**Introduction**

The replacement of missing teeth has been a functional and esthetic necessity for each individual.[1] Prosthodontics has continuously developed as a result of the progress in laboratory technology, biomaterial science, clinical techniques, and multidisciplinary advancements. Perhaps more than any other dental specialty, prosthodontics has shown itself capable of evolution in response to changing needs and will probably continue to change.[2]

In the current era of dentistry, for replacement of single as well as multiple teeth there are various restorative materials commercially available. In the past decade several all-ceramic materials and processing techniques have been introduced due to the increasing demand for esthetics. Excellent esthetics has been successfully achieved for restoring anterior and posterior teeth using all-ceramic restorations.[2] Although all-ceramic crowns have better biocompatibility and esthetic properties,

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**Background and Aim:** Increased demand for metal-free restorations in posterior areas has increased the focus on zirconia restorations because of its advantages in excellent mechanical properties, patient comfort, and acceptance. Although all-ceramic crowns have better biocompatibility and esthetic properties, there are some clinical reasons for the fracture of the veneer or the core materials in the posterior region. This study aims at comparing the influence of zirconia coping designs on the fracture resistance of all-ceramic crowns. **Materials and Methods:** A total of 32 zirconia copings (n = 8 for each group) were designed and fabricated based on the marginal collar height of zirconia coping. The groups were the following: Group 1: 0.0 mm zirconia coping; Group 2: 0.5 mm collar; Group 3: 1.0 mm collar; and Group 4: 1.5 mm collar. All these zirconia copings were veneered with porcelain. Master die with cemented ceramic-layered zirconia copings was tested using Universal testing machine. Data obtained were statistically evaluated by one-way analysis of variance and post hoc test. **Results:** There was statistically significant difference between the groups with P < 0.001. Group 4 has the highest strength (3318.89 ± 395.67) followed by Group 3 (2910.0 ± 219.22), then Group 1 (2320.02 ± 547.36) that is the control group and the least strength with Group 2 (2286.59 ± 547.36). **Conclusion:** On the basis of the results obtained from this study, it can be concluded that, the more the height of the zirconia collar, the higher the fracture strength of the all-ceramic crowns. Thus ceramic-layered zirconia coping design with 1.5 mm marginal collar height is recommended for functional long life, at least in the posterior higher load-bearing areas with lesser esthetic demands.

**Keywords:** All-ceramic crowns, CAD/CAM, coping design, zirconia

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there are some clinical reasons for the fracture of the veneer or the core materials in the posterior region.\(^3\)

One of the most popular core material used for all-ceramic restorations is zirconia, which is considered as a material of choice, both in anterior and posterior regions of the mouth, due to its superior mechanical properties.

Similar to the technique employed in the construction of metal ceramic restorations, zirconia-based restorations use high-strength ceramic material for the framework, in order to provide sufficient resistance against cyclic loading.\(^2\) Zirconia have the flexural strength ranges from 800 to 1000 MPa, and zirconia ceramics and metal ceramics have shown similar shear strength.\(^3\)

Despite of all this superior mechanical properties, clinicians are faced with failures in these restorations too, as a result of fracture of the veneering or core material.

The purpose of this study was to investigate the influence of zirconia coping designs on the fracture resistance of all-ceramic crowns.

**Aims and objectives**

The aim of this study was to evaluate the fracture resistance of all-ceramic crowns with different zirconia coping designs.

**Study design**

This is an *in vitro* study.

**Materials and Methods**

**Master die fabrication**

A metallic stainless steel master mold with retrievable master die with a diameter of 8 mm at the occlusal surface and 10 mm at the margin was fabricated to simulate a prepared lower molar tooth. The axial surface of the master die had a taper of 6° and a height of 5.0 mm. The finish line is designed as a deep chamfer having a curvature radius of 1.0 mm [Figure 1].

**Scanning of master die**

The master die was sprayed with scanning spray (Telescan; DFS-Diamon, Riedenburg, Germany) and then scanned with CAD/CAM scanner (Ceramill map 400; Amann Girrbach, Koblach, Austria).

