10.5005/jp-journals-10004-1034

REVIEW ARTICLE

Implant Failures—Diagnosis and Management

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ABSTRACT

Despite the high success rates and stability of dental implants, failures do occur. While surgical trauma together with bone volume and quality are generally believed to be the most important etiological factors for early implant failures, the etiology of late failures is more controversial. Early detection and treatment of early progressive bone loss around dental implants by mechanical debridement, antimicrobial therapy, and regenerative therapy are the keys for saving early failing implants. The decision-making tree should be aimed at assisting and simplifying the process of selecting the appropriate alternative once a failure has occurred.

Keywords: Dental implants, Implant failure, Osseointegration, Risk factors, Smoking.

How to cite this article: Mantena SR, Gottumukkala SNVS, Sajjan S, Rama Raju A, Rao B, Iyer M. Implant Failures—Diagnosis and Management. Int J Clin Implant Dent 2015; 1(2):51-59.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Dentistry has undergone many changes during the past quarter century; however, no changes have been more profound than those in the field of implant dentistry. As the patient population able to benefit from implant therapy increases, the clinician is faced with increasingly complex options. Though the success rates reported with this form of therapy are relatively high, failures do occur. Hence, a thorough knowledge regarding the various aspects of failure is deemed necessary.

Difficulties can arise in any area of biological function; however, implant dentistry has been fraught with compromises and complications, which are often very frustrating to the patients as well as dentists. Avoiding those conditions that contribute to poor results, choosing cases that offer ideal surgical and prosthetic circumstances and scrupulously evading complex clinical challenges can improve favorable outcome data substantially. Anticipating and diligently observing for implant fixture and restoration failure are the first steps in managing and interdicting a declining clinical circumstance. Hence, it is mandatory for every clinician to know, how and why the failures occur and how best we can prevent them in order to give the upcoming branch of dentistry a new horizon.

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Implant Cumulative Success Rates

Criteria are required for the definition of implant success *vs* loosening or failure. Various criteria have been proposed for the evaluation of implant success (Table 1).[1-3] Cumulative success rates of dental implants are evaluated in years (Flow Chart 1) and are affected by many factors.[4] These include implant location in the upper or lower jaw and its position in the dental arch, implant type, diameter and length, prosthetic construction, and whether they are used for single tooth replacement or in an edentulous month.[5] In 1978, the National institute of health recommended the following criteria for removal of a dental implant: (1) chronic pain, (2) significant movement, (3) infection, (4) significant progressive loss of supportive bone, (5) intolerable dysthesia (anesthesia or paresthesia), (6) Oroantral or oronasal fistulae, (7) bone fracture, (8) psychological or other significant medical problems, (9) uncorrectable implant breakdown, (10) possible irreversible damage to adjacent teeth, and (11) cosmetic problems (Flow Chart 2).

RISK FACTORS FOR DENTAL IMPLANTS

Dentist-related Risk Factors

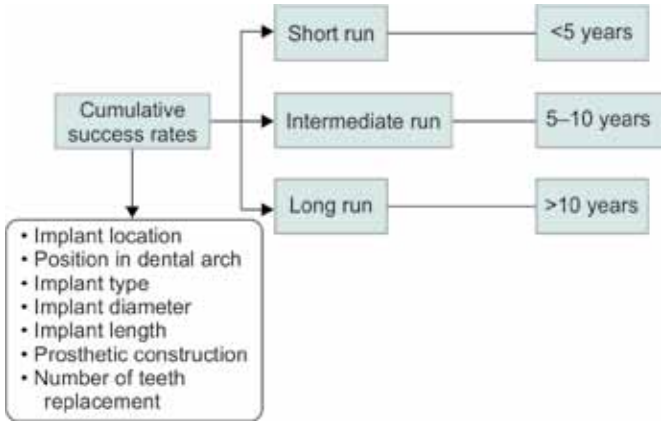
Preoperative Factors

Various radiographic methods have been used for the diagnostic evaluation of bone quality and quantity as well as treatment planning, which include periapical radiographs, the panoramic radiographs, computed tomography, and magnetic resonance imaging. However, it has been reported that conventional intraoral radiographs are associated with an approximately 14% magnification, and panoramic radiographs with approximately

