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Article

Evaluation of the effects of Different Polishing Protocols on the Surface Characterizations of 3D-printed Acrylic Denture Base Resins

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Abstract: A chairside polishing kit is an alternative to a laboratory polishing technique. This study aimed to evaluate the effects of different polishing techniques on the surface roughness of three-dimensional (3D)-printed acrylic denture bases (ADB). One hundred twenty disc-shaped specimens were fabricated from one conventional heat-polymerized (HP) ADB resin and two 3D-printed (Asiga (AS) and NextDent (ND)) ADB resins (n=40 per ADB resin). Each group was furtherly divided based on the polishing protocol (n=10) as follows: convectional polishing protocol (C), Microdont chairside polishing kit (M), Shofu chairside polishing kit (S), and unpolished group (U). The surface roughness (surface roughness average (Ra) and average maximum profile height (Rz)) of the printed specimens were measured using an optical profilometer, and the scanning electron microscope (SEM) was used to capture the surface at ×1000. Two-way ANOVA and post hoc tests were used for data analysis ($\alpha = 0.05$) at significant levels. In unpolished groups, there was a statically significant difference between HP vs 3D-printed ADBs ($p < 0.0001$). For Ra values, the lowest values were presented in HP-C, AS-S, and ND-C. While the highest values were shown in all unpolished groups. Within the material, there were statistically significant differences between the three polishing protocols (C, M, and S) vs unpolished ($p < 0.0001$), while there was no significant between C, M, and S groups ($p = 0.05$). The Rz values had the same pattern as the Ra values. The two chairside polishing kits were comparable to conventional polishing technique, and it could be recommended for the clinical application.

Keywords: Additive manufacturing; Chairside kit; SEM; Surface roughness; and Rapid prototype.

1. Introduction

Poly-methyl methacrylate (PMMA), a type of acrylic resin, has been widely applied in prosthodontics and orthodontics fields for the fabrication of various types of dental prostheses [1–4]. The use of PMMA acrylic denture base (ADB) is enormous due to biocompatibility, ease of fabrication, pleasant esthetics, lighter weight, and relatively low cost [5–8]. Despite these advantages, PMMA has limitations such as porosity, poor surface properties, discoloration over time, and possible hypersensitivity reaction [9,10]. Some of these deficiencies can be managed by proper polishing of the ADB, however, if ignored, they can cause serious denture-related conditions such as denture stomatitis and trauma to the underlying tissues [11–13]. Other, like porosity and allergic reaction, can be overcome by Computer-aided design–Computer-aided manufacture (CAD-CAM) technology for denture base fabrication [14].

A dental prosthesis can be prepared using CAD-CAM via two methods: subtractive manufacturing, where a milling device cuts PMMA blocks, and additive manufacturing, where acrylic resin is 3D printed [15,16]. In the literature, studies have reported comparable surface roughness values of milled PMMA ADB to heat-polymerized (HP) ADB [17,18]. However, several studies have shown that 3D printed ADB displays similar or

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higher surface roughness values compared to HP ADB [19–24]. This can be attributed to the material composition and printing parameters [19].

In daily clinical scenarios, the ADB of the removable appliance is susceptible to corrective grinding and trimming, which will result in creating a rougher surface [3,25]. For that, it is recommended to polish the adjusted part with pumice slurry followed by the use of aluminum oxide (Al_2O_3) polishing paste in a laboratory setting [3,25,26]. Efforts were conducted to develop several chairside polishing kits for the immediate use after the clinical adjustments of ADB and occlusal or orthodontic appliances. It was reported that laboratory polishing produced the smoothest surface, and the clinical application of chairside polishing techniques can be a convenient and useful alternative procedure [27].

The impact of various chairside polishing kits on the surface characterization of heat-processed, auto-polymerized, injection-molded, microwave-cured, and CAD-CAM-milled ADBs was evaluated previously [3,27–29]. However, there is a lack of studies investigated the effect of chairside polishing protocols on the surface roughness average (Ra) and average maximum profile height (Rz) of 3D printed resins. Therefore, the objective of this in vitro study was to analyze the effect of using different chairside polishing protocols on the surface roughness of 3D-printed ABDs. The null hypothesis was the use of different polishing protocols will produce similar surface roughness values.

2. Materials and Methods

One hundred and twenty disc-shaped specimens (forty samples from each type of ADB material) with 10 × 2.5 mm dimensions were allocated to twelve subgroups (four subgroups per acrylic resin). The sample size was determined as 10 specimens per group (n = 10) by using the power analysis in which the averages and standard deviations (SD) were acquired from previously published related studies and the power was set as 90% with a 0.05 level of significance [3,30]. The study flowchart, including groupings and polishing protocols, is presented in Figure 1.

