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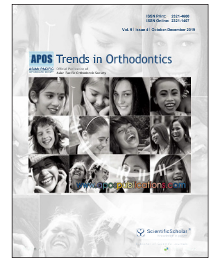

Original Article

Comparative effect of three polishing systems on porcelain surface roughness after orthodontic bracket debonding and composite resin removal: An atomic force microscopy

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ABSTRACT

Purpose: Porcelain polishing after orthodontic bracket debonding and resin removal is imperative to eliminate surface roughness and minimize the risk of plaque accumulation, periodontal disease, and porcelain discoloration. This study aimed to assess the effect of three polishing systems on porcelain surface roughness after orthodontic bracket debonding.

Materials and Methods: Thirty porcelain blocks were divided into three groups. Surface roughness of the samples was first measured using atomic force microscopy (AFM) and recorded as baseline. Orthodontic brackets were bonded to blocks by composite resin. After bracket debonding, resin remnants were removed by tungsten carbide bur. The blocks were then polished with Sof-Lex discs, Meisinger, and Jota porcelain polishing kit. Surface roughness was measured again using AFM. The Shapiro–Wilk test, one-way ANOVA, and Tukey's *post hoc* test were used for data analysis through SPSS version 18.0. Level of significance was set at 5%.

Results: The mean change in surface roughness after polishing with Jota kit (56.6 nm) was significantly greater than that compared to Sof-Lex discs (10.7 nm) ($P = 0.003$) and Meisinger kit (26.6 nm) ($P = 0.024$). The mean change in surface roughness was not significantly different between Sof-Lex and Meisinger groups. Surface roughness significantly increased in all three groups ($P < 0.05$).

Conclusion: Meisinger polishing kit and Sof-Lex discs were not significantly different in terms of the resultant surface roughness. Thus, the conventional use of Sof-Lex discs seems to be more cost-effective due to their lower cost.

Keywords: Porcelain, Atomic force microscopy, Orthodontic bracket, Surface roughness

INTRODUCTION

Demand for orthodontic treatment has greatly increased among adults who usually contain one or more restored teeth in the recent years.[1] Thus, dentists have to use novel bonding agents and techniques for bonding of orthodontic brackets to dental restorations such as porcelain crowns.[2]

Porcelain is a commonly used dental material for replacement of the lost teeth or restoration of severely damaged teeth and defective enamel surfaces due to its optimal strength and durability, excellent esthetics, and favorable biocompatibility.[3-6]

Two factors should be taken into consideration in bracket bonding to porcelain. First, the optimal bond strength should be 6–10 MPa to prevent easy debonding as the result of application of orthodontic or masticatory forces during the course of treatment.[7] Furthermore, in the process of debonding after completion of orthodontic treatment, irreversible iatrogenic damage such as surface roughening, vertical cracks, and loss of the outer tooth layer should be prevented.[8] In this process, the color of porcelain is also affected because a rough surface, compared to a glazed (polished) surface and reflects less light and in an irregular fashion.[9]

Residual adhesive and composite resin remaining on the surface after orthodontic bracket debonding and the resultant rough surface can lead to bacterial plaque accumulation, development of periodontal disease, porcelain discoloration, and compromised esthetics.[5,9-11]

Porcelain polishing is one method to eliminate surface roughness, improve esthetics and translucency of the porcelain surface, and decrease the accumulation of bacterial plaque.[9,12] Several techniques are currently applied for this purpose including the use of manual instruments (scalers or band remover pliers), rotary instruments (carbide bur with high-speed and low-speed handpiece), ultrasound, air abrasion with aluminum oxide particles, and laser irradiation.[13-15] Sof-Lex discs and Super-Snap kit (a type of aluminum oxide disc) are commonly used for resin removal and provide highly polished surfaces.[16] A number of studies have shown that Sof-Lex discs can decrease porcelain surface roughness after glazing and are highly effective for prosthodontic or restorative treatments.[12,17] Several polishing systems have been introduced into the market, and their manufacturers claim that they all provide a smooth surface after orthodontic bracket debonding and resin removal, comparable to the baseline porcelain surface.

Porcelain surface roughness after bracket debonding has been evaluated using profilometer and electron microscope.[5,9,18] Atomic force microscopy (AFM) is an efficient tool for qualitative and quantitative assessment of surfaces.[19] Atomic force microscope is a probing microscope with biological application that provides high-resolution scans for the assessment of surface irregularities in nanometer scale. This microscope has advantages such as not requiring staining of samples and their minimum preparation, providing two-dimensional and three-dimensional images simultaneously and repeatability of assessments.[20,21] Considering the controversy in the results of previous studies in terms of changes in porcelain surface roughness after orthodontic bracket debonding and removal of resin remnants[5,6] and the variations of the newly introduced systems for this purpose, this study aimed to assess the surface roughness of porcelain following the use of three polishing systems, namely Sof-Lex discs, Meisinger polishing kit, and Jota polishing kit using AFM.

