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Research Article

Comparative Evaluation Of Load To Failure Testing Of An All-Ceramic Material Based On Their Processing Techniques.

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ABSTRACT

Aim: To evaluate and compare the **load to failure testing** of an **all-ceramic** material based on their processing techniques.

Methods: 24 copings of all ceramic lithium disilicate were fabricated using the press technique (n=12, Group 1) and milling technique (n=12, Group 2) on mandibular molar teeth with uniform reduction of 1.2mm axially and 1.5mm occlusally. The intaglio surface of all copings were subjected to conditioning: etched using 5% hydrofluoric acid followed by the application of silane coupling agent (Monobond-S) and the application of Primer (Multilink N Primer) on the surfaces of prepared teeth. The copings were bonded to their corresponding tooth using luting agent (Multilink N). After 24 hours of storage in water at room temperature, specimens were loaded on a universal testing machine with the application of compressive load along the long axis of the specimens at a crosshead speed of 1mm/min until fracture. Fracture load values (N) were recorded and resulted to statistical analysis using Student unpaired't' test.

Result: The mean **load to failure** values (SD) of (Group 1) pressed lithium disilicate copings 2134.17 + 289.72 N were significantly ($p<0.05$) lower when compared to the mean **load to failure** values of (Group 2) milled lithium disilicate copings (2399.92 + 285.35 N).

Significance: Group 2 demonstrated significantly greater **load to failure** value as compare to the Group 1 ($p<0.05$).Though, the **load to failure** values for milled lithium disilicate is significantly greater than that of pressed lithium disilicate but both of its variants can be effectively utilized for posterior restorations where high masticatory forces are present.

Key Words: Lithium disilicate press; Lithium disilicate CAD; Load to failure testing.

Introduction

Esthetic restorative treatment in dentistry has made dental ceramics an often-used alternative for both anterior and posterior restorations. The dental profession seeks an ideal all-ceramic restoration with excellent physical properties, strength, marginal fit and esthetics necessary for anterior, as well as posterior restorations.[1,2] With such a wide variety of all-ceramic restorative materials available today, one could refer to the present as the Ceramic Age of Dentistry. Among all the **all-ceramic** restorative materials available today Lithium disilicate stands out in its use for anterior restorations because of its enhanced esthetics,

biocompatibility and improved strength [3].The manufacturer and literature are now suggesting the use of lithium disilicate crowns for posterior restorations [3]. One of the most important desirable mechanical property of dental ceramic restorative material to be used as a posterior restoration is its load to failure because a dental restoration is routinely subjected to masticatory loads [4, 5].The strength of a clinical ceramic crown is also influenced by several factors such as the shape of the prepared tooth [6], microstructure of the ceramic material [3,7] final surface finish of the crowns [8], way of luting [9], and the loading conditions [4,10]. Lithium disilicate restorations can be adhesively bonded to tooth structure, as they contain a glassy phase [3] in their chemical structure, these adhesively bonded lithium disilicate restorations forms a monoblock with the tooth structure.Another advantage of lithium disilicate is that they can be fabricated either by pressing or by milling techniques. The technique of fabrication may also influence the strength properties as the CAD crowns may involve less defects in the materials compared to the pressed materials and also CAD materials are fabricated under controlled environment except for the milling compared to the pressed technique where intertechnician and interlaboratory variations can occur [8].

The aim of the present investigation was to compare the **load to failure values** which is one of the important criteria for posterior restorations of **an all-ceramic material** using the two techniques of fabrication with adhesive cementation to the tooth.

Materials and methods

To simulate the required clinical conditions in vitro, factors were standardized such as the preparation of tooth, [11] type & procedure of ceramic fabrication, the supporting material, [12]and means of luting, [13] all of which may influence the study findings of the **load to failure** properties of these all-ceramic crown restorations.Extracted 24 mandibular molar teeth were selected and minor carious lesions, which could be removed during crown preparation without extending the standardized preparation design [14], were accepted and were cleansed of surface debris, sterilized in 0.5%sodium hypochlorite [15] (Safco Dental Supply Co,USA) immediately following extraction and then stored in tap water.The stored molar teeth were divided into two groups (n=12) [16] for receiving the respective ceramic copings. The group 1 (n=12) for pressed lithium disilicate copings and group 2 (n=12) for milled lithium disilicate copings. The teeth were positioned along their vertical alignment with the CEJ 1mm above the top of plastic mounting cylinders filled with auto polymerizing acrylic resin (DPI-RR Cold cure, Denture Base Polymer Resins, Mumbai, India).Crown preparation, on the mounted teeth with uniform reduction of 1.2mm axially and 1.5mm occlusally with a modified chamfer margin was done. All the preparations were performed by a single operator to standardize the measurements.

