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A Comparative *in vitro* Study of the Load at Fracture of All-ceramic Crowns with Various Thicknesses of In-Ceram Core

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Abstract

Aim: The aim of this study was to investigate the influence of three different thicknesses of In-Ceram core on the load at fracture of all-ceramic crowns.

Methods and Materials: Thirty standardized crown-shaped nickel-chromium alloy dies were fabricated using a milling machine. Twenty dies were prepared with a 1 mm shoulder for Groups A and B. The only difference in the ten dies used for Group C was a smaller 0.5 mm lingual shoulder. The thicknesses of In-Ceram were 0.5 mm, 1.5 mm, and 0.75 mm for Groups A, B, and C. All all-ceramic crowns were fabricated in accordance with the manufacturer's instructions. After cementation of the crowns, their fracture resistance was tested with a universal testing machine. The load was directed to a point located 3 mm from the lingual aspect of the incisal edge at 30 degrees to the long axis of each specimen until catastrophic failure occurred.

Results: The mean loads at fracture for Groups A, B, and C were 1117±388 N, 2083±385 N, and 1439±368 N, respectively. No statistically significant difference in load at fracture between Groups A and C was found ($p>0.05$). However, the differences were statistically significant between Groups A and B ($p<0.001$) and Groups B and C ($p<0.001$).

Conclusion: Under the guidelines of this study, increasing the thickness of the In-Ceram core increased the fracture resistance of the all-ceramic crowns.

Clinical Significance: The sufficient thickness of the In-Ceram core of all-ceramic crowns is an important factor in fracture resistance. Therefore, dental practitioners should be careful in patient selection; if the horizontal overlap of a tooth to be restored is too limited, then all-ceramic crowns may not be a feasible option.

Keywords: All-Ceram, In-Ceram, porcelain, fracture load, crown fracture

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Introduction

An equilibrium between remaining tooth structure and providing sufficient retention and resistance-form should be established in a crown preparation. Full veneer metal-crown preparations are generally more conservative of tooth structure than those for either metal-ceramic or all-ceramic restorations. However, there is an increasing demand for metal-free restorations due to an increasing interest in esthetics and concerns about toxic and allergic reactions to certain alloys.[1,2] Both patients and clinicians, especially in the anterior locations, have been seeking suitable metal-free tooth-colored restorations during the last decade.[1-5]

It is possible to replicate the esthetic characteristics and vitality of natural teeth by using ceramics.[6] However, although strong in compression, ceramics can be inherently brittle and weak when placed under tensile and torsional stresses.[7,8] Strong alumina cores have been produced to obtain the all-ceramic restorations with more fracture resistance.[9-11] In-Ceram (Vita Zahnfabrik, Bad Sackingen, Germany) is made of a high alumina core which is subsequently glass infiltrated. However, the challenge of the overlying veneer porcelain is to mask the opaque alumina core and provide the desired contours needed.[11]

Many factors including the shape and thickness of the restoration; microstructural inhomogeneties; size and distribution of surface flaws; residual processing stresses; the magnitude, direction, and frequency of the applied load; the restoration-cement interfacial defects; the elastic modulus of the restoration components; and environmental effects may be related to crack initiation and propagation within a dental ceramic.[12-15]

When the horizontal over-lap is limited, the clinicians' decision about the patient selection for all-ceramic restorations has been difficult since the mechanical properties of the ceramics remain a concern. Therefore, numerous *in vitro* studies including the investigation of mechanical properties of all-ceramic crowns can be found in the dental literature.[16-20] However, to date there is no study that solely focuses on the influence of the thickness of an In-Ceram core on the failure of all-ceramic crowns in the dental literature.

This *in vitro* study was designed to compare the fracture strengths of all-ceramic crowns when supported by three different thicknesses of In-Ceram core. Anterior crown-shaped restorations were utilized since they potentially represent the clinical situation more closely than ceramic disks.[21]

Methods and Materials

Standardized Allow Die Fabrication

Thirty standardized crown-shaped nickel-chromium (Ni-Cr) alloy dies were fabricated using Ni-Cr alloy blocks in a milling machine. Each die was milled to manufacture a crown preparation shape with a 6 degree convergence angle, 8 mm in height, and 7 mm in diameter between opposing finish lines. The finish line with a 90 degree angle and a 1 mm shoulder was used for 20 dies utilized for both Groups A (ten dies) and B (ten dies). The remaining ten dies used for Group C had a 0.5 mm lingual shoulder. Detailed measurements of Ni-Cr alloy dies shown in Figures 1a, b and 2a, b.