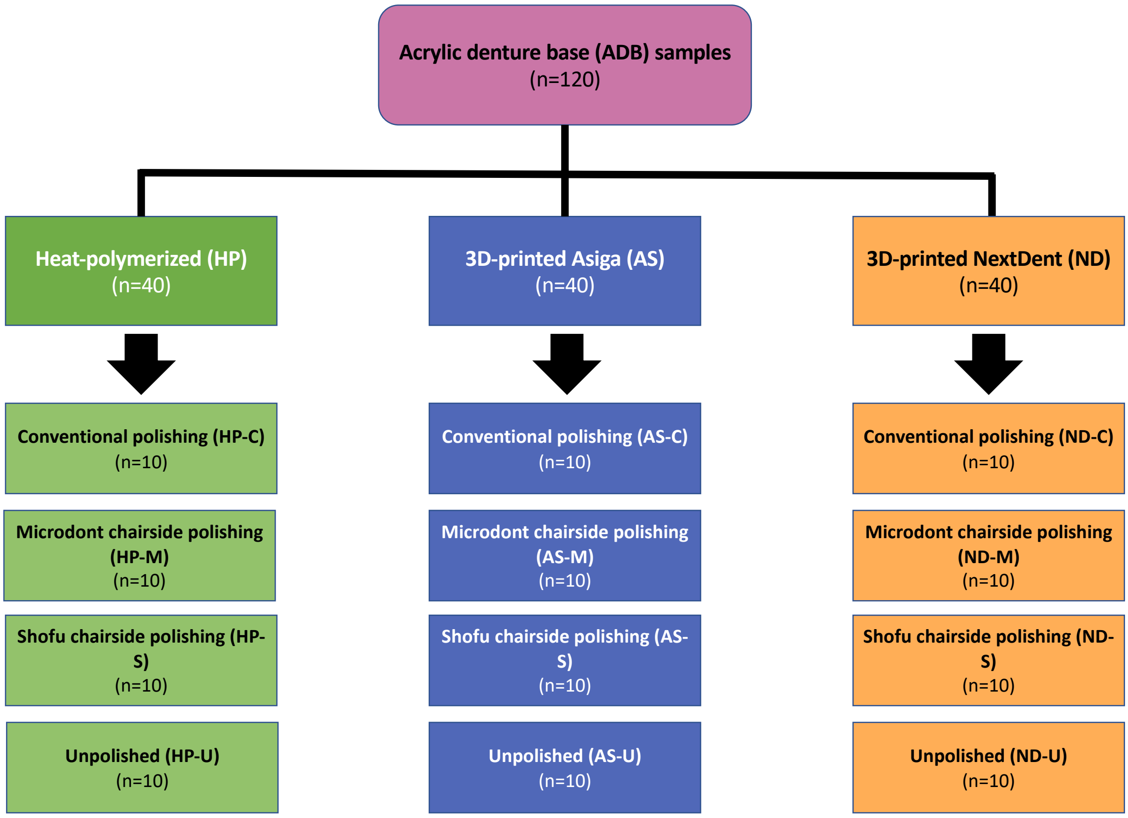

Figure 1. Study flowchart, including specimen distribution over the three different ADB materials and four polishing protocols. n=sample size.

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2.1. Materials Selection and Specimens Preparation

Two experimental ADB resins that were 3D-printed and one control HP ADB resin were chosen for this study. For all groups, disc-shaped specimens were planned using CAD software (123D design, Autodesk, version 2.2.14, San Rafael, CA). Afterward, the virtual designs were saved as standard tessellation language (STL) files and transferred into 3D printing systems (ASIGA and NextDent printers). The material composition, printing parameters, and fabrication methods are presented in detail in Table 1.

Table 1. Material composition, fabrication methods and printing parameters.

Material	Major (HP)	Asiga (AS)	NextDent (ND)
Brand name	Major Base.20, Major Prodotti Dentari Spa, Momcalieri, Italy)	ASIGA DentaBASE (ASIGA, Erfurt, Germany)	NextDent Base; Denture 3D+, 3D systems, Vertex Dental B.V., Soesterberg, Netherland
Composition	Powder: Methyl methacrylate polymers, Benzoyl peroxide Liquid: MMA, ethylene glycol, dimethacrylate, N,N-dimehyle-p-toluidine, benzophenone-3	N/A	Ethoxylated bisphenol A dimethacrylate, 7,7,9(or 7,9,9)-trimethyl-4,13-dioxo- 3,14-dioxa-5,12- diazahexadecane-1,16-diyl bismethacrylate, 2-hydroxyethyl methacrylate, Silicon dioxide, diphenyl(2,4,6- trimethylbenzoyl)phosphine oxide, and titanium oxide
Fabrication methods	Heat polymerization using castable 3D-printed resin patterns replacing the baseplate wax. The castable 3D-printed resin patterns were removed before PMMA packing.	3D-printed using denture base resin	3D-printed using denture base resin
Printer	NextDent 5100, 3D systems, Vertex Dental B.V., Soesterberg, Netherland	ASIGA MAXTM	NextDent 5100, 3D systems, Vertex Dental B.V., Soesterberg, Netherland
Printing technology and parameters	N/A	LED-based Digital Light Processing (DLP) Layer thickness: 50µm Printing orientation: 45 degrees	Stereolithography (SLA) Layer thickness: 50µm Printing orientation: 45 degrees
Post printing procedures	N/A	120 minutes in Asiga Flash (ASIGA, Erfurt, Germany)	120 min in LC-D Print Box (3D systems, Vertex Dental B.V., Soesterberg, Netherland)

Before printing, the resin container was homogenized using LC-3D, and then the exported STL file was transferred to ASIGA MAXTM and NextDent 5100 printers and the specimens were printed according to manufacturer's recommendations (Table 1) [16,19]. After printing, an Isopropyl alcohol (99.9%) was used to clean and remove uncured materials from the printed specimens followed by post-curing process. Following, the printing support structures, and access materials were removed from the specimens by using tungsten carbide bur (AcryPoint No. 0620 bur, Shofu Dental Corp, San Marcos, CA) and low-speed rotary instruments.

Regarding HP group specimens' preparation, a castable 3D-printed resin (NextDent Cast) was used to replace the wax pattern made from baseplate wax that commonly used in heat-cured polymerization to standardize specimens' dimensions. Briefly, the same virtual design was transferred to NextDent 5100 printer to fabricate the specimen patterns using castable resin, and the printed disc-shape patterns were invested in dental plaster and dental stone using the conventional flasking procedure (Figure 2A). After 2 hours, the printed patterns were removed from the flask and acrylic resin base material (Major Base) was inserted into the negative molds and then processed following the manufacturer's instructions (Figure 2B).

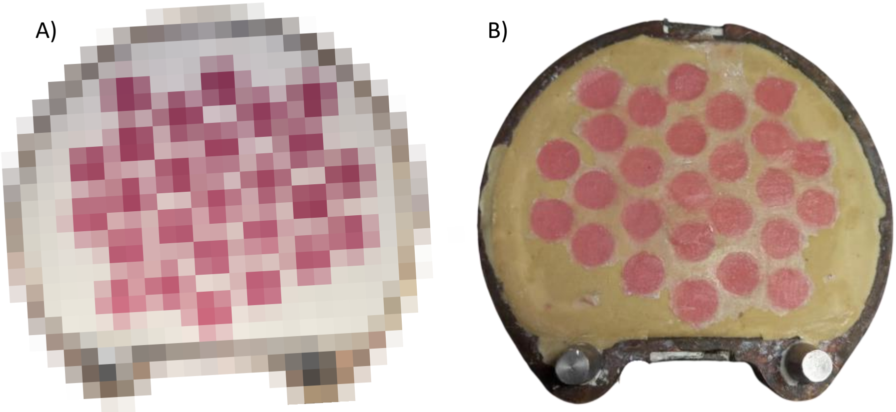

Figure 2. (A-B) Photo of the heat-polymerization process. **(A)** 3D-printed castable resin placed in the dental plaster during flasking. **(B)** HP specimens after heat processing immediately after Deflasking.

