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ORIGINAL ARTICLE

Effects of Surface Abrasion on the Flexural Strength of Glazed and Re-glazed Metal Ceramics: An In Vitro Study

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Abstract The functional surfaces of the porcelain fused to metal fixed partial dentures are often abraded to adjust occlusion, such restorations are often found to fail in service. This study was therefore conducted to study the effect of surface abrasion on flexural strength of glazed porcelain fused to metal samples. It was also the aim of this study to find the effect of re-glazing on flexural strength of abraded samples. A total of ninety glazed porcelain fused to metal bar samples of the dimension 15 mm × 2 mm × 1.5 mm were fabricated. These samples were then divided into three groups (30 samples each) according to the surface treatments: group A-glazed (control); group B-abraded and group C-abraded and then re-glazed (self-glazed). Flexural strength was measured by using three point bend test on universal testing machine (texture analyser) with a cross-head speed of 0.6 mm/min. Peak force at the time of failure for all the samples was recorded. Statistical analysis found that mean flexural strength was highest for group A-80.65 ± 12.81 MPa; as compared to group B-74.18 ± 10.74 MPa and group C-77.85 ± 9.39 MPa. Student's *t* test indicated that the difference in the flexural strength between groups A and B was significant while it was non-significant between groups B and C and also between groups A and C. The '*f*' test indicated that the difference between the groups was non-significant. This study therefore showed that there is a marked decrease in the flexural strength of the porcelain fused to metal restorations after occlusal abrasion. The study also found that reglazing of these restorations may not restore their flexural strength significantly.

Keywords Flexural strength · Glazing · Occlusal adjustments · Reglazing

Introduction

Ceramics is one of the most popular restorative materials of our times [1]. However failures in form of chipping or cracking of the surface porcelain are seen when abraded for occlusal adjustments [2]. This occlusal adjustment causes removal of the smooth glazed surface layer and introduction of surface flaws which can act as focal point for crack propagation [3, 4].

Refiring of these abraded restorations prior to cementation produces a self glaze layer which is said to increase the strength of the porcelain layer [3]. The effectiveness of these strengthening mechanisms is not well-established [5]. This study was aimed to find the difference in flexure strength between glazed, abraded and reglazed samples.

Materials and Methods

This in vitro study with sample size of 90 was conducted with the objective to find out the effect of surface abrasion and re-glazing on the flexural strength of porcelain fused to metal samples. During the course of this study the materials used were Ceramco-3 body Porcelain (Dentsply;

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USA), Wiron-99 Ni–Cr alloy (Bego; Germany), crown wax, hard (Bego; Germany), silicon duplicating material (Bego; Germany), phosphate bonded investment material-Biosint and investment liquid-Biosol (Degudent-dentsply; USA).

These porcelain fused to metal bar samples were made as per International Standards Organization specification for testing of dental ceramics (ISO 6872-1984), and were of dimension 15 mm × 2 mm × 1.5 mm. Thickness of 1.5 mm was kept to simulate the clinical conditions, of which metal bar with opaque layer was of 0.5 mm and the body porcelain layer was of 1 mm thickness (Fig. 1).

Fabrication of Metal Bars

To achieve standardized wax patterns for metal bar samples a silicone mold was fabricated. The mold had 08 ditches of dimension, 15 mm length, 2 mm width and a depth of 0.3 mm (Fig. 2). Pattern wax was melted and flown into these ditches. Once the wax cooled the patterns were retrieved, checked for dimensions and then casted as per manufacturer's instructions. All the samples were then checked by digital vernier caliper to verify the predetermined dimensions of 15 mm × 2 mm × 0.3 mm at three varied points in length, width and depth. Necessary dimensional changes were made if required to achieve correct dimensions. These metal samples were cleaned ultrasonically and by steam cleaning before opaque layer was applied.

Application of Opaque Layer and Porcelain Build Up

All the samples were coated with a thin layer of opaque paste and fired. The samples were considered acceptable for further porcelain build up if the opaque layer completely masked the samples and the total thickness was 0.5 mm. To achieve a standardized layer of body porcelain of equal thickness on all the finished metal bars, a customized (medium hardness steel) three piece mold was fabricated (Fig. 3). The middle plate in the mold had a ditch with a length 15 mm, width of 2 mm and depth of 1.6 mm.

For application of the porcelain layer the mold was first lubricated with ceramic separator (Ceramco3 Die Release).

