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A Study of Two Commercial Systems for Polishing Aluminum Oxide, Zirconia and Feldspathic Dental Porcelain

Sureeporn Charudilaka

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A Study of Two Commercial Systems for Polishing Aluminum oxide, Zirconia and Feldspathic Dental porcelain

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D.D.S., Chulalongkorn University School of Dental Medicine, 2002

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Master of Dental Science Thesis

A STUDY OF TWO COMMERCIAL SYSTEMS FOR POLISHING ALUMINUM OXIDE, ZIRCONIA AND FELDSPATHIC DENTAL PORCELAIN.

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DEDICATION

This thesis project is dedicated to my mom, Dr. Jiraporn Charudilaka, and my dad, Dr. Sutat Charudilaka, whose unconditional love and support encourage me through this project.
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I. INTRODUCTION

With the advances in dental materials and new techniques in restorative dentistry, the demand for esthetic restorations has increased tremendously. Dentists and dental technicians are now challenged to routinely produce restorations that duplicate form, function, and esthetics of the natural dentition. Metal-ceramic restorations are perhaps the most currently used options for restoring missing or defective teeth. The metal and opaque porcelain, however, restrict their potential use when there is high esthetic demand.

The use of all ceramic restorations, having no metal substructure, are the best option when superior translucency is the best alternative for esthetic areas, especially maxillary anterior teeth.

Among the first article reported describing ceramic in dentistry, Kelly et al. has described ceramics in both historical and current perspectives. The use of CAD/CAM technology has become a viable option in fabricating ceramic restorations. Many important physical and optical properties are directly dependent on how the ceramic is made.

In 2004 Raigrodski described long term success rate of all ceramic fixed dental prosthesis using computer-assisted design/computer assisted manufacturing (CAD/CAM) technology. He found that the long-term stability of ceramics is closely related to substantial crack propagation and stress corrosion.
caused by water in the saliva reacting with the glass, resulting in decomposition of the glass structure, lead to increased crack propagation in glass-containing systems. However, glass-free systems having a polycrystalline microstructure, such as Yttrium tetragonal zirconia polycrystals (Y-TZP), when used as a ceramic core material, do not exhibit this phenomenon.

Surface finish of ceramic restorations has become a major factor in wear of opposing natural dentition. There have been several studies 3-21 about wear of human enamel when contacting polished, unpolished and glazed ceramic surfaces have shown different results and levels of wear. Therefore the results are still controversial.

In a limited restorative space when restoring upper anterior teeth, lingual surfaces have to be reduced enough for the ceramic material. Occlusion will often have to be adjusted when the restoration is overcontour and demonstrating a high spot which often exposed the ceramic core material. The method of treating a ceramic core material has not been demonstrated.

The aim of this study is to investigate whether a core ceramic material can be polished and which polishing system will provide a smoother surface finish.
II. OBJECTIVES

Metal ceramic restorations have been widely used with predictable results for a long period of time. In more recent years, all ceramic restorations have become a popular alternative for maxillary anterior teeth. Alumina and zirconia are used as core materials and they are believed to be stronger yet potentially more abrasive than feldspathic porcelain. Little data exists to support how to treat the core ceramic material if exposed during occlusal adjustment. Several porcelain polishing systems have been shown to smooth the surface of a feldspathic dental porcelain after adjustment but there is little, if any, research on polishing the ceramic core materials.

The two main objectives of this research were: 1) to provide data on surface roughness of two commonly used ceramic core materials and one feldspathic dental porcelain, and 2) to provide relevant clinical information to the restorative practitioner to aid in the selection of a porcelain polishing system when polishing ceramic restorations after adjustments have exposed the core material.

Two Hypotheses tested were:

1. There will be no difference between the surface roughness of alumina, zirconia and feldspathic dental porcelain before and after polishing with the Brassler polishing system.
2. There will be no difference between the surface roughness of alumina, zirconia and feldspathic dental porcelain before and after polishing with the Shofu polishing system.