MATERIALS AND METHODS

In this *in vitro*, experimental study, 30 feldspathic porcelain blocks measuring 10 mm×10 mm with 1.5 mm thickness (to simulate the thickness of porcelain crowns in the clinical

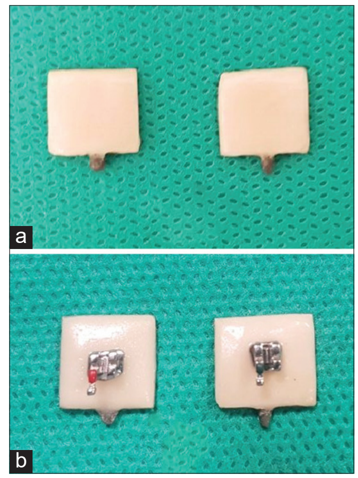

Figure 1: Porcelain blocks: (a) before bracket bonding and (b) after bracket bonding.

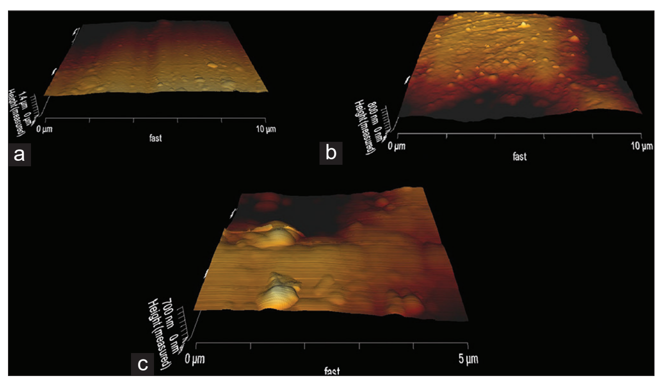

Figure 2: Three-dimensional view of porcelain block after polishing: (a) Sof-Lex disc, (b) Jota polishing disc, (c) Meisinger polishing kit.

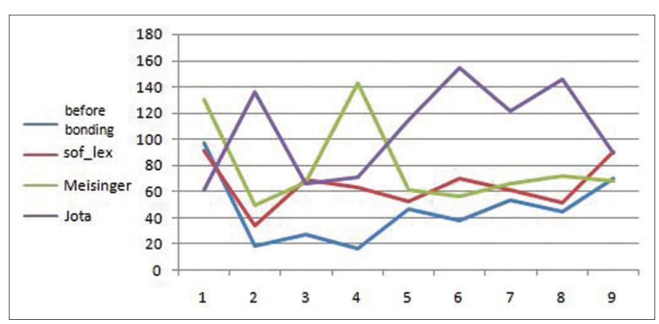

Figure 3: Ra change before bonding and after polishing with three polishing systems.

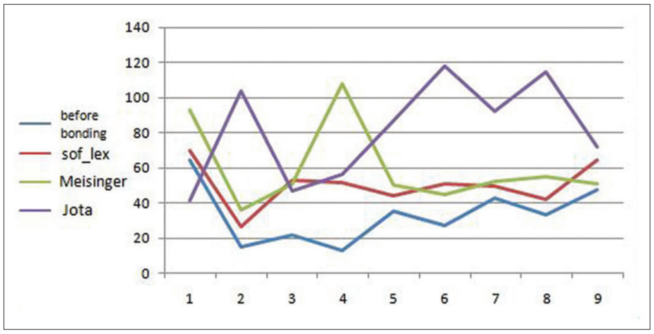

Figure 4: Rt change before bonding and after polishing with three polishing systems.

