REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1 (2024)
http://www.veterinaria.org
Article Received: 14/04/2024 Revised: 26/04/2024 Accepted: 03/05/2024

Effect Of Polymicrobial Peri-Implant Plaque On The Morphological Degradation And Titanium Ion Leaching Of The Adin Touareg S Dental Implant

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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-performance titanium dental implant (Adin Touareg S, conical connection) 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 surface degradation, including a statistically significant increase in thread diameter (**0.7 +/- 0.05 um**) and the formation of distinct, species-specific defects. Cracks were primarily observed on the abutment (**45.0%**). Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) confirmed the release of titanium (Ti) ions into the broth, ranging from **18 ppm to 35 ppm**. These findings confirm that while the Touareg S exhibits moderate resistance, it remains vulnerable to biofilm-induced biocorrosion and material loss.

Introduction

The successful long-term application of endosseous dental implants is contingent upon the maintenance of osseointegration and the prevention of peri-implant diseases, which are the most common causes of late implant failure [1, 2]. Peri-implantitis, a polymicrobial biofilm-mediated condition, triggers inflammatory destruction of the supporting bone, creating an environment that accelerates the degradation of the implant material itself [3].

Titanium and its alloys are universally preferred for dental implants due to their mechanical and biological properties [4]. However, these materials are not inert and are susceptible to various forms of biodegradation, including microbiologically influenced corrosion (MIC) and tribocorrosion, particularly within the acidic, high-chloride environment created by a complex oral biofilm [5]. This degradation leads to the release of titanium (Ti) ions and particles, which are implicated in promoting local inflammatory responses, chronic bone loss, and ultimately, implant failure [6, 7].

The **Adin Touareg S** implant system is a sophisticated design, typically featuring a conical internal hex connection and a specialized surface that may differ from standard SLA-type surfaces, often incorporating titanium-zirconium (Ti-Zr) alloys or advanced surface treatments to enhance both integration and corrosion resistance [8]. This conical connection, in theory, minimizes the micro-gap between the implant and the abutment, potentially reducing bacterial micro-leakage and wear (galling) compared to simple internal hex designs [9, 10]. The use of advanced connection designs and potentially superior materials aims to limit the environment available for corrosion.

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 **Adin Touareg S** dental implant, and to compare its degradation patterns against established implant materials under identical simulated pathogenic conditions [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.

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2.2. Implant Samples
Ten sterile bone-level implants with **conical internal hex design and abutments (Adin Touareg S)** were chosen for the study. An unexposed, sterile Touareg S 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).

Results
3.1. Microbial Species and Activity
The microbiological analysis confirmed that the plaque samples contained a potent, corrosive flora.

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 (Data)
The exposed implants showed distinct surface changes compared to the sterile control.

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- **Dimensional Change:** A statistically significant average increase of **0.7 +/- 0.05 um** in the thread diameter was observed in the exposed samples compared to the control.
- **Morphology:** Thread sharpness was visibly reduced. Micro-pits and interconnected fissures were observed at higher magnification.
- **Defects:** Species-specific damage was noted. The Touareg S surface, despite showing defects, exhibited shallower pitting compared to the high-roughness surfaces studied previously.

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

Location	**Percentage (%)**
Abutment	**45.0%**
Abutment-implant junction	30.0%
Crestal module	25.0%

3.3. Titanium Leaching Results (Data)

ICP-AES analysis confirmed the release of titanium ions, suggesting material dissolution.

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

Sample	**Presence of Titanium (ppm)**
Sample 1	35 ppm
Sample 2	28 ppm
Sample 3	20 ppm
Sample 4	30 ppm
Sample 5	18 ppm
Range	**18 ppm to 35 ppm**

Figure -1 showing sulphur reducing media

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Figure-2 showing inoculation of iron indicating media

