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Treatment strategies for dental implant removal: A literature review

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ABSTRACT

Dental implants have been widely used with success, but long-term usage sometimes leads to implant loss. The purpose of this review was to summarize the etiology of early and late failure requiring dental implant removal and the treatment strategies for the removal of failed implants and reimplantation. Early failures are often caused by patient-related factors, such as smoking, diabetes, radiotherapy, bone quality, and periodontitis of the remaining natural teeth. The most common cause of late failure is peri-implantitis, followed by implant fracture and implant malpositioning. Implants should be removed if they are mobile or if their superstructure cannot be maintained (e.g., implant fracture). For peri-implantitis, implant removal should be determined based on the patient's age and esthetic needs, the implant site, and the severity of bone loss. Many reports have been published on implant removal techniques. The reverse torque technique should always be the first choice because of its low invasiveness. The weighted survival rate for the replacement of failed implants is 86.3%, with a much lower survival rate after the second or subsequent implantations. Therefore, patient-specific problems, such as smoking habits and bruxism, should be checked before reimplantation and controlled to the greatest extent possible.

1. Introduction

Dental implants are likely to function for an extremely long period [1]. The success of dental implantation hinges not only on the initial surgical and prosthetic aspects, but also on the ability of dental professionals to address challenges that may arise during long-term maintenance [2]. Therefore, dentists involved in implantation should have the knowledge and skills to cope with variances and problems during long-term maintenance, as well as the ability to perform the surgical procedure and prosthetic design. When an implant has been removed because of exacerbation of peri-implantitis, which results in a loss of bone support during maintenance, or implant fracture, which occurs infrequently, retreatment should be considered. Several methods for removing implants have been developed [3], and each method should be applied appropriately according to the circumstances of the implant failure. Background factors relating to the implant failure should also be considered before retreatment. However, unified treatment strategies for dental implant removal and replacement have not yet been established. This paper narratively reviews and discusses the etiology of implant failure requiring implant removal, including classification into early and late failure. The techniques of implant removal and replacement after removal are also discussed.

2. Early failure

Early failure can be characterized as failure that occurs within the first few weeks or months after implant placement or before functional loading with a prosthetic superstructure [4,5]. Failed or inadequate osseointegration achievement causes early failure [4,6]. The reported prevalence of early failure (implant level) ranges from 0.5% to 5.2% [4,7–10]. The wide range of prevalence may reflect differences in the implant type (turned / rough surface, length, diameter), procedure (graftless/graft), and characteristic of included samples.

2.1. Etiology

Early failure occurs when osseointegration is inadequate or nonexistent [4,6]. Patient-related factors such as systemic and local diseases, health-compromising behaviors, and operator-related factors are outlined below.

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2.1.1. Smoking

Smoking is a well-known risk factor in implant treatment [11]. Smoking harms the immune system and impedes wound healing; consequently, it adversely affects almost all outcomes of surgical procedures performed in the oral cavity, including implant placement. Smoking also negatively affects bone metabolism [12]. One systematic review that focused on early failure also indicated that smoking increased the risk of early failure [13]. Dentists should consider counseling their patients in smoking cessation, which has been shown to improve success rates for osseointegration in smokers [14]. However, not all patients follow smoking cessation counseling; in fact, only 15–25% of subjects provided with smoking cessation counseling by a dentist or dental hygienist stopped smoking [15,16].

2.1.2. Diabetes mellitus

Diabetes mellitus is a common metabolic disorder characterized by hyperglycemia caused by a defect in insulin secretion or insulin action, or both [17]. Diabetes mellitus causes many symptoms such as delayed wound healing [18], immune dysfunction [19], and abnormal bone metabolism [20]. Poorly controlled diabetes negatively affects implant treatment [21,22], although some systematic reviews concluded that well-controlled diabetes mellitus was not a risk factor in implant treatment [22,23]. Focusing on early failure, one systematic review indicated that patients with diabetes mellitus showed an increasing trend of implant failure during the period of osseointegration [24], suggesting that diabetes mellitus is a risk factor for early implant failure. It is notable that 6 out of the 7 studies covered in the systematic review included patients with well-controlled diabetes mellitus [24], which suggests that even well-controlled diabetes mellitus might increase the risk of implant failure up to the end of the early period.

