Dental Implant Failure

A Clinical Guide to Prevention, Treatment, and Maintenance Therapy

Thomas G. Wilson Jr.
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Editors

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Introduction and Rationale

1

Thomas G. Wilson Jr. and Stephen Harrel

1.1 Introduction

Some implants will fail.

This can be devastating to the patient as well as the dentist. The information we provide in this book is aimed at helping you reduce implant problems and failures.

The material in this text is a combination of our over 100 years of clinical implant experience combined with the current available literature. While we use the approaches described here, our techniques are constantly changing as new information becomes available.

We have learned that attention to detail always leads to better outcomes. Shortcuts may be less expensive in the short term but too often lead to increased long-term problems. The same applies to selection of implant systems. Few implant companies have the economic wherewithal to produce a consistently quality product, pay to have their product tested, and maintain an ongoing inventory of replacement components. The same is true for prosthetic components and the overlying restorations. Parts made by the company that manufactured the implant fit more precisely than those made by third parties. Components that do not match can lead to premature failure. Select wisely. Bacterial plaque and foreign bodies are related to many implant failures, therefore an emphasis on personal oral hygiene and approriate maintenance proceedures is important.

Our text is in three sections, prevention, etiology, and management. The section on prevention emphasizes proper patient selection, treatment planning surgical techniques as well as appropriate prosthetic approaches. Our current understanding of the etiology of implant failure will be detailed in the second section. The third section deals with reducing the probability of future problems once the implant has

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been placed along with methods currently suggested for treatment of implants and their components that have experienced problems.

It should be emphasized that while our understanding of the etiology and treatment of bone loss around implants has increased over the last few years, there are still large gaps in our knowledge. It is therefore suggested that our readers stay current with emerging information on these most vexing of problems.

1.2 Current Definitions

The 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions [1] has defined the following conditions:

- Peri-implant health
- Peri-implant mucositis
- Peri-implantitis
- Peri-implant soft and hard tissue deficiencies

Peri-implant mucositis is defined by bleeding on probing and visual signs of inflammation with no progressive bone loss. Peri-implantitis is defined as progressive loss of supportive bone characterized by inflammation in the peri-implant soft and hard tissues (see Chap. 8 for details). The consensus of the report was the sole etiology of peri-implantitis and peri-implant mucositis was plaque associated as will be seen throughout this text, other factors may play incidental or significant roles of the etiology of these problems.

1.3 Summary

This book will review prevention of implant failure, potential causes of failure, and the current treatment of failing implants.

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1. Caton JG, Armitage G, Bergludh T, et al. A new classification scheme for periodontal and peri-implant diseases and conditions-introduction and key changes from the 1999 classification. J Periodontol. 2018;89:S1–8.

Prevention of Peri-Implant Problems: Patient Selection

2

Pilar Valderrama

Key Points

- Patient selection is a key factor when considering the success of dental implant therapy.
- Appropriate screening of candidates for dental implants can help prevent future complications.
- Exhaustive medical and dental history should be obtained and risk factors evaluated and discussed with patient.
- Manageable conditions are addressed and chronic conditions controlled.
- Discussing all these circumstances with the patient prior to implant surgery to evaluate the patient and allow informed consent is important since lack of compliance is frequently associated with complications.

2.1 Patient Screening

There is an increased demand for dental implants due to a heightened awareness in the general public about this treatment alternative. Due to the vast number of publications demonstrating the high predictability of this type of treatment, dentists are offering implant therapy to their patients more than ever before [1]. Dental implants are now considered the standard of care for fully edentulous patients and single edentulous spaces. Many clinicians and patients are opting for extracting teeth with poor prognosis or poor esthetics and replacing them with implant supported prostheses. At the same time we are finding an increasing number of reports about biologic and mechanical complications. It is estimated that peri-implantitis affects

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18.5% of the patients who have dental implants and 12.8% of the implants placed [2]. Therefore it is important to identify those patients at risk of having complications before those occur.

When a patient is examined for the first time and the chief complaint is related to replacing missing teeth the first consideration must be to determine if they are a good candidate for implants.

Listening to the patient's needs and expectations should be emphasized. Many complications arise from a poor understanding of the patient's desires and ability to undergo implant therapy. Allowing an open communication for the patients to express their specific needs and concerns is a necessary part of treatment planning. Once a problem has been identified it is important to educate the patient about how this situation could affect their treatment outcomes. In most cases patients have heard about implants but are not familiar with all of the components and their interactions with the bone and soft tissues. It is important to define the terms to be used during treatment planning and therapy so that the patient is fully informed about their treatment. A patient with a higher dental IQ will be more cooperative in case of complications. The use of audiovisuals and models to explain implant therapy will help patients understand the sequence of events and the timing of the procedures. Once the patient understands what dental implants are and how they work and is interested in proceeding with implant therapy a comprehensive medical and dental history must be completed to determine if they are a candidate for implant therapy.

2.2 Medical History

Demographic information including age and gender at the time of consultation should be documented. For gender, there is a slightly higher risk of failure of implants placed in males compared with females [3]. The gender of the patient does not seem to indicate greater risk of failure or complications; however, the American academy of periodontology (AAP) and center for disease control (CDC) reported greater percentage of periodontitis in males than females and since periodontitis is a risk for peri-implantitis this could account for the association with gender [4].

The age of the patient at the time of implant placement should be considered. There does not seem to be an upper limit for age, however it has been documented that implants placed at an early age, before the growth of the maxilla and the mandible has been completed, may be associated with esthetic failures. As an example, it is common to find cases in which implants are placed at an early age in patients suffering from ectodermal dysplasia (ED) or tooth agenesis. According to a review of the literature published in 2009, implant survival rates vary between 88.5% and 97.6% in patients with ED. [5] Individuals with hypohidrotic ED, presenting with dryness of the mouth seem to present special challenges due to structural as well as direct effects of the mutations on bone which seem to compromise osseointegration [6], and may be more susceptible to peri-implantitis.

The next step is to obtain a complete medical history. It is known that systemic conditions can affect the healing of soft and hard tissues in the oral cavity. Some

systemic diseases are associated with increased risk of periodontal disease and therefore with peri-implantitis. Thus, a complete interrogatory should be conducted. Known risk factors include diabetes and smoking. Having diabetes makes the patient almost twice as likely to have peri-implantitis compared to nondiabetic patients; and patients with hyperglycemia had a 3.39-fold higher risk for peri-implantitis compared with those with normoglycemia [7]. In cases of patients with poorly controlled diabetes impaired osseointegration, elevated risk of peri-implantitis and higher level of implant failure has been observed. However, when diabetes is under control, implant procedures are safe and predictable with a complication rate similar to that of healthy patients [8]. Poorly controlled type 2 diabetes has been shown to induce increased probing depths and radiographic marginal bone level changes around implants [9].

Some studies have reported an effect of cardiovascular disease on implant survival. There could be a confounding variable related to the fact that patients with periodontal diseases are associated with a higher prevalence of cardiovascular disease and the likelihood of comorbidity expressed by a history of cardiovascular diseases and periodontitis [10].

Emerging risk factors include rheumatic disorders. In a prospective study, implants placed in patients with rheumatoid arthritis (RA) demonstrated a 93.8% success rate at 3.5-year post treatment. In the same study, patients with RA and concomitant connective tissue diseases presented increased bone resorption and more bleeding on probing [11]. A rigorous maintenance program including optimal oral hygiene should be implemented to avoid complication in patients with vulnerable soft tissue conditions [12]. For patients with Sjögren a mean success rate of 86.33% has been reported; for ectodermal dysplasia, success varied between 35.7 and 100%; for epidermolysis bullosa between 75% and 100%; and for oral lichen planus (OLP) in just a few studies reported the implant survival rate (SR) was 100% [13]. In another systematic review with longer follow-up periods of up to 5 years OLP showed an SR of 95.3%. For epidermolysis bullosa after 3 years, SR was 98.5%. In general the reported SR is comparable to patients without these conditions [14].

Osteoporosis has been widely investigated without any conclusions about its effect on implant survival. Cross-sectional studies have shown that diagnosis of osteoporosis and osteopenia did not contribute to increased risk of implant failure unless it is associated with smoking habit [15]. The use of bone antiresorptive agents like bisphosphonates could potentially affect the way the bone heals after implant surgery and the osseointegration itself. There is a slightly increased risk of implant failure (1.5%) for patients taking bisphosphonates (BP), however, there is not enough evidence to make definitive statements on the subject due to the lack of publications reporting on these patients [16]. A systematic review reported that for patients taking oral BP for 1–4 years before the implant surgery, none of the patients developed osteonecrosis during a 3-year follow-up period and osseointegration was not affected by the medication; with an SR between 95% and 100%. When reviewing published guidelines for patients receiving intravenous BP for cancer treatment, there is a consensus for contraindicating implants [17]. However, a publication

reporting 19 cases of bisphosphonates related osteonecrosis of the jaw (BRONJ) showed that osteonecrosis around the implant after BP administration can occur. En bloc bone sequestration might be one of the characteristics of implant-related BRONJ, which is different from peri-implantitis-induced bone destruction. The authors of this paper recommended a need to study the possible role of bone microcracks in this type of bone destruction [18]. Other conditions affecting the immune system and putting the patient at risk of aggressive periodontitis like hematological conditions and immunodeficiencies must be considered. For HIV-positive patients with controlled risk factors and normal CD4+ cell counts the success rate after 4 years follow-up has been reported to be 94.7%; when calculated at the implant level it was 94.53% [19]. Prophylactic antibiotic treatment, the administration of highly active antiretroviral therapy, and control of the CD4+ T lymphocyte counts appear to be important to avoid complications [20]. However, it is important to consider that there is limited published scientific evidence in regard to possible increased risks of invasive oral procedures associated with the HIV status of the patient [21].

A complete questionnaire including review of all medical systems and family history should be completed. Since habits like smoking and bruxism have been associated with implant failure, social history and patient's habits must be documented. The data suggest that individuals, who smoke before or after implantation, have 35–70% higher risk of dental implant failure, compared to non-smokers. However, there are no statistically significant differences when comparing former smokers and non-smokers success rate, indicating that smoking cessation protocols might be beneficial [22]. Both water pipe and electronic cigarettes (ECIG) deliver nicotine. Water pipe tobacco smoking has been associated with periodontitis, dry socket, premalignant lesions, and oral and esophageal cancer. The health effects of long-term ECIG use are unknown [23].

A complete list of medications should be obtained. If the patient reports a psychiatric condition like dysmorphophobia or other similar diseases, which could interfere with their capability to adjust to the new prosthesis, a psychiatric consultation should be initiated. If the patient is under medical treatment, the treating physician information should be obtained and if deemed necessary a medical consultation may be requested.

A review of medical systems must be performed. For all conditions listed, the duration and severity should be documented. If necessary, lab results can be ordered. A review of systems can also help to identify possible signs and symptoms of undiagnosed medical conditions. For patients with a history of prosthetic joint replacement, patients should be aware of the guidelines for antibiotic prophylaxis recommended by the different specialties and consultation should be initiated. This is especially important in those patients with a history of failure and replacement of pre-existing medical prostheses. Consultation with the treating orthopedic surgeon is recommended to inquire about the possible etiology of the failure since similarities have been found in studies of orthopedic joint failure involving corrosion of the titanium surfaces and similar condition found in peri-implant bone loss.

In cases of cancer therapy with a history of radiation, the total radiation dose, areas affected by radiation, and concomitant use of chemotherapy should be

documented. Radiation doses higher than 55 Gray units significantly decrease implant survival [24]. The calculated survival rate of implants placed in irradiated bone is approximately 84%; significantly lower when compared with no irradiated bone tissue. Strict monitoring and close follow-up of implants are recommended to avoid complications [25]; however the type of cancer therapy and the use of bone graft in reconstructive surgery after cancer don't seem to affect implant survival [26]. The timing of these anti-cancer therapies in relationship with the implant surgery must be considered. In general, there is a better success rate (92%) when the irradiation happens after the implants have been placed and success is usually higher for the mandible than for the maxilla [24]. There is also risk associated with implant loss due to tumor recurrence requiring resection of the bone in which implants were placed [26]. Although some data suggests that there is no association between the timing and success of implants placed in radiated bone the interval reported in publications varied between 6 and 15 months with a success rate ranging from 62% to 100% [27]. The type of bone graft used for reconstruction after cancer can be related with survival. If the graft is vascularized (retains its original blood supply), survival is higher (89%) than for nonvascularized bone grafts (81%) [24]. If implants are placed immediately after grafting, there is a higher risk of failure and for implant non-restorability due to inappropriate placement [28]. Chemotherapy does not seem to be related with higher risk of peri-implantitis, however there are a limited number of studies published [29].

If the patient has a past history of oral squamous cell carcinoma (OSCC), it is important to consider that some isolated cases of OSCC have been found in the vicinity of implants. According to the available literature, it is not possible to establish a cause-effect relation between the implants and the development of OSCC. However, its presence can be confused with peri-implantitis, therefore in the cases where an inflammatory lesion around an implant appears suddenly, does not respond to conventional treatment with or without anesthesia or paresthesia, a biopsy should be obtained [30]. Peri-implant malignancy may represent up to 1.5% of oral cancer cases. Squamous cell carcinoma (85%), basal cell carcinoma, and carcinoma of metastatic origin have been reported in the literature. Risk factors include previous oral malignancy, potentially malignant conditions, and smoking [31].

Neurological disorders like Parkinson's, multiple sclerosis, amyotrophic lateral sclerosis, tremors, or other conditions affecting the patient's capability of performing adequate oral hygiene should be documented. Case reports about dental implants placed in patients with neurodegenerative diseases including dementia, Parkinson's disease, and Huntington's disease have demonstrated that implants can improve the quality of life of these patients. In these cases the authors recommend to use the minimum number of implants and ideally to use them to support removable prostheses in order to facilitate access for oral hygiene [32].

Although infrequent, we must inquire about allergic reactions to the chemical elements used to fabricate dental implants and the prosthetic components. Reports on clinical allergy to titanium and adverse events have rarely been published [33]. However, several studies have reported cases of metal allergy caused by

titanium-containing materials. It is recommended that pre-implant patients should be asked about a history of hypersensitivity reactions to metals, and patch testing should be performed on patients who have experienced such reactions. The diagnosis of Ti allergy is still based primarily on clinical evaluation [34].