Table 1: Criteria for evaluation of implant success

The US National Institutes of Health 1978[1]	• Bone loss no greater than one-third of the vertical height of the implant • Good occlusal balance and vertical dimension • Gingival inflammation amenable to treatment • Mobility of less than 1 mm in any direction • Absence of symptoms and infection • Absence of damage to adjacent teeth • Absence of paresthesia or anesthesia or violation of the mandibular canal, maxillary sinus or floor of the nasal passage • Healthy collagenous tissue without PMNs • Provision of functional service for 5 years in 75% of the cases
Albrektsson et al 1986[2]	• Implants are clinically immobile • A radiograph not demonstrating any evidence of peri-implant radiolucency • Vertical bone loss less than 0.2 mm annually following the implant's first year of service • Individual implant performance to be characterized by an absence of persistent and irreversible signs and symptoms, such as pain, infections, neuropathies, paresthesia, or violation of the mandibular canal • Success rate of 85% at the end of a 5-year observation period and 80% at the end of a 10-year period to be the minimum criterion for success
The American Academy of Periodontology 2000[3]	• Absence of persistent signs/ symptoms, such as pain, infection, neuropathies, paresthesias, and violation of vital structures • Implant immobility • No continuous peri-implant radiolucency • Negligible progressive bone loss (less than 0.2 mm annually) after physiologic remodeling during the first year of function • Patient/Dentist satisfaction with the implant-supported restoration

Flow Chart 1: Cumulative success rates of dental implants



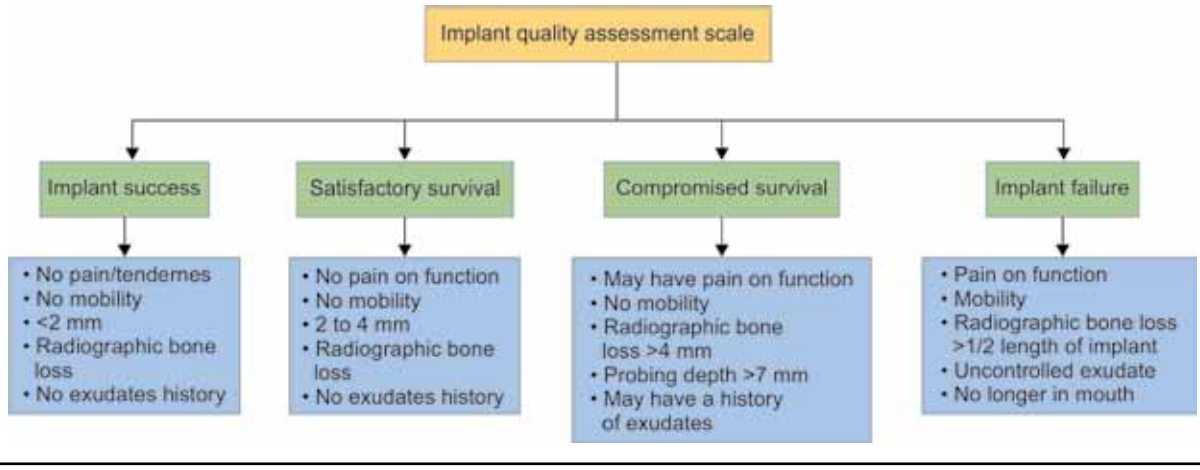
25% magnification.[6] X-ray magnifications may thus lead to mistakes in planning and in performance of dental implantations, making special methods necessary to correct for eventual magnification which will enable recording of exact anatomical measurements (Flow Chart 3).