**Fabrication of zirconia coping on master die**

On the basis of the marginal collar height of zirconia coping, total of 32 zirconia copings (\(n = 8\) for each group) were designed and fabricated.

*Fabrication of Group 1 (0.0 mm—no collar) zirconia coping*

Zirconia coping was designed using Ceramill Mind software (Amann Girrbach) [Figure 2]. Without incorporating the collar height, the occlusal surface and the axial walls were designed to have an overall thickness of 0.6 mm and maintaining a 0.06 mm gap width of cement space in the design. This design was nested on to 12 mm Ceramill zirconia blanks (Ceramill CAD/CAM Material—ZI 12 mm; Amann Girrbach). Dry milling of this coping design was performed using a milling machine (Ceramill Motion 2; Amann Girrbach). Once the milling was completed, the collected zirconia coping was de dusted and placed on to the zirconia holding tray and placed inside the sintering furnace (Ceramill Therm; Amann Girrbach). A sintering cycle of 12 h was used in total, with an average rise in temperature of 8°C/min and peak temperature of 1450°C and holding time of 2 h. Same process was repeated to achieve eight zirconia copings in this group.

*Fabrication of Group 2 (0.5 mm collar) zirconia coping*

With Ceramill Mind software, a collar height of 0.5 mm was selected all around the margin to design a collar height of 0.5 mm, and then milling and sintering were performed similar to Group 1 to procure eight zirconia copings in this group.

![Figure 1: Schematic diagram of metal master die. (A) Frontal view. (B) Occlusal view](image1)

![Figure 2: CAD/CAM design of Group 1 (0.0 mm—no collar)](image2)
Fabrication of Group 3 (1.0 mm collar) zirconia coping
With Ceramill Mind software, a collar height of 1.0 mm was selected all around the margin to design a collar height of 1.0 mm, and then milling and sintering were performed similar to Group 1 to procure eight zirconia copings in this group.

Fabrication of Group 4 (1.5 mm collar) zirconia coping
With Ceramill Mind software, a collar height of 1.5 mm was selected all around the margin to design a collar height of 1.5 mm, and then milling and sintering were performed similar to Group 1 to procure eight zirconia copings in this group [Figure 3].

Application of Zirliner
Once the sintered zirconia copings were ready, they were subjected to oxidation and a thin coat of Zirliner (IPS e.max; Ivoclar Vivadent, Amherst, NY) was applied all over the sintered zirconia coping to provide white zirconium oxide frameworks with a shaded character. These were then heat treated in the baking furnace (Programat P 310; Ivoclar Vivadent) for 20 min at a temperature of 960°C.

Ceramic layering over zirconia coping
The Zirliner-coated sintered zirconia coping was layered with porcelain (IPS e.max Ceram Dentin; Ivoclar Vivadent) by an experienced dental mechanic following manufacturer’s instructions and then fired in a porcelain furnace for 14 min at a temperature of 650°C. Layered ceramic had a thickness of 2.0 mm on the occlusal surface and gradually decreased to 1.6 mm thickness on the axial surface and 1.0 mm thickness toward the margin. Trimming was performed with ceramic trimming burs to achieve the dimensions described earlier. This was standardized with the use of digital caliper and metal caliper [Figures 4 and 5]. The ceramic-layered zirconia coping was finished with glaze liquid (IPS e.max Ceram Dentin) and fired for 22 min at a temperature of 725°C. Same process was repeated to achieve all the eight ceramic-layered zirconia copings for Group 1.

For groups 2, 3, and 4, ceramic was layered occlusal to the existing collar and finished similar to ceramic-layered zirconia coping in Group 1. Same process was repeated to achieve all the eight ceramic-layered zirconia copings for groups 2, 3, and 4, respectively.

Cementation of ceramic-layered zirconia coping
The ceramic-layered zirconia coping was cemented to the master die to prevent its dislodgement during the test for fracture resistance. The cement used for luting was Type 1 glass ionomer cement (GC Gold label Glass ionomer luting and lining)- 5 Tampines Central 1, Singapore, and the process was performed following the manufacturer’s instruction. The luted ceramic-layered zirconia coping was held under finger pressure for 5 min and then upon initial set the excess cement was removed.