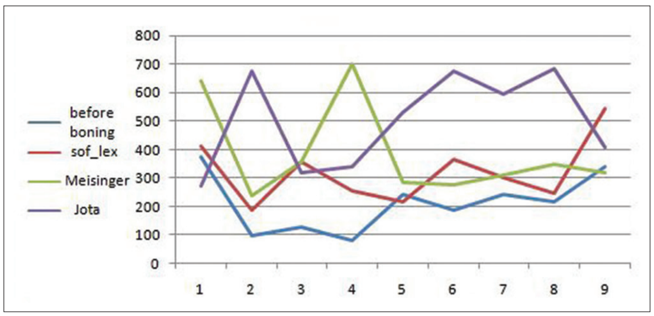

Figure 5: Rq change before bonding and after polishing with three polishing systems.

setting) were fabricated using a mold [Figure 1]. The blocks were coded, and their surface roughness was measured using AFM (JPK Instruments, Germany). For this purpose, the blocks were hypothetically divided into three horizontal and three vertical segments, and then, 5 images measuring 10 μm×10 μm were obtained from the square at the center of each sample. The Ra, Rq, and Rt values of each image were calculated in nanometers (nm), and the mean of five values for each parameter was calculated separately for each porcelain block:

- Ra: The arithmetic mean of the height of peaks and depth of valleys from a mean line in nanometers
- Rq: Root mean square roughness, the height distribution relative to the mean line in nanometers
- Rt: Maximum roughness height, representing the isolated profile features on the surface.[22]

Ra indicates mean roughness and does not account for the presence of an occasional peak or valley. It is the most common surface roughness parameter to measure the quality of a surface. Other parameters including Rt and Rq would supplement Ra data.[23]

Thus, the mean Ra, Rq, and Rt values for each porcelain block were obtained and recorded in a checklist. Next, the porcelain surfaces were etched with 9/6% hydrofluoric acid gel (Porc-Etch; Reliance Orthodontic Products Inc., Itasca, IL, USA) for 2 min. After gel removal and rinsing and drying of the samples, silane (Reliance) was applied for 60 s, and then, Transbond XT primer (3M Unitek Corp, Monrovia, CA, USA) and adhesive were applied. Stainless steel mandibular second premolar brackets (due to their mild flat bases which best fit the flat surface of the porcelain blocks) (Victory Series; 3M Unitek Corporation, Monrovia, CA, USA) with 022 slot and 0° angulation and inclination were bonded to porcelain blocks, and excess composite was removed by the sharp tip of an explorer. Light curing (3M Unitek) was then performed for 20 s (Unitek 3M, USA). The brackets were debonded by peeling from mesial toward distal using a bracket removing plier (Unitek, 3M, USA) to minimize traumatization of porcelain surface.[13] A 12-flute tungsten carbide bur (US# 7404 Football; Brasseler, Savannah, GA, USA) was used to remove resin remnants. A new bur was used for each sample with cooling and high-speed handpiece.[23] Debonding was performed by an experienced orthodontist who was not involved in the study and not aware of the system being used. The samples were then randomly divided into three groups of 10, and each group was polished by one of the following three systems: Porcelain polishing kit (Sof-Lex discs, 3M ESPE, USA), porcelain polisher (Jota discs, Switzerland), and porcelain polishing discs kit (Meisinger discs, Germany) until a smooth surface was achieved. To control for the effect of practice bias (better performance in final samples), every other sample was polished with a different system. Next, surface roughness of the samples was measured again using AFM, and the Ra, Rq, and Rt values were calculated as explained earlier Figure 2.

The secondary surface roughness of the samples was compared with baseline values. The Shapiro–Wilk test, one-way ANOVA, and Tukey's *post hoc* test were used for data analysis through SPSS version 18.0. Level of significance was set at 5%.

RESULTS

Of each polishing group, one sample was excluded due to inability of measurement or incorrect data. No significant difference was noted in the mean surface roughness of the samples at baseline (P for Ra = 0.851). The results of surface roughness, separately for each parameter, in each group were as follows:

Ra (average roughness value)

Table 1 presents the mean and standard error of Ra before and after polishing and its trend of change. Sof-Lex, Meisinger, and Jota polishing systems increased Ra by averagely 10.7 nm, 26.6 nm, and 56.6 nm, respectively; these changes were statistically significant (P = 0.003). The increase in Ra by the Jota system was higher than that by Sof-Lex (P = 0.003) and Meisinger (P = 0.024) systems, but Sof-Lex and Meisinger kit were not significantly different in this respect (*P* = 0.645). All three systems significantly increased the Ra value [Table 1 and Figure 3].

Rq (root mean square roughness)

The Sof-Lex, Meisinger, and Jota systems increased the Rq by averagely 18.5 nm, 32.9 nm, and 70.3 nm, respectively, which were all statistically significant [*P* = 0.003, Table 2 and Figure 4]. The increase in Rq value by Jota was significantly greater than that by Sof-Lex (*P* = 0.004) and Meisinger (*P* = 0.043). The difference in this respect between Sof-Lex and Meisinger polishing systems was not statistically significant (*P* = 0.590). All three systems significantly increased the Rq value (*P* = 0.015 for Sof-Lex, *P* = 0.029 for Meisinger, and *P* < 0.001 for Jota).

