Bioengineering

AIMS Bioengineering, 10(2): 141–152.
DOI: 10.3934/bioeng.2023010
Received: 20 December 2022
Revised: 21 April 2023
Accepted: 22 April 2023
Published: 17 May 2023

http://www.aimspress.com/journal/Bioengineering

Review

Etiology of dental implant complication and failure—an overview

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Abstract: Dental implant treatment is turning into a widely accepted and popular treatment option for patients. With the growing era of dental implant therapy, complications and failures have also become common. Such intricacies are becoming a vexing issue for clinicians as well as patients. Implant failures can be due to mechanical or biological reasons. Failure of osseointegration of the implant falls under biological failures, whereas mechanical complications include fracture of the implant, framework or prosthetic components. Diligently observing the implant after placement is the first step in managing the declining circumstances. It is important to have a thorough understanding of how and why implants fail to achieve successful treatment outcomes in the long run. In dentistry, nanoparticles are used to make antibacterial chemicals that improve dental implants. They can be used in conjunction with acrylic resins for fabricating removable dentures during prosthetic treatments, composite resins for direct restoration during restorative treatments, endodontic irrigants and obturation materials during endodontic procedures, orthodontic adhesives and titanium coating during dental implant procedures. This article aimed to review the etiological factors that lead to implant failure and their solutions.

Keywords: implant failure; complications of implants; peri-implantitis; bone loss; osseointegration; prosthesis

1. Introduction

Edentulism impairs normal physiological functions and has a direct impact on the general health of the patients. There are several choices available for replacing lost teeth, including removable dental prosthesis, traditional fixed partial dentures, resin-bonded prosthesis and implant-supported prosthesis. Dental implants provide an advantage over the traditional tooth-supported prosthesis as unnecessary restoration of the adjacent sound teeth can be prevented [1]. The concept of replacement of missing teeth with dental implants has become an emerging trend [2]. Successful rehabilitation with high survival rates has been reported for single and multiple implants [3–6]. In spite of the high success rates, failures are not uncommon [7]. Implant failure rates of 1–19% have been observed in previous studies [8]. Complications and failures are inevitable; however, vigilant preoperative evaluation can reduce the occurrences [9].

Implant failure is the total failure of the implant to fulfill its functional or esthetic purpose due to biological or mechanical reasons [10]. Failures can be early or late, as described by Truhler: Early failures occur within a few weeks or months, and late failures arise in previously osseointegrated implants [11]. Misch and Wang in 2008 categorized implant complications into four categories: anatomy-related, procedure-related, treatment plan-related and others [12]. Biological and mechanical complications along with the probable causes have been compiled in the review by Prashanti et al. in 2011 [13]. The complications which are relatively minor are easily corrected, but others are more significant, resulting in loss of implants, failure of prosthesis and occasionally severe loss of tissue around implants. Biological complications may be minor, such as inflammation and proliferation, or may be significant, involving progressive bone loss. The ultimate biological complication is implant failure. Surgical complications include compromised esthetics, prosthetic results, soft tissue dehiscence and ultimately implant failure, but unfortunately the extent of problems that arise from implant malposition are not evident until the time of restoration. Mechanical complications of implants include material loss, like implant fractures, which most often lead to implant failure. The final outcome of serious dental implant complications is implant failure, establishing the link between dental implant complication and failure.

Understanding the causes is essential for the prevention of failures. Knowledge regarding the etiologies and factors influencing implant failure and diligent observation of the implant after placement are the first steps in managing any declining circumstances. Various materials are used nowadays that help in improving the life of dental implants. Various factors associated with implant failure and complications are briefly discussed in Table 1.

In this review, the etiologies and factors which could lead to implant failure have been elaborated on and discussed.

Table 1. Factors leading for Implant failure and complications.

Type of complication	Failure	Factors/Etiology
Immediate implant placement	Biological failure leading to gingival recession, poor quality and inadequate quantity of bone, surgical trauma, infection, fenestration and dehiscence, poor implant stability, malpositioning of implant and unesthetic results	Lack of keratinization leads to poor adherence to the implant surface with a reduced capacity for regeneration and proliferation. Implants placed in poor quality and inadequate quantity of bone have comparatively higher failure rates [14]. Overheating of the bone can lead to necrosis of peri-implant bone [15]. Optimal functional and esthetic outcomes cannot be achieved due to inaccurate positioning of the implant. Implant displacement, screwdriver aspiration, devitalization or damage to adjacent teeth or anatomic tissues and necrotizing mediastinitis are among the rare encountered complications [16].
Early complications - arising within weeks or a few months	Lead to biological failures wherein the implants fail to be osseointegrated. Normal or altered healing responses can be seen in such situations [13]. Infection, swelling, ecchymoses and hematomas, emphysema, sensory dysfunction, excessive bleeding, and dehiscence of the flap are all early-stage problems. These may cause inconvenience to the patient during food intake and oral cleanliness support [17].	Factors that lead to early failure are related to the surgical technique, surface conditioning of implants, early loading and bacterial contamination [9].
Late complications	Perforation of the mucoperiosteum, maxillary sinusitis, mandibular fracture, failed osseointegration, bony abnormalities, and periapical implant lesion are all late problems.	Such failures are due to the progressive bone changes that result after loading and peri-implantitis [9,13].