Testing for fracture resistance
Master die with cemented ceramic-layered zirconia coping was mounted on a Universal testing machine.
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(Tec-sol, Chennai, India), and on the occlusal aspect a 9.0 mm in diameter stainless steel ball indenter was placed with a crosshead-speed of 1.0 mm/min. Compressive load was applied till the ceramic-layered zirconia coping fractured [Figure 6]. Reading was obtained from Universal testing machine software. Load in Newton was recorded when the cemented ceramic-layered zirconia coping fractured. This process was carried out for all the ceramic-layered zirconia copings of Group 1, Group 2, Group 3, and Group 4.

Statistical evaluation

SPSS software, version 23.0 (IBM, Armonk, NY), was used for analyzing the data. Mean and standard deviation of fracture strength values of all groups were obtained. One-way analysis of variance (ANOVA) was conducted to check for significant difference of fracture strength between the test groups. Tukey’s post hoc test was performed to check for intergroup significance of fracture strengths.

Results

This study compared the fracture resistance of all-ceramic crowns involving different zirconia coping designs.

The fracture resistance of all-ceramic crowns was tested using Universal testing machine. The strength of all-ceramic crowns was calculated in Newton (N). The fracture strength was evaluated for each group. The mean fracture strength and standard deviation for group were calculated.

Statistical analysis was carried out using SPSS software. We performed one-way ANOVA to compare the four groups with fracture strength. Highest mean fracture strength was recorded in Group 4, followed by Group 3, then Group 1 and Group 2.

\[ F_{(3)} = 7.502 \]

A value of \( P < 0.05 \) was considered as significant.

Here we observed that, there was a statistically significant difference between the groups with \( P < 0.01 \).

Group 4 has the highest strength (3318.89 ± 395.67) followed by Group 3 (2910.0 ± 219.22), then Group 1 (2320.02 ± 547.36) that is the control group, and the least strength with Group 2 (2286.59 ± 496.66) [Table 1 and Graph 1].

Further Tukey’s post hoc test was performed for multiple comparison. From post hoc test, we observed that strength of Group 4 is significantly different from Group 2 and Group 1, but not significant difference from Group 3. Group 3 is also significantly different from Group 2 and Group 1. But there was no significant difference among Group 1 and Group 2 [Table 2].

Discussion

The strength of all-ceramic restorations depends not only on the fracture resistance of the material but also

| Collar design          | Mean      | Std. deviation | 95% Confidence interval for mean |
|------------------------|-----------|----------------|---------------------------------|
|                        |           |                | Lower bound | Upper bound             |
| Strength               |           |                |              |                          |
| Group 1 (0.0 mm—no collar) | 2320.0200 | 547.36952      | 1862.4076   | 2777.6324              |
| Group 2 (0.5 mm collar)  | 2286.5913 | 496.66851      | 1871.3660   | 2701.8165              |
| Group 3 (1.00 mm collar) | 2910.0000 | 219.22251      | 2726.7254   | 3093.2746              |
| Group 4 (1.5 mm collar)  | 3118.8963 | 395.67728      | 2788.1018   | 3449.6907              |

Table 1: Descriptive statistics of mean and standard deviation of strength between Group 1, Group 2, Group 3, and Group 4
on an appropriate preparation design with sufficient material thickness. Copings can be designed to provide resistance to fracture of the layered porcelain. In this study, we evaluated the fracture resistance of all-ceramic crowns involving different zirconia coping designs.

In this study, the mean fracture strength of all-ceramic crowns had statistically significant difference with different coping designs. Group 4, that is, with a collar height of 1.5 mm had the highest mean fracture strength when compared with the no-collar group. The results of this study revealed that the more the height of the zirconia collar, the higher the fracture strength of ceramic-layered zirconia coping. The stresses are transferred to the marginal area of veneering porcelain when static or cyclic load is applied to occlusal surface of the crown. Although porcelain is a brittle material that is susceptible to fracture/delamination, this fracture or chipping of the veneered porcelain is avoided by incorporation of zirconia collar, which has supporting function. The result of this study is in accordance with the studies conducted by Cho et al.,[4] Liu et al.,[5] and Øilo et al.[6] who also concluded that more thickness of the zirconia collar resulted in higher fracture strength of ceramic-layered zirconia coping. For both the functional long life and esthetics of zirconia–ceramic restoration, Cho et al.[4] and Liu et al.[5] also recommended zirconia coping design with 2.0 mm marginal collar width in posterior higher load-bearing areas. Øilo et al.[6] also concluded that monolithic zirconia crowns had more strength than the zirconia crowns with cervical collar as monolithic zirconia has more material thickness.

