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COMPARISON OF THE SURFACE ROUGHNESS OF DENTAL IMPLANT ABUTMENT AND TOOTH ROOT

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ABSTRACT: *One of the complications of dental implants treatments is bacterial infiltration due to poor adhesion of soft tissue to the abutment. To improve soft tissue cell adhesion and decrease biofilm adsorption and adhesion, one of the possible procedures is to change the surface roughness of abutment dental implants. The objective of this work is to compare the abutment dental implants surface roughness before and after acid treatment with dental cementum. The cementum is a tissue inherent of the tooth root surface and belong functionally to the periodontium apparatus. Adhesion of soft tissue to the cementum reduces bacterial infiltration. Scanning electron microscopy and 3D laser non-contact profilometer were used for surface analysis and roughness parameters measurement, respectably. The results showed that the abutment surface roughness increases exponentially with acid temperature treatment and the cementum roughness Ra parameter is slightly similar to the sample acid etched at 80℃. In vivo tests are needed to analyze the adhesion of fibloblasts cells on the abutment surface to reduce bacterial infiltration***.**

KEYWORDS: biomimetic, surface treatment, dental implants, cementum

INTRODUCTION

The dental implant superstructures to support the dental prosthesis exhibit some deficiencies like poor adaptation among themselves and bacterial colonization at the abutment-implant interface. Bacterial colonization at the dental implant surface can induce bone loss and reduce treatment success rate. The bacterial infiltration depends on several factors, among them the quality of the sealing that results from adhesion of the peri-implant tissues to the abutment surface prosthetic components.The adequate abutment surface roughness improves soft tissue cell attachment and minimizes biofilm adsorption and adhesion. This feature allows for better mucosal sealing, minimizes peri-implantitis and bone loss. Besides, the smooth surface reduces the adhesion of macrophages, which exhibit rugophilia and prefer rough surfaces. One way to understand the physical properties of cell adhesion on biomaterials such as dental implants and prosthetic component (abutment) is to study the cells and fibers attachment on hard and soft tissue surfaces. Tooth surface is a remarkable example of

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cell adhesion, where cementum plays an important role to maintain the integrity of periodontium.

The dental root surface is covered by a cementum, which is a mineralized tissue. The main function of cementum is to provide attachment of collagen fibers from the periodontal ligament to the root surface, in this way maintaining the occlusal relationship and protecting the structure of root surface against bacterial infiltration. The cementum is categorized by its structure into five types as follow: acellular extrinsic fiber (AEFC), cellular intrinsic fiber cementum (CIFC), cellular mixed stratified cementum (CMSC), acellular afibrillar cementum (AAC), and intermediate cementum (IC) [Yamamoto, Tsuneyuki *et al.* (2016) e Gonçalves, P. F. *et al.* (2005)].

Cell adhesion on dental implants surfaces isn't the least important, because when is all about long term success, the maintenance of epithelium sealing plays a crucial role by the type of implant abutment in every aspect (design, material, system connection, surface treatment, etc.) [Al Rezk, F. *et al.* (2018) e Vélez, J. *et al.* (2020)]. Dental implant inflammatory disease may be caused by bacterial colonization on the abutment surface, creating epithelial down-growth and subsequently periimplantitis and bone loss [Berglundh, T. *et al.* (1991)]. To reduce bacterial infiltration and periimplantitis it is necessary to seal the soft tissue by fibroblasts' adhesion on the abutment surface. The mechanical barrier that protects teeth and implants against bacterial infiltration is known as "biologic width". Gargiulo et al. described a distinct relationship between epithelial attachment and connective tissue fastening [Gargiulo, A. W. *et al.* (1961)].

The quality, orientation and amount of collagen fibers produced by fibroblasts are possible factors in shaping the protective field of the connective tissue. In fact, high-density collagen clustered perpendicularly to the tooth axis promotes high resistance to physical contamination from oral cavity's microorganisms [Shimono, M. *et al.* (2003) e Stern, I. B. (1981)].

