Original Article

Porcelain Refinishing with Two Different Polishing Systems after Orthodontic Debonding

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ABSTRACT

Objective: To compare the effects of two polishing systems on the surface roughness of three types of porcelain after orthodontic debonding.

Materials and Methods: A total of 90 porcelain discs were fabricated from feldspathic (n = 30), leucite-based (n = 30) or lithia disilicate–based (n = 30) ceramics. Ten samples in each group served as the control and received no surface treatment. The remaining 60 samples in three of the porcelain groups were bonded with lower incisor brackets and debonded using a testing machine in shear mode at a rate of 1 mm/minute crosshead speed. After debonding, the remaining adhesive resin was removed with a tungsten carbide bur. Then, two experimental subgroups (10 each) in each porcelain group were treated as follows: in the first subgroup, porcelain polishing wheel and polishing paste were applied, whereas in the second, polishing was performed using a series of Sof-Lex discs. The average surface roughness (Ra) of the all samples was evaluated using SPM/AFM (surface probe microscope/atomic force microscope). Data were statistically analyzed by analysis of variance for each porcelain material and polishing method.

Results: The polishing techniques affected surface roughness significantly. There were significant differences between the groups; higher Ra values were obtained with the use of porcelain polishing wheel and polishing paste ($P < .001$).

Conclusion: The application of Sof-Lex discs can produce smoother porcelain surfaces than porcelain polishing wheel and polishing paste.

KEY WORDS: Debonding; Surface roughness; Porcelain; Polishing

INTRODUCTION

Dental ceramic is commonly used as a restorative material in the replacement of a lost or damaged tooth or an unattractive enamel surface because of its esthetic features, durability, and biocompatibility. The demand for more successful restorations has generated the development of more advanced porcelain systems. There are different types of porcelain for ceramic restorations. In addition to traditional feldspathic porcelain, leucite-based or lithia disilicate–based ceramic systems are successfully used to fabricate prosthetic restorations. However, the composition and physical properties of leucite-based or lithia disilicate–based ceramics are different from feldspathic porcelain.[1]

In orthodontic bonding to porcelain, combinations of various mechanical and chemical conditioning methods were suggested to alter the surface characteristics of ceramic. The purpose of mechanical alteration of the porcelain surface is to remove the glaze and roughen the surface to provide mechanical retention for the orthodontic adhesive. This alteration can be achieved by sandblasting[2–6] or using a coarse diamond stone.[2,7] However, mechanical roughening with burs or sandblasting causes irreversible damage to the porcelain glaze,[8–12] and porcelain restorations may be fractured at bracket debonding.[13] For chemical conditioning, hydrofluoric acid and acidulated phosphate fluoride can be used.[3,7,14] Also, the effect of silica coating[15–17] and laser irradiation on the porcelain surface has been investigated as an alternative conditioning technique.[18] After tribochemical silica coating, a layer of small silica particles remains on the surface and improves chemomechanical bonding via silane application.[17]

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Glazing generally promotes fracture resistance and decreases the potential wear of the ceramic by covering the porosity on the fired porcelain. The glaze layer over the porcelain consists of colorless glass powder applied to obtain a smooth porcelain surface.[19] The debonding procedure after orthodontic treatment breaks the glaze layer and creates a rougher surface. Refinishing or polishing after these procedures is necessary to restore a glossy surface. In orthodontic practice, there is no practical way to remove ceramic restorations and reglaze them under laboratory conditions. Therefore, intraoral polishing of the restorations is the best alternative.