2. Tissues around implant

2.1. Hard tissue

Marginal bone loss is the most important indicator of implant failure. As per the review by Goodacre et al. that compiled data from 15 clinical studies, mean bone loss during the first year ranged from 0.4 to 1.6 mm [18]. Plaque, poor oral hygiene, periodontal pockets, smoking and lack of keratinized gingiva have all been associated with bone loss. A significant correlation has been established between plaque associated marginal inflammation and bone loss. Radiographic assessment of bone loss is considered as a more reliable indicator of bone loss compared to clinical parameters like bleeding on probing, probing depth, gingival index, plaque index and crevicular fluid volume [17].

2.2. Soft tissue

The health of the peri-implant soft tissue might affect its susceptibility to peri-implant disease. Peri-implant mucosal recessions are more frequent in patients with thin alveolar morphologies. Other soft tissue complications include fenestration, dehiscence, fistulas and gingival proliferations [18].

The rough surface of an exposed implant complicates oral hygiene and increases bacterial adherence, thus increasing the implant's vulnerability to infection. Dreyer et al. in their systematic review stated that thin gingival biotypes have a significant relationship with the severity of peri-implant infection [19]. However, conclusions are impossible to reach due to the paucity of clinical data. For peri-implant hygiene and brief stability, a 2 mm zone of keratinized soft tissue has been recommended. Nonetheless, its essential need is still debatable. It is linked to improved plaque management and reduced soft-tissue inflammation, mucosal recession and attachment loss.

3. Complications

3.1. Mechanical complications

There are two major reasons for mechanical failures, vertical bone loss and biomechanical overloading [20]. Mechanical complications like prosthesis screw loosening, metal framework fracture, fixture fractures and overdenture attachment fracture are commonly encountered when the loads are excessive or the capacity of the bone to transmit the loads is hampered. Implant fractures can also be attributed to flaws in the implant design and manufacturing [21,22].

The framework fractures in edentulous jaws can be complicated considering the greater moment loads they are subjected to. Construction related distortion is greater when the length of the framework is greater and can be significantly worsened by nonparallel implants.

Metal-ceramic restorations are the most commonly used in clinical dentistry, especially due to esthetic demands. The fracture of ceramic veneering is another serious complication. All precautions taken pertaining to proper implant occlusion while restoring the dental implant reduce the incidence of such complications [21]. The esthetic outcome is also considered an essential trait for success [23].

3.2. Biological complications

Biological failures are subcategorized as early and late implant failures, where the early failures are due to implant placement mishaps, and the late complications are commonly peri-implants and contamination from bacterial infiltration [24]. Peri-implant pathologies are characterized as by inflammation that happens in the tissues encompassing the implant. Such peri-implant illness usually happens as the result of the difference between the host defense and expanding bacterial burden. A period of five years is required for the display of clinical signs and symptoms after the infection. Long-term follow-ups are important for assesing the frequency of implant failure. In ideal peri-implant conditions, the tissues assume a vital part in forestalling the spread of pathogenic bacteria. If the barrier of tissues is penetrated, it could prompt bacterial tainting, bringing about the degradation of the tissues [25].

Excessive moment loads affect osseointegration and cause crestal bone resorption [26,27]. Such inconsistent occlusal load distribution leads to the loosening of the superstructure, contamination of the encompassing region and failure. Uncontrolled factors like diabetes mellitus, osteoporosis, extensive steroid therapy, chemotherapeutics, smoking, periodontitis and radiation treatment can further increase the possibility of complications [28]. Nonsurgical mechanical debridement along with antimicrobial therapy, as well as careful debridement with bone grafting, can further reduce the spread of infection and prevent failure. Implant explantation is justified only when there is over 60% of bone loss.