In terms of difference between dental implant and natural tooth is the mode of attachment to the jawbone. Osseointegrated dental implants essentially bond to bone trough protein and cells. This is from the biocompatibility feature of implant made with titanium with an oxide coating. The implant attachment does not have the periodontal ligament. Consequently, dental implants have a high chance of infections than natural tooth due biofilm. The peri-implant mucosa possesses a sealing barrier structure. This soft tissue consists of sulcular epithelium at the deeper part of the sulcus, peri-implant epithelium (PIE) at the epithelial attachment, and connective tissue at the site of fastening [Zheng, Z. *et al.* (2021)].

Periimplantitis diseases are common complications in implant dentistry. The prevalence of periimplantitis amounted to 8.9–43.3% [Zhuang, L.-F. *et al.* (2016)]. The combination of fewer fibroblasts, reduced vascularity, lower tissue attachments, and the parallel orientation of collagen fibers induces a weak transmucosal seal around dental

implants [Heitz-Mayfield, L. J. A. *et al.* (2010)]. Unlike gingival barrier around natural teeth, peri-implant mucosal tissue looks like scar tissue, which is unable to wall off alveolar bone from the oral cavity [Carcuac, O. *et al.* (2014)]. These structural differences may explain why bacterial accumulation would lead to a more obvious and rapid inflammatory response in peri-implant mucosal tissues in comparison with the dentogingival unit [Takamori, Y. *et al.* (2017)]. Therefore, it is desirable to establish a well-formed soft tissue seal at the transmucosal interface of dental implants-abutment system.

Bacterial colonization on implant surface depends on several factors, among them the quality of the abutment sealing. To minimize peri-implantitis, some procedures were adopted, for instance implants with switching platforms, implants with internal connections, prosthetic components with antibacterial coating, and the use of laser therapy. These procedures reduced peri-implantitis but did not eliminate the disease.
The biologic width is the distance between the point where the junctional epithelium attaches to the tooth enamel and the connective tissue-root surface binding site. The surface finish of dental implant prosthetic abutments will allow the epithelial attachment of connective tissue binding.

The influence of the substratum surface roughness on cell adhesion has been interpreted in terms of variation of the contact area between the cell surface and the material. For example, Terada et al. (2005) showed that the bacterial adhesion increases on surface roughness, which was not due changing in the surface physicochemical properties but to the increase in surface area available for bacterial adhesion [Terada, A. *et al.* (2005)].

In terms on cell phenotype and size, the separation and area of peaks will determine how cell will respond on a specific surface due by the quantity of focal adhesions [Anselme, K. *et al.* (2010)].
Dental implant surface treatment increases the treatment success rate due to improve biological response. However, there is a lack of knowledge of how abutment surface roughness influences the full health of soft and hard tissues. Based on this lack, the aim of this work is to development the abutment surface roughness and compared with tooth root.

Materials and Methods

In the present work samples of dental implant abutment made of Ti-6Al-4V (ASTM F136) were used. The samples supplied by Conexão Sistema e Prótese Co (Arujá, SP – Brazil) were divided in 5 groups:

- As machined
- Mechanical polished
- Mixture of sulfuric and hydrochloric acid etching at 60 °C
- Mixture of sulfuric and hydrochloric acid etching at 70°C

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- Mixture of sulfuric and hydrochloric acid etching at 80°C

The abutments were analyzed using scanning electron microscopy and surface roughness measurements before and after surface treatment. The same procedure was used for tooth characterization. The morphology was observed using a Quanta FEG250 (FEI Corporate, Hillsboro, Oregon, USA) scanning electron microscope. The external abutment and surface roughness was measured with an optic laser profilometer New View 7100 (Zygo Co, Laurel Brook Road, Midlefield, CT 06455 – USA). The surface roughness parameters measured were Ra, valley density, peak density, valley area and peak area. These parameters were chosen because they have the greatest influence on soft tissue adhesion. Every sample was measure in 5 different regions. The surface roughness measurement made on the tooth's root (cementum) was only on the cervical portion of the root.
All data taken from the surface parameters were analyzed using variance analysis (ANOVA) and Tukey test with 5% of significance.