Three secondary Hypotheses tested were:

1. There will be no difference between the surface roughness of alumina before and after polishing.
2. There will be no difference between the surface roughness of zirconia before and after polishing.
3. There will be no difference between the surface roughness of feldspathic dental porcelain before and after polishing.
III. LITERATURE REVIEW

INTRODUCTION

Ceramics are commonly used restorative materials in dentistry. The use of ceramics in dentistry has roots from the 18th century. A French apothecary Alexis Duchateau with assistance of Parisian dentist Nicholas Dubois de Chemant made the first successful porcelain dentures in 17741. After those years several types of dental ceramics have been described and both the esthetics and the versatility had huge improvement. The interest in dental ceramics is increasing every year and the number of published articles in this area comprises a significant portion of the restorative dentistry literature.

Several in vitro, in vivo and clinical studies sought to find the optimal restorative material for particular indications, in which the material shows greatest esthetic, function and convenience. Handling and finishing the porcelain affects the success of the restoration in many ways. Providing the best porcelain surface texture with minimal cost and patient visits have been the aim of many studies regarding this issue.

PROVIDING SMOOTH PORCELAIN SURFACE

The smoothness of a porcelain surface is essential for prevention of the wear of opposing surfaces, reducing the inflammation of soft tissue around the
contacted porcelain and reducing discoloration. It has been claimed that irregularities up to 0.3 micrometer can be detected by patients tongue, thus smooth surface is also important for patients comfort. Although oven glazed porcelain had been accepted as the gold standard for obtaining best polishing characteristics recently, a number of methods have been proposed for refinishing the porcelain and a number of polishing kits are available in the market for this purpose. The main purpose of testing is to obtain the smoothest surface, to reduce the delivery time and the laboratory cost.

FINISHING WITH AUTOGLAZED, GLAZED OR POLISHED PORCELAIN

Occlusal or contour adjustments of porcelain restorations have negative impact on neighboring structures due to abrasive properties after adjustments. It is also known that trimming of the porcelain may cause a reduction in the strength of a ceramic restoration. Although many studies suggest that glazed porcelain provides the smoothest and most dense surface, there are studies available showing better results with polishing. Other than smoothness, the mechanical properties, discoloration of the porcelain, wear on the opposing enamel or other structures have been the interest of several studies.

Klausner et al (1982, 47:157, J Prosth Dent) compared 4 different polishing techniques with autoglazed porcelain surfaces. They used quantitative measurement of smoothness of the surfaces (Surfanalyzer 150). The results
were obtained with autoglazed porcelains. There was no statistical difference between 4 polishing kits.

*Al-Wahadni* 20 *(2006, 37;311, Quintessence Int)* compared surface roughness of two different ceramic materials (glazed and unglazed forms of IPS Empress and In-Ceram Alumina). For measuring the surface roughness they use Surtronic Device. The results of the study suggest that any adjusted ceramic should be reglazed or subjected to a finishing sequence that is followed through to a final stage of polishing with diamond paste. They also found that unglazed IPS Empress 2 is rougher than unglazed In-Ceram Alumina.

**EVALUATION OF THE TEXTURE OF PORCELAIN SURFACE:**

The studies regarding the surface characteristics of the porcelain have used qualitative and quantitative measurements. Several methods have been described to measure the texture of the surface in the literature. They include contact stylus tracing, laser reflectivity, non-contact laser stylus metrology, scanning electron microscopy, compressed air measuring and atomic force microscopy. Stylus tracing method has been one of the most commonly used quantitative technique and scanning electron microscope SEM analysis has been a commonly preferred qualitative method. There are also studies available that compare surface analysis methods.
Whitehead et al (1999, 15:79, Dent Materials) compared the performance of contact and non-contact laser stylus methods to evaluate the texture of ceramic surfaces. There was no significant difference between the two methods.

Heintze et al (2006, 22;166, Dent Mater) compared the effectiveness of two wear stimulation methods (OHSU and Ivoclar Method) on different ceramics and composites. They concluded that pressable ceramic materials can be used as a substitute for enamel in wear testing machines. There was not a significant difference between Ivoclar and OHSU Method.

STRENGTH OF THE CERAMICS

Strength of the ceramics is important for the long term success of the restoration especially for all-ceramic restoration. It has been claimed that the architecture of the materials as well as surface treatments like grinding, polishing, glazing and heat treatment play role on the strengthening of the ceramics. There are also other factors affecting strength of the materials like hardness of the polishing materials and speed of the handpiece used for finishing.

