Identification of *Staphylococcus aureus* at the internal and external implant surfaces in individuals with periimplant disease: A cross-sectional study

**Abstract**

The objective of this study was to investigate the prevalence of *Staphylococcus aureus* (*S. aureus*) at internal and external dental implant surfaces in patients with periimplant disease.

**Materials and methods**

Samples for microbiological analysis were obtained from four types of sites in the following order: (1) the periimplant sulcular fluid (PISF) of each implant; (2) the gingival sulcus (GS) of the adjacent teeth; (3) the implant–abutment connection and abutment inner portions (IIP) of each implant; and (4) the oropharyngeal complex (OF)—oral, tongue and pharynx swabs were also collected.

Quantitative real-time polymerase chain reaction assays were carried out for total bacterial counts. The Kruskal–Wallis test was used to compare the *S. aureus* levels at the various sites.

**Results**

Mean bacterial counts of *S. aureus* were as follows: GS = 5.02 × 10^2; PISF = 0, IIP = 0 and OF = 0. A positive value was found for one out of the 35 sites for each group, but under the limit of quantification. For GS, one out of the 35 sites presented with a total bacterial count of 2.11 × 10^4. No statistically significant differences were found among groups regarding site location (*p* = 0.40).

**Conclusion**

Within the limits of this study, *S. aureus* could not be quantified in the PISF and inside the IIP affected by periimplantitis.

**Keywords**

Periimplantitis, periimplant disease, microbiological analysis, opportunistic pathogens, implant connection, *S. aureus*. 
Introduction

Dental implantology is a central part of modern dentistry concerned with the replacement of missing teeth in various clinical situations. In the past 30 years, the materials and methods of implant dentistry have undergone a substantial process of development and evolution. Implant surface, macrodesign and type of implant–abutment connection have been found to be of major relevance to initial healing and long-term stability. Since the number of implants placed has increased in the last ten years, optimal maintenance has become increasingly important. While in many cases, it has been reported that dental implants are a safe and predictable treatment method with high survival rates, they are not immune from biological and iatrogenic complications associated with improper treatment planning, surgical and prosthetic execution, or material failure, as well as maintenance problems. Also, the biological complications of periimplant mucositis and periimplantitis, which may result in soft- and hard-tissue defects, have been suggested to be relevant for later marginal bone loss.

Several approaches have been followed in seeking to understand the pathomechanism of periimplantitis. According to a consensus conference of the American Academy of Periodontology, bacterial colonization of the implant surface and the occurrence of bone loss indicate the point of no return in periimplantitis. Periimplantitis is characterized by an inflammatory process around an implant that includes both soft-tissue inflammation and progressive loss of periimplant supporting bone. Periimplantitis occurs primarily as a result of overwhelming periodontal insult and subsequent immune response. The connection to periodontitis as an infectious disease with comparable symptoms and outcomes suggests that investigating the associated local bacteria is fundamental to establishing the pathomechanism of periimplantitis.

The implant surface may be colonized with different pathogens other than periodontal bacteria. According to Albertini et al., opportunistic pathogens such as Pseudomonas aeruginosa, Staphylococcus aureus (S. aureus) and Candida albicans may be associated with implant failure. As suggested in an American Academy of Periodontology report, secondary diagnostic measures, that is, bacterial culturing, inflammatory markers and genetic factors, may be useful in the diagnosis of periimplant disease. According to Canullo et al., bacterial agglomerates around dental implants and their prosthodontic adjacent structures have been identified. These results suggested that all of the connections were contaminated after five years of functional loading; thus, the implant–abutment connection design might influence bacterial activity levels qualitatively and quantitatively, especially inside the implant connection. Furthermore, Cosyn et al. found that intracoronal compartments of screw-retained fixed restorations were heavily contaminated. Further investigations have shown that the restorative margin is the principal pathway for bacterial leakage and contamination of abutment screws, and bacteria most likely pass from the periimplant sulcus through the implant–abutment and abutment–prosthesis interfaces.

With the aim of identifying the pathogens that contribute toward the development of periimplantitis defects, different working groups have reported a cluster of bacteria, including Treponema forsythia and S. aureus, associated with periimplant disease. The presence of S. aureus as an opportunistic pathogen in the early stage of active periimplantitis in patients has also been confirmed by Mombelli and Décaillet. In addition, Salvi et al. reported that detection or lack of S. aureus at implant sites at 12 weeks resulted in the highest positive (i.e., 80%) and negative (i.e., 90%) predictive values for the incidence of periimplantitis, respectively. Moreover, Canullo et al. showed that S. aureus is present on the external and internal abutment surfaces if these are not cleaned before screwing.

The aim of the present study is to investigate the prevalence of S. aureus in the oral cavity of patients with active periimplantitis. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.

