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SEM and profilometric evaluation of enamel surface after air rotor stripping – an in vitro study

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The aim of the study was to evaluate roughness of the enamel surface after Air Rotor Stripping (ARS). Thirty interproximal surfaces of human premolars were used as the biological material. Research was conducted using a contact profilometer and a scanning electron microscope (SEM). Sets of 3D parameters and topographical maps of enamel surface before and after ARS treatment were used to define roughness of the surfaces. SEM images of stripped surfaces were taken with microscopic magnification of 100× and 1000×. The data revealed a general roughness of enamel arising after ARS procedure. Summarized values of chosen parameters increased after ARS procedure compared to the values of untreated enamel. Topographical maps showed areas of both well polished and badly polished enamel. In conclusion, comparison of the mean values of the measured parameters of ARS treated enamel surfaces indicated that roughness of the enamel arises after ARS, but it must be emphasized that on every evaluated surface well polished areas were also present. Moreover, the well polished areas were smoother than those on the untreated enamel surfaces. Contact fluoridation and improved oral hygiene after ARS appear to be necessary because of the presence of areas of increased roughness on evaluated surfaces.

Key words: human enamel, SEM, contact profilometry, ARS, stripping

1. Introduction

Interdental stripping has been applied in orthodontic therapy for many years. Commonly, the use of stripping has been concerned with anterior teeth (especially lower incisors). Air Rotor Stripping (ARS) described in 1985 by SHERIDAN is a variation of stripping which focuses on posterior teeth. SHERIDAN defined the amount of space gained by ARS as 6.4 mm per arch [1], [2]. One can say that space created by ARS can resolve many problems in the treatment of dental crowding, but ARS also removes superficial surfaces of enamel and this can increase the susceptibility of interproximal enamel surfaces to demineralization [3]. Some studies have emphasized that well-polished surfaces can be

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provided by the use of burrs with sufficient coarseness and polishing disks [4], [5]. Other studies have reported that enamel remineralization occurs about one year after the ARS procedure, but it is impossible to obtain 100% well polished surfaces [6], [7]. The use of descriptive terms such as "roughness of surface" creates the need for a proper quantitative tool for accurate evaluation of such roughness. A tool especially prepared for this kind of evaluation is a profilometer. Stylus profilometer measurements are better for naturally curved surfaces [8]. Evaluation of human enamel can be conducted by microscopic and profilometric techniques which can describe surfaces in both quantitative and qualitative ways. Studies done with the use of contact profilometry gave varying results: a sequence in polishing discs from fine to the finest was advocated [9].

The aim of the study presented herein is: 1) to determine the roughness of the enamel before and after ARS procedures by means of 3D profilometric measurements; 2) to confirm the profilometric results mentioned above by using the SEM images of enamel after ARS.

2. Experimental

Fifteen human premolars (30 mesiodistal surfaces) were used for this study. Teeth were intentionally free from hypoplasia, caries, restorations and were acquired from Caucasian patients of both sexes, aged 12–18. After extraction, the teeth were washed under running water and underwent profilometric measurements. The examined area of untouched enamel was 4 × 2 mm and was located in the middle of the interproximal contacts. A total of 200 profiles were recorded (with a distance of 10 μm between the rows) per surface. A set of 3D parameters and 3D topographical maps of the untreated enamel surfaces was obtained. Afterwards the teeth were mounted in rubber forms that simulated natural arch form, and the forms were filled with plaster.

Air rotor stripping of the proximal surfaces was performed. Dental burrs chosen from the Sheridan protocol were used. The initial smoothing was done using a No. 699lc burr (Raintree Essix, Inc., Metairie, LA, USA) followed by a No. 848fd burr (Raintree Essix, Inc.). Final polishing was accomplished using Sof-Lex disks No. 8692F (3M ESPE, Monrovia, CA., USA) with 45 seconds of polishing time (for Sof-Lex discs). The whole procedure was done under water cooling. We have used a brand new Sof-Lex disk per one surface and new burrs per two surfaces.