2.1.3. Radiotherapy

It is known that the adverse effects of radiotherapy negatively influence the outcome of implant treatment [25]. Although a retrospective study revealed that radiotherapy was a local factor for early implant failure [7], radiotherapy is rarely cited as a significant factor in systematic reviews focusing on early implant failure [4,5,13]. This may be because implant treatment is rarely conducted on patients undergoing radiation treatment. Although there is no clear upper limit of radiation dose for the success of implant treatment, a recent study suggested that patients receiving less than 38 Gy radiation therapy for head and neck cancer can safely undergo implant treatment [26].

2.1.4. Bone quality

Bone quality is possibly related to early failure. Nicolielo et al. revealed that a particular trabecular bone pattern of very sparse and very dense bone is a cause of early implant failure [27]. It is speculated that very sparse bone causes low implant insertional torque, which is known to be associated with early implant failure. Bone quality is further determined by factors such as turnover, damage accumulation, and mineralization [28]; these factors warrant further study. An animal study indicated that vitamin K2 enabled bone microstructural and mechanical recovery in an ovariectomized model, suggesting that nutritional guidance may be an important factor in bone turnover during implant treatment in postmenopausal patients [29].

2.1.5. Periodontitis

Some systematic reviews indicated that periodontitis is a risk factor associated with early implant failure [5,30]. The microbiota of diseased implants and that of teeth are similar, indicating that periodontal pathogens may extend into the peri-implant tissue [31]. Furthermore, periodontitis activates the immune inflammatory response [32], which may negatively affect osseointegration. Periodontal disease should be treated prior to implant placement to decrease the risk of peri-implantitis [33].

2.1.6. Allergic reactions

Titanium is the main material used for implants because it has long been regarded as a biocompatible material with high corrosion resistance as a result of its thin protective oxide layer [34]. However, recent studies indicated that mechanical stress can cause wearing of titanium [35,36]. Additionally, high serum fluoride has been shown to increase corrosion susceptibility and accelerate titanium ion release, especially in an acidic environment [37]. Released titanium particles can have adverse effects on local soft and hard tissues surrounding implants via activation of the immune system [38]. Previous studies have estimated that the prevalence of titanium allergy is 0.6–2.7% [39,40]. Although patch tests may not always show up as positive [41], titanium allergy may present as rash, urticaria, pruritus, redness, swelling, dermatitis, pain, stomatitis, lichen planus, pustulosis, and gingival hyperplasia, necessitating implant removal [42]. Consequently, it should be noted that implants can provoke allergic reactions that result in implant failure.

2.1.7. Poor surgical skills

The expertise of the surgeon is a significant factor in the success of implants [43]; thus, poor surgical skills may induce early implant failure. Implant surgery requires skills in maintaining sterility, preventing bone overheating, and placing implants in areas with adequate bone, as well as the use of correct flap technique and insertion with a steady hand [44].

3. Late failure

Late failure is defined as failure that occurs after osseointegration and functional loading with a prosthetic superstructure; in other words, failure after osseointegration has been achieved, and thereby need to be removed [45,46]. The previously reported prevalence of late failure (implant level) was 0.5–7.8% [4,8–10]. As in early failure, the range of variation in the prevalence may be related to implant type (turned / rough surface, length, diameter), procedure (graftless/graft), and characteristic of included samples. Furthermore, the length of the observation period could affect the prevalence of late failure.

3.1. Etiology

Late failure could occur as a result of either biological or mechanical complications. Representative complications related to late failure are outlined below.

3.1.1. Peri-implantitis

Peri-implantitis is a biological complication characterized by inflammation around the implant tissue including the surrounding bone. It has been reported that peri-implantitis occurs in approximately 28% to 77% of patients and in 12% to 43% of implants [47]. The prevalence differed among studies because diagnosis was not standardized; however, peri-implantitis is a common clinical complication. Diabetes mellitus and smoking are often cited as risk factors for peri-implantitis. Some systematic reviews concluded that uncontrolled or poorly controlled diabetes mellitus was associated with a greater risk of peri-implantitis [21,48]. Although the study by Alasqah et al. investigating the effect of well-controlled diabetes mellitus on peri-implantitis is not conclusive, they found that crestal bone around implants could remain stable in type 2 diabetic patients in a manner similar to non-diabetic patients if glycemic levels are strictly controlled [49]. A recent systematic review of the impact of smoking on peri-implantitis cited evidence of moderate certainty that smoking is associated with peri-implantitis [50]. However, it is unknown how the frequency of smoking affects peri-implantitis, because most studies did not report this. Another systematic review focusing on the effect of smoking on implant failure indicated that implant failure increased in line with the number of cigarettes smoked per day: more than 20 cigarettes per day was a risk factor for implant failure [11].