2.3 Dental History

A comprehensive dental history must be completed and reviewed. While maintaining focus on the patient's chief complaint the dental history will provide information about how previous dental treatments have worked for this patient and if the patient has been compliant with maintenance. It is not necessary to lower the patient expectations but to be realistic about achievable goals. First, it is important to determine the cause of tooth loss if possible. If the tooth was lost to periodontal disease, it is important to know how long ago the patient was diagnosed with periodontal disease and what type of treatment the patient has received as well as the frequency of periodontal maintenance visits and the date of the last appointment. Significant risk for implant loss, significant bone loss, and an increased risk of peri-implantitis is present if there is history of periodontal disease when compared with patients without periodontitis [35]. There is also a significant risk on the occurrence of postoperative infections when implants are placed in patients with active periodontal disease [36]. In patient with a history of aggressive periodontitis the risk ratio for failure in patients is significantly higher when compared with periodontally healthy patients and those with chronic periodontitis [37]. More bone loss and significant lower survival rate at 3 years follow-up (97.98%) compared to healthy patients (100%) has been also reported [38]. When patients with periodontal disease were observed for a longer period of time (16 years) they showed decreased implant success (96%), higher incidence of mucositis (56%), and higher rate of peri-implantitis (26%) [39]. However, successful treatment of periodontitis prior to implant placement lowers the risk for peri-implantitis [22].

Oral hygiene habits like tooth brushing and the use of interproximal aids like dental floss or interproximal brushes, flossers, floss threaders or other devices should be noted. Dental plaque accumulation around implants has been associated with the development of peri-implant mucositis and peri-implant bone loss. It has been shown that almost 50% of the implants presenting with peri-implantitis are those with no accessibility/capability for proper oral hygiene [22]. Scientific evidence based on studies on animals and humans indicate that biofilm accumulation leads to a higher frequency of bleeding sites around implants as compared with teeth [40]. The microbial composition of peri-implantitis-associated biofilms is mixed, non-specific, and very similar to that of periodontitis [41]. Therefore, lack of periodontal maintenance or poor adherence to it results in significantly more sites with mucosal bleeding, deeper peri-implant pockets or alveolar bone loss and with higher implant loss [42]. When compared to periodontitis, peri-implantitis has more inflammatory infiltrate and severity of tissue destruction at a faster progression rate [41]. Thus, patient compliance with regular anti-infective therapeutic protocols has

shown to be effective in the management of biological complications and prevention of implant loss [43]. Also, habits like bruxism should be controlled since the presence of wear facets has been associated 2.4 times when wear facets were displayed on the prosthetic crowns [44]. The use of oral rinses, toothpaste, or gels containing fluoride should be recorded, since fluoride has been associated with titanium corrosion. For fully edentulous patients, it is important to determine for how long the patient has been edentulous and what type of prosthesis has been used and for how long. This could dictate the residual ridges shape and amount of bone resorption. If there is history of trauma, the deformity of the residual bone could limit the alternatives for rehabilitation. In case of tooth loss due to endodontic complications and pre-existing periapical lesions, it is necessary to know if any biopsy was obtained of periapical lesions and what was the diagnosis and if grafting procedures were performed at the time of extraction.

For patients wearing full dentures or fully edentulous, there seems to be a lower risk of peri-implantitis. Overall prevalence of peri-implantitis in fully edentulous patients after 5 years has been shown to be 0% compared to partially edentulous 3.4% and 5.8% versus 16.9% after 10 years of implant placement, respectively. Paradoxically, fully edentulous patients harbored more plaque on their implants and had significantly higher bleeding than partially edentulous patients but no deeper pockets [45]. This could be explained by the fact that partially edentulous patients harbor a potentially more pathogenic peri-implant microflora than fully edentulous. Therefore the quality of the plaque seems to be more important than the quantity of it [46].

2.4 Summary

A complete medical and dental history is mandatory before the placement of implants. Multiple conditions can influence the long-term outcome of implant therapy and some conditions may contribute to implant failure or loss. The patient should be counseled on all factors that may influence the success of implant treatment so that they are fully informed of the potential risks to implant success and can then provide informed consent.

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Prevention of Peri-Implant Problems: Treatment Plan

3

Jeffrey Pope

Key Points

- The best way to manage peri-implant problems is to avoid them in the first place.
- Many peri-implant problems can be attributed to poor treatment planning.
- Implant site evaluation is a critical step in the treatment planning process.
- Adequate radiographs, study models, and hard and soft tissue evaluation are required.

3.1 Introduction

The best way to manage peri-implant problems is to avoid them in the first place. Most peri-implant problems can be attributed to poor treatment planning or poor case selection. It is critical to the success of the implant to ensure that there is adequate bone, adequate attached tissue, proper implant angulation, proper placement, and proper planning of the restorative materials. If an implant is not appropriately treatment planned, there is a high chance of implant failure.

In order to properly plan an implant restoration, multiple pieces of diagnostic information are required. Skipping any step in the process can lead to complications at the time of implant surgery or at the time of restoration fabrication and placement. A comprehensive work-up of the implant patient should include a site-specific evaluation as well as a comprehensive evaluation of the patient's systemic health (Chap. 2), dentition, occlusion, temporomandibular joints, and oral soft tissues. It is important to obtain a set of radiographs (periapical, panoramic, and/or computed tomography scan), study models/casts, and photographs prior to finalizing the treatment plan.

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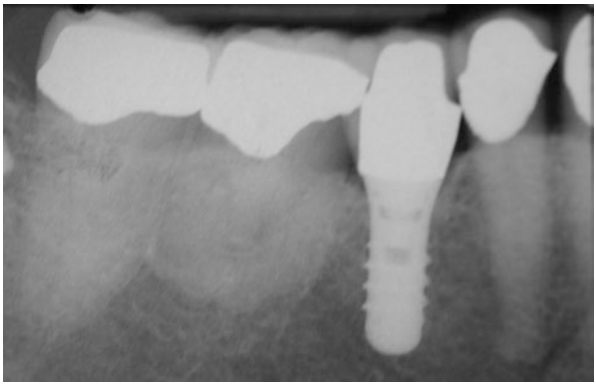

Fig. 3.1 Properly angled periapical radiograph

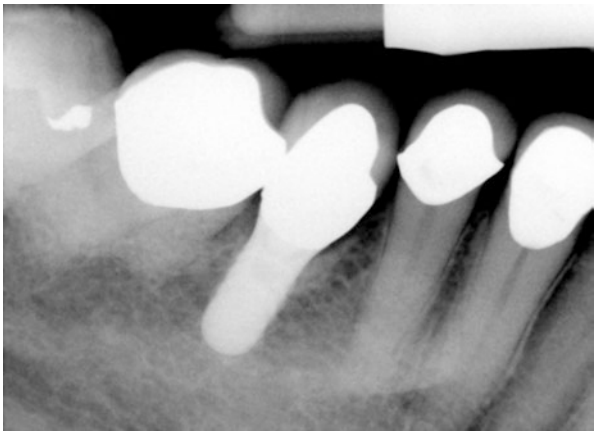

Fig. 3.2 Poorly angled periapical radiograph

One of the most important aspects of implant treatment planning is a set of good-quality, diagnostic radiographs. Periapical radiographs are appropriate for evaluating the bone in two-dimensions: corono-apically and mesial-distally. Periapical radiographs are often used during the surgical placement of the implant to verify the proximity of the implant osteotomy and implant body to the surrounding structures. It is of paramount importance that the radiographs be taken at right angles to the teeth and implant in order to give an accurate representation and measurement of the implant site (Fig. 3.1). Poorly angled radiographs can give the clinician a false measurement due to foreshortening or elongation and could possibly result in damage to adjacent structures or nerves (Fig. 3.2).

In addition to periapical radiographs, a panoramic radiograph can help clinicians identify gross structures such as the inferior alveolar canal, mental foramen, maxillary sinuses, etc. (Fig. 3.3). While a panoramic image allows the operator to get a sense of the adjacent teeth and structures, it is important to remember that panoramic radiographs can be distorted by up to 25% [1]. For this reason, cone beam computed tomography (CBCT) would be more appropriate if additional evaluation of the implant site is required (Fig. 3.4). It is highly recommended that a CBCT be obtained

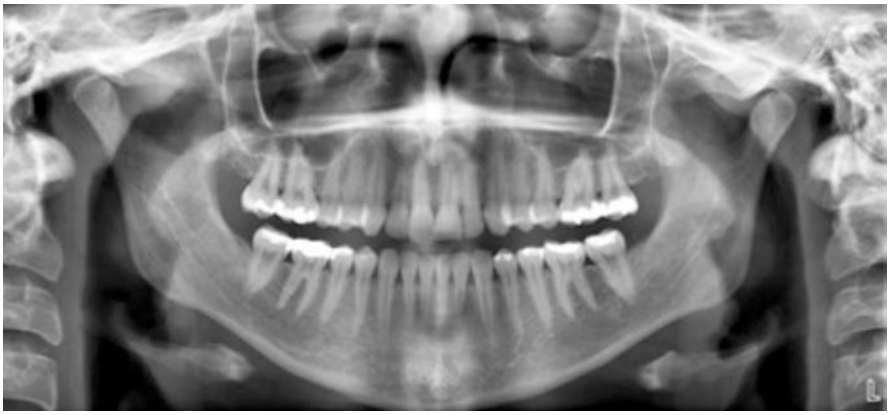

Fig. 3.3 Panoramic radiograph

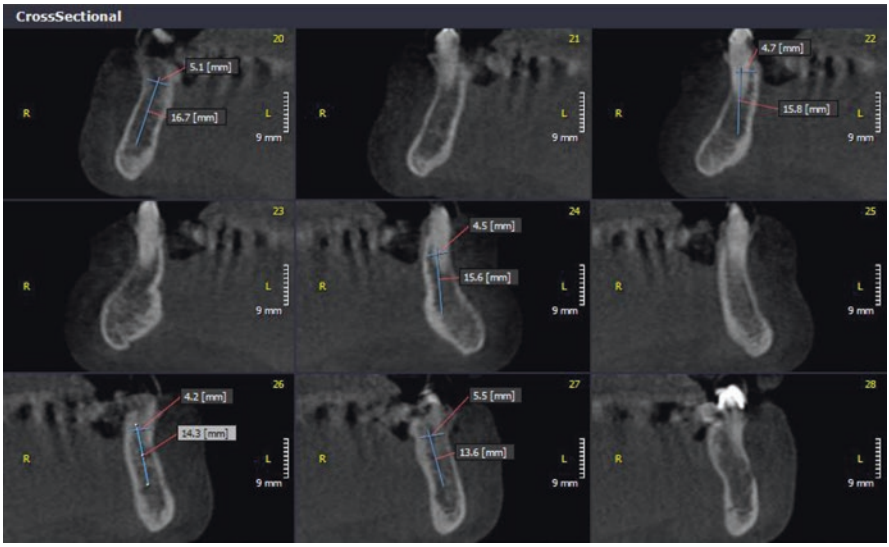

Fig. 3.4 Cross-sectional view of a cone beam computed tomography (CBCT) scan

for implant site evaluation for placement of implants in the anterior esthetic zone, in the posterior maxilla if the implant will be in close proximity to the maxillary sinuses, the mandibular second premolar region (due to the proximity of the mental foramen), the mandibular second molar region (due to the proximity to the inferior alveolar nerve and possible undercuts) and any other site where the clinician does not feel that a clinical exam and conventional two-dimensional radiography are adequate for implant site evaluation. With the advances in digital dentistry and treatment planning, the CBCT can also be used to plan and develop a surgical guide to aid the dentist in proper placement of the implant at the time of surgery (see Chap. 4).

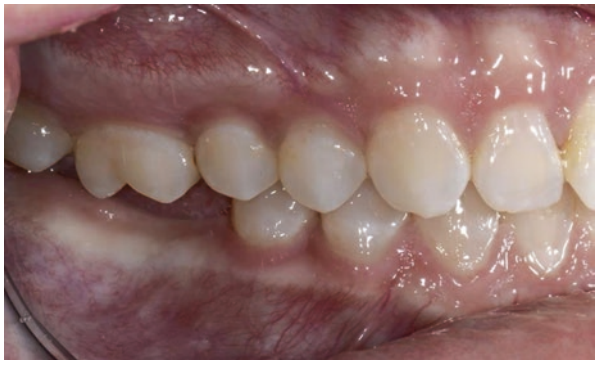

Fig. 3.5 Limited restorative space in the posterior right quadrant for implant placement due to supra-eruption of the maxillary molars

Study models and photographs are a critical component of the implant site evaluation process. Often, spacing and implant angulation issues could have been prevented with pre-operative evaluation of study casts. This is especially important to ensure there is adequate restorative space at the implant site. Sites that have been edentulous for extended periods of time will often result in supra-eruption of the opposing tooth, thus limiting the clinician's restorative space and materials options (Fig. 3.5). A full evaluation of the inter-arch space is imperative. The study models will often be used in the fabrication of a surgical guide to aid with placement of the implant at the time of surgery (see Chap. 4 for more information regarding surgical guides).

Evaluation of the bone at the surgical site can give the clinician important information that relates to the recommended length of time that the implant needs to integrate, the best method for preparing the osteotomy, as well as a possible predictor for implant success. Sites that have poor quality bone are more likely to have implant complications and failure of the implant to integrate. Bone is typically classified as Types I–IV [2]. Type I bone is very dense and almost completely cortical. There is a limited blood supply to this type of bone and it can often take longer for an implant to integrate. There is a higher failure rate associated with implants placed in type I bone. Type I bone is typically found in the anterior mandible. Type IV bone, on the other hand, is the least dense type of bone and is completely comprised of cancellous bone. Clinicians often describe type IV bone as being "spongy" or like Styrofoam. Type IV bone requires the greatest amount of time for implant integration and is associated with the highest failure rates [3]. Type IV bone is typically found in the posterior maxilla. Whether or not the surgical site has been augmented with bone (guided bone regeneration or GBR) also plays a role in the timing of implant placement. It is recommended that sites where bone grafting has been performed should be allowed to heal for approximately 3–8 months prior to placing the implant depending on the size of the graft and the area in which the bone was placed. Entering the graft site too early will result in greater risk of implant failure due to the inability to achieve implant stability at the time of implant placement. The type of bone graft material used (i.e. human bone vs. bovine bone) will impact the quality of bone at the surgical site. A CBCT can be used to give the clinician a

general idea of the density of the bone by assessing the Hounsfield Units (HU), or units of density, at the surgical site [4].