Several studies have been conducted on different finishing and polishing techniques to restore optimum smoothness to porcelain. Generally, intraoral polishing techniques using rotary instruments such as diamond burs and rubber abrasives can provide a clinically acceptable smoothness. Studies have also concluded that diamond polishing paste is better than polishing stones in restoring porcelain surfaces.[13,20]

Atomic force microscopy (AFM), introduced by Binning et al[21] in 1986, is an important tool for qualitative and quantitative evaluation of surfaces. AFM directly investigates the sample surface by means of mechanical scanning without using any lens or photon. In this technique, a sharp tip at the end of a cantilever is scanned over a surface, and by measuring the deflection a topographic image of the surface can be obtained. With sufficient sensitivity in the spring deflection sensor, the tip can reveal surface profiles with nanometer scale resolution.[22] Three kinds of operation modes (contact, noncontact, and tapping) can be applied to different materials. AFM offers unique features: high magnification with high resolution, minimal sample preparation, and the ability to detect atomic-scale defects and obtain two-dimensional or three-dimensional images of the sample from a single data collection.[23]

Therefore, the aim of this study was to investigate the effects of two polishing techniques on the surface roughness of three types of porcelain systems by means of AFM evaluation after orthodontic debonding.

MATERIALS AND METHODS

A total of 90 disc samples were fabricated from three types of porcelain materials. Feldspathic porcelain (IPS d.sign, Ivoclar-Vivadent, Schaan, Lichtenstein) at a thickness of 2 mm was fired onto the metal discs. Leucite-based ceramic (IPS Empress, Ivoclar-Vivadent) and lithia disilicate–based ceramic (IPS Empress 2, Ivoclar-Vivadent) samples were obtained without alloy bases according to the manufacturers' recommendations. Each ceramic group consisted of 30 samples divided equally into three subgroups; 10 samples in each group served as the control and had no surface treatment.

In the experimental groups all samples with glazed surfaces were prepared for bonding using sandblasting and acid etching. First, the samples were sandblasted with 50 μm aluminum oxide (Al_2O_3) (GAC, New York, NY) for 3 seconds with an intraoral sandblaster (Microetcher II, Danville Materials, San Ramon, Calif) and left unglazed. Then, HF acid 9.6% (Pulpdent porcelain etch gel, Pulpdent Corp, Watertown, Mass) was applied for 2 minutes, washed, and dried. After application the porcelain primer (ESPE-Sil, 3M ESPE, Seefeld, Germany) metal brackets were bonded to surfaces using Transbond XT (3M Unitek, Monrovia, Calif). The excess resin was removed, and the adhesive was light cured for 40 seconds using conventional halogen (Ortholux XL 3000, 3M Unitek).

All samples were stored in water for 24 hours and thermocycled 500 times between 5°C and 55°C. The shear bond test was performed with a universal testing device (Testometric M500 25kN, Rochdale, UK). The sample and blade were secured to the device so that the bonded surface of porcelain was parallel to the direction of the force. Shear force was applied to the porcelain-bracket interface with a crosshead speed of 1 mm/min until debonding occurred. After debonding, residual adhesive resin was removed with a spiral 12-fluted tungsten carbide bur (Dentsply, Surrey, UK) in a slow-speed handpiece. Adhesive removal was performed until a visually smooth surface was obtained. Then the three groups of porcelain were divided into two subgroups. In the first group; porcelain polishing wheel (Cera Master, Shofu Dental, Menlo Park, Calif) and polishing paste (Ultra II, Shofu Dental) were applied. First the polishing wheel was used, and then the polishing paste was applied onto the sample surface using a rubber cup until a glossy surface was obtained. In the second group, the samples were polished using a series of Sof-Lex discs: coarse, medium, fine, and extra fine (3M ESPE). The adjustment kit consisted of four discs with different grain size from black to light blue, which were used until the smoothness was obtained. New discs were applied to each sample. All polishing procedures were performed by the same operator using a slow-speed handpiece, as recommended by the manufacturer. In addition, these procedures were performed until the surfaces appeared shiny to the naked eye, simulating the clinical conditions. Table 1 shows the polishing materials and manufacturers' names.