3.1.2. Implant fracture

Fractured implants should be removed because they cannot effectively support the superstructure. Several studies have reported incident rates for implant fracture: 0.49% of several types of implants over 6.9 years [51], 0.2% of external implants over 5 years [52], 0.92% of internal connection implants over 4.95 years [53], and 3.5% of internal connection implants over 14 years [54]. An in vivo study reported that the type of implant fracture varied depending on the implant diameter: narrow (3.3 mm) implants fractured at the second or third thread of the implant, regular (3.75 mm) diameter implants fractured at the implant neck or second thread, and wide-diameter (5 mm) implants rarely fractured, but the abutment or screw fractured [55]. Narrow diameter, [51,53,56], implant location (posterior region) [53], higher grades of titanium [56], direct adjacency to a cantilever [56], and bruxism have been proposed as potential risk factors for implant fracture [56,57]. Chrcanovic et al. reported the detailed effects of each factor on implant fracture (increase/decrease in fracture probability) as follows: use of higher grades of titanium (decrease 72.9%), bruxism (increase 1819.5%), direct adjacency to a cantilever (increase 247.6%), every 1 mm increase in implant length (increase 22.3%), and every 1 mm increase in implant diameter (decrease 96.9%) [56]. Nightguards are commonly recommended for bruxism patients to decrease mechanical implant complications; however, there is no evidence that nightguards prevent implant facture, so further study is required.

3.1.3. Implant positioning errors

Even if osseointegration has been established, incorrectly positioned implants can cause functional or esthetic complications, which might lead to implant removal. When the implant is placed too close to an adjacent implant or tooth, resorption of the surrounding bone may occur, which reduces the height of the implant–implant or tooth–implant papilla. Implant positioning that is too shallow, too far facially, or too far inclined axially may cause exposure of the implant shoulder, which causes esthetic compromise and poor cleanability [58,59]. To prevent implant positioning errors, correct diagnosis and planning are required, taking into account the width of the edentulous space, the gingival phenotype, and the bone anatomy [58]. During the implant surgery, computer guidance is useful to reduce positioning errors [60, 61]. However, clinicians should be aware that errors can still occur even when using a computer-guided system [62].

3.1.4. Medication

Some medications, including antiresorptive agents such as bisphosphonates and RANK ligand inhibitors, are known to be related to implant failure. Some systematic reviews suggest that low-dose antiresorptive therapy for osteoporosis does not cause a significant increase in implant failure [63–66] while others could not conclude whether it negatively affected implant treatment or not [67,68]. However, many studies have reported medication-related osteonecrosis of the jaw (MRONJ) associated with dental implants [69–72]. Therefore, patients receiving antiresorptive therapy must be informed about the possible risk of developing MRONJ as a complication related to implant treatment. Additionally, as described in the American Association of Oral and Maxillofacial Surgeons' position paper, implant placement should be avoided in oncology patients receiving high-dose antiresorptive therapy [73].

Medications such as selective serotonin reuptake inhibitors (SSRIs), proton pump inhibitors (PPIs), β-blockers and non-steroidal anti-inflammatory drugs modulate bone metabolism [74–77]. A recent systematic review reported that SSRIs and PPIs significantly increase implant failure [65]. However, the number of included studies was small (two studies for each medication); therefore, further study is required.

4. Management of peri-implantitis

A gold standard method for treating peri-implantitis has not yet been established, although the protocol proposed by Heitz-Mayfield and Mombelli consisting of nonsurgical and surgical treatment has become widely accepted [78]. Their nonsurgical treatment includes oral hygiene instruction, counseling for smoking cessation, assessment of the prosthesis for plaque control, removal and adjustment of the prosthesis, nonsurgical debridement, and antimicrobial therapy. Surgical treatment, such as decontamination of the implant surface with a full-thickness mucoperiosteal flap, and regenerative therapy are recommended when resolution is not achieved by nonsurgical treatment. Recent studies have reported the efficacy of other treatment methods such as laser or photodynamic therapy [48,79]. Implant removal may be chosen in cases in which bone resorption is severe or at the request of the patient. There is probably no reason not to remove an implant that is mobile or is causing uncontrolled pain; however, it is debatable whether implants in which supporting bone is resorbed should be removed. The clinician should take into account the patient's symptoms, rate of disease progression, age, preferences, and systemic conditions.