Rosenstiel et al compared the fracture toughness and stability of metal ceramic alloys with either polished or glazed surface finished.(4) (Rosenstiel, 1989) In polished specimens higher fracture toughness was found. No difference has been found between staining characteristics in three groups.

Albakry et al (2004, 32:91, J Dent) appraised the effects of the effects of different surface treatment procedures, sandblasting, grinding and polishing on the
flexural strength of IPS Empress and Empress 2 and to test the hypothesis that their strength is dependent on surface roughness. They had 7 different kinds of surface treatments (untreated, polished, polished and glazed, sandblasted, sandblasted and glazed, ground, groud and glazed). They found that surface treatments didn't affect the strength of material. They proposed that the microarchitecture of the material determines the strength.

Ahmad et al (2005, 94;421, J Prosthet Dent) evaluated the effects of handpiece speed, abrasive characteristics and polishing load on smoothness of an aluminous dental ceramic material. They evaluated the flexural strength and surface smoothness of the material by using 4-point bending test and SEM analysis. Polishing with high polishing speed (20,000 rpm) diamond burs reduced the strength of the material. Autoglazing did not cause any improvement in flexural strength. Polishing with fine-diamond-bonded abrasive wheel alone reduced flexure strength. Overglazing did not change the flexural strength.

WEAR ON THE ENAMEL

The term 'Wear' refers to a net loss of a material from its surface under operational conditions. (Heintze 2). The wear of dentin or enamel is dependent on many factors including the surface texture of the opposite restoration. Effects of different finishing techniques on the opposing structures have been researched by some studies.
Jagger et al (1994, 72:320 J Prosthet Dent) compared the wear on enamel surface opposite to unglazed, glazed and polished porcelain specimens in vitro. They used Softlex and Shofu polishing kits to polish the porcelain groups. The results of the study showed reduced enamel wear in the polished porcelain groups. However the difference between the glazed and the unglazed porcelain group was not statistically significant.

Wahandi et al (1999, 26:538, J Oral Rehab) compared the wear on the material (persex specimens) opposite glazed, unglazed and refinished porcelain. The amount of wear on the persex specimens was evaluated using surfometer tracing and image analysis. It was found that the shallowest traces and least t wear on the Perspex was opposite to discs of glazed porcelain. It was also noted that finishing with the diamond paste also creates low wear on the opposite surface.

FINDING THE OPTIMAL POLISHING METHOD

Success of polishing the porcelain yielded to studies seeking to achieve the smoothest porcelain surface.

Newitter et al (1982,48(4):388, Fixed Prosthodontics Operative Dentistry) used six different stones for polishing porcelain samples with 11 finishing-polishing regimen. They studied the smoothness of the surfaces utilizing SEM technique. The type of the stone had no effect on smoothness however best results were obtained with finishing wheels followed by pumice or porcelain polishing pate.
Haywood et al. (1988, 4:116, Dent Mater) compared the polishing properties of Micron polishing kit (diminished particle size diamond bur followed by 30 fluted carbide bur and finished by a porcelain paste) with autoglazed porcelain. They found equal smoothness of veneer porcelains finished with the glazing and polishing.

Raimondo et al. (1990, 64:553, J Prosthet Dent) compared 6 polishing techniques of previously polished and roughened porcelains. They didn't do any statistical analysis. Subjective SEM analysis and macro inspection were used. In SEM analysis oven-reglazed samples were found superior. Macro inspection showed equal smoothness with oven-reglazed and using Truluster systems. Shofu system, which is the only system without polishing paste showed some satisfactory results.

Sulik et al. (1991, 46:217, J Prosthet Dent) developed a polishing technique for porcelains, that had been oven-glazed and then roughened as an alternative to reglazing porcelain. They claimed that after adjustment the finished porcelain most of the time need to have the occlusal surfaces repolished. But oven-reglazing is not desired. In their technique they used a hard rubber wheel, fine wet pumice and wet tin oxide respectively. A comparison of their technique with the vacuum-fired porcelain showed similar smoothness both clinically and under an SEM.

Schlissel et al. (1980, 43:258, J Prosthet Dent) claim that reglazing porcelain on partial dentures in the oven is impossible due to acrylic resin damage at high temperatures. They compared the polishing efficacy of 11 different
polishing techniques on grided porcelain surfaces. The found that the Shofu polishing kit provided best results, which comprises of adjusting stones and rubber wheels.