Invested Die Fabrication

Invested dies were made from the standardized alloy dies by placing one coat of die spacer (Nice Fit, Shofu Inc, Kyoto, Japan) to within 1 mm of the finish line. A polysiloxane impression (Speedex, Coltene AG, Altstatten, Switzerland) was made of each individual Ni-Cr alloy die. Thirty invested dies were obtained after the impressions were poured.

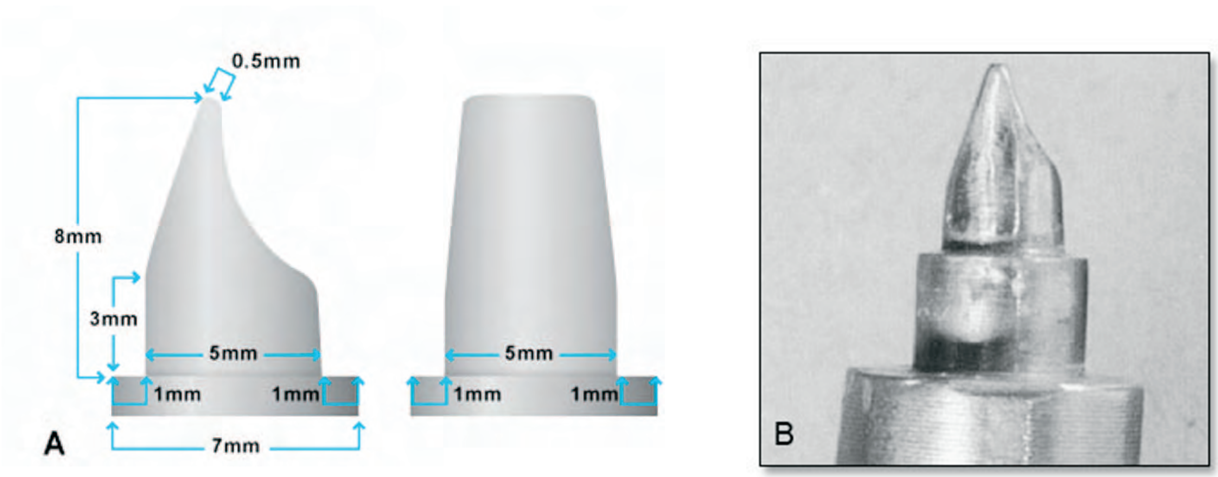


Figure 1. The graphical views with detailed dimensions of the dies **(A)** and Ni-Cr dies **(B)** used in Groups A and B.

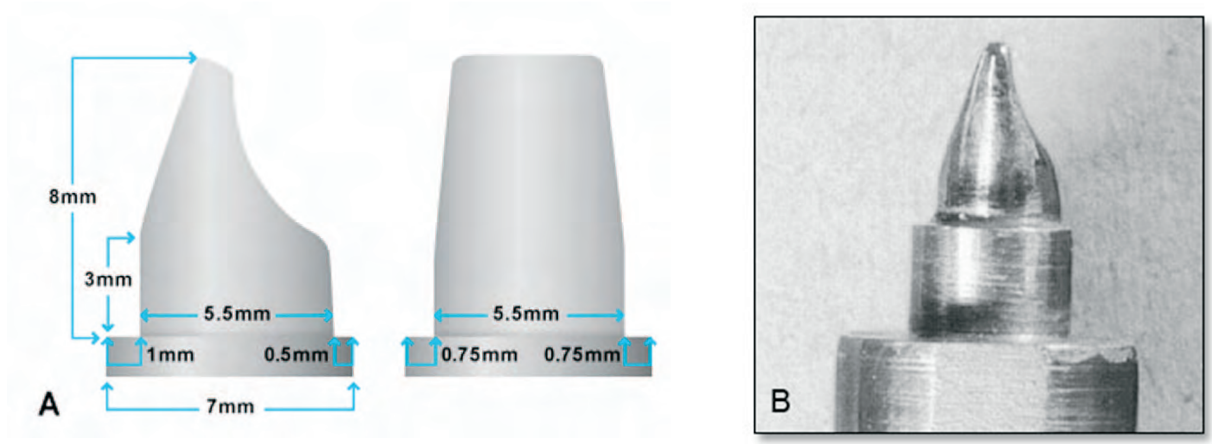


Figure 2. The graphical views with detailed dimensions of the dies **(A)** and Ni-Cr dies **(B)** used in Group C.

Group A: Inlay wax (Thowax, Yete Dental Products, Engen, Germany) of 0.6 mm was used to create a wax pattern for each In-Ceram core one day after the invested dies were poured. A new polysiloxane impression was taken of each invested die with the 0.6 mm wax pattern in place for an In-Ceram core. After the impression material was set, the wax pattern was removed and the In-Ceram material was injected into its space between the new impression and invested-die.