Prior to the polishing procedures, the specimens underwent finishing via a series of sandpapers (1,000 and 2,500 grit), followed by the use of tungsten carbide bur on low-speed rotary instruments. Then, all specimens were examined, rinsed, and kept in 37◦C distilled water as described previously [19].

2.2. Polishing Protocols

Three polishing groups per each ADB material were tested in this study, one conventional polishing group (control), two groups using chairside polishing techniques (Microdont and Shofu), and the fourth group left with only finishing (unpolished) to stimulate the clinical adjustment procedure (Figure 1). A summary of the polishing protocols and materials and is catalogued in Table 2.

Table 2. Groupings and polishing protocols used for acrylic denture base materials.

Group name	Polishing system	Manufacturer	Composition	Protocol	Recommended speed (rpm)
Conventional (C)	Pumice slurry	Steribim Super, BEGO GmbH & Co KG; Bremen, Germany	N/A	I. Polished with the pumice slurry brush attached to a grading motors machine for 90 sec	1,500
	Universal Polishing Paste	Ivoclar Vivadent AG; Schaan; Liechtenstein	Aluminum oxide (Al_2O_3) particles in paste	II. Polishing with the paste and lathe bristle brush for 15 sec	3,000
Microdont (M)	Microdont chairside acrylic polishing kit	Microdont, São Paulo, Brazil	Bonded abrasives in silicone matrix	I. Trimming with coarse polisher (green) (No. 10232.004) for 1 min II. Finishing with standard polisher (blue) (No. 10232.005) for 1 min	5000-10,000

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				III. Polishing with fine polisher (red) (No. 10232.006) for 1 min	
Shofu (S)	AcryPoint chairside acrylic polishing kit	Shofu Dental Corp, San Marcos, CA	Bonded abrasives in silicone matrix	I. Trimming with dark grey coarse grit polisher (No. 0426) for 1 min II. Finishing with brown medium grit polisher (No. 0427) for 1 min III. Polishing with light grey fine grit polisher (No. 0428) for 1 min	5000-10,000
Unpolished (U)	Finishing only	Shofu Dental Corp, Menlo Park, CA	N/A	Tungsten carbide cutter (No. 0620) for 15 seconds to simulate a clinical adjustment	10,000-15,000

For the conventional polishing groups, the specimens were polished with the pumice slurry (Steribim Super, BEGO GmbH & Co KG; Bremen, Germany) on a brush (Abraso-Soft Acryl, bredent GmbH & Co. KG, Senden, Germany) attached to a grading motors machine (Wassermann WP-Ex 3000, Dental-Maschinen GmbH. Rudorffweg, Hamburg, Germany) followed by using polishing paste (Universal Polishing Paste, Ivoclar Vivadent AG; Schaan; Liechtenstein) with a lathe bristle brush. For the second set of groups, a Microdont chairside acrylic polishing kit (Microdont, São Paulo, Brazil) was used. The kit consists of three polishing burs (coarse, standard, and fine polisher). For all third groups, an AcryPoint chairside acrylic polishing kit was selected, in which three different girts (coarse, medium, and fine) were used. The last groups left as-as unpolished to stimulate the clinical adjustment.

To standardize the direction and orientation of polishing, the polishing burs were attached to a fixed laboratory motor (Cutty Rapida, Manfredi, Turin, Italy), and the denture base resin material sample was secured into a dental stone mold (Figure 3). In addition, all the polishing procedures were conducted by one operator to control the applied weight.

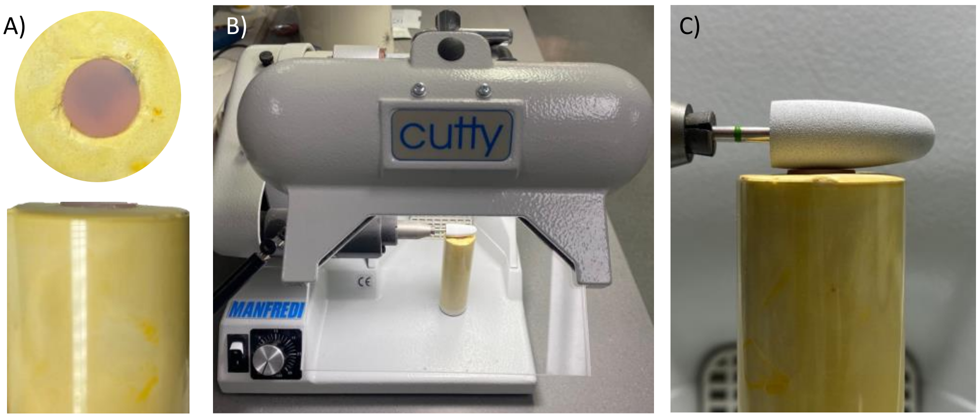

Figure 3. (A–C) Visualization of the polishing process of the ADB specimens. **(A)** Dental stone mold with secured sample in place, **(B)** Laboratory motor machine, **(C)** Orientation of the polishing bur to the mounted sample.

2.3. Surface Roughness and Scanning Electron Microscope (SEM) evaluations

A non-contact optical profilometer (Contour Gt-K1 optical profiler; Bruker Nano, Inc., Tucson, AZ) was utilized to assess the surface roughness values (Ra and Rz) of all specimens. The evaluation involved mounting each specimen on an automated x-y stage

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and scanning three random scanning points using the previously prescribed method [31]. Afterwards, the capture images underwent analysis to derive the Ra and Rz values per specimen, and the results were expressed in µm [22].

Prior to SEM evaluation, a single random specimen was selected from each group and was coated with gold using an ion sputter coater (G20, GSEM, Suwon, Korea). The SEM analysis was conducted using a CUBE-II tabletop machine (EmCrafts Co., Gwangju-si, Korea) at an accelerating voltage of 10 kV with a secondary electron detector. The micrographs of the HP, AS, ND, and ADB groups were captured and analyzed under different magnifications (x100, ×250, ×500, and ×1000) to assess the surface characteristics of the ADB materials. A representative micrograph from all groups was demonstrated at a magnification of ×1000.