Goldstein et al 11 (1991, 65:627 J Prosthet Dent) compared 5 different polishing systems on two different dental porcelains (Bibond Porcelain and Ceramco Porcelain). For evaluation of the polishing efficacy they used profilometer (quantitative) and SEM analysis (qualitative) techniques. They concluded that Brassier, Dedeco, Dentsply and Shofu porcelain polishing systems were clinically acceptable for finishing. The Brassier system was superior with Ceremco porcelain and the Den-Mat system was found unacceptable.

Patterson et al 12 (1991, 65:383, J Prosthet Dent) evaluated the efficacy of Chameleon Diamond Polishing paste on Vita bonded porcelain. They concluded that this polishing kit provides some degree of improvement in the surface smoothness, the smoothness was incomparable to autoglazed porcelain.

Wright et al 16 (2004, 92:486, J Prosthet Dent) compared three polishing kits (Axis Dental, Jelenko and Brassler) for the polishing of an ultra-low fusing dental porcelain. They left an autoglazed porcelain group as control. They utilized surface profilometry SEM technique for the evaluation of the smoothness. The Axis system produced best results, there was no difference between Brassler and Jelenko. The three polishing systems provided smoother surfaces than autoglazed group.

Heintze et al 21 (2006, 22;146, Dent Mater) aimed to seek if the press-on force and the polishing time have effects on the polishing results. They found that
surface roughness shows improvement after 5 seconds of polishing. Surface roughness increased after applying 4 N forces instead of 2 N Force.
IV. MATERIALS AND METHODS

Specimens preparation

Core ceramic disc fabrication

Alumina and zirconia blocks were milled and sectioned from the Vident company into 1 mm in diameter and 1.5 mm thick. 16 alumina and 16 zirconia discs for a total of 32 core ceramic discs. (Figure 1)

Feldspathic porcelain fabrication:

16 feldspathic dental porcelain discs (Vita VM7, Vident, USA) were fabricated. A putty mold was made in a rectangular shape of 15 mm by 50 mm thickness (Fig 2). Porcelain powder and liquid were mixed (Fig 3) and then condensed into the putty mold (Fig 4). Tissue was used to absorb excess moisture (Kleenex; Kimberly-Clark, Neenah, Wis) After fully condensed the porcelain was gently removed from a putty mold and put in the firing oven (.........) for a first dentine firing cycle (Fig 5). After firing the porcelain block was sectioned into a size as close to the aluminum oxide and zirconia specimens as possible which was 12 mm by 15 mm and 15 mm thick.

Flattening of specimens

Specimens were mouthed on aluminum rings (Fig 6) then attached to
a Buehler grinder and polisher with a Vector power head (Buehler, LTD, Lakebuff USA) (Fig 7). Specimens were ground flat to establish uniform surface roughness for all specimens by using three series of diamond discs with diamond particles size of 165μ, 125μ and 30μ with 15 N loads for 2 minutes, total of 6 minutes. The flattening procedure was done to simulate post adjustment made by a diamond bur with a red band (Brasseler, USA) which has an equal diamond particle size.(Fig 8)

Pre polishing surface roughness analyzing in a Stylus Profilometer

The 48 alumina, zirconia and feldspathic specimens were analyzed in a Stylus Profilometer (Dektak 8, Veeco, USA) (Fig. 9). An average surface roughness (Ra) was measured using a measuring unit of micrometers. Before specimens were put in the stylus profilometer, black dots were placed on each specimen in order to relocate the starting point for stylus (Fig.10). A stylus profilometer then explored the surface of the specimens in an area of 4000 microns by 4000 microns for a total area of 16000000 microns or 16 mm with an 8 milligram stylus force. All data were recorded.

Randomization of specimens:

The 16 alumina, 16 zirconia and 16 feldspathic specimens were then randomized and divided into 2 equal groups of 8 specimens. Two polishing
systems (Dialite, Brasseler, USA and Ceramiste, Shofu, USA) were assigned to each group (Fig 11 and 12).

Polishing of the alumina, zirconia and feldspthic porcelain:

All specimens were polished by using a low speed lab handpiece (NSK, USA) and motor (Brasseler, USA) with a rate of 20,000 rpm (Fig 13). Specimens were polished in one direction for 30 seconds, rotated 90 degrees and polished again for another 30 seconds. Total polishing time of 1 minute per each bur. The two polishing systems have 3 steps using 3 different burs. The polishing procedure was done by completing all 3 steps using a total time 3 minutes of polishing. All specimens were polished by the same operator while attempted to apply constant pressure. All polishing burs were replaced after a single use.