5. Removal

As in early implant failures in which osseointegration could not be achieved, late failures resulting from peri-implantitis with loss of most of the supporting bone and implant fixture fracture require implant removal and retreatment. Nontraumatic implant explantation should be selected wherever possible to preserve the surrounding bone, followed by implant replacement.

5.1. Criteria for implant removal

Mechanical incidents can generally be treated by repair or refabrication of the superstructure or replacement of screws. However, implant removal is required for implant fractures. For peri-implantitis, no criteria have been established as to whether peri-implantitis should be aggressively treated to preserve the implant or whether reimplantation should be performed after implant removal. Misch et al. recommended the removal of nonmobile implants with 50% bone loss as failures [80]. Greenstein et al. recommended the removal of implants with $\geq$ 75% bone resorption or $\leq$ 3-mm apical bone around the implants [81]. Surgical therapy for peri-implantitis with $\geq$ 50% or $\geq$ 5 mm bone loss has a poor prognosis [82–84]. Therefore, for implants with $\geq$ 50% bone loss, dentists should actively discuss implant removal with patients. Even for moderate bone resorption, surgical management for peri-implantitis may be required, depending on the patient's age and wishes. For mild bone resorption, implant removal may be actively performed for reimplantation after comprehensive assessment of the situation. Fig. 1 shows a flowchart for the treatment of peri-implantitis, including the removal of implants. In cases in which dental problems such as gingival recession, poor plaque control, and bone resorption are caused by implant malpositioning, proper reimplantation should be performed after implant removal.

5.2. Techniques of implant removal

Implant removal is performed using reverse torque, trephines, burs, piezosurgery, laser-assisted explantation, and combinations of these tools [3,85–88]. A systematic review of explantation techniques for osseointegrated dental implants revealed that the reverse torque technique is most commonly selected, with a success rate of 87.7% for 284 implants, followed by burs (100% for 49 implants), trephines (94% for 35 implants), and piezosurgery (100% for 11 implants) [87]. Fig. 2 shows some clinical recommendations for the removal of dental implants.