Peroperative Factors

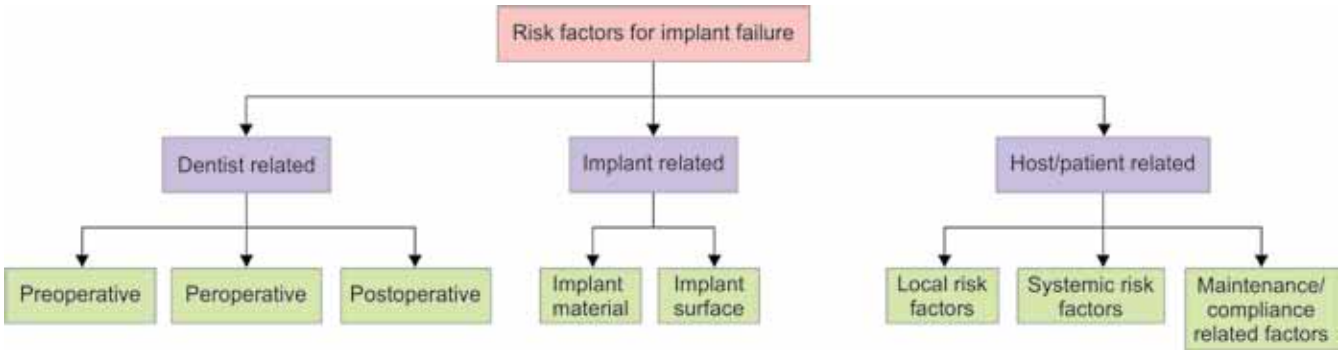
Overheat, which is produced by friction from high torque equipment, damages the implant bone bed and contributes to early-stage failure of implants. About 3.6% of implant failures have been estimated to be related to surgical trauma.[7] Secondly, a non-ideal position for the dental implant may subject it to non-axial loading during mastication. This increases risk for implant fractures and peri-implant bone fractures, which usually occurs in the posterior region that is subjected to a high load, in particular if the patient has comparatively low bone density in this region. Hollow implants lead to increased implant fracture rates if the implant is too small in diameter. This usually happens with the use of two-stage external hex screw-type implant systems. Selection of too-short implants may also increase the failure rate.[7]

Thermally-induced bone necrosis is a rare phenomenon and is one of the causes of early implant failure.

Flow Chart 2: Implant quality assessment scale



Flow Chart 3: Risk factors for dental implant failure



The frictional heat generated at the time of surgery causes a certain degree of necrosis of the surrounding differentiated and undifferentiated cells, thereby representing a significant risk for the failure of bone integration. It was established that the temperature threshold level for bone survival during implant site preparation is 44 to 47°C, and with a drilling time of less than 1 minute.[7,8] Since then, several studies have been performed both *in vivo* and *in vitro* for investigating this issue. *In vivo* studies have demonstrated the harmful role of heat production in subsequent bone healing and the critical temperature that the bone can tolerate without necrosis.[7] *In vitro* studies have revealed the factors that affect heat generation by simultaneously comparing one or two factors.[8] However, few case reports describing implant failure due to bone overheating have been published.

Postoperative Factors

Improper design and guidance of the crown contribute to failure. Too high a cusp or too high an occlusal alignment can increase occlusal loading to an unacceptable level. The crown can also contribute to too-wide contact between the counter tooth and the implant, which leads to high occlusal load of the implant in bone. Occlusal forces contribute to implant fractures and peri-implant bone fractures. Crown width, cusp height, guidance, and occlusal alignment can all be used to control occlusal forces.[9]

Implant-related Risk Factors

Dental Implant Material and Surface Characteristics

The ideal dental implant material should be: (1) biocompatible, (2) of appropriate rigidity for prosthetic function, (3) intimately adaptable to both bone and gingiva surrounding the implant, (4) functionally able to dissipate forces resulting from occlusal load on the prostheses supported by the implant to the underlying bone, and (5) resistant to the large and diverse peri-implant microbial load.[10] Use of bioincompatible implant materials leads to implant failure initiated by adverse host tissue responses.[11] The implant surface coatings comprise titanium oxide (TiO_2) coating, ceramic coating, or diamond coating.[11,12] Biodegradable ceramic coating may have the best future prospects. Most dental implant materials presently used in clinics are quite biocompatible in human tissues in their specific dental application. They are usually made of titanium, titanium-aluminum-vanadium (Ti-6Al-4V), cobalt-chromium-molybdenum, and more rarely of other alloys.[13,14]

Dental implant materials have been remarkably improved in the past half century to meet all kinds of demands. However, research and development are needed to develop even more biocompatible and functional materials to prevent implant failures and to prolong implant life in service.