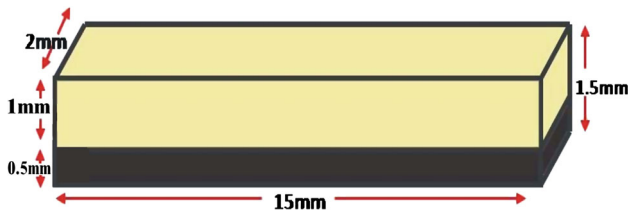

Fig. 1 Schematic figure of porcelain fused to metal bar samples

Sample bars were then placed inside the ditch in the central plate and both the peripheral plates were closed and finally porcelain was applied. Once the porcelain was properly condensed the sample was removed from the mold and fired in a programmable furnace (Touch & Press-Dentsply; USA). The firing schedule consisted of: (1) drying at 650 °C outside the muffle for 05 min, (2) preheating at 650 °C inside the muffle for 05 min, (3) increasing the temperature at 55 °C/min from 650 to 960 °C under vacuum of 29 Hg. The specimens were then held at 960 °C for 10 s and then bench-cooled. The samples were tested for accurate dimensions and accepted only if three points in the middle one-third of the porcelain fused to metal bar measured 1.5 mm using digital vernier caliper.

The samples were then randomly divided into three groups of thirty samples each and were called group A, group B and group C. Group A was kept as a control group. The entire porcelain surface of samples of group B and C were abraded to mimic occlusal adjustment in clinical situations using sintered diamond bur with a grit size of 30 μm at 350 rpm for 15 s. Group B samples were not modified further while group C samples were reglazed (autoglazed). During this procedure the samples were first fired at a constant temperature increase of 70 °C/min from 650 to 960 °C, held at 960 °C for 0.5 min and finally bench cooled (Fig. 4).

Testing of the Samples

The samples were tested for their flexural strength using the three point bend test using a universal testing machine (texture analyser [5 kg pay load]; Stable Micro Systems, UK). A plunger of 1 mm cross-section with a cross-head speed of 0.6 mm/min was used (Fig. 5). Force for fracture was recorded for each sample and corresponding flexural strength was calculated using the formula:

$$\sigma = 3Fl / 2xy^2$$

where, σ is the flexural strength; F is the maximum force at the point of fracture; l is the distance between the supports (taken as 10 mm); x is the width of the specimen (taken as 2 mm); y is the depth or thickness of the specimen (taken as 1.5 mm).

Results

Peak force at the time of failure of all the samples was recorded and tabulated. Using these values the corresponding flexural strength was calculated for each of the ninety samples. Descriptive statistics, including the mean, standard deviation, standard error, minimum and maximum values were calculated for each of the groups tested.