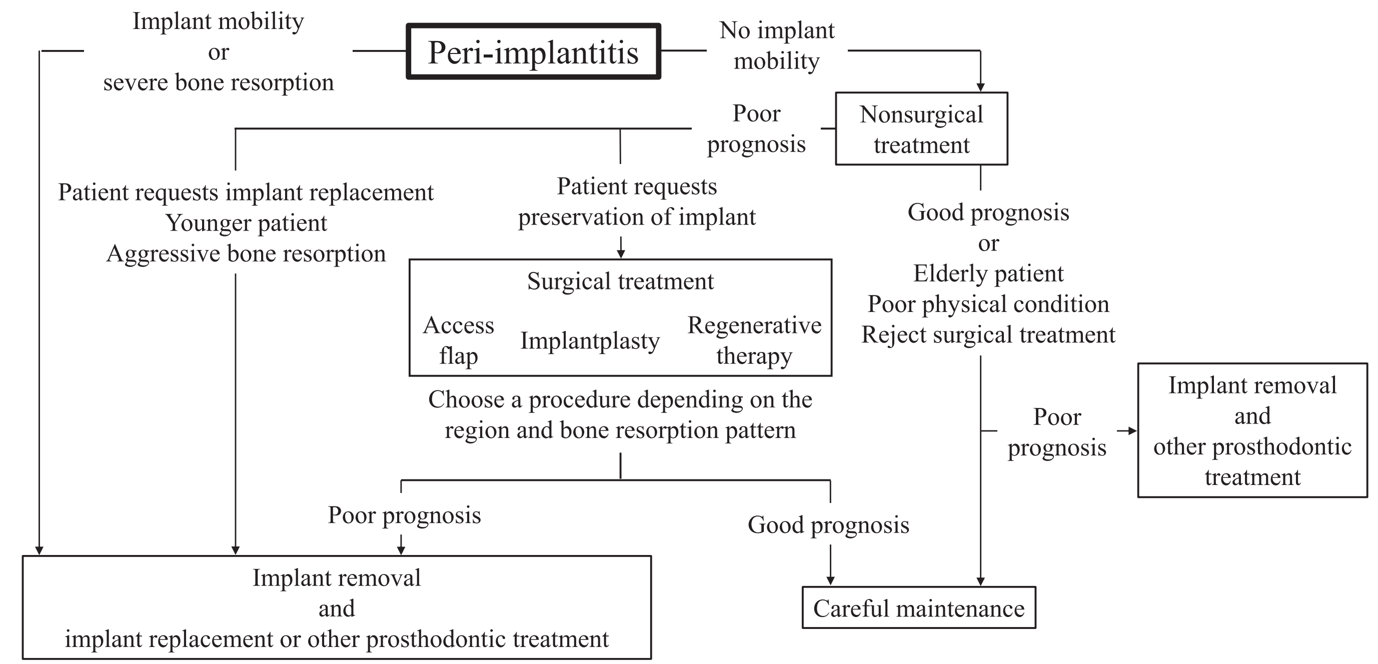

Fig. 1. Flow chart for treatment of peri-implantitis including implant removal.

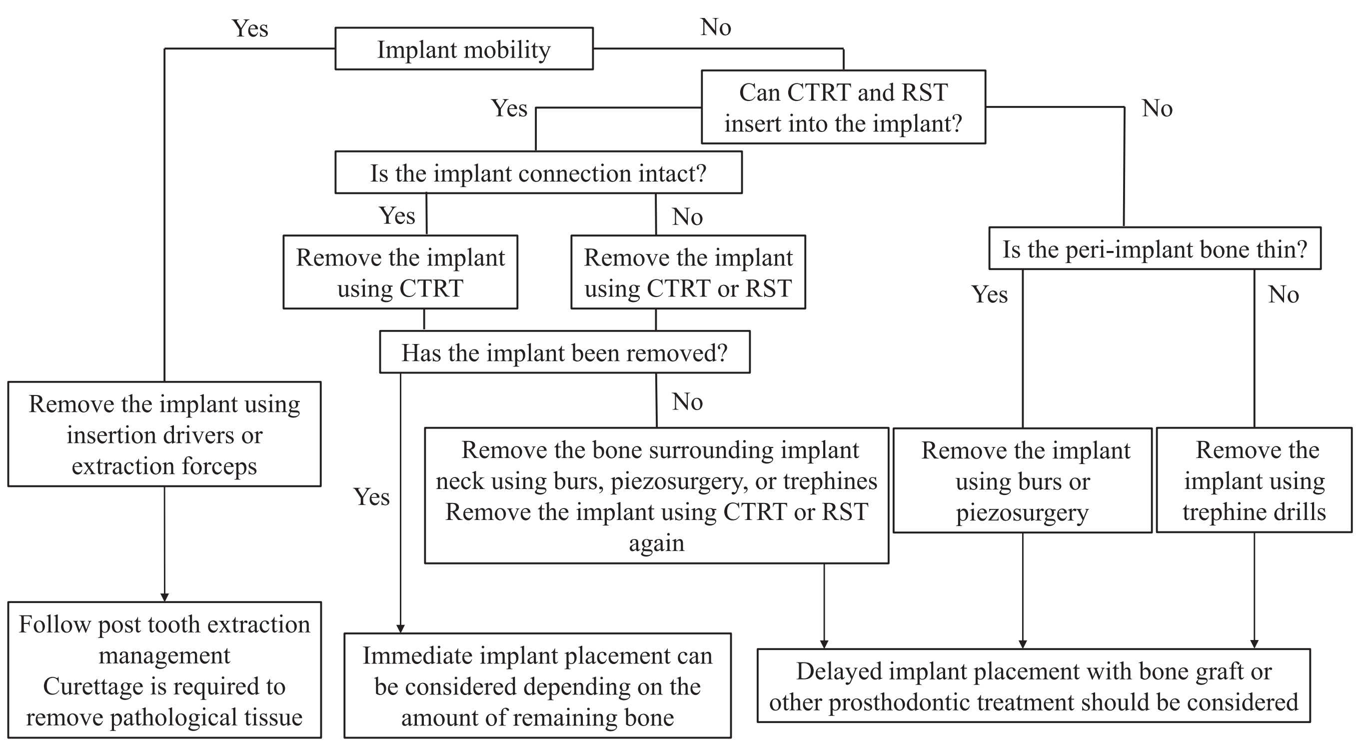

Fig. 2. Flow chart of clinical recommendations for removal of dental implants. CTRT: counter torque ratchet technique; RST: reverse screw technique.