After these procedures, surface roughness of all samples was evaluated using SPM/AFM (Surface Probe/Atomic Force Microscope). AFM (MMAFM-2/1700EXL, Digital Instruments, Santa Barbara, Calif) is

Table 1. Polishing Materials and Manufacturers' Names

Polishing Material	Manufacturer
Polishing wheel	Cera Master, Shofu Dental, Menlo Park, Calif
Polishing paste	Ultra II, Shofu Dental, Menlo Park, Calif
Polishing discs	Sof-Lex, 3M ESPE, Seefeld, Germany

operated in the contact mode first to obtain the topographic images over randomly selected areas on the surface. To measure the roughness values, the tip was moved across the surface, and two different points were measured on the same surface located in the center of the samples. The average surface roughness values, Ra, of each scanned area were used for statistical analysis. The Ra value is the arithmetic mean of the height of peaks and depth of valleys from a mean line. The differences between Ra values, expressed in nanometers, were statistically analyzed using analysis of variance (ANOVA) for each ceramic material and polishing methods. Statistical significance was set at the $\alpha = .05$ level.

RESULTS

For each group, mean Ra values and standard deviations are shown in Table 2. For all surface roughness measurements, there was a difference in prebond and debond values. This difference between the surface roughness of the prebond and debond samples is in accordance with the views obtained by the AFM scans. The prebond glazed surfaces in three of the porcelain groups were smooth, whereas significantly rougher surfaces were visible on three-dimensional views of the polished porcelain surfaces (Figures 1 through 3).

In statistical evaluations, a two-way ANOVA (using porcelain type and polishing type as factors) was performed on the surface roughness values. The results indicated that surface roughness was not affected by porcelain type ($P = .132$), but surface roughness differed significantly by polishing technique ($P = .000$). With this information, a one-way analysis on roughness (for polishing technique) was performed.

One-way ANOVA on Ra values for polishing procedures indicated that there was a significant difference between the prebond and debond surface roughness values, according to the surface treatment (Table 3). Polishing techniques significantly affected surface roughness ($P < .001$). Also, the polishing wheel plus paste groups and the polishing disc groups were significantly different from each other. Higher Ra values were obtained with the use of the polishing wheel and polishing paste than with the polishing disc ($P < .001$).

When porcelain types were evaluated, the lithia disilicate–based porcelain had the highest mean Ra value (192.4 $\pm$ 37.6 nm) among all groups after treatment with the polishing wheel plus paste. On the other hand, the lowest mean Ra value (58.2 $\pm$ 30.5 nm) was also achieved with the same porcelain type after applying polishing discs. The descriptive statistics of surface roughness (nm) for the groups are presented as box plots in Figure 4.

DISCUSSION

After debonding an orthodontic appliance bonded to a porcelain surface, chair-side polishing systems are considered for improving the smoothness of the restoration. This is important to minimize plaque retention, maximize the life span of restoration, and increase the patient's comfort. The effectiveness of porcelain polishing systems is a controversial issue in the literature. Several studies have reported that the final ceramic surfaces obtained with polishing are comparable to those of glazed surfaces.[13,20,24–28] However, some authors have reported that polishing systems cannot recreate a surface that is as smooth as the original glaze.[29–33]

Because the roughness value depends on the measurement technique, the investigation protocol used to study surface roughness is important. The evaluation of smoothness of porcelain surfaces from scanning electron microscope photomicrographs is unreliable and subjective.[20] Surfaces can be quantitatively evaluated with a profilometer, which determines roughness by the undulations of the profile relative to some baseline. However, it was reported that some profilometer measurements of ceramic surfaces may be misinterpreted because of the pores in the ceramic material.[33]

Table 2. Porcelain Surface Roughness before Bonding and after Polishing

		Before Bonding (Glazed Surfaces)		Debonded			
				Polishing Wheel Plus Paste		Polishing Disc	
Porcelain Type	n	Mean	SD	Mean	SD	Mean	SD
Feldspathic	10	4.8	0.6	166.5	39.2	102.5	39.8
Leucite-based	10	3.9	0.9	150.4	41.9	72.1	30.5
Lithia disilicate–based	10	2.7	1.2	192.4	37.6	58.2	30.5
All	30	3.8	1.3	169.8	42.1	77.6	37.7