2.4. Statistical Analysis

Statistical analyzes were performed. All data are presented as the means ± SD (n = 10). Data normality and distribution were checked using the Shapiro-Wilk test. Two-way analysis of variance (ANOVA) and post hoc Tukey tests were used to analyze the data using Sigma Plot 12.0 software (Systat Software Inc. (SSI), San Jose, CA). The statistical significance was set at 5%.

3. Results

Figures 4 and 5 show the color parameter representing the average Ra and Rz values, ranging from red (at the top) to blue (at the bottom), with intermediate colors in between. The red areas represent the peaks, while the blue areas reveal the depth of the valleys. Therefore, the arranged color bar displays the overall smoothness of a surface [32].

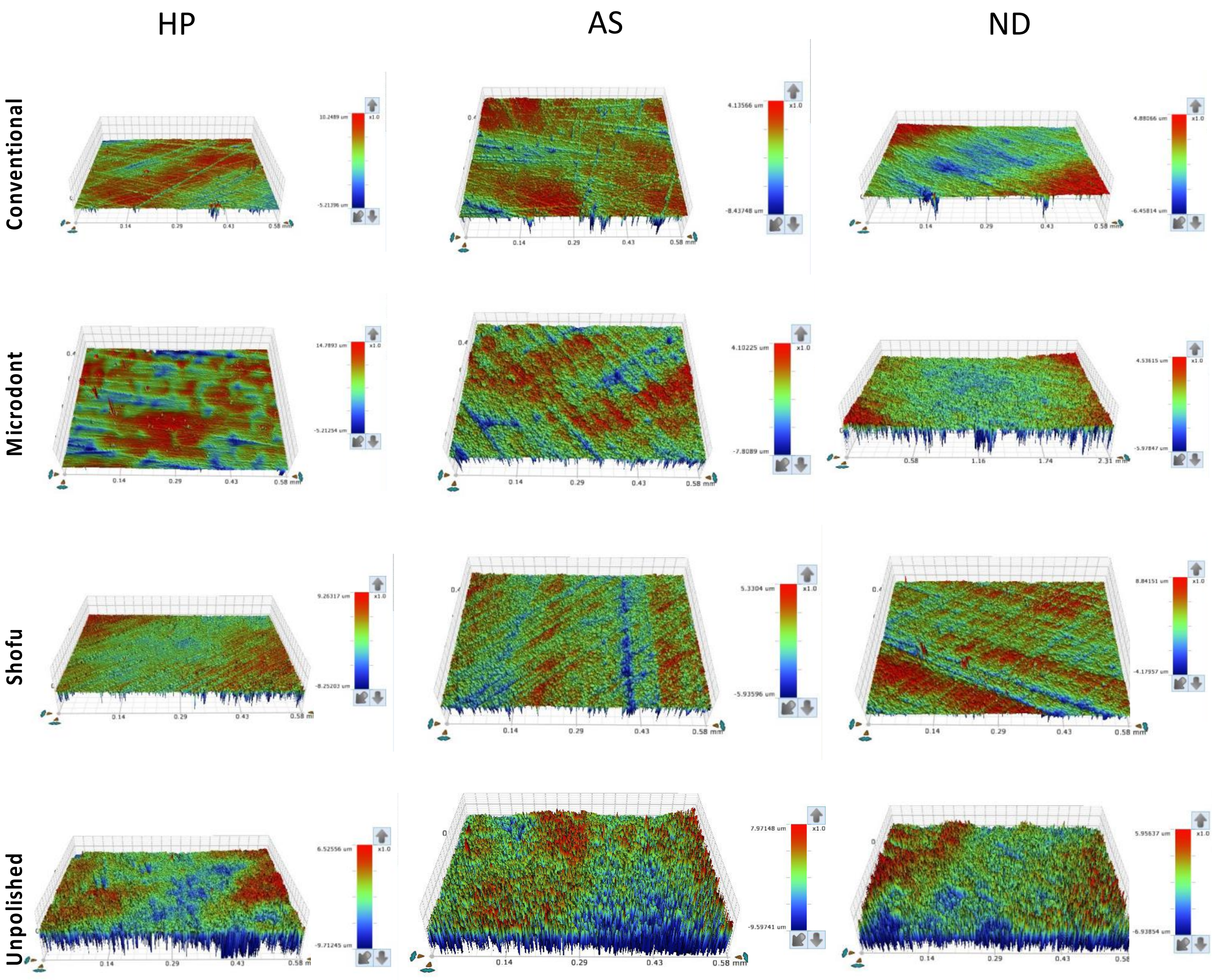

Figure 4. Representative of the scanned specimens for average surface roughness (Ra) of tested groups. HP: heat-polymerized ADBs, AS: Asiga 3D-printed ADBs, and ND: NextDent 3D-printed ADBs.

