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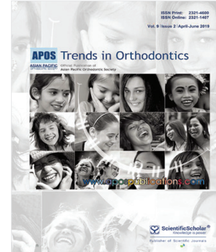

Original Article

Effect of two polishing systems on color and surface roughness of feldspathic porcelain following orthodontic bracket debonding and composite resin removal

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ABSTRACT

Objectives: Orthodontic bracket removal from a porcelain crown can roughen the surface and lead to plaque accumulation, discoloration, and esthetic problems. Porcelain polishing after debonding is one strategy to decrease such consequences. This study aimed to compare the efficacy of two polishing systems (Sof-Lex discs and Meisinger polishing system) for correction of surface roughness and discoloration of porcelain after orthodontic bracket debonding.

Materials and Methods: Twenty porcelain blocks were evaluated in two groups of 10. First, the baseline surface roughness and color parameters of the samples were measured using atomic force microscopy and spectrophotometry, respectively. After bracket bonding, a fine cutter was used for bracket debonding, and resin remnants were removed by a tungsten carbide bur and low-speed handpiece. Samples were then polished using Sof-Lex discs (group 1) and Meisinger porcelain polishing kit (group 2). Surface roughness and color parameters were measured again. Data were analyzed using SPSS 18 through the Shapiro–Wilk test, Student's *t*-test, and paired *t*-test at 5% level of significance.

Results: Porcelain color change (ΔE) was significantly greater in the Meisinger system than Sof-Lex ($P < 0.001$). The Rq, Ra, and Rt surface roughness parameters significantly increased in both the groups after the intervention compared to baseline ($P < 0.05$), but the two groups were not significantly different in this respect after the polishing procedures ($P > 0.05$).

Conclusion: The porcelain color after polishing with Sof-Lex discs was closer to the baseline. Furthermore, the two systems were not significantly different regarding surface roughness. However, Sof-Lex discs may be recommended due to lower cost.

Keywords: Porcelain, Surface roughness, Color, Orthodontic brackets

INTRODUCTION

Evidence shows that age is not a limiting factor for orthodontic treatment.[1] By an increase in demand for orthodontic treatment among adults, researchers are searching for methods to enhance reliable bonding of orthodontic brackets to metal, porcelain, and other restorative materials and allow their easy debonding as well.[2,3] At present, porcelain crowns are increasingly used for the replacement of the lost or severely damaged teeth and those with enamel defects due to optimal esthetics and durability and favorable biocompatibility.[4-6]

After completion of orthodontic treatment and following bracket removal, bonding agent and resin may remain on the porcelain surface and roughen the surface, which leads to bacterial plaque accumulation, periodontal problems, discoloration, and esthetic problems.[7-9] The influential factors with respect to the susceptibility of porcelain to damage in the process of bracket debonding include the type of porcelain, rough or glazed porcelain surface, type of bonding agent, and the magnitude and direction of debonding force.[10]

The porcelain polishing techniques have been widely studied to find the most efficient method to obtain a smooth porcelain surface. In general, intraoral techniques such as the use of diamond burs and abrasive rubbers can cause a clinically smooth surface.[5]

Porcelain glaze is composed of a colorless glass powder, which confers a smooth surface. The glazing procedure creates a shiny transparent gloss on the restoration surface. This is often achieved by heating a thin glass layer on the ceramic surface or by heating the restoration for 1 or 2 min until reaching the glazing temperature.[11,12] Orthodontic bracket debonding can damage the glaze layer and create a rough surface. In this process, the porcelain color is also negatively affected because a rough surface, compared to a glazed/polished surface, reflects light irregularly and in lesser amount.[5] Thus, it is imperative to find a method with minimal damage to porcelain crowns.