Materials & methods

Study design

This cross-sectional study evaluated data collected from 51 consecutive, partially edentulous patients aged 18 or older, who had been treated with a single implant-supported, cemented or screw-retained restoration functionally loaded for at least 12
months, with adjacent healthy teeth, but presenting signs of periimplant disease according to Mombelli and Décailliet.13 The patients were invited to participate and were enrolled after being given a detailed explanation of the study protocol. Written informed consent was obtained for each patient. All of the patients were recruited from the Department of Oral Surgery, University of Valencia, Spain, between September and December 2013. The investigation was conducted according to the principles outlined in the Declaration of Helsinki of 1975 for biomedical research involving human subjects, as amended in 2008. All patients were evaluated clinically and radiographically, and their medical histories were recorded. Bone volumes were analyzed using periapical radiographs.

The inclusion criteria were:
- presence of periimplant disease with a vertical bone defect of > 3 mm after implant integration according to Mombelli and Décailliet13
- age > 18
- no relevant medical conditions.

The exclusion criteria were:
- pregnancy or lactation
- known systemic disease or metabolic disorders (e.g., HIV) treated with medication detrimental to soft tissue and/or bone healing (e.g., high-dose steroid therapy, systemic treatment with tetracycline or tetracycline analogs, bone therapeutic levels of fluorides, bisphosphonates, medication affecting bone turnover, antibiotics for more than seven days or any investigational drug)—topical application of steroids and steroid application through inhalation were not exclusion criteria
- malignant diseases or other diseases treated with radiotherapy or chemotherapeutic agents (chemotherapy) during the past five years
- a history of head and neck radiation treatment owing to certain medical conditions
- a suspected allergy or incompatibility with any of the bone graft substitute components (calcium phosphates, PLGA, NMP)
- inability to comply with the protocol requirements, including severe alcohol or drug user
- involvement in any other clinical trial during the course of the present trial, or within a period of 30 days prior to its beginning or after its completion
- acute abscesses localized in the proximity of the prospective surgical field.

After full screening, 16 patients were to be excluded: 13 had taken systemic antibiotics during the three months prior to the microbiological sampling, two were pregnant, and one refused to participate. The final sample consisted of 35 individuals (20 male, 15 female) and 63 affected dental implants.

**Microbiological sampling**

Samples for microbiological analysis were obtained from four sites in each patient in the following order: (1) the periimplant sulcular fluid (PISF) of each implant; (2) the gingival sulcus (GS) of the adjacent teeth, used as control group; (3) the inner portions of the implant connection and the abutment of each implant (IIP); and (4) the oropharyngeal complex (OF). In all of the groups, the microbiological samples were taken using the GUIDOR Perio-Implant Diagnostic Kit (Sunstar Iberia, Sant Just Desvern, Spain), consisting of five sterile absorbent paper tips and an empty sterile 2 ml microtube.

Prior to collection of the subgingival plaque, supragingival plaque was eliminated from implants and teeth using a cotton tip, without penetrating the GS. OptraGate (Ivoclar Vivadent, Schaan, Liechtenstein) was used to retract the lips and cheeks completely and to ensure relative isolation. After light drying of the area with an air syringe, paper tips were inserted into the periimplant or periodontal sulci for 30 s. The samples from the inner surfaces of the implant–abutment complex were obtained after careful removal of both the restorations and the abutments, seeking to avoid contamination. One drop of RNA- and DNA-free water (Water Molecular Biology Reagent, W4502, Sigma-Aldrich, St. Louis, Mo., U.S.) was placed inside the implant connection and three paper tips were inserted for 30 s. The inner surface of the abutment was wet with a drop of RNA- and DNA-free water and smeared with two paper tips. The paper tips were placed into the microtubes and sent for microbiological analysis to the Institut Clinident laboratory (Aix-en-Provence, France) in the provided mailing envelopes. Finally, an oral environment analysis was performed using sterile cotton swabs collected from the cheeks, tongue, throat and pharynx of each patient.

After sample collection, the inner part of the implants and the abutment–restoration complex were cleaned with a 5% chlorhexidine
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Table 1: Investigated sites and bacterial counts.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Positive sites/ number of sites</th>
<th>TBC</th>
<th>Mean bacterial counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS</td>
<td>1/35</td>
<td>$2.11 \times 10^4$</td>
<td>$5.02 \times 10^2$</td>
</tr>
<tr>
<td>PISF</td>
<td>1/35</td>
<td>1 positive case, but below level of quantification</td>
<td>0</td>
</tr>
<tr>
<td>IIP</td>
<td>1/35</td>
<td>1 positive case, but below level of quantification</td>
<td>0</td>
</tr>
<tr>
<td>OF</td>
<td>1/35</td>
<td>1 positive case, but below level of quantification</td>
<td>0</td>
</tr>
</tbody>
</table>

GS: gingival sulcus of the adjacent teeth; PISF: periimplant sulcular fluid; IIP: inner parts of connection; OF: oropharyngeal complex.

solution in an ultrasonic bath for 10 min. After-ward, a new abutment screw was connected using a torque wrench (Torq Control, Anthogyr, Sallanches, France) until it reached a torque of 30 N cm, according to the manufacturer’s instructions. In order to verify proper fit between the dental restoration and the implant, standardized digital periapical radiographs were taken using a dental radiographic film holder (Rinn Centrator Bite, DENTSPLY RINN, Elgin, Ill., U.S.) and the paralleling technique.

