INVESTIGATION OF ACID RESIDUE ON THE SURFACE OF DENTAL IMPLANTS AFTER DIFFERENT SURFACE CLEANING PROCESSES

KAAN ÖZTOPRAK[1], ECE ÖZTOPRAK[2]

[1] *Mustafa Kemal University, Dentistry Faculty, Oral Surgery Department, Hatay-TÜRKİYE, alpkaan83@hotmail.com*

[2] *DDS, PHD Pedodontic Private Practice Department, DentAnkara Tunalı Hilmi Cad. 82 Ankara-TÜRKİYE, eceoztoprak@hotmail.com*

For dental implants to osseointegrate well, all clinical and production conditions must be perfect. Due to some negativities in production conditions, unwanted residual materials may remain on the implant surfaces, and these may adversely affect osseointegration. While producing implants, some surface treatments are required. These processes are generally based on the principle of increasing the surface area. Thus, they can provide attachment to the bone on more surfaces. Most methods applied to increase the implant surface area include acidic chemicals. After the acid is applied to the implant surfaces, the acid in the pits formed on the surface must be removed entirely. In cases where the acid cannot be completely removed, the remaining acid may cause bone destruction and cause implant loss. For this reason, some processes must be applied to remove residual acid. In this study, we aimed to find better ways to clean the acid residues on the implant surface. We created 2 groups of 20 implants in our study. Micro arc oxidation was applied with sulfuric acid in 2 groups and then washed with distilled water in a 180-watt ultrasonic cleaner. One group of implants was washed with pure water only, and the other group was washed with pure water and chemically neutralized. Sodium Bicarbonate 10% solution was prepared and washed for neutralization; the second group was kept in this solution for 10 minutes and washed with distilled water again. The implants in both groups were placed in 10cc ph7 distilled water and left for one day. After one day, the liquids were measured with a digital pH meter. In the measurement of the water in the group that was washed only with pure water, the average pH was 6.8, while the average pH of the water in the other group was 7. Our study concluded for the first time that basic neutralization on the implant surface could neutralize the acid residue in the microwells. We recommend chemical neutralization in implant manufacturing processes and think it can reduce implant failure rates.

Keywords: dental implants, surface treatments, acid residue

INTRODUCTION

Dental implants can get contaminated due to the ecological system in the mouth cavity with many bacteria or the environmental system outside the oral cavity with inorganic wastes (Yu *et al*., 2016). Common elemental contamination from organic carbon and traces of elements such as oxygen (O), nitrogen (N), calcium (Ca), and phosphorus (P) observed on dental implant surfaces are likely connected to failure in re-osseointegration when areas of an implant have lost osseointegration (Wheelis *et al*., 2017). It has been demonstrated that re-osseointegration occurs when a direct structural and functional union forms between an implant and bone. It has also been demonstrated that properly cleaned implants may re-osseointegrate (Schlee *et al*., 2019). As a result, surface topography, chemical purity, the thickness and composition of the oxide layer, surface cleanliness, and the presence of metallic and non-metallic chemicals on the surface appear to impact the effectiveness of implant osseointegration (Turkyilmaz, 2011). An increasing body of research (Anil *et al*., 2011; Dhaliwal *et al*., 2019) shows that implant surface topography and chemistry have a significant impact on osseointegration by influencing protein signaling and cell migration or differentiation. Surface roughness improves bone-implant contact area, mechanical interlocking, and stress distribution compared to smooth surfaces, favoring osteoblast-like cell

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colonization (Wennerberg and Albrektsson, 2010). However, it has been demonstrated that roughened surfaces increase the deposition of pollutants (Rezaei *et al*., 2018). Nonetheless, the methods through which inorganic and organic pollutants interact with implant surfaces are unknown. Although numerous techniques of implant cleaning have been tried, none have shown reliable outcomes. Implant surface cleansing remains challenging, necessitating the development of newer, efficient procedures (Al-Hashedi *et al*., 2016; Mombelli *et al*., 2018).