5.2.1. The reverse torque technique

For nonmobile implant fixtures, the minimally invasive reverse torque technique is the first choice for implant removal. Insertion drivers from various manufacturers can be used in reverse torque removal. A strong torque of $\geq$ 100 Ncm is generally required for implant fixture removal, so the insertion drivers should be carefully selected to avoid deformation. Various techniques, such as the counter torque ratchet technique (CTRT) (Neo Fixture Remover Kit, Neobiotech, Korea) and the reverse screw technique (RST) (BTI Implant Extraction System, Biotechnology Institute S.L., Spain and implant retrieval tool, Nobel Biocare, Switzerland), have been developed for implant removal. These instruments allow removal while minimizing damage to the surrounding bones. CTRT is recommended for intact connection with the implant without any implant fracture; in cases where the implant connection is damaged, RST should be adopted [85]. However, care should be exercised when using RST because, unlike CTRT, RST may cause tool fractures upon application of a strong torque with the insertion direction of the implant retrieval tool deviated from the axial direction of the implant fixture.

The reverse torque technique allows removal with minimal damage to the surrounding bone, thereby allowing implantation immediately after removal, depending on the amount of remaining bone. With > 200 Ncm removal torque, the surrounding coronal 3–4 mm of bone should be removed using burs, piezosurgery, or trephines, followed by removal in conjunction with the reverse torque technique [89,90]. Anitua et al. removed 139 of 158 implants using only CTRT with 146 ± 5 Ncm removal torque, and the remaining 19 using CTRT after cutting into the first 3–4 mm using a trephine bur with 161 ± 13 Ncm removal torque [90]. For zirconia implants, CTRT may cause fractures and therefore can be selected only for cases with extensive bone resorption, although relevant data are limited [91].

5.2.2. Burs and piezosurgery

If removal cannot be achieved by the reverse torque technique, the surrounding bone should be removed. In such cases, cone-beam computed tomography (CBCT) should be employed to determine the width of the surrounding bone, especially the buccolingual bone. Then, the side with sufficient bone (usually the mesiodistal bone) is gradually removed using burs and piezosurgery to move the implant fixture using elevators and forceps until it becomes unstable. Advantageously, piezosurgery allows bone cutting while preventing soft tissue damage. Additionally, bone healing can be improved in comparison to using a bur [92,93]. However, piezosurgery is inefficient for significant bone cutting. Intermittent injection with physiological saline is recommended to prevent overheating of the piezo tip. The implant fixture may sustain surface damage, resulting in the entry of titanium particles into the surrounding tissues.

5.2.3. Trephines

Trephine drills are often used to remove fractured dental implants [94–96]. They should only be selected when other removal tools cannot be used because of the large bone defect remaining after removal, requiring extensive bone grafting for reimplantation. Trephine drills of various sizes are available. The smallest effective size should be selected to reduce bone loss. The recommended rotation speed is 1200–1500 rpm, although this varies with the manufacturer. Caution should be exercised when using trephine burs to avoid complications such as fatigue fracture of the mandible and osteomyelitis [85]. Applying a trephine bur to thin peri-implant bone may increase the risk of a significant loss of surrounding bone. Therefore, a diagnosis should be made by CBCT before removal.

5.2.4. Patients' perception of implant removal

Although implant removal after dental implant failure may negatively affect the patient's perception of implantation, a cross-sectional study of patient's satisfaction after dental implant removal using a self-reported questionnaire showed that 83.3% of patients were satisfied with the new implants placed after implant removal [97]. Implant removal seemingly does not affect the patient's satisfaction or quality of life. However, the presence of signs of infection before implant removal may have a negative impact on the quality of life score after implantation [97]. Patients who desire reimplantation after implant removal are characterized by younger age, root form implant type, and prosthetic-related complications as a reason for removal [98].

5.3. Hard tissue dimensional changes following implant removal

A retrospective study to examine the dimensional changes of hard tissue after implant removal caused by peri-implantitis demonstrated that the mean decreases in the ridge width at 1 and 3 mm below the crest were 11.3% and 4.4%, respectively [99]. The buccal and lingual ridge heights significantly decreased to 2.2% and 6.3%, respectively. Bone regeneration along with implant removal can minimize dimensional changes both vertically and horizontally. Use of a reverse torque removal kit was effective in reducing dimensional changes [99]. Additionally, preclinical research demonstrated that, after implant removal by the reverse torque technique, osteocytes existed in the lacunae on the bone surface adjacent to the site of the implant removal. These cells had normal morphology without any damage [100]. Although bone healing mechanisms after implant removal remain unclear, nontraumatic implant explantation should be effective in minimizing dimensional changes after implant removal. Covani et al. reported that approximately half of implant removal cases did not require regenerative procedures for reimplantation, while the other half required bone grafts and a resorbable membrane [101]. The use of biologics such as autologous blood-derived products for ridge preservation after implant removal may also be effective in enhancing the healing process [102].

