# Why Implants Fail

Over the last 25 years the public awareness of dental implants as a means of replacing missing teeth has grown considerably, from patients not having heard of dental implants in the late nineties to knowing someone who has had implant treatment today.

The improved awareness is also reflected in the demand for dental implant treatments in general practice where it is now widely available with growing numbers of implants being placed across most of the globe. The successful integration of dental implants is almost taken for granted, with reported osteointegration rates of over 95% (1, 2).

Despite the revolutionary impact that dental implants have had on dentistry they are not without complications and although the failure rates are low they can cause catastrophic bone loss resulting in a clinical scenario where the patient can end up worse off anatomically than when they started.

The aim of this article is to give a brief overview of the generally accepted causes for implant failure and to highlight the need for a better understanding of some of the competing theories.

It is important to define what we mean by success and failure from the outset, as without this there cannot be clarity on diagnoses, management and outcome measures. For the dental clinician success needs to mean achieving the patient's desired outcome, without any complications. When further treatment is required following the completion of the procedure, this can be defined as a complication; for example if the patient is not happy with the appearance of the prosthesis, despite the treatment being clinically successful it has not achieved the patient's desired outcome and therefore classed as a complication due to more chairside work required. With this definition, the reported success rates would be considerably lower than the widely reported rates for successful integration. For the purposes of this article the term failure refers to the loss of the implant fixture, rather than not achieving the patients' desired outcome, such the aesthetic aspect. The latter is

usually as a result of poor surgical and/ or restorative planning and failure to communicate with the patient to manage the expectations.

**Early implant failure**

Implants can fail before the prothesis is fitted and functionally loaded, which is referred to as early failure and is usually discovered at the time of implant exposure or taking impressions when the lack of integration results in implant mobility.

The causes of early implant failure include surgical trauma to the alveolar bone with overheating during the osteotomy or implant placement as a result of poor surgical technique. This can result in osteonecrosis and fibrous encapsulation as opposed to osseointegration (3). Post-operative infection, although rare, can also result in early implant failure. The risk for this can be mitigated with a single dose of pre-operative antibiotic as prophylactic cover, although there are conflicting opinions on the need for the use of antibiotic cover for implant treatment (3). Other reasons for early implant failure include systemic predisposing factors, such as immunocompromised patients, smoking and patients on selective serotonin re-uptake inhibitors (SSRI's) (4). The mechanism for the failure of osseointegration with SSRI's is not certain. Nevertheless, it is important for patients on SSRI's having implant treatment to be made aware of this risk as part of the consent process.

**Late implant failures**

Late implant failure refers to the loss of an implant after successful integration has taken place. It is more likely to be associated with significant bone loss as a result of peri-implantitis which is the main cause of late implant failure and will be the focus of the rest of this article.

The consensus opinion for the aetiology of peri-implantitis is plaque related which implies a bacterial origin (5). In support of this theory, there is an increased risk of peri-implantitis in patients with a history of periodontitis, which is also plaque related. Furthermore, peri-implantitis is more likely to be seen in poorly positioned implants and poor prosthesis design as both can affect the maintenance of dental implants by

making appropriate oral hygiene measures difficult to achieve, and thereby encouraging plaque accumulation and bacterial invasion.

The comparative anatomy of the transmucosal component of an implant where the biologic width is found lacks the strong collagen attachment and hence physical barrier seen around a natural tooth's root. This provides a weak point for bacterial invasion around an implant compared to a natural tooth, where inflammation caused by bacterial invasion is limited, or slowed down by the collagen attachments which insert in the root cementum and the alveolar bone at opposite ends. The collagen fibres are present around implants, but run parallel or circumferentially around the neck of the abutment of the implant (6, 7). The significance of the lack of collagen attachment around the implant neck is that bacterial invasion and inflammation can spread rapidly to the alveolar bone with very little resistance. With a natural tooth one can review the patient a few months after treatment, however, with inflamed peri-implant tissues the patient needs to be reviewed within a couple of weeks to ensure control of the progression of the inflammatory process has been achieved. This anatomical weak point also fits the bacterial aetiology theory.

