Nano topography evaluation of NiTi alloy exposed to artificial saliva and different mouthwashes

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Introduction

During application of NiTi alloy in oral cavity, it is exposed to different mediums that induce its corrosion attack. Corrosion of NiTi is undesirable because it leads to releasing of ions that may cause allergic reactions of human body. Evaluation of NiTI alloy corrosion in the conditions that exists in human oral cavity still remains a great characterization challenge. To avoid difficulties in characterization of nano-structural and nano-topographic changes of the surface, a vast number of investigation employs accelerated corrosion tests. But, these tests does not sufficiently reassemble the real situation. Additionally, in numerous studies with the accelerated tests, corrosion was characterized by breakdown potential, count of released ions, and changes in mass. However, by these parameters alone the effect of specific corrosive medium on surface characteristics cannot be easily explained. Therefore, the motivation of this work was to perform a non-accelerated corrosion test of NiTi in various corrosive media, characterize and quantify the changes in nano topography.

Materials and methods

The corrosion behavior of NiTi alloy orthodontic wires (Denataurum) was evaluated in this study. Samples were prepared of the wire in as-received state. Each sample was exposed to medium for 21,5 day at room temperature. Sample denotations and the corresponding corrosive media are shown in Table. 1.

Sample	Corrosive medium
Sample 1	Artificial Saliva
Sample 2	Aquafresh® Mouthwash
Sample 3	Eludril® Mouthwash
Sample 4	Listerine® Mouthwash

Table 1. Sample denotations and used media

Corrosion was characterized by means of changes induced in surface topography. For these purposes, atomic force microscopy (AFM) (CP-II, Veeco) in contact mode was employed. Before and after the corrosion tests, surface of each sample was analyzed on 5 different locations. Image analysis software (SPIP, Image Metrology) was employed for the analysis of topographic images and calculation of surface roughness parameters. Statistical analysis of obtained data was performed by paired T-test and one-way Anova.

Results and discussions

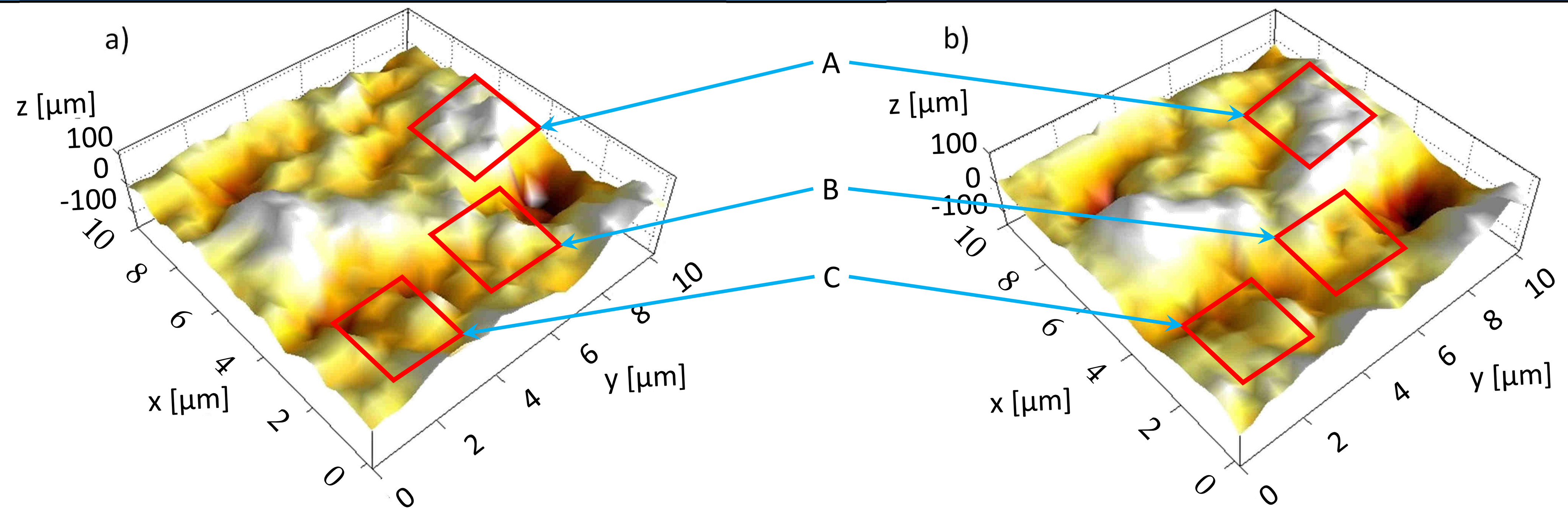

Fig 1. Representative topographic images: a) before exposure and b) after exposure

The changes in topography induced by corrosion are presented using the examples shown in Fig 1. By comparing the locations designated as A, B, and C the effects of corrosion can be recognized. The surface appears to become smoother, new surface features did not form but the shape of the existing ones were modified.

