Finishing procedures action on mechanical characteristics of pressed ceramics

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ABSTRACT

Objectives: The choice of material and sequence of finishing & polishing of pressed ceramics which are broadly used for indirect restorations applying different polishing methods on the glazed ceramic surfaces has not been agreed on yet so a comparison of different finishing protocols on the mechanical strength of pressed ceramics in a clinical simulating trial is of a paramount significance, in this study The effect of different grinding & finishing procedures on the biaxial flexural strength of pressed ceramics was evaluated.

Material and methods: all ceramic Ips emax press discs were fabricated with a circular projection in the middle to simulate a high spot in the finished restoration. The discs were divided randomly according to grinding Speed into 2 groups (n = 30) high speed grinding & low speed grinding then were distributed into 3 sub groups (n = 10) according to finishing procedures. Determination of biaxial flexural strengths of the disks was done using The universal testing machine then 2 way ANOVA test and Pearson correlation analysis were done.

Results: Finishing procedure with High speed grinding showed lower flexural strength compared to low speed grinding with different groups. (Grinding with no finishing) group showed lowest value followed by (Grinding and finishing with rubber tips) group followed by (Grinding and finishing with rubber tips & diamond paste) group with high speed and low speed.

Conclusions& significance: Grinding & finishing procedures of pressed ceramics showed significant effect Of drill speed and polishing technique over flexural strength, As Grinding with no finishing and polishing procedure showed lowest flexural Strength values followed by finishing and polishing with polishing paste procedure.

1. Introduction

Since 1990, it has been possible to fabricate all-ceramic restorations using the heat-pressing technique (Wohlwend, 1990). This technique permits dental laboratories to fabricate high quality veneers, inlays, onlays, anterior crowns, posterior crowns and all-ceramic bridges using a timesaving and simple procedure [1].

1.1. Pressable lithium disilicate

Based on glass technology manufacturing process e.max Press is produced according to a unique bulk casting production method by constant optimized nucleation and growth of two different crystals preventing defects formation.

The material microstructure consists of approximately 70% volume of needle-like lithium disilicate crystals measuring approximately 3 μm–6 μm in length in a glassy matrix [2].

During sintering the development of surface micro porosities is a major problem with all-ceramic restorations As These micro porosities can predispose to crack initiation and propagation leading to failure of the restoration [3,4] ceramic restoration may require adjustment in the circumstances that may be necessary to correct

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occlusal interferences and improve esthetic appearance as well. Currently removing of high spot is done resulting in loss of ceramic restorations intact surface glaze which generates rougher surfaces, wearing of the opposing teeth and several periodontal problems that preclude reglazing which subjecting the ceramic material to another cycle of firing that may cause structural changes and be time consuming but An alternative approach is that adjustment can be done at the same visit to reduce chair side time.

The choice of material and sequence of finishing & polishing of pressed ceramics which are broadly used for indirect restorations was compared by several authors applying different polishing methods on the glazed ceramic surfaces but has not been agreed on yet. [5–7].

Shofu points were reported by Goldstein to be the best instruments for the final finishing of porcelain. On the other hand when using diamond paste jointly with Shofu points Raimondo et al. reported the production of better surface polishing with smoothness similar to glazed ceramics.

Clinical recommendations that ceramics after any kind of adjustments should be subjected to re-glazing or to a final finishing and polishing using diamond paste concluded from Al-Wahadni and Martin studies, However, they have not compared polishing methods on pressed ceramic, which justifies the study of this work [8,9].

The effect of different grinding & finishing procedures on the biaxial flexural strength of pressed ceramics was evaluated in this study. The null hypothesis was there is no difference with different protocols of grinding & finishing procedures of pressed ceramics.

2. Materials and methods

2.1. Disk construction

A specially designed mould was fabricated with internal depression to produce the discs wax pattern in the test groups (see Fig. 1).

