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Surface Roughness of Enamel and Dentin after Preparation Finishing with Rotary Burs or Piezoelectric Instruments

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Abstract: This study compares the effect of different handpieces (turbine, high-speed electric handpiece and piezoelectric device) on surface roughness of enamel and dentin when using diamond-coated working tips and burs of the same grit size. The experiment was conducted on 15 extracted first molars from patients aged 45 to 60 years. The occlusal portion was removed using a diamond-coated water wheel and then refined with a 120–130 µm grit bur in order to obtain a flat surface with an adequate exposition of the dentin core. Each surface was divided into three portions and every portion was finished with one of the three tested instruments. The rotary burs and piezoelectric tips had the same grit size (60 µm), and the load on handpiece during preparation never exceeded 150 g. Roughness parameters (Ra, Rsk, Rku) were recorded with a profilometer, and a SEM analysis of treated surfaces and working tips was conducted. Ra and Rsk differed significantly between enamel and dentin only after using turbine ($p = 0.004$ and $p = 0.007$, respectively). No significant differences were observed in Ra, Rsk and Rku between enamel and dentin when using a high-speed electric handpiece or piezoelectric device. The turbine produced higher Ra and Rsk values on dentin than the other devices, while no significant differences were found between piezoelectric handpiece and high-speed electric contra-angle on both substrates. Summarizing, the findings of the present study demonstrated that turbine generated rougher surfaces on dentin compared to the other handpieces. Moreover, the turbine produced more asymmetrical surface profiles on both enamel and dentin. However, it should be considered that these differences in roughness (Ra) were within the range of 0.25–0.30 µm: it is still unclear if these variations, although statistically significant, will influence final clinical outcomes.

Keywords: finishing line; prosthetic preparation; piezosurgery; surface profilometer

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1. Introduction

When planning dental-supported prosthesis, several steps are involved to ensure a successful outcome. Among them, an accurate and precise preparation of the prosthetic margin or finishing line, which is the interface between the prepared tooth and the dental prosthesis, is crucial to ensure longevity and satisfactory aesthetic results to the final restoration [1,2]. The finishing line can be positioned either supragingival or subgingival, depending on various factors such as aesthetics, accessibility and periodontal condition. The margin should be well-defined, properly finished and polished, to facilitate impression taking and manufacturing of a fixed prosthesis with a seamless transition between the natural tooth and the prosthetic material [2,3]. A precise margin, exhibiting a smooth and continuous contour, is crucial to ensure accurate adaptation and seating of the prosthesis, minimizing gaps or discrepancies that could compromise restoration integrity [3]. Diamond or carbide finishing burs, diamond stones of descending grit and rubber points mounted on rotary handpieces, such as turbines and high-speed electric handpieces, are commonly used to finalize the preparation margin [4].

The introduction in dentistry of ultrasonic-driven devices specifically designed for osseous surgery opened broader possibilities in the treatment of hard tissues, including tooth structure [5]. Piezoelectric devices for bone surgery have a wide range of applications in various fields of oral and maxillofacial surgery, such as impacted teeth removal, maxillary sinus floor elevation, ridge splitting, implant site preparation, crown lengthening and orthodontic corticotomies [6–11]. The active tip of piezoelectric handpieces, vibrating at ultrasonic frequencies (typically in the range of 25–30 kHz), allows for precise and controlled action on mineralized tissues while sparing surrounding soft tissue [12]. This selectivity is due to the difference in physical properties and vibrational characteristics between hard and soft tissues. Hard tissues have a higher density and stiffness, and ultrasonic vibrations produce linear elastic micro-fractures [13]. The ultrasonic blade sets up stress conditions in the hard tissues such that cracks propagate ahead in a controlled mode. Soft tissues are more flexible and may vibrate without rupture at the same frequency as the tip of the instrument. Nevertheless, damage may occur when soft tissue is tightly entrapped or bound to the bone and, subsequently, cannot freely vibrate [14]. This selective cutting capability may also be useful in prosthodontics during finishing of subgingival prosthetic margins, diminishing the risk of damaging adjacent soft tissue and possibly enhancing the gingival response to the preparation procedures [15].