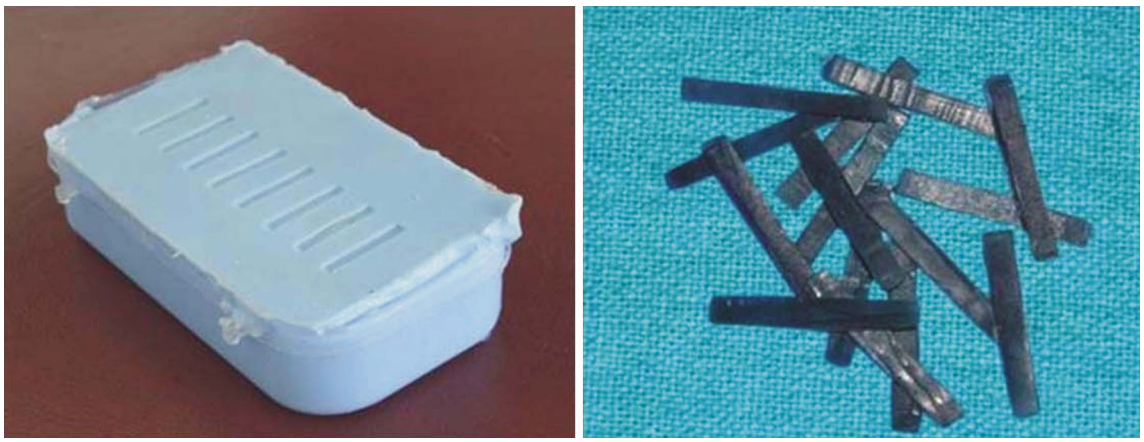

Fig. 2 Wax patterns fabricated using customized mold

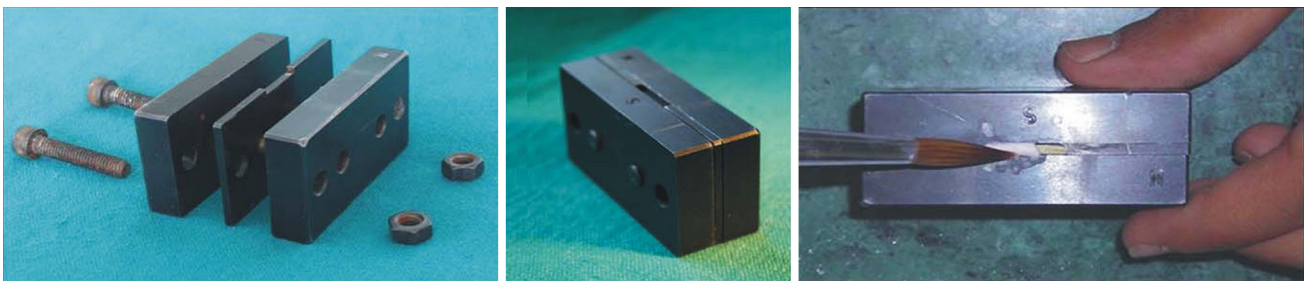

Fig. 3 Application of ceramic on metal bar using three piece customized mold

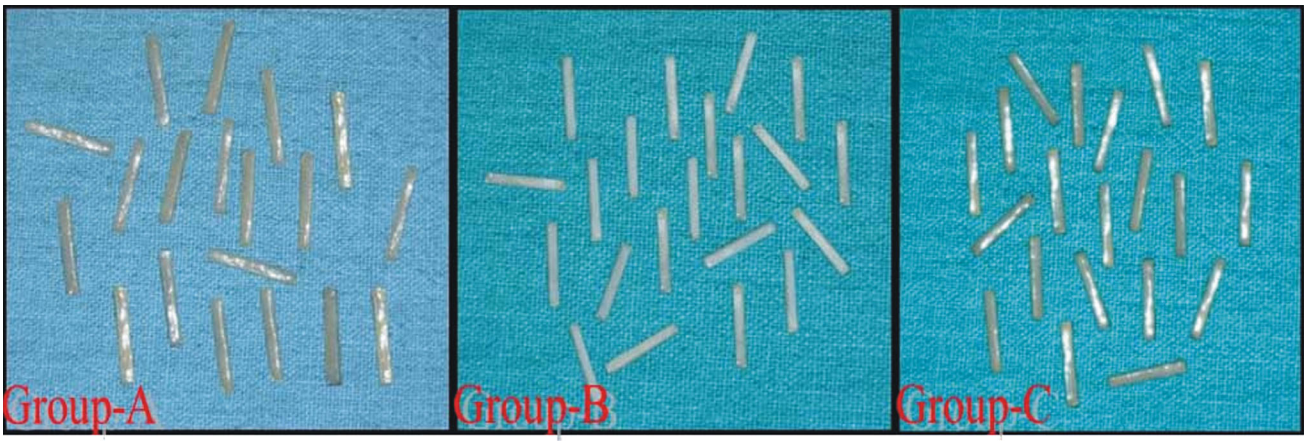

Fig. 4 Glazed samples—group A; abraded samples—group B; reglazed samples—group C

Student's *t* test was used to analyze the significant differences between two groups and '*f*' test was used to determine significant difference between control and other groups.

The results from all the three experimental groups are shown in (Table 1). On application of Student's *t* test on the means of group A and B, a value of 0.038 was found which meant that the difference in the flexure strength was significant ($P < 0.05$); for the groups B and C a value of 0.164 was found which meant that ($P > 0.05$) there was no major difference in flexure strength between groups and for group A and C test a value of 0.338 was obtained ($P > 0.05$), that showed that there was no statistical difference between these groups.

On comparison of the flexural strength of control group with the other groups using the '*f*' test a value of 2.57 was obtained which at a probability level of 0.082 meant that the difference between the groups was non-significant (Table 2).

Fig. 5 Universal testing machine (texture analyser) and samples being tested under it

Table 1 Mean, range and standard deviation of force and flexural strength of group A, group B and group C

S. No.	Groups	Flexural strength (MPa)			Standard deviation
		Mean	Range		
			Minimum	Maximum	
1	A	80.65	60.00	99.43	±12.81
2	B	74.18	60.57	96.36	±10.74
3	C	77.85	60.23	94.87	±9.39

Discussion

Whenever a patient chews with a fixed partial denture in place the prosthesis is subjected to flexural stresses. These flexural stresses are combination of compressive and tensile stresses. Unlike gold which is ductile in nature ceramics are brittle materials which exhibits a major weakness of decreased tensile strength leading to their inability to flex and hence tendency to fracture at a minimum deformation of 0.1 % [6]. This problem is compounded by the presence of microscopic surface defects or flaws.

