# Evaluation Of Fracture Resistance Of Monolithic Zirconia Full Veneer Restoration Fabricated On Teeth Prepared With Rounded Shoulder Finish Lines Of Two Different Widths – An Invitro Study

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**Abstract**

**Introduction:** The cause of replacement of porcelain fused metal restoration by monolithic zirconia was chipping. Different finish lines have been recommended for monolithic zirconia restorations of different widths. Majority suggests 1mm and 2mm of width of finish lines for monolithic full veneer restoration.

**Aim:** To evaluate and compare the fracture resistance of monolithic zirconia full veneer restoration fabricated on teeth prepared with rounded shoulder finish lines of 1mm and 0.5mm widths.

**Material & Methods:** 2 typodont mandibular molars were embedded in self cure acrylic and tooth preparation was done to receive a rounded shoulder finish line of 1mm width & 0.5mm width which was verified using a digital vernier caliper. Duplication was done and a total of 40 brass dies were fabricated using ringless casting system and they were labeled as

Group A and Group B with rounded finish lines of 1mm & 0.5 mm respectively. Monolithic zirconia restorations were cemented on their respective brass dies & samples were subjected for fracture resistance test using universal testing machine.

**Results:** Group A had mean fracture of 1423.5 N and Group B had mean fracture resistance 1608.5 N which was almost similar in both groups. Comparison with Mann Whitney test showed statistically non-significant results.

**Conclusion:** There was no significant difference found in fracture resistance of monolithic full veneer restoration on teeth prepared with rounded shoulder finish lines of 1mm width & 0.5 mm width, both finish lines can be used in clinical practice, although 0.5mm should be preferred as it is more conservative. Values of fracture strength of zirconia full veneer restorations are significantly higher than the average biting forces or clenching forces so they can be successfully used for in-vivo verification for other factors for a successful restoration.



**Keywords:** biting forces, finish line width, fracture resistance, monolithic zirconia, shoulder finish line

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## Introduction

Conventional fixed dental prosthesis requires a considerable amount of tooth structure removal. A major concern of restorative & prosthetic dentistry is the preservation of the remaining tooth structure. When full coverage veneers are indicated, reduction of dental hard tissue structure is necessary for maintaining structural durability, restoring natural anatomy & aesthetics.Amount & geometry of reduction, type of finish lines & materials used resists the stresses acting on the teeth maximizes the longevity of the restorations & also protects the neighbouring tissues. Marginal fit and adaptation are essential components in the long-term success of a prosthesis.[1]

Porcelain fused metal restorations have proved to be of standard modality for full veneer restorations due to their good mechanical properties and satisfactory aesthetic results. Chipping of porcelain remained a primary problem occurring in a prosthesis and delineates the cause of their replacement. Patients growing demand for highly aesthetic and tooth-colored restorations resembling natural teeth increased the use of all-ceramic materials. All dental material requires sufficient physical properties to achieve good esthetic results, marginal integrity and high strength to withstand occlusal load. However, elimination of the metal substructure has raised concerns in resistance to fracture for all ceramic materials.

Zirconia is considered the most suitable material due to its high fracture strength & indentation fracture toughness as compared to other ceramics. Monolithic zirconia restorations, manufactured exclusively by the CAD/CAM technology, exhibit high flexural strength, require more conservative dental preparation, minimize wear on the antagonists, exhibit satisfactory aesthetics, require less laboratory time and as monolithic, they lack the unwanted complication of chipping.[2-4] One of the disadvantages is an opacity of monolithic zirconia which is the reason for low esthetic demands.[5] However, recent modifications in composition, structure, and fabrication methods have led to monolithic zirconia ceramics of superior translucency, but with a significant reduction in strength.[6-9]

Finish lines are designed in such a manner so that restorations can withstand high occlusal forces & resist fracture of prosthesis. Several studies have been advocated for width & different configurations of finish lines such as chamfer, rounded shoulder of 1mm & 2mm. With new advances in materials, it's important to assess whether finish lines of lesser width which conserves more tooth structure can be advocated to achieve an appropriate clinical outcomes. So, the effect of 1mm and 0.5mm width of shoulder finish lines on fracture resistance of monolithic zirconia full veneer restorations were studied. The aim was The aim was to evaluate & compare the fracture resistance of monolithic zirconia full veneer restoration fabricated on teeth prepared with rounded shoulder finish lines of 1mm and 0.5mm widths.