After the ARS procedure, the teeth were recovered from the forms and prepared for profilometric evaluation (washed under running water and cleaned with rice brush). A 3D profilometric examination was performed on all enamel surfaces which had been treated with ARS technique. Initially, 3D evaluation was performed over 4 × 2 mm areas. We obtained 3D topographical maps and profilometric photosimulation images of treated enamel surface and chose 2 × 2 mm areas with visible scratches and furrows ("rough") and areas on which scratches and furrows were not visible ("smooth"). Subsequently, we performed a 3D analysis over these areas. On each surface 200 profiles were measured, with a distance of 10 μm between the rows. The 3D analysis was performed perpendicularly to the polishing direction. The following 3D parameters were used to describe the surfaces: *Sa* – arithmetic mean of the deviation from the mean surface [μm]; *Sq* – quadratic mean of the deviation from the mean surface [μm]; *St* – total height of the surface [μm]. A contact profilometer Form Talysurf 120L Rank Taylor Hobson Ltd., cooperating with a Dell Pentium III computer with software 3D Talymap Expert, was used. According to the profilometer description, the accuracy of evaluation was up to 0.25 μm in the horizontal direction and 0.01 μm in the vertical direction. A diamond stylus with a tip radius of 2 μm was used.

After profilometric measurement, the teeth were removed from forms and prepared with required procedures for SEM investigation (distilled water, ultrasonic washer, alcohol, sputterd with spectral silver). We used a BS 300 Tesla scanning electron microscope. Recorded images were acquired with the use of secondary electrons and pictures were taken at 100× and 1000× magnification.

3. Results

1. Profilometric measurements

The parameters of the untreated and treated enamel surfaces are shown in the Table. We also give the parameters for the chosen "rough" and "smooth" areas.

2. 3D images

A Tylor–Hobson photosimulation of an untreated surface is presented in Figure 1. A treated enamel surface is shown in Figure 2. Figure 3 shows a colour image of the treated surface. Figures 4 and 5 present in sequence "smooth" and "rough" areas chosen from the colour simulation of photosimulation shown in Figure 2. A 3D map of part of Figure 1 is presented in Figure 6.

Roughness parameters	ARS procedure			
	Before	After	After "rough" area	After "smooth" area
Sa [µm]	1.06 +/– 0.19	1.24 +/– 0.91	1.98 +/– 0.68	0.50 +/– 0.32
Sq [µm]	1.37 +/– 0.35	1.70 +/– 1.09	2.55 +/– 0.83	0.85 +/– 0.49
St [µm]	11.27 +/– 7.55	13.67 +/– 7.20	18.44 +/– 6.58	8.90 +/– 3.87

Sa – arithmetic mean of the deviation from the mean surface [µm].
Sq – quadratic mean of the deviation from the mean surface [µm].
St – total height of the surface [µm].
"rough" – chosen areas with visible scratches and furrows.
"smooth" – chosen areas on which scratches and furrows are not visible.

