it, Weibull modulus and characteristic strength can be calculated (ISO, 2015). The Weibull modulus was calculated with MATLAB, R2023a (The MathWorks, Inc., Natick, MA, USA).

5. Young's modulus

Young's modulus, *E* can be calculated with equation below.

$$E = \frac{Fl^3}{4wb^3d}$$

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where

F is the load applied on the center, in newtons;

l is the test span (center-to-center distance between support rollers), in millimeters;

w is the width of the specimen, i.e. the dimension of the side at right angles to the direction of the applied load, in millimeters;

b is the thickness of the specimen, i.e. the dimension of the side parallel to the direction of the applied load, in millimeters

d is the deflection due to the load F. (ISO, 2019)

6. Statistical analysis

The data from the experiment was statistically analyzed using SPSS 26.0 (SPSS Inc., Chicago, IL, USA). Data following normality distribution was analyzed with student's t-test, whereas data not following normal distribution was analyzed with Mann-Whitney test.

Likelihood ratio test was used to know if the two groups have significantly different Weibull parameters or not. It compares the likelihood of that two groups follow same Weibull distribution with the likelihood of that they follow different Weibull distributions.

The significance level was set at p=0.05.

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7. Scanning electron microscope image

Specimens were made as mentioned above. Each specimen was etched with 4% hydrofluoric acid (Porcelain Etchant, BISCO, IL, USA) for 30s, washed with distilled water, cleaned with ultrasonic device, and dried for 24h at room temperature. They were coated with Platinum by ion sputter (EM ACE600, LEICA, Hessen, Germany) and observed with a field emission Scanning Electron Microscopy (MERLIN, ZEISS, Oberkochen, Germany) at an accelerating voltage of 15 kV under x 20,000 magnification.

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III. Results

1. Mechanical properties

Flexural strengths for each group are presented on Table 2. Median value of e.max® was 225.3 MPa, and of Tessera™ was 214.0 MPa. Mann-Whitney test was used for comparison of two groups, because results of Tessera™ didn't follow normal distribution (Shapiro-Wilk test, $p<0.05$). There was no statistically significant difference between two groups ($p=0.852$).

The Weibull modulus for each group were 7.82 and 5.22, respectively. The Weibull characteristic strengths (σ_0), which is the strength at which 63.2% of specimen would fail, were 230.9 and 241.1 respectively. (Table 3., Figure 2.) Likelihood ratio test was used, and there was no significant difference between two groups ($p=0.1994$).

Young's modulus was also calculated from the data. The mean value and standard deviation of e.max® and Tessera™ were 9.69(± 0.95) GPa and 10.50(± 0.79) GPa respectively. (Table.3) Student's T-test was used to compare, and there was significant difference between two groups ($p<0.05$).

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Group (n=15)	Flexural strength (MPa)		
Material	Mean(SD)	Min-Max	Median(Q3-Q1)
IPS e.max® CAD	216.4(± 36.7)	134.4-256.7	225.3(64.3)
CEREC Tessera™	223.7(± 41.8)	153.3-334.6	214.0(27.2)