RESULTS

Figure 1 shows the abutment surface morphology before and after acid etching at 70°C. Figure 2 shows the tooth root surface.

Figure 1. **Prosthetic abutment surface before (left side) and after (right side) acid treatment.**

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Figure 2. **Tooth surface. Left side is a buccal view, and right side is a lateral view. The surface roughness measurements were on the ovoid pointed line area.**

Figure 3 shows the abutments surface roughness before and after polishing. Figure 4 also shows the cementum's roughness. It is possible to observe the peaks and valleys distribution on the cementum surface.

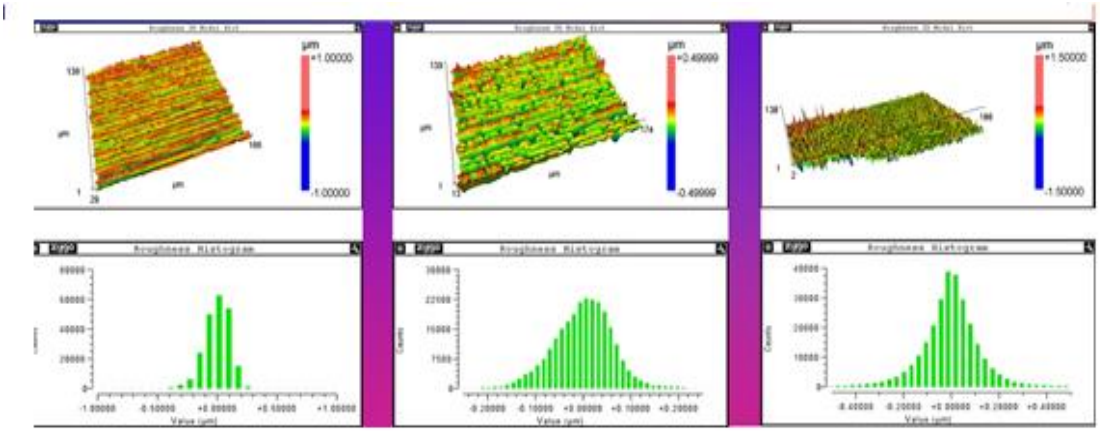

Figure 3. **Abutment before (Left side) and after surface polishing (Middle), and tooth canine surface (Right side). It is important to observe that roughness on the polished abutment more number of small peaks than unpolished abutment. The tooth root has a difference between all samples.**

Figure 4 shows the abutment surface after dual acid etching at different temperature. The surface roughness increases as the temperature increases. The histogram shows the number of peaks and valleys with acid etching temperatures.

It is evident to appreciate in figures 3 and 4 that the roughness among all samples is dynamically changing over each sample, however in contrast with the roughness of cementum that doesn't seems to have any similarities with any of the samples in terms of morphology.

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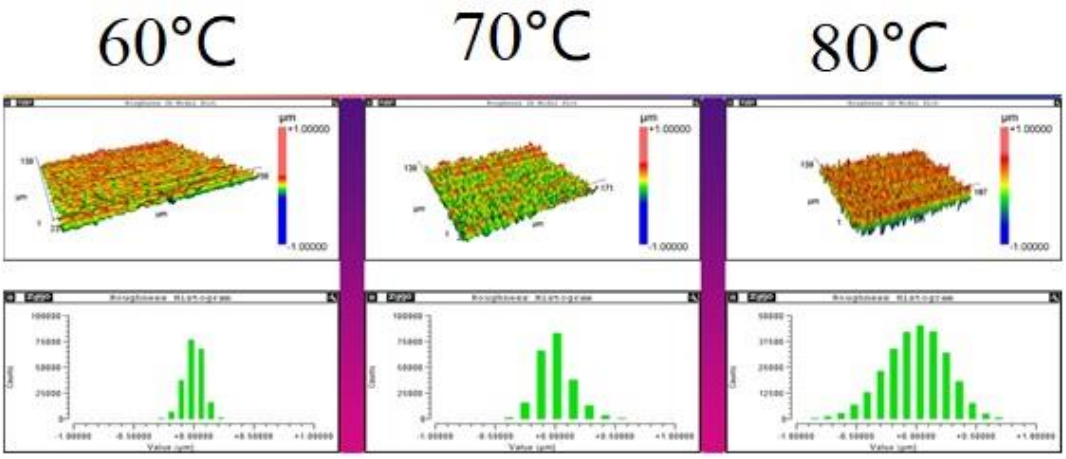

Figure 4. The abutments surface morphologies and number of peaks after acid etching treatment at different temperatures.

