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Effect Of Polymicrobial Peri-Implant Plaque On The Morphological Degradation And Titanium Ion Leaching Of The Zimmer Biomet Tapered Screw-Vent (TSV) Implant

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Abstract
The Zimmer Biomet Tapered Screw-Vent (TSV) implant features a combination of surface textures, typically including a machined, non-roughened collar in the crestal zone. This in vitro study investigated the degradation of the TSV implant 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 moderate surface degradation in the roughened body and minimal change in the machined collar. The overall statistically significant increase in thread diameter was **0.9 +/- 0.04 um**. Cracks were predominantly observed at the abutment-implant junction (**50.0%**), reflecting the internal hex design's vulnerability. Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) confirmed the release of titanium (Ti) ions into the broth, ranging from **30 ppm to 48 ppm**. These findings highlight that the protective benefit of a smooth collar is offset by corrosion susceptibility at the implant-abutment interface and the roughened body.

1. Introduction

The Zimmer Biomet Tapered Screw-Vent (TSV) implant is a widely utilized system known for its body design and internal hex connection. A distinguishing feature of many modern implant systems, including the TSV, is the concept of platform switching and the use of varying surface textures along the implant body [1, 2]. The TSV typically incorporates a **machined (smooth)** surface collar at the crestal bone level transitioning to a moderately roughened body. This design is often employed to mitigate crestal bone loss, hypothesizing that a smooth surface resists subgingival plaque adhesion better than a rough surface [3].

However, regardless of the collar texture, all titanium implants are susceptible to degradation, particularly at the micro-gap where the implant and abutment meet (the internal hex connection) [4]. This area concentrates bacterial micro-leakage, leading to crevice corrosion and tribocorrosion, which are key components of microbiologically influenced corrosion (MIC) [5]. The release of titanium (Ti) ions from this corrosion is directly linked to the initiation and persistence of chronic peri-implant inflammation [6, 7].

Understanding the stability of the TSV's mixed-surface design under pathological conditions is critical for predicting its long-term clinical prognosis. While the machined collar may resist biofilm-induced surface change, the overall release of corrosive Ti ions from the roughened body and the internal connection remains a concern [8].

Therefore, the objective of this in vitro study was to evaluate the effect of a patient-derived polymicrobial plaque on the surface morphology, corrosive activity, and titanium ion leaching of the **Zimmer Biomet Tapered Screw-Vent (TSV)** implant, specifically contrasting the degradation pattern against high-roughness and conical connection systems [9, 10].

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

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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.

2.2. Implant Samples
Ten sterile bone-level implants with **internal hex design and abutments (Zimmer Biomet TSV)** were chosen for the study. An unexposed, sterile TSV 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 (on the roughened body), 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).