Table 2. Flexural strength of each group

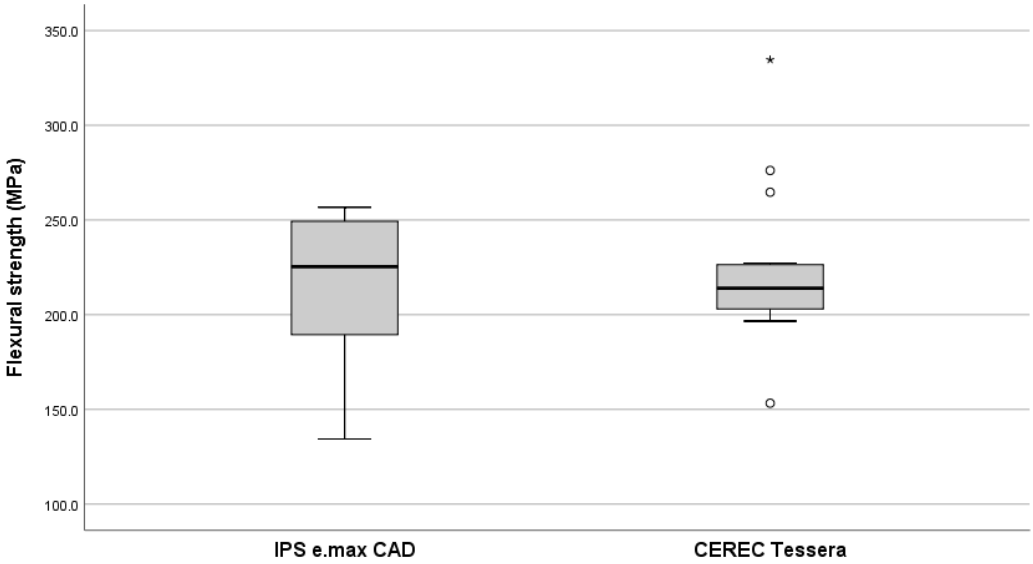

Figure 1. Box plot of flexural strength of glass ceramic.

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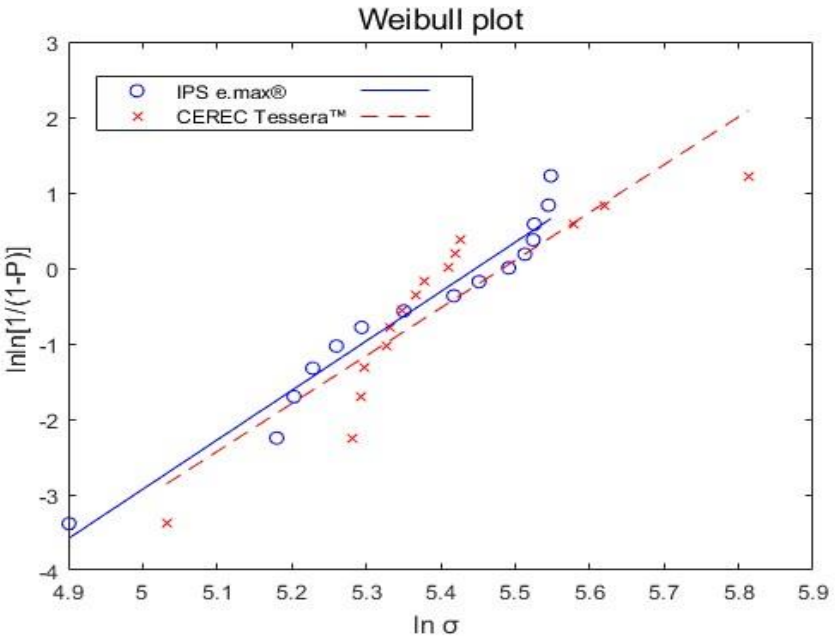

Figure 2. Weibull plot for glass ceramic.

It is Weibull plot with lnln[1/(1-P)] on the y-axis and lnσ on the x-axis. The Weibull modulus *m* is equal to the slope of the linear regression fit (ISO, 2015).

Group (n=15)	Parameters of Weibull distribution		Young's modulus (GPa)
Material	Weibull modulus (95% Confidence Interval)	σ_0 (MPa)	Mean(SD)
IPS e.max® CAD	7.82 (5.11-11.95)	230.9	9.69(± 0.95)
CEREC Tessera™	5.22 (3.69-7.40)	241.1	10.50(± 0.79)

Table 3. Parameters of Weibull distribution and Young's modulus of each group

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2. Scanning electron microscope image