These surface flaws behave as sharp notches whose tips may be as narrow as the spacing between the atoms in the material. The tips of these minute scratches causes the localized stress to reach the theoretical strength of the material at relatively low average stress thus acting as areas of "Stress concentration" and eventually leading to failure of restoration [7].

The practice of occlusal adjustments before final cementation results in both removal of the surface glaze and introduction of microscopic surface flaws which can result into chipping of the porcelain layer from the metal sub-structure [3]. Rotating surface of the grinding instrument causes multipoint surface grinding on the porcelain surface. This produces numerous cracks both parallel and perpendicular to the surface. These surface cracks intersect with each other and with microscopic internal flaws and porosities, thus acting as areas of crack propagation and finally resulting in failure of the restoration [8].

Refiring these restorations prior to final placement produces a self glaze layer. Binns (1983) believed that the self glaze layer has a lower thermal expansion coefficient than the leucite rich interior, thus placing the internal surface under compression when cooled. This compressive stress state diminishes the local tensile stress produced from applied loading at the surface flaws, thus increasing the strength of the dental porcelain [3]. Kazuyuki H and Tomozawa M (1987) also claimed that during glazing, the low fusing surface layer melts and fills in the surface flaws reducing their depth and blunting the flaw tips. This produces a strength increase because of decreasing flaw depth and sharpness [5].

While some researchers like Fairhurst CW, Lockwood PE, Ringle RD and Thompson WO (1992) found no difference in the flexural strength of the glazed and as ground samples [6].

In this study on comparison of mean flexural strengths of glazed samples and abraded samples, it was concluded

Table 2 Analysis of variance for flexural strength between group A (control) and other groups (B and C)

Source of variation	Degrees of freedom	Sum of squares	Mean square	*F* value	Probability
Flexural strength (MPa)					
Between groups	2	630.91	315.46	2.57 NS	0.082
Within groups	87	10,661.6	122.55		
Total	89	11,292.5			

that there was statistically significant decrease in the flexural strength values of abraded samples. Almost similar results were also found by Jones and Wilson [9].

The study also found no statistical difference between abraded and reglazed samples, these results can be explained by the 'Maturation Theory' proposed by Brackett et al. [10]; according to which repeated firing of the porcelain used in porcelain fused to metal restorations results in decrease in the flexural strength of the samples. Thus an extra glaze re-firing in current study may have resulted in decreased flexural strength.

Further a study done by Mackert and Evans [11] have indicated that size of the leucite particles in the feldspathic porcelain increases during heat treatment within the normal porcelain firing range. Above a critical particle size, the stresses created during cooling can induce microcracks circumferential to the leucite particles. As the porcelain used in the study had leucite were reglazed, it may be possible that this resulted in micro-cracking and eventually decrease in the flexural strength.

Another possible factor is that residual stresses created during grinding provided a strengthening effect (to group B samples), as found by Giordano et al. [8] that machining damage produced by grinding of feldspathic porcelain, results in a residual compressive surface and when these abraded samples were reglazed (group C) these stresses were removed due to annealing during re-firing.

This study also did not find any statistically significant difference in the flexural strengths of glazed (group A) and reglazed group (group C). Almost similar results were found by Fairhurst et al. [5] who did not find an increase in the bi-axial flexural strength of porcelain after self-glazing but stated that self-glazing treatment is appropriate for clinical use since it provides smooth hygienic surface.

Some studies suggests that abraded (unglazed) porcelain surfaces are more prone to plaque accumulation and therefore poorly tolerated by the underlying gingival [12–15]. They are both unesthetic and easily stained [14]. Unglazed porcelain is also highly abrasive, causing significantly greater wear on opposing surfaces than results from glazed porcelain [16].

Limitation of the Study

Further studies are required to test the effect of other surface treatments like overglazing and polishing on the flexural strength of abraded samples.

Conclusions

Under the conditions of testing and materials used the primary conclusions drawn were that surface abrasion of the porcelain fused to metal samples decreases there flexural strength significantly. This result implies that occlusal adjustments in porcelain fused to metal restorations should be done before the final glaze cycle. The study also found that reglazing did not increase the flexural strengths of the samples significantly, but at the same time this increase in the flexural strength was not significantly different from the controlled group. These results suggest that if occlusal adjustments are done after glazing, the restorations should be reglazed. This procedure not only increases the flexural strength but also as pointed out by some other studies makes the porcelain surface more hygienic and less abrasive for the opposing teeth.

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