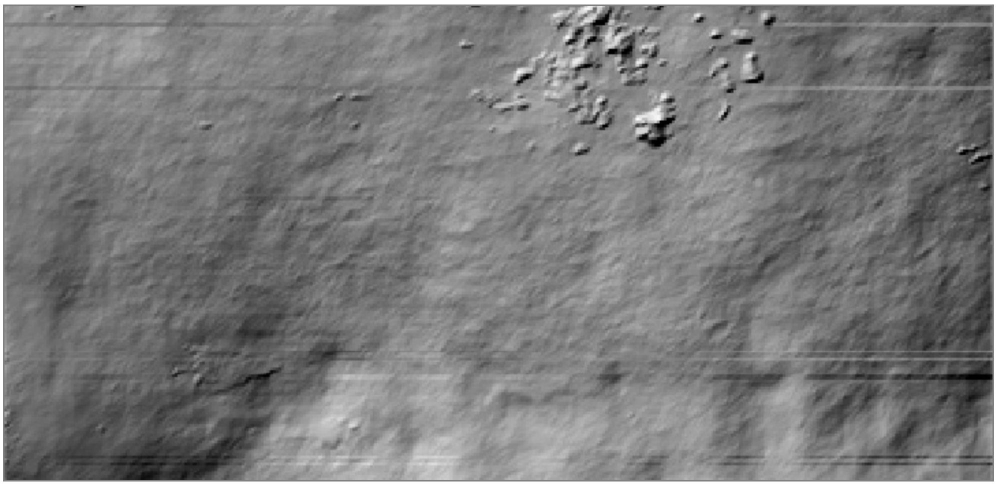

Fig. 1. Profilometric photosimulation image of untreated enamel surface

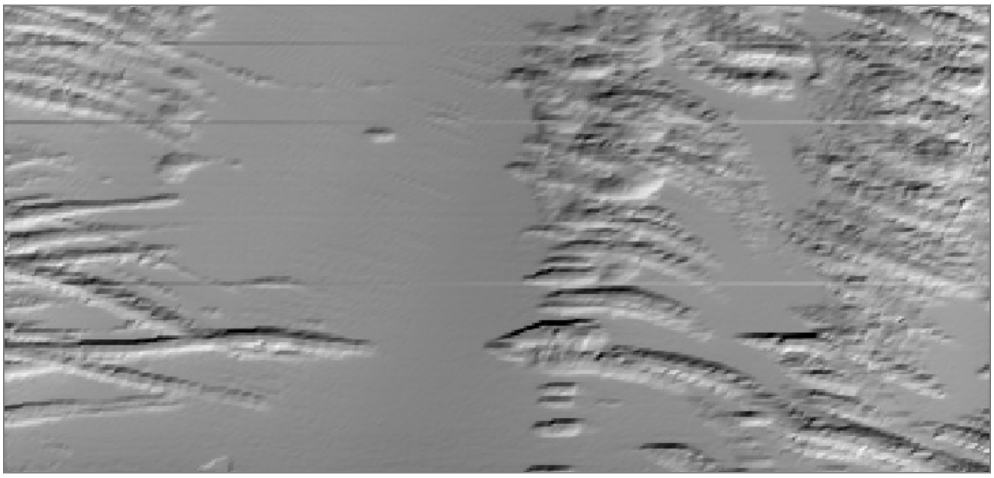

Fig. 2. Profilometric photosimulation image of enamel surface which had undergone ARS procedure

3. SEM evaluation

Figure 7 shows a typical image after ARS containing well polished areas of enamel bordering with rough surfaces (magnified 100×). The borderline between the polished and rough surfaces is shown in Figure 8 (magnified 1000×). Well polished enamel is clearly visible in Figure 9 (magnified 1000×).

The Student's test and Wilcoxon test revealed statistically significant difference in values of *Sa*, *Sq* and *St* for "smooth" and "rough" areas (P<.0001)