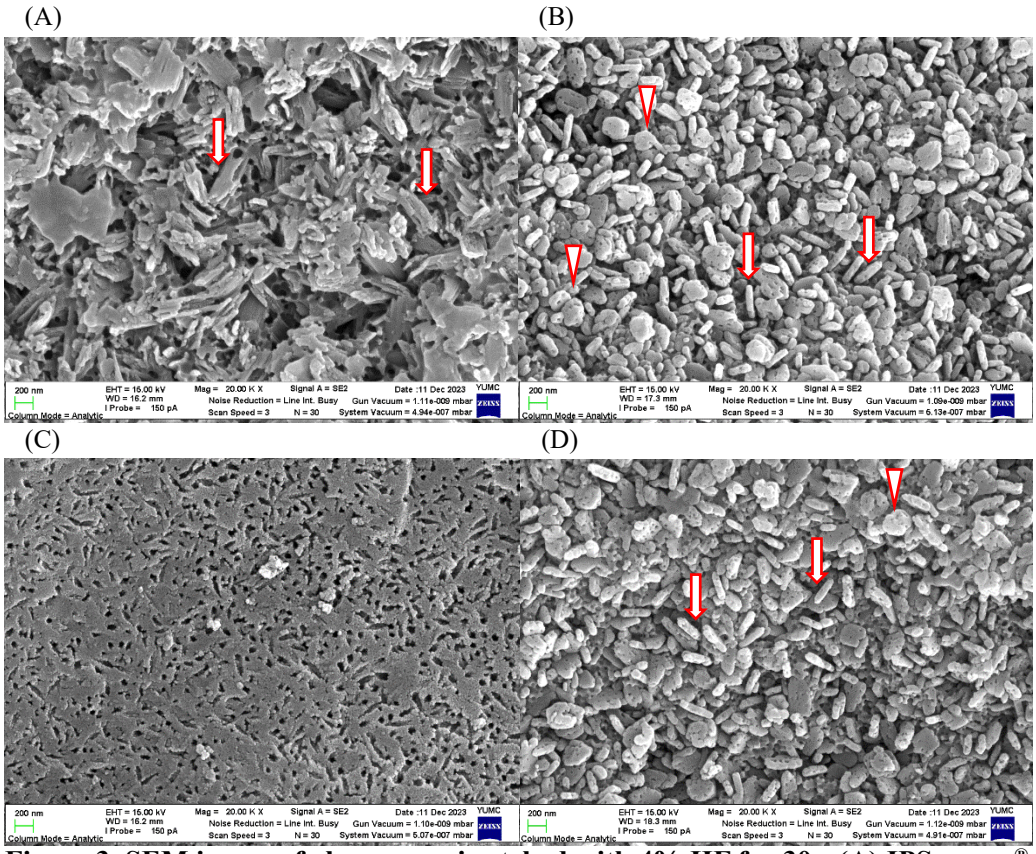

Figure 3. SEM image of glass ceramic etched with 4% HF for 30s. (A) IPS e.max® CAD after firing (B) CEREC Tessera™ after firing (C) IPS e.max® CAD before firing (D) CEREC Tessera™ before firing (magnification x20,000)

Rod-like lithium disilicate crystals (arrow) and Spherical shape virgilite crystals (arrowhead) are observed.

Rod-like lithium disilicate crystals of size over 1.0μm are shown on IPS e.max® CAD only after firing. On the other hand, shorter lithium disilicate crystals which is smaller than 0.5μm are observed on CEREC Tessera™ both before and after firing. Spherical shape virgilite crystals under 0.3μm size are also observed on it.

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IV. Discussion

The hypothesis (1) there would be no difference in flexural strength between CEREC Tessera™ and IPS e.max® CAD was accepted. There was no difference in strength between the two materials in this study (p=0.852). Tessera™ didn't show better strength than e.max®, and this is consistent result with other studies (Reid et al., 2023) (Demirel et al., 2023). But, measured values were lower than previous studies. In the present study, median flexural strength of e.max® was 225.3 MPa, and of Tessera™ was 214.0 MPa. In the previous study, mean flexural strength were e.max®=384.14, Tessera™=243.61MPa with 3 point-bending test (p<0.05) (Reid et al., 2023), and e.max®= 424.3, Tessera™= 463.22MPa with biaxial flexure test (p=0.41) (Demirel et al., 2023).