**Other reported causes of peri-implantitis with limited evidence**

The inadvertent introduction of cement in the peri-implant tissues when used to secure the implant crown has been reported to cause peri-implantitis (often referred to as cementitis). This is due to the weak soft tissue barrier at the neck of the implant. The use of cement is generally avoided nowadays with a preference for screw retained crowns for this reason.

The link between peri-implantitis and occlusal overload has limited evidence, which is partly due to the multiple variables that are involved in occlusal load assessment and the inability to have standardised clinical data. For example, a long clinical crown height of a dental implant may result in large forces at the coronal few millimetres (neck) of the implant due to the lever effect. This is in turn can result in

marginal bone loss and recession with subsequent implant thread exposure and bacterial colonisation. In such a scenario the occlusal load did not directly cause per-implantitis, but rather the prosthetic design with a large lever effect.

## Competing theories to plaque induced peri-implantitis

Particle release

One school of thought is that per-implantitis is initiated with a foreign body reaction to the implant particle material and that the bacterial invasion is a secondary component (8, 9).

*In vitro* studies have shown particle release immediately after placement of the implant fixtures and particle uptake by cells (10).This suggests that particles are released from the rough implant surface due to friction at the time of placement. Particle release from implants can also be as a result of wear between the abutment and the implant fixture due to functional load. Fatigue degradation, debridement with metal instrumentation and corrosion can also result in particle release. Although titanium is resistant to corrosion, it is not immune to it and the oral environment provides an acidic environment with salivary pH 6.3 - 7 which can drop to 3.5 with acidic drinks (11) and in presence of inflammation.

Titanium particles in sites with peri-implantitis have been found at higher concentrations than in healthy sites, which implies an association between particle release and peri-implantitis (12). The argument can be made that particles are released following the establishment of bacterial infection, however, this is difficult to demonstrate and the inflammatory effect of particles has been established and accepted in orthopaedic hip replacements as sterile osteolysis (13-15).

Macrophages phagocytose particles released in the tissues which are recognised as foreign bodies and are not degradable. Phagocytosed particles can disrupt cellular function and result in apoptosis. In order to avoid apoptosis, cells can fuse resulting in the formation of foreign body giant cells (FBGC), mediated through the release of IL4 and IL13. This establishes chronic inflammation which in turn results in bone loss around the implant (8).

In patients with dental implants titanium particles have been found within the oral environment in peri implant bone, soft tissues and submucosal plaque as well as in distant sites such as lymph nodes, lungs, kidneys, liver and spleen. These particles may have been transported by phagocytic cells or plasma proteins in the blood circulation (16-19). The distant spread of titanium and titanium alloy particles may have wider systemic implications including for the cerebral blood flow which are as yet unknown.

There are different grades of titanium used in dental implants. The commonest ones are grade 4 commercially pure titanium (4-CP), the alloyed grade 5 made up of 90% titanium, 6% aluminium, 4% vanadium (Ti6Al4V) and the alloyed Roxolid® made up of 85% titanium and 15% zirconium (Ti15Zr).

Ti6Al4V implants have been shown to release higher quantity and smaller sized (including nanoparticles of 40 nm) particles at placement compared to 4-CP or Ti15Zr *in vitro* (10). Grade 5 implant particles have also been shown to have a proinflammatory influence with increased inflammatory cytokine release (IL6, IL1β, TNFα) from different cell lines and M1 (pro-inflammatory) polarisation of macrophages when compared to 4-CP and Ti15Zr implant particles which were comparable to controls (20). The likely reason for this reaction is the presence of vanadium which is known to be toxic, and possibly aluminium.

Tissue response to nanoparticles is not fully understood but there is some evidence that Titanium oxide ($TiO_2$) nanoparticles can cause inflammatory reaction and DNA damage (20, 21).

There is also evidence for Ti particles' ability to influence the bacterial colony make-up in biofilm by increasing the pathogenic species (22). This can potentially increase the risk of peri-implantitis.