## Material & Methodology

Study was conducted in the Department of Prosthodontics, Crown & Bridge and Implantology, Rural Dental College & Hospital, Loni, after IEC approval.

### METHODOLOGY:

#### 1. Mounting of master dies

2 typodont mandibular molars were mounted 3mm below the cervical margin of teeth in a specially fabricated round silicone mold of size 20 x 25 mm containing freshly mixed self-cure polymethylmethacrylate (PMMA) such that the crown portion of the teeth was exposed. 

#### 2. Design of tooth preparation:

Tooth preparation was done on the master dies using a high-speed air-rotor according to the recommendations for all ceramic veneers having 10-12 degrees of total occlusal convergence, 4 mm occluso-cervical height, occlusal reduction of 2mm & a rounder shoulder finish line. The first die was designed to have a rounded shoulder finish line of 1mm width & were labelled as Group A and the second die was designed to have a rounded shoulder finish line of 0.5mm width & were labelled as Group B **(Figure 1).** Standardization was done using diamond points of sizes of 1.8 mm & 0.8 mm diameter. Half side of the diamond point was immersed for making a rounded shoulder finish line of 1mm and 0.5 mm width respectively on the teeth. Verification of width of the finish lines was done using a digital vernier calliper of 1mm & 0.5mm for Group A & Group B respectively **(Figures 2).**

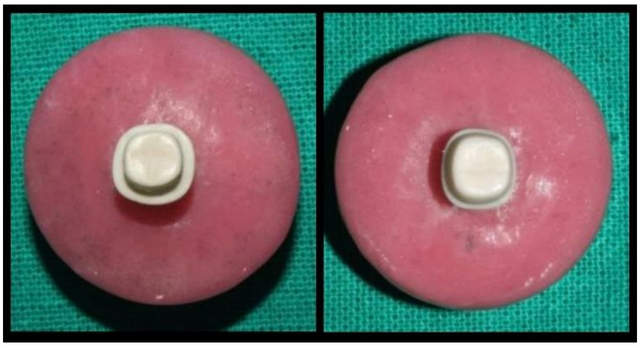


**Figure 1 – Group A: Rounded shoulder finish line of 1 mm width**
**Group B: Rounded shoulder finish line of 0.5 mm width**


**Figure 2 – Group A & B: Verification of 1 mm & 0.5 mm width**
**with the help of digital vernier caliper**

**3. Making an impression followed by wax patterns:**

A spacer of modelling wax sheet of thickness 1.5 mm was adapted on the teeth and acrylic surface**.** Impression procedure was carried out by two-step double mix impression technique with a light body and putty elastomeric impression material. Firstly, the impression of the master die was made with putty by mixing base & catalyst according to the manufacturer's recommendations, spacer removal was done and a light body impression was made of the master dies by dispensing base & catalyst paste according to the manufacturer's recommendations of Group A & Group B Both the impressions were visualized under a stereomicroscope to check for any flaws in the impression.

A total of 40 wax patterns, 20 in each group were made from putty & light body impressions with the help of inlay wax & modelling wax **(Figure 4).** Inlay wax was used for making upper portion of the master die involving the rounded shoulder finish line & modelling wax was used for making the base of the master die**.** All wax patterns were visualized under a stereomicroscope for checking any flaws in the finish line of wax patterns.

All the wax patterns of both groups that are Group A & Group B were inscribed with numbers 1A - 20A & 1B - 20B respectively.

**Figure 3 – Light body & putty impressions of Group A & Group B followed by wax pattern fabrication**



**4. Fabrication of brass dies**

Base of the wax patterns worked as base formers which were invested in phosphate bonded investment material according to manufacturer's recommendations and casting was done by a ringless casting system. Following that, wax elimination was done in a burnout furnace at 800 degree Celsius for one hour. Molds were cast using pellets of brass weighing 70 grams in an induction casting machine. The ringless molds were divested immediately after cooling at room temperature. A total of 40 fabricated brass dies were finished & sandblasted with alumina oxide (50 microns) under 1 bar pressure. Then all the samples were again evaluated for widths of 1mm & 0.5mm of Group A & Group B respectively with the help of a digital vernier calliper and those which didn't suffice were rejected.