Implant Position Related

The most common type of failure is caused by poor treatment planning and/or poor surgical execution. The incidence of this type of failure has been estimated at 10%; however, if more stringent criteria are applied it is likely to be higher. This type of failure can easily be avoided with proper treatment planning, proper site development, use of surgical guides and a good understanding of the restorative aspects of implant dentistry by the surgeon.[15,16]

Malposition of the implant can lead to biomechanical problems to the screw joint, or in severe situations to the implant itself, due to overload.

Host-related Factors

Host-related factors can be divided into local and systemic risk (prognostic) factors.

Local Risk Factors

Bone quality and quantity: The most important local patient factor for successful implant treatment is the quality and quantity of bone available at the implant site. Patients with low quantity and low density of bone were at highest

risk for implant loss. Jaffin and Berman,[17] in their 5-year analysis, reported that as many as 35% of all implant failures occurred in type IV bone due to its thin cortex, poor medullary strength, and low trabecular density. Systemic osteoporosis has also been mentioned as a possible risk factor for osseointegration failure. In the study conducted by Dao et al, local rather than systemic bone density seemed to be the predominant factor.[18,36]

Irradiated bone: Implants can be used to provide anchorage for craniofacial prostheses. Radiotherapy in combination with surgical excision is the treatment generally employed for malignant tumors in that region, and osteoradionecrosis is one of the oral effects of radiation therapy. Although radiation therapy is not an absolute contraindication to implant treatment, the reported success rate is only about 70%. Long-term studies are limited, but Jacobsson et al showed increasing implant loss over time.[19]

Biomechanical occlusal loading: Even well-performed and optimally occlusally restored dental implants tend to lead to peri-implant bone loss. Dental implants lack the stress receptors located in the tensional periodontal ligament tissue in natural teeth, and their stomatognathic sensor system is less sensitive than that of healthy teeth.[20] Therefore, due to non-optimal load protection and force-absorbing and distributing systems, a dental implant is subjected to implant micromotion ranging from 50 to 150 micrometers.[21] It has been concluded that occlusal loading strains the hard peri-implant bone because implants lack the protective periodontal ligament system. The relationship of displacement and implant loading continues to be almost linear, without a smoothing or break in the curve after the first moving stage, as is seen in natural teeth.

High mechanical loading leads to increased bone resorption. Osteocytes increase their collagenase-1 [Matrix metalloproteinase-1 (MMP-1)] production under mechanical load, which may initiate bone resorption.[22,23] The MMP-1 degrades bone type I and III collagens, the main structural collagen of bone. Tartrate-resistant acid phosphatase and cathepsin K increase in osteoclasts during mechanically-induced bone resorption.[24] The occlusal overload may result in progressive bone loss around the implant, thus leading to the failure of the implant. The implants which suffer from traumatic failure have subgingival microflora resembling that which is present in a state of periodontal health, with cocci and nonmotile rods as the predominant morphotypes, i.e. *Streptococcous* and *Actinomyces* species as the predominant microflora.[25]

Smoking as a Risk Factor for Implant Failure

Studies suggest that smokers have an increased prevalence of periodontal diseases, tooth loss and oral cancer.[26] There are several studies associating implant failures with smoking.[26-29] Bain and Moy suggested that smoking caused both systemic and local injury to the tissues and is a common contributor to decrease tissue oxygenation, which negatively affects wound healing.[28] Nicotine, presenting the main element of cigarette, reduces proliferation of red blood cells (RBCs), macrophages, and fibroblast, which are the main element of healing.[28] It also increases platelet adhesiveness which can lead to poor perfusion due to microclots. It also acts as sympathomimetics by increasing the release of epinephrine and nor epinephrine, and causes increased vasoconstriction which limits over all tissue perfusion. These all studies hypothesized that smoking compromises wound healing.