One of the most overlooked aspects of the implant site evaluation is the oral soft tissue. It is important to perform a periodontal examination of the adjacent teeth as well as the entire mouth to check for evidence of periodontal disease and biotype, which could increase the patient's risk for implant failure [5]. Additionally, bone loss at an adjacent site could result in soft tissue recession following the surgical procedure, which could have dramatic consequences for the esthetics of the case. Sites where inflammation is present should be addressed prior to performing any elective therapy. The amount of keratinized or attached tissue at the implant site is important for the long-term maintenance of the implant. Many peri-implant problems can be attributed to a lack of adequate of this tissue, even when the implant is adequately placed in bone and the restoration is ideal. It is recommended that there be a minimum of 2 mm of attached tissue on all aspects of the dental implant in order to provide adequate long-term maintenance of the implant [6]. For surgeons, a minimum of 4 mm of attached tissue is necessary at the surgical site (2 mm on the lingual aspect and 2 mm on the buccal aspect of the implant). If there is not adequate soft tissue present, a connective tissue graft or soft tissue allograft should be performed prior to or at the time of implant placement.

Finally, evaluation of the dentition is important to check for caries, subgingival restorative margins, and signs of occlusal wear prior to placement of the dental implant. Caries at an adjacent site may affect the overall treatment plan for the patient as well as provide an environment where plaque and debris collects adjacent to the implant. Trauma from occlusion has been shown to be a possible etiology responsible for implant failure [7] and patients that are known bruxers should be fitted for an appropriate occlusal guard device, preferably in hard acrylic.

Another aspect of the treatment plan involves the appropriate selection of the dental implant. There are over 200 dental implant systems available in the USA. It is recommended that the clinician use a reputable implant company that has a long track record of success in the dental literature. Small companies that are short-lived may result in the inability to acquire parts in the future should the implant company go out of business. The type of implant material, titanium vs. ceramic, is also a consideration (Fig. 3.6). For over 30 years, titanium implants have been the most widely used implant prosthesis in the jaws. Recently, ceramic implants have begun to gain traction in the market place. The data on the long-term success of these implants is limited at best and only time will tell whether zirconia is an acceptable alternative to titanium for the osseointegration and long-term maintenance of dental implants.

Another consideration is the type of implant platform (bone level vs. tissue level), length, shape (parallel walled vs. tapered), and diameter of the implant. Typically, the type of implant platform is determined by the restorative dentist, and sometimes surgeon, based on the proposed final outcome. Tissue level implants provide a polished collar that shifts the implant–abutment interface away from the bone (Fig. 3.7). However, in areas of thin tissue or limited restorative space, this can result in show-through of the titanium through the soft tissues or inadequate restorative space for a ceramic restoration. Bone level implants provide greater restorative

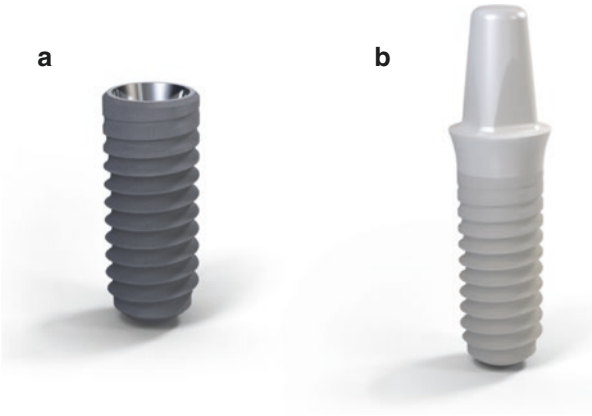

Fig. 3.6 Titanium (**a**) vs. ceramic implant (**b**)

Fig. 3.7 Straumann tissue level implant

space, but shift the implant–abutment interface to the level of the crest of bone (Fig. 3.8). The length of the dental implant is determined by the site evaluation and proximity to adjacent structures. It is recommended that the apex of the implant remain at least 2 mm away from any vital structures (nerves, maxillary sinus, undercuts, etc.) [8]. The shape of the dental implant, parallel-walled vs. tapered, is a personal choice. Frequently, tapered dental implants provide a more "aggressive"

Fig. 3.8 Straumann bone level implant

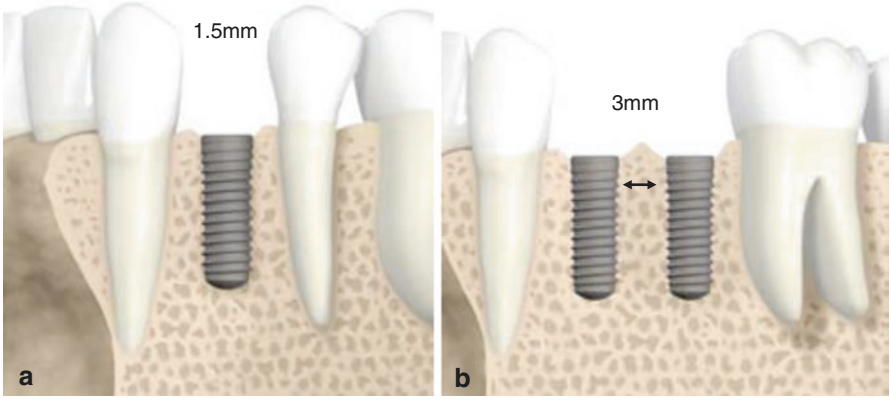

Fig. 3.9 There should be at least 1.5 mm (**a**) from the implant to the adjacent tooth, and a minimum of 3 mm (**b**) between adjacent dental implants to provide adequate room for papilla formation

thread design, which can be better for engaging bone, particularly in situations where clinicians are trying to place the implant immediately into an extraction socket. Parallel-walled implants provide a greater surface area and thus more total bone-to-implant contact. It is up to the clinician to determine which would be best for the patient. The diameter of the implant is also critical in the long-term success of the implant. It is recommended that there be a minimum of 2 mm of bone on all aspects of the implant [9]. There should be at least 1.5 mm from the implant to the adjacent tooth, and a minimum of 3 mm between adjacent dental implants to provide adequate room for papilla formation [10] (Fig. 3.9). Planning for and executing proper placement of the dental implant relative to the adjacent dentition will allow

the restorative dentist to fabricate a final prosthesis that has ideal contours to help prevent food impaction and allow the patient adequate cleansability.

Finally, there is the question of who determines the implant position. Is it the surgeon, restorative dentist, or both? In many cases the surgeon and restorative dentist are the same, but in situations where this is not the case, it is important for the surgeon and restorative dentist to work together to determine the final position, size, shape, and type of dental implant. It is important that the placement of the implant be in a position that allows the restorative dentist the opportunity to fabricate an ideal final prosthesis. However, sometimes there are anatomic limitations that may prevent the placement of the implant in the ideal restorative position. This is where it is critically important that the dental team is on the same page regarding the position of the implant. Oftentimes, this communication between the surgeon and restorative dentist results in the formation of a surgical guide (Chap. 4) which will help convey to the surgeon the agreed-upon final position.

When adequate time is spent on the treatment planning process, the chance of implant success is high. It is important that the clinician be competent in all aspects of treatment planning and that no steps are skipped in the process. Even when the placement and restoration of the dental implant is carried out and executed in an ideal fashion, problems with the implant and/or prosthesis can still occur. This book will focus on these problems and how to address them in subsequent chapters.

3.2 Summary

It is imperative that adequate time be dedicated to the treatment planning process. Many implant problems can be avoided with proper planning. Diagnostic data should be acquired via radiographs, study models, and photographs. Both the restorative dentist and surgeon should work together to determine the proper implant size and position.

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Prevention of Peri-Implant Problems: Surgery

4

Thomas G. Wilson Jr., Stephen Harrel, and Danieli Rodrigues

Key Points

- Implants should be surrounded by at least 1 mm of bone (2 mm on the facial) and 2 mm of keratinized tissue.
- Guided bone regeneration in sockets or lateral ridges can produce adequate bone in the vast majority of cases.
- Larger diameter implants have a better prognosis than those of reduced diameter.
- Relating the position of the implant to the final proposed restoration increases the probability of success.
- Restrictive surgical templates yield the best surgical results.

4.1 Surgical Site

As noted in Chap. 3 a critical factor for the prevention of implant failures is the presence of adequate bone. This bone must allow the implant to be placed in the proper orientation to the final restoration. Inadequate bone can be a major contributor to problems ranging from unaesthetic outcomes to failure.

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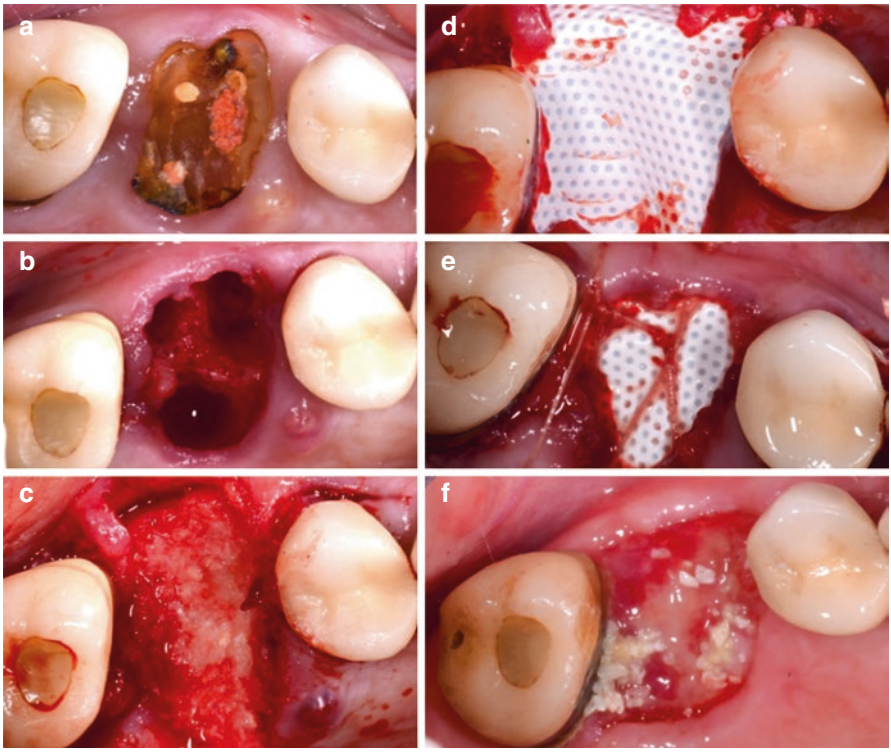

Fig. 4.1 (**a**) A fractured maxillary molar. (**b**) The tooth was sectioned then removed. The socket was degranulated and cleaned with iodine. (**c**) A mixture of human decalcified and calcified freeze-dried bone and enamel matrix derivatives was placed in the socket. (**d**) The socket was covered with a dense PTFE membrane. (**e**) One third of the membrane is left exposed, then removed at 1 month. (**f**) Immature tissue with bone graft particles seen immediately after membrane removal. The soft tissue will mature with 2–3 weeks and the site ready to place an implant in 4–6 months

The minimum thickness of bone is 1 mm (2 mm is preferred on the facial surface). Inadequate bone is often present in sites that were not grafted at the time of tooth extraction [1]. When adequate bone is not available, this problem can usually be solved by bone grafting, also referred to as socket enhancement or ridge preservation, at the time of tooth extraction [2]. The authors' preferred bone-grafting material for extraction sites is human freeze-dried bone (Fig. 4.1c). If this is not available due to local regulations, autogenous, or properly prepared bovine bone may be substituted. Predictable results can be obtained when the bone graft is mixed with enamel matrix derivative, placed in the socket and covered by a PTFE membrane [3]. The authors use this approach routinely in non-esthetic areas. In esthetically sensitive areas, a connective tissue graft is used to act as a membrane.

In healed sites, augmentation may be performed before, contemporaneous with, or in rare instances, after implant placement. The timing of these procedures is dictated by the amount and location of the bony defect. A common problem is inadequate facial bone. Lateral ridge augmentation using autogenous or human freeze-dried bone mixed with enamel matrix derivatives and covered with a membrane can predictably augment bone laterally (Figs. 4.2 and 4.3).