4. Factors

4.1. Iatrogenic factors

Implant surgery necessitates meticulous planning and execution. There are a lot of sequential steps that have an influence on the outcome. If the doctor does not rigorously track all of these events, there is a higher risk of failure and complications. There are technologically advanced imaging and reliable software for diagnosis and treatment planning. The capacity to diagnose bone morphology, existing disease and anatomic aberrations is enhanced with these instruments. Before placement of an implant, the dimensions of the alveolar ridge, proximity to the maxillary sinus and inferior alveolar canal, visibility of the mandibular canal and width of the cortical plates should be examined [29]. Cortical bone calcification, as well as thickness, influences the support it will provide to the implants [30].

Placement of an implant in a site that is adjacent to crucial anatomic features (e.g., inferior alveolar nerve, the morphology of a concave mandibular ridge, anterior mandible and posterior maxilla) is very critical. Even with precise imaging, such as computed tomography (CT) or cone-beam computed tomography (CBCT) scans, if the clinical picture is not correlated with the imaging, placement accuracy can be affected. Improper implant placement might lead to complications [31].

Furthermore, iatrogenic failure owing to surgical execution, such as fracture of the alveolar bone, sinus penetration or any excessive force, might result in a quick loss of stability, necessitating the procedure's cancellation. Iatrogenic failure can also be caused by the improper use of surgical equipment, such as blunt tools, insufficient cooling procedures, and most significantly, insufficient cleanliness of the instruments and surgical site [32]. The length of the surgery and the number of implants implanted are two risk factors for an intraoperative infection that might lead to early failure owing to poor healing. Early failures are thought to be caused by a reduction in blood flow, increased

working duration and wound infection. Appropriate training in diagnostics, treatment planning and surgical abilities reduces such errors. Failures occur twice as frequently in inexperienced surgeons as they do in expert surgeons [33].

4.2. Host factors

Despite the fact that it has been a contentious risk factor for many years, there is mounting data to show that patients who are predisposed to periodontitis have a higher risk of implant failure. Several published systematic reviews have aimed to establish a link between chronic periodontitis and implant failure or complications. All of these studies depicted a positive correlation between periodontitis and implant failure. Implant therapy is not contraindicated in periodontitis-prone individuals since implant survival rates are still good, as long as sufficient infection control and a personalized maintenance program are provided. However, the greater prevalence of peri-implantitis seen in these individuals might threaten the implant prognosis [8].

Other host-related variables, such as a patient's overall health, might contribute to early implant failure [34]. The patient's capacity to recover during the key phase of osseointegration may be hampered by poor systemic health. The impact on the patient's overall health is little known and recorded. Uncontrolled diabetes, osteoporosis and radiation therapy are examples of health concerns [35]. Esposito et al. failed to find a link between implant loss and these parameters; however, there appears to be an agreement that numerous factors are concurrently involved in the mechanism of implant failure [36].

Genetic vulnerability and genetic polymorphisms are poorly understood. Many people are skeptical about the relationship between host genetics and implant failure. Implant failures frequently occur in groups for a proportion of individuals. IL-1 gene variation is now linked to clustering early implant failures. IL1A-889, IL1B511 and IL1B+3954, in particular, have been related to minor bone loss surrounding implants. Two investigations have found that IL1A-889, IL1B-511, IL1B+3954 and IL1RN VNTR are linked to marginal bone loss in late implant failures [34]. Although the IL-1 gene polymorphism has been linked to implant failure, particularly among Caucasian smokers who had late failures, this genetic marker, which has also been linked to periodontitis risk, needs to be studied further in order to be confirmed as a diagnostic marker for implant failure and peri-implantitis. Numerous definitions of implant failure, as well as the unpredictability of different factors related to implant placement, research design and demographic heterogeneity, restrict the amount to which data may be extrapolated from different studies [37].

Smoking has been linked to poor wound healing and has been shown to reduce implant success rates. It is known to affect osseointegration, as the process of bone healing is undermined by nicotine. The precursor cell proliferation which is essential for bone healing is inhibited by smoking. This leads to a delay in the healing process. Thus, selecting the right time for loading dental implants becomes critical for smokers compared to non-smokers. Heavy smoking has also been related to accelerated crestal bone loss and the development of pockets. Tobacco and smoking are known to adversely affect the overall survival rate of dental implants [8,35].

5. Solutions regarding implant failure and complications

Prevention and management of implant failures also depend on the etiology. Strategies to prevent implant failures can lead to more successful outcomes. Nanoscale implant surface modification with

TiO_2 can lead to the enhancement of osseointegration. Such nanomodified implants have also been treated with platelet derived growth factors, bone morphogenetic protein (BMP), alendronate, and N-acetyl cysteine. Silver and Zinc nanoparticles are not only osteogenic but also have antimicrobial action. The use of drug-loaded hydroxyapatite and biopolymers like silk fibroin-based nanoparticles, chitosan and cellulose can provide superior anti-microbial properties to the implants [38–40]. Treatment of peri-implant defects with cellulose or collagen membrane can lead to bone regeneration and healing [41]. The use of BMP and epigallocatechin-3-gallate (EGCG) can help in the enhancement of remodeling and regeneration in dehiscence defects around dental implants [42,43].