Bain and Moy were the first to evaluate the influence of smoking on the failure rate of dental implant.[28] They compared the results between smokers and nonsmokers patients in which implants were placed. They found an overall failure rate of 5.92%, and specifically implant failure in smokers was 11.28% as compared to 4.76% in nonsmokers. Bain did a prospective study which constituted 223 consecutive Branemark implant placed in 78 patients. Patients were divided into three groups: nonsmokers (NS), smokers cessation protocol (SQ), and smokers who continued smoking (SNQ).[30] He found that there was statistically significant difference between failure rate in NS and SNQ group ($p < 0.005$), and between SQ and SNQ group ($p < 0.5$), but none between NS and SQ groups.

A study tested the hypothesis that interrupted cigarette smoke inhalation would reverse the bone quality around implant and found that smoking may affect bone quality in cancellous bone and smoke cessation could result in a return toward the level of control group.[31] With only few studies failing to establish a significant result on the smoking effects on implants, Studies suggest smoking as the factor associated with complications like marginal bone loss, peri-implantitis, bone quality, and quantity, which in turn affect the implant success rate. In fact, success rate of dental implant is found to be twice in nonsmokers as compared to smokers and that too maxillary implant is more affected.[28]

Para-functional Habits and Bruxism

Para-functional habits and bruxism are very common occlusal diseases. Heavy occlusal forces constitute a risk factor for loosening of dental implants. Metal fatigue and

implant fractures occur more frequently in these patients than in controls.[32] More than 77% of all implant fractures have been reported to occur in patients who have signs and a history of chronic bruxism.[33] Para-functional habits are also related to increased peri-implant bone loss.[34]

Systemic Factors

Systemic factors affect both the quality and quantity of bone, which constitute important prognostic factors for dental implant survival. These systemic factors comprise poorly controlled diabetes, osteoporosis, osteomalacia, irradiation and medications.[35]

Diabetes Mellitus

Diabetic lesions involve bone, gingival, and vascular tissues.[35] The disease is thought to suppress collagen synthesis, and it increases the expression of MMPs. The activities of MMP-8 and MMP-9 in saliva correlate with clinical periodontal findings, such as gingival bleeding and pocket depth. The MMP-8 and -9 act cooperatively in degradation of type I collagen in gingival and bone tissues. These conclusions have been confirmed in a rat model. Although most studies of diabetic lesions have been focused on periodontitis, diabetes mellitus has also been considered a risk factor and occasionally even a contraindication for performing dental implantations. Recently, it has been reported that dental implants in diabetes are successful, at least in the short-term.[36]

Osteoporosis

Osteoporosis is a very common disease, with the number of elderly people affected increasing. The main pathological features of osteoporosis are low bone mass and a microarchitectural deterioration of bone leading to fragility, and then to an increased fracture risk. The multiple pathogenic factors related to osteoporosis comprise genetic predisposition and subtle alterations in systemic and local hormones, together with environmental influences.[37] Currently, research interest is focused on the role of cathepsin K in the degradation of bone matrix in osteoporosis.[37] Both the maxilla and mandible can be affected by osteoporosis, which has been considered a risk factor for implant failures and periodontal diseases. The local bone quality of the implantation bed is a more sensitive prognostic factor in this respect than that of peripheral bone, in general, in osteoporosis patients.[38] Implants in osteoporosis have been successful in the short-term, but long-term results have not been reported.

Medication and Irradiation Therapy

Some medications widely used in clinics cause bone loss. In particular, glucocorticosteroids cause iatrogenic osteoporosis by increasing bone resorption via stimulation of osteoclastogenesis.[39] Other drugs with deleterious effects on bone include chemotherapeutic agents, such as doxorubicin and methotrexate, which inhibit osteoblasts and diminish bone formation. Implants are often used in cancer-surgery patients. In oral cancer patients, however, tumor resection is usually combined with irradiation, which locally impairs bone quality and impairs the prognosis of dental implants in the long-term. In one study, irradiation had no effect on implant success rate in the short-term.

