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An In vitro study to compare the effect of chamfer and shoulder on the Fracture resistance of all ceramic Restorations

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ABSTRACT

Background and aim: The fracture of all ceramic restorations due to the occlusal and lateral forces is one of the major problems these days. This problem arises mainly due to high intensity of masticatory forces in the molar and premolar area along with the brittle nature of ceramic restorations. The aim of this present in-vitro study is to compare the fracture resistance of chamfer and shoulder margins under a cyclic load of Inceram crowns.

Materials and methods: First maxillary premolar without any cracks and caries extracted for orthodontic purposes were included in the present study. Using appropriate burs, 50 in. chamfer and 90 in. shoulder margins were prepared on the tooth. 10 impressions were taken using a polyvinylsiloxane and then dies were fabricated by pouring with epoxy resin.Again 10 polyvinylsiloxane impressions were made and ten epoxy resin dies were created from these impressions. After setting the stone dies were coated with a space liner and were sent to a dental laboratory where the alumina cores with 0.5 mm thickness were fabricated (Vita, Germany). The fit of each alumina core on their respective epoxy resin was verified under a 2.5stereomicroscope. Using a universal testing machine called Instron, mechanical testing was carried out.

Result: The mean ± standard deviation for the resistance of fracture came out to be 610.1880±58.79526 N for chamfer margin and 502.7270±105.83233 for that of shoulder margin. The difference between the two groups was statistically significant as revealed by Student's t-test ($p = 0.011$).

Conclusion: Fracture caused by the occlusal and lateral masticatory forces seems to be one of the main problems of all ceramic restorations. These restorations can sometimes lead to unesthetic appearance and many biologic problems because of the metal present in these restorations

Keywords: Chamfer; Shoulder; Fractureresistance; Allceramic; Inceram

INTRODUCTION

One of the major problems of the all ceramic restorations is their probable fracture against the occlusal and lateral force [1]. The prominent restorations contain metal which brings about toxic, chemical and allergic affects. The difference between their color and natural tooth is another problem. Most of the people prefer tooth color crowns. All ceramic crowns have esthetics and biocompatibility [2]. In the past few years such restorations have been used in the restorations of posterior teeth. However, some crown fractures due to the relatively low mechanical resistance of ceramic crowns have become more apparent. This is mainly due to the magnitude of the biting forces applied on the premolar and molar teeth and to the inherent brittleness of ceramics [3,4]. Ceramic materials are particularly susceptible to the tensile stresses, and mechanical resistance is also strongly influenced by the presence of superficial flaws and internal voids. Such defects may represent the sites of crack initiation. This phenomenon may be influenced by different factors such as marginal design and thickness of the restoration, residual processing stress, magnitude and direction and frequency of the applied load, elastic modulus of the restoration components, restoration–cement interfacial defects, and oral environmental effects [5]. In one research, finite element analysis (FEA) wasused to study the stress distribution during mastication in maxillary second premolars restored with metal–ceramic crowns and compared them to non-restored teeth. They registered high stresses at the cervical line of the restored teeth within the dentin–metal interface and within the ceramic–metal interface [6]. The FEA method was used to study the stress distribution in the lower first molar restored with all ceramic crowns. The result of that study suggested the concentration of stress at the cervical site [7].

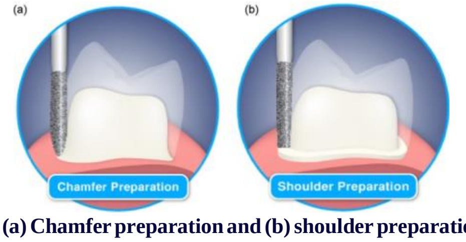

Fig. 1. (a) Chamfer preparation and (b) shoulder preparation.