Atomic force microscopy (AFM) is an important tool for qualitative and quantitative assessment of surfaces.[13] It requires minimal preparation and no staining of samples and provides both two-dimensional (2D) and three-dimensional (3D) images simultaneously. It also allows a reproducible assessment of samples.[14]

Porcelain color can be quantitatively measured and may be affected by the surface properties of porcelain. Adhesive and composite remnants on the porcelain surface can cause its color change after bracket debonding. The magnitude of color change (ΔE) depends on the smoothness/roughness of porcelain surface.[10] A spectrophotometer can be used for the assessment of color change. Compared to other colorimetry tools (optical methods and instruments such as chromometer), spectrophotometers have the advantage of enabling clinical interpretation of results. Color change detected by this system is compatible with color perception by the human eye.[15]

To date, many studies have assessed enamel surface changes following orthodontic bracket debonding and removal of resin remnants by different tools.[7,14,16,17] However, considering the scarcity of data regarding porcelain surface changes following orthodontic bracket debonding and removal of resin remnants and the existing controversy regarding the efficacy of available techniques for this purpose,[5,18,19] this study aimed to assess the color change and surface roughness of porcelain after orthodontic bracket debonding and polishing by Sof-Lex discs (which are highly popular among dentists due to their easy use) and Meisinger polishing kit (which, according to the manufacturer, yields a completely smooth surface in the shortest time possible in three simple steps without requiring a polishing paste) using a spectrophotometer and AFM.

MATERIALS AND METHODS

This *in vitro* study evaluated 20 feldspathic porcelain blocks measuring 10 mm×10 mm with 1.5 mm thickness (equal to the thickness of porcelain crowns) fabricated in a laboratory using the same mold [Figure 1]. Feldspathic ceramics are suitable for use as an esthetic restoration because their translucency is similar to natural teeth.[9] The blocks were first coded. The baseline color parameters of the samples were measured using a spectrophotometer (X-RITE, Ci64, Canada), and baseline surface roughness was measured using AFM (JPK Instruments, Germany). Next, 022 slot stainless steel orthodontic brackets with 0° angulation and inclination (Victory Series, 3M/Unitek Corporation, Monrovia, CA, USA) were bonded to porcelain blocks using an etch and bond system (Reliance, Itasca, IL) according to the manufacturer's instructions. Stainless steel brackets have been used most frequently for fixed orthodontic treatment and are economically preferable for more patients.[20]

Brackets were bonded as follows

The central part of porcelain blocks was etched with 9.6% hydrofluoric acid for 2 min. After rinsing with water for 120 s and drying with air spray, bonding agent (Single Bond, 3M, USA) was applied to the center of porcelain blocks using a microbrush. A small amount of composite resin (3M ESPE, USA) was applied on the back of each bracket using a composite instrument, and the bracket was gently positioned at the center of porcelain block and compressed. Excess composite was removed by the sharp tip of an explorer, and

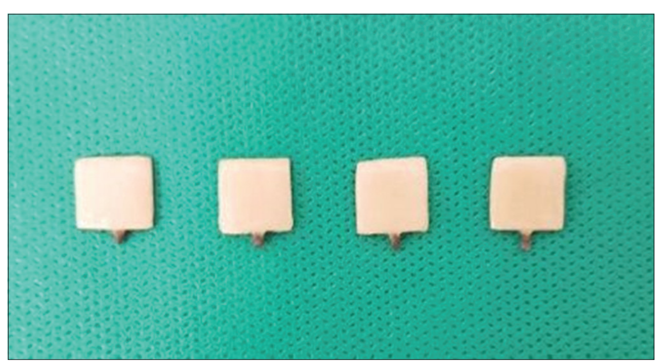

Figure 1: Porcelain samples before bonding orthodontic brackets.

light curing was performed using a light-curing unit (Unitek, 3M, USA) for 20 s.

The blocks were then immersed in water at 37°C for 24 h to allow polymerization of resin. Brackets were then debonded from the porcelain surface using a fine cutter bracket removing appliance (American Orthodontics, USA). The brackets were held from the mesial and distal and debonded using the peeling method to minimize porcelain damage. To remove resin remnants, a 30-flute tungsten carbide bur (0197, D&Z, Germany) along with a low-speed handpiece was used. Debonding was performed by an experienced operator who played no part in this study. The samples were then randomly divided into two groups (n = 10) and subjected to polishing using Sof-Lex discs (3M ESPE, St. Paul, MN, USA) in Group 1 and Meisinger polishing kit (Meisinger, Dusseldorf, Germany) in Group 2. To eliminate the confounding effect of the clinician's learning curve and his possibly better performance on final samples, the samples were polished with the two systems in an alternating fashion. After completion of finishing, the color parameters and surface roughness of the samples were measured again as described earlier.