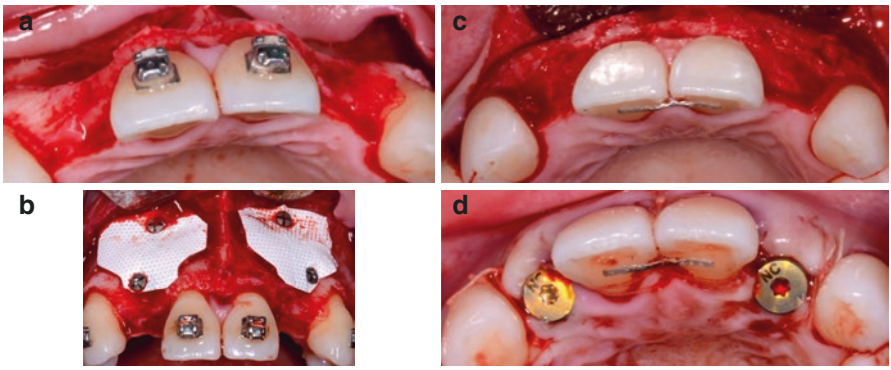

Fig. 4.2 (**a**) Deficient facial bone associated with congenitally missing maxillary lateral incisors. (**b**) Dense PTFE membranes were used to cover a mixture of human decalcified and calcified freeze-dried bone and enamel matrix derivatives. (**c**) Six-month post-surgical view showing bone regeneration. (**d**) Implants in place

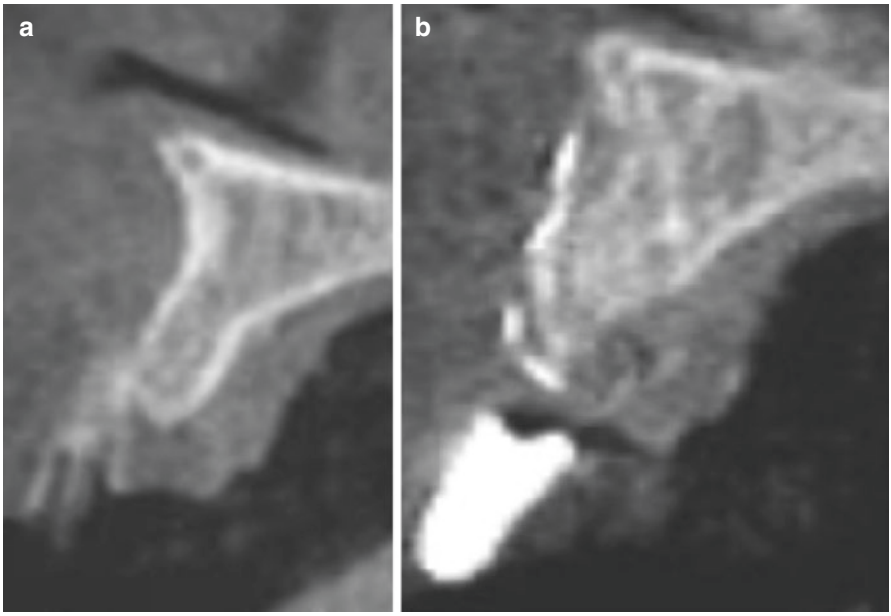

Fig. 4.3 (**a**) Cone-beam computerized tomogram (CBCT) cross-section before ridge augmentation. (**b**) CBCT cross-section 6 months after lateral ridge augmentation

Long-acting collagen membranes are used to cover small (2–3 threads exposed) facial exposures. These small defects are usually grafted at the time of implant placement. With proper technique, these procedures are predictable in non-esthetic sites. With ridge augmentation gaining vertical height of more than 2–3 mm is more challenging and is not in most cases predictable [4].

4.2 Esthetic Zone

Achieving predictable outcomes following implant placement in the esthetic zone is difficult and requires advanced techniques and training. If the dentist is not familiar with treating these sites, referral is indicated. For those with proper expertise, anterior extraction sites where the implant can be stabilized, and an intact buccal plate of bone exists, immediate implant placement is preferred [5]. Placement in these areas is accompanied by hard and soft tissue grafting. Material in contact with the implant should be human autogenous or freeze-dried human bone with a connective tissue graft placed on the buccal aspect of the implant. The addition of a soft tissue graft increases the probability of an esthetic result with an acceptable emergence profile [6]. Immediate implants following extraction of muiltirooted teeth are not predictable and socket grafting with delayed implant placement is suggested.

4.3 Implant Selection

Implant selection is critical. If the surgeon has used the treatment planning process outlined in Chap. 3 choosing the proper implant will be simplified. During the treatment planning process available bone is determined in three dimensions along with proximity of critical structures including contiguous teeth, nerves, nasal floor, and the maxillary sinuses. In many instances, this will require a cone-beam computerized tomogram (CBCT). It is also critical to have visualized the relationship of the implant to the final prosthesis since incorrect implant/prosthesis interface can have negative effects on long-term prognosis (see Chap. 9). In more complex cases requiring several crowns or in potentially esthetically difficult areas, mounted casts and a diagnostic wax-up are beneficial to preview the position and shape of the final restoration. This process is termed “crown-down” planning [7].

4.4 Occlusal Forces

Occlusal forces can have negative effects on the prognosis of an implant (see Chap. 9). This is especially true in patients with parafunctional habits such as bruxing [8]. Consequently, placement of implants of sufficient strength and dimension that will best accommodate excess occlusal forces is appropriate. The recent emphasis on reduced diameter implants in posterior sextants is troubling since even the newer generations of these devices have shown increased failure in these areas [9]. There is a high probability that many of these failures are associated with some form of occlusal overload.

Long-term clinical observation has led the authors to conclude that the following factors increase the longevity and ease of repair of implants with problems arising after placement:

- Choose implants made by one of the larger companies. This is important because long-term problems often involve replacement of component parts and not the implants themselves. Larger companies have the economic wherewithal to continue to stock the parts that may be needed years after implant placement.
- The authors currently use Grade IV cold worked titanium/zirconia implants. Titanium alloy implants with various surface treatments have a long history of success. Other materials used for implants such as zirconium have shown initial success but at this time their long-term viability is unknown [10].
- Implant diameters of 4+ mm and lengths of 8 to 12 mm are suggested for molar sites.
- Smaller diameter or shorter implants especially those in posterior sextants tend to be more successful if splinted together [9].
- Moderately rough implant surfaces are currently suggested (see Chap. 6). These surfaces should be covered by bone since exposure of the rough surface to the oral cavity usually results in increased microbial contamination, which can lead to implant failure.

4.5 Surgical Technique

Guided Surgery with a laboratory designed restrictive template increases the probability of appropriate implant placement [11].

In areas where accuracy is critical, digital planning and construction of surgical templates is suggested. A preoperative CBCT and digital images of the proposed final restoration are loading into an implant-planning program. Digital implants are placed in the program and related to the proposed restoration (Fig. 4.4). When the

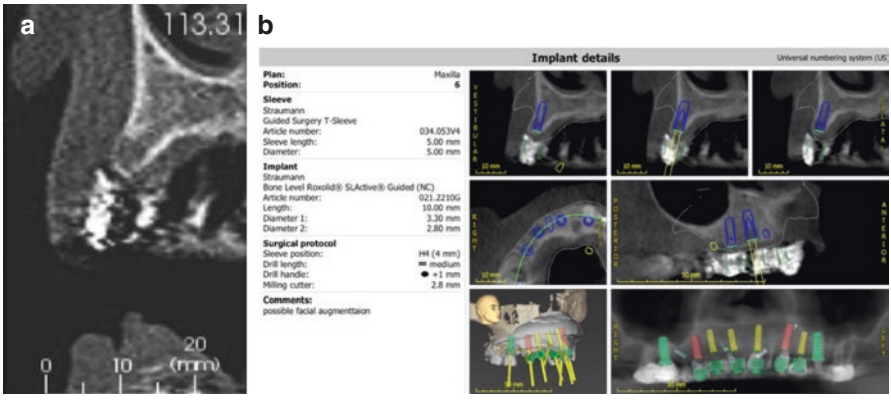

Fig. 4.4 (**a**) A cross-section from a CBCT of a proposed implant site. An opening in the radiographic template indicates the relation of the proposed final crown to the implant site. (**b**) A digital implant has been placed and related to the proposed final position of the crown and bone. The process was repeated in the other proposed implant positions

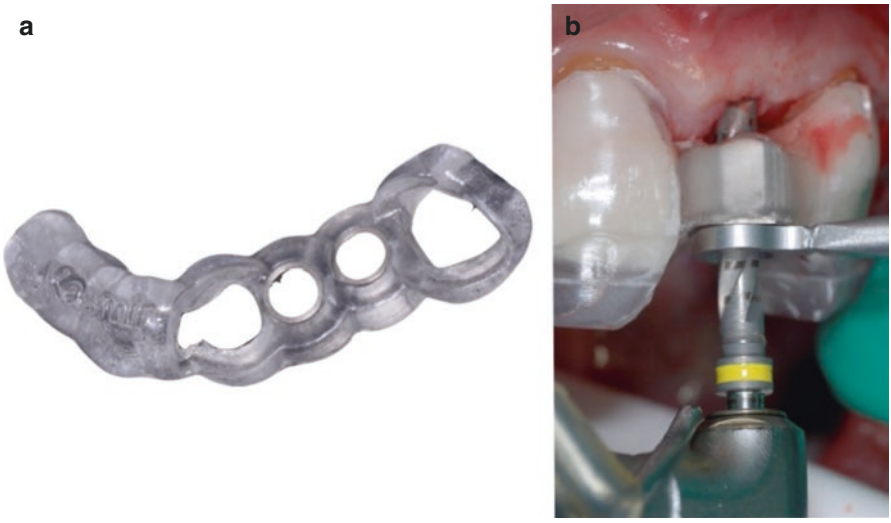

Fig. 4.5 (**a**) A digitally generated guided surgical template. (**b**) Drilling with a reduction sleeve through the surgical template

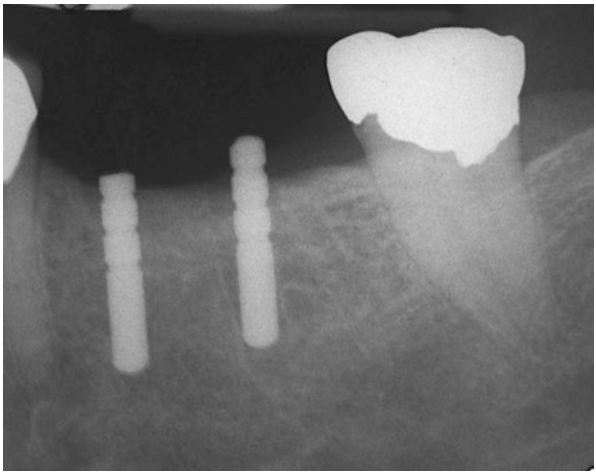

Fig. 4.6 Radiographic points in place. The final osteotomy was to be 10 mm deep. These were placed after drilling to 8 mm and were used to check depth and alignments

plan is completed, a computer guided surgical template is fabricated. These are used with restrictive devices of increasing diameter to place the implant (Fig. 4.5).

A radiopaque depth marker is placed after advancing the initial drill a short distance into the osteotomy site, and then a right angle peri-apical radiograph is exposed (Fig. 4.6). After any needed adjustments are made, the osteotomy is completed. Step-by-step drilling with copious irrigation is appropriate to avoid overheating bone. Overheated bone is a common cause for early implant failure. Care should be taken to place the rough surface of the implants at or slightly apical to the bone crest.

The use of adequately planned and fabricated surgical templates or "guides," along with intraoperative assessment of soft and hard tissue support for the implant, can usually avoid the problems associated with inadequate bone or improper implant placement. In short, the best way to avoid post-surgical problems with implants is through pre-surgical treatment planning and critical evaluation of placement during the surgical procedure.

Our patients receive broad-spectrum antibiotics before during and after surgical placement [12].

Immediately before surgery the patient rinses with chlorhexidine for 30-s. Appropriate aseptic measures including cleaning the peri-oral tissues, having sterile work surfaces and draping the patient can reduce the chance of postoperative infection. The patient is provided with a postoperative chlorhexidine rinse for 3–6 weeks to be used twice a day. Postoperative instructions include avoiding the surgical site (i.e., no touching or chewing).

Newer surface treatments can in some cases allow rapid loading of implants splinted together, but a 12-week loading interval is appropriate for single implants and those not connected around the curve of the arch. The patient is followed through the restorative phase after which a right angle radiograph is taken as a baseline and the patient placed in a maintenance schedule (see Chap. 10).

In summary, adequate planning and surgical technique lead to more favorable long-term success.

4.6 Summary

Many factors can contribute to implant failure. Attention to detail in many areas is necessary for a successful implant outcome and the prevention of implant failure.

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Prevention of Peri-implant Problems: Prosthodontics

5

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Prosthetic peri-implant complications may happen during different phases of treatment. From the diagnostic phase to the final restoration, relevant biological, mechanical, and functional principles must be followed to minimize the risk of complications.

During the treatment planning phase, the site for implant placement must be carefully evaluated three-dimensionally with the final restoration in mind; this is known as "crown-down planning." This process starts with study casts and a wax-up (analog or digital) that will serve as a blueprint for the final restoration. The next step is to work backwards from the proposed restoration position in order to determine the location of the implant. The goal is to have both the implant and the crown in a position that is biologically, functionally, and esthetically appropriate.

The alveolar ridge must be evaluated at this initial stage of treatment and any bone or soft tissue deficiencies should be identified. The pre-treatment "crown-down" evaluation will guide the pre-implant/prosthetic surgical phase which may include both soft and hard tissue grafting [1–3]. When the site is ready for implant placement, the prosthetic goals should be re-evaluated. At this point a surgical guide can be fabricated to assist the surgeon in placing the implant in a restoratively driven position [4–6] (see Chap. 4).

This chapter will deal with the prosthetic factors which should be considered by both the surgeon and the restorative dentist in the planning of a successful implant.

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5.1 Implant Placement to Allow Adequate Crown Contours

Implant placement angulation should ideally allow for screw access through the cingulum of anterior teeth restorations or central fossae of posterior teeth; this is best achieved utilizing a surgical guide for implant placement. Adequately planned implant placement will allow the clinician to deliver a restoration with an ideal contour, which entails an adequate emergence profile, proper embrasures and interproximal contact areas.

The emergence profile is "the contour of a tooth or restoration, as it relates to the emergence from circumscribed soft tissues" [7]. It should be concave to allow for long-term stability and adequate thickness of the soft tissue around the restoration to help prevent further recession and esthetic/functional compromise (Fig. 5.1). The emergence profile can be shaped by the provisional restoration; it should be transferred to the final restoration with an adequate impression technique [8–10].

Adequate embrasure space should be incorporated to the crown contour by positioning the interproximal contact area ideally 5–6 mm from the bone crest [11]. Planning for this distance will increase the probability of complete papilla fill to prevent "black triangles" and minimize food impaction (Fig. 5.2). A "tight" (<3 mm horizontally at the base of the papilla) embrasure space should be avoided to prevent excessive pressure on the papilla that could cause soft tissue "impingement," soft tissue recession, and lack of space for hygiene [12, 13]. Satisfactory interproximal contact will help prevent food impaction, and improve the cleansability of the restoration, which can lead to a lower incidence of peri-implant inflammation.