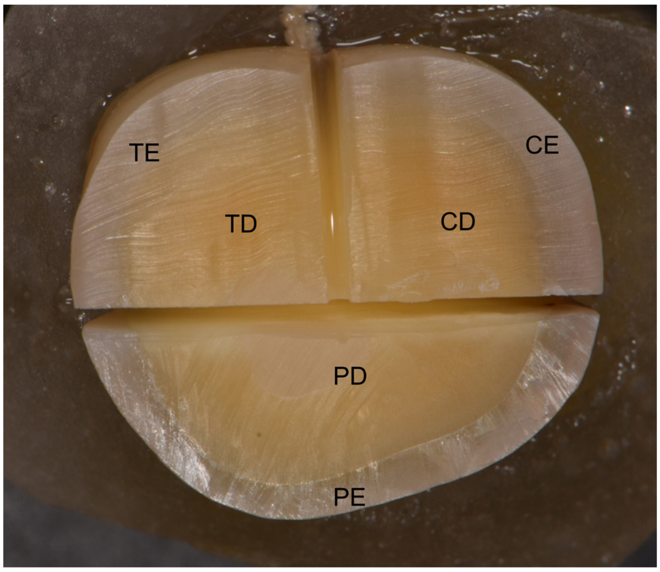
Previous studies comparing rotary and ultrasonic instruments in this specific application are present in the literature, with the aim to determine which approach produced the smoothest surface [16–20]. However, grit standardization was not performed in these investigations, where various handpieces (turbine, ultrasonic and high-speed electric handpiece) were compared in terms of surface roughness but using active tips with different granulometry in the different handpieces. Use of burs and ultrasonic inserts with different granulometry may significantly influence surface roughness [21], making it difficult to discern the real impact of the tip movement (rotation vs. vibration) on the final roughness of the samples.

Hence, the aim of the present study is to compare the influence of the type of movement generated by different handpieces (turbine, high-speed electric handpiece and piezoelectric device) on surface roughness of enamel and dentin when using diamond-coated working tips of the same granulometry. The null hypothesis is that no differences in surface roughness are present in enamel and dentin after treatment with rotary (turbine and high-speed electric handpiece) or piezoelectric handpieces using active tips with the same grit (60 μm).

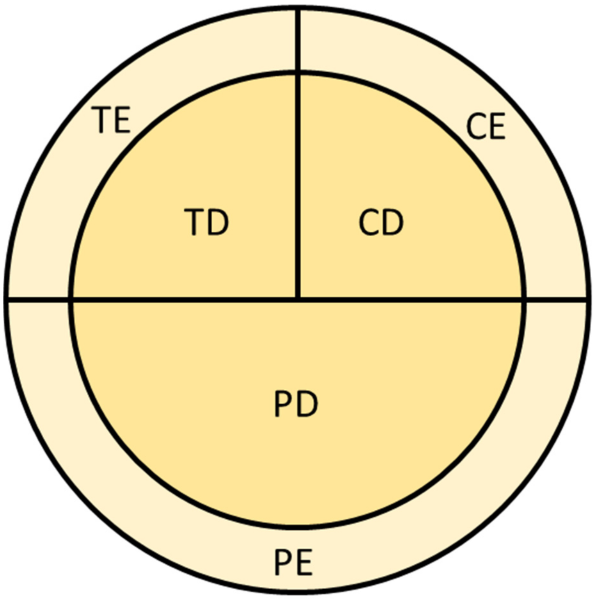
2. Materials and Methods

2.1. Sample Preparation

The present in vitro study was conducted on human maxillary first molars without tooth decay, fillings or other reconstructions, extracted for periodontal reasons from 45 to 60 year old patients and stored in saline solution at room temperature. The use of extracted teeth for the present study was authorized by the Ethical Committee of Friuli Venezia Giulia (C.E.U.R. Friuli-Venezia Giulia, Italy no. 194/2019). Before beginning the experimental phase, the samples were rinsed with fresh saline solution and incorporated in a gypsum matrix. The occlusal portion was removed using a diamond-coated water wheel and then refined with a 120–130 μm grit bur (405LC, Intensiv, Collina d'Oro, Switzerland) in order to obtain a flat and homogeneous surface with adequate exposure of the dentin core, avoiding pulp involvement. Each tooth surface was then divided into three portions and every portion was finished with one of the three tested instruments under abundant irrigation: turbine (Synea Vision TK98L, W&H, Bürmoos, Austria), high-speed electric handpiece (Synea Vision WK99LT, W&H, Bürmoos, Austria) and piezoelectric handpiece (Piezosurgery Touch, Mectron, Carasco, Italy) (Figure 1a,b). The piezoelectric unit was set at "Perio" power. A diamond-coated bur (FG862M/016C, Sweden & Martina, Padova, Italy) and a diamond-coated tip (TF12D60, Mectron, Carasco, Italy) were used with the different devices by the same experienced operator (CS) with 4× magnification loupes (Figure 2). Tooth preparation was conducted with the samples placed on a compression load cell to verify that load applied to the handpieces never exceeded 150 g [22,23]. The working part of rotary burs and piezoelectric tips presented the same granulometry (60 µm). The instruments were changed every five sample preparations, as suggested in the literature [24]. Burs and tips were used with the longitudinal axis parallel to the occlusal surface and moved with homogenous and monodirectional movement for 30 s.