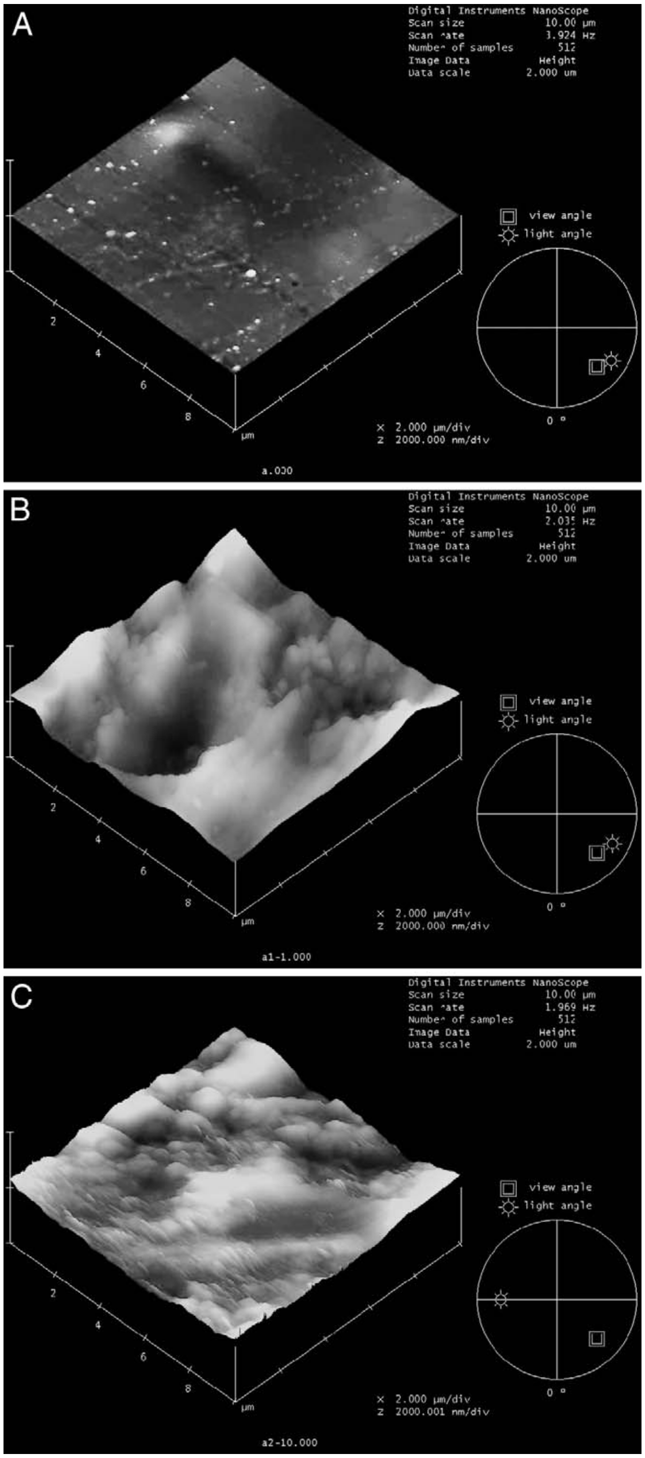

Figure 1. Atomic force microscopy observation of the surfaces of feldspathic ceramic groups: (A) glazed surface (control); (B) polished with polishing wheel plus paste; (C) polished with Sof-Lex disc.