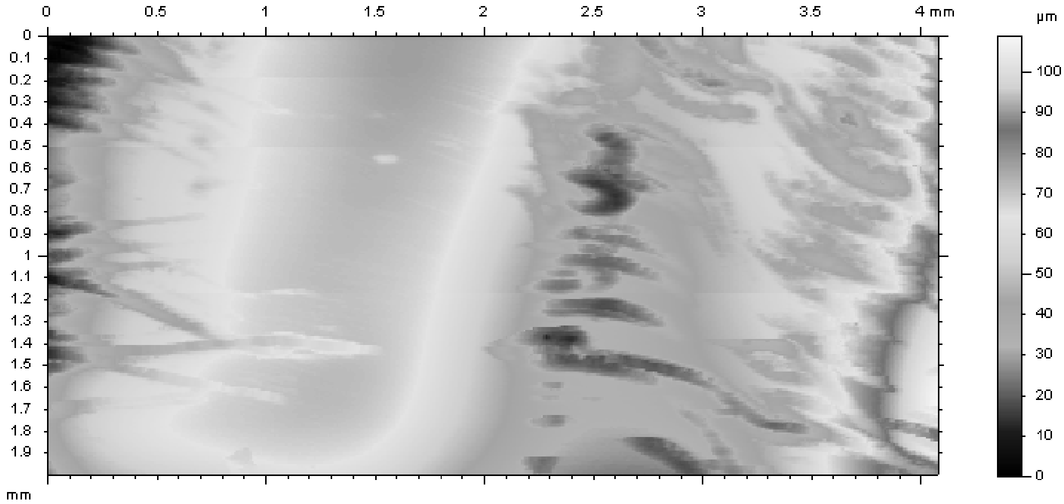

Fig. 3. Image of enamel surface which had undergone ARS procedure

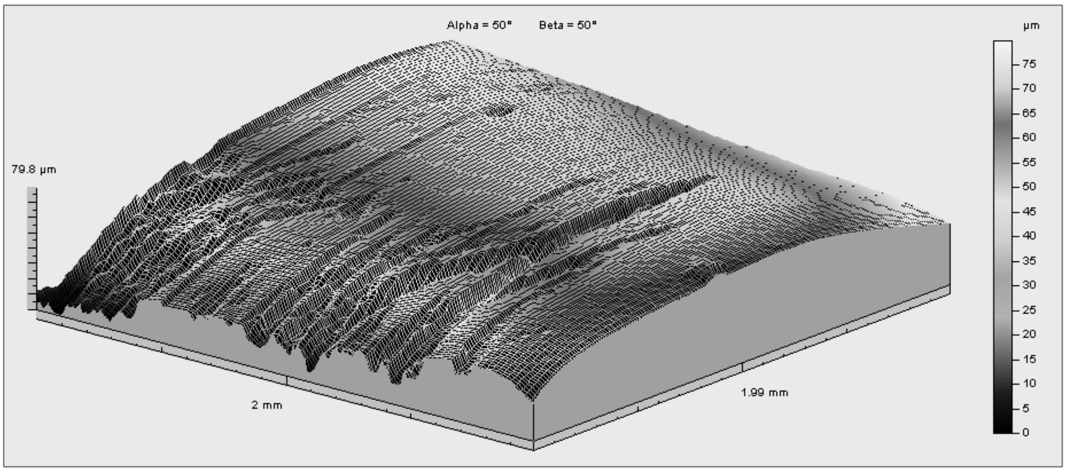

Fig. 4. 3D map of "rough" surface, extracted from image of Figure 3

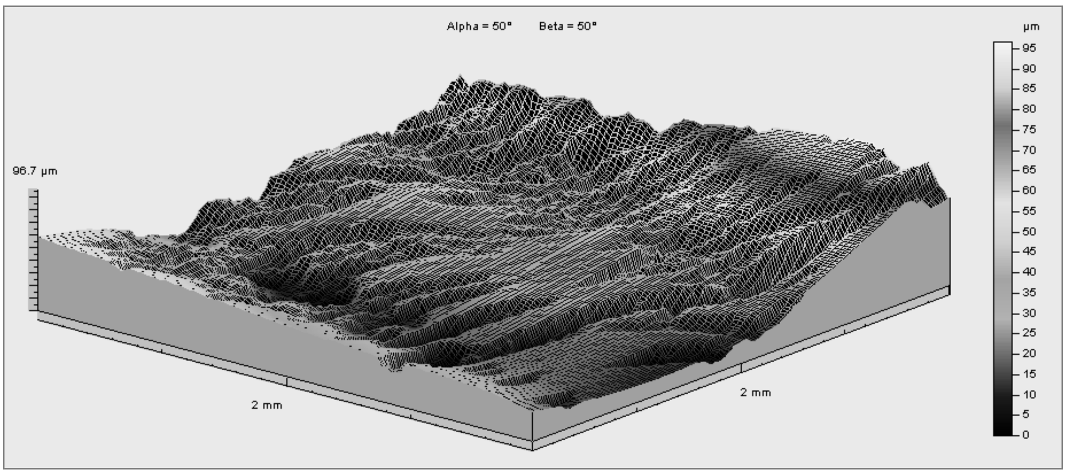

Fig. 5. 3D map of "smooth" surface, extracted from image of Figure 3

and between values for "rough" areas and those of untreated enamel (P<.0001). For "smooth" areas and untreated enamel surface only *Sa* and *Sq* parameters had statistically significant difference (P<.0001).

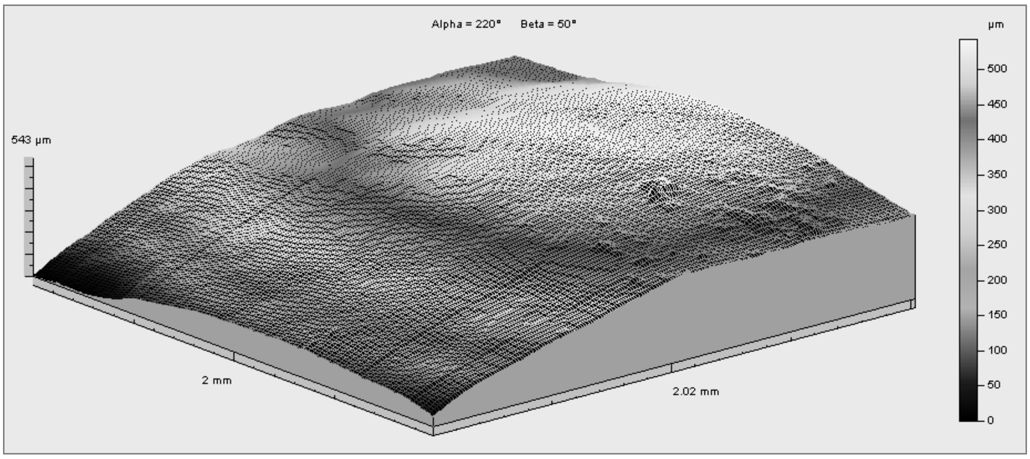

Fig. 6. 3D map of untreated enamel surface, extracted from photosimulation in Figure 1