It is very important to compare the abutment surface roughness and the cementum of the tooth, because they have different morphologies and the roughness influences on the fibroblast adhesion.

After treatment at 60℃ the surfaces have rounded roughness. After treatment at 70℃ the number of small peaks size increased. After treatment at 80℃ the number of small peaks sizes decreased and the number of high peaks increased.

After abutment acid etching at 60℃, the surface roughness variation range is smaller than that of the machined sample. As the acid etching temperature increased, the roughness variation range increased and the number of peaks and valleys reduced. With the treatment at 80℃, the roughness variation range and the number of peaks and valleys were similar to that of the tooth.

To calculate the Ra parameter, a mathematical equation is used that considers the values of peak heights and valley depths. For the statistical analysis of the data, the ANOVA test and the Tukey test with 5% of significant difference were used. The statistical analyses shows that all abutments have surface roughness statistical difference. Figure 5-8 show the surface roughness parameters difference among samples.

The sum of peak area and valley is the total surface area. The sum of peak density (number of peaks by total surface area) and valley density is the PV density.

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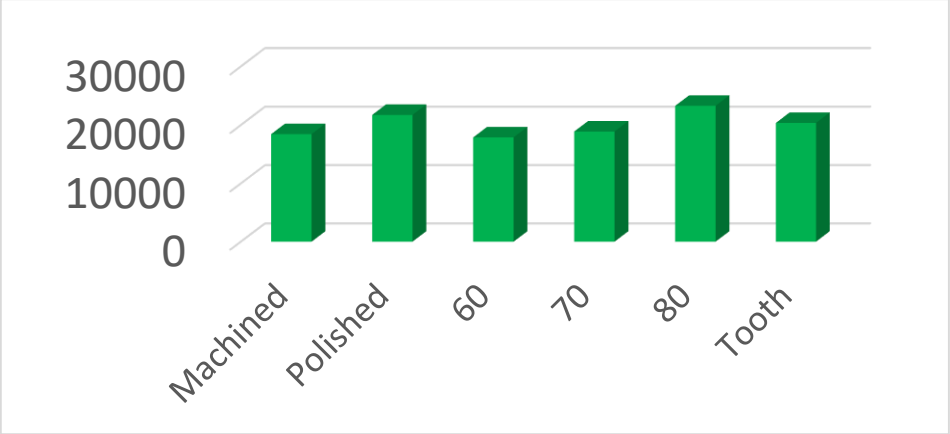

Figure 5. Sample`s Ra (µm) roughness parameter.

