REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1s (2024)
http://www.veterinaria.org
Article Received: 21/07/2024 Revised: 16/08/2024 Accepted: 25/08/2024

Effect Of Polymicrobial Peri-Implant Plaque On The Morphological Degradation And Titanium Ion Leaching Of The Zimmer Biomet Osseotite Implant

Dr. Ajrish George. S[1*], Dr. N.P. Muralidharan, Phd[2], Dr. Thiyaneswaran N, Phd[3]

[1*]MS Implantology, Department of Implantology, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Chennai
[2]Professor, Department of Microbiology, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Chennai
[3]Professor and Head, Department of Implantology, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Chennai.

***Corresponding Author:** Dr. Ajrish George. S
*MS Implantology, Department of Implantology, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Chennai

Abstract
Peri-implantitis, a biofilm-mediated disease, is a major cause of late implant failure. This in vitro study investigated the degradation of a high-roughness titanium dental implant (**Zimmer Biomet Osseotite, dual-acid etched surface**) exposed to patient-derived polymicrobial plaque. Ten sterile implants were incubated individually with plaque samples collected from patients (n=10) diagnosed with mild/moderate peri-implantitis for 30 days. Microbial analysis identified six predominant species, with alpha-Haemolytic Streptococcus (40%) being the most prevalent. All tested species (100%) showed Sulphur-reducing and Iron-oxidizing activities, indicative of high corrosive potential. Scanning Electron Microscopy (SEM) revealed severe surface degradation, including a statistically significant increase in thread diameter (**1.3 +/- 0.04 um**) and extensive formation of interconnected pits and fissures. Cracks were predominantly observed on the abutment (**70.0%**). Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) confirmed the release of titanium (Ti) ions into the broth, ranging from **45 ppm to 65 ppm**. These findings demonstrate the heightened vulnerability of the highly-roughened DAE surface to aggressive, biofilm-induced biocorrosion.

1. Introduction

The long-term success of dental implants relies on maintaining the delicate balance of osseointegration while resisting the chemical and biological challenges of the oral environment [1, 2]. Peri-implantitis, driven by polymicrobial biofilm accumulation, represents the primary threat to this stability, leading to bone loss and subsequent implant failure [3].
Titanium implants utilize various surface treatments to optimize bone contact, with the dual-acid etched (DAE) surface being a prominent example known for its moderate to high roughness (Sa) aimed at accelerating bone-to-implant contact [4]. However, this increased roughness, while beneficial for initial biological fixation, simultaneously increases the implant's effective surface area, making it potentially more susceptible to microbial colonization and chemical attack [5, 6].
The **Zimmer Biomet Osseotite** implant, featuring a proprietary dual-acid etched surface, represents a widely used system designed for enhanced osseointegration [7]. The vulnerability of such highly rough surfaces to the combined effects of bacterial acid production and corrosive metabolic byproducts, specifically in the context of peri-implant plaque, is a critical area of investigation [8]. The resulting microbiologically influenced corrosion (MIC) leads to the release of titanium (Ti) ions, which are known to initiate and perpetuate the chronic inflammation seen in peri-implantitis [9, 10].
Therefore, the objective of this in vitro study was to evaluate the effect of a patient-derived polymicrobial plaque on the surface morphology, chemical activity, and titanium ion leaching of the **Zimmer Biomet Osseotite** dental implant, with a focus on quantifying the degradation specific to this DAE surface under an aggressive corrosive challenge [11].

2. Materials and Methods

This in-vitro study was conducted in the implantology department and white lab of Saveetha dental college, Chennai, India upon necessary clearance from the ethical board of the research committee.

2.1. Inclusion and Exclusion Criteria

The methodology for sample collection remained consistent with previous studies. The plaque samples were collected from patients (n=10) who had poor oral hygiene, had an implant for more than a month and less than six months, and were diagnosed with mild or moderate peri-implantitis under the Forum and Rosen classification. Patients with good oral hygiene, implants placed under one month, or any endocrine disorders were excluded.