Color change (ΔE) was calculated using the formula: $\Delta E = \sqrt{(\Delta L)^2+(\Delta a)^2+(\Delta b)^2}$

In this formula, L indicates lightness (black to white), a indicates redness/greenness, and b indicates yellowness/blueness. Increase in L parameter translates to lightening, while its reduction translates to darkening of the sample. The a parameter ranges from −70 to +90; negative values indicate greenness and positive values indicate redness. The b parameter ranges from −80 to +100. Negative values indicate blueness and positive values indicate yellowness. To assess the surface roughness, five images were obtained on the surface of each porcelain block under a microscope. Using the respective software of the microscope (JPKSPM Data processing), the Ra, Rq, and Rt parameters were determined within a square measuring 2 nm×2 nm on each image, which was randomly drawn on each image at different points. The mean of the five numbers obtained for each parameter in each porcelain block was calculated, and the mean Ra, Rq, and Rt for each porcelain block was calculated and recorded as such.

Average roughness value (Ra) was defined as the arithmetic mean of the height of peaks and depth of valleys from a mean line. The root mean square roughness (Rq) was defined as the height distribution relative to the mean line, and the maximum roughness depth (Rt) was defined as the mean peak to valley value. 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.[21]

Data were analyzed using SPSS version 18 (SPSS Inc., IL, USA) through the Shapiro–Wilk test, t-test or Mann–Whitney test, Student's t-test, and paired t-test at 0.05 level of significance.

RESULTS

Since one sample was missed after polishing, the surface roughness of nine samples was measured in the two groups. The results of color change and surface roughness separately for each parameter were as follows:

ΔE: The mean (±standard deviation) ΔE was 1.07 ± 0.35 in the Sof-Lex and 2.38 ± 1.11 in the Meisinger group. The mean ΔE in the Meisinger group was significantly higher than that in the Sof-Lex group [P < 0.001, Table 1 and Figure 2].

Average roughness value (Ra)

Table 2 shows the mean and standard deviation of Ra before and after polishing and its trend of alteration. The Sof-Lex system increased the Ra value by averagely 17.0 nm, while the Meisinger system increased the Ra value by averagely 26.6 nm compared to the baseline Ra value. This increase was significant in both the Sof-Lex (P = 0.00) and Meisinger (P = 0.019) groups, but the difference in this respect was not significant between the two groups (P = 0.387).

Root mean square roughness (Rq)

The Sof-Lex system increased the Rq parameter by averagely 18.5 nm, while the Meisinger system increased the Rq parameter by averagely 32.9 nm compared to the

Table 1: Mean, median, and SD of ΔE in the two groups of Sof-Lex and Meisinger polishing systems.

Polishing system	Mean	SD	Median	IQR	*P* value
Sof-Lex	1.07	0.35	1.21	0.42	<0.001
Meisinger	2.38	1.11	1.74	1.98	

IQR: Interquartile range, SD: Standard deviation

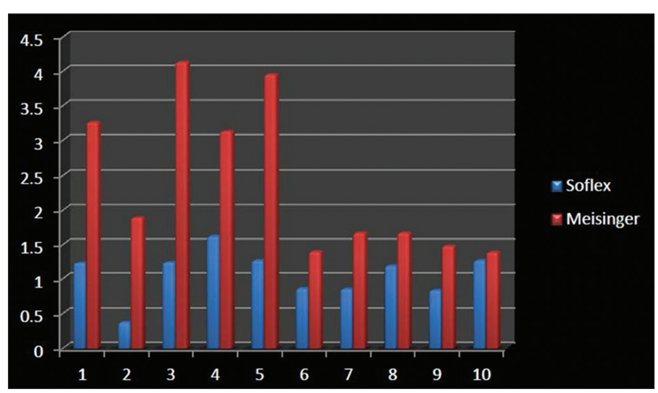

Figure 2: ΔE column changes in both polishing systems.

baseline Rq value; this increase was significant in both the Sof-Lex (P = 0.015) and Meisinger (P = 0.029) groups, but the difference between the two systems was not significant [P = 0.489, Table 3].