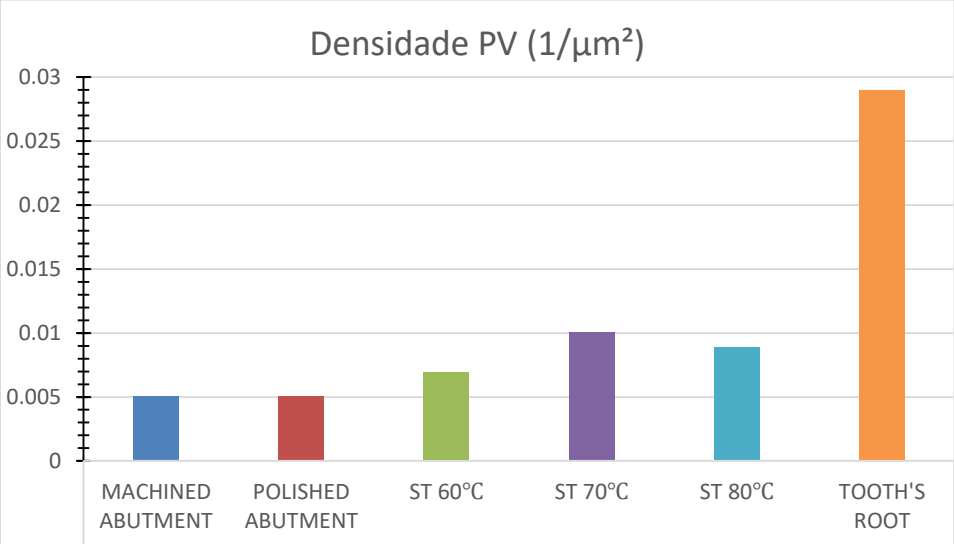

Figure 6. Samples peak-valley density (1/µm²) roughness parameter.

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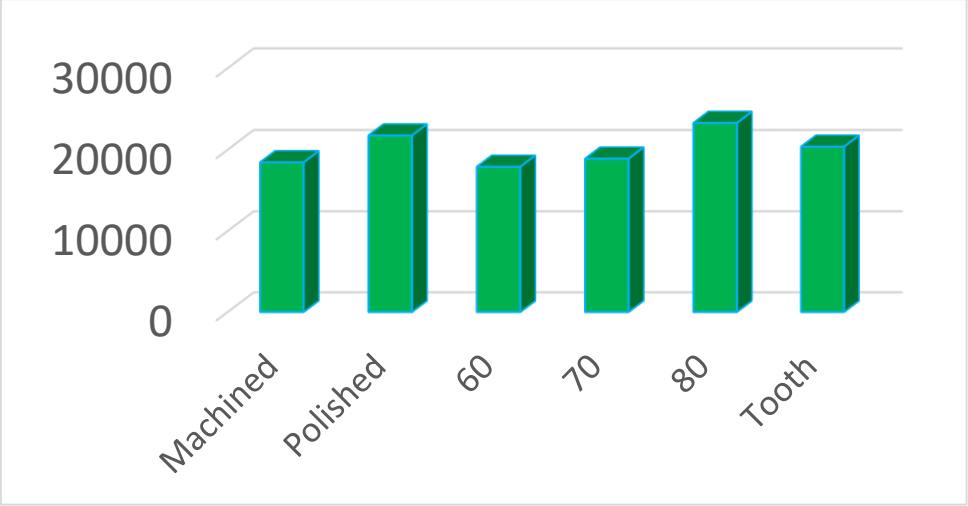

Figure 7. Samples total surface area (µm²).