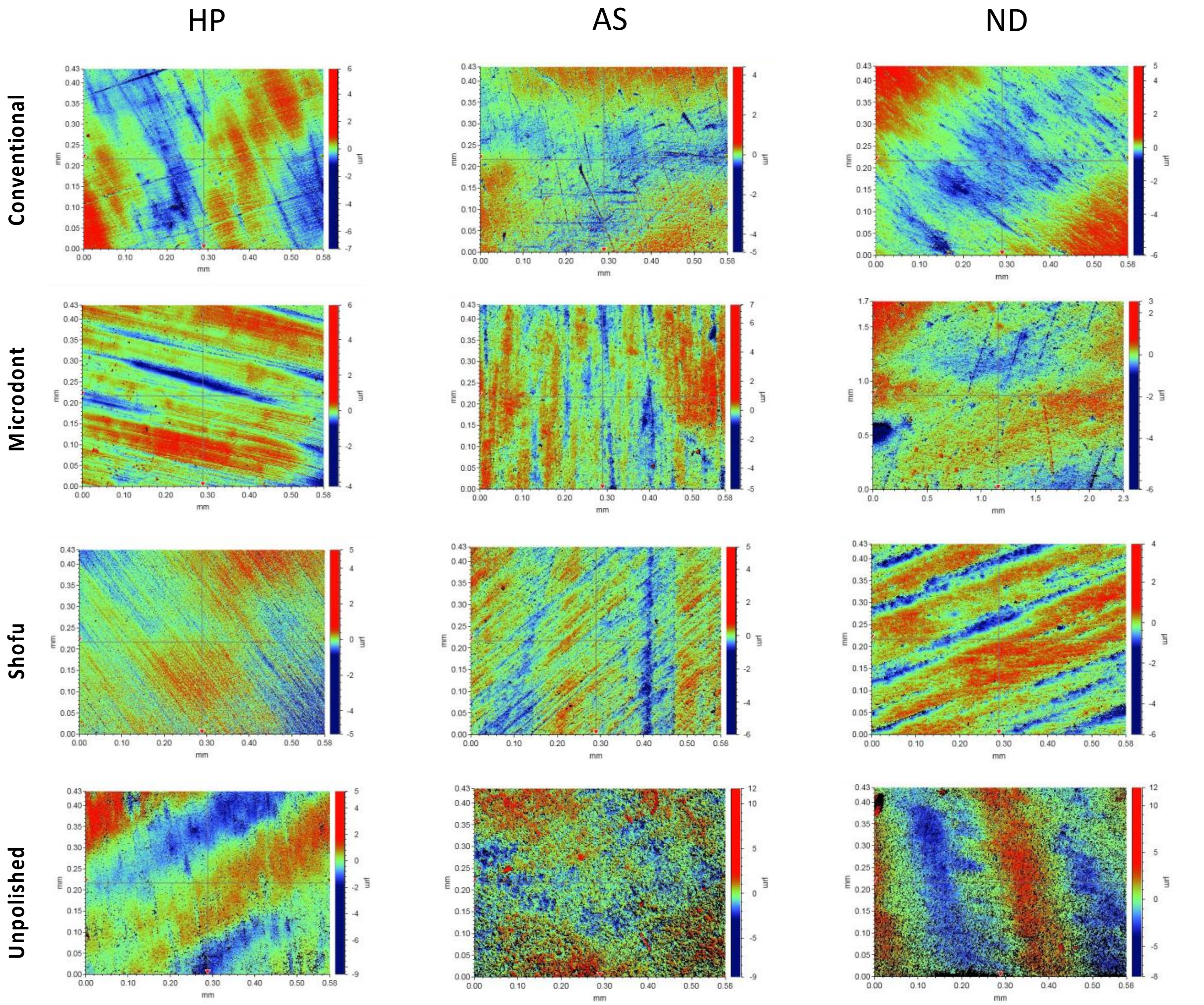

Figure 5. Representative of the scanned samples for average maximum profile height (Rz) of tested groups. HP: heat-polymerized ADBs, AS: Asiga 3D-printed ADBs, and ND: NextDent 3D-printed ADBs.

Figure 6 displays the mean and SD of the Ra values for all examined groups. Results from statistical analysis indicate that both the polishing protocol and ADB materials have a significant impact on Ra values (as shown in Table 3). For HP ADB groups, the conventional polishing technique produced the lowest Ra value, followed by the Shofu and Microdont chairside polishing kits. In contrast, the unpolishing group produced the highest Ra value. A two-way ANOVA confirmed that there was a statistically significant difference between the HP-U and three other polishing groups (HP-C, HP-M, and HP-S) ($p < 0.0001$). Similarly, the AS ADB groups showed that the lowest Ra value was achieved using the Shofu chairside polishing kit, followed by the conventional polishing technique and Microdont chairside polishing kit, respectively. Again, like the HP groups, the AS-U group had the highest Ra value. Furthermore, the two-way ANOVA demonstrated a statistically significant difference between the HP-U and three other polishing groups (HP-C, HP-M, HP-S) ($p < 0.0001$). For ND ABD groups, the Ra values of the three polishing protocols were comparable to the HP groups (ND-C < ND-S < ND-M < ND-U). The two-way ANOVA also showed a statistically significant difference between the ND-U group and all other ND groups ($p < 0.0001$). Finally, comparing the different ADB materials revealed that the HP-U group had a statistically significantly lower Ra value compared to both the AS-U and ND-U groups ($p < 0.0001$).

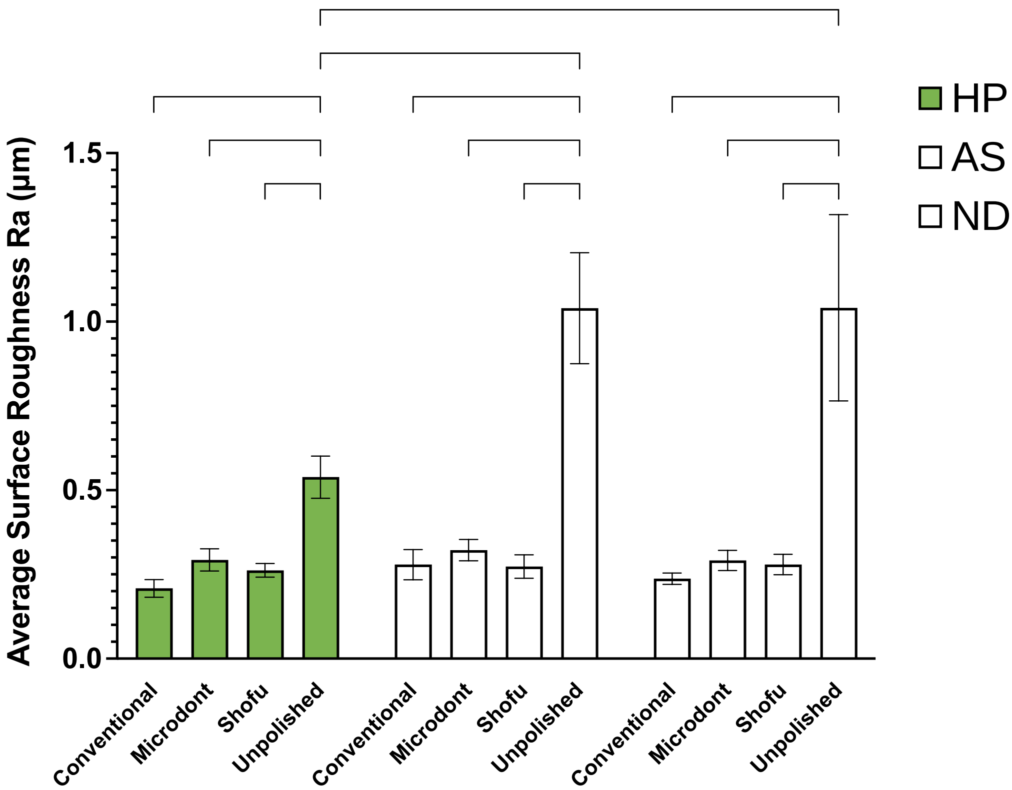

Figure 6. Mean ± SD, and significance of the average surface roughness values (Ra _ µm) for the tested groups (level of significance: ****: $p < 0.0001$).