Pores are inherently present within the ceramic because of the manufacturing technique, and they will open up after removal of the glaze.[19] AFM analysis is an alternative method that uses multiple mechanical scans in high resolution, and it is recommended for the analysis of such surfaces with nanoscale irregularities.[33–35] Furthermore, this method has several advantages, such as minimal sample preparation, the ability to obtain two-dimensional and three-dimensional images at the same time, and the possibility of reexamining the same sample.[23,33,36]

This study showed that the final roughness of the ceramic surfaces was higher than the initial values, and it varied significantly for different polishing procedures. The mean initial surface roughness measurements suggest that there is no considerable difference between the porcelain systems used in this study before bracket bonding. The AFM values in Table 2 indicate that there is a significant difference in the prebond and debond measurements. This result was also reported by several authors,[29–33] so it can be concluded that orthodontic bonding and debonding procedures change the porcelain surface texture in an irreversible manner, regardless of the porcelain type or polishing technique used to improve the surface smoothness. Abrasive stones can remove irregularities from the porcelain surface, but the restoration cannot be returned to its original condition. After debonding, when polishing the samples with either of the polishing techniques, the researcher tried to achieve surfaces that were smooth and shiny to the naked eye to simulate clinical practice. The fact is that roughness changes when the observation scale itself changes. Surface irregularities viewed with magnification may go unnoticed when examined with the naked eye.

Compared with the original glazed surfaces, applying a polishing wheel plus paste produced feldspathic and leucite-based ceramics that were 35 and 38 times rougher, respectively, whereas applying polishing discs produced feldspathic and leucite-based ceramics that were 21 and 18 times rougher, respectively. The smoothest surfaces were achieved with polishing discs when applied on lithia disilicate–based ceramic. On the other hand, in the case of using a polishing wheel plus paste, the roughest surfaces were obtained with lithia disilicate–based ceramic. Every dental material needs its own treatment protocol to obtain and maintain a surface that is as smooth as possible. However, the differences among the three types of porcelain with respect to roughness after polishing were statistically insignificant, so clinicians can select the porcelain polishing protocol after debonding even if they do not know the type of porcelain used.

In our protocol, we used two different polishing systems that have been recommended as quick and efficient. Because the use of polishing paste alone is not effective,[27,31] we chose the combination of a polishing wheel filled with high-density diamond particles and polishing paste. However, use of the polishing stone followed by polishing paste did not result in a signifi-