6. Replacement in failed sites

There are advantages and disadvantages related to the timing of reimplantation after implant removal, as observed for implantation after tooth extraction. Immediate placement after removal shortens the treatment duration and eliminates the need for additional surgical procedures, providing a great benefit to patients, although removal tools are required to prevent the loss of the surrounding bone during the removal. Additionally, the implant site should be checked for peri-implant infection and inflammatory bone sclerosis before removal [88]. Even if the implant fixture can be removed with minimal damage to the surrounding bone, an implant of the same size as the previously placed implant cannot be used. Therefore, the implant diameter or length should be increased [103], and adequate bone width and height should be ensured by CBCT before implant removal. In cases in which there is inadequate surrounding bone, bone healing after removal should be confirmed before reimplantation.

Delayed placement after removal has the advantages of reducing the risk of infection and more easily obtaining primary implant stability, but has the disadvantage of a greater patient burden as a result of the prolonged treatment duration and the need for bone grafting. If removal and reimplantation are needed because of malpositioning of the implants, early implantation can be safely performed after soft tissue and bone healing following removal, instead of immediate reimplantation, because of the differences in the implant's explantation sockets and reimplantation sites.

In cases of implant fracture or peri-implant bone resorption caused by overloading, reimplantation should be accompanied by additional measures such as an increase in the number of implants, use of an implant with a larger diameter, and use of a night guard.

6.1. Survival rate after reimplantation

A systematic review of replacement after implant removal revealed that the timing of reimplantation was generally 4–6 months after removal and the weighted survival rate at 1–5 years after reimplantation was 86.3% [104]. Furthermore, rough-surfaced implants had a higher survival rate than smooth-surfaced implants (90% vs 68.7%). Kim et al. found no significant difference in the failure rate after implant removal between delayed and immediate reimplantation [105]. Delayed placement seemingly has no advantage if there is adequate bone to use an implant with a greater length and diameter than those of the initial implant to achieve primary stability. Another systematic review of reimplantation revealed a lower survival rate of 67.1% for second reimplantations, relative to 88.7% for the first reimplantation, with 91.8% for reimplantation into a site with a previous early failure [106]. Machtei et al. reported that during reimplantation, implants with a larger diameter tend to have a slightly higher survival rate than those with a smaller diameter [103].

6.2. Risk factors and patient selection for reimplantation

Risk factors for reimplantation include patient-related factors (e.g., general health status, smoking habits, uncontrolled diabetes, periodontal disease, and oral hygiene maintenance), implant characteristics (e.g., dimensions, surface characteristics, and loading), and site characteristics (e.g., bone quality and density, vertical and horizontal dimensions, and peri-implant soft tissue) [107]. Occasionally, "cluster effects" (i.e., multiple implant failures in one patient) have been reported as a patient-related factor [108–110]. Park et al. reported that reimplantation failures are more frequently caused by patient factors than by implant factors [111]. Of note, smokers had more frequent reimplantation failures than non-smokers (hazard ratio, 4.79). Patient-specific problems, such as smoking habits and bruxism, should be checked before reimplantation [81]. Reimplantation should ideally only be considered in cases with no patient-related risk factors or if such risk factors have already been resolved.

7. Conclusion

Various tools have been developed to facilitate implant removal, bringing great benefit to both patients and dentists. Because implant removal with a trephine bur results in a large defect in the surrounding bone, minimally invasive procedures for implant removal using the reverse torque technique are the first treatment choice. Implant problems can be solved temporarily by implant removal. However, for subsequent prosthetic treatment, the patient's age and general condition and retreatment costs should be considered, and a new treatment plan should be established after the causes of the problems are determined. Therefore, we should evaluate the cause of the problem, such as diabetes, smoking, or overloading, to see if it can be resolved before proceeding with reimplantation or considering a change to a removable denture. In this review, we have summarized the current research regarding implant removal and reimplantation; however, it is clear that insufficient evidence is available and further research is required in this field.

Conflict of interest

The authors declare that there are no conflicts of interest related to this study.

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