Management of implant failure can be possible by eliminating or controlling the etiological factor at an initial stage when the implant is ailing. Failed implants require explantation and re-implantation. The risk factors that lead to the failure of the implant in the first attempt would however affect the prognosis or survival of the re-implantation.

Table 2. Application of nanoparticles in dental implants [44].

Nanoparticles	Properties
Copper – magnesium alloy	Offer antimicrobial properties [45,46]
titanium–aluminum–vanadium (Ti–6Al–4V)	Enhance Mechanical Properties [47]
ZnO nanoparticles(NPs) and nano hydroxyappetite(HP) on the surface of glass substrates	Inhibit bacterial adhesion and promote osteoblast growth [48]
ZnO: Ag nanoparticles in gelatin and pure ZnO	Creating a sealant with the right properties to reduce root canal microleakage and have good antibacterial properties [49]
ZrNPs	Offer better integration [50]
ZrNPs with chitosan	Better compressive strength, improved proliferation [51]

6. Discussion

Correlating implant failures to their etiology is critical. Various etiologies and risk factors can be involved when an implant fails. Implant failure refers to the situation where the implant is unable to fulfill its intended function due to variety of reasons, such as mechanical failure, loosening or infection. For instance, in the case of a dental implant, it may fail if it does not properly integrate with the jawbone, leading to implant displacement, bone loss and, ultimately, implant failure.

On the other hand, complications refer to any adverse events that occur following an implantation procedure. Complications may occur due to a variety of reasons, such as infection, inflammation, nerve damage or an allergic reaction.

Therefore, implant failure is a specific type of complication that occurs when the implant cannot perform its intended function. However, not all complications result in implant failure, and some complications may be resolved with proper management and treatment. Peri-implantitis is the most common cause of failure and presents in almost 34% of patients [52]. Zitsmann et al. concluded that peri-implantitis occurred in almost 28–77% of patients and in 12–43% of implant sites. This indicates that peri-implantitis is a prevalent condition, affecting a significant proportion of patients and implant sites. Therefore, preventive measures, such as proper oral hygiene and regular professional cleaning,

are crucial to minimize the risk of peri-implantitis [53]. According to Theibot et al., the most common complication was peri-implantitis, and the most important risk factor was type III/IV bone followed by pre-implant surgery [54]. Specifically, 70% of implant failures occurred in type III or type IV bone, 55% occurred in pre-implant surgery sites, and 8.3% of failures were associated with active smoking. Systemic diseases and surgical site infections were other causes that led to implant failure. This study highlighted the importance of bone quality and pre-implant surgery in predicting implant failure. It is essential to assess bone density and anatomy before implant placement and carefully plan the surgical approach to minimize the risk of complications [54]. Rehman Pyare et al. concluded that greater failures were associated with implants having lengths less than 10 mm (17%) and diameters less than 3.75 mm (12.4%). Furthermore, 16.8% of failures were encountered in type IV, and 9.4% were failures in type III. Another major factor in implant failure was smoking (41%). This was followed by cardiovascular diseases (35.7%), diabetes (30.8%) and hypertension (18.8%) [55]. Rehman Pyare et al.'s findings suggest that implant dimensions and patient comorbidities such as smoking and systemic diseases can significantly impact implant success rates. Therefore, it is essential to consider these factors when selecting implant dimensions and assessing the patient's overall health status.

In summary, understanding the etiology of implant failures can help clinicians develop effective treatment strategies and improve patient outcomes. Regular monitoring, preventive measures and careful planning are essential to minimize the risk of implant failure. Various nanoparticles and their properties are listed in Table 2.

7. Conclusions

Implant failure happens despite the best treatment planning and execution strategies. Most common failures can be attributed to peri-implantitis, followed by host factors like bone quality and smoking. Systemic diseases are the next major factor affecting implant survival. However, utmost care should be taken during each step to avoid such complications. Implant failure has a huge impact on patients as complications and mishaps are usually accompanied by additional procedures and costs. Treatment failure not only bothers the patients but also creates a huge burden on the clinicians. Consequently, for the success of dental implants, it is important to have a keen understanding of the etiologies and factors that could lead to failure.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Conflict of interest

The authors declare no conflict of interest.

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