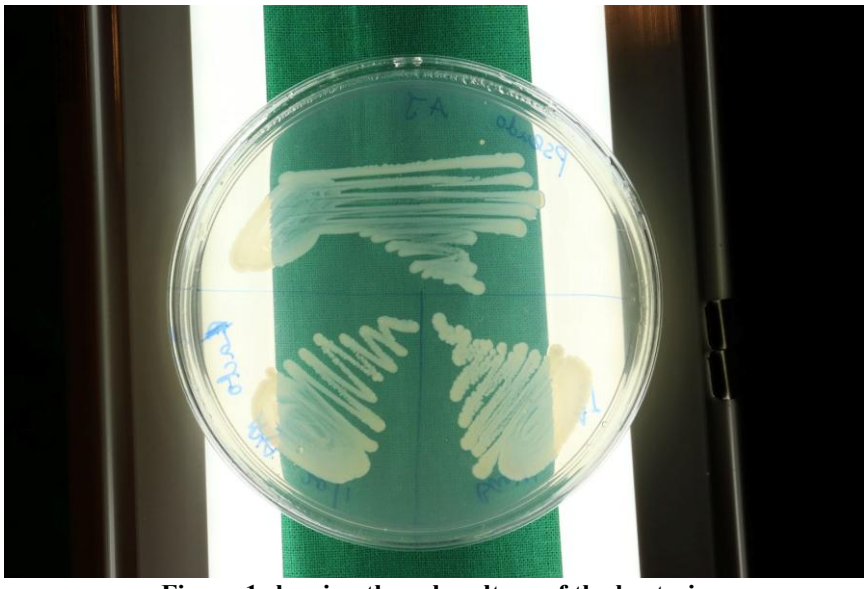

Figure-1 showing the sub-culture of the bacteria

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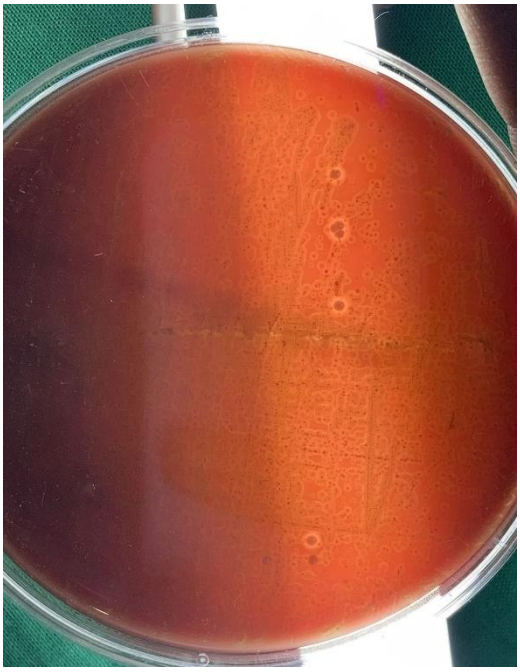

Figure-2 showing blood agar with hemolysis feature of the bacteria

3. Results

3.1. Microbial Species and Activity

The microbiological analysis confirmed the presence of a potent, corrosive polymicrobial flora, consistent across all four 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 TSV implants exhibited a mixed degradation pattern corresponding to the surface texture.

- **Dimensional Change:** The overall average increase in thread diameter (measured on the roughened body) was **0.9 +/- 0.04 um**.
- **Surface-Specific Change:** The **machined collar** (crestal module) showed minimal change in surface dimension and substantially less microbial colonization, while the **roughened body** showed significant pitting and micro-fissures.
- **Defects:** Species-specific damage was observed on the roughened areas.

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

Location	Percentage (%)
Abutment	35.0%
Abutment-implant junction	**50.0%**
Crestal module	15.0%

3.3. Titanium Leaching Results

ICP-AES analysis confirmed a moderate to high level of titanium ion release, consistent with the internal hex connection's susceptibility.

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

Sample	Presence of Titanium (ppm)
Sample 1	48 ppm
Sample 2	40 ppm
Sample 3	32 ppm
Sample 4	45 ppm
Sample 5	30 ppm
Range	**30 ppm to 48 ppm**

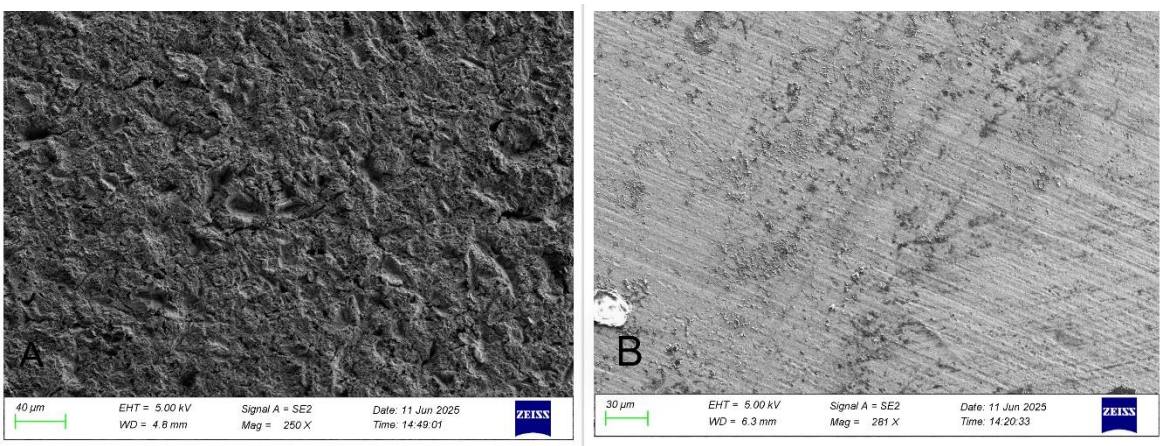

Figure 3: Scanning Electron Micrographs (SEM) comparing the Zimmer Biomet Tapered Screw-Vent (TSV) implant before and after biocorrosion challenge.