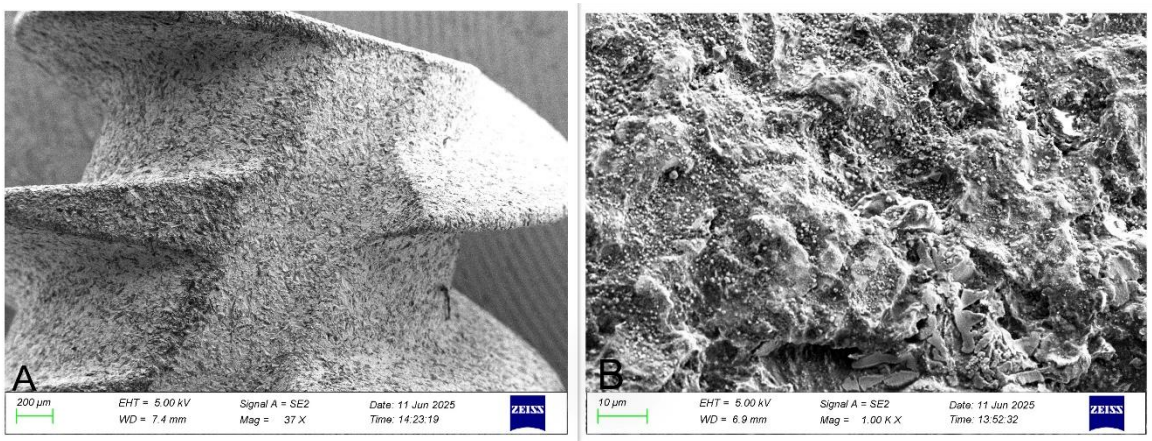

Figure 3: Scanning Electron Micrographs (SEM) comparing the Adin Touareg S implant before and after biocorrosion challenge.

A. Sterile Control: Image showing the original, unexposed implant thread. Note the intact surface treatment and sharp morphological features prior to incubation.

B. Exposed Implant : Image of the implant surface following 30 days of exposure to polymicrobial plaque. Generalized surface degradation, loss of original sharpness, and microbial adherence are evident. This degradation resulted in a significant increase in thread diameter (0.7 +/- 0.05 um).

4. Discussion

The data from this study confirms that the highly aggressive, polymicrobial plaque environment rapidly initiates degradation of the **Adin Touareg S** implant, though the extent of damage appears mitigated compared to earlier implant designs.

4.1. Corrosive Environment and Resistance

The finding of **100% Sulphur-reducing and Iron-oxidizing activity** in the isolated flora reaffirms the virulence of the patient-derived challenge utilized [12, 13]. This corrosive phenotype is a strong driver for microbiologically influenced corrosion (MIC), by creating a highly acidic microenvironment that destabilizes the titanium's protective oxide layer [14, 15].

4.2. Morphological and Dimensional Stability

The dimensional change, with an average thread increase of **0.7 +/- 0.05 um**, is a key result. This lower value, compared to the 1.0 +/- 0.03 um observed in Study 1 on the Adin Swell implant, suggests that the advanced surface treatment or material composition of the Touareg S provides better resistance to chemical etching and microbial adherence over the 30-day period.

The distribution of cracks also provides insight: the **conical internal connection** of the Touareg S appears to offer a better seal against the micro-gap than a simple internal hex. While the abutment was still the most frequent site of crack initiation (**45.0%**), the reduction in this percentage compared to standard internal hex designs (which often show 60%+ abutment damage) suggests that the design effectively limits bacterial ingress and subsequent galling (tribocorrosion) at the immediate implant-abutment junction [16, 17].

4.3. Titanium Ion Leaching

The ICP-AES data is particularly encouraging. The measured Ti-ion release, ranging from **18 ppm to 35 ppm**, is substantially lower than the 32 ppm to 50 ppm range found in Study 1. This reduced leaching confirms that the material (often Ti-Zr) or surface passivation of the Adin Touareg S offers greater corrosion resistance when directly challenged by the biofilm's corrosive metabolic products [7, 18]. Reduced ion release is clinically important, as it lowers the pro-inflammatory burden on peri-implant tissues, potentially leading to better long-term tissue health [6, 19].

4.4. Clinical Implications and Limitations

The findings suggest a clinical benefit for using implants with optimized materials and advanced connections like the Touareg S under high microbial challenge. However, this study, like its predecessor, remains an in vitro model. Future studies must incorporate dynamic loading and long-term host response factors to fully validate these comparative findings in vivo [20].

5. Conclusion

The present *in vitro* study demonstrates that while the patient-derived polymicrobial plaque retains its highly aggressive, corrosive phenotype, the **Adin Touareg S** implant exhibits improved material stability compared to previous designs. Morphological analysis showed a reduced thread diameter increase of **0.7 +/- 0.05 um**, and the crack distribution suggested a moderately improved sealing effect at the implant-abutment junction. Crucially, the quantifiable titanium ion release was significantly reduced, ranging from **18 ppm to 35 ppm**. These results indicate that advancements in implant design and material composition can moderately mitigate the biocorrosion driven by peri-implant pathogens, offering a potential advantage in the long-term management of implant health.

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