The Weibull modulus of both materials was also measured. The Weibull modulus is a measure of the reliability of the strength of a brittle material and is represented by the slope of the linear regression fit on Weibull plot. High value of it indicates that there is small deviation between specimens. In this study, the Weibull modulus of e.max® and Tessera™ were 7.8167 and 5.2246, respectively and there was no significant difference between two materials (p=0.1994). So, the hypothesis (2) that there would be no difference in Weibull modulus between CEREC Tessera™ and IPS e.max® CAD was accepted. The results of previous studies (Reid et al., 2023) reported different result with the present study. Compared to Tessera™, e.max® has a higher Weibull modulus in that study (e.max® =14.05, Tessera™=7.92, p<0.05). This means that the strength of e.max® is more reliable, and

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Tessera™ is relatively more likely to fracture at far below the average strength. However, generally, a high Weibull modulus is defined as 20 or more (Bona et al., 2003), and ceramics typically have values between 5~15(Bradt et al., 1983). Therefore, it can be said that Weibull modulus of both materials are within the normal range of ceramics.

Young's modulus of two materials also measured. The hypothesis (3) that there would be no difference in Young's modulus between CEREC Tessera™ and IPS e.max® CAD was rejected. Tessera™ had higher Young's modulus than e.max® and it means that less deformation is occurred at same bending force. Lawson et al. said that "Elastic flexure of crowns under occlusal loading can be credited for creating hoop stresses and microseparation at the interface between the crown and the tooth." (Lawson et al., 2016) In that view, Tessera™ crown has advantage over e.max® crown, because Tessera™ showed higher Young's modulus than e.max® in the present study. (e.max®=9.69, Tessera™=10.50, $p<0.05$)

Tessera™ was expected to have superior mechanical properties to traditional materials. The strength of a ceramic depends on its crystal structure(Wang et al., 2015). Tessera™ is known to have virgilite in it. Virgilite has the chemical formula γ-$LiAlSi_2O_6$ and is made by increasing the Al_2O_3 content of base glass. It is known that it can increase toughness of lithium disilicate glass ceramic because its thermal expansion mismatch between lithium disilicate makes residual stress and microcracks which create crack tip shielding

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(Monmaturapoj et al., 2013). Virgilite was first introduced by French. According to their definition, to be called virgilite, it must have a $LiAlSi_2O_6$ - SiO_2 ratio of at least 50% (French et al., 1978). In some other studies, the requirement is over 25 mol% of $LiAlSi_2O_6$ or under 75 mol% SiO_2 (Covino et al., 1986) (Soares and Zanotto, 2016). However, according to another study (Hurle et al., 2022), measured SiO_2 content of crystal from Tessera™ is 85 mol%, and $LiAlSi_2O_6$ content is 15 mol%. It has higher $LiAlSi_2O_6$ content than Amber® Mill (HASSbio, Kangneung, Korea) and Iinitial™ LiSi Block (GC, Tokyo, Japan), but it does not meet criteria of French nor of other studies (Covino et al., 1986) (Soares and Zanotto, 2016). So Hurle et al,(2022) suggest that the phase from Tessera™ should be rather addressed as stuffed quartz solid solution instead of “virgilite”.

Whether the crystal in it is virgilite or not, high Al_2O_3 content on base glass can be helpful for increasing strength of material. As mentioned above, according to Hallman et al. (Hallmann et al., 2018) appropriate Al_2O_3 additive makes Li_2O-SiO_2 system denser and improves its mechanical property. On the other hand, too much Al_2O_3 additives can affect the microstructure of these glass ceramic negatively. The microstructure becomes denser, but its crystals become spherical shape instead of needle shape. This spherical shape crystal is hard to form interlocked microstructure which is highly important for strength enhancement. So, appropriate concentration of Al_2O_3 additive is important. At the study about effect of Al_2O_3 and K_2O additives on mechanical property of lithium disilicate glass ceramic, the middle concentration group with 2.63 mol% of Al_2O_3 had better mechanical properties than group with 0 mol% or 3.94 mol% (Fernandes et al., 2010). According to

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another study, there is 1.56 mol% of Al_2O_3 in the base glass of Tessera™, and it can be said that it is within appropriate range to enhance its strength (Lubauer et al., 2022).

However, at least in the present study, mechanical properties of two materials were similar. There are some explanations for results of the present study.

