A review of dental implants and infection


Glasgow Dental Hospital and School, Faculty of Medicine, Glasgow University, Glasgow, UK
Infection Research Group, Glasgow Dental Hospital and School, Faculty of Medicine, Glasgow University, Glasgow, UK

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Summary
Dental implants have become increasingly common for the management of tooth loss. Despite their placement in a contaminated surgical field, success rates are relatively high. This article reviews dental implants and highlights factors leading to infection and potential implant failure. A literature search identified studies analysing the microbial composition of peri-implant infections. The microflora of dental peri-implantitis resembles that found in chronic periodontitis, featuring predominantly anaerobic Gram-negative bacilli, in particular Porphyromonas gingivalis and Prevotella intermedia, anaerobic Gram-negative cocci such as Veillonella spp. and spirochaetes including Treponema denticola. The role of Staphylococcus aureus and coagulase-negative staphylococci that are typically encountered in orthopaedic infections is debatable, although they undoubtedly play a role when isolated from clinically infected sites. Likewise, the aetiological involvement of coliforms and Candida spp. requires further longitudinal studies. Currently, there are neither standardised antibiotic prophylactic regimens for dental implant placement nor universally accepted treatment for peri-implantitis. The treatment of infected implants is difficult and usually requires removal. In the UK there is no systematic post-surgical implant surveillance programme. Therefore, the development of such a project would be advisable and provide valuable epidemiological data.

Introduction
Dental implants are inert, alloplastic materials embedded in the maxilla and/or mandible for the management of tooth loss and to aid replacement of lost orofacial structures as a result of trauma,
neoplasia and congenital defects. The most common type of dental implant is endosseous comprising a discrete, single implant unit (screw- or cylinder-shaped are the most typical forms) placed within a drilled space within dentoalveolar or basal bone. Commercially pure titanium or titanium alloy are the common constituents of dental implants. However, alternative materials include ceramics such as aluminium oxide and other alloys (gold and nickel–chrome–vanadium). Generally, endosseous implants have a coating which may comprise plasma-sprayed titanium or a layer of hydroxyapatite to enhance early osseointegration.

Osseointegration

After endosseous implant fixtures are surgically inserted into bone, the process of osseointegration begins. Osseointegration is considered ‘a direct, structural and functional connection between organised vital bone and the surface of a titanium implant, capable of bearing the functional load’. This is possible as the titanium surface oxide layer (mainly titanium dioxide) is biocompatible, reactive and spontaneously forms calcium-phosphate-apatite.

Furthermore, the titanium oxide surface of implants achieves a union with the superficial gingivae restricting the ingress of oral microorganisms. Consequently, the implant/soft tissue interface is similar to the union between tooth and gingivae.

Success and failure

Criteria for successful integration of dental implants have been proposed. Of these, a lack of mobility is of prime importance as ‘loosening’ is the most often cited reason for implant fixture removal. Adell reported the success rate of 895 implant fixtures over an observational period of 5–9 years after placement. Eighty-one percent of maxillary and 91% of mandibular implants remained stable.

Despite high success rates, implant fixture failure may occur and is defined as ‘the inadequacy of the host tissue to establish or maintain osseointegration’. One review suggested that ~2% of implants failed to achieve osseointegration following placement. Using a meta-analysis, failure rates for Brånemark dental implants were 7.7% (excluding bone grafts) over five years. Interestingly, failure rates within edentulous patients were almost double those for partially dentate patients (7.6% versus 3.8%). In addition, failure in the edentulous maxilla was approximately three times higher compared to the edentulous mandible.

Peri-implantitis is considered ‘an inflammatory process affecting the tissues around an osseointegrated implant in function, resulting in loss of supporting bone’. Signs of a failing dental implant are detected both clinically and radiographically with the diagnosis made in a similar way to periodontitis. This involves measuring clinical parameters including peri-implant loss of gingival attachment, bleeding on probing, plaque/gingivitis indices, suppuration and mobility. Other relevant assessments include a peri-implant radiographic examination and microbiological sampling. Peri-implantitis has been reported in 5–8% of cases within selected implant systems.