To simulate a high spot in the finished restoration, each wax pattern had a 1 mm circular projection in the middle. (see Fig. 2).

An axial sprue (diameter 3 mm, length 5 mm) was attached in the direction of flow of ceramic material and each pattern was angled 45–60° making sure that all sprue attachment were flared and attached to the silicon ring base.

According to manufacturer instructions Ips e.max special investment material was used and after pressing, the investment ring was removed from the furnace. Immediately after the process was completed. The investment ring was allowed for about 60 min to cool down on a wide-meshed grid at room temperature (ips e.max cooling rack) which ensured quick and even cooling of the investment ring, and then a separating disc was used to separate the investment ring at the predetermined length.

According to manufacturer instructions polishing jet with medium polishing alumina beads (type 100 µm) was used for rough divestment at 4 bar (60 psi) pressure.

Immersion of the pressed coping in invex liquid (<1.0% hydrofluoric acid) for 30 min followed by rinsing thoroughly under running water and alumina sandblasting at pressure of 1 bar to remove reaction layer then proper thickness checking by vernier caliper. (see Fig. 3).

The discs were covered with ips e.max ceram glaze and fired as
follows in a program. The glaze firing was conducted on a honeycombed tray. (see Fig. 4).

2.2. Grinding apparatus

2.2.1. Disc holding device

A custom-made holding device was designed to stabilize the discs during grinding and finishing procedures. The holding device consisted of a metallic base with two sliding holding arms and two lateral tightening screws to stabilize the disc during grinding & finishing procedures. (see Figs. 5 and 6).

2.3. Grinding & finishing procedures

The discs were divided randomly according to grinding speed into

Group (I):

High speed Grinding by rotary diamond instruments (n = 30 discs).

Group (II):

Discs were ground with a low speed micromotor using diamond rotary cutting instruments (n = 30 discs).

Each group were subdivided into 3 subgroups according to finishing procedures.

Subgroup (A):

Grinding with no finishing (n = 10 discs).

Subgroup (B):

Grinding and finishing & polishing with siliconized points (n = 10 discs).

Subgroup (C):

Grinding and finishing & polishing with siliconized points. And diamond paste (n = 10 discs).

2.3.1. Grinding procedure

The holding device carrying the discs was assembled. The high-speed handpiece and the low speed micromotor were adjusted to be above the holding device, producing contact of the disc central projection with the rotating grinding instruments. (see Figs. 7 and 8).

The instruments were oriented approximately parallel to the disk surfaces. The direction of applied force produced a horizontal cut on the central disc projection with the parallel part of rotating instrument until it was removed completely.

2.3.2. Finishing procedure

The finishers and polishers consists of synthetic rubber, diamond granules and titanium dioxide. The nylon brushes consist of nylon fibers. (see Fig. 9).

The diamond paste contains diamond dust with a particles ranging from 2 to 4 μm in an emulsion of glucrine, sodium lauryl sulpha and propylene glycol.

According to the manufacturer instructions, the operating speed was 10,000 rpm, and the duration was 20 s per working step. Cooling was provided during operating with the finishers and polishers, diamond paste and brush were used without water spray.

2.3.2.1. Finishing & polishing e.max press discs with siliconized points. The central area surface of ceramic disc was finished with the optrafine finishers. The subsequent finishing procedure was performed with the optrafine polishers.

The low speed micromotor were adjusted to be above the holding device. The instruments were oriented approximately parallel to the disk surfaces producing a horizontal contact of the disc central area with the parallel part of rotating finishing instruments located 1 mm from the finisher shank.
2.3.2.2. Finishing & polishing e.max press discs combining diamond paste & siliconized points. Ceramic disc central area was finished with the optrafine finishers. The subsequent finishing procedure was performed with the optrafine polishers then for final finishing; the optrafine nylon brushes are used together with diamond paste perpendicular on the central disc area.