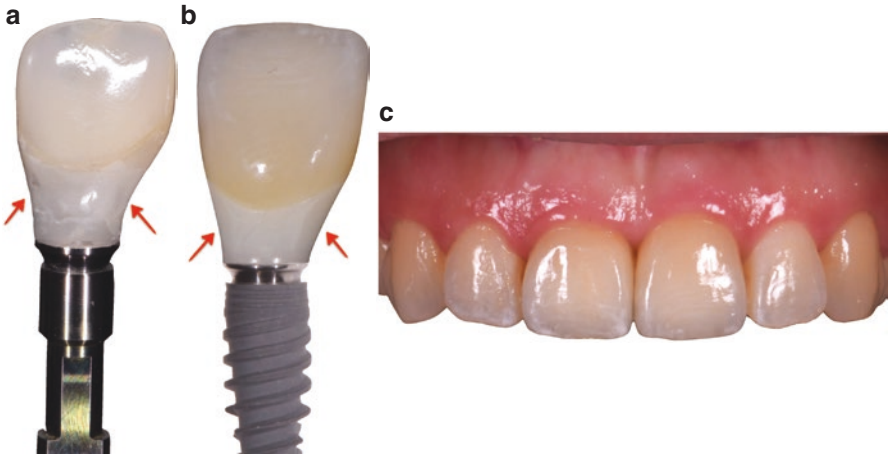

Fig. 5.1 Emergence profile: (**a**) temporary restoration, (**b**) final restoration duplicating concave contours from temporary restoration (arrows), (**c**) final screw retained restoration maxillary left central incisor placed in the mouth, after one month

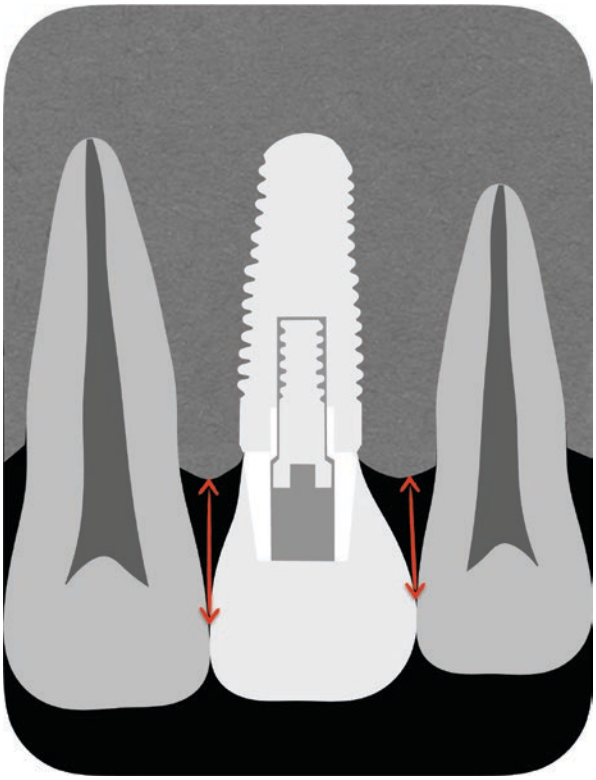

Fig. 5.2 The distance between the interproximal contact of the implant restoration and the alveolar crest should be 5 to 6 mm to allow for adequate papilla fill (arrows)

5.2 The Implant-Abutment Connection

Osseointegrated implants are connected to the restoration at the most coronal portion of the implant. A stable implant-abutment connection is crucial for the long-term success of the treatment. A stable connection will help prevent screw loosening, bacterial infiltration, and damage to the implant and restorative components. Internal connections between the implant and restorative components are preferred over external connections due to their superior long-term stability and reduced screw loosening observed [14, 15] (Fig. 5.3).

To insure a stable connection of the abutment and crown to the implant, it is imperative that restorative components and the implant be manufactured by the same company. The use of aftermarket or "copycat" components increases the possibility of screw loosening or breakage, and an increased gap between the implant and the abutment surfaces [16].

Several studies have shown that the use of platform switching connections where the abutment diameter is smaller than the diameter of the implant leads to improved

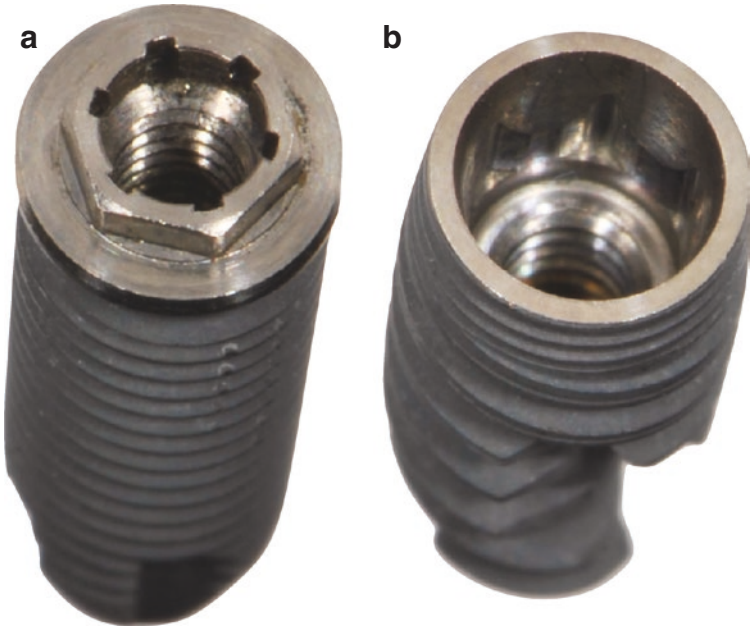

Fig. 5.3 (**a**) External hexagon connection, (**b**) Internal implant connection

long-term stability of peri-implant bone levels, when compared to platform-matching connections. This is postulated to be associated with the microgap between the abutment and the implant being placed further away from the interface between the soft tissue and bone attachment [17–19].

Final prosthetic screws are typically fabricated utilizing gold or titanium alloys. Laboratory screws are usually fabricated of stainless steel or similar alloys. The use of laboratory screws must be avoided when delivering temporary or final restorations to prevent screw fracture, thread stripping, or implant corrosion due to ion interchange and incompatibility of the metals. Prosthetic implant screws must be tightened following the manufacturer recommendations using a torque measuring device to prevent screw loosening and/or fracture. Using the manufacturer's specified torque on the screw is critical for long-term success of the restoration.

5.3 Custom Abutments

The abutment used to support the crown should be matched with the clinical situation. Custom abutments can correct for angulation problems and raise the abutment-crown interface, which may not be possible with stock abutments. Custom abutments are typically utilized for cemented restorations.

Custom abutments can be waxed and cast, or milled out of different alloys or ceramics. When designing custom abutments, the emergence profile should have a proper concave design (ideally reproduced from the provisional restoration).

The restorative margin should be placed at the level of the gingival margin to allow for cement removal. In esthetic sites, margins can be placed 0.5 mm subgingival to prevent margin exposure, but great care should be taken to remove excess cement. The present of excess cement has been shown to be closely associated with peri-implant bone loss [20–22].

5.4 Screw-Retained or Cemented Restorations?

Screw-retained restorations are preferred over cemented crowns. Screw-retained restorations have the advantage of being retrievable if some repair is needed in the future or if the screw loosens and needs to be replaced. A cement-retained crown cannot be retrieved in most cases and has to be destroyed if it needs to be repaired or the abutment screw replaced. Additionally, excess cement and the resulting peri-implant bone loss is a concern with cemented restorations (Fig. 5.4).

Proper implant placement is needed to allow the screw access opening to be placed properly. This position should be in the center of the occlusal surface of posterior teeth and on the cingulum of anterior teeth (Fig. 5.5). Improper implant to restoration orientation can make the use of a screw-retained restoration difficult or impossible.

Screw-retained implant crowns can be fabricated utilizing the porcelain fused to metal (PFM) technique with metal base UCLA abutments. An alternative to PFM is the use of "screwmentable" crowns. This type of restoration is composed of an abutment (stock or custom) and a cementable crown that has a screw access on its

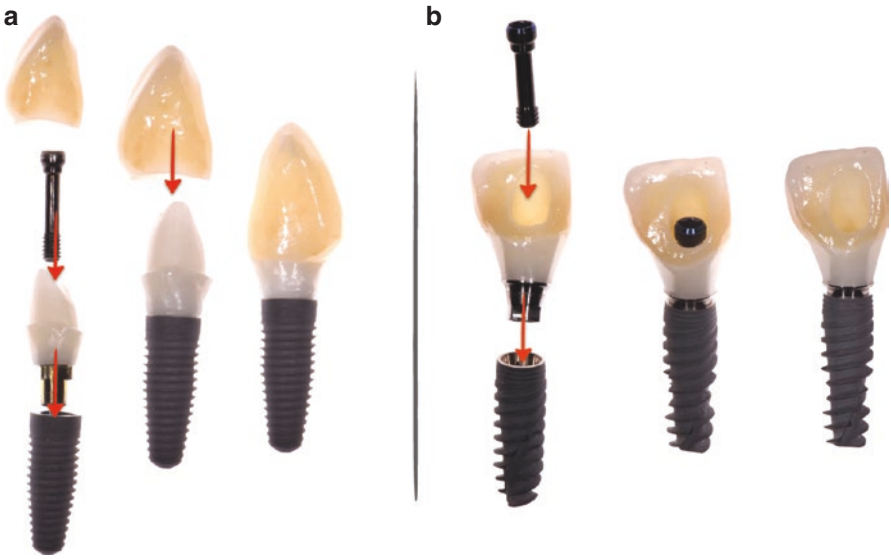

Fig. 5.4 (**a**) Cement-retained implant restoration: all ceramic abutment, final screw and all ceramic crown, (**b**) Screw-retained implant restoration: One piece crown and abutment, final screw

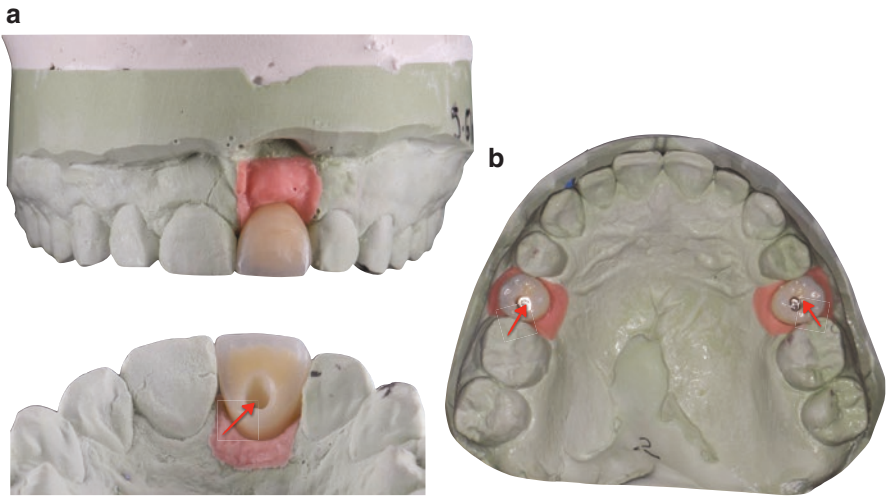

Fig. 5.5 Screw access (arrows): (**a**) on cingulum of implant crown maxillary left central incisor, (**b**) on central fossae of implant crowns maxillary right and left second bicuspid

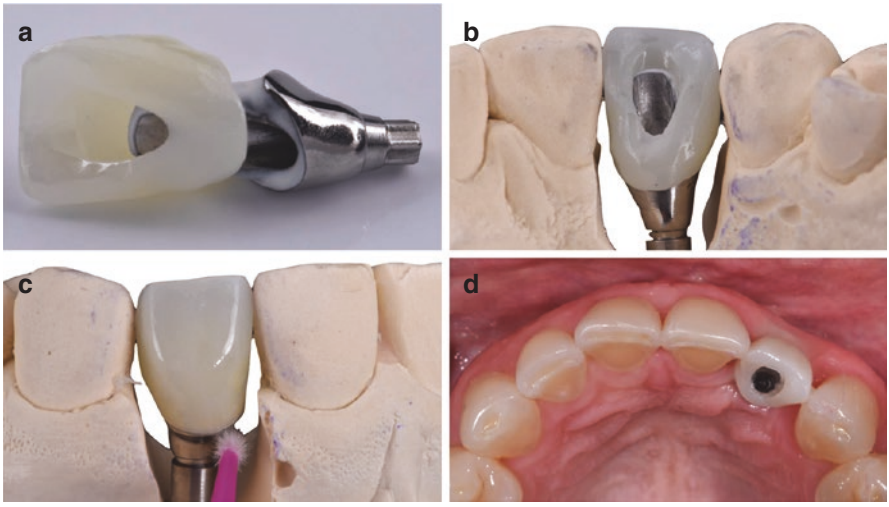

Fig. 5.6 "Screwmentable" implant crown: (**a**) Custom titanium abutment and monolithic zirconia crown, (**b**) implant crown cemented on the abutment in the working model, (**c**) excess cement removed utilizing a brush, (**d**) implant restoration in the mouth after delivery

surface; both components are cemented on the model, therefore allowing for adequate cement removal (Fig. 5.6).

Some implant companies have developed angulated screw systems to allow for screw-retained restorations, even if implant placement would not normally allow for adequate access orifice utilizing traditional screws (access openings on the incisal edges or buccal surfaces). These systems typically allow for up to 25-degree correction. Specialized screws and instrumentation is necessary to use these angulated screw systems (Fig. 5.7).