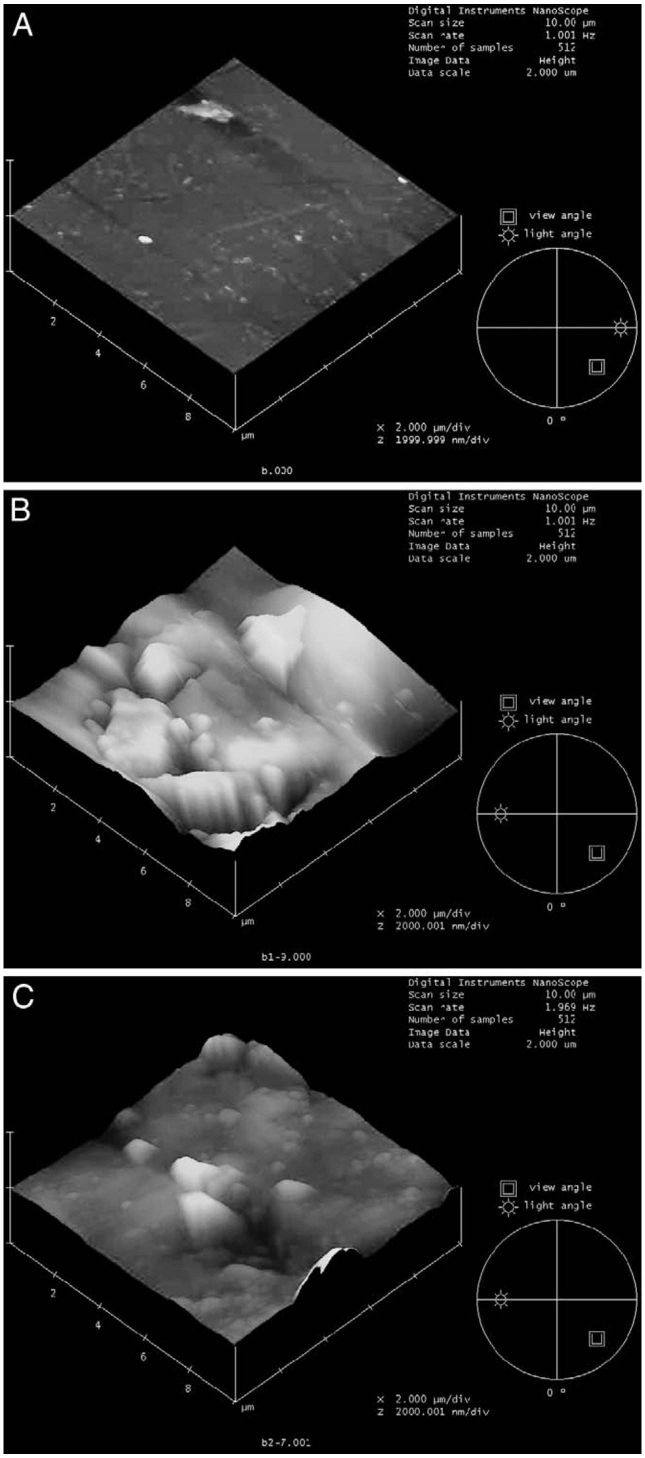

Figure 2. Atomic force microscopy observation of the surfaces of leucite-based ceramic groups: (A) glazed surface (control); (B) polished with polishing wheel plus paste; (C) polished with Sof-Lex disc.