To produce the requisite surface characteristics, topographical modification is often employed in titanium-based implants. This involves using a variety of surface treatments, including sandblasting, chemical etching, anodization, laser treatment, and surface coatings (Katona *et al*., 2015). Although these surface treatments can alter the characteristics of the implant surfaces, they can also result in undesirable qualities and hence contamination of the implant surfaces in rare instances. Our bones are made up of collagen, hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$, and several anionic and cationic substituents such as carbonates (H_2CO_3), sodium (Na), magnesium (Mg), zinc (Zn), fluorine (F), chlorine (Cl), potassium (K), and silicon (Si) (Šupová, 2015). As a result, when foreign materials are implanted in the human body, they are exposed to a hostile corrosive environment that includes blood, water, Na, Cl, plasma, amino acids, and mucus in saliva (Sasikumar *et al*., 2019). Because of their favorable biocompatibility and mechanical qualities, inorganic metal oxides such as titanium oxide (TiO_2) and related alloys are extensively utilized in dental implants. The capacity of the titanium (Ti) oxide layer to tolerate corrosion in saline and acidic environments makes it an effective implant material that increases the possibility of osseointegration (Chaturvedi, 2009). However, following prolonged contact with live tissue, TiO_2 will emit trace quantities of corrosion products, resulting in dental implant contamination (Chaturvedi, 2009). Corrosion caused by body fluids can induce changes in material structure and the production of undesired inflammatory by-products, compromising the mechanical stability of the implant (Bahraminasab *et al*., 2019). Dental implants may potentially be infected during the marketing process, i.e., before any contamination from the mouth cavity. As a result, contaminations may be influenced by factors other than biological in situ effects. As a result, manufacturers must evaluate and confirm that sterile packaged medical equipment is free of surface contaminants regularly (Duddeck *et al*., 2019). Galvanic corrosion is another source of dental implant contamination. This electrochemical reaction happens when electrons may easily flow between two materials with sufficiently differing electrical potentials (Noumbissi *et al*., 2019). The surgical variables, the timing of implant surgery, site of implant placement, type of implant osteotomy, implant design, and implant stability are the essential parameters that might impact the early healing phase of the implant site and the survival rate of dental implants (Shadid *et al*., 2014). These factors significantly influence the likelihood of pollutant exposure. These pollutants have the potential to cause dental implants to fail in their function of replacing missing teeth. Furthermore, there is a financial burden on the patient and health care providers to spend on cleaning technologies. As a result, it is important to investigate the cause of dental implant failures. We will search for residual acid contaminants in this study. The purpose of this paper is also to discuss the possible effects of these pollutants on Ti dental implants.

The mouth contains Sulphur (S) compounds, as well as Na, K, Ca, PO_4, CO_2, and mucin (Oshida *et al*., 2010). As a result of the implant surfaces' sandblasting and etching, traces of sulfates, fluorides, magnesium oxides, silicates, and calcium oxides

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are discovered (Henningsen *et al*., 2018). Pre-processed Ti surfaces are typically treated with hydrochloric acid (HCl) and sulfuric acid (H_2SO_4). S was found in the residual S_2O_8 2 or SO_4 2 from samples treated with either sodium persulfate ($Na_2S_2O_8$) or H_2SO_4. However, the Ti acid complexes (titanium sulfate) were less soluble in water and hence unsuitable for Ti surface cleaning because they might disrupt the chemical modification of the Ti surface (Takeuchi *et al*., 2003). Giner *et al*. revealed that a twofold acid etching procedure with hydrofluoric acid followed by sulfuric acid resulted in a dual roughness Ti surface that promoted osteoblast adhesion, proliferation, and differentiation, hence improving osseointegration. Non-thermal plasma treatment can entirely remove S from Ti samples, while UV treatment cannot (Giner *et al*., 2017).

MATERIAL AND METHODS

In our study, we created two groups of 20 implants each. 4L %5 by weight sulfuric acid solution prepared. Voltage and current computer-controlled anodization machine used and implants put on the anode side. In the bath we use stainless steel plates as cathode. At 110v 10A current micro-arc oxidation completed in 5 minutes. Then implants are taken out immediately. All implants were washed with distilled water in a 180-watt ultrasonic cleaner. One group of implants was washed with pure water only, and the other group was washed with pure water and chemically neutralized. Sodium Bicarbonate 10% solution was prepared and washed for neutralization, Sodium Bicarbonate group was kept in this solution for 10 minutes and washed with distilled water again. The implants in both groups were placed in 10cc pH7 distilled water and left for one day. After one day, the liquids were measured with a digital pH meter (Metravi Ph-600).

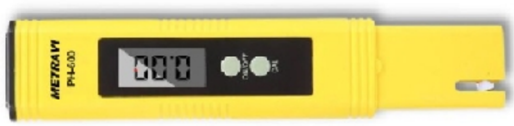

Figure 1. Ph meter

Table 1. pH data on groups

Cleaning type	Lowest pH	Highest pH	Average
Pure water group	6.7	6.9	6.8
Sodium Bicarbonate	7	7	7

$$NaHCO_3 + H_2SO_4 = Na_2SO_4 + H_2O + CO_2 \quad (1)$$

In the measurement of the water in the group that was washed only with pure water, the average pH was 6.8, while the average pH of the water in the Sodium Bicarbonate group was 7. The experiment shows that there are also left H_2SO_4 remnants on the surface after washing with pure water.