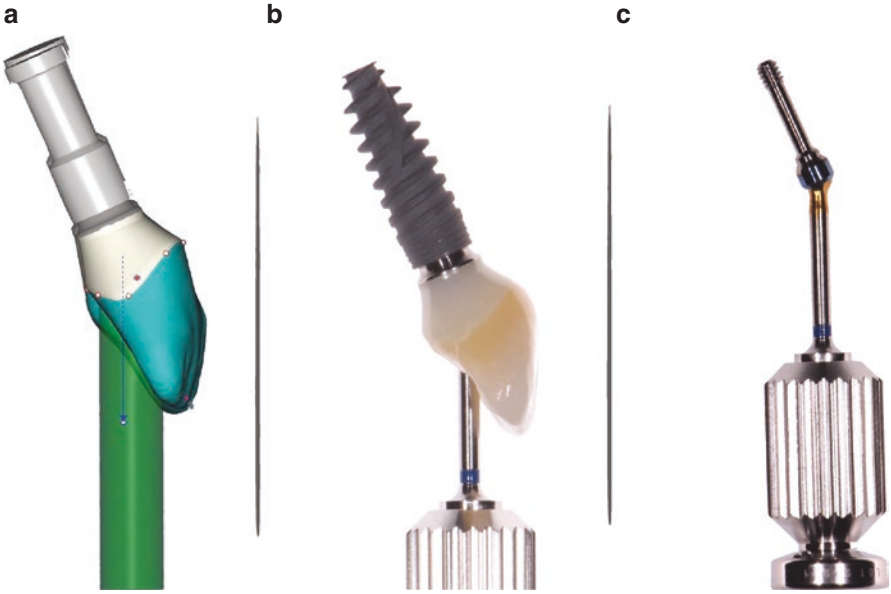

Fig. 5.7 Angulated screw channel abutment: (**a**) virtual design utilizing Procera® software for up to 25º correction of screw access; (**b**) screw access corrected on final crown; (**c**) Omnigrip® angle correction screwdriver and screw

There are instances where screw retention is not possible. This will necessitate cemented restorations. Excess cement can lead to implant failure and must be avoided. Excess cement is a leading cause of peri-implantitis [20, 22, 23]. Excess cement is not as much of a problem with a natural tooth because the supra-crestal fibers attach to the cementum and protect the sulcus from excess cement that can be pushed apically. Implants do not have protective gingival fibers. Without this protection, it appears that it is easier for excess cement to be forced apical to the restoration margin and into the attachment area between the implant surface and bone [24]. Additionally, it appears that microscopic cement particles can enter the intact connective tissue surrounding the implant and cause a foreign body type of inflammatory response [21, 25].

The amount of cement utilized should be controlled to minimize excess cement. There are several techniques to avoid excess cement flow subgingivally. One technique is to fabricate a replica of the intaglio (internal) surface of the crown prior to cementation [26]. The replica can be created by flowing bite registration material inside the crown. Cement is placed in the crown and the crown is then seated on the replica outside the mouth. The excess cement is cleaned from the surface of the crown while it is on the replica and immediately after the crown is seated in the mouth. This will limit the excess cement flowing into the peri-implant sulcus (Fig. 5.8).

Another technique is to pack retraction cord or the "thick" portion of superfloss around the abutment prior to cementation, so the cord can prevent the apical flow of cement. Great care should be exercised when utilizing this technique due to the potential of cord segments being left intrasulcular if it becomes embedded in the cement and a portion of the floss or retraction cord breaks [27].

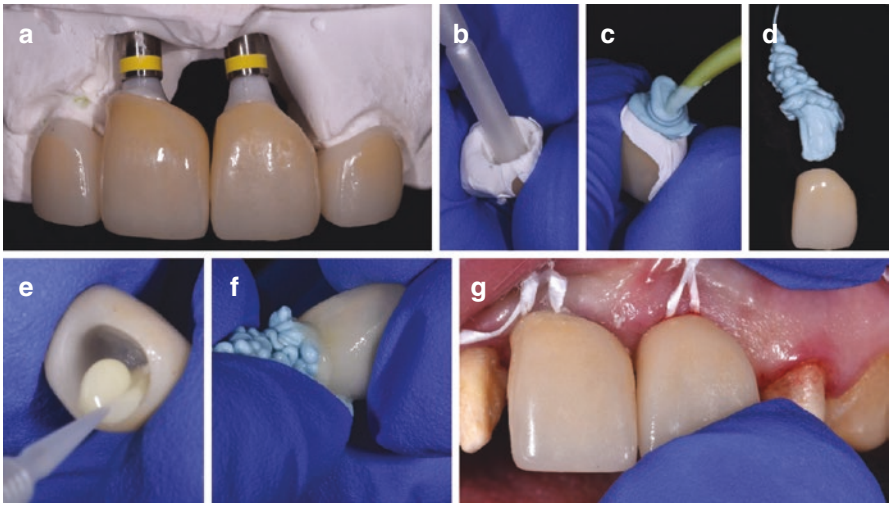

Fig. 5.8 Steps for cementing implant restorations: (**a**) final zirconia abutments and lithium disilicate crowns on working model; (**b**) Teflon tape coating on intaglio surface of the crown to serve as spacer and protect the ceramic surface; (**c**) bite registration material to create cementation index; (**d**) cementation index after material has set; (**e**) final cement applied to crown; (**f**) seating of crown with uncured cement on bite registration index; (**g**) final seating of implant crown with minimal cement extrusion

5.5 Full-Arch Edentulism

Totally edentulous patients may be candidates for removable or fixed dental prostheses supported by dental implants.

Implant-assisted complete removable dentures, also known as "overdentures," can be beneficial for patients that are not looking for a fixed complete denture, but need extra retention of the complete removable denture, which is not provided by the alveolar ridge. Implant overdentures can rely on different designs of metal bars/clips (either casted or milled) supported by at least two implants; an alternative to the use of bars that has become popular in the past few years is the use of overdenture abutments (e.g., ball abutments, Locator® abutments) [28].

Fixed prostheses can be multiple implant supported fixed partial dentures (FPDs) or a one-piece fixed-detachable full-arch prostheses (hybrid prostheses). The type of full-arch implant restoration is selected after treatment planning. Part of the treatment planning should include a careful evaluation of: (1) available restorative space, (2) opposing dentition, (3) available bone for implant placement, (4) the possible need for soft or hard tissue grafting pre-prosthetically, and (5) financial concerns [29].

Treatment with multiple implant supported partial dentures (bridges) typically entails 3 or 4 separate implant fixed partial dentures per arch. Adequate bone height/width is essential for rehabilitation with implant bridges because only the interocclusal height of the clinical crowns will be replaced. This means that in cases with pre-existing bone loss, the esthetic result may be compromised by elongated crowns. This restorative alternative follows regular implant FPD's principles and procedures. Typically, 6 to 8 implants are placed to support a full-arch restoration.

5.6 Hybrid Prostheses

When vertical ridge resorption is beyond the normal height of clinical crowns, and interocclusal space is more than 15 mm, hybrid prosthesis can be utilized. Hybrid prostheses are usually indicated when it is necessary to prosthetically recreate gingival contours (Fig. 5.9).

1. Implant placement

Typically, 4–6 implants are placed in each arch to support hybrid dentures. The most posterior implants can be placed at up to a 30° angle to avoid anatomical structures (maxillary sinus or mental nerve) and minimize or suppress distal cantilevers since adequate antero-posterior implant spread is crucial to limit damaging forces (Fig. 5.10) [30–35].

2. Prosthetic space requirements

Adequate interocclusal distance is essential for the fabrication of a hybrid prosthesis. This will allow for the prosthesis to have adequate thickness of the metal framework, acrylic resin, and denture teeth, and to place the prosthesis-ridge transition above the lip line when the patient smiles. Less corono-apical height can result in mechanical failure of the prosthesis. A minimum of 15 mm of clearance per arch should be present. If proper room is not available, it must be created by means

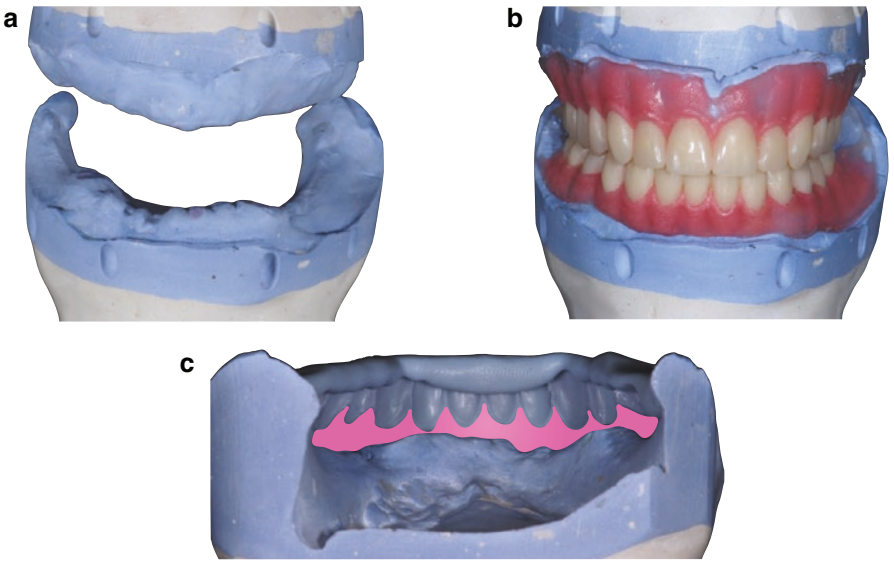

Fig. 5.9 Diagnostic steps for fixed-detachable full arch prosthesis (hybrid denture): (**a**) edentulous ridges, (**b**) diagnostic teeth set-up, (**c**) missing alveolar ridge height to be replaced with restorative materials (pink), based on diagnostic set-up

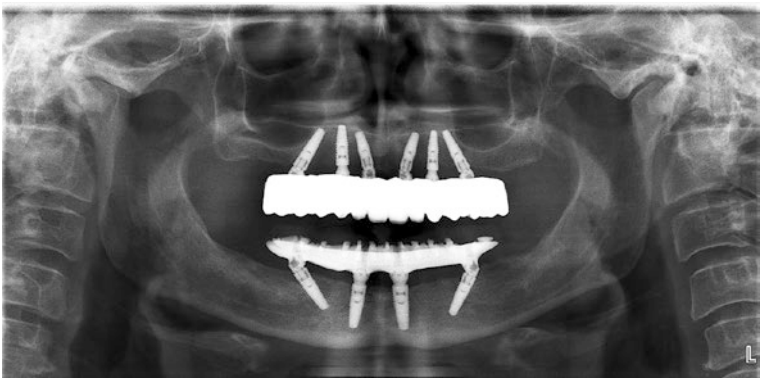

Fig. 5.10 All on 4® angulated implant placement

of alveoloplasty or by increasing the vertical dimension of occlusion (VDO) "opening the bite" [36–39].

3. Prosthetic design

Hybrid dentures can be fabricated utilizing different materials. Traditionally, a metal framework (noble alloy or milled titanium) was connected to the implants or transmucosal abutments. Recently, zirconia has been used for fabrication of these devices [40].

Passive fit of the framework to the implants/abutments is crucial to prevent stress on the implants. A precise impression is essential to prevent non-passive fit. Framework fabrication with CAD/CAM systems can help prevent material distortion during the laboratory phase [41–44]. The metal framework is overlaid with pink acrylic resin that replaces the missing alveolar height, recreates gingiva, and holds the prosthetic denture teeth (Fig. 5.11).

Advantages of metal frameworks with acrylic are ease of repair and modification. The disadvantages include potential debonding/fracture/wear of prosthetic resin teeth, the need for prosthetic tooth replacement every 3–5 years, acrylic resin pigmentation changes, and higher rates of plaque retention compared to ceramics [45].

A more recent approach for the fabrication of hybrid dentures uses monolithic zirconia. The monolithic zirconia block is milled to replace the gingiva and the teeth as well as the surface next to the soft tissue between implants. A thin layer of porcelain can be added to enhance esthetics in areas replicating gingival contours (Fig. 5.12).

Advantages of this material include high esthetic properties, low plaque retention, minimal occlusal wear, and no need for prosthetic teeth replacement. Disadvantages are the possibility of chipping of the layered porcelain and difficulty repairing any fracture of the body of the prosthesis [46–51].

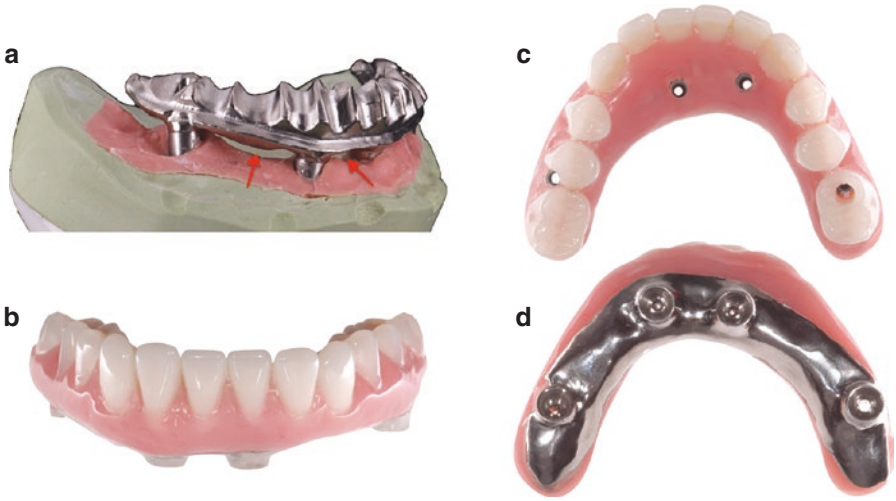

Fig. 5.11 (**a**) Titanium framework, high water design to facilitate hygiene (arrows). Processed hybrid prosthesis, ready for delivery: (**b**) buccal view, (**c**) occlusal view, (**d**) intaglio surface

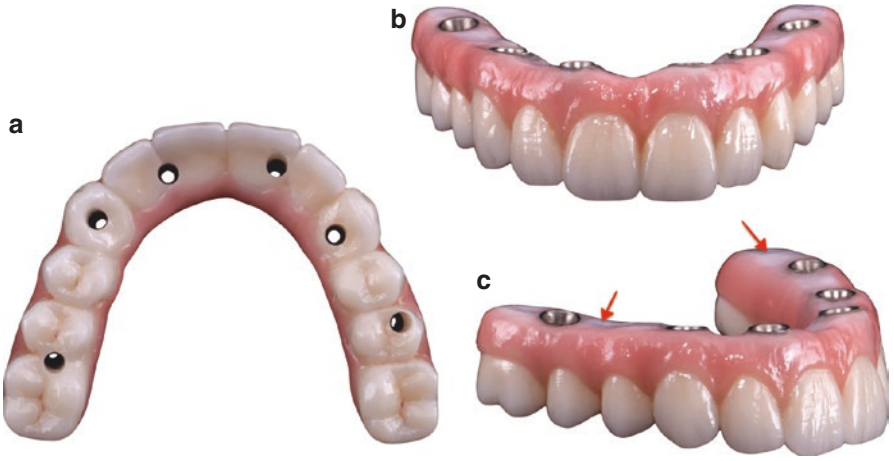

Fig. 5.12 Monolithic zirconia prosthesis: (**a**) occlusal view, (**b**) frontal view, (**c**) buccal view, intaglio surface design avoiding ridge lap design (arrows)

Fabrication principles for hybrid prostheses are similar for any type of material utilized. The portion of the prosthesis in contact with the ridge (intaglio surface) should be convex. It is suggested that passive or slightly positive (not applying excessive pressure) tissue contact for the maxillary prostheses to be used to prevent air escaping and to prevent food impaction. For a mandibular prosthesis, the intaglio surface can also achieve passive tissue contact or, if preferably, provide a high-water design when tolerated by the patient for improved cleansability (Fig. 5.13) [37, 38].