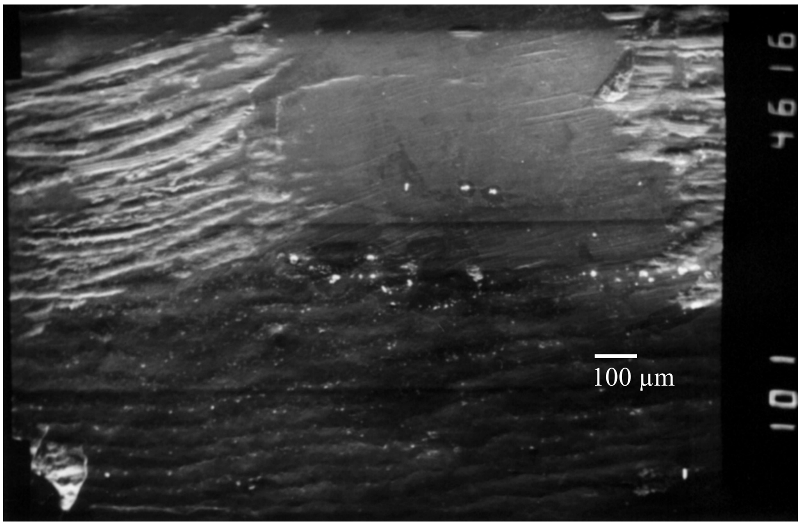

Fig. 7. SEM image of polished enamel surface after ARS procedure, areas well polished and visible unpolished scratches and furrows (magnified 100 ×)

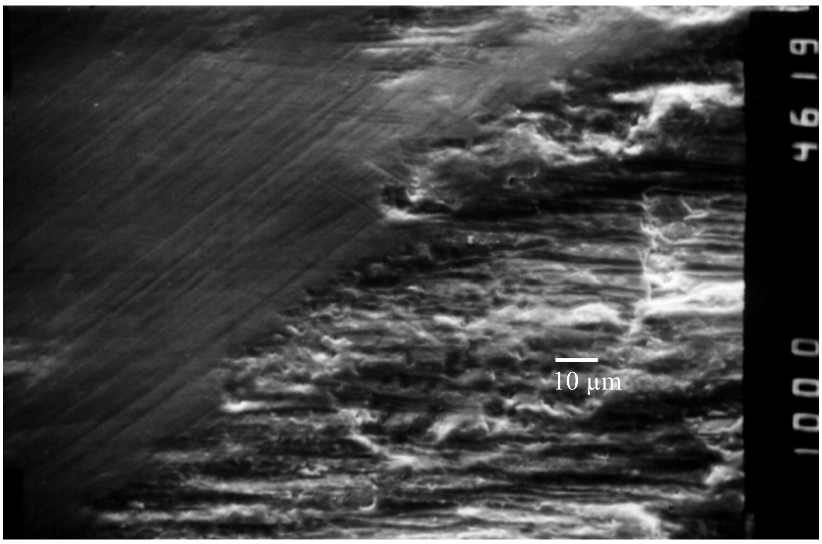

Fig. 8. SEM image of polished enamel surface after ARS, borderline between very well polished areas and rough areas (magnified 1000×)

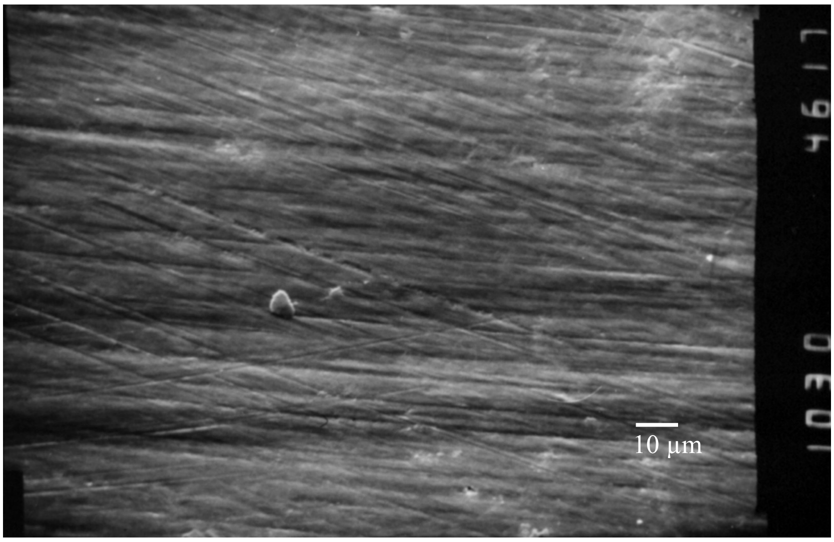

Fig. 9. SEM image of polished enamel surface after ARS, very well polished area (magnified 1000×)