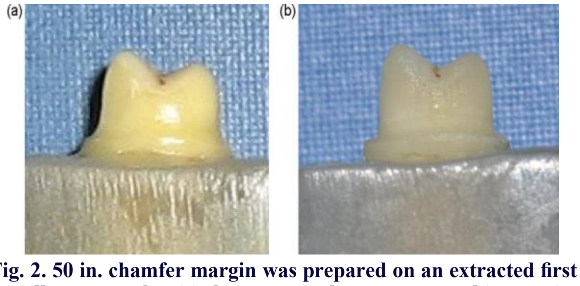

Fig. 2. 50 in. chamfer margin was prepared on an extracted first maxillary premolar (a) the same tooth was converted into 90 in. shoulder margin (b).

The hypothesis of the present study is the effect of marginal design of crowns on an improved mechanical performance of Inceram crowns,from aclinicalpointofview.Suchacondition can be achieved preparing a chamfer margin in crowns instead of a shoulder margin (Fig. 1). Sadan et al. proposed that both of these types of finishing lines are considered to be adequate for the tooth [8]. But Di Lorio et al. suggested that the shoulder margin could improve the biomechanical performance of single crown alumina restorations [9]. De Jager et al. discovered that for long lasting restorations in posterior region it is advisable to make a chamfer with collar preparation [10]. Cho et al. found out that the fracture strength of chamfer finishing line (0.9 and 1.2 mm) was greater than 1.2 mm rounded end shoulder and 1.2 shoulder finishing line [11]. Potiketetal.suggestedthata1 mm deep shoulder finishing line with a rounded internal line angle has good fracture strength for the natural teeth restored with all ceramic crowns [12]. Rammersberg et al. discovered that a minimally invasive 0.5 mm axial chamfer tooth preparation has the greatest stability for posterior metal free crowns [13].

The aim of the present in vitro study is to compare the resistance to fracture under a cyclic load applied to chamfer and shoulder margins of Inceram crowns.

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2. MATERIALS AND METHODS

A caries-free first maxillary premolar extracted for orthodontic reasons (without any crack) was selected for the present study. The tooth was prepared with a 50 in. chamfer margin (0.7 mm depth) using a torpedo diamond bur [14,15] (Fig. 2). For more strength resistance occlusal surface was prepared with a cusp shaped [16]. Ten impressions were made using a polyvinylsiloxane (Zhermack, Italy). The impressions were poured using Epoxy resin CW2215 (Hunstman, Germany) [17] to create ten identical resin dies with a 50 in. chamfer margin (Fig. 3). Afterwards, the tooth was retrieved and the 50 in. chamfer was converted into a 90 in. shoulder using a cylindrical diamond bur (1 mm depth) [14,15] (Fig. 2). Again 10 polyvinylsiloxane impressions were made and ten epoxy resin dies were created from these impressions (Fig. 3).

Impressions of each epoxy resin dies were taken using apolyvinylsiloxane impression material and poured using die stone. After setting the stone dies were coated with a space liner and were sent to a dental laboratory [18] where the alumina cores with 0.5 mm thickness were fabricated (Vita, Germany) [19]. The fit of each alumina core on their respective epoxy resin was verified under a 2.5stereomicroscope. Each core was cemented using a resin luting agent, Panavia F2.0 (Kuraray, Japan) on the decontaminated epoxy resin dies. After cementation, excess luting agent was removed and samples were stored in a saline solution at room temperature for 24h.

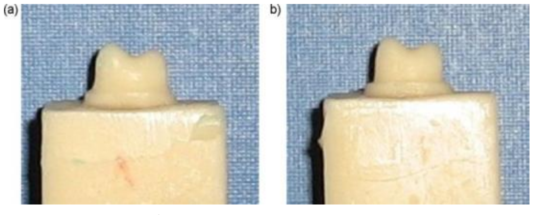

Fig. 3. Impressions from the first maxillary premolar with 50 in. chamfer margin were poured with epoxy resin and make epoxy resin dies with chamfer margin (a) impressions with 90 in. shoulder margin were poured with epoxy resin and make epoxy resin dies with shoulder margin (b).