(**a**)



(**b**)

Figure 1. (**a**) The occlusal portion was removed using a diamond-coated water wheel and then refined with a 120–130 µm grit bur to obtain a flat and homogeneous surface with adequate exposure of the dentin core; (**b**) Tooth surface was then divided into three portions and every portion was finished with one of the three tested instruments (CE: high-speed contra-angle on enamel; PE: piezoelectric handpiece on enamel; TE: turbine on enamel; CD: high-speed contra-angle on dentin; PE: piezoelectric handpiece on dentin; TD: turbine on dentin).

Figure 2. Diamond-coated rotary bur (**left**) and piezoelectric tip (**right**) tested in the present study (both with 60 µm grit).

2.2. Roughness Analysis

The quantitative analysis of the surface roughness of the different surfaces was carried out using a surface profilometer (Talysurf CLI 1000, Taylor Hobson, Leicester, UK) operating in a linear mode. Before proceeding with the analysis, samples were observed under an optical microscope to carry out the measurements perpendicularly to the main orientation of the grooves. Equal portions of enamel and dentin were analyzed for each sample:

5 linear profiles (length: 3 mm each) were obtained for each sample using an inductive transducer with 494 μm vertical range and 8.4 nm of resolution with an acquisition speed set at 50 μm/s. From the raw linear profiles, the following 2D roughness parameters were analyzed by means of TalyMap Expert software (Taylor Hobson, Leicester, UK), average roughness (Ra), skewness (Rsk) and kurtosis (Rku), in order to evaluate the symmetry of the profile relative to the midline (Rsk) and the sharpness of peaks and valleys (Rku).

2.3. Scanning Electron Microscope (SEM) Analysis

Qualitative analysis was performed by scanning electron microscope SEM (Quanta 250, FEI, Hillsboro, OR, USA) operating in environmental conditions. Surface details of the different dental samples, burs and ultrasonic inserts were acquired before and after use at different magnification (200×–800× for tooth samples and 30×–100× for burs and inserts).

2.4. Statistical Analysis

A statistical software (Primer of Biostatistics 6.0, Mc Graw-Hill, New York, NY, USA) was used to calculate the sample size of the present in vitro investigation, basing on Ra values after using rotary and ultrasonic instruments (0.75 μm ultrasonic; 1.63 μm rotary) recorded in a previous pilot study [16]. A sample of 11 specimens for each group was required to detect significant differences between the three groups (confidence level 5% with statistical power of 80%).

Statistical analysis was performed with SPSS v.24 software (IBM, Armonk, NY, USA). Data distribution was analyzed with Shapiro–Wilk test. Due to non-normal distribution, non-parametric tests were performed. Kruskal–Wallis test was used to compare roughness produced by the different handpieces within the same substrate and Mann–Whitney test was used for one-to-one comparison between the different handpieces according to the different substrates. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Roughness Analysis

Fifteen maxillary first molars were treated and analyzed in the present study. Ra and Rsk were significantly different between enamel and dentin only after the use of turbine ($p = 0.004$ and $p = 0.007$, respectively). No significant differences for all roughness parameters (Ra, Rsk and Rku) were demonstrated between enamel and dentin when using high-speed electric handpiece or piezoelectric device. Complete results are reported in Table 1.

Table 1. Two-dimensional roughness parameters on enamel and dentin with different handpieces.