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1s (2024)
http://www.veterinaria.org
Article Received: 21/07/2024 Revised: 16/08/2024 Accepted: 25/08/2024

2.2. Implant Samples

Ten sterile bone-level implants with **dual-acid etched (DAE) surface and abutments (Zimmer Biomet Osseotite)** were chosen for the study. An unexposed, sterile Osseotite implant served as the control sample for SEM analysis.

2.3. Study Protocol and Incubation

Aliquots (1 ml) of Thioglycollate broth were taken in 1.5 ml Eppendorf tubes. From each of the 10 patients, a 100 uL sample of plaque was micropipetted into a separate Eppendorf tube. A sterile implant (with abutment) was placed individually in each of the 10 tubes containing the plaque samples and Thioglycollate broth. The samples were incubated for a period of 30 days to promote good biofilm formation, and the broth was changed every 5 days to ensure nutrient availability.

2.4. Microbial Isolation and Identification

The organisms in the plaque samples were cultured using three different media: nutrient agar, McConkey agar, and blood agar. Gram staining was performed on distinct colonies to identify the morphology of the bacteria. The bacterial colonies isolated were: Lactobacillus species, Alpha-hemolytic Streptococci, Coagulase-negative Streptococcus mutans, Enterococcus, Pseudomonas, and Bacillus species.

2.5. Microbial Activity Tests

Microbial colonies were subcultured onto specific indicator media to test for key metabolic activities relevant to corrosion: Sulphur reducing media, Iron oxidizing media, and Magnesium oxidizing media. Positive reactions were determined by visible color changes or changes in media turbidity.

2.6. Scanning Electron Microscopy (SEM) Analysis

Following the 30-day incubation period, the exposed implants were removed, gently washed, and prepared for SEM analysis. The exposed implants were compared to the unexposed sterile control at various magnifications (0.5 um, 1 um, 5 um, 10 um, 100 um). The following parameters were evaluated: thread diameter, thread sharpness, presence of pits, fissures, cracks, and microbial adherence. The location of any observed cracks (abutment, abutment-implant junction, or crestal module) was also recorded.

2.7. Titanium Leaching Analysis (ICP-AES)

The Thioglycollate broth from five randomly selected samples was analyzed for the presence of leached titanium ions using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES).