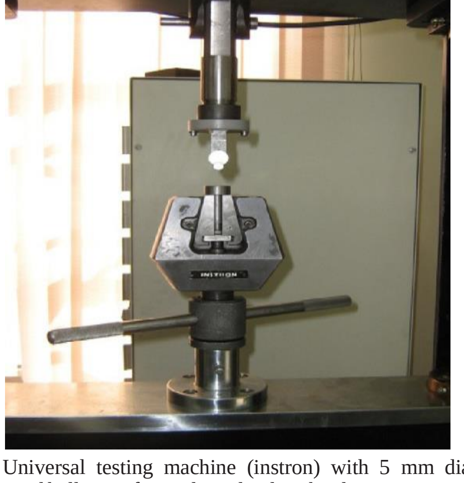

Fig. 4. Universal testing machine (instron) with 5 mm diameter stainless steel ball using for applying load on the alumina cores.

Mechanical tests were carried out using a universal testing machine (Instron). Each specimen underwent a load with a minimal load of 5N with a 5 mm diameter stainless steel ball (Fig. 4). The load was applied at the center of the occlusal surface along the long axis with a crosshead speed of 1 mm/min until fracture occurred [20]. The fracture load data were automatically recorded using Nexigion software. Samples were investigated from the point of view and steriomicroscope of the origin of the failure (Fig. 5).

For statistical analysis data we collected, a mean SD was calculated for each group. The difference between groups was tested for statistical significance with the Student's t-test at a significance level $p < 0.05$.

3. RESULTS

The mean SD offracture resistancewere 610.18 ±58.79N (chamfermargin)and502.72 ±105.83N(shouldermargin).The Student's t-test revealed a statistically significant difference between the groups ($p = 0.012$) (Tables 1 and 2).

Error-bar graph shows the mean fracture resistance of shoulder margin and chamfer margin with 95% confidence interval (Fig. 6, graph).

Coeffcient Of variation (SD/mean = CV) in shoulder margin is more than chamfer margin.

Kaplan–Meir graph shows the cumulative distribution of fracture/load in the chamfer and shoulder finishing lines (Fig. 7, graph).

4. DISCUSSION

One of the major problems of all ceramic restorations is their probable fracture against the occlusal and lateral force [1]. The prominent restorations contain metal which brings about biologic problems and have no esthetical appearance [2]. This study that was a comparison between the resistance to fracture under a cyclic load applied to chamfer and shoulder margins of Inceram crowns showed that the mean fracture resistance of chamfer margin is 610.18N and the shoulder margin is 502.72N. The Student's t-test revealed a statistically significant difference between the groups and fracture resistance of chamfer margin was more than shoulder margin. Elastic modulus of the supported materials of the core affected the fracture resistance of the core [21]. For this reason, in this study, we use epoxy resin dies that are much better than brass dies [22]. Another difference from clinical conditions is the unknown nature of the bonding between luting agent and die material. It is reasonable to suppose that the presence of a hybrid layer at the dentin–cement interfaces the biomechanical behaviour of the core/supporting die system. However, both of these factors equally influenced the samples in the present study therefore it is possible to make a comparison between the two groups. Fracture resistance of the two groups are more than biting forces [23] so we could use both marginal designs successfully in the posterior all ceramic crowns, and it is a very good replacement for PFM crowns. We use resin cements for cementation, hence we have a strong unity in the margins that make strength against the fracture [24]. But there is a statistically significant difference between the two groups that reveals that the chamfer margin has more fracture resistance than shoulder margin. This may be because of a much better marginal fitness in chamfer margin that happens because of a curve in the chamfer finishing line and that causes a better spread in the load. However, we do not have such a condition in a 90 in. shoulder margin that have sharp endings. It seams that shoulder margin has the worse marginal fitness in all ceramic materials because as illustrated in Fig. 8.

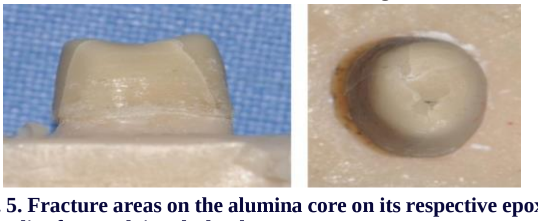

Fig. 5. Fracture areas on the alumina core on its respective epoxy resin die after applying the load.

Table 1: Fracture resistance of shoulder edge and chamfer edge alumina cores.