Handpiece	Roughness	Enamel Median (IQR)	Dentin Median (IQR)	*p* Value
C	Ra (μm)	1.05 (0.34)	1.08 (0.40)	0.982
	Rsk	−0.26 (0.40)	−0.30 (0.49)	0.902
	Rku	3.40 (1.18)	3.69 (1.46)	0.967
T	Ra (μm)	1.06 (0.40)	1.30 (0.55)	0.004 *
	Rsk	−0.08 (0.63)	0.10 (0.46)	0.007 *
	Rku	3.42 (1.61)	3.29 (1.39)	0.999
P	Ra (μm)	1.1 (0.25)	1.04 (0.34)	0.296
	Rsk	−0.33 (0.54)	−0.28 (0.53)	0.642
	Rku	3.32 (0.96)	3.69 (1.50)	0.096

C: high-speed contra-angle; T: turbine; P: piezoelectric handpiece; *: statistically significant.

In detail, Ra measured on enamel showed no significant differences between the three devices (turbine-piezoelectric handpiece $p = 0.562$; turbine-high-speed electric handpiece $p = 0.738$; piezoelectric handpiece high-speed electric handpiece $p = 0.806$) (Figure 3).

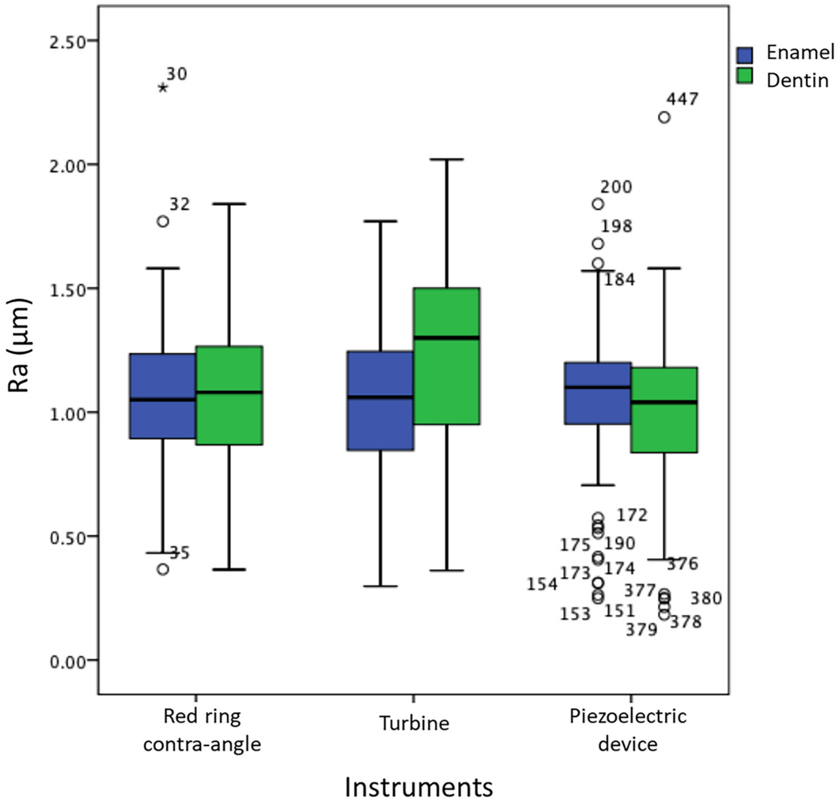


Figure 3. Boxplot illustrating the distribution of Ra values recorded after preparation of enamel and dentin with high-speed electric contra-angle, turbine and piezoelectric device. *: outlier.

Turbine used on dentin produced a significantly higher Ra both when compared to piezoelectric handpiece ($p = 0.001$) and when compared to high-speed electric handpiece ($p = 0.012$). No significant Ra differences were demonstrated on dentin between high-speed electric handpiece and piezoelectric handpiece ($p = 0.411$).

Rsk resulted significantly higher on enamel when using the turbine in comparison with the high-speed electric handpiece ($p = 0.048$) or the piezoelectric handpiece ($p = 0.005$). Rsk was significantly higher also on dentin when using the turbine in comparison with both other handpieces ($p = 0.000$), whilst no significant differences were recorded on both substrates when comparing piezoelectric handpiece and high-speed electric handpiece (enamel: $p = 0.410$; dentin: $p = 0.813$). All the comparisons made for Rku parameter in both substrates did not show significant differences between the various handpieces. Complete results are listed in Table 2.