For Group 1 copings, the prepared teeth were scanned on a model scanner (Maestro, Italy) and copings were designed measuring 1.2mm axially and 1.5mm occlusally. The resultant copings were milled on a wax disc (Figure 1) (Yeti Dentalprodukte GmbH, Germany) of 10mm thick using a wax milling machine (MB Dental Milling system, Germany). After milling, the copings were measured using a vernier caliper (Absolute Digimatic, Mumbai, India) for the accuracy of measurements. Then resultant wax patterns were sprued on to the special sprue former of the IPS E-max investment system (Ivoclar Vivadent, Schaan, Liechtenstein).The sprued wax patterns were invested using IPS PressVEST Speed investment material (Ivoclar Vivadent, Schaan, Liechtenstein) using proper powder/liquid ratio of (100g of powder: 27ml of liquid). Once the investment material was set after 40 minutes, it was placed in the burnout furnace (Zeus, Carlo de Giorgi, Italy) and heated gradually to 850 C for 30 minutes. After reaching the final temperature the Lithium disilicate Press Ingots (E-max Press, Ivoclar Vivadent, Schaan, Liechtenstein) were placed in the sprue cavity and the corresponding plunger was placed over it and whole assembly was placed inside the press furnace (Programat EP 600, Ivoclar Vivadent, Schaan, Liechtenstein) and the pressing procedure was completed at a temperature of 1075 to 1180 C under air pressure of 1500 psi for 15 minutes. After cooling to room temperature (approximately 60 minutes) the pressed copings were divested. First mark the length of the alox plunger on the cooled investment ring. Separate the investment ring using a separating disk. This predetermined breaking point enables reliable separation of the alox plunger and the ceramic material. Break the investment ring at the predetermined breaking point using a plaster knife. Rough divestment is carried out with glass polishing beads at 4 bar (60 psi) pressure. Fine divestment is carried out with glass polishing beads at 2 bar (30 psi) pressure. Do not use Al_2O_3 for rough or fine divestment. After divestment checked the copings for the accuracy of the fit and the measurements.

For Group 2 copings, the prepared teeth were scanned in the InEos model scanner and copings were designed measuring 1.2mm axially and 1.5mm occlusally using the CAD software. The resultant copings were milled (Figure.2) on a CEREC InLab CAD/CAM system (CEREC systems, Sirona, Germany) using Lithium Disilicate CAD blocks (E-max CAD, Ivoclar Vivadent, Schaan, Liechtenstein).After milling the resultant copings were in the intermediate crystalline state in which the material shows its characteristic bluish shade (Figure 2). This is followed by a simple, quick crystallization process (30 minutes) in a conventional ceramic furnace (Zeus 4, Carlo de Giorgi, Italy) in which the copings reaches its final strength and the desired esthetic properties such as tooth color, translucence and brightness.

Group 1 and Group 2 copings were further subjected to glaze using ceramic furnace (Zeus 4, Carlo de Giorgi, Italy) at temperature of 400 C for 6 minutes. After the glazing procedure, the fitting surfaces of the copings of both the groups were etched using 5 % Hydrofluoric acid (IPS Ceramic Etching gel, Ivoclar Vivadent, Schaan, Liechtenstein) for 20 seconds for press copings [3] and 60 seconds for milled copings [3] and rinsed thoroughly. After which they were silanated for 60 seconds using a silane coupling agent (Monobond S, Ivoclar Vivadent, Schaan, Liechtenstein) provided in the cementation kit. After that, prepared teeth surfaces were cleaned for any surface debris and were primed for 15 seconds by applying the mix of the multilink N Primer liquids A and B in a 1:1 mixing ratio (Multilink N Primer, Ivoclar Vivadent, Schaan, Liechtenstein) provided in the cementation kit. After the application of primer, teeth were rinsed thoroughly and air dried. Next, the cement (Multilink N, Ivoclar Vivadent, Schaan, Liechtenstein) was dispensed into the fitting surface of the copings and was bonded to the corresponding prepared teeth under finger pressure. Excess cement was removed immediately with a microbrush and light cured for 20 seconds as per the instruction of the manufacturer. Once all the copings were bonded to their respective prepared teeth, they were stored in water for 24 hours at room temperature before testing to simulate the clinical conditions. After 24 hours, the Group 1 and Group 2 specimens were subjected to the **load to failure** test.