There is clearly a complex interaction between the implant materials used, the bacterial biofilm and the patient's immune response, which are not fully understood.

Hypersensitivity

It is also important to note that dental implants have impurities and trace elements including iron, nickel, cobalt, chromium, which can be toxic, or allogenic (23). Even as trace elements the impurities have the potential to set off a delayed

hypersensitivity reaction.
Consideration should therefore *also* be given to the possibility of a hypersensitivity reaction to implant materials as the reason for the inflammatory responses leading to peri-implantitis and bone loss. There have been reports of suspected Ti delayed hypersensitivity (24). The chronic accumulation of particles in the surrounding tissues as a result of wear, or corrosion could reach a threshold for FBGC formation or hypersensitivity reaction resulting in clinical bone loss and implant failure.
This would fit the clinical picture of peri-implantitis occurring only in some individuals, including those with no known risk factors often several years after fixture placement.

It is important to take into account the purity of titanium dental implants and the potential for toxic, or allogenic contaminants within the fixtures. Dental implant manufacturing standards are set by the ISO standard 5832 and the American Society for Testing and Materials (ASTM) standard F67-13. The standards list the required composition of the elements in implants with ASTM grades 1-5 (commercially pure grades 1-4 and Ti6Al4V alloy grade 5).

The most commonly used grade of titanium in dental implants is grade 4, for which the standardised elemental composition is listed below with the maximum mass% values for each element with titanium as the balance. Nitrogen: maximum of 0.05 mass%, Carbon: maximum of 0.08 mass%, Hydrogen: maximum of 0.0125 mass%, Iron: maximum of 0.5 mass%, Oxygen: maximum of 0.4 mass%.

Despite the ISO and ASTM standards for grades 1-5 titanium implants, impurities have been found which included chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), arsenic (As) and in zirconia implants thorium (Th-232) and uranium (U – 238) radionuclides (23). There has therefore not been enough attention paid to metal contaminants, especially those that are known to have allogenic and toxic properties. Contaminants may be introduced during surface treatments such as abrasion, etching and anodisation. As the various implant systems use different techniques for surface topography treatment, the level and type of contaminants will vary between different implant systems.

The relationship between tissue reaction to different implant systems and their potential contaminants is difficult to ascertain, especially as this may differ not only between systems but also between different batches of the same system. The majority of the clinical data looking at the hypersensitivity reactions to implants have been case reports (23), which limits the data and the conclusions that can be drawn. There is therefore a clinical challenge not only in determining the cause of peri-implant inflammation between bacterial invasion, foreign body reaction, or hypersensitivity reaction but also in the case of the latter, whether it was instigated by one of the standardised component elements or by a contaminant.

**In summary**

The main reason for the late failure of dental implants after they have successfully osseointegrated is Peri-implantitis, which is currently believed to be related to invading bacterial colonies from dental plaque biofilms (5). The treatment of peri-implantitis is complex with unpredictable outcomes (25), which may reflect the lack of full understanding of its pathophysiology. Various competing theories to the bacterial aetiology have been provided which may have systemic implications beyond the peri-implant tissues.

Dental implant manufacturers currently test the implant fixtures for toxicity as a whole unit. Although in vitro experimental results cannot be directly related to the clinical situation, there is enough evidence in the literature to suggest that testing of tissue response to particles should be considered as part of the standard manufacturing procedure to ensure patient safety, especially as new materials are being developed. The Dental surgeons' decision on which material to use needs to be based on evidence and consideration needs to be given to the possible adverse effects from particles released from their choice of implant such as grade 5 implants. Clinical researchers in peri-implantitis need to take into account the materials used in the implants and include this data in their results for a better understanding of the role of materials; this is currently often missing and may therefore mask any influence on the onset of peri-implantitis.

The aim of this article was to highlight some of the evidence and the importance of considering the potential role of biomaterial interactions in peri-implantitis and the implications for dental implant manufacturing companies, dental surgeons, and for researchers.

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