4. Discussion

A 3D topographical analysis gives a number of parameters and thereby instantly presents difficulties in choosing parameters that best describe the surface. The literature available suggests that it is impossible to create a universal set of standard parameters for every surface [10]. We found a study of STOUT et al. [11] suitable for confirming the adequacy of the parameters we choose. These authors evaluated the surface of human root after ultrasonic scaling using the *Sa*, *Sq*, *St*, and other 3D parameters. We have chosen three roughness parameters *Sa*, *Sq* and *St*. For defining the roughness of a surface advantage is commonly taken of arithmetic mean *Sa* and quadratic mean *Sq* of the deviation from the mean surface. A growing value of *Sa* and *Sq* indicates an increase of the general surface roughness. The third parameter *St* – total height of the surface, is sensitive to the appearance of single valleys and peaks on the surface. In our study, the values of 3D parameters showed that the roughness of enamel after ARS procedure underwent serious changes. The parameter values representing badly polished "rough surfaces" have increased in comparison to the values of untreated enamel, being accordingly: *Sa* +87%, *Sq* +86%, *St* +64%. On the other hand, in comparison to the values of untreated enamel the values of "smooth surfaces" had also slightly decreased: *Sa* –53%, *Sq* –38%, *St* –21%, (see the Table). The results indicate areas of well polished enamel in contact with rough ones. In a study of LUNDGREN et al., use was made of a contact profilometer to evaluate surface texture after stripping and 2D parameters were compared. The authors underlined that stripped surfaces had undergone some serious changes and there was a broad range of the mean values of 2D parameters. Because the study was conducted using coarse strips, the authors suggested that the coarsest strips should be avoided and stripping should start with coarse strips followed by gradually finer and finer strips [9]. Research performed with SEM proved that it was impossible to eliminate furrows produced by ARS done with diamond burrs, diamond disks and 16-blade tungsten carbide burrs with normal polishing and cleaning methods. The use of 8-straight blade tungsten carbide followed by Sof-Lex disks for polishing resulted in well polished (which appeared smoother than untreated enamel) surfaces [4]. RADLAŃSKI et al. concluded in a SEM study carried out on human premolars that, even after polishing, furrows on the surface remained wide and deep enough to facilitate more plaque accumulation than that observed on untreated enamel surface [12]. Similar conclusions were drawn in a study of JOSEPH et al., where the authors stated that mechanical stripping could have the advantage of quick enamel removal, but the process produced deep furrows that would add to the retention of plaque in interproximal areas which are difficult to clean [13]. On the other hand, CRAIN and SHERIDAN did not find an increased occurrence of caries after ARS reduction (from two to five years after procedure) [14]. Similarly, ZHONG et al. stated that more than 90% of stripped surfaces were very well or well polished and seemed to be smoother than those of untreated enamel. Moreover, they stated that surfaces which stayed less perfectly polished were no more plaque retentive than untreated enamel [5]. This corresponds to our results, but the total difference in the mean values for roughness parameters between stripped surfaces and untreated enamel was not so good in our study. The means of parameters *Sa*, *Sq*, and *St* after ARS procedure in comparison to appropriate parameters of untreated enamel surface have risen: *Sa* – 17%, *Sq* – 24%, *St* – 21% accordingly (Table). Roughness, as a factor which enables plaque accommodation after ARS procedure, has risen. Other studies have shown that ARS causes a significant increase in susceptibility of proximal enamel surfaces to demineralization [3]. Clinical research findings suggest *cautiousness* in applying air rotor stripping. Uncareful application of ARS may lead to cariogenic implications. Relaying on the parameters from our study for "rough surfaces" it may be stated that such areas may be potential gates for developing caries. Many authors emphasized that ARS should be limited to patients with good oral hygiene, Class I arch-length discrepancies with orthognathic profile (or minor Class II – non-growing patients) and contact fluoridation is necessary after ARS [15], [16]. Results from our investigation underline the above mentioned limitations and ARS should be viewed with exceptional meticulousness.

5. Conclusion

Comparison of the mean values of the roughness of enamel surfaces under study strongly indicated that the roughness of enamel rises after ARS treatment. However well polished areas (smoother than untreated enamel surfaces) were also found on every surface after ARS treatment. These well polished areas were not dominant ones.

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