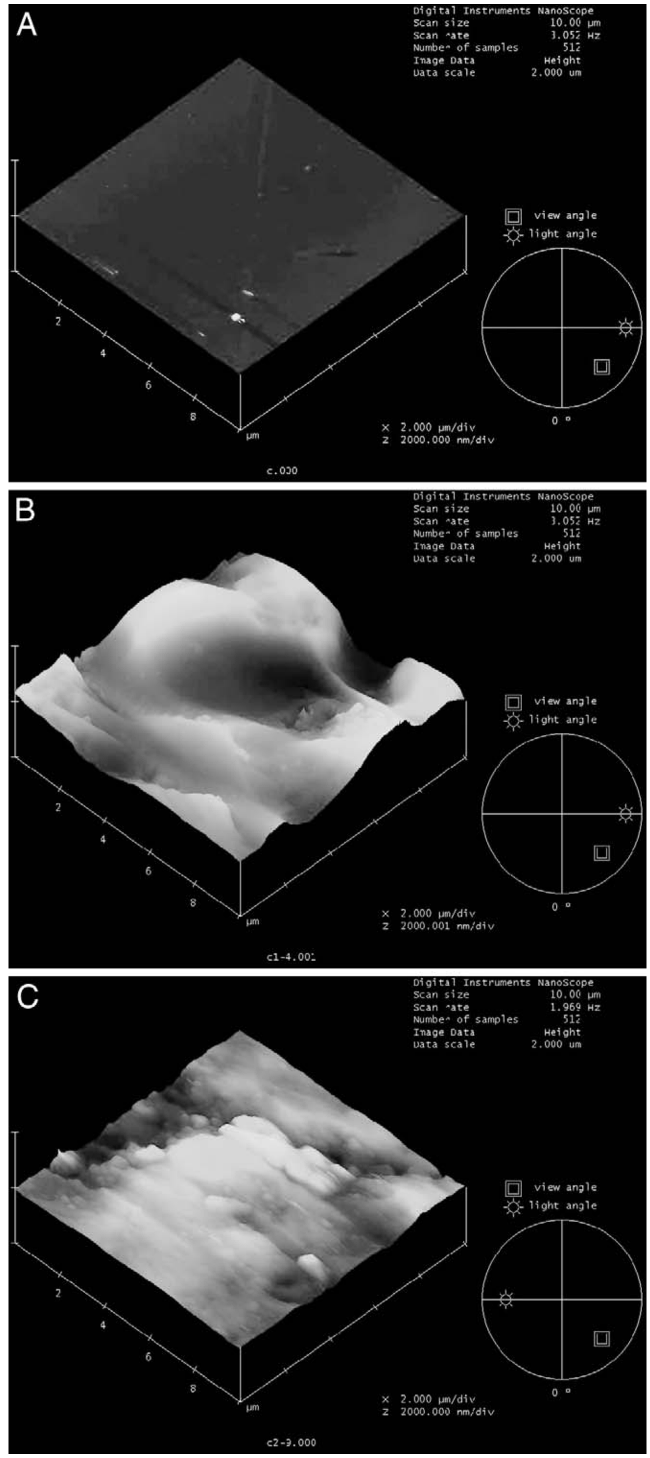

Figure 3. Atomic force microscopy observation of the surfaces of lithia disilicate–based ceramic groups: (A) glazed surface (control); (B) polished with polishing wheel plus paste; (C) polished with Sof-Lex disc.

cantly smoother ceramic surface. The Ra values obtained with polishing discs had the lowest surface roughness among all the groups. Although the main indication for polishing discs, which are commonly used in dental clinics, is finishing and polishing dental composite resins, the best polishing results for several types of porcelain were also achieved using the Sof-Lex system in earlier studies.[37–39] Furthermore, it was reported that only flat and convex surfaces can be ef-

Table 3. One-way Analysis of Variance Results of Surface Roughness for Polishing Methods

	Sum of Squares	df	Mean Square	F	Significance
Between groups	414,705.2	2	207,352,6	194,6	0
Within groups	92,699.2	87	1065.5		
Total	507,404.5	89			

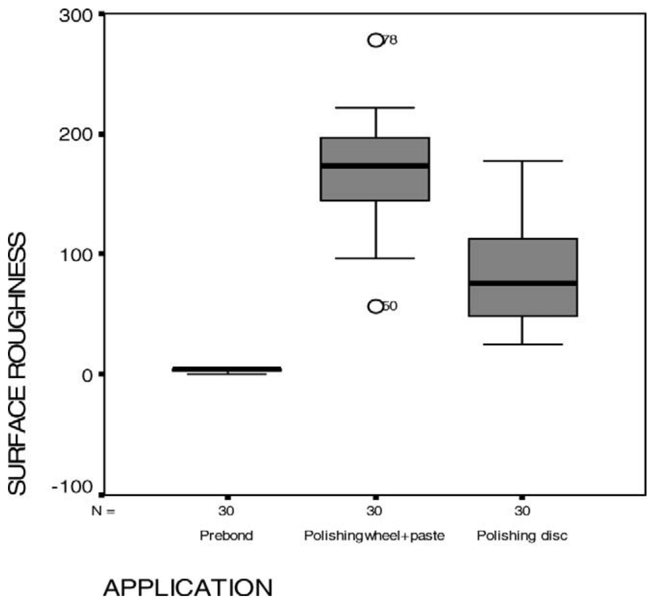

Figure 4. Box plot diagram showing the surface roughness of porcelain systems evaluated in this study. The horizontal line in the middle of each box plot shows median value; the minimum and maximum values are illustrated via the upper and lower stroke. "O" marks outliers.

fectively polished with flexible polishing discs such as the Sof-Lex system.[39] Therefore, based on the findings of the present study, polishing discs seem to be effective for polishing porcelain surfaces after orthodontic appliances have been removed.

CONCLUSIONS

- The polishing methods used in this study did not restore the porcelain to the original glazed surface.
- There were no statistically significant differences in porcelain surface roughness among the three porcelain systems (feldspathic, leucite-based porcelain, or lithia disilicate–based porcelain), regardless of the polishing system.
- Use of polishing discs was found to be more effective for smoothing the porcelain surfaces compared with use of a polishing wheel and polishing paste.

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