**5. Scanning & Wax-Up of the brass dies:**

Scanning of brass dies was accomplished with the help of a laboratory scanner to obtain virtual scan models**.** Three-dimensional (3D) digital files were used for designing of the framework**.** Virtual wax-up was made with the help of CAD software which included spacer thickness of 40 microns which was short by 1mm. Full contoured wax up was done on all dies of Group A & Group B & were inscribed with numbers 1A - 2A & 1B - 20B respectively.

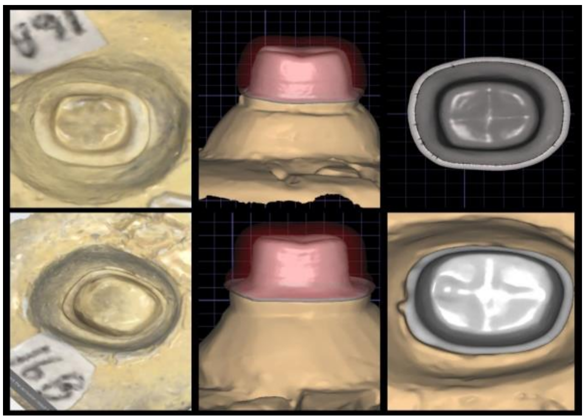


**Figure 4 – Virtual scan models & virtual wax-up of Group A & Group B**

**6. Milling:**

Monolithic zirconia was the choice of material for fabrication of the prosthesis. Milling was done using 5 axis milling machine. Sintering of milled prosthesis was completed at 1400 degree Celsius using a sintering furnace**.**

**7. Cementation:**

Each veneer was cemented on its respective brass die by using adhesive resin cement **(Figure 5).** Veneer was seated by finger pressure for 10 mins and excess cement was removed with the help of explorer. Specimens were stored in distilled water at 37 degree Celsius for 24 hours before testing the fracture resistance.




**Figure 5 – Cementation of Group A & Group B**

**8. Fracture resistance test:**

Fracture resistance test was performed using universal testing machine with a capacity of 10KN (v=1mm/min, UNITEST-10, Accuracy of machine±1%). Universal testing machine was controlled via a computer software program, which also recorded the stress-strain diagram and breaking load. Load was applied at the center of the full veneer restoration using a stainless-steel ball (3mm) at crosshead speed of 1 mm/mm until fracture of the sample**.**

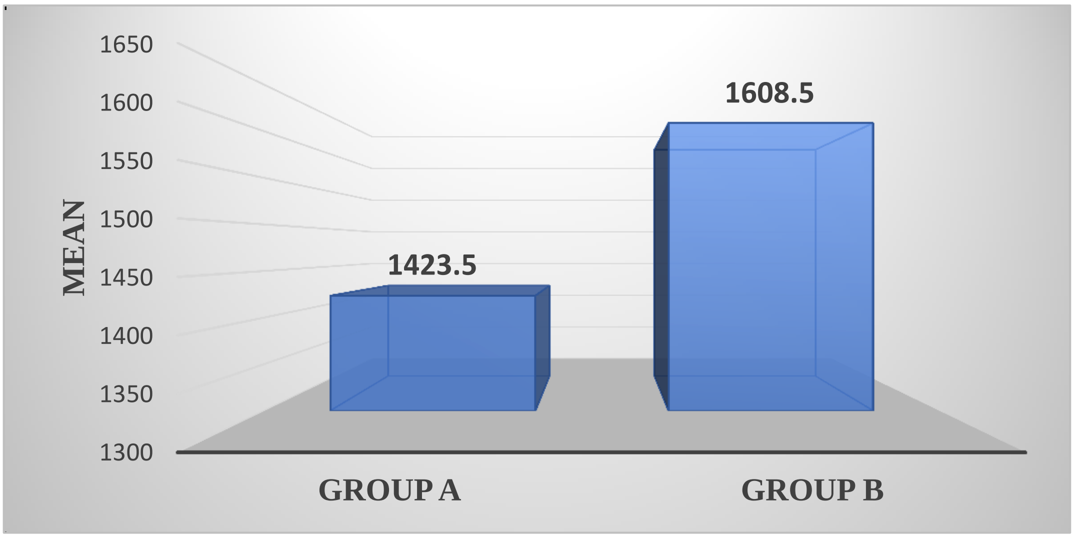
**Figure 22- Application of load & fractured sample Universal testing machine controlled via a computer software program**

## Results

Comparison of mean & standard deviation of fracture resistance values was done between Group A & Group B. Group A had mean fracture resistance 1423.5 newton and Group B had mean fracture resistance 1608.5 newton which was almost similar in both groups **(Table no. 1 & Graph no. 1).** The highest mean value for Group A was 2290 N & for Group B was 2250. Comparison was done with Mann Whitney U test which showed statistically no significant results.