Age

Theoretically, patients with increased age will have more systemic health problems, but there is no scientific evidence correlating old age with implant failure.

Parameters Used for Evaluating Failing/Failed Implants

While it is possible to clearly differentiate between a successful and a failed implant, it still remains difficult to identify failing implants. The parameters which have been employed clinically to evaluate implant conditions were discussed by Esposito et al, with the attempt to identify the most reliable ones.[40] The ideal parameter for monitoring implant conditions should be sensitive enough to distinguish early signs of implant failure. The following parameters have, therefore, been proposed.

Clinical Signs of Early/Late Infection

A progressive marginal infection can lead to implant failure. However, clinical signs of infection, such as hyperplastic soft tissues, suppuration (spontaneous, on probing or under pressure), swelling, fistulation, color changes of the marginal peri-implant tissues, etc., are signs which call for intervention. In the absence of mobility and radiographic changes, these signs indicate more a complication (amenable to treatment) than a failure.[40] Mobelli et al compared clinical and microbiological finding related to healthy and failing dental implants. Unsuccessful implant sites were characterized by probing depths 6 mm or greater, suppuration, bone loss, and microbiota consisting primarily of Gram negative anaerobic rods.[41] Becker et al reported that failing implants showed evidence of increased mobility and a high incidence of peri-implant radiolucencies.[38]

Bleeding on Probing

Bleeding on probing has been employed to measure peri-implant tissue conditions. However, recent findings suggest that it cannot be used to discriminate between a healthy or diseased peri-implant state and it does not have a scientific support.[40]

Probing Depths

Probing depths around teeth is an excellent proven means to assess the past and present health of natural teeth, but it may be of little diagnostic value, unless accompanied by signs (e.g. radiographic radiolucencies, purulent exudate, bleeding) and/or symptoms (e.g. discomfort, pain). The benefit of probing the implant sulcus has been challenged in the literature, because sound scientific criteria are lacking. Increasing probing depths over time may indicate bone loss, but not necessarily indicate disease for an endosteal implant.

Sulcus depths greater than 5 to 6 mm around implants have a greater incidence of anaerobic bacteria and may require intervention in the presence of inflammation or exudate (e.g. surgery, antibiotic regimens). Probing not only measures pocket depth, but also reveals tissue consistency, bleeding, and the presence of exudate. It is of benefit to probe and establish a baseline measurement after the initial soft tissue healing around the permucosal aspect of the implant. Increases in this baseline measurement over time most often represents marginal bone loss.

Pain or Sensitivity

Subjective findings of pain or tenderness associated with an implant body are more difficult to assess than these conditions with natural teeth. Once the implant has achieved primary healing, absence of pain under vertical or horizontal forces is a primary subjective criterion. Pain should not be associated with the implant after healing. When present, it is more often an improper fitting prosthetic component, or pressure on the soft tissue from the prosthesis. Percussion and forces up to 500 gm (1.2 psi) may be used clinically to evaluate implant pain or discomfort. Pain during function from an implant body is a subjective criterion that places the implant in the failure category. Sensitivity from an implant during function may place the implant in the survival criteria, and may warrant some clinical treatment.