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CONCLUSIONS

Almost all dental implants contain acidification and etching processes as fabrication. After the surface is dispersed with acid, very small micro-pits are formed on the surface. In the anodization process, these micro-wells are much smaller and reach nano-structures. It is doubtful that these small pits of implants that are naturally treated in acid can be completely cleaned and the lowest points of the holes can be completely cleansed from acid. The lengths of these pits are in the size of micrometers and the pit diameters of the implants in nanostructure take the shape of a much longer well than the diameters of the holes since they are in Nano diameter. TiO_2 nanotube arrays with an average diameter of 60~80 nm and an average length of 2~4 micrometer (Shang *et al*., 2019). Since this process takes place in acid, it is very possible for acid molecules to remain in these pits at depths that cannot be removed by water.

This study shows us that after washing the surface with pure water, we still see Sulfuric acid residues on the surface. We know from chemical equations that when sulfuric acid combines with sodium bicarbonate, sodium sulfate salt which is pH neutral is also released, carbon dioxide and water. When the sulfuric acid residues that water cannot completely remove, combine with sodium bicarbonate, a neutral sodium sulfate salt is formed by chemical reaction, which can be easily removed by dissolving in water. If this acid cannot be completely removed from the surface after the implants are etched with Sulfuric acid, it may interact with the body during implantation and affect the osseointegration significantly negatively by making primary resorption of the bone with which it is in direct contact. For this reason, our study shows that instead of removing the chemical acid residue on the surface with normal water, it can be removed in a completely healthy way after chemically neutralizing it with alkaline components. Despite the acid residues on the surface of the implants, there have been no large-scale studies so far. As a result of some implant surgeries, early implant losses that cannot be attributed to any cause can be seen. If there is acid residue left on the surface and if contact with these acid molecules directly with the bone in the surgical area, this can cause direct primary bone destruction. For this reason, our study may be a new perspective in light of the primary resorption and osseointegration problems of implants.

REFERENCES

Al-Hashedi, A.A., Laurenti, M., Benhamou, V. and Tamimi, F. (2016), “Decontamination of Titanium Implants Using Physical Methods”, *Clinical Oral Implants Research*, 28, 1013–1021, https://doi.org/10.1111/clr.12914.

Anil, S., Anand, P.S., Alghamdi, H. and Jansen, J.A. (2011), “Dental Implant Surface Enhancement and Osseointegration”, in: I. Turkyilmaz (ed.), *Implant Dentistry – A Rapidly Evolving Practice*, 83-108, https://doi.org/10.5772/16475.

Bahraminasab, M., Bozorg, M., Ghaffari, S. and Kavakebian, F. (2019), “Electrochemical Corrosion of Ti-Al_2O_3 Biocomposites in Ringer’s Solution”, *Journal of Alloys and Compounds*, 777, 34–43, https://doi.org/10.1016/j.jallcom.2018.09.313.

Chaturvedi, T.P. (2009), “An Overview of the Corrosion Aspect of Dental Implants (Titanium and Its Alloys)”, *Indian Journal of Dental Research*, 20, 91–98, https://doi.org/10.4103/0970-9290.49068.

Dhaliwal, J.S., Rahman, N.A., Knights, J., Ghani, H. and de Albuquerque Junior, R.F. (2019), “The Effect of Different Surface Topographies of Titanium Implants on Bacterial Biofilm: A Systematic Review”, *SN Applied Sciences*, 1, 1–16, https://doi.org/10.1007/s42452-019-0638-6.

Duddeck, D.U., Albrektsson, T., Wennerberg, A., Larsson, C. and Beuer, F. (2019), “On the Cleanliness of Different Oral Implant Systems: A Pilot Study”, *Journal of Clinical Medicine*, 8(9), 1280, https://doi.org/10.3390/jcm8091280.

Giner, L., Mercade, M., Torrent, S., Punset, M., Perez, R.A., Delgado, L.M. and Gil, F.J. (2017), "Double Acid Etching Treatment of Dental Implants for Enhanced Biological Properties", *Journal of Applied Biomaterials and Functional Materials*, 16, 83–89, https://doi.org/10.5301/jabfm.5000376.

Henningsen, A., Smeets, R., Heuberger, R., Jung, O.T., Hanken, H., Heiland, M., Cacaci, C. and Precht, C. (2018), "Changes in Surface Characteristics of Titanium and Zirconia after Surface Treatment with Ultraviolet Light or Non-Thermal Plasma", *European Journal of Oral Sciences*, 126(2), 126–134, https://doi.org/10.1111/eos.12400.

