Compressive strength and Weibull distribution of lithium disilicate dental ceramics

Kekuatan tekan dan distribusi Weibull dari keramik dental disilikat lithium

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ABSTRACT
Objective: To compare the compressive strength of three types of commercial lithium disilicate ceramics. **Methods**: Three groups of lithium disilicate ceramics (IPS e.max Press, Vintage LD Press, and Celtra Press) total of twelve cylindrical specimens (diameter 4 mm x length 6 mm) were produced by laboratory processing. The compressive strength was conducted using Shimadzu universal testing machine with load cell F 50 kN, cross head speed of 1 mm/s. Micromorphology were observed using scanning electron microscope. Anova test and Weibull test were performed and $p<0.05$ was considered significant. **Results**: There are no significant differences between three groups of lithium disilicate dental ceramics compressive strength ($p=0.531$). However, IPS e.max Press group show higher compressive strength compared to the other two materials. IPS e.max Press and Vintage LD Press groups show significantly higher coefficient corelation than Celtra Press group. **Conclusion**: IPS e.max Press lithium disilicate dental ceramic have higher compressive strength compared to the other groups, but the reliability of Celtra Press is lower than those of lithium disilicate dental ceramics.
Keywords: dental ceramics, lithium disilicate, compressive strength, weibull

ABSTRAK
Tujuan: Untuk membandingkan kekuatan tekan dari tiga jenis keramik lithium komersial. **Metode**: Tiga kelompok keramik disilikat lithium (IPS e.max Press, Vintage LD Press, dan Celtra Press) total 12 spesimen silinder (diameter 4 mm x panjang 6 mm) diproduksi oleh pengolahan laboratorium. Kekuatan tekan dilakukan menggunakan Shimadzu Universal Testing Machine dengan *load cell* F 50 kN, *cross head speed* 1 mm/dtk. Morfologi mikro diamati menggunakan *scanning electron microscope*. Uji Anova dan uji Weibull dilakukan dan $p<0,05$ dianggap signifikan. **Hasil**: Tidak ada perbedaan yang signifikan kekuatan tekan antara tiga kelompok keramik dental disilikat lithium ($p=0,531$). Namun, IPS e.max Press group menunjukkan kekuatan tekan yang lebih tinggi dibandingkan dengan dua bahan lainnya. IPS e.max Press dan Vintage LD Press menunjukkan koefisien korelasi yang jauh lebih tinggi daripada kelompok Celtra Press. **Simpulan**: Keramik dental disilikat lithium IPS e.max Press memiliki kekuatan tekan yang lebih tinggi dibandingkan dengan kelompok yang lain, tetapi keandalan Celtra Press lebih rendah daripada keramik dental disilikat lithium.
Kata kunci: keramik dental, disilikat lithium, kekuatan tekan, Weibull
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INTRODUCTION

In dentistry, ceramic materials are widely used for fixed prosthodontic treatment to restore function, aesthetics and comfort.[1] All-ceramic materials can be used for single-tooth restorations such as veneers, inlays, onlays, crowns and posts. Lithium disilicate ceramic can be used for 3-unit bridges either in anterior or premolar region, whereas multi-unit bridges can be fabricated only by stabilized zirconia.[2]

All ceramic materials has been rapidly developed and having many advantages such as high aesthetics appearance due to optical properties especially in translucency and transparency, biocompatibility and durability, chemical inertness, low thermal conductivity, their excellent mechanical properties such as high flexural strength, fracture toughness, wear resistance and low abrasive properties.[1–3] The term porcelain refers to a ceramic produced by sintering a mixture of feldspar, silica, alumina, other metal oxides, pigments, and opacifying agent.[4,5] Dental ceramics can be classified by their microstructure, processing technique, fusion temperature and clinical application.[5,6] Mechanical and optical properties of dental ceramic depends on the nature and amount of crystalline phase.[6] Dental ceramic have some disadvantages such as brittle nature, ~~and~~ fracture, and wear tendencies of antagonist teeth.[3,6]

Lithium disilicate glass ceramic is broadly used as all ceramic restorations in dentistry due to adequate mechanical properties and the high aesthetic quality.[7] The strength of dental ceramic depends on presence of surface ingredients, nature, amount, particle size and coefficient of thermal expansion.[6] The composition among manufactures are varies. Manufacturers adding zirconia to the ceramic system as reinforcing component.[7,8] Zirconia-reinforced lithium silicate is glass-ceramic material enriched with highly dispersed zirconia.[2] The ob-

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jective is to increase its strength.[7,8]

There are limited study of lithium disilicate compressive strength; many studies used flexural strength, shear strength, fracture toughness and hardness to compare mechanical properties of this material.[3,7,9,10] Compressive strength is the ability of a material to withstand 2 forces that are directed toward each other in a straight line until the material fractures.[4,5]

Weibull distribution analysis was used to characterize the flexural strength of these materials. Weibull modulus is a parameter instrument to understanding the statistical behaviour of the strength of materials.[11] So, this article aims to compare the compressive strength of three types of commercial lithium disilicate ceramics

METHODS

Three commercial lithium disilicate with zirconia consist of IPS e.max Press (Ivoclar Vivadent AC), Vintage LD Press (Shofu Inc, Kyoto) and Celtra Press (Dentsply Sirona, Germany) were used in this study and produced following manufacturer instructions. Twelve specimens were prepared in cylinder of 4 mm diameter and 6 mm height. The specimens were produced with the press technique. Compressive strength was measured using universal testing machine (AGS-X series Shimadzu Japan) at a crosshead speed of 1mm/min with 50 kN load cell until fracture occurred. The results were recorded in megapascals (MPa).