The In-Ceram core material was prepared as follows

- An In-Ceram slip was made by adding 38g of In-Ceram Alumina Powder to 5mL of In-Ceram Mixing Liquid and 1 drop of Additive.
- Each In-Ceram core was allowed to set for 24 hours.

After the cores set, the polysiloxane impression material was removed from each invested die. Each In-Ceram core was fired in the Vita-Inceramat furnace at 1120ºC following the application of one coat of Stabilizer (Vita Zahnfabrik, Bad Sackingen, Germany). The thickness of In-Ceram cores were reduced to 0.5 mm using diamond burs after the firing procedure and homogeneous final thickness of each In-Ceram core (0.5 mm) was obtained (Figure 3).

The sintered specimens were then infiltrated with molten glass and fired at 1100ºC. Each sintered specimen has meticulously been checked for microcracks. The cores were steam cleaned and air-dried, and their fit was confirmed on the Ni-Cr dies using a microscope at x10 magnification. The external surface of the cores was air abraded with 50 μm aluminum oxide and steam-cleaned.

Vitadur Alpha porcelain (Vita Zahnfabrik, Bad Sackingen, Germany) was used for veneering all crowns. The crowns were fired in accordance with the specific manufacturer's instructions and each crown was shaped as a maxillary central tooth

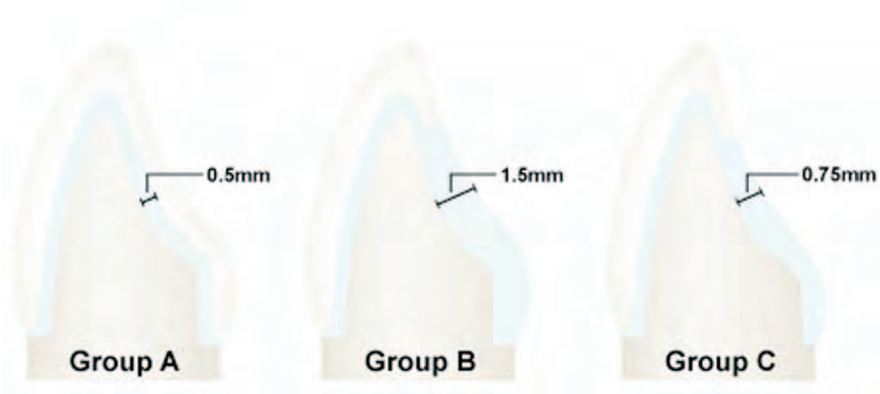


Figure 3. Showing the thicknesses of In-Ceram cores according to the groups.

would be fabricated. Each crown was carefully checked to confirm the seating of the crown on the corresponding Ni-Cr die. A total of 33 points (9 at labial side, 9 at lingual side, 3 at incisal edge, 6 at mesial side, and 6 at distal side) were used to check the final thinkness of the crowns for the standardization. Finally, all all-ceramic crowns were autoglazed.

Group B: The crowns were fabricated with the same manner used for Group A. However, the thickness of the In-Ceram core of each all-ceramic crown used in Group B was 1.5 mm at lingual side which was created by applying additional wax to the wax pattern.

Group C: These crowns were also fabricated with the same manner used for Group A. However, the dies used for Group C had 0.5 mm lingual shoulder, and the lingual thickness of the In-Ceram core of each all-ceramic crown used in Group C was 0.75 mm at lingual side which was created by applying additional wax to the wax pattern.

Each all-ceramic crown was cemented using zinc-phosphate cement (SpofaDental, Praha, Czech Republic). Manual pressure was initially applied to seat each crown on its corresponding die, and each crown was held in place while excess cement was removed. The crowns were placed in a vertical static load device for ten minutes under a 5 kg load.

Fracture Resistence Testing

The fracture resistance of the crowns was tested with an Instron universal testing machine (High Wycombe, Buckinghamshire, UK). Each crown was placed in the universal test machine at 30 degrees to the long axis of the crown and the load was directed at a point located 3 mm from the lingual aspect of the incisal edge (Figure 4). Each crown was subjected to a linear-load at a speed of 1 mm/sec using the universal test machine until the fracture occurred. The load at fracture of each specimen was recorded in Newtons.

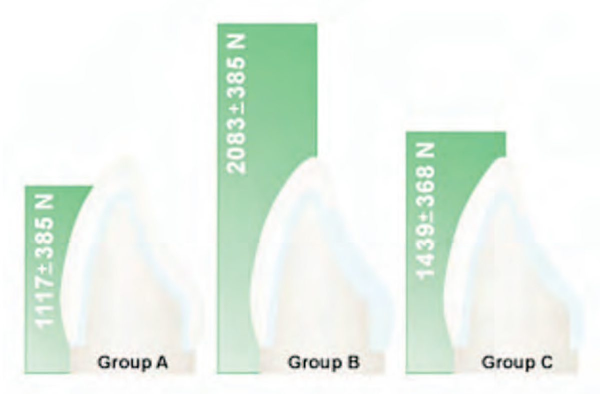
Figure 4. Showing the universal testing machine including the Ni-Cr die cemented to the all-ceramic crown and the application of the load.