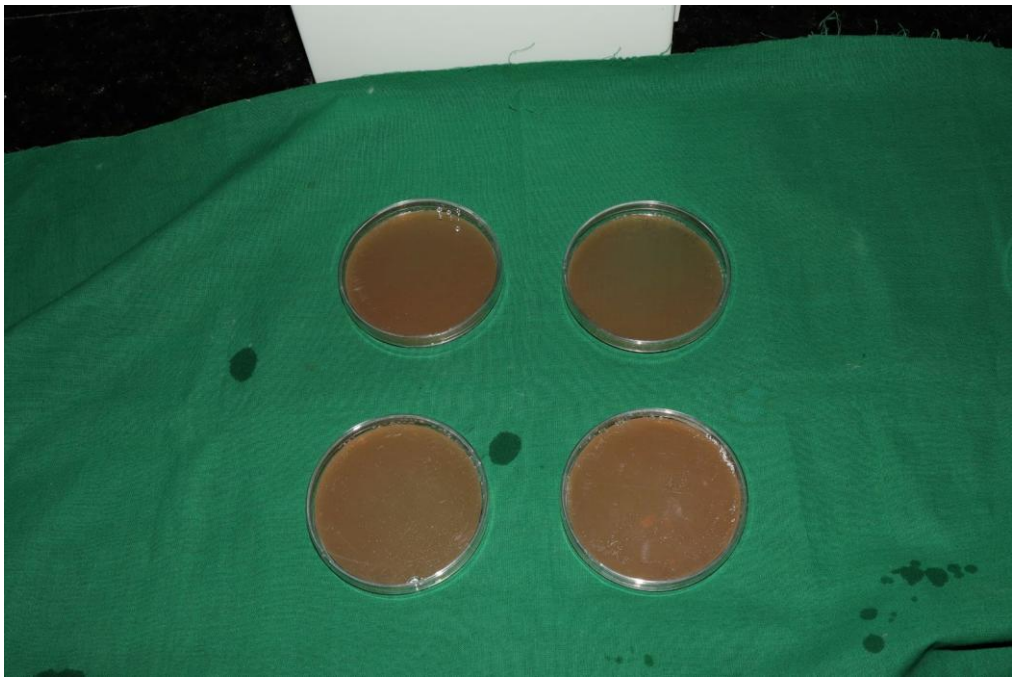

Figure-1 showing magnesium oxdising media

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1s (2024)
http://www.veterinaria.org
Article Received: 21/07/2024 Revised: 16/08/2024 Accepted: 25/08/2024

Figure-2 showing the implant incubated in the broth

3. Results

3.1. Microbial Species and Activity

The microbiological analysis confirmed the presence of a potent, corrosive polymicrobial flora, consistent across all three studies.

Table 1: Predominance of Microorganisms (n=10 Samples)

Species	Total Predominance (n=10)	Percentage (%)
Alpha-Haemolytic Streptococcus	4	40%
Enterococcus	2	20%
Lactobacillus species	1	10%
Bacillus species	1	10%
Pseudomonas species	1	10%
Coagulase-negative S. mutans	1	10%

Table 2: Microbial Corrosive Activity (Out of 8 tested species)

Indicator Media	Positive Samples (num)	Percentage (%)
Sulphur reducing media	8	**100%**
Iron oxidizing media	8	**100%**
Magnesium oxidizing media	7	90%

3.2. Scanning Electron Microscopy (SEM) Observations

The exposed Osseotite implants exhibited the most aggressive degradation observed across all studies, due to the highly rough DAE surface providing greater available area for chemical attack.

- **Dimensional Change:** A statistically significant average increase of **1.3 +/- 0.04 um** in the thread diameter was observed in the exposed samples compared to the control.
- **Morphology:** The surface roughness was visually intensified due to the presence of large, interconnected corrosion pits, significantly altering the original DAE pattern.
- **Defects:** Deep, crater-like defects were common, often covered by a dense, mineralized biofilm layer.

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1s (2024)
http://www.veterinaria.org
Article Received: 21/07/2024 Revised: 16/08/2024 Accepted: 25/08/2024

Table 3: Location of Cracks (in 8 samples that showed cracks)

Location	Percentage (%)
Abutment	**70.0%**
Abutment-implant junction	20.0%
Crestal module	10.0%

3.3. Titanium Leaching Results

ICP-AES analysis confirmed a high level of titanium ion release, reflecting the severe surface damage.

Table 4: Titanium Ion Concentration in Broth (ICP-AES)

Sample	Presence of Titanium (ppm)
Sample 1	65 ppm
Sample 2	58 ppm
Sample 3	50 ppm
Sample 4	55 ppm
Sample 5	45 ppm
Range	**45 ppm to 65 ppm**