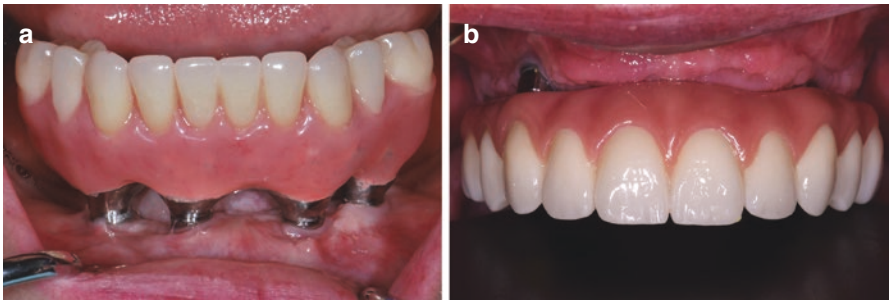

Fig. 5.13 Prosthetic-alveolar ridge interface: (**a**) high water, (**b**) positive tissue contact

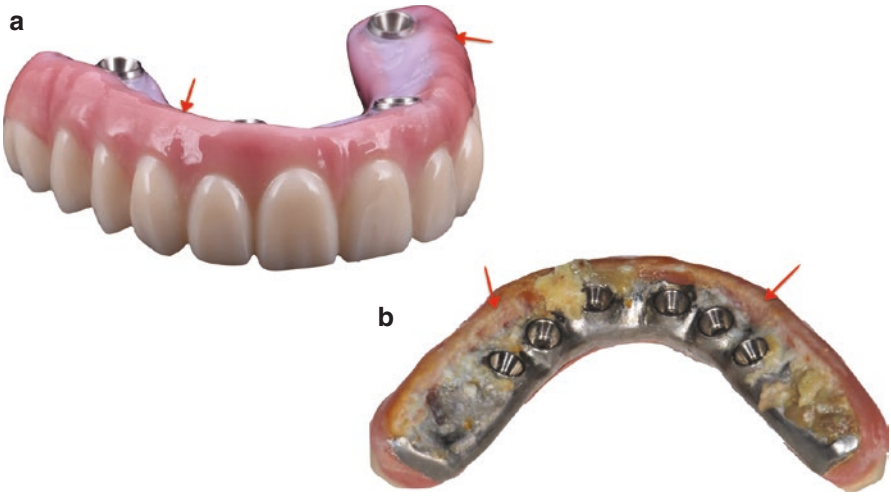

Fig. 5.14 (**a**) Modified ridge lap design, buccal tissue extension designed to hide prosthesis-ridge transition (arrows). (**b**) Excessive plaque accumulation due to poor hygiene and buccal flange (arrows)

A ridge-lap design should be avoided whenever possible because it impedes adequate personal oral hygiene. If for any reason, tissue coverage and contact is required on the buccal surface of the ridge (i.e., to prevent excessive air escape, prosthesis-ridge transition is displayed in high smile), a hygienic modified ridge-lap design must be utilized and concavities must be avoided (Fig. 5.14).

"Flossing notches" should be incorporated in the prosthetic design around the implants to allow the insertion of floss threaders, super floss, and interproximal brushes to achieve proper hygiene (Fig. 5.15).

4. Maintenance

An adequate maintenance phase is crucial for the long-term success of treatment with hybrid prostheses. The patients that will undergo treatment with this type of prosthesis must understand that they will not get a new set of natural teeth, but a prosthetic replacement of the missing teeth requires a different set of hygiene and maintenance procedures.

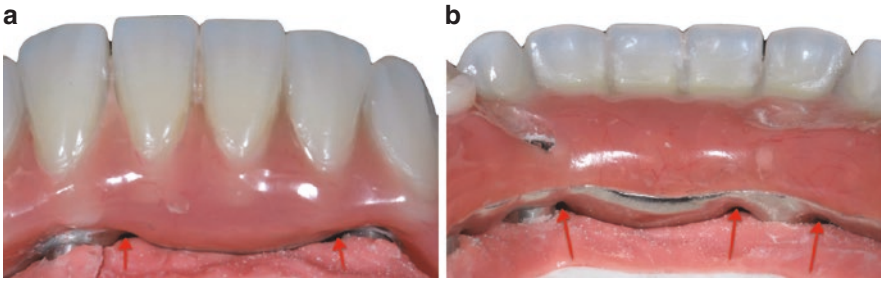

Fig. 5.15 Flossing notches (arrows): (**a**) buccal view, (**b**) lingual view

(a) Homecare

Personal oral hygiene for these prostheses should be done at least twice per day. Hygiene instruction must be provided by the dental practitioner upon delivery of the prosthesis. A custom hygiene plan should be detailed for each patient, depending on their specific needs, and should include the use of hygiene aids such as dental floss, interdental brushes, water flossers, and manual or electric toothbrushes.

Correct personal hygiene procedures must result in the complete removal of biofilm from every surface of the prosthesis. Manual or electric toothbrushes can be used to clean the teeth and gingival buccal, occlusal, and lingual portions of the prosthesis. Dental floss, interdental brushes, and water flossers/irrigators can be utilized to remove debris and biofilm from the inter-implant segment of the intaglio surfaces. A light shoe-shine motion with thick floss around each implant, and mesiodistally from one implant to another, will allow for proper biofilm removal from a properly designed hybrid prosthesis that does not contain concave surfaces (Fig. 5.16).

(b) Office maintenance visits

A strict recall regimen is crucial for correct maintenance of hybrid prostheses. Patients should visit the dental office at least every 6 months. It is recommended to have shorter time spans between visits (every 3–4 months) for the first year; this shorter schedule should be maintained for patients that are unable to achieve adequate homecare.

During each visit, the clinician should carefully inspect the implants and the prosthesis. Implants should be probed utilizing a plastic implant probe to look for any signs of peri-implant mucositis or peri-implantitis (bone loss, bleeding on probing, suppuration). If any of these signs are observed, further treatment should be provided to prevent the advance of peri-implant disease.

The prosthesis should be professionally cleaned on a regular basis. The prosthesis should be removed from the mouth and cleaned in an ultrasonic device. If necessary, it can also to be re-surfaced, have contour improvement and surface polishing if indicated. There is no set time interval for removal and professional cleaning of the prosthesis. The time interval is dependent on the judgment of the clinician and the need for cleaning or repairs. It is advised to remove it at least once a year for

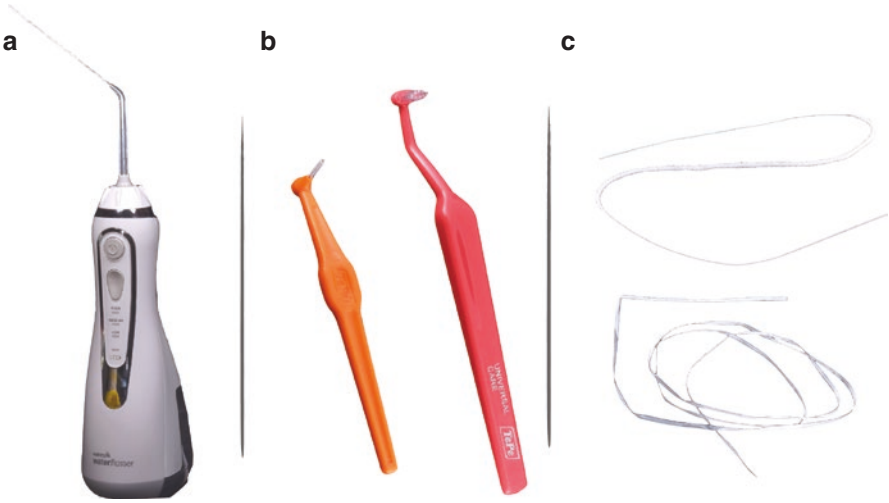

Fig. 5.16 Homecare armamentarium: (**a**) Water flosser, (**b**) 90º brushes, (**c**) floss threaders

patients with adequate oral hygiene. More frequent professional cleaning is necessary when the patient is unable or unwilling to perform adequate daily hygiene procedures. When the prosthesis is removed, a new set of prosthetic screws should be used when replacing the prosthesis to provide adequate torque values and prevent screw loosening/breaking [52–57].

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Etiology of Peri-Implant Diseases

6

Danieli C. Rodrigues

Key Points

- Implant failure is multifactorial
- Early failures can result from:
  - Infection
  - Trauma
  - Poor planning and technique
- Late failures can result from:
  - Infection
  - Trauma
  - Foreign body reaction
- Implant surfaces:
  - Titanium (Ti)
  - Zirconia (ZrO_2)
  - Titanium-zirconium (TiZr)

6.1 Dental Implants: Successes and Failures

The use of dental implants for replacement of teeth has grown tremendously in the last few years. The popularity of this device is a result of its high success rate (~95%), predictability, and improved designs with a number of surface treatments and geometries currently available. The long-term clinical success of dental implants is dependent on the integration of the surface with hard and soft tissues, i.e. osseointegration, which will ensure implant stability and function [1, 2]. Although most systems perform well, the number of complications and failed implants has increased in recent years [3, 4]. These complications can generate pain, discomfort and lead

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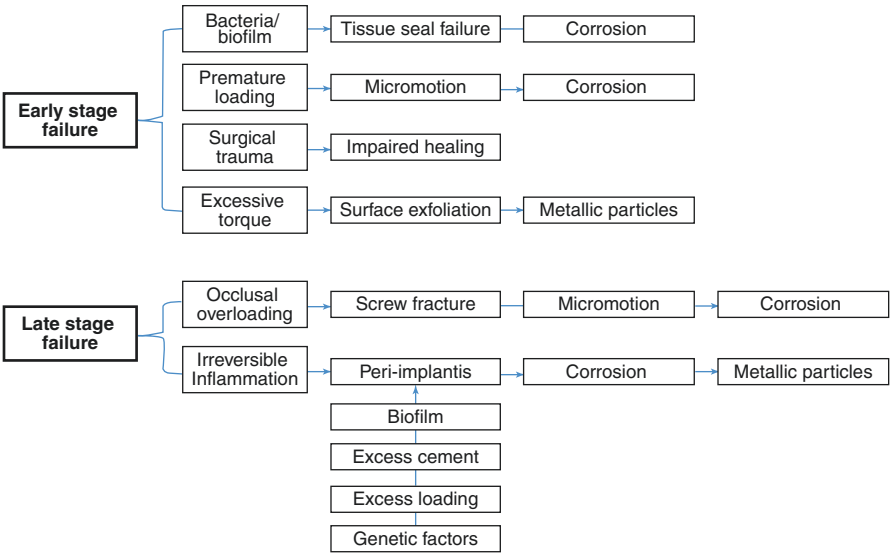

Fig. 6.1 Summary of implant failure modes. A multitude of individual or synergistic events can cause implant failure

to eventual failure. Moreover, treating these conditions can result in significant health and economic burden to patients. Dental implant failures are reported to range from 1.9% and 11% [5]. This is concerning because, in the USA, three million people already have implants and this number is growing by 500,000 every year [6]. Factors such as surgical skills, patient health, implant design, osteotomy, and mechanical loading are classical events known to contribute to implant success or failure. Thus, implant failure can be induced by a number of individual or synergistic events [6–9], and those have been classified in the literature as either early or late stage failures (Fig. 6.1) [3, 10, 11].

6.2 Early Stage Failure

Early stage implant complications occur before attachment of prosthetic components due to interference with the initial healing process, which can eventually result in failure to achieve osseointegration. Early losses are reported to account for more than 50% of failures being induced by bacterial contamination (early biofilm adhesion), premature loading, lack of primary stability, impaired healing, and excessive surgical trauma [3, 11, 12]. Manor et al. reported in a retrospective study of 194 patients with failed implants that half of the patients experienced early failures with lack of osseointegration being the main etiological factor (73% of early stage failures) [3]. Patients reported with higher plaque scores [13] and implants affected by infections have been associated with higher rates of early failures [14]. Bacteria are key players in early stage complications; bacterial contamination can occur shortly after implantation and

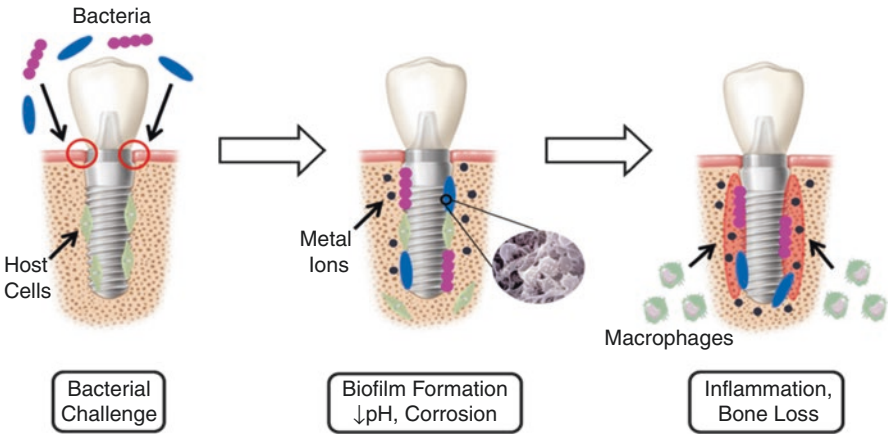

Fig. 6.2 Following implantation the simultaneous interplay between mechanical and biological factors will dictate healing and integration. Bacteria and host cells race for surface colonization. If an early biofilm is adhered to the implant surface a microenvironment of differential aeration, and thus lower pH, is established between the biofilm and implant surface. This region of acidic pH (crevice) can lead to metallic corrosion and consequent metal ion generation, inducing an adverse immune response and chronic inflammation that may ultimately trigger bone loss. Thus, an important factor to ensure healing is first to promote the conditions for soft tissue closure

has been observed to occur on all implant materials regardless of surface chemistry or roughness [2, 15]. A recent study showed that implant surface performance is dependent on a "race-for-the-surface" between human gingival fibroblasts and biofilm (Fig. 6.2) [2]. Such early stage events can be initiated by surface adhesion of early colonizers such as streptococci and *Actinomyces* species, which upon formation of a biofilm may prevent sealing of soft tissues on the implant neck [16, 17]. Attachment of these early colonizers will then initiate the formation of biofilm providing favorable anaerobic conditions for growth of pathogenic late colonizers such as *Porphyromonas gingivalis*, *Aggregatibacter actinomycetemcomitans*, *Fusobacterium nucleatum,* etc. These aggressive pathogens can induce inflammation and consequent bone resorption [18, 19]. These earlier observations have prompted a number of studies to investigate dental implant surface modifications to mitigate initial bacterial adhesion or to promote anti-bacterial activity on the surface [20–22]. Other factors such as un-intentional loading during healing can lead to a lack of primary stability generating micromotion and interference with implant integration. Excessive surgical trauma may cause prolonged chronic inflammatory response hindering the tissue repair process and implant integration.