Surface roughness parameters, obtained before and after the tests are shown in Fig.2. Every corrosive media induced a specific change of the average value of roughness parameters, while the confidence intervals mostly remained the same after the corrosion test. The observed changes of parameters are much smaller than the confidence intervals. This, together with the differences in the initial surface roughness, makes it difficult to determine the effect of a specific medium on the surface topography. For these purposes, a paired T-test and one-way Anova analyses were employed in this study.

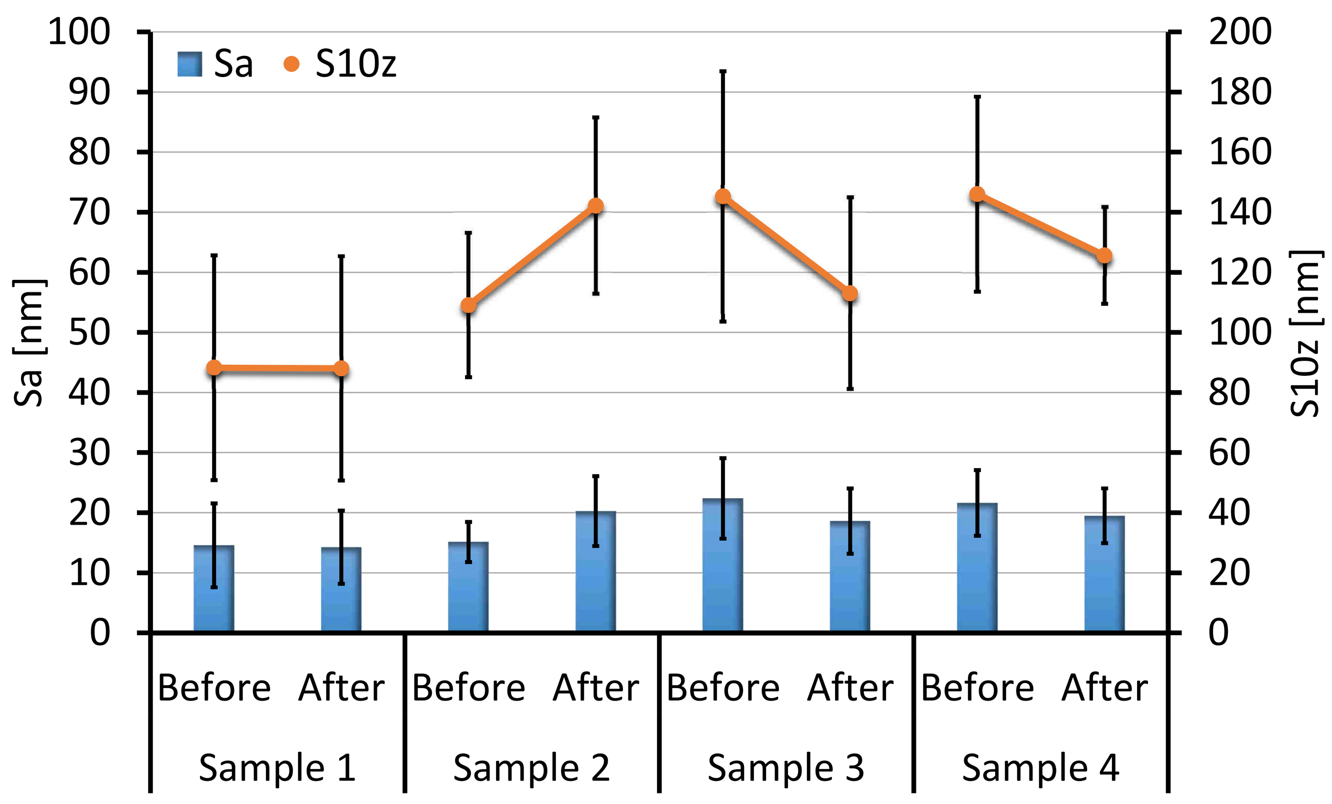

Fig. 2 Average values of surface roughness parameters (Sa and S10z) and corresponding confidence intervals

The changes in roughness parameters were analyzed by T-test and these results are presented in Fig.3. The change of the Sa parameter is insignificant for the sample 1 and 4. While the change of S10z parameter is insignificant only for sample 1. Unlike other samples, sample 1 exhibited insignificant change of both parameters. Sample 2 display a significant increase in both parameters, which indicate topographic changes of features located beneath the mean surface plane (valleys). Sample 3 display a significant decrease in both roughness parameters, which indicate changes of topographic features located above the mean plane. Sample 4 display a significant decrease in parameter S10z, which indicate that changes are localized in the peaks above the mean plane. We came to these conclusions by analyzing the changes in topography and results of paired T-test.