Table 3. Two-way ANOVA for the effect of resin material and polishing protocol on the average surface roughness (Ra) of each ADB.

Source of Variation	Type III Sum of Squares	*df*	Mean Square	*F*-Value	*p*-Value
Resin material	0.565	2	0.283	29.25	<0.001
Polishing protocol	8.194	3	2.731	282.622	<0.001
Resin material * Polishing protocol	1.146	6	0.191	19.762	<0.001
Error	1.044	108	0.00966		
Total	10.949	119	0.092		

* Statistically significant at 0.05 level of significance.

Figure 7 and Table 4 summarize the mean, SD, and the two-way ANOVA statistical analysis of Rz values. Among the HP groups, the lowest Rz value was observed in the HP-C group, followed by HP-M and HP-S group, while HP-U group showed the greatest Rz value. A two-way ANOVA demonstrated statistically significant differences between HP-U and HP-C group ($p < 0.0001$), and slight significant differences between HP-U and HP-M and HP-S groups ($p < 0.01$). Among AS groups, the lowest Rz values were observed in the AS-S group, followed by AS-C and AS-M groups, while the highest value was observed in the AS-U group. Furthermore, the two-way ANOVA showed statistically significant differences between AS-U and all other AS groups (AS-C, AS-M, and AS-S) ($p < 0.0001$). Regarding Rz values of the ND groups, the lowest value was observed in the ND-C group, followed by the ND-M and ND-S groups. Similar to HP and AS, the highest value was observed in the ND-U group with a statistically significant difference ($p < 0.0001$). Finally, when comparing the 3D-printed ADB materials (AS and ND groups) to HP groups, the two-way ANOVA demonstrated significant differences between HP-U Vs AS-U ($p < 0.001$) and HP-U Vs ND-U ($p < 0.0001$).

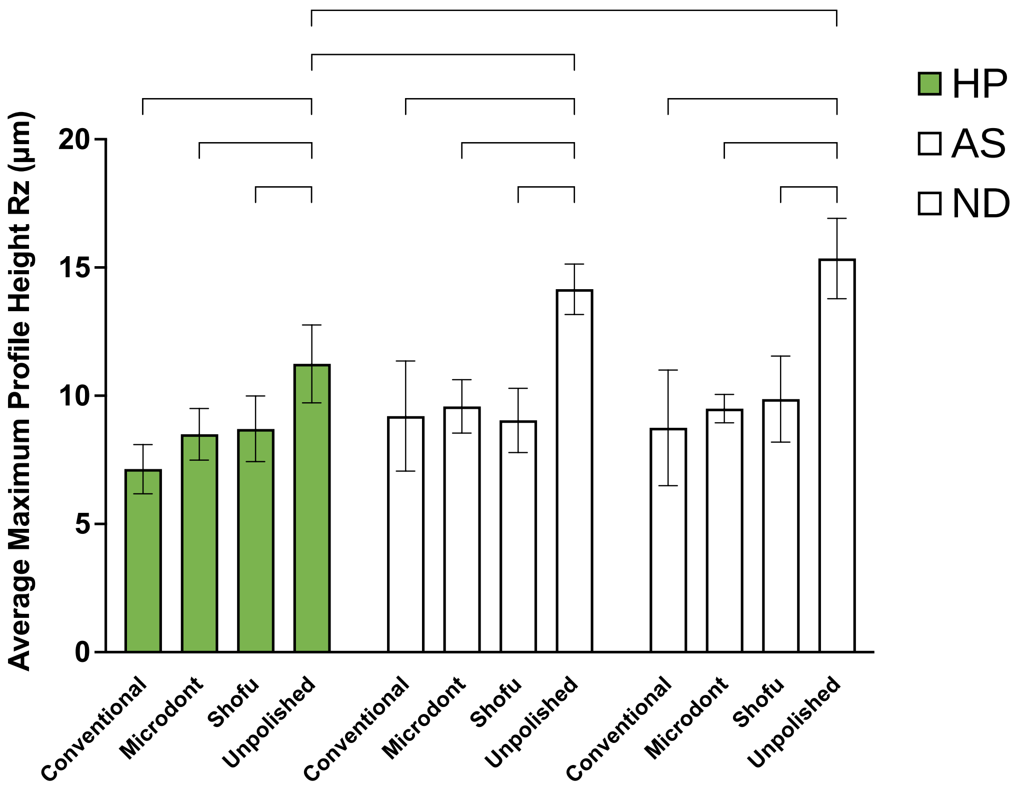

Figure 7. Mean ± SD, and significance of the average maximum profile height values (Rz _ µm) for the tested groups (level of significance: **: $p < 0.01$, ***: $p < 0.001$, ****: $p < 0.0001$).

Table 4. Two-way ANOVA for the effect of resin material and polishing protocol on the average maximum profile height (Rz) of each ADB.

Source of Variation	Type III Sum of Squares	*df*	Mean Square	*F*-Value	*p*-Value
Resin material	2	87.743	43.872	21.245	<0.001
Polishing protocol	3	503.25	167.75	81.233	<0.001
Resin material * Polishing protocol	6	39.699	6.617	3.204	0.006
Error	108	223.025	2.065		
Total	119	853.717	7.174		

* Statistically significant at 0.05 level of significance.

Figure 8 show the representative SEM images of one randomly selected specimen of each group at ×1000 magnification. Unpolished specimens showed obvious irregular and rougher surfaces with faint striations in HP while multiple grooves and depressions are found with ND and AS. The striations in the HP specimens can be attributed to the use of a tungsten carbide bur during the clinical adjustment stimulation. The specimens of 3D-printed resin revealed replicated oblique ridges, which are characteristic of the layer-wise printing method. Furthermore, the surface topography of the polished specimens has been altered, showing different surface features with smooth backgrounds. However, some faint striations with different orientations were observed, which represent the direction of the abrasive particle during polishing protocols.