Crystal size and shape of lithium disilicate can be the cause. In previous study, e.max® has interlocked 1.5 μm long lithium disilicate crystals on it, while Tessera™ has 0.5 μm long lithium disilicate crystals in a glassy matrix together with 0.2–0.3 μm platelet like virgilite crystal (Phark and Duarte, 2022). In the present study, crystals are observed similarly on scanning electron microscopy images. (Figure 3.) Rod-like lithium disilicate crystals of size over 1.0μm are shown on IPS e.max® CAD, and shorter lithium disilicate crystals which is smaller than 0.5μm with spherical shape virgilite crystals under 0.3μm size are observed on CEREC Tessera™.

Interlocking effect is one of the predominant strengthening mechanisms of glass ceramic. Interlocked crystals of glass ceramic can stop propagation of crack, and it leads to strengthen the glass ceramic (Fu et al., 2020). According to Lubauer et al. (2016), mechanically, crystal sizes over 1 μm benefit the fracture toughness. On the other hands, materials with sub-micro crystal have low fracture toughness despite their high crystal fractions, because too short, small crystal has low interlocking effect. Thus, crystals size and aspect ratio of Tessera™ could be too small to have optimal mechanical strength.

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Of course, bigger crystal is not always better. Thermal expansion coefficient (TEC) of glass and crystal are different with each other, so micro residual stress is caused by different shrinkage of glass and crystal during cooling from transition temperature to room temperature. For leucite glass ceramics, it affects positively. Crystal of leucite glass has higher TEC than glass matrix and it cause residual compressive stress on glass matrix. This compressive stress diverts crack force and improve fracture resistance. But for lithium disilicate glass ceramic, it affects negatively. Lithium disilicate crystal has lower TEC than glass matrix, and it cause tensile compressive stress. It makes lithium disilicate glass ceramic much vulnerable to crack (Li et al., 2016).

Li et al. (2016) divided lithium disilicate specimens into 4 groups and fired at different annealing temperatures. At higher temperature, crystals became larger and longer. Group with larger and longer crystals had stronger interlocking effect but at the same time, higher residual stress was caused. As a result of combination of two effects, group with middle size crystals had the strongest flexural strength.

There are also limitations to this study. According to Mecholsky et al. (1995), preexisting initiating cracks in ceramics can affect the strength. In addition, cracks, bubbles, etc. in the processing of the specimen can significantly reduce the flexural strength (Harrer et al., 2012). The method of this study, which used a cutting machine to cut and manually trim to match the thickness, may cause unnecessary damage to the specimen, and create

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cracks, resulting in errors between specimens and lower strength measurements than the exact value. Compared to a previous study (Reid et al., 2023) that measured flexural strength and Weibull modulus similarly with this study, the results of this study showed a much lower Weibull modulus, suggesting that the specimens in this study may have suffered relatively more damage during processing. If the specimen is fabricated using a milling machine, it will be possible to reduce unnecessary damage and improve the accuracy of the experiment.

In addition, the study about four-point flexural strength of several ceramics found that 25% of fractures initiated at the corner(Bona et al., 2003). Using specimens with sharp corners can lead to fracture at lower strengths and give inaccurate results. ISO6872 recommends chamfering the corners of the specimen, which is beneficial for obtaining accurate values with less error.

Other methods of measuring flexural strength include the four-point bending test and biaxial flexural strength. In the four-point bending test, the loading is applied using two rollers so that the maximum loading stress is applied between the two rollers and a constant force is applied over a long area. This can be more representative of the strength of the specimen compared to the three-point bending test where the maximum loading stress is applied to a single point. However, it requires a more complex fixture, which increases the difficulty of the test compared to the 3 point bending test (Kumar, 2013).

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Biaxial flexural testing uses a cylindrical specimen instead of a bar-shaped specimen. This test method provides a more accurate measurement because the tensile strength is concentrated in the center, so, the edges do not become weak points anymore (Kumar, 2013). In a study comparing the three-point bending test and the biaxial test, the biaxial test had a higher Weibull modulus, making it a more reliable test. (Seo and Roh, 2006)

However, all three of these methods are listed in ISO 6872 as acceptable methods for measuring flexural strength, and it cannot be said that their use is inappropriate.