Katona, B., Dobos, G. and Kiss, G. (2015), "Examination of the Surface Phosphorus Content of Anodized Medical Grade Titanium Samples", in: T. Berecz, K. Májlinger, I.N. Orbulov and P.J. Szabó (eds.), *Materials Science Forum*, 812, 339–344, https://doi.org/10.4028/www.scientific.net/msf.812.339.

Mombelli, A., Hashim, D. and Cionca, N. (2018), "What is the Impact of Titanium Particles and Biocorrosion on Implant Survival and Complications? A Critical Review", *Clinical Oral Implants Research*, 29(S18), 37–53, https://doi.org/10.1111/clr.13305.

Noumbissi, S., Scarano, A. and Gupta, S. (2019), "A Literature Review Study on Atomic Ions Dissolution of Titanium and Its Alloys in Implant Dentistry", *Materials (Basel)*, 12(3), 368, https://doi.org/10.3390/ma12030368.

Oshida, Y., Tuna, E.B., Aktören, O. and Gençay, K. (2010), "Dental Implant Systems", *International Journal of Molecular Sciences*, 11(4), 1580–1678, https://doi.org/10.3390/ijms11041580.

Rezaei, N.M., Hasegawa, M., Ishijima, M., Nakhaei, K., Okubo, T., Taniyama, T., Ghassemi, A., Tahsili, T., Park, W., Hirota, M. and Ogawa, T. (2018), "Biological and Osseointegration Capabilities of Hierarchically (Meso-/Micro-/Nano-Scale) Roughened Zirconia", *International Journal of Nanomedicine*, 13, 3381–3395, https://doi.org/10.2147/ijn.s159955.

Sasikumar, Y., Indira, K. and Rajendran, N. (2019), "Surface Modification Methods for Titanium and Its Alloys and Their Corrosion Behavior in Biological Environment: A Review", *Journal of Bio- and Tribo-Corrosion*, 5, 1–25, https://doi.org/10.1007/s40735-019-0229-5.

Schlee, M., Rathe, F., Brodbeck, U., Ratka, C., Weigl, P. and Zipprich, H. (2019), "Treatment of Peri-implantitis – Electrolytic Cleaning Versus Mechanical and Electrolytic Cleaning – A Randomized Controlled Clinical Trial – Six-Month Results", *Journal of Clinical Medicine*, 8(11), 1909, https://doi.org/10.3390/jcm8111909.

Shadid, R.M., Sadaq, N.R. and Othman, S.A. (2014), "Does the Implant Surgical Technique Affect the Primary and/or Secondary Stability of Dental Implants? A Systematic Review", *International Journal of Dentistry*, 2014, 204838, https://doi.org/10.1155/2014/204838.

Shang, F., Chen, S., Liang, J. and Liu, C. (2019), "Preparation and Photocatalytic Properties of ZnO Deposited TiO_2 Nanotube Arrays by Anodization", *Journal of Nanoscience and Nanotechnology*, 19(4), 2070–2077, https://doi.org/10.1166/jnn.2019.15797.

Šupová, M. (2015), "Substituted Hydroxyapatites for Biomedical Applications: A Review", *Ceramics International*, 41(8), 9203–9231, https://doi.org/10.1016/j.ceramint.2015.03.316.

Takeuchi, M., Abe, Y., Yoshida, Y., Nakayama, Y., Okazaki, M. and Akagawa, Y. (2003), "Acid Pretreatment of Titanium Implants", *Biomaterials*, 24(10), 1821–1827, https://doi.org/10.1016/s0142-9612(02)00576-8.

Turkyilmaz, I. (Ed.) (2011), *Implant Dentistry – A Rapidly Evolving Practice*, InTech, https://doi.org/10.5772/706.

Wennerberg, A. and Albrektsson, T. (2010), "On Implant Surfaces: A Review of Current Knowledge and Opinions", *The International Journal of Oral & Maxillofacial Implants*, 25(1), 63–74.

Wheelis, S.E., Wilson Jr., T.G., Valderrama, P. and Rodrigues, D.C. (2017), "Surface Characterization of Titanium Implant Healing Abutments before and after Placement", *Clinical Implant Dentistry and Related Research*, 20(2), 180–190, https://doi.org/10.1111/cid.12566.

Yu, Y, Jin, G., Xue, Y., Wang, D., Liu, X. and Sun, J. (2016), "Multifunctions of Dual Zn/Mg Ion Co-implanted Titanium on Osteogenesis, Angiogenesis and Bacteria Inhibition for Dental Implants", *Acta Biomaterialia*, 49, 590–603, https://doi.org/10.1016/j.actbio.2016.11.067.

https://doi.org/10.24264/icams-2022.II.20

https://doi.org/10.24264/icams-2022.II.20