Finish line	N	Mean		Std. deviation	Std. error mean
Fracture resistance Shoulder	10	502.7270		105.83233	33.46712
Chamfer	10	610.1880		58.79526	18.59269
Table 2 p-Value.					
		t-Test for equality of means			
		t	df	Sig. (two-tailed)	Mean difference
Fracture resistance Equal variances assumed		2.807	18	0.012	107.4610
Equal variances not assumed		2.807	14.072	0.014	107.4610

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d = D cos b and d = D sin a [14], D is vertical discrepancy between the restoration and tooth and d is horizontal discrepancy between the restoration and tooth.

In addition we know that horizontal discrepancy is more important than vertical discrepancy, which is the real gap between the restoration and teeth. The lower horizontal discrepancy makes better fitness between the restoration and teeth. In chamfer margin d = D cos 50 so d = D 0.64 (horizontal discrepancy <vertical discrepancy) but in the shoulder margin d = D cos 0 so d = D furthermore in this situation we have the worse marginal fitness in addition there is not a strong unity between the restoration and teeth that makes a lower fracture resistance than the chamfer margin does. In the studies that we have done on the marginal fitness of these two finishing lines we found that marginal fitness in chamfer margin is 27 mm and in shoulder margin it is 43 mm so it is vivid to have more fracture resistance in chamfer margins. In other words in chamfer finishing line we have an angled cut of enamel that makes the higher width of enamel in exposure to etch and bonding, so we have strong bonding and unity between the restoration and teeth that makes higher fracture resistance than shoulder margin because as we know in this finishing line we have the lower width of enamel that is important in the bonding of the restoration and teeth. As a result, the present study indicates that chamfer finishing line could have more fracture resistance than shoulder finishing line. Furthermore, good fitness on the occlusal surface would greatly enhance strength resistance against fracture force, and a gap directly under where the pressure is being applied (between the base die and the core) could influence the fracture resistance. This fitness is different from the marginal fitness and we have this vertical discrepancy (D) in the occlusal surface. In similar studies we found that fitness of the alumina cores in the occlusal surfaces is about 60 mm in both of the samples. So in our study this gap is the same in all dies because we did not change the occlusal surface therefore this factor equally influenced the samples hence it is possible to make a comparison between the two groups.

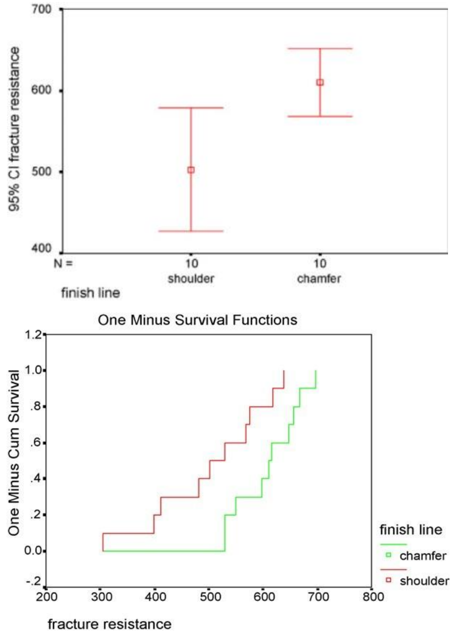

Fig. 7. Graph: Kaplan–Meir, survival analysis for fracture resistance in the 2 finishing line.

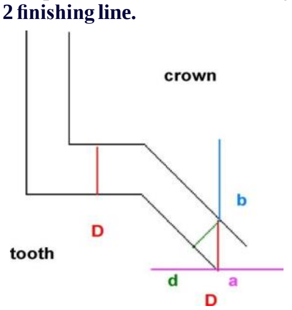

Fig. 8. Discrepancies between the restoration and tooth, in shoulder margin D = d so we have the worse marginal fitness.

5. CONCLUSION

Both of the marginal designs have a strong fracture resistance that is more than biting forces so we could use the both. But because of the more fracture resistance of chamfer margin, this finishing line is recommended and could improve the biomechanical performance of posterior single alumina restorations.

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