Table 2. Inter-group comparisons of roughness parameters on enamel and dentin with different handpieces.

Roughness	Group	*p* Value Enamel	*p* Value Dentin
Ra	T vs. C	0.738	0.012 *
	T vs. P	0.562	0.001 *
	C vs. P	0.806	0.411

Table 2. *Cont.*

Roughness	Group	*p* Value Enamel	*p* Value Dentin
Rsk	T vs. C	0.048 *	0.000 *
	T vs. P	0.005 *	0.000 *
	C vs. P	0.410	0.813
Rku	T vs. C	0.840	0.968
	T vs. P	0.790	0.942
	C vs. P	0.967	0.525

C: high-speed contra-angle; T: turbine; P: piezoelectric handpiece; *: statistically significant.

3.2. SEM Analysis

Surface qualitative analysis showed a clear parallel trend of the micro-grooves in the samples treated with turbine and high-speed electric handpiece; this characteristic is less evident in the samples prepared with piezoelectric handpiece (Figure 4). Piezoelectric tips appeared more worn than burs after the preparation of five samples. Burs used with high-speed electric handpiece appeared more consumed than burs used with the turbine (Figures 5 and 6).

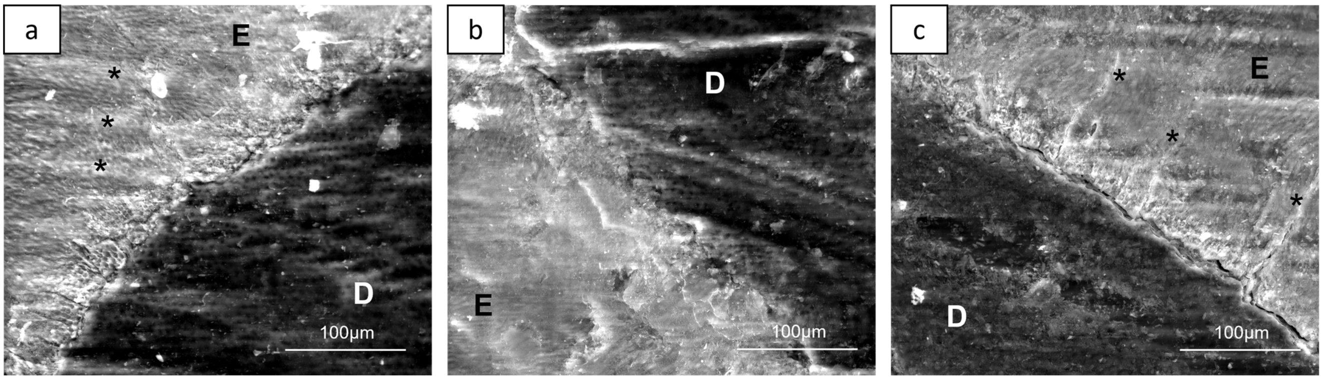


Figure 4. SEM images of samples treated with (**a**) turbine; (**b**) piezoelectric handpiece; (**c**) high-speed contra-angle. E: enamel; D: dentin; *: microgrooves.