The specimens were mounted on a Universal Testing Machine (Instron-5500R). A cylindrical OHNS steel stamp with a flat top area of 8mm diameter and rounded edges was used to transmit the force on to the occlusal surface of the copings (Figure 3). The stamp was placed in such a way that, there was a 3 point contact with the occlusal surface of the copings during the force transmission. The copings were loaded axially to their occlusal surface at a crosshead speed of 1mm/min until the fracture occurred. The **load to failure** values were recorded continuously in Newton (N) starting with 100N and a stress-strain curve was plotted on a PC connected to the testing machine using a digitizing card. Force transmission proceeded until the complete fracture of the specimen. The stress–strain curves were analyzed and the drop point of the curve indicated the fracture of the coping and **load to failure values** were recorded in Newton.
For the statistical analysis, **load to failure** values for Group 1 and Group 2 were entered into Statview program (Brain Power, USA) and distribution of group data presented as box-plot diagrams. Student unpaired't' test was carried out (SPSS 12.0,SPSS Inc,Chicago.III).

Results

Load to failure values for group 1 (pressed lithium disilicate) and group 2 (milled lithium disilicate) in Newton were presented in Table I & II. Comparison of **load to failure values** for the group 1 & group 2 by student unpaired't' test presented in Table III. Means and standard deviations of **load to failure values** for group 1(pressed lithium disilicate) & group 2 (milled lithium disilicate) are illustrated in Figure 4.Student unpaired 't' test revealed significant difference in **load to failure values** between Group 1(pressed lithium disilicate) and Group 2 (milled lithium disilicate) was found with respect to the mean **load to failure value** ($p<0.05$). Statistically, group 2 (milled lithium disilicate) demonstrated significantly greater **load to failure values** compared to the group 1 (pressed lithium disilicate) ($p<0.05$)

Discussion

The mean masticatory forces during mastication and swallowing in human beings have been reported to be approximately 40 N, [4,5] whereas mean maximum posterior masticatory forces vary from 200 N to 540 N.[4,5] The mean **load to failure value** for the lithium disilicate all ceramic crowns in the present study were higher than reported mean maximum masticatory forces. In the present study that (Group 2) Milled lithium disilicate restorations have higher **load to failure value** compared to the (Group 1) pressed lithium disilicate restorations. The increase in the **load to failure value** of Milled lithium disilicate restorations could be attributed to the manufacturing process [3] and the micro structure of the Lithium disilicate [3, 7].
The pressable lithium disilicate is produced according to a unique bulk casting production process in order to create the ingots. This involves a continuous manufacturing process based on glass technology (melting, cooling, simultaneous nucleation of two different crystals, and growth of crystals) that is constantly optimized in order to prevent the formation of defects (e.g. pores, pigments). The microstructure of the pressable lithium disilicate material consists of approximately 70% needle-like lithium disilicate crystals that are embedded in a glassy matrix. These crystals measure approximately 3 µm to 6 µm in length [3] (Figure 5).

Machinable lithium disilicate blocks are manufactured according to a similar process, but only an "intermediate" crystallization is achieved in order to ensure that the blocks can be milled efficiently in a crystalline intermediate phase (blue, translucent state) (Figure.2). The intermediate crystallization process leads to the formation of lithium metasilicate crystals, which are responsible for the material's processing properties, machine ability, and good edge stability. After the milling procedure the restorations are fired so that they reach their final crystallized state and their high strength. The microstructure of intermediate crystallized CAD lithium disilicate consists of 40% platelet-shaped lithium metasilicate crystals embedded in a glassy phase. These crystals range in length from 0.2 to 1.0 µm. Post crystallization microstructure of CAD lithium disilicate material consists of 70% fine-grain lithium disilicate crystals embedded in a glassy matrix

[3] (Figure 6).It may also be noted that the Post processing of the milled lithium disilicate is minimal compared to that for the Pressed lithium disilicate which has to undergo an elaborate processing in the laboratory wherein the processing conditions and also the skill of the technician may come into play [8].