Statistical Analysis

Descriptive analysis of the raw data was performed using statistical software (SPSS Inc., Chicago, IL, USA). The results have additionally been analyzed using one-way analysis of variance (ANOVA) and the Tukey test.[11] A value of $p<0.05$ was considered significant.

Results

The mean loads at fracture for Groups A, B, and C were 1117±388 N, 2083±385 N, and 1439±368 N, respectively. There was no statistically significant difference in load at fracture between Groups A and C ($p>0.05$), while the differences were statistically significant between Groups A and B ($p<0.001$) and Groups B and C ($p<0.001$).



Discussion

This *in vitro* study was designed to determine the influence of the thickness of In-Ceram core on the load at fracture of the all-ceramic crowns. The results captured provide an indication of the influence of thickness of an In-Ceram core on the load-bearing capacity of experimental all-ceramic crowns, but this finding cannot be directly transfered to the clinical situation.

In the present study the differences were statistically significant between Groups A and B and Groups B and C. However, no significant difference was detected between Groups A and C. It is not possible to make a direct comparison between the present and previous studies since previous studies have involved different materials and techniques (die, core and porcelain materials, preparation techniques, and type and magnitude of application of loads).[11,14,18,19]

Webber et al.[11] reported the fracture load of 2581±715 N for twenty In-Ceram crowns, which was higher than the findings in Group C of the present study. However, brass dies, In-Ceram crowns with 0.9 mm thick-veneer of Vitadur Alpha porcelain, and the load was axially applied onto the crowns represent differences in the Webber study. Numerous studies have also reported the use of metal dies.[18,22,23] Although they were not replicating the elastic modulus of teeth, they were homogenous in composition. However, the fracture load of ceramic may be greater if crowns are supported by dies with a high modulus of elasticity.[24] This factor should also be considered when interpreting the results of the studies utilizing different die materials.

The study by Pallis et al.[18] compared the *in vitro* fracture resistance and origin of failure of simulated first molar crowns fabricated using three all-ceramic systems (IPS Empress, Procera AllCeram, In-Ceram Zirconia). They used the resin die material produced using a stainless steel definitive die. The center of the occlusal surface on each of 15 specimens per ceramic system was axially loaded to fracture in a universal testing machine. The maximum load at fracture recorded varied from 998 N to 1183 N for In-Ceram crowns, which are lower than those obtained in the present study. This difference may result from the variations in the die material and the direction of load applied.

Yoshinari and Derand[14] reported the average fracture load of 1276±207 N for In-Ceram crowns luted using zinc phosphate cement which is similar to that of the present study. The thickness of In-Ceram core of specimens was 0.5 mm, and the specimens were loaded with 10 degrees to the long axis of the specimen. Although the die material was different, the In-Ceram material and its thickness and the cement used were the same in both their study and the present study.

The previous studies included either axial or angled loads on specimens for fracture testing.[1,6,11,19] One of the drawbacks of this study was the use of a single-type (30 degrees to the long axis of each specimen) of load to failure which does not replicate all of the clinical loads to which a restoration is subjected.[1,3] Fatigue of materials can occur when cyclic loads are applied, such as under the physiologic conditions of mastication. Therefore, this study included one aspect of loading chosen because it appeared to be appropriate for anterior teeth. The study by Waltimo and Konenen[25] included 129 young adults (56 men and 73 women), and they reported mean maximal bite force values for men were 909±177 N in the molar region and 382±133 N in the incisal region. This was significantly higher than the corresponding figures for women, 777±168 N in the molar and 325±116 N in the incisal region. Although the results of the present study cannot be directly compared with the *in vivo* situation, the mean loads at fracture for all groups exceed the clinically anticipated loads. This is also in agreement with previous studies reporting a die with a high modulus of elasticity can result in increased fracture loads of ceramic crowns.[24]

Conclusion

Within the limitations of this study increasing the thickness of the In-Ceram core from 0.5 mm to 0.75 mm did not significantly increase the load at fracture, but increasing the thickness of the In-Ceram core from 0.5 mm to 1.5 mm and 0.75 mm to 1.5 mm significantly increased the load at fracture for all-ceramic crowns which may help clinicians make the determination of an appropriate indication for all-ceramic crowns. However, it should be kept in mind data from *in vitro* studies may not completely represent the clinical situation.

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