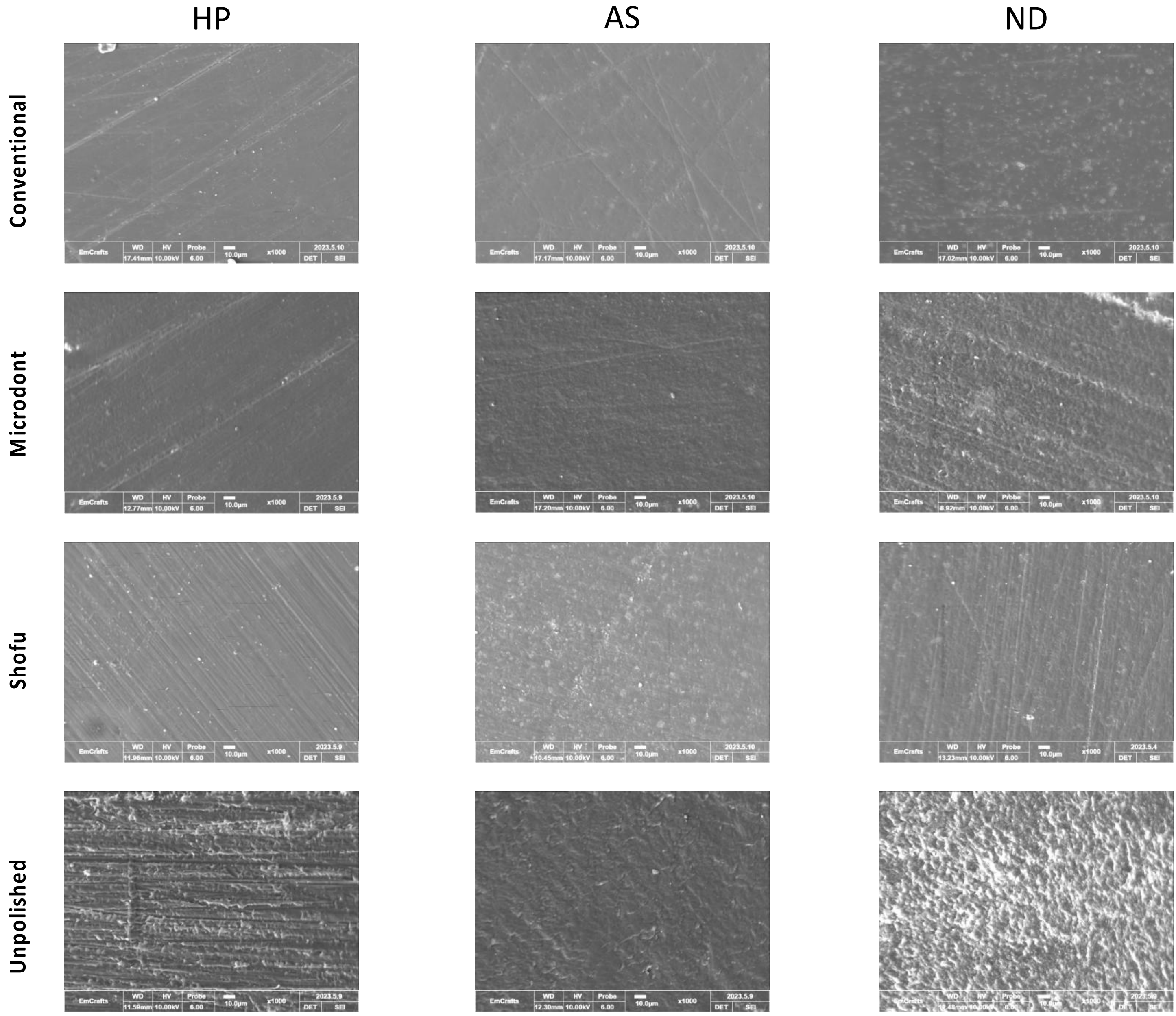

Figure 8. Scanning Electron Microscope (SEM) at ×1000 magnification of the 3 ADB specimens that were subjected to different polishing protocols.

4. Discussion

The longevity of a removable prosthesis depends on the surface roughness of the ADB. A rougher surface can cause plaque accumulation, discoloration, material degradation, and increase patient dissatisfaction [10,22,30,33,34]. Therefore, this research was conducted to investigate the effects of different polishing protocols on the surface characterization of 3D-printed ADB. Based on the results, the null hypothesis was accepted. The presented results showed that the conventional polishing technique and chairside polishing kits produced comparable surface roughness (Ra and Rz) values regardless of the ADB material. In addition, the unpolished 3D-printed ADB (AS-U and ND-U) showed

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statistically significant higher Ra and Rz values compared to unpolished heat-polymerized ADB (HP-U).

Shim et al. compared the surface roughness of unpolished 3D-printed ADB using three different orientations (0°, 45°, and 90°) [33]. The Ra results of this work (AS-U 1.04 ± 0.17 µm and ND 1.04 ± 0.28 µm) were comparable to their results (1.09 ± 0.07 µm). Furthermore, all polished groups showed significantly lower values. In another study that evaluated the surface roughness of 3D-printed ADB with the same printing parameters [19], the Ra surface values after polishing with different grits of sandpapers were 0.98 ± 0.13 µm for AS and 0.83 ± 0.13 µm for ND. Comparing their results, the Ra values of all polishing protocols (C, M, S) in this study were significantly lower.

To the author best knowledge, only one investigation has been published in the literature that evaluated the effects of using JOTA® denture polishing kit (Jota AG, Rüthi, Switzerland) on the surface roughness of 3D-printed ADB [35]. However, only one chairside polishing get was used in that study [35]. Other studies have been conducted on heat-pressed, auto-polymerized, injection-cured, and CAD-CAM-milled ADBs [3,14,27,29,30]. Their results were in agreement with the present results, showing that the lowest Ra value is associated with conventional laboratory polishing, and that chairside polishing techniques produced comparable results to the conventional procedure.

The surface roughness of heat-cured ADB can be influenced by several factors, including the powder/liquid ratio, proper handling and mixing, and the dental stone texture. In this study, the wax patterns that were commonly used to produce the heat-polymerized (HP) specimens were replaced by 3D-printed castable resin (Figure 2A). While the surface microtexture of printable resin is different than baseplate wax, the results of this study showed that it did not affect the Ra values after polishing. This confirms that the higher roughness values of unpolished 3D-printed ADB (AS-U and ND-U) can be attributed to the nature of the resin and the mechanism of fabrication. Due to the printing nature (layer-by-layer object building), the layering affects the surface properties at the layer interface, forming edge stepwise effects. These edge stepwise effects are considered the main reason for the increase in surface roughness when compared to conventional ADB [22].