Classification of failures

Implants can be described as failing or failed. A failing implant demonstrates a progressive loss of supporting bone but is clinically immobile, whereas a failed implant is clinically mobile. When an implant has failed, removal is recommended while a failing implant may be salvaged if it is diagnosed early and treated appropriately.

Implant failures may also be categorised as early or late. Early failures occur before osseointegration and prosthetic rehabilitation has taken place with late failures occurring afterwards. Factors affecting early failure of dental implants may be broadly classified as: implant-, patient- and surgical technique/environment-related (Table I). Late failures...
usually concern a small number of patients with their aetiology less well understood. Late failures may be subclassified into late—early or late—delayed depending on whether they occur during or after the first year of loading. Late-delayed failures are likely due to changes in loading conditions in relation to the quality/volume of bone and peri-implantitis. The likelihood of bacteria producing infection depends on their virulence and host factors. While the above factors relate to the failure of implants with regard to their anchorage in bone, occasionally the infectious process is limited to the soft tissues overlying the healing implant site causing peri-implant mucositis. An implant compromised by soft-tissue problems has a more favourable prognosis than one undergoing bone loss. Nevertheless, infection originating in the soft tissues may potentially progress deeper into the bone and undermine the osseointegration process. Some of the most frequent causes of soft tissue infection during the healing period involve residual suture material, poorly seated cover screws, protruding implants and trauma from inadequately relieved dentures or occlusal trauma from opposing teeth.

### Microbiology of failing dental implants

Infection represents one of many factors contributing to the failure of dental implants. Presently, no single micro-organism has been closely associated with colonisation or infection of any implant system. Failing dental implants are associated with a microbial flora traditionally associated with periodontitis. Thus, a transition is observed from a predominately Gram-positive non-motile, aerobic and facultative anaerobic composition towards a flora with a greater proportion of Gram-negative, motile, anaerobic bacteria. If this predominates for significant time periods then peri-implantitis and eventual implant failure may result. Table II highlights studies investigating the microbiology of failing implants.

Interestingly, micro-organisms not usually associated with periodontitis or dental abscesses such as staphylococci, coliforms and Candida spp. are commonly isolated from peri-implant lesions in some studies. Staphylococci are present within the oral cavity and their isolation from peri-implant infection is significant as both Staphylococcus aureus and coagulase-negative staphylococci are frequently responsible for infections associated with metallic biomaterials and indwelling medical infections in general. More recently, Staphylococcus aureus has been demonstrated to have the ability to adhere to titanium surfaces. This may be significant in the colonisation of dental implants and subsequent infections.

### Guidelines for the placement of dental implants

There are few published guidelines on infection control during the placement of dental implants. Those available advocate that the surgical field should be isolated and free of contamination. This is clearly not readily achievable within the oral cavity. However, it has been elucidated that contamination of the operative site by patient’s saliva does not preclude success. Additionally, no significant differences were found in osseointegration success rates for implants placed under controlled operating
theatre conditions compared to a less environmentally controlled dental school clinic. This may imply that the operative environment is not as critical to the success of dental implants compared to implant placement within other body sites. Several strategies to reduce contamination from the oral flora during surgery have been postulated. One such strategy involves rinsing preoperatively with chlorhexidine as this may reduce microbial complications following implant placement. An in-vivo study showed that chlorhexidine in suspension form is more effective in inhibiting Porphyromonas gingivalis than the use of antibiotics. Others, however, failed to reach these conclusions.

During the surgical procedure, the implant should be stored in the manufacturer’s sterile packaging and only used in conjunction with the recommended instruments. Previously, the drills used for bone preparation were not designated single use and were decontaminated according to local protocols. Manufacturers are gradually introducing single-use drills for use with their implant systems.

### The role of antibiotics

The use of prophylactic antibiotics during implant placement remains controversial. A Cochrane review found insufficient evidence advocating or dissuading their use. An update of the review, however, determined there was some evidence that 2 g of amoxicillin given orally 1 h preoperatively significantly reduced early failures of dental implants. The review concluded by recommending the routine use of one dose of 2 g of prophylactic amoxicillin immediately prior to placing dental implants. However, it also stated that further research was required to confirm the findings.