Maximum roughness depth (Rt)

The Sof-Lex system increased the Rt parameter by averagely 110.7 nm, while the Meisinger system increased the Rt value by averagely 178.4 nm compared to the baseline Rt value; this increase was significant in both the Sof-Lex (P = 0.006) and Meisinger (P = 0.02) groups, but the difference between the two systems was not significant [P = 0.546, Table 4].

DISCUSSION

This study assessed the color change and surface roughness of porcelain after orthodontic bracket debonding and resin remnant removal using two polishing systems. Polishing of porcelain is imperative after orthodontic bracket debonding. The efficacy of polishing systems depends on the type of polishing system and method of work. In fact, the size and amount of abrasive fillers, the geometry of the polishing system, the magnitude and direction of applied load, and the time spent for polishing are among the variables affecting the quality of polishing.[22] Since several porcelain polishing systems are available, this study compared the Sof-Lex discs and the Meisinger polishing kit.

A spectrophotometer was used for color assessment of samples in our study. Spectrophotometer is among the most accurate and most efficient tools for color measurement and assessment of color match in dentistry.[23] It presents data in CIE LAB system. The sensitivity and reproducibility of this system for colorimetry have been previously confirmed.[23,24]

The current study assessed all three color parameters in Mansell's system. The L parameter increased after polishing with both the Sof-Lex and Meisinger systems, which indicated a shift toward lightening. However, these changes were not significant in the Meisinger system. The b parameter shifted toward positive after polishing with the Sof-Lex system, which indicated yellowness of samples. However, the Meisinger system caused a negative shift indicative of blueness of samples. These changes were not significant in the Meisinger system. The change in a parameter was negative following polishing with the Sof-Lex discs, which indicated a shift in porcelain color toward green. These changes were positive and toward redness in the Meisinger system. However, the changes were not significant in any of the two groups.

Table 2: Mean and SD of Ra before and after polishing and its trend of alteration in the Sof-Lex and Meisinger groups.

Polishing system	Before bracket bonding	After polishing	Alterations	*P* value
	Mean±SD	Mean±SD	Mean±SD	
Sof-Lex	33.2±5.5	50.2±4.2	17±3.9	0.002
Meisinger	31.1±5.2	57.7±8.6	26.6±9.1	0.019
P value	0.789	0.441	0.387	-

SD: Standard deviation

Table 3: Mean and SD of Rq before and after polishing and its alteration in the two groups.

Polishing system	Before bracket bonding	After polishing	Alterations	*P* value
	Mean±SD	Mean±SD	Mean±SD	
Sof-Lex	46.4±8.6	64.8±6.1	18.5±6.0	0.015
Meisinger	43.0±8.0	75.9±12.0	32.9±12.4	0.029
P value	0.775	0.863	0.489	-

SD: Standard deviation

Table 4: Mean and SD of Rt before and after polishing and its alteration in the two groups.

Polishing system	Before bracket bonding	After polishing	Alterations	*P* value
	Mean±SD	Mean±SD	Mean±SD	
Sof-Lex	211.8±33.6	322.5±37.3	110.7±30.3	0.006
Meisinger	194.2±29.8	372.6±59.0	178.4±61.7	0.020
P value	0.700	0.796	0.546	-

SD: Standard deviation

Eventually, ΔE of the two groups was compared. The ΔE was greater in the Meisinger system than the Sof-Lex system, which indicated that the difference between the baseline and final color in the Sof-Lex system was smaller than that in the Meisinger system. The color of samples polished with the Sof-Lex system was closer to the baseline color. ΔE >1 means that the color change is detectable by 50% of individuals. Since ΔE <3.7 is the same in different environments, such a color change may not be detected in uncontrolled clinical conditions. In our study, ΔE ≥2 was not seen in any sample in the Sof-Lex group, while ΔE <1 was not seen in any sample in the Meisinger group and values >3.7 were also reported (which were clinically significant). These values indicated that polishing with Sof-Lex discs yielded a superior color match compared to the Meisinger system.