Several properties should be considered to determine whether CEREC Tessera™ can be used in the same way as IPS e.max® CAD. According to the ceramic classification for fixed prostheses presented in ISO 6872, both materials have a flexural strength of 300 MPa or less, which is class 2, and can be used as an occlusal monolithic crown if cemented adhesively. (ISO 6872) However, in a previous study (Demirel et al., 2023) that measured the flexural strength of both materials in similar way with this study, both materials showed values above the class 3 threshold of 300 MPa, which means that it is strong enough to be used at anterior 3-unit prosthesis.

The case report using Tessera™ is only a case of 1 year follow up with a single crown in the molar area (Hölken and Dietrich, 2022), and there are no cases of long term observation or 3-unit prosthesis, so the use of Tessera™ as a material for prosthesis that needs to bear a lot of force is risky until further research with positive results come out.

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Although there is no significant difference in flexural strength and Weibull modulus, CEREC Tessera™ has several advantages over IPS e.max® CAD. As mentioned above, previous study showed that Tessera™ wear less than e.max® (Rosentritt et al., 2022). Furthermore, it takes less time for firing. Therefore, clinically, the results of this study suggest that CEREC Tessera™ can be successfully used as IPS e.max® CAD.

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V. Conclusion

Within the limitation of our study, there is no difference in flexural strength and Weibull modulus between CEREC Tessera™ and IPS e.max® CAD. However, CEREC Tessera™ has other advantages over IPS e.max® CAD. It can therefore be said that CEREC Tessera™ can be successfully used as IPS e.max® CAD.

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Abstract (In Korean)

리튬 디실리케이트 기반 글래스 세라믹 CAD/CAM 블록의 굴곡 강도에 대한 연구

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치의학과

(지도교수 노 병 덕)

본 연구의 목적은 최신 리튬 디실리케이트 CAD/CAM 블록인 CEREC Tessera™의 굴곡 강도를 측정하고 현재 CAD/CAM 방식의 수복물 제작에서 널리 쓰이고 있는 IPS e.max® CAD 와 비교해 보는 것이다.

두 재료 (IPS e.max® CAD, CEREC Tessera™)를 이용해서 각각 15개의 시편이 제작되었다. (길이 15.0mm, 너비 4.0mm, 두께 3.0mm, ISO6872의 기준을 따름.) Wet polishing paper 이용하여 시편의 모든 면이 연마되었으며 Universal glaze(Dentsply Sirona, Charlotte, NC, USA) 와 함께 각각 제조사의 권고사항대로

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firing 하였다. 시편의 굴곡 강도는 3점 굽힘 시험을 이용하여 측정되었다. 3점 굽힘 시험에는 Instron Universal Testing Machine (Instron 3366, Instron, MA, US)이 사용되었으며, 10mm 길이의 지지길이, 분당 1.0mm 의 crosshead 속도로 실험이 진행되었다.

실험 결과 e.max®와 Tessera™의 굴곡강도의 중앙값은 각각 225.3, 214.0 MPa 이었으며 Mann-Whitney test 를 이용하여 두 그룹 간의 통계적 유의성을 확인하였고 통계적 유의성은 없는 것이 확인되었다(p=0.852). 각 그룹의 와이블 계수는 e.max®: 7.8167, Tessera™: 5.2246이었으며 재료가 63.2%의 확률로 파괴되는 강도인 와이블 특성 강도(σ_0)는 230.9MPa, 241.1MPa 이었다. 우도비 검정 시행하였을 때 두 그룹간 유의미한 차이는 없었다 (p=0.1994). 각 그룹의 굴곡 탄성률은 각각 9.69(± 0.95)GPa, 10.50(± 0.79)GPa 이었으며 student's t-test 로 검정하였을 때 통계적으로 유의미한 차이가 존재하였다 (p<0.05).

본 연구에 한해서는 최신 리튬 디실리케이트 CAD/CAM block 인 CEREC Tessera™와 IPS e.max® CAD 의 굴곡강도와 와이블 계수는 통계적으로 유의미한 차이가 없는 것이 확인되었다. 그렇지만 CEREC Tessera™에는 다른 장점들이 있기 때문에 IPS e.max® CAD 만큼 성공적으로 쓰일 수 있을 것이다.

핵심 되는 말 : 글래스 세라믹; 캐드캠; 3점 굽힘시험; 굽힘 강도; 와이블 계수, 버질라이트