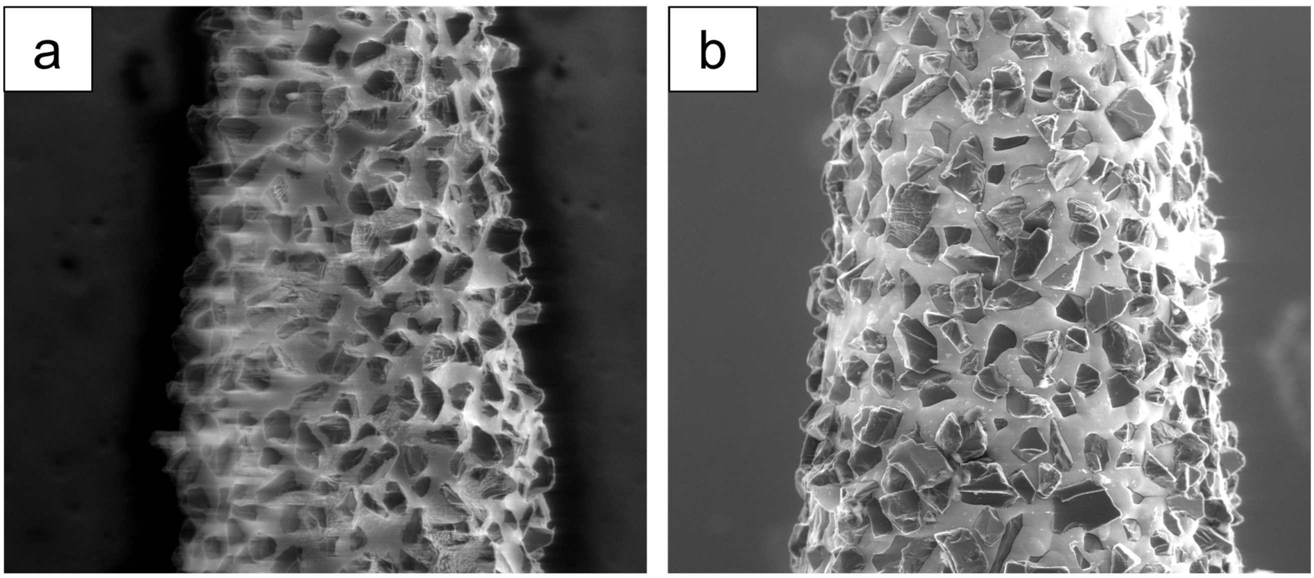


Figure 5. SEM images of 60 µm grit rotary bur (**a**) and piezoelectric tip (**b**) before use.

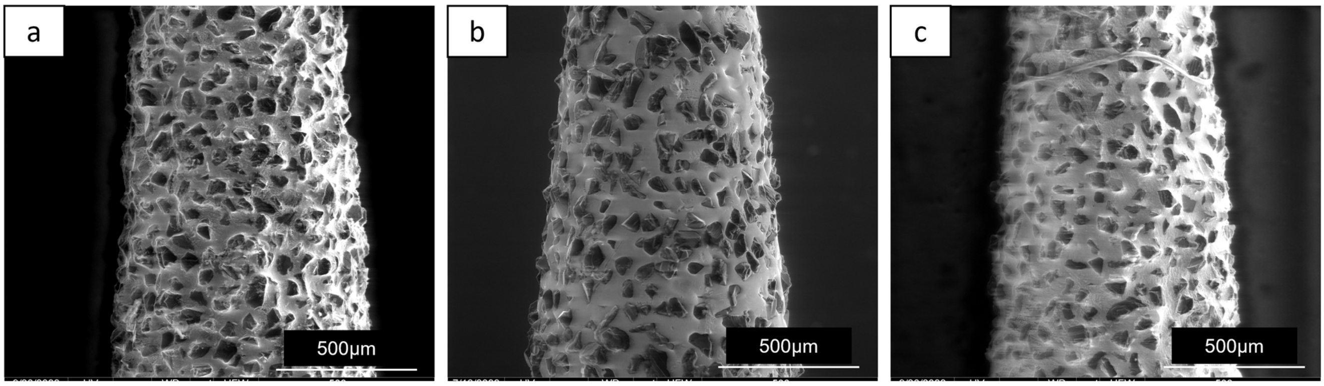


Figure 6. SEM images of burs and tip after the preparation of five samples. (**a**) turbine; (**b**) piezoelectric handpiece; (**c**) high-speed contra-angle.

4. Discussion

A precise and smooth finishing line of tooth preparation facilitates the entire prosthetic workflow, from impression taking to the manufacturing of a restoration with a precise marginal fit, which could contribute to a long-term satisfactory esthetic and functional results [1–4]. The present study aimed to investigate the surface roughness produced by different dental handpieces (turbine, high-speed electric contra-angle and piezoelectric handpiece) on enamel and dentin substrates when using diamond-coated working tips of the same grit size (60 µm). The analysis of surface roughness parameters, including average roughness (Ra), skewness (Rsk) and kurtosis (Rku), along with qualitative analysis using scanning electron microscopy (SEM), provided insights into the performance and wear characteristics of the tested instruments.