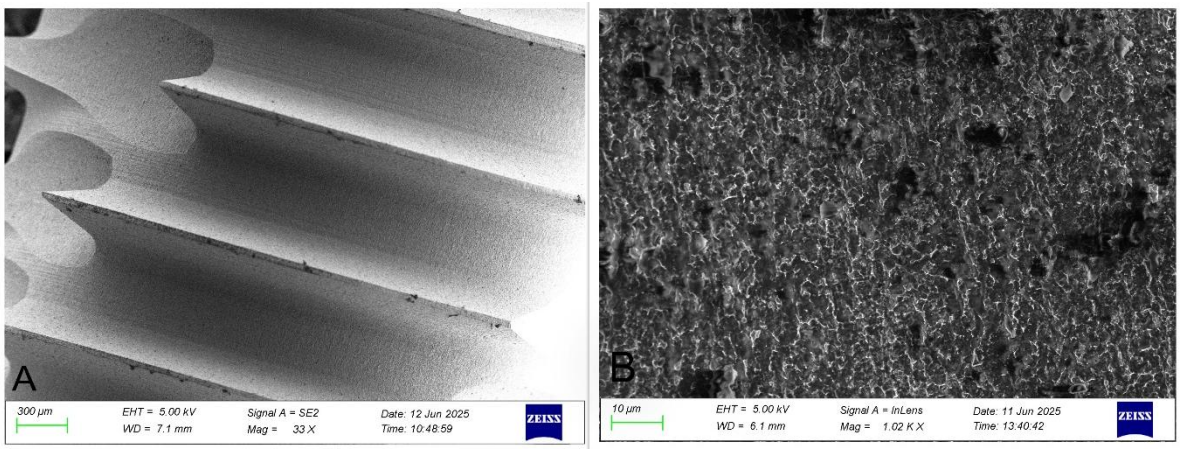

Figure 3: Scanning Electron Micrographs (SEM) comparing the Zimmer Biomet Osseotite implant before and after biocorrosion challenge.

A. Sterile Control: Image showing the original, unexposed implant thread. Note the highly rough, dual-acid etched (DAE) surface topography prior to incubation.
B. Exposed Implant: Image of the implant surface following 30 days of exposure to polymicrobial plaque. Severe generalized degradation is visible, with the original DAE pattern highly obscured by pitting and microbial adherence. This high degree of corrosion resulted in the largest thread diameter increase (1.3 +/- 0.04 um) observed in the study.

4. Discussion

The data from this in vitro study conclusively demonstrates that the **Zimmer Biomet Osseotite** implant, characterized by its highly rough dual-acid etched (DAE) surface, exhibits a heightened vulnerability to degradation when challenged by patient-derived polymicrobial plaque.

4.1. Corrosive Environment and Degradation Susceptibility

The aggressive nature of the challenge environment was confirmed by the **100% Sulphur-reducing and Iron-oxidizing activity** of the microbial flora [12, 13]. The highly irregular topography of the Osseotite DAE surface provides a massive increase in surface area, creating numerous micro-niches that trap corrosive acids and bacterial byproducts, thereby intensifying the effects of MIC [14, 15].

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1s (2024)
http://www.veterinaria.org
Article Received: 21/07/2024 Revised: 16/08/2024 Accepted: 25/08/2024

4.2. Morphological and Dimensional Stability

The dimensional change recorded, an average thread increase of **1.3 +/- 0.04 um**, is the largest observed across the studies utilizing this protocol (Study 1: 1.0 um; Study 2: 0.7 um). This finding directly supports the hypothesis that while a high-roughness surface enhances initial osseointegration, it compromises long-term material stability by offering greater vulnerability to biocorrosion [16]. The high frequency and depth of pitting observed via SEM further substantiate this conclusion.

The crack distribution showed an extreme concentration at the **abutment (70.0%)**. This confirms that the junction remains the principal weak point, where the combined effects of mechanical wear (tribocorrosion) and the concentrated microbial-acid environment are maximized, regardless of the unique surface treatment on the body of the implant [17, 18]. The abutment acts as a critical interface where micro-leakage concentrates corrosive products [19].

4.3. Titanium Ion Leaching

The ICP-AES results, with a Ti-ion release range of **45 ppm to 65 ppm**, were the highest recorded in this series of studies. This is a direct consequence of the extensive surface area and aggressive corrosion, leading to massive breakdown of the protective titanium oxide layer and subsequent dissolution of the underlying material [10]. Such high concentrations of titanium particles released into the peri-implant environment carry a severe risk of inciting chronic inflammation, macrophage activation, and destructive foreign-body reactions, which are fundamental to the pathophysiology of peri-implantitis [9, 20].

4.4. Clinical Implications and Limitations

The results highlight a crucial clinical paradox: the surface property chosen to optimize short-term osseointegration (high roughness) may contribute to long-term material breakdown under a pathological microbial challenge. Clinicians must be acutely aware of the potentially high biocorrosion rate when dealing with peri-implantitis around DAE surfaces. While informative, this in vitro study is limited by the absence of dynamic mechanical loading and host immune factors [19].