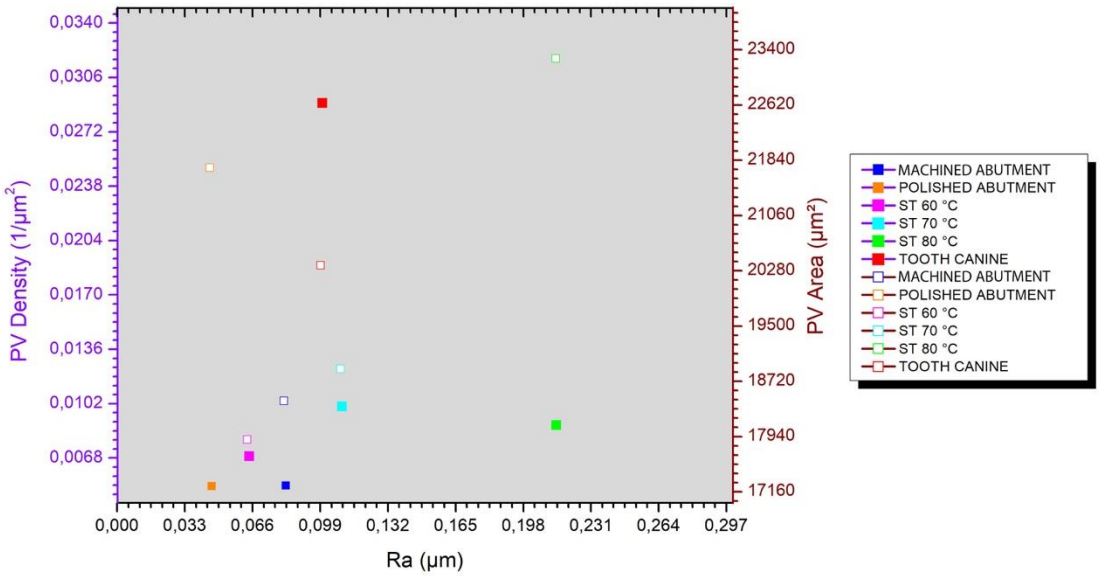

Figure 8. Comparison between samples' roughness parameters.

DISCUSSION

In the present work we analyzed and compare the surface roughness differences among dental implants abutments and cementum tooth root. The cementum´s surface is a tissue poorly study but with such a huge impact in teeth and occlusal health.

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The attachment and interactions among cells and biomaterials` surfaces must be analyzed to allow the development of implants and prosthetic components with biomimetic characteristics.

The result on Fig 4-8 shows that the abutment`s surface Ra parameter changes after acid treatment. The roughness increases exponentially with acid temperature treatment (figure 5) and the cementum roughness Ra parameter is slightly similar to the sample which was treated with dual acid etching at 80℃.

Now it is important to analyze other parameters to translate the surface characteristics that Ra by itself won't show up. Figure 7 shows the peaks and valleys area have and how much difference these parameters are when comparing with every sample. Figure 6 shows the density of peaks and valleys, which all samples have lower number of density than cementum. Now if we take this numerical information a little bit further and correlate the Ra, PV density, and PV area parameter in a graphic (figure 8), we are going to be able to observe interesting numerical arrangements. For the case of each abutment, when the Ra parameter changes, the other parameters show irregular behavior.

The Ra roughness parameter on the cementum is closer to the abutments' roughness after acid etching at 80℃. The abutment and cementum have similar number of peaks and valleys and similar size ranges at the histogram in figure 3 and 4. Now these observations must be explained in a biological way to be able to correlate our findings with the ones founded in the literature.

The surface of cementum is divided into five types depending on its third portion. In the present work the analysis was made on the acellular extrinsic fiber cementum (AEFC), because is the one that is located at the cervical root surface in both permanent and deciduous teeth. AEFC contains collagen fibers and non-collagen fibers proteins as an organic matrix, which are completely mineralized. These fibers serve as a bridge, connecting the principal fiber of the root surface to the periodontal ligament; besides these collagen fibers are dense packaged and arranged perpendicular to the root surface [Yamamoto, Tsuneyuki *et al.* (2016) e Gonçalves, P. F. *et al.* (2005)].

In the development of cementum, cementoblasts and fibroblasts extend wing or platelet like processes and surround the immature fibril bundle. They then form tubular compartments by connecting the processes, and add collagen fibrils linearly and laterally to the immature fibril bundles within the compartments where hydroxyapatite and collagen fiber are well organized [Yamamoto, Tsuneyuki *et al.* (2016) e Gonçalves, P. F. *et al.* (2005)].

There are several proteins that are involve in the process cementum formation and the integration of periodontal ligament. Cementum major non-collagenous proteins, sialoprotein and osteopontin secreted from cementoblasts bind tightly to the

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collagenous matrix and hydroxyapatite, and they possess cell attachment properties through the RGD sequence, that binds to integrins. Periodontal ligament fibers develop further and change their arrangement to form principal fibers. At this point the fiber fringe is organized into extrinsic fibers and the tooth anchorage system is stablished in the cervical region. Then cementoblasts concentrate on secretion on non-collagenous proteins to induce further AEFC mineralization and strengthen the anchorage system [Yamamoto, Tsuneyuki *et al.* (2016) e Gonçalves, P. F. *et al.* (2005)].

Cementum microenvironment encloses every component necessary for cell recruitment, proliferation and differentiation, thus dentin not covered by cementum undergoes resorption.