<table>
<thead>
<tr>
<th>Table II</th>
<th>Summary of studies investigating microbiology of failing implants</th>
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<tr>
<td>Type of implant (no. of patients/implants)</td>
<td>Method of detection</td>
</tr>
<tr>
<td>Brånemark (37/1—4 per patient)</td>
<td>Culture</td>
</tr>
<tr>
<td>Not stated (41/not stated)</td>
<td>Culture/indirect immunofluorescence</td>
</tr>
<tr>
<td>Titanium hollow cylinder implants (7/not stated)</td>
<td>Culture/dark field microscopy</td>
</tr>
<tr>
<td>Not stated (13/20)</td>
<td>Culture</td>
</tr>
<tr>
<td>Not stated (21/28)</td>
<td>Checkerboard DNA—DNA hybridization technique</td>
</tr>
<tr>
<td>IMZ (12/18)</td>
<td>Culture</td>
</tr>
<tr>
<td>Various (10/12)</td>
<td>PCR</td>
</tr>
<tr>
<td>9 Astra 16 Brånemark 5 ITI Staumann (17/30)</td>
<td>Culture</td>
</tr>
</tbody>
</table>

PCR, polymerase chain reaction.
Table III  Suggested treatments for infected dental implants\textsuperscript{20,29,57}

<table>
<thead>
<tr>
<th>Mechanical debridement</th>
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<td>Pharmaceutical treatment — irrigation with chlorhexidine, local antibiotics (e.g. tetracycline fibre) and systemic antibiotics</td>
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<tr>
<td>Surgical procedures — open flap debridement (to decontaminate and smooth the implant surface)</td>
</tr>
<tr>
<td>Correct anatomical conditions that impair plaque control and encourage the formation of an anaerobic environment (includes both resective procedures and regenerative techniques such as guided tissue regeneration)</td>
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At present, there is no reliable evidence for the most successful method of treating peri-implantitis.\textsuperscript{56} Despite a variety of therapeutic options (Table III), infected implants are difficult to treat and usually require removal.\textsuperscript{21} Some clinicians advise systemic antibiotics for the treatment of failing implants and a variety of drug regimens are described.\textsuperscript{58} Oral agents such as doxycycline, clindamycin, co-amoxiclav, penicillin V, amoxicillin and a combination of amoxicillin and metronidazole have been recommended. Nevertheless, no double-blind, randomised, placebo-controlled trial has been undertaken.

**Monitoring of success/failure**

In the UK there are no surveillance programmes in place providing epidemiological data on the microbiology, success and failure rates of dental implants. Conversely, in Finland an Implant Register provides comprehensive data on the number of implants inserted and removed together with any complications related to the treatment.\textsuperscript{14} The programme strives to ensure safe treatment for patients and has been operational for nearly 20 years.

**Conclusion**

Dental implants are an increasingly common form of prosthetic device implanted into patients. The apparent high success rate for the placement of endosseous dental implants under uncontrolled environmental conditions and through a heavily colonised oral environment appears counterintuitive. If dental implants become infected the causative micro-organisms are usually those implicated in periodontal disease and include a range of Gram-negative anaerobes and spirochaetes. Since \textit{S. aureus} and coliforms are infrequently detected in oral infection, their presence at implant infection sites may represent cross-infection episodes although further data are required to support this. As occurs with orthopaedic implants, infected dental implants are difficult to treat and removal is frequently required.

Data on failure and complications of dental implants should be collected and reported in a systematic fashion. This would enable a more detailed analysis of the microbiology, treatment outcomes and assist in the formulation of clinical guidelines in implant placement and treatment of implant-associated infections. Concerns have been raised over the efficacy of dental instrument decontamination, and this, coupled with the highly invasive nature of the insertion of dental implants, suggests that the introduction of a generic surveillance programme with appropriate microbiological monitoring should be urgently considered.

**Conflict of interest statement**

None declared.

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None.

**References**