The results of Ra values of all polished groups demonstrated relatively lower SD. This can be attributed to two main factors, first: all the polishing procedures were conducted by the same operator, and second: a fixed laboratory motor was utilized during the polishing to control the direction and orientation of polishing burs. However, there was limited control of pressure that was applied on the specimen by the polishing bur. This can be managed by the fabrication of a locked mount that allows control of the pressure.

Ra and Rz are two commonly utilized parameters for determining the surface roughness of dental materials [36]. The Ra value represents the average distance and deviation from the mean line between peaks and valleys across the entire surface using an algorithmic measurement within a single sampling length [36,37]. Conversely, Rz is estimated by averaging the vertical space between the highest peak and the lowest valley over five different sampling lengths [36,37]. It is of great important to evaluate and report both values hence there is a strong correlation between surface roughness and microbial adhesion [10,38–41]. Moreover, rougher surface can be produced from two possible causes; 1) the increase in surface area of the irregularities, which can be evaluated by Ra value, and 2) the depth of these variabilities that can be evaluated by measuring the Rz value.

Only one study investigated the Rz value of a 3D-printed ADB, in which coating, plashing, and both surface treatment were evaluated [14]. Also, limited numbers of studies reported the Rz values of the conventional and CAD-CAM-milled ADB materials [42–44]. Sampaio-Fernandes et al evaluated the Rz values of conventionally polished injectable-cured PMMA and compared them to polypropylene and polyolefin [42]. Their results showed a significantly lower Rz value (0.34 ± 0.049) in compassion to the HP-C group (7.14 ± 0.96). This was in agreement with another study by Eghtedari et al [44].

One way to improve the properties of the resin is to cross-link the polymer chains, which prevents them from sliding against each other [45]. The HP polymer used in the present study contains ethylene glycol dimethacrylate (EGDMA) as a cross-linking agent, while the UV-light activated 3D-printed resin has substance components, such as bisphenol A-glycidyl dimethacrylate (Bis-GMA) or urethane dimethacrylate (UDMA) [46]. Thus, the uncured residual monomer (RM) requires additional post-curing treatment to form the full-structure cross-linking, resulting in improving the properties by achieving ultimate polymerization [47–49] Additionally, HP ADB is fabricated using compression molding, which has a high polymerization rate and minimal residual monomer. The present study utilized photo-polymerized resins, which are generally linked with a low degree of conversion and a high level of RM [22,50]. The amount of RM might affect the abrasion resistance of printed specimens, as reported in previous studies due to the inherent material composition and the process of printing layers [51].

Among the factors affecting the surface properties of 3D-printed resin is the printing technology [52]. In the present study, two technologies were implemented: stereolithography (SLA) as in ND fabrication and digital light processing (DLP) as in AS specimens. However, no significant difference in Ra and Rz values was found between the two materials after polishing. The author expected that the composition may affect the surface properties of 3D-printed resins, but based on this study, the polishing protocols have the same effect regardless of material type and printing technology. Therefore, further investigations with different printing parameters and different polishing protocols are required.

The topography (Ra and SEM representative images) of specimens confirmed the findings of unpolished and polished specimens, as there were dramatic changes from rough surfaces for all materials to slightly smooth after polishing. Even with insignificant changes in surface features of polished specimens according to polishing protocol, the surface roughness was reduced significantly.

One of the possible limitations of this study is the use of a single printing orientation, specifically 45°. Studies have shown that the surface roughness of 3D-printed resin can be affected by different printing orientations [19,33]. Another limitation is the absence of clinical environment stimulations. Dietary solutions, biofilm complexity, and changing the pH and temperature of the oral cavity can alter the surface properties of the 3D-printed resin. Additionally, the disc-shaped specimens used in this study do not resemble the actual form of ADB. This could affect the results of the study, as the surface properties of 3D-printed resin may be different depending on the geometry of the specimen.

Although the in vitro study [53,54] established a clinically acceptable value for Ra at 0.2 µm, only the conventional polishing technique with pumice of HP ADB specimens produced values that met this standard. Further investigation is required to assess the nature of biofilm accumulation on the 3D-printed ADB and those that were polished with chairside polishing kits. One possible future direction is to evaluate the effect of using these polishing protocols on several different printing parameters, including printing orientation and thickness, post-curing time and conditions, and different printable resins. Another future direction of this study is the evaluation of wettability, contact angle, and water adsorption of 3D-printed ADBs after being polished by a chairside polishing kit. It has been reported that the hydrophobicity of the ADB surface can lead to microbial adhesion [41]. In addition, future studies should take into the consideration the biological and mechanical impacts on the longevity and durability of ADB.

5. Conclusions

It can be concluded that the conventional polishing protocols produced the smoothest surfaces in heat-cured and 3D-printed ABD materials. Within the ADB materials, there were no significant differences between both chairside polishing kits compared to the conventional polishing technique. In addition, the unpolished groups of the two 3D-printed ADBs (Asiga and NextDent) have higher Ra and Rz values compared to heat-polymerized

ADB. Moreover, the use of chairside polishing kits in the clinical seating can be an efficient and effective technique when access to the dental laboratory is limited.

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Abbreviations

Abbreviations	**Description**
3D	Three-dimensional
ADA	American Dental Association
ADB	Acrylic Denture Base
ANOVA	Analysis of Variance
AS	ASIGA 3D-printed resin
Bis-GMA	Bisphenol A-Glycidyl Dimethacrylate
C	Conventional polishing protocol
CAD-CAM	Computer-Aided Design and Computer-Aided Manufacturing
DLP	Digital Light Processing
EGDMA	Ethylene Glycol Dimethacrylate
HP	Heat-polymerized
M	Microdont chairside polishing kit
ND	NextDent 3D-printed resin
PMMA	Poly-methyl Methacrylate
Ra	Surface roughness average
RM	Residual Monomer
Rz	Average maximum profile height
S	Shofu chairside polishing kit
SD	Standard Deviations
SEM	Scanning Electron Microscope
SLA	Stereolithography
STL	Standard Tessellation Language
U	Unpolished
UDMA	Urethane Dimethacrylate

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