Rex et al (2005) perform a quantitative analysis of the calcium (Ca), phosphorus (P), and fluoride (F) concentrations in human first premolars. Their results shown a decreasing gradient of Ca, P, and F concentration from the cervical to the apical third of the root. These results confirm why the AEFC is more mineralized. This result gives us a good indication of the quantity of roughness present in the root's cervical third of our results [Rex, T. et al. (2005)].

Corald et al (2016) studied the AEFC using Raman spectroscopy, with the intention to provide information about the composition and the structure of AEFC. As the periodontal ligament is made of collagen fibrils, which formed thick bundles near the AEFC surface. These bundles are parallel between them and perpendicular to the cementum surface. They cross the mineralization front and enter the AEFC [Colard, T. *et al.* (2016)].

There are two types of fibers that can be distinguished. The main portion is represented by the thick orthogonal Sharpey's fibers (in relation to the AEFC surface), and the other fibers, which are present in other orientations (i.e., parallel to the surface) and are sometimes called "intrinsic fibers", are due to the branching and bending of the Sharpey's fibers. Thus, all of these fibers are interconnected, and this network exhibits a strong biomechanical potential. They notice that all the molecules parallel to the laser beam will produce an absolute isotropic response, they call them parallel circumferential fibers. The anisotropy pattern observed in their study is due to the molecules tilted perpendicularly from the laser beam direction (tilted circumferential fibers). those perpendiculars fibers to the tooth surface are called Sharpey's fibers. Those findings are in agreement with the cementum roughness image (figure 9) where it's possible to see the same circumferential parallel pattern and the perpendicular pattern of cementum surface [Colard, T. *et al.* (2016)].

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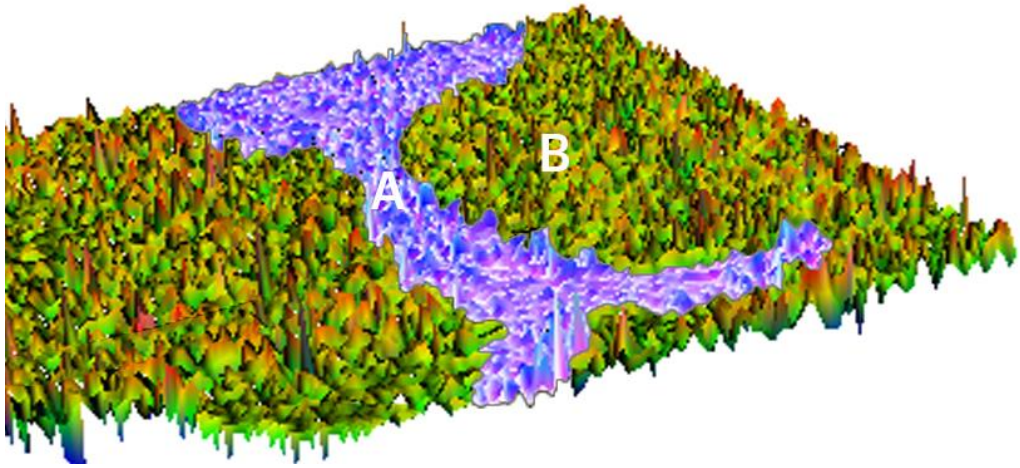

Figure 9. Cementum roughness showing A) parallel circumferential fiber and B) perpendicular Sharpey's fibers.

CONCLUSION

By treating the surface of the abutments with acid, it is possible to obtain roughness similar to that of the tooth root. The best result was with the treatment at 80°C.

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Future Research

This study will help to develop study models in order to constantly keep reaching the best for a technological improvement, in this case the study of biological materials such as cementum is the best way to develop surface treatments for dental implants that could be close as nature does.

Implication to Research and Practice

In this study we demonstrate the importance to research dental implants abutments with surface features similarly to nature teeth.

Every abutment samples show us the necessity of keep developing surface treatments until we can get the right roughness that could induce cell attachment as cementum does in natural teeth.

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