Studies on color and shine of porcelain after debonding are limited. However, a number of studies have evaluated porcelain surface roughness after bracket debonding and polishing. The majority of these studies used tools such as a profilometer and a scanning electron microscope for this purpose.[18,19] In this study, AFM was used for the assessment of surface roughness. This microscope has advantages such as taking 2D and 3D images simultaneously and not requiring staining of samples. One major advantage of this microscope compared to a profilometer and a scanning electron microscope is that it enables quantitative calculation of surface roughness, does not damage the samples during inspection, and has high accuracy for the measurement of surface roughness.[14] Moreover, in the present study, the Rt and Rq values were measured in addition to Ra. Many previous studies only measured the Ra parameter as an indicator of surface roughness; however, calculation of Ra alone has limitations.[5,25] However, despite higher accuracy of results when calculating all three surface roughness parameters, these data should be interpreted with caution because the stylus used for the measurement of surface roughness parameters has several features.[26]

The current results showed that both polishing systems significantly increased the surface roughness compared to baseline, but the difference between the two systems was not significant in this respect.

In contrast to the current study, Sarac *et al.* evaluated the changes in surface properties using a profilometer and a scanning electron microscope and assessed the porcelain color using a colorimeter following the application of three polishing systems, namely a polishing paste (Ultra II), polishing stick (Diamond Stick), a polishing wheel (CeraMaster), and an adjustment kit (Porcelain Adjustment Kit, Meisinger). They concluded that polishing by the porcelain adjustment kit after the application of polishing paste can create a surface as smooth as a glazed surface. They also discussed that porcelain color change was within the acceptable range after polishing with all three polishing systems.[18] Their results regarding the Meisinger system were not in agreement with our findings. Factors such as the quality of porcelain samples, clinician expertise and hand pressure, type of polishing system used, various methods of measuring color and surface roughness changes and type of bonding agent are responsible for the controversy of results.

Shetty *et al.* evaluated 40 samples of feldspathic porcelain and observed that the Shofu Ceramaster system had the highest efficacy for the elimination of surface roughness compared to Kohinoor diamond polishing paste and Sof-Lex discs, while the Sof-Lex discs had the lowest efficacy. The difference between their results and ours can be attributed to the use of profilometer for the assessment of surface roughness in their study. Profilometer has a lower accuracy than AFM for the measurement of surface roughness and qualitatively evaluates the surface roughness.[19]

Jarvis *et al.*, in Greece, evaluated the surface roughness, color, and glaze of two porcelain systems (low-fusing and high-fusing) after orthodontic bracket debonding. In their *in vitro* interventional study, they used two carbide bur polishing systems with/without Sof-Lex discs on 40 porcelain samples. They evaluated the samples using a profilometer and gloss meter and found that the color and gloss of porcelain significantly changed following resin removal, irrespective of the type of polishing system used. No significant difference was noted in color, glaze, or surface roughness of the two porcelain models after bracket debonding.[10] The polishing systems could not reverse the created surface roughness. In the current study, surface roughness was still higher than the baseline value after polishing with the Sof-Lex discs and the porcelain color changed as well. Similarly, Anmol *et al.* stated that Sof-Lex polishing system was more successful than the white silicon and gray rubber in polishing of feldspathic and fluorapatite leucite porcelains.[27]

CONCLUSION

Considering the current results regarding the color parameters, application of Sof-Lex discs is recommended for porcelain polishing after bracket debonding because they yield a smaller ΔE compared to the use of the Meisinger system. Furthermore, since no significant difference existed regarding surface roughness between the Meisinger and Sof-Lex discs, it seems that using the conventional Sof-Lex discs is more cost-effective than the Meisinger system.

Declaration of patient consent

Patient's consent not required as there are no patients in the study.

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Conflicts of interest

There are no conflicts of interest.

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