Rt (maximum roughness depth)

The Sof-Lex, Meisinger, and Jota systems averagely increased the Rt value by 110.7 nm, 178.4 nm, and 323.1 nm, respectively. This increase was statistically significant [*P* = 0.020, Table 3]. The increase in Rt by Jota system was significantly greater than that by Sof-Lex (*P* = 0.017), but the difference between Jota and Meisinger (*P* = 0.127) and Sof-Lex and Meisinger (*P* = 0.615) was not statistically significant (*P* > 0.05).

All three systems significantly increased the Rt value (*P* = 0.006 for Sof-Lex, *P* = 0.020 for Meisinger, and *P* < 0.001 for Jota and Figure 5).

DISCUSSION

Porcelain surfaces should be necessarily polished after bracket debonding because a rough porcelain surface compromises esthetics, enhances plaque accumulation, and decreases the durability of porcelain. Roughening of a glazed surface decreases the light reflection and subsequently affects the porcelain color.[9-11] Increased porcelain surface roughness also decreases the flexural strength of porcelain and increases the risk of porcelain fracture in lower than normal stresses.

Table 1: Mean and standard error of Ra before bonding and after polishing and its trend of change following the use of three polishing systems (*n*=9).

Polishing system	Before bonding		After polishing		Change in Ra		*P* value
	Mean	Standard error	Mean	Standard error	Mean	Standard error	
Sof-Lex	33/2	5/5	50/2	4/2	17/0	3/9	0/002[a]
Meisinger	31/1	5/2	57/7	8/6	26/6	9/1	0/001[b]
Jota	29/2	3/9	85/9	8/3	56/6	8/5	<0/001[c]
P value	0/851		0/005[d]		0/003[e]		-

[a,b,c,d,e]Significant (*P*<0.05)

Table 2: Mean and standard error of Rq before bonding and after polishing and its trend of change following the use of three polishing systems (*n*=9).

Polishing system	Before bonding		After polishing		Change in Rq		*P* value
	Mean	Standard error	Mean	Standard error	Mean	Standard error	
Sof-Lex	46/4	8/6	64/8	6/1	18/5	6/0	0/015[a]
Meisinger	43/0	8/0	75/9	12/0	32/9	12/4	0/029[b]
Jota	40/0	5/7	110/3	10/7	70/3	11/4	<0/001[c]
P value	0/836		0/009[d]		0/005[e]		-

[a,b,c,d,e]Significant (*P*<0.05)

Table 3: Mean and standard error of Rt before bonding and after polishing and its trend of change following the use of three polishing systems (*n*=9).

Polishing system	Before bonding		After polishing		Change in Rt		*P* value
	Mean	Standard error	Mean	Standard error	Mean	Standard error	
Sof-Lex	211/8	33/6	322/5	37/3	110/7	30/3	0/006[a]
Meisinger	194/2	29/8	372/6	59/0	178/4	61/7	0/020[b]
Jota	190/2	26/9	513/3	49/8	323/1	53/8	0/001[c]
P value	0/866		0/032[d]		0/020[e]		-

[a,b,c,d,e]Significant (*P*<0.05)

Furthermore, risk of staining of a roughened porcelain surface increases compared to smooth and glazed surfaces.[24]

The efficacy of porcelain polishing systems is an interesting topic in orthodontics. Some studies have discussed that polished surfaces are comparable to glazed surfaces,[25] while some others believe that polishing systems cannot create surfaces as smooth as glazed surfaces.[26-28]

On the other hand, several porcelain polishing systems are available in the market, and the manufacturers claim that their products have higher efficacy than the conventional methods such as Sof-Lex discs. In this study, two new polishing systems, namely the Meisinger and Jota polishing kits, were used for polishing of feldspathic porcelain, and the surface roughness of polished samples was measured and compared with baseline surface roughness. The results showed that the remaining roughness after surface polishing with Sof-Lex discs and Meisinger kit was significantly lower than that caused by Jota disc. Furthermore, the difference in surface roughness of samples in Sof-Lex and Meisinger groups was not significant.