The increase **load to failure value** of the milled lithium disilicate (Group 2) could be attributed to their fine grain crystal size [3] and minimal post processing [8] compared to the pressed lithium disilicate (Group 1).
The **load to failure value** of both the restorations is also enhanced as they have been adhesively bonded to the tooth structure as the restoration and tooth behave like a monoblock [17-20]. In similar studies for determining the **load to failure value**, composite replicas of the teeth were used [21]. In our study we have used extracted natural teeth and also after the bonding of the restorations we have stored in water for 24hrs to simulate the oral environment as closely as possible. Previous studies have yielded adequate power to detect clinically important differences using a sample size of twelve [16]. A limitation of this study was that it was undertaken without a clinical group. Although in vitro studies aim to replicate in vivo conditions closely, the intraoral environment is too complicated to be fully replicated in an in vitro study. Therefore, a long-term clinical study is necessary to evaluate the longevity of these all-ceramic crowns systems clinically. Another limitation of this study was that the specimens were prepared according to standardize preparations criteria. However, different preparations criteria, such as position of the finish line and the amount of tooth reduction, may influence the **load to failure value** of all ceramic materials.

Two of the primary objectives of in vitro studies are the elimination of influential parameters and limitation of the variables. Hypothesis-driven focus on narrowly defined parameters may not sufficiently simulate intraoral conditions, but it allows for preliminary testing and identification of superior materials and methods that may later be tested in a more relevant setting [22].

Conclusion

Within the limitations of this in-vitro study, the following conclusions can be drawn as:-

1. **Load to failure values**:
GROUP 1- Pressed Lithium Disilicate - 2134.17 (+289.72) N
GROUP 2- Milled Lithium Disilicate - 2399.92 (+285.35) N

2. Statistically significant difference in **load to failure value** between Group 1 and Group 2 with respect to the mean **load to failure value** ($p<0.05$) was observed. .
3. Statistically, Group 2 demonstrated significantly greater **load to failure value** as compared to the Group 1 ($p<0.05$).

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Tables

Table I: Load to failure value for Group 1(pressed lithium disilicate)

Number of specimens	Group 1
1	2650 N
2	2240 N
3	1940 N
4	2130 N
5	2180 N
6	2040 N
7	1650 N
8	2000 N
9	1920 N
10	1980 N
11	2230 N
12	2650 N

Table II: Load to failure value for Group 2(milled lithium disilicate)

Number of specimens	Group 1
1	2820 N
2	2640 N
3	2500 N
4	2580 N
5	2160 N
6	2300 N
7	1900 N
8	2040 N
9	2200 N
10	2350 N
11	2650 N
12	2659 N

Table III: Comparison of two groups (1 and 2) with respect to load to failure value (N) by unpaired't' Test.

Group	**Mean**	**SD**	**t-value**	**p-value**
Group I	**2134.17**	**289.72**	**2.2638**	**0.0338***

Group II	**2399.92**	**285.35**		

***p<0.05**

Figure 1: Milling of wax copings on wax disc for Press technique (Group 1)

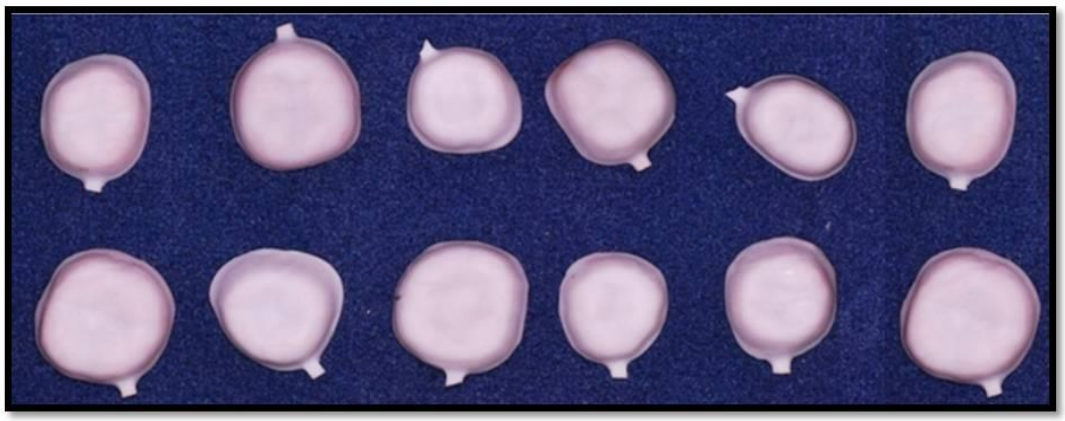

Figure 2: Copings of Lithium Disilicate after Milling (Group 2)