**Table no 1: Comparison of mean and standard deviation values of fracture resistance (N) in Group A - Rounded shoulder finish line of 1 mm width & Group B - Rounded shoulder finish line of 0.5 mm width.**

| | Mean | Std. Deviation | P value |
|---|---|---|---|
| Group A | 1423.50 | 398.818 | 0.12 |
| Group B | 1608.50 | 342.380 | |




**Graph no 1: Comparison of mean and standard deviation values of fracture resistance (N) in Group A - Rounded shoulder finish line of 1 mm width & Group B - Rounded shoulder finish line of 0.5 mm width.**

### Statistical Analysis

Statistical analysis was done by descriptive statistics as mean and standard deviation. All assessment variables under study were compared by Mann Whitney U test at 5% (p, 0.05) and 1% (p, 0.01) level of significance. Statistical analysis software namely SPSS version 20 (IBM SPSS Statistics Inc, Chicago, Illinois, USA) Windows software program was used to analyze the data.

### Discussion

Success of restoration is based on principles of mechanical preparation, maintenance of biological integrity & achieving esthetics. The concept of minimally invasive preparation is essential for successful outcome. Ultimate goal of reconstructive dentistry is to obtain excellent esthetic results while simultaneously respecting the biological structures. Various studies by El-khodary & colleagues suggest that the most common failure of porcelain fused metal restoration is chipping of porcelain which led to the increased demand for all ceramic restorations.[10]

Zirconia is a polycrystalline ceramic with favourable mechanical properties. It shows excellent biocompatibility, low plaque retention, low wear of opposing natural teeth and can be used as a core material or in a monolithic form.[11] Zirconia-based restorations are preferred by clinicians at posterior sites because of the strength and esthetic properties of such restorations. However, all-ceramic restorations fracture at higher rates than do metal-based restorations. Of the numerous reasons for fracture, margin design is one of the factors that can affect the fracture strength of all-ceramic restorations.[12] Ceramic materials are sensitive to tensile forces and their mechanical resistance is highly influenced by presence of superficial scratches and internal voids which may serve as sites of initiation of cracks. Masticatory loads in molar area are high & flaws in prosthesis are related to fracture resistance of a material. The masticatory force of healthy and young adults in the posterior region was reported to be approximately 597 N for females and 847 N for male. Biting forces can significantly increase up to 900-1000N in bruxers.[13,14] An average posterior biting force of 700 N was reported by Ferrario.[15]

Ceramics lacks the property of plasticity unlike that of metals which deform due to plasticity and results in fracture.[16] Fracture strength can be described as a stress at which material tends to fracture. The most critical factors restricting the resistance to fracture are size and distribution of load and fracture toughness. Also, compressive strength is a helpful parameter in evaluation of the fracture resistance of ceramic materials. Konstantinidis et al. suggested that monolithic zirconia crowns have a high fracture resistance & allows preparation without excessive tooth reduction. This is one of the reasons that monolithic zirconia can be used as an alternative to metal-ceramic or ceramic restorations.[17] Finish lines are designed in such a manner so that restorations can withstand high occlusal forces & resist fracture of prosthesis. Roh et al. & colleagues suggested that rounded shoulder, chamfer and deep chamfer finishing line designs are considered to be adequate for the fracture strength of all-ceramic restorations.[18] Shillingburg proposed that due to the omitted internal sharp angles and the subsequently decreased concentration of stress inside the tooth and crown, rounded shoulder margin is better than 90° shoulder for all-ceramic restorations.[19]

Al-Joboury and Zakaria had shown that monolithic zirconia CAD/CAM crowns with a 90-degree shoulder margin have a higher average breaking load than with a deep chamfer margin. And these 2 types of finish line margins are considered to be suitable in the premolar and molar regions.[20]