In this study, there was no statistically significant difference between the no-collar group and 0.5 mm collar group. Similarly, according to the study conducted by Kim et al.,[7] there was no statistically significant difference in fracture resistance between the collarless coping group and coping group of 0.2 mm facial collar height. In another study conducted by Nikzadjimani et al.[8] comparing the fracture resistance of the standard collarless coping with 0.3 mm facial collar, the results showed no statistical significance in the fracture resistance between the groups studied. This shows that there is no much difference in fracture strength between very thin collar and no-collar. This study also showed that a minimum of 1 mm collar height is required to achieve better fracture strength.

Because of the dimensions of core and veneer materials, inherent and processing defects within the porcelain and the preparation design fracture of all-ceramic restoration is very complicated process. Oram et al.[9] and Osilo[10] reported that presence of pores inside the ceramic results in weakness and eventual fracture of ceramic. So it can be a reason for the decrease in fracture strength in the 0.5-mm collar group compared to the control group, which is not significant. Considering that porosities play a role in initiation of crack propagation, during the porcelain build-up process, a technique that can minimize the formation of porosity should be used.

The use of a smaller diameter ball indenter increased the contact pressure on the crown compared to that of a clinical scenario.[11] The contact pressure is effected by the ratio of the elastic modulus of the dental porcelain to the elastic modulus of the loading ball, and by the radius of the loading ball.[11] Alternative methods such as use of a loading ball with a modulus of elasticity lesser than that of the stainless steel ball, a tin sheet between the load applicator and crown as stress breaker, or a stainless steel loading piston with its end machined to a curvature equivalent to 40–50 mm diameter can be used to reproduce clinical contact pressure.[11]

![Graph 1: Bar chart showing mean fracture strength of four different groups](image)

![Table 2: Data on the mean and standard deviation of load and fracture strength among four groups using one-way ANOVA test](table)

|                              | Sum of squares | df | Mean square    | F       | Sig.  |
|------------------------------|---------------|----|----------------|---------|-------|
| Strength (MPa) between groups| 4224809.741   | 3  | 1408269.914    | 7.502   | 0.001 |
| Within groups                | 5256384.112   | 28 | 18728.004      |         |       |
| Total                        | 9481193.852   | 31 |                |         |       |
the production of zirconia-based ceramic crown with conventional layering technique was chosen because of esthetic and economic reasons; after chipping, restoration must be repaired or renewed.[12] Other studies with higher fracture strength values were obtained with CAD-on technique when compared with multilayer, press-on, or conventional layering techniques.[12,13]

Thus from this study, it can be concluded that there is no difference in fracture strength between no-collar and 0.5 mm collar design in the ceramic-layered zirconia crown. A minimum of 1 mm and optimum of 1.5 mm collar design in the ceramic-layered zirconia crown is recommended for functional longevity, at least in the posterior higher load-bearing areas with lesser esthetic demands.

Limitations

• The load applied by the Universal testing machine does not simulate the clinical loading situation.
• The samples were not treated with cyclic loading, which restricts the portability of the results to clinical situations.
• This study does not simulate all the oral conditions.
• This study investigated only limited combinations of materials for the core and veneering porcelain, and the results cannot be generalized to other systems.

Conclusion

Within the limitation of this in vitro study, the following conclusions can be drawn from the results of this study.
• Coping design affects the fracture strength of ceramic-layered all-ceramic crowns.
• More the height of zirconia collar, higher is the fracture strength of ceramic-layered all-ceramic crowns.
• Minimum of 1 mm of collar height is required to achieve better fracture strength.
• For optimum fracture strength, 1.5 mm collar height is required.

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Conflicts of interest

There are no conflicts of interest.

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