Clinical Discernible Mobility

Mobility is always a clear sign of failure. Once the clinician has distinguished between the mobility of a poorly connected abutment and the mobility of the underlying implant, the implant must be suspected to be surrounded by a fibrous tissue capsule. Occasionally, clinically discernible mobility can be present without distinct radiographic bone changes. Therefore, mobility is the cardinal sign of implant failure.[40]

Radiographic Signs of Failure

There seems to be unanimous consensus that progressive marginal bone loss is a pathological sign, which can lead to implant failure. Adell et al determined that the mean bone loss for Branemark osseointegrated implants is 1.5 mm for the first year, followed by a mean bone loss of 0.1 mm per year.[1] This value was confirmed by Cox and Zarb with their 3-year report showing a mean bone loss of 1.6 mm for the first year and a mean of 0.13 mm in subsequent years.[11] There can be two well-distinct radiographic pictures: a thin peri-fixtural radiolucency surrounding the entire implant, suggesting the absence of a direct bone-implant contact and possibly a loss of stability, and an increased marginal bone loss. Since, the distinction between the two radiographic pictures is not always clear, when a suspected peri-fixtural radiolucency or excessive marginal bone loss is observed, it is recommended to remove the prosthetic construction and cheek the implants for stability. Clinically discernible mobility after bridge removal can confirm the presumptive radiographic diagnosis of implant failure.

Dull Sound at Percussion

It has been suggested that a subdued sound upon percussion is indicative of soft tissue encapsulation, whereas a clear crystallization sound indicates successful osseointegration.[40] Although it is a rather subjective test without a solid scientific background, it can provide a useful indication to the examiner.

Methods of Implant Removal

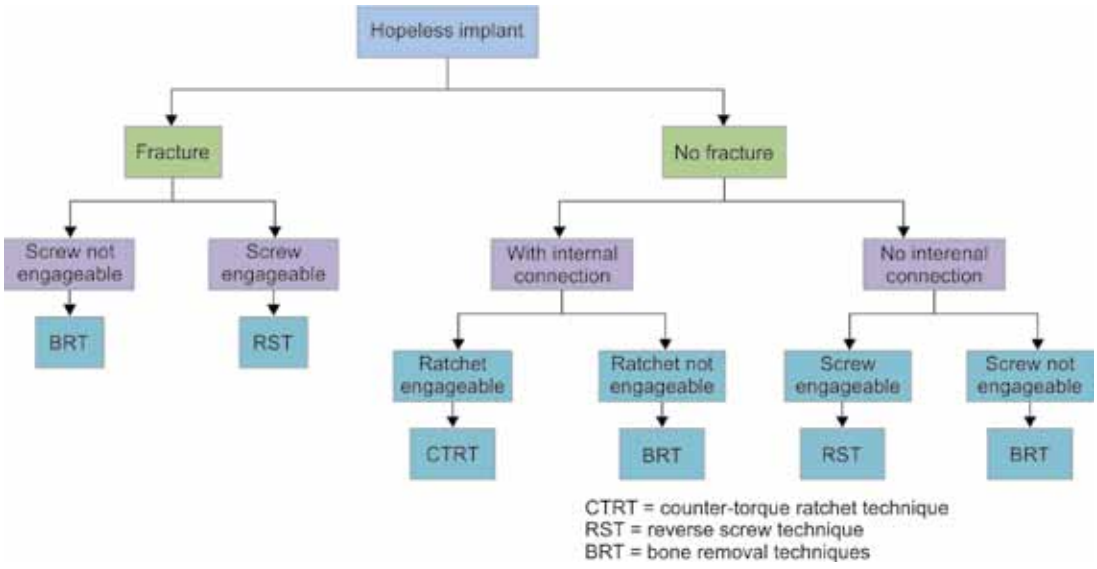
A mobile implant may easily be removed by rotating it counter clockwise using a driver, counter-torque ratchet technique (CTRT), or forceps. Rotating with minimum luxation allows reduced trauma and damage to the surrounding bone and soft tissue. Methods of immobile implant removal include: use of counter torque ratchets, screw removal devices, piezo tips, high-speed burs, elevators, forceps and trephine burs.

The CTRT is the least invasive technique for removing an implant without damaging surrounding structures. The use of CTRT should be considered only if the implant is able to be engaged and reverse-torqued until mobile. The reverse screw technique (RST) is indicated in the removal of a fractured implant when the connection is damaged or in the removal of an external connection implant when the ratchet cannot be engaged to use the CTRT. Piezo tips and high speed burs can be used in conditions where CTRT and RST are not useful to loosen the abutment (Flow Chart 4).