Quantitative real-time polymerase chain reaction assays

Quantitative real-time polymerase chain reaction (PCR) assays were carried out for total bacterial counts (TBCs) for each target species, in a volume of 10 μL composed of 1× QuantiFast SYBR Green PCR (Qiagen, Hilden, Germany), 2 μL of DNA extract, and 1 μM of each primer. The species-specific PCR primers used in this study were provided by Institut Clinident and manufactured by metabion (Martinsried, Germany). Assays were carried out on the Rotor-Gene Q thermal cycling system (Qiagen) with the following program: for TBC, 95 °C for 30 s, followed by 40 cycles of 10 s at 95 °C, 10 s at 60 °C, and 35 s at 72 °C; for S. aureus, 95 °C for 5 min, followed by 40 cycles of 10 s at 95 °C, 10 s at 66 °C, and 35 s at 72 °C. A final melting curve analysis (70–95 °C in 1 °C steps for 5 s increments) was performed. Fluorescence signals were measured every cycle at the end of the extension step and continuously during the melting curve analysis. Serial dilutions of standard DNA, provided by Institut Clinident, were used in each reaction as external standards for absolute quantification of the target pathogen. Finally, the data were analyzed using Rotor-Gene Q Series Software (Qiagen).

Statistical analysis

The mean and standard deviations for TBCs at each inspected site (PISF, GS, IIP, OF) were recorded and analyzed according to a pre-established analysis plan. A bio-statistician with expertise in dentistry analyzed the data using statistical software (SigmaPlot, Version 13, Systat Software, San Jose, Calif., U.S.). Before running the statistical analysis, the TBCs for each site were transformed (log transformation [log$_{10}$]) in an attempt to render less skewed distributions, making the data more interpretable and helping to meet the assumptions of inferential statistics. As the normality test failed, a nonparametric test (Kruskal–Wallis) was used. The level of significance was set at $\alpha = 0.05$.

Results

No implants were lost, and all of the prostheses were in situ at the time of examination. At the end of the study, just one site (out of 35) in the GS of the adjacent teeth presented a TBC of $2.11 \times 10^4$. The mean bacterial count of S. aureus was $5.02 \times 10^2$; therefore, this value was taken as control. Conversely, in the PISF of each implant, the IIP and the OF complex, the mean bacterial counts of S. aureus were 0, with only one site (out of 35) positive, but below the level of quantification. The data are reported in Table 1. No statistically significant differences were found among groups regarding site location (Kruskal–Wallis test; $p = 0.40$).

Discussion

Currently, there are neither standardized antibiotic prophylactic regimens for dental implant place-
ment nor universally accepted treatment for peri-
implantitis. The treatment of infected implants is
difficult and usually requires removal.18 However,
it has become clear that therapy of periimplant
mucositis should be considered a preventive
measure for the onset of periimplantitis. Compli-
tion of active periodontal therapy should precede
implant placement in periodontally compromised
patients.19

\textit{S. aureus} is a facultative coccus and Gram-posi-
tive bacterium normally associated with surgical
wounds in orthopedic patients.20 Part of this can
be explained by the impedance seen on cultured
osteoblasts, with \textit{S. aureus} surviving up to 48 h
after internalization by those bone cells and still eliciting interleukin 6 and interleukin 8 res-
penses,21 which have pro-inflammatory effects
and are involved in osteoclastogenesis22 and for-
eign body reactions.23 In addition, \textit{S. aureus} has
the ability to form a biofilm and lead to chronic
infection.24

A retrospective study has demonstrated that
patients capable of maintaining high immuno-
globulin G antibody titers to \textit{S. aureus} had suc-
cessful implants compared with nonosseointe-
grated fixtures.25

In the present study, the lack of significance
regarding the bacterial counts of \textit{S. aureus} at IIP
and PISF must be considered, since \textit{in vitro}
this pathogen has shown an affinity for titanium sur-
faces,26 and two studies have related its levels to
deep perimplant pockets with bleeding on prob-
ing.27, 25 One study has demonstrated that the
bacterial counts of \textit{S. aureus} increase from 5% to
15% at implant sites 12 weeks after surgery.28
However, another study pointed out that even
after seven years of follow-up the presence of
\textit{S. aureus} at tooth sites could be indicative of the
presence of the same pathogen at implant
sites,29 while another study indicated that the
lack of \textit{S. aureus} at implant sites after 12 weeks
demonstrated a high negative predictive value
after 12 months.29 More recently, an article
demonstrated that regardless of health status,
periodontal and perimplant sites harbored
\textit{S. aureus} cells, being the highest load of all six
species analyzed.30

**Conclusion**

Within the limits of this study, \textit{S. aureus} could not
be quantified inside and around dental implants
in detectable limits. However, clinicians must
bear in mind that, in the early stage of healing,
this pathogen can influence the immune re-
sponse and lead to perimplant bone loss.

**Competing interests**

The study was supported by Sweden & Martina
(Due Carrare, Italy), which paid for the kits, and by
the Institut Clinident, which performed the
analysis free of charge. The authors declare that
they have no competing interests related to this
study.

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