In terms of surface roughness, the present results revealed variations between different handpieces and substrates. When analyzing enamel surface, no significant differences in Ra were observed among the three devices. However, turbine generated significantly higher Ra values on dentin if compared to both piezoelectric handpiece and high-speed electric handpiece. This finding is in accordance with a previous study demonstrating that rotary cutting instruments used with electric handpieces produced the smoothest surface, whereas the same instruments used with a turbine or sonic instruments achieved similar surface roughness [25]. The differences in surface roughness between the sonic instruments investigated in this latter study and the piezoelectric device tested here may be explained by reduced amplitude (20–60 µm) and higher frequency (25–30 kHz) of ultrasonic vibrations in comparison with sonic oscillations [26].

The skewness parameter (Rsk) reflects the symmetry of the surface profile relative to the midline. In the present study, Rsk values were significantly higher on enamel and dentin surfaces when using the turbine compared to high-speed electric handpiece and piezoelectric handpiece. This suggests that the turbine handpiece may produce more asymmetrical surface profiles with pronounced peaks and valleys on both substrates. Conversely, the three investigated handpieces used on both substrates did not show significant differences for the kurtosis parameter (Rku), measuring the sharpness of peaks and valleys on the surface.

Hence, the null hypothesis of the present study can be only partially rejected: turbine generated rougher surfaces on dentin compared to the other two handpieces, but the effect of the three devices on enamel is comparable. Moreover, the turbine produced more asymmetrical surface profiles on both enamel and dentin than high-speed electric handpiece and piezoelectric device. However, it should be considered that these differences in roughness (Ra) are within the range of 0.25–0.30 µm: it is still unclear if these variations, although statistically significant, will affect final clinical outcomes.

SEM analysis indicated that piezoelectric inserts, after the preparation of five samples, showed greater wear in comparison with burs. Moreover, the bur used with the high-speed electric handpiece exhibited more wear than the bur used with the turbine. These findings suggest that the use of piezoelectric device and high-speed electric handpiece may result in higher working tip wear compared to the turbine handpiece. This aspect, together with the initial investment for the device which can be higher due to the advanced technology involved, should be also considered by the operator in a cost/benefit analysis when selecting the most appropriate tool in the clinical practice.

The present in vitro study presents some limitations as it did not consider some relevant factors influencing the operative choices in the clinical practice, such as the ease of control of the different handpieces or the risk of injury to marginal gingiva during margin finishing. The high-speed electric handpiece works at high rotational speeds (200,000 rpm) and is associated with a constant high torque. These high-torque values provide the clinician with greater tactile feedback in comparison with turbine, allowing for more controlled operative action [27,28]. On their part, piezoelectric devices exploit micrometric vibrations of the working tip and the absence of rotatory movements to enhance intra-operative control in comparison with rotary instruments [29,30]. Furthermore, the selective cut on hard tissues of piezoelectric instruments may reduce the risk of gingival lesions when refining the preparation margin in comparison with rotary instruments [5,31]. All these factors, together with the outcomes investigated in the present study, should be carefully considered and balanced by the clinician when choosing the most appropriate tool to finalize tooth preparation.

It should be also underlined that surface roughness assessment was not carried out before the finishing procedure. Even if samples preparation followed standardized steps using specific instruments, this factor constitutes a limitation of the study.

Moreover, the surface profilometer used in the present investigation can only perform bi-dimensional evaluations of surface roughness (Ra, Rsk and Rku). Further research on this topic conducted with an optical profilometer is recommended, as it could also provide three-dimensional data (Sa, Ssk and Sku), allowing a more comprehensive understanding on the effect of rotary and piezoelectric handpieces on the different substrates.

5. Conclusions

Within its limitations, the present study demonstrated that turbine generated rougher surfaces on dentin compared to the other tools (high-speed electric handpiece and piezoelectric device). Moreover, turbine produced more asymmetrical surface profiles on both enamel and dentin. However, it should be considered that the recorded differences in roughness (Ra) between the three handpieces are within the range of 0.25–0.30 μm: it is still unclear if these variations, although statistically significant, could affect final clinical outcomes.

At SEM analysis, piezoelectric tips showed greater wear when compared with burs after the preparation of five samples. In addition, burs used with the high-speed electric handpiece exhibited more wear than burs used with the turbine. This factor should be also evaluated by the clinician in a cost/benefit analysis when selecting the most convenient tools and procedures for clinical practice.

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Informed Consent Statement: Not applicable.

Data Availability Statement: The complete dataset is available from the corresponding author upon reasonable request.

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Conflicts of Interest: The authors declare no conflict of interest.

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