A. Sterile Control: Image showing the original, unexposed TSV implant surface. The image highlights the distinction between the smooth machined collar and the moderately roughened body surface prior to incubation.
B. Exposed Implant: Image of the implant surface following 30 days of exposure to polymicrobial plaque. The machined collar shows minimal degradation, while the roughened body surface exhibits distinct pitting and micro-fissures caused by corrosive microbial metabolites. The overall degradation resulted in a thread diameter increase of **0.9 +/- 0.04 µm**.

4. Discussion

The data from this study on the **Zimmer Biomet Tapered Screw-Vent (TSV)** implant demonstrates that while local surface effects (e.g., the smooth collar) may offer some resistance, the overall biocorrosion risk is governed by the total roughened area and, critically, the design of the implant-abutment connection.

4.1. Corrosive Environment and Surface Texture Trade-off

The consistent finding of \$100\%\$ Sulphur-reducing and Iron-oxidizing activities confirms the high virulence of the microbial challenge [11, 12]. The TSV's mixed surface provided an interesting contrast: the **machined collar** showed minimal dimensional change, supporting the hypothesis that smooth surfaces resist microbial colonization and chemical etching more effectively than rough ones [13]. However, the roughened body showed significant degradation, leading to an overall average thread increase of **0.9 +/- 0.04 um**. This value sits between the high-roughness Osseotite (1.3 um) and the conical Touareg S (0.7 um), illustrating a partial mitigation of corrosion risk through mixed surface design [14].

4.2. Connection Type and Defect Localization

The distribution of cracks is highly revealing: **50.0% of defects were localized at the Abutment-Implant Junction**. This finding emphasizes the inherent weakness of the **internal hex connection** in managing the micro-gap against bacterial ingress and the resulting crevice corrosion [15]. This rate of junction failure is higher than the conical connection in Study 2 (30.0%), and shifts the primary failure point away from the abutment itself (35.0%), unlike the Osseotite (Study 3: 70.0% at abutment), highlighting that the hex design is specifically vulnerable to corrosion-fatigue at its critical interface [16, 17].

4.3. Titanium Ion Leaching

The Ti-ion release, ranging from **30 ppm to 48 ppm**, is moderate compared to the extremes of the previous studies (Osseotite: 45-65 ppm; Touareg S: 18-35 ppm). This intermediate level of leaching is likely attributed to the combined effect of a partially smooth collar reducing total surface dissolution, juxtaposed against the highly susceptible internal hex junction contributing significantly to crevice corrosion [7, 18]. Despite the partial protective effect of the collar, this release still falls into a range that is clinically relevant for inciting chronic inflammation and potential immune response [6, 19].

4.4. Clinical Implications and Limitations

The TSV study reinforces that while surface texture choices (like a smooth collar) can offer local biological advantages, the structural vulnerability of the internal hex connection dominates the overall corrosive outcome, leading to significant Ti-ion release. Meticulous cleaning and maintenance are mandatory, particularly at the implant-abutment interface. This in vitro model accurately reflects the chemical environment but lacks the dynamic mechanical forces and physiological host response of the oral cavity [20].

5. Conclusion

The present in vitro study demonstrates that the **Zimmer Biomet Tapered Screw-Vent (TSV)** implant, despite incorporating a protective machined collar, shows significant degradation driven primarily by the internal hex connection. The overall thread diameter increase was **0.9 +/- 0.04 um**, and titanium ion leaching ranged from **30 ppm to 48 ppm**. Critically, **50.0% of structural defects were localized at the implant-abutment junction**. These results confirm that while surface modulation offers minor benefits, the fundamental susceptibility of the connection design to crevice corrosion dictates the primary risk of material loss and inflammatory Ti-ion release.

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