Post polishing surface roughness analyzing in a stylus profilometer:

All the alumina, zirconia and feldspathic porcelain specimens were re analyzed in a stylus profilometer. The stylus was relocated at the black dots on all specimens. Surface roughness was analyzed and recorded.

Statistical Analysis

The data was recorded and the mean and standard deviation for each material and porcelain polishing system was calculated. A non-parametric test was used to determine any differences among the groups. Pairwise comparisons
were tested at the $p \leq 0.05$ level for each materials and at the $p \leq 0.0167$ for each porcelain polishing systems using Wilcoxon Sum-Rank Test.
V. RESULTS

Surface analysis of the specimens as described in the Materials and Methods section resulted in 48 samples, 16 samples each for aluminum oxide, zirconia and feldspatic porcelain.

Data was collected for the 48 samples and the raw data for the 3 materials and 2 porcelain polishing systems is presented in ascending order within each group in Table 3. This table presents the mean surface roughness before and after polishing with the two polishing systems, as well as their standard deviations.

The non-parametric statistics resulted a significant difference between each porcelain polishing systems at p ≤ 0.0167. However, there was no statistical difference (p=0.0017) observed in surface roughness of zirconia specimens polished with the Brasseler polishing system and feldspatic porcelain specimens polished with the Shofu polishing system. Multiple comparison analyses suggested that of the porcelain polishing used, the Shofu system demonstrated the least surface roughness (p=0.0121) compared with the Brasseler system.

An analysis of surface roughness of aluminum oxide, zirconia and feldspatic porcelain was also performed. The finding showed that surface roughness of these materials were changed after being polished with the two polishing
systems (p=0.05). Aluminum oxide after polished by Shofu polishing system demonstrated the same amount of surface roughness but significantly rougher after polished by Brasseler polishing system. For zirconia after polished by Shofu polishing system demonstrated significantly smoother in surface roughness but was rougher after polished by Brasseler polishing system. Finally, feldspathic dental porcelain after polished by Shofu and Brasseler polishing system demonstrated significantly rougher surfaces.
VI. DISCUSSION

Chairside porcelain adjusting and polishing are important consideration in many restorative and prosthodontic procedures. Dentists often adjust occlusion using diamond burs and then polished chairside with porcelain polishing systems. There are many studies involving surface roughness of different surfaces polishing techniques, and polishing systems. Glazed, unglazed or polished surface have been tested. The method of polishing porcelain surfaces and porcelain polishing systems have been studied but none of the studies evaluated polishing the ceramic core material.

This study examined the efficacy of the two widely used porcelain polishing systems with aluminum oxide, zirconia and feldspathic dental porcelain. Aluminum oxide and zirconia core ceramic were used and a veneering porcelain which compatible with both core ceramic were tested. As a result we found that after polishing with Brasseler polishing system ceramic surfaces were rougher. Shofu polishing system on the other hand made feldspathic dental porcelain surfaces rougher, smoother for zirconia and the same roughness for aluminum oxide.

The result of this study agreed with a previous study by Peterson et al that compared the surface roughness of porcelain post adjustment with a diamond bur (Brasseler, red band), after polishing with the porcelain polishing kit and a glazed surface. They found porcelain post adjustment with a diamond bur produced a rougher surface compare to a glazed surface and even after re
polished with a polishing kit, porcelain surfaces were still rougher than glazed porcelain.

The brasser polishing system produced a very rough surface after polishing that might cause greater pitting and surface irregularities. (1) The stylus profilometer only detects the valleys and hills on the specimen surfaces. These hills and valleys are how roughness is determined. When inspected by only the naked eyes results may be deceiving, specimens polished with Brasseler systems seemed to be smoother than the specimens polished with a Shofu system. However, this was because the shape of the specimens was changed and not the actual roughness. Manufacturers claim that ceramic core material should not be adjusted because hardness of these materials makes it impossible to adjust them. This study found that ceramic core material can be altered by using both Shofu and Brasseler polishing systems. However, these alterations did not generally result in smoother specimens.