2.4. Biaxial flexural strength test

All discs of different groups were measured for biaxial flexural strength with a computer controlled testing machine (LLOYD) *, testing was done with a load cell of 5 kN at a cross-head speed of 0.5 mm/min, and using computer software data were recorded. For each disc the fracture load was recorded and using the following equation the biaxial flexural strength was calculated:

$$[-0.2387 \frac{P(X - Y)}{d^2} = S]$$

Where: $S$: biaxial flexural strength $P$: fracture load (N) $S$: biaxial flexural strength (MPa) $d$: disc thickness at fracture origin (mm).

X and Y were determined as follows:

$$(1 + \nu) \ln(r_2 / r_3)^2 + [(1 - \nu) / 2] (r_2 / r_3)^2 = X$$

$$(1 + \nu) [1 + \ln(r_1 / r_3)^2] + (1 - \nu) (r_1 / r_3)^2 = Y$$

$r_1$: the support circle radius; Poisson’s ratio $(0.25)$ $r_2$: the loaded area radius; $r_3$: the specimen radius.

3. Results

3.1. Biaxial flexural strength results

2 way ANOVA showed significant effect of grinding speed and finishing procedure over flexural strength and no significant effect of interaction between grinding speed and finishing procedure (see Table 1).
3.2. Finishing procedure effect on flexural strength

Grinding procedure with no finishing showed lowest flexural strength followed by Grinding and finishing with rubber tips followed by Grinding and finishing with rubber tips & diamond paste and tukey post hock showed significant difference between all treatments. (see Fig. 10 and Table 2).

3.3. Effect of grinding speed on flexural strength

High speed grinding showed lower flexural strength compared to low speed grinding and difference was statistically significant. (see Fig. 11 and Table 3).

3.4. Interaction between grinding speed and finishing procedure

High speed grinding showed lower flexural strength compared to low speed grinding with different groups of finishing procedure. (see Table 4).

Grinding with no finishing showed lowest value followed by Grinding and finishing with rubber tips followed by Grinding and finishing with rubber tips & diamond paste with high speed and low speed. (see Fig. 12).

4. Discussion

The effect of different finishing procedures on pressed ceramics was investigated in this study.

According to this study, the flexural strength values among of the test groups were significant. Therefore, the study null hypothesis which states that the flexural strength of pressed ceramics would not be different with different types of grinding & finishing procedures was rejected.

Despite dental ceramic is routinely glazed adjustments are necessary in some clinical situations to re-establish function and esthetics, In these situations, the dental ceramics receives only polishing rather reglazing allowing the dental professional to cement the prosthesis in the same clinical session, This procedure is done to prevent the return of the prosthetic element to the laboratory for new glazing.

Pressable lithium disilicate material (i.e., Li2Si2O5) microstructure consists of approximately 70% volume of needle-like crystals in a glassy matrix measuring approximately 3 μm—6 μm in length.

Surface micro porosities developing during sintering is a major problem with all-ceramic restorations which can predispose to crack initiation and propagation and leading to restoration failure [10,11].

Various ceramic finishing kits & techniques have been described for finishing ceramic surfaces in the mouth and numerous varied Reports of the results were reported [12–17]. Nonetheless, the material choice and finishing sequence used for indirect restorations have not been well established yet [18–20].

In the current study Based on the results, the flexural strength of pressed ceramics was significantly affected by all finishing

Table 1
2 way ANOVA showing effect of different grinding speed and finishing procedure over flexural strength.

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>9020.154*</td>
<td>5</td>
<td>1804.031</td>
<td>13.804</td>
<td>.000</td>
</tr>
<tr>
<td>Intercept</td>
<td>2,833,963.814</td>
<td>1</td>
<td>2,833,963.814</td>
<td>21,684.699</td>
<td>.000</td>
</tr>
<tr>
<td>Technique</td>
<td>1435.509</td>
<td>1</td>
<td>1435.509</td>
<td>10.984</td>
<td>.002</td>
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<tr>
<td>Finishing procedure</td>
<td>7484.198</td>
<td>2</td>
<td>3742.099</td>
<td>28.633</td>
<td>.000</td>
</tr>
<tr>
<td>technique *finishing procedure</td>
<td>100.447</td>
<td>2</td>
<td>50.224</td>
<td>.384</td>
<td>.683</td>
</tr>
<tr>
<td>Error</td>
<td>7057.241</td>
<td>54</td>
<td>130.690</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2,850,043.209</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>16,077.395</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* R Squared = .561 (Adjusted R Squared = .520).