The influence of fluoride contained in corrosive media (mouthwashes) can be presented by analyzing the changes that occurred on samples 2 and 4. Mouthwash used for testing the sample 2 contains more fluoride than the one used for sample 4. Compared with sample 4, the topography of sample 2 underwent a more pronounced change during the test. This agrees with the findings from the literature from the field.

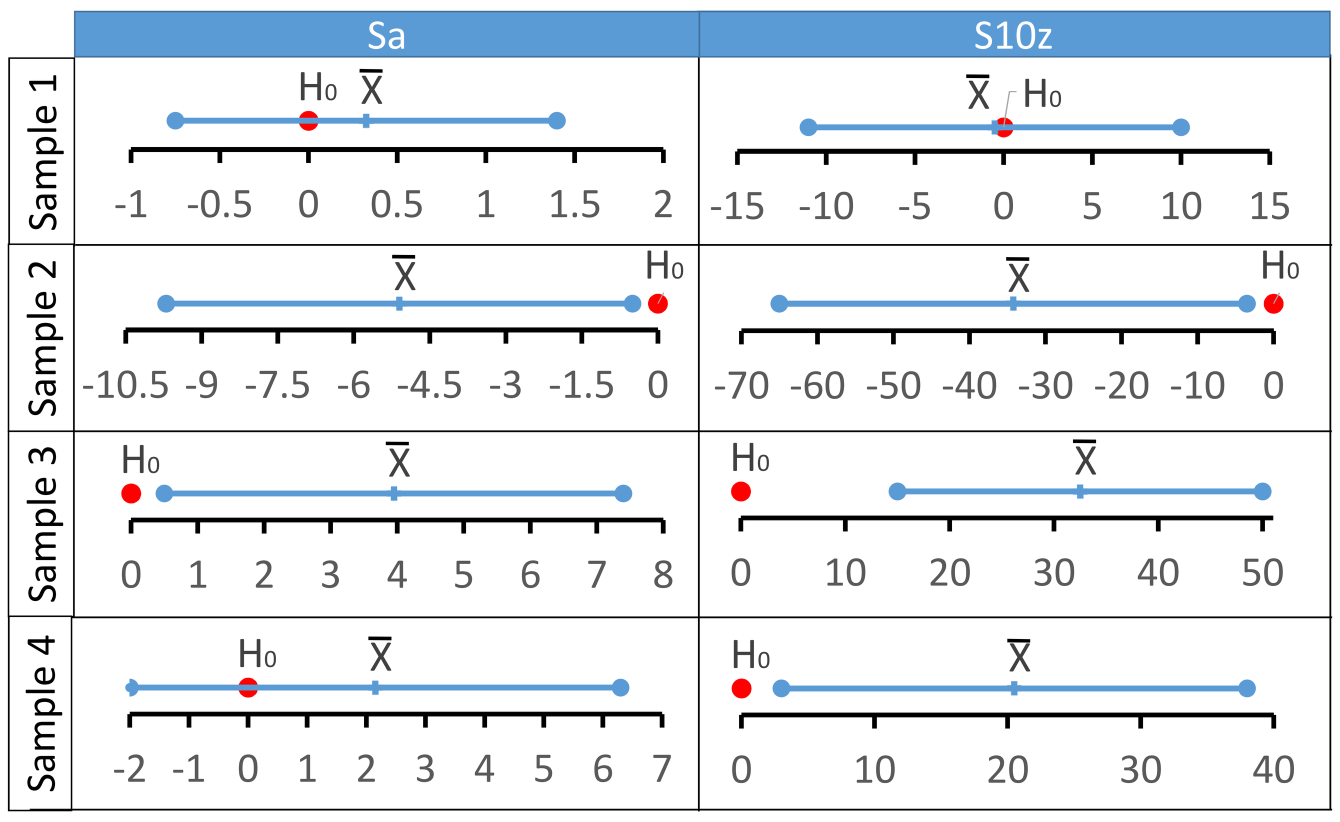

Fig.3 Results of paired T-test: statistical analysis of the changes in surface roughness parameters, before and after the tests

The comparison of the effects of corrosive media on surface roughness parameters are given in Fig. 4. Regarding the Sa parameter, the difference is significant for comparisons of sample 1 and sample 3 and the comparisons of sample 2 and other samples. On the other side, regarding the S10z parameters, the difference is insignificant only for comparison between sample 3 and sample 4.