AFM was used for the assessment of surface roughness of samples in our study. One major advantage of AFM compared to profilometry and scanning electron microscopy (SEM) is that it enables quantitative assessment of surface roughness and does not damage the samples.[6,29]

In this study, the surfaces were polished by the operator until a smooth and shiny surface was observed with the naked eye. However, some irregularities may still be present, which can only be seen under magnification. Shetty *et al*.[5] evaluated 40 feldspathic porcelain samples and observed that Shofu Ceramaster system compared to Kohinoor diamond polishing paste, and Sof-Lex discs had the highest effect on surface roughness, whereas the Sof-Lex discs had the lowest efficacy in this respect. Difference between their results and ours may be due to the fact that they used profilometer for the assessment of surface roughness. The presence of a control group was strength of their study; however, profilometer has lower accuracy than AFM for measurement of surface roughness. Furthermore, type of bonding agent, type of bracket, magnitude of force applied for bracket debonding, and the polishing tool can all affect the surface roughness of porcelain after orthodontic bracket debonding and resin removal, and a combination of these factors may be responsible for the controversy in the results of studies.[13]

Karan *et al*. polished 90 samples made of feldspathic porcelain and leucite-based ceramic and lithium disilicate-based ceramic and measured their surface roughness using AFM. They reported that surface roughness of samples after polishing does not depend on the type of porcelain, but the polishing technique has a significant effect on surface roughness. They observed that Sof-Lex discs yielded a smoother surface compared to porcelain polishing wheel used with polishing paste.[6]

Tholt de Vasconcellos *et al*., in 2006, measured the surface roughness of dental ceramics after polishing with different systems using AFM and profilometer. They used three types of ceramics and three polishing systems, namely Identoflex, Shofu, and Eve system. They measured the Ra by AFM and Ry by profilometer. In contrast to the current study, they concluded that some commercial intraoral polishing kits can create a smooth surface comparable to initially glazed surfaces. Regarding Ry, they discussed that profilometer found no difference between polished samples and the primarily glazed samples regarding Ry, but AFM revealed a significant difference in surface roughness between the polished and primarily glazed groups.[29]

Osorio *et al*. compared the efficacy of six methods of resin removal from the enamel surface after orthodontic bracket debonding and reported that Sof-Lex discs yielded the smoothest surface. They used 35 freshly extracted caries-free human premolars and measured the surface roughness using SEM. The level of surface roughness following the use of high-speed and low-speed tungsten-carbide bur was average while high-speed Arkansas bur under water coolant yielded the roughest surface. Osorio *et al*. also discussed that no method is available for composite removal without roughening the surface.[30] However, it should be noted that they evaluated resin removal from the enamel surface, which is different from resin removal from dental porcelain surface.

Ulusoy evaluated the enamel surface of 80 premolars after polishing with different systems and stated that Super-Snap discs had a less destructive effect than Sof-Lex discs and yielded a smoother enamel surface. They also used SEM for the evaluation of enamel surface, which is different from our methodology and may explain the difference in the results of the two studies.[31]

Patil *et al*. evaluated the effect of different polishing techniques on enamel reflectivity (shine) following orthodontic bracket debonding. In their *in vitro*, interventional study, which was conducted on 61 extracted premolars (one tooth served as control), the samples were evaluated using a reflectometer. The results showed that samples polished with Sof-Lex discs had greater reflectivity than those polished with Astropol. Tungsten carbide bur yielded the least reflectivity.[32]

Mohebbi *et al*. evaluated the effects of resin removal techniques following orthodontic bracket debonding on enamel surface roughness using AFM. They compared white stone bur and tungsten carbide bur with/without dental loupe magnification and found no significant difference among the groups in terms of surface roughness. However, considering faster resin removal by tungsten-carbide bur compared to white stone bur and high cost of dental loupe, tungsten carbide bur is the preferred method of resin removal from the enamel surface following orthodontic bracket debonding.[33]

We also calculated the Rq and Rt parameters in addition to Ra for more accurate assessment of the profile of samples in this study. Several studies have only used Ra parameter as the only indicator of surface roughness although its use alone has some limitations.[6,14] However, despite the higher accuracy of results using several surface roughness parameters, these findings should be interpreted with caution because the stylus used for measurement of surface roughness parameters has several features.[34] We used the diamond contact stylus while features such as non-contact laser stylus also exist. Although both have been shown to be valid, the only significant agreement between the two styli was recorded for the Ra parameter; thus, caution should be exercised when comparing the results of surface texture studies of restorative materials using various types of stylus.[34]

It should be noted that the measurement scale in both AFM and SEM is nanometers, which is a minute scale relative to tooth and porcelain surface. On the other hand, other tools such as stereomicroscope and profilometer are not as accurate as AFM.[13]

CONCLUSION

Considering the current results and absence of a significant difference between the Meisinger kit and Sof-Lex discs in terms of the resultant surface roughness, the conventional use of Sof-Lex discs seems to be more cost-effective due to their lower cost.

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Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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