Potikel et al. in 2004 evaluated the fracture resistance of restored teeth with different types of all ceramic restorations and showed no significant difference among groups. They proved that the fracture resistance of natural teeth restored with all ceramic restorations with shoulder finish line with 1 millimetre depth and a round internal angle was similar to the other restoration types.[21] On the contrary, Di Lorio et al. in 2008 stated that the fracture resistance of shoulder finish line design of the core of Procera all ceramic crowns was higher than that with chamfer finish line design.[22] Jalali et al. compared the fracture resistance and adaptation of the margin in two preparation designs chamfer and shoulder of zirconia based all-ceramic restoration and the results showed that less aggressive finish line design and tooth preservation in all-ceramic restorations does not adversely affect the adaptation of margin and fracture strength of the restoration with shoulder or chamfer finish line designs.[23] Studies by Jalalian E, Aletaha NS included chamfer and shoulder margins, concluded that chamfer margin could improve the biomechanical performance of posterior single crown alumina restorations because of the strong unity in the chamfer margin and round internal angle in chamfer margin.[24] Kasem et al have shown that there is no significant difference in the breaking load between a shoulder margin and a knife-edge margin.[25]

Comparision between the zirconia-reinforced glass ceramic crown (Celtra Duo) and the monolithic zirconia crown (KATANA), monolithic zirconiz showed high breaking load for both types of margns. Monolithic zirconia crown can be employed in the premolar and molar region with a margin thickness of 0.5 mm. Ardakani et al. evaluated the effect of 2 marginal designs (shoulder 90°, shoulder 135°) on the fracture resistance of zirconia copings & concluded that marginal design of zirconia cores significantly influences their fracture resistance and had clinically acceptable fracture resistance. A 135° shoulder finish line design can improve the fracture resistance of the zirconia crowns due to rounded internal angles.[26] The results of these studies helped in choosing rounded shoulder finish lines of 2 different widths.

Null hypothesis was accepted as there was no significant difference in fracture resistance of monolithic zirconia full veneer restoration on teeth prepared with rounded shoulder finish lines of two different widths of 1 mm & 0.5mm. The 2 marginal designs had clinically acceptable fracture resistance. The results of our study indicate no significant difference between 2 finish line widths indicating no effect of marginal width on fracture resistance. The results of our study are similar to other studies by Juntavee and Kornrum who determined the fracture resistance of a highly translucent monolithic zirconia crown with different types of margins in terms of marginal thickness and collar height & found that the deep chamfer margin (1.2 mm) provided a zirconia crown which had high fracture resistance than the slight chamfer (0.8 mm) but both types of margins gave a breaking load higher than the maximum chewing force of humans. Therefore, they suggested that the slight chamfer margin would be clinically acceptable for high translucency monolithic zirconia crowns.[27]

The minimum and maximum forces resulting in fracture of monolithic full veneer restorations with 1mm width was 720 N & 2290 N respectively while with 0.5mm width it was 1140 N & 2250 N respectively. Therefore, according to the results of the fracture resistance test, fracture loads of both groups were higher than the average masticatory force in the molar and premolar region. Since all of samples exceeded the normal physiologic as well as habitual masticatory force values, it can be presumed that all tested zirconia restorations have the potential to withstand both physiologic and pathologic occlusal forces and remain intact during load. It can be concluded that monolithic zirconia had shown clinically acceptable results with the margin widths of 1mm and 0.5 mm & its fracture resistance is comparable to or more than that of tooth enamel/structure. Hence it can be the material of choice for posterior restorations and also rounder shoulder of 0.5 mm & 1mm width both are clinically acceptable.

Limitations include that since it is an invitro study, oral environments weren't simulated, also thermocyclic loading wasn't considered, which had shown significant changes in fracture load values in previous studies. Hence, further research must be conducted for in-vivo verification.

## Conclusion

Following conclusion can be drawn, they are as follows:

1. As there was no significant difference found in fracture resistance of monolithic full veneer restoration on teeth prepared with rounded shoulder finish lines of 1mm width & 0.5 mm width, both finish lines can be used in clinical practice, although 0.5mm should be preferred as it is more conservative.
2. Values of fracture strength of zirconia full veneer restorations are significantly higher than the average biting forces or clenching forces so they can be successfully used for in-vivo verification for other factors for a successful restoration.

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## Conflict of Interest

None

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