![Fig. 10. Effect of finishing procedure on flexural strength (M P).](image-url)
procedures, high speed group showed lower flexural strength compared to low speed group with different of finishing procedures. No finishing procedure showed lowest value followed by finishing with rubber tips procedure followed by finishing with rubber tips & diamond paste procedure and Difference was statistically significant.

### Table 2
Biaxial flexural strength using different finishing procedure on pressed ceramics.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Mean</th>
<th>SD</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grinding with no finishing</td>
<td>204.7750</td>
<td>10.85</td>
<td>646</td>
</tr>
<tr>
<td>Grinding and finishing with rubber tips</td>
<td>215.3105</td>
<td>13.03</td>
<td>642</td>
</tr>
<tr>
<td>Grinding and finishing with rubber tips &amp; diamond paste</td>
<td>231.9075</td>
<td>12.82</td>
<td>430</td>
</tr>
</tbody>
</table>

### Table 3
Effect of grinding speed on flexural strength.

<table>
<thead>
<tr>
<th>Speed</th>
<th>Mean</th>
<th>SD</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>High speed</td>
<td>212.4397</td>
<td>14.28</td>
<td>826</td>
</tr>
<tr>
<td>Low speed</td>
<td>222.2223</td>
<td>17.34</td>
<td>180</td>
</tr>
</tbody>
</table>

### Table 4
Interaction between grinding speed and finishing procedure.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>High speed Mean</th>
<th>S D</th>
<th>Low speed Mean</th>
<th>S D</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grinding with no finishing</td>
<td>201.3760</td>
<td>10.33</td>
<td>208.1740</td>
<td>10.78</td>
<td>692</td>
</tr>
<tr>
<td>Grinding and finishing with rubber tips</td>
<td>208.7560</td>
<td>8.91</td>
<td>221.8650</td>
<td>13.55</td>
<td>687</td>
</tr>
<tr>
<td>Grinding and finishing with rubber tips &amp; diamond paste</td>
<td>227.1870</td>
<td>8.87</td>
<td>236.6280</td>
<td>14.79</td>
<td>498</td>
</tr>
<tr>
<td>P value</td>
<td>&lt;0.001</td>
<td></td>
<td>0.189</td>
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</tr>
</tbody>
</table>

**Fig. 11.** Effect of grinding speed on flexural strength (MP).

**Fig. 12.** Interaction between grinding speed and finishing procedure.
Grinding with No finishing showed lowest flexural strength followed by grinding and finishing with rubber tips followed by grinding and finishing with rubber tips & diamond paste and tukey post hock showed significant difference between all treatments.

This is on same line Giordano et al. [21] evaluating the mechanical effects of surface finish of three different sintered porcelain groups with total number of 105 bars of the feldspathic ceramic. They reported significant increase in the flexural strength with all surface finishes.

5. Conclusions

In the essence of this study, these conclusions could be established:

1. Grinding with no finishing and polishing showed significant effect of drill speed and polishing over flexural strength.
2. Grinding with no finishing and polishing showed lowest flexural strength followed by finishing and polishing followed by finishing and polishing with polishing paste.
3. High speed showed lower flexural strength compared to low speed and difference was statistically significant.

5.1. Recommendations

Several problems are associated with poorly finished ceramic restorations including lower flexural strength accordingly finishing procedures are recommended to provide an adequate surface texture and mechanical strength, further clinical studies are required.

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