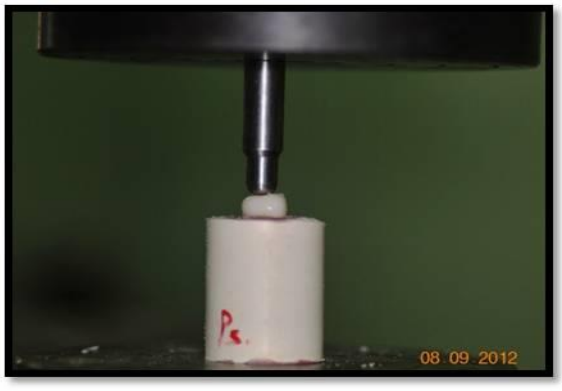

Figure 3: Specimen Positioned On the Fixture Mount on Universal Testing Machine

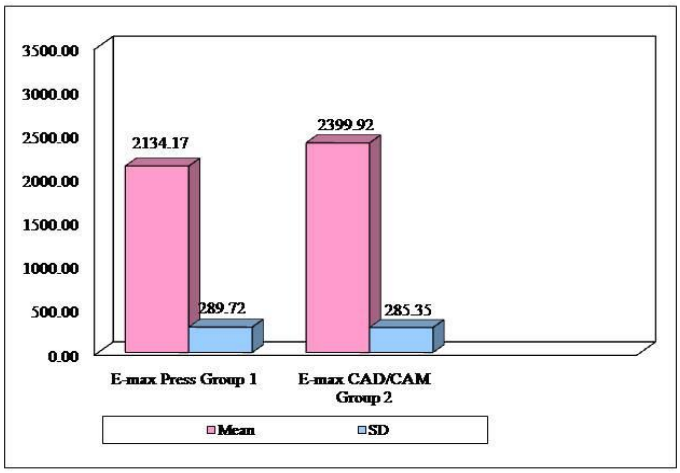

Figure 4: Means and standard deviations of **load to failure value** for group 1(e-max press) & group 2 (e-max CAD).

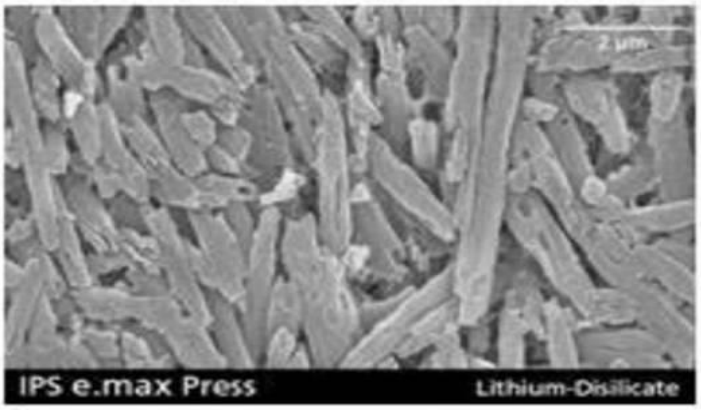

Figure 5: SEM view of pressed lithium disilicate

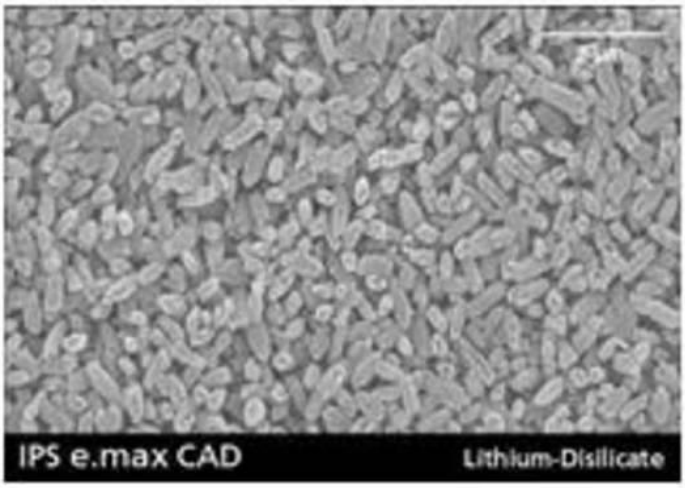

Figure 6: SEM view of milled lithium disilicate.