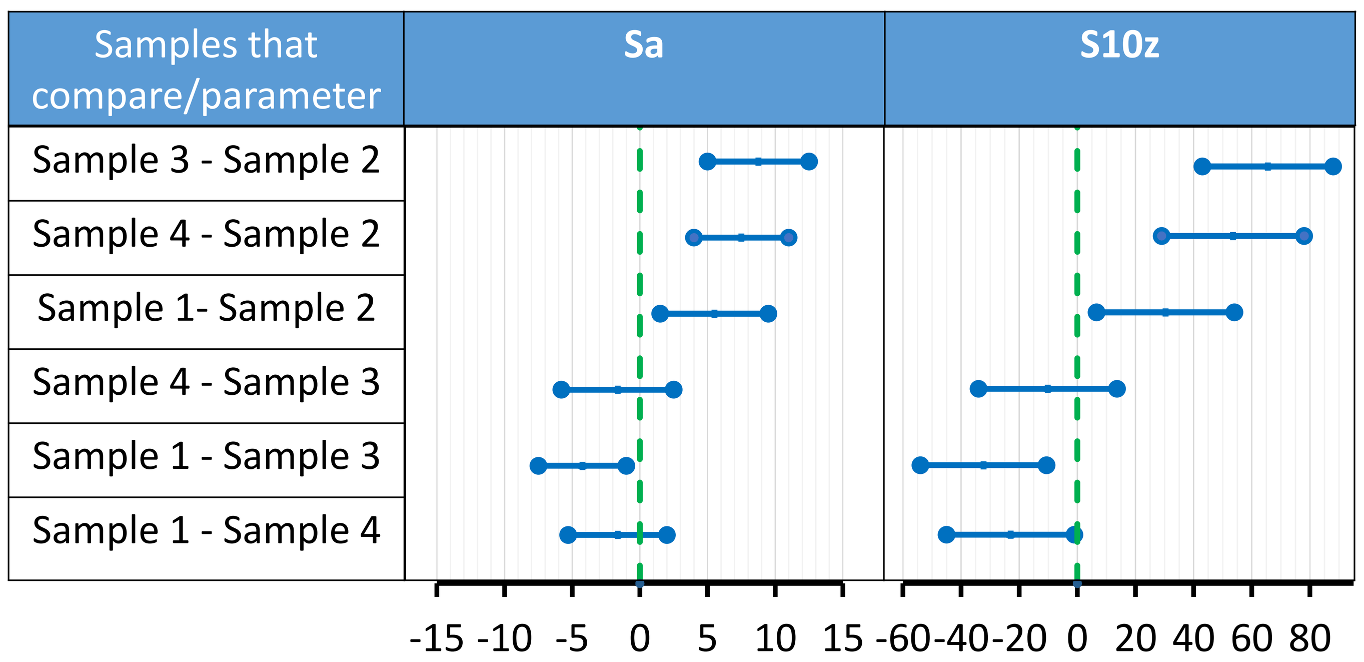

Fig 4. Results of one-way Anova: comparisons of differences in roughness parameters Sa and S10z caused by corrosive mediums

Considering the presented results, it is evident that mouthwashes cause more changes in surface topography than artificial saliva.

Analysis of the results for samples 3 (5 %Cl) and 4 (0.5 %F), indicate that chlorine cause more localized changes on the surface than fluorine. On the other side, these results also show that fluorine is more aggressive to the protective layer of NiTi than chlorine. These findings agree with the findings from the literature from the field. However, more detailed investigation is required to confirm these effects.

Conclusions

- Corrosion processes that induce nano topographic changes of NiTi can be successfully characterized by AFM analysis performed, before and after test, on the same on micro-location.
- Paired T-test has been proved as a useful tool for the evaluation of changes in nano topography caused by corrosion;
- One-way ANOVA has been proved as a great statistical tool useful in comparisons of the effects of different corrosive media;
- A small increase in concertation of fluorine in mouthwashes significantly increase the magnitude of NiTi alloy corrosion;
- Fluorine containing mouthwashes induce uniform changes in surface topography while the chlorine containing cause more localized (pitting) changes

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No. 872370