Scanning electron microscope (SEM) (JEOL JSM-6360LA) were used to analyse specimen microstructure of three lithium disilicate ceramic groups. The specimens etched using hydrofluoric acid for 90 seconds (Ultradent Porcelain Etch, USA), rinsed using water spray and dried before the scanning procedure.

The results data analysed statistically using statistical software Minitab 17 (2013 Minitab Inc). All compressive strength data were analysed using one-way Anova and Weibull distribution.

RESULTS

IPS e.max Press showed greater mean values of compressive strength (341,0 MPa) followed by Celtra Press and Vintage LD Press respectively (Table 1). One-way Anova revealed there isn't statistically significancy (p-value>0,05) among the three groups (Table 2). Weibull coefficient from 3 groups showed IPS e.max has the higher value than the others (Table 3). Figure 1,2 and 3 showed SEM of three lithium disilicate with magnification 5000x.

Table 1 Descriptive statistic for compressive strength

Lithium disilicate group	Compressive strength mean (MPa)
IPS e.max Press	341,0 ± 59,4
Vintage LD Press	274,7 ± 26,2
Celtra Press	318,8 ± 28,5

Table 2 Result of one-way Anova

Source	F-Value	P-Value
Factor	0,68	0,531

Table 3 Distribution Weibull for compressive strength

Lithium Disilicate Group	Shape	Scale	Coefficient
IPS e.max Press	4,10	377,6	0,951
Vintage LD Press	7,19	294,2	0,935
Celtra Press	9,94	338,4	0,918

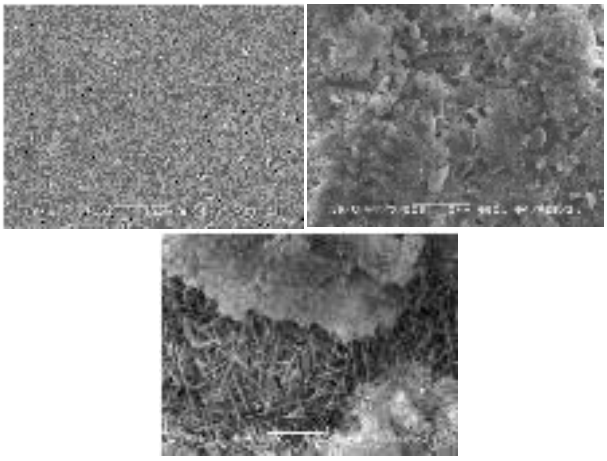

Figure 1 SEM micrograph (magnification 5000x); **A** IPS e.max Press, **B** Vintage LD Press, **C** Celtra Press

DISCUSSION

Recent developments of dental ceramic have led to development of crystalline porcelain with fillers such as alumina, zirconia and hydroxy apatite. Strengthening dental ceramics by reinforced the materials with a dispersed crystalline phase such as alumina or partially stabilized zirconia can strengthen the glass and improve the strength.[6] Mechanical properties of ceramic especially glass-ceramic depend of their microstructure of their crystals.[12]

The microstructure of IPS e.max Press is crystals lithium disilicate which are embedded in a glassy matrix (Fig.1A), the crystal content to about 70% which translates into 30-35% glassy matrix.[5,13] Size of IPS e.max Press lithium disilicate crystals were 1.0-4.0 μm and crystals of Vintage LD size 1.0-3.0 μm.[14] Celtra Press had a high content of P_2O_5 (4.9 wt%), ZrO_2 (9.3 wt%) and lower SiO_2 compared to IPS e.max Press. IPS e.max Press had lower content of ZrO_2 and higher SiO2 than Celtra Press.[12] Crystals distribution of Vintage LD Press (Fig.1B) sparser than e.max Press so the glassy matrix proportion higher and might affect the extension of cracks.[14] Celtra Press (Fig.1C) contains about 10% zirconia besides lithium disilicate crystals, Li_2O and SiO_2, higher than IPS e.max but showed lower compressive strength compared to IPS e.max even no significant statistical differences. Both materials consist of lithium disilicate and zirconia as reinforced but different values

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of compressive strength, it might have been caused the different values of composition and crystals size. SEM micrographs showed differences in size, form and density of crystals.

Distribution Weibull is one of probability distribution for assessing the lifetime problem, in ceramic fields, this distribution has been common to indicate the brittleness of materials.[11] The Weibull coefficient of IPS e.max showed the higher value than the others, it means the greater goodness of fit of this material.[15] Weibull analysis is a rule to testing the strength of brittle materials.[11]

Compressive strength test of three different ceramic materials shows that IPS e.max Press lithium disilicate dental ceramic have higher compressive strength compared to the other groups, but the reliability of Celtra Press is lower than those of lithium disilicate dental ceramics.

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