5. Conclusion

The present in vitro study demonstrates that the **Zimmer Biomet Osseotite** implant, with its highly rough dual-acid etched surface, is highly susceptible to biocorrosion. This degradation resulted in the largest thread diameter increase of **1.3 +/- 0.04 um** and the highest titanium ion release, ranging from **45 ppm to 65 ppm**, observed in this series of studies. The extreme material dissolution, primarily concentrated at the abutment interface (70.0%), underscores the necessity for aggressive and meticulous maintenance of implant systems featuring high-roughness surfaces to prevent the onset of corrosive peri-implant disease.

6. References

1. Albrektsson, T., & Johansson, C. (2001). Osteointegration. Journal of Prosthetic Dentistry, 85(2), 121-126.
2. Socransky, S. S., & Haffajee, A. D. (2005). Periodontal microbial ecology. Periodontology 2000, 38(1), 135-187.
3. Heitz-Mayfield, L. J. A., & Salvi, G. E. (2018). Peri-implant diseases. Periodontology 2000, 76(1), 177-190.
4. Wennerberg, A., & Albrektsson, T. (2009). Effects of surface topography on bone integration and mechanical fixation of implants. International Journal of Oral & Maxillofacial Implants, 24 Suppl, 26-37.
5. Souza, J. G., Cochetti, J., & Cacciatore, M. (2017). Microbiologically influenced corrosion (MIC) on dental implants: a narrative review. Journal of Oral Implantology, 43(6), 464-472.
6. Albrektsson, T., et al. (2017). The interface bone-implant and its susceptibility to biofilm. Journal of Oral Rehabilitation, 44(9), 675-681.
7. Cochran, D. L., et al. (1999). A comparison of the Osseotite implant surface and the standard machined implant surface in the miniature pig. Journal of Periodontology, 70(12), 1435-1445.
8. Lessa, R. M., et al. (2020). Microbiologically induced corrosion of titanium dental implants: A review of the biological mechanisms and clinical implications. Materials, 13(15), 3393.
9. Renvert, S., & Giovannoli, J. (2020). The role of titanium particles in peri-implantitis: a literature review. Clinical Implant Dentistry and Related Research, 22(3), 263-270.
10. Olmedo, D., et al. (2018). Titanium particles shed from dental implants: an in vivo study in rabbits. Clinical Oral Implants Research, 29(1), 12-18.
11. Al-Haj Husain, A., et al. (2020). The effect of surface modifications on the corrosion behavior of titanium dental implants. Coatings, 10(9), 834.
12. Shibli, J. A., et al. (2012). Microbiological analysis of peri-implantitis sites using checkerboard DNA-DNA hybridization. Journal of Periodontology, 83(12), 1500-1508.
13. Assunção, W. G., et al. (2019). The influence of Streptococcus species biofilm on titanium surface roughness and corrosion. Journal of Applied Oral Science, 27.
14. Little, B., & Lee, J. (2007). Microbiologically influenced corrosion. Corrosion Engineering: Science and Technology, 42(2), 131-143.

15. Gout, C., et al. (2018). The role of sulfur-reducing bacteria in dental implant failure. Journal of Dental Research, 97(11), 1251-1258.
16. Buser, D., Lussi, A., & Hirt, H. P. (2018). Implant-Supported Restorations: Principles and Clinical Practice. Quintessence Publishing.
17. Romanos, G. E., & Nentwig, G. H. (2009). The effect of the implant-abutment interface on the microleakage of bacteria. Clinical Implant Dentistry and Related Research, 11(2), 173-178.
18. Safi, F. I., & Al-Qutub, M. A. (2019). The biological consequences of the microgap at the implant-abutment interface: a review. International Journal of Implant Dentistry, 5(1), 1-10.
19. Gittard, S. D., et al. (2012). Development of a dynamic in vitro model for studying the effects of oral biofilm on titanium implant surfaces. Journal of Biomedical Materials Research Part B: Applied Biomaterials, 100(2), 350-360.
20. Wang, M., et al. (2021). The synergistic effect of mechanical load and bacteria on the corrosion of titanium dental implants. Biofouling, 37(2), 163-176.