Treatment Alternatives Following Removal of Failed Implants

The literature pertaining to treatment alternatives following the loss of dental implants could best be described as

Flow Chart 4: Methods of implant removal



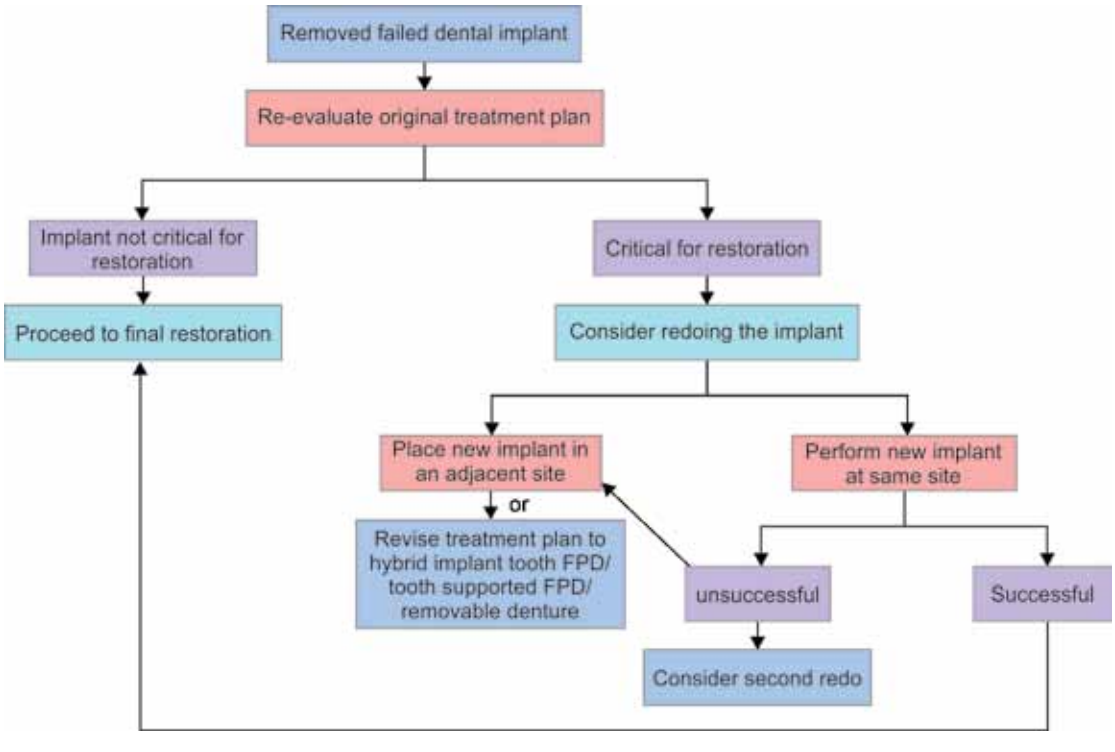
negligible. The decision as to which of these alternatives should be selected is complex and involves both biologic and mechanical considerations, as well as psychological aspects with financial considerations being a silent partner. The treatment of choice should be a team decision with the surgeon, restoring clinician and patient having an equal say in the final outcome (Flow Chart 5).

CONCLUSION

Despite the high success rates and stability of dental implants, failures do occur. While surgical trauma together with bone volume and quality are generally believed to be the most important etiological factors for early implant failures, the etiology of late failures is more controversial. Early detection and treatment of early progressive bone loss around dental implants by mechanical debridement, antimicrobial therapy, and regenerative therapy are the keys for saving early failing implants.

A lost dental implant constitutes an ever-growing problem in clinical practice, one which is likely to intensify in the coming years since, the number of implants placed annually is still growing. The decision-making tree should be aimed at assisting and simplifying the process of selecting the appropriate alternative once a failure has occurred. Failure of dental implants should be perceived as part of the overall risk and consequences of modern dentistry.

Flow Chart 5: Treatment alternatives following removal of failed dental implants



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