Although there have been studies regarding wear of enamel when opposing ceramic restorations. Further work should aim to relate surface roughness (Ra) of ceramic to the amount of wear produced.
VII. CONCLUSIONS

The following conclusions were made:

1. Brasseler porcelain polishing system made ceramic rougher than before polishing.

2. Shofu porcelain polishing system produced less surface roughness on aluminum oxide, zirconia and feldspathic porcelain than the Brasseler polishing system.

3. Surface roughness of aluminum oxide, zirconia and feldspathic porcelain can be altered after polishing by both Brasseler and Shofu porcelain polishing systems.
VIII. FUTURE RESEARCH

The results of this study provide some of the data on the efficacy of two porcelain polishing systems on the alumina and zirconia core ceramic material. As such, this research provides a methodology with which further studies can expand upon.

This study covered only 2 commercialshing systems and 3 different ceramic materials. These porcelain polishing systems and ceramic materials represent the most generally used materials in private practice. Other porcelain polishing systems and other ceramic materials should be considered for future studies, along with wear of the opposing teeth when in contact with these materials.

Variables that simulate clinical conditions can also be further evaluated. Force application to the specimens and polishing directions when polishing prior to the surface roughness analyzing might be clinically relevant variables to consider.
IX. SUMMARY

This study compared the surface roughness of 3 porcelain materials with the use of 2 porcelain polishing systems. An aluminum oxide, a zirconia and a feldspathic porcelain were examined with Brasseler and Shofu polishing systems.

48 porcelain samples were included in this study; 16 of aluminum oxide, 16 of zirconia and 16 of feldspathic dental porcelain. All surfaces of the specimens were analyzed by a stylus profilometer for a pre-polishing surface roughness. Then each 16 specimens were randomly assigned in to 2 groups for a polishing procedure with Shofu and Brasseler porcelain polishing systems. After polishing all specimens were analyzes again by a stylus profilometer. Pre-polishing and post-polishing surface roughness was recorded.

A statistically significant difference was found between 2 porcelain polishing systems at $p \leq 0.0167$. Shofu polishing system demonstrated lesser surface roughness compare to Brasseler polishing system. In addition, surface roughness of aluminum oxide, zirconia and feldspathic dental porcelain were changed after polishing with each polishing systems at $p \leq 0.05$. 
Table 1  Ceramic Materials Tested

<table>
<thead>
<tr>
<th>Material</th>
<th>Type</th>
<th>Manufacturer</th>
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</thead>
<tbody>
<tr>
<td>Alumina</td>
<td>In-ceram alumina</td>
<td>Vita, Vident, USA</td>
</tr>
<tr>
<td>Zirconia</td>
<td>In-ceram zirconia</td>
<td>Vita, Vident, USA</td>
</tr>
<tr>
<td>Feldspathic</td>
<td>VM 7</td>
<td>Vita, Vident, USA</td>
</tr>
<tr>
<td>Brand</td>
<td>Company</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>------------------</td>
<td></td>
</tr>
<tr>
<td>Dialite</td>
<td>Brasseler, USA</td>
<td></td>
</tr>
<tr>
<td>Ceramiste</td>
<td>Shofu, USA</td>
<td></td>
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</table>
Table 3  Mean surface roughness of aluminum oxide, zirconia and feldspathic porcelain before and after polishing with two polishing systems.

<table>
<thead>
<tr>
<th>Polishing system</th>
<th>Material</th>
<th>Measure</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>Std Dev</th>
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<td>Shofu</td>
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<td>2239</td>
<td>1810</td>
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Fig 1  Core ceramic discs
Figure 2  Rectangular shaped putty mold
Figure 3  Mixed feldspathic dental porcelain
Figure 4  Feldspathic porcelain in a putty mold
Figure 5  Feldspathic porcelain block before firing
Figure 6  Specimens were mouthed on the aluminum rings.
Figure 7  Specimens were mouthed in the grinder and polisher
Figure 8    Brasseler diamond bur
Figure 9  Specimens were run in a stylus profilometer (Dektak 8)
Figure 10  A stylus was positioned on a black dot.
Figure 11  Dialite Brasseler polishing system
Figure 12  Ceramiste Shofu polishing system
Figure 13 A low speed lab handpiece and motor.
X. References