6.3 Late Stage Failure

Late stage complications involve breakage of osseointegrated interfaces, which is typically experienced after an implant is restored and exposed to functional loading

[23]. Thus, occlusal overloading, screw fractures, and peri-implantitis are considered major contributors to late stage failures [24–26]. In a recent review by Fretwurst et al., potential mechanisms leading to peri-implant bone loss included micromovements, microbial biofilm, cement excess, implant malposition, particle debris stripped off during insertion procedures and biocorrosion [27]. Thus, late stage complications can be further distilled in two main groups: (1) mechanically induced and (2) biologically (inflammation) induced, although synergy of both or one triggering the other can be considered the main mechanisms for failure. For clarity of discussion, these etiological groups will be discussed separately. In terms of mechanically induced events, it is a general assumption that bone loss precedes implant fractures. A common observation is that fatigue to the interfacial bone due to high stresses and strains secondary to implant loading can result in bone microdamage, which can lead to implant micromotion and loosening [28]. Furthermore, micro-fractures along the bone-implant interface can lead to fracture of prosthetic components or the implant body. Thus, several factors can contribute to implant mechanically induced failures including implant design, superstructure design, material flaws, inadequate fit of superstructure, occlusal and implant bearing forces, bruxism, implant size, metal fatigue, and occlusal overloading. Among these several events that can affect the surface of a dental implant are metallic particles that are wear generated during insertion procedures. These metallic particles have been recently discussed as a potential mechanism of failure. Frictional forces generated during implant insertion have the potential to damage the protective metal oxide layer, thus increasing the susceptibility of the metal to wear and ion generation, which deposited in peri-implant tissues can trigger an early or late immune response. Previous in vitro and in vivo studies have reported cases of particle generation during implant insertion, however these observations are contradictory [29–32] given different implant surfaces, bone qualities (in vivo, animal versus simulated bone materials), and different implant roughness have been used among the different studies. For example, in vivo studies have indicated that plasma sprayed and rougher surfaces could increase particle generation during insertion procedures [33, 34]. An in vitro study used bone simulating materials of different densities to demonstrate the impact of insertion procedures on the surface of titanium dental implants. Post-insertion, implants, and bone simulating materials were investigated with powder X-ray diffraction technique, which revealed that the insertion procedure did not result in premature metal exfoliation and debris irrespective of the bone simulating material density used [32]. Finally, occlusal overloading is not only associated with bone and implant micro-fractures, but has been observed to induce adverse inflammatory response leading to peri-implantitis. As mentioned in previous chapters, peri-implantitis is the continuous loss of bone surrounding an implant, which can eventually lead to failure. This severe clinical condition has been reported to affect 15–56% of implants [10]. Thus, peri-implantitis is a current concern with a number of studies focusing on understanding the underlying mechanisms of this disease, prevention, and development of alternative biomaterials/surfaces that can enhance osseointegration to mitigate the potential for late stage bone loss. According to recent remarks at the Academy of Osseointegration (AO), about 50% of

implantations will be affected by peri-mucositis the precursor of peri-implantitis. Its triggering factors are associated with bacterial biofilm, residual cement, excessive occlusal stresses, smoking, genetic factors, corrosion, and the interplay among these events [4, 10]. Wilson et al. established earlier a positive relationship between excess residual cements and peri-implantitis development [35]. In a subsequent study, it was observed that cement particles were present in peri-implantitis soft tissue biopsies being surrounded by inflammatory cells [12]. Undetected residual cement remaining in tissues can act as an irritant eventually triggering the process of soft tissue inflammation. In three recent in vitro studies, it was demonstrated that different dental cement compositions, setting times, and the contact of residual cements of different compositions with titanium surfaces impacted host cell response and the electrochemical behavior of the metal in simulated oral environment conditions [36–38]. The results indicated that not only the presence of residual cement, but its chemical composition may also contribute to peri-implantitis development. However, inflammation due to bacterial biofilm is considered to be the primary etiological factor for the disease [39].

It has been proposed that bacterial adhesion on dental implants can change the electrochemical environment of the surface, leading to disruption of the oxide layer (Fig. 6.2) [12, 40–44]. In a recent in vitro study, it was demonstrated that serial passage of Ti implants in *Streptococcus mutans* for 60 days led to significant changes in surface morphology, with evidence of corrosion and metal ions generation in solution [44]. In one human biopsy study not only dental cement but also Ti particles were found in tissues as predominant foreign bodies [12]. Retrospective studies of Ti implants that were retrieved from patients with peri-implantitis also illustrated the degree of damage that can be imparted by late colonizers with evidence of corrosion features such as surface pitting, etching, discoloration, and cracking [41, 42]. Thus, two mechanisms can be proposed to explain the damage observed on surfaces after bacterial colonization: (1) Early-colonizing bacteria colonize and adhere to implant surfaces and release organic acids as fermentation products, thereby decreasing the pH of the local environment, which leads to metal ion dissolution; and (2) Biofilm adhesion on implant surfaces [44]. Biofilm is suggested to form localized crevice areas within implant interfaces, which due to oxygen depletion will further decrease pH and induce metal surface attack. Metal ions and wear release resulting from these processes can trigger inflammation and bone loss as illustrated in Fig. 6.2. Changes in the oxide layer structure due to biofilm adhesion is expected to impact immune cell response that will in turn affect soft and hard tissue formation and remodeling.

6.4 Materials Choice and Future Innovations in Dental Implants

Material selection is dependent on the structure and function of the biological component that is being replaced (crown, abutment, implant). Metals and ceramics are the primary materials choice for load bearing components with over 40 years of

clinical history [45]. Here, a brief overview of materials used for endosseous dental implant design will be presented.

Titanium is the most employed material in the design of dental implants due to good mechanical properties, biocompatibility, and corrosion resistance [46, 47]. Particularly, its commercially pure form (cpTi) is the "gold standard" in dental implant design due to a combination of advantageous physical and chemical properties. In comparison with other metallic systems, such as stainless steels or CoCrMo alloys, the Young's modulus (modulus of elasticity, stiffness) of cpTi is closer to that of cortical bone in the maxilla or mandible, which ensures better mechanical matching with the properties of the host tissue. Additionally, its excellent biocompatibility is a result of the material's ability to spontaneously form and reform a passive oxide layer (TiO_2) in oxygen-rich environments. This is a result of the reactive nature of this metal, thus Ti has the ability to undergo passivation (formation/reformation of its oxide layer) upon exposure to oxygen. This natural oxide layer provides a kinetic barrier to continued metallic dissolution and corrosion. Moreover, the oxide layer provides natural roughness to the surface being essential for surface biomineralization, allowing for incorporation of calcium and phosphate ions [48]. However, based on experimental and clinical observations, it has been shown that even the most corrosion-resistant metals can be subjected to significant corrosion attack upon prolonged implantation periods [49]. Previous retrospective implant retrieval studies have illustrated the severity of corrosion processes that can be triggered on the surface of titanium dental implants regardless of implantation times [41]. A series of surface modification techniques have been proposed to enhance the surface properties of the material. Surface treatments applied included anodization to increase oxide layer thickness and corrosion resistance, plasma spraying hydroxyapatite (HAP) coatings to induce bone growth, grit-blasting to increase surface roughness, acid etching to improve bone-to-implant contact, laser treatment to create microporous structures for bone integration, and a number of antimicrobial coatings [21, 22].

Another strategy employed to improve biological, mechanical, and physicochemical properties of Ti is the incorporation of alloying elements including aluminum (Al), vanadium (V), niobium (Nb), and zirconium (Zr). Among the different compositions being investigated, titanium-zirconium alloy (TiZr), primarily with 15% zirconium composition, has emerged as a superior choice due to its lower corrosion susceptibility, enhanced mechanical strength, greater fatigue endurance limit, and increased microhardness as compared to Ti while maintaining conditions for cell compatibility, as shown both in vitro and in vivo [50–54]. In particular, the response of mesenchymal stem cells (MSCs) on TiZr surfaces has been evaluated [52, 55]. Initial cellular adhesion, proliferation, and differentiation of MC3T3-E1 pre-osteoblast cells was shown by Sista et al. to be similar to or greater on TiZr relative to Ti and significantly greater than that on a TiNb alloy confirming its osseointegrative potential in vivo [55]. TiZr implants exhibited bone-to-implant contact and histological outcome comparable to Ti after 12 weeks post-implantation in a rabbit model [53]. Gomez-Florit et al. found increased levels of proteins (ITGB3 and MMP1)

responsible for cell attachment and extracellular matrix remodeling being expressed by human gingival fibroblasts (HGF) when grown on TiZr as compared to Ti [52]. Similarly, other studies have shown TiZr to have similar cellular response in comparison with the traditional Ti implant system [56]. Since this material has been recently introduced, limited clinical data is available which restricts estimation of its long-term performance.

Zirconia (ZrO_2) has emerged as a candidate to replace Ti-based dental implants due to its fracture toughness, tribological properties, esthetic appearance, corrosion-resistant nature, and osseointegrative ability. Initially, this material was considered as an alternative for metallic abutments [57] because clinical studies reported on the bluish appearance of metallic abutments in patients with thin gingival tissue biotype, so ZrO_2 was suggested to improve the appearance of this esthetic zone [58]. Current studies have further elucidated on the biocompatibility of this material and overall similar physical performance in comparison with Ti implants. However, despite one study reporting survival rates of 95% after 5-years post-implantation for one-piece ZrO_2 dental implants, the literature is still divided over the perceived advantages of using ZrO_2 [59–64]. Like Ti, ZrO_2 possesses an oxide layer, in fact the entire material is composed of an oxide structure. Moreover, ZrO_2 has been shown to undergo surface modifications to improve fatigue behavior and resistance to degradation in addition to attachment of osteoblast cells in vitro [61, 65]. Previous studies have explored the effects of surface treatments applied to ZrO_2 on host cell adhesion, biofilm formation, and mechanical performance [60, 61]. Chappuis and collaborators, in an in vivo investigation, observed the presence of multinucleated giant cells (MNGCs) and their effect upon tissue integration on surface modified implants made of yttria-stabilized and alumina toughened ZrO_2 in comparison with Ti [66]. The study demonstrated that MNGCs were not associated with an inflammatory cell infiltrate and that Ti induced less MNGCs adhesion compared to the ceramic substrates. In another in vivo study, Saulacic et al. determined the effect of acid and alkaline etching of sandblasted ZrO_2 implants on osseointegration [67]. Results of this study demonstrated that acid etching induced more bone-to-implant contact than the sandblasted surface; however, both acid and alkaline etching of ZrO_2 increased the formation of MNGCs [67]. Although ZrO_2 appears to be a promising material and has been suggested as a strategy to reduce corrosion induced failures, biofilm adhesion, and improve esthetic appearance, limited long-term clinical data has restricted estimation of its survival, being difficult to conclude whether ZrO_2 is a competitive alternative for metallic dental implants.

6.5 Summary

At the current time the causes of implant failures are not completely understood. Multiple factors from improper surgical technique, improper prosthetic technique, and implant surface corrosion may play a part in failure.

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Examination for Patients with Dental Implants

7

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Key Points

Examination data collected over time allows the clinician to more accurately determine the status of the perio-implant diseases.

- Right angle radiographs taken at the time of definitive implant restoration placement are necessary for monitoring bone levels.
- Routine probing around implants needed to determine the status of the soft tissues.
- Patient ability and motivation for personal oral hygiene should be assessed.
- Presence or history of periodontitis should be determined.
- Prosthetic components should be evaluated at each examination.

7.1 Introduction

Dental implants fail for many of the same reasons that teeth are lost. It therefore is important to perform routine examinations around these devices. To perform a meaningful examination for maintenance patients with implants, the clinician must be aware of the local and systemic risk factors that can effect these devices.

The risk factors for implants are in many ways similar to those for natural teeth. This means that the therapist should inquire about medical issues and social habits like smoking that may affect tooth and implant longevity. Patients should be informed about these risk factors and given options for eliminating or modifying these problems. A medical consultation may be necessary to have a complete picture of the patient's health status.

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It is assumed in this chapter that appropriate extraoral and intraoral examinations will be performed, including evaluating joints, muscles, as well as a cancer screening.

As with all patient examinations, the examiner should follow a systematic step by step examinations process. By following the same sequential pattern with each patient, the examiner will be less prone to overlook essential portions of the examination process and records taking. In our opinion, the following pattern which starts with the basics of examination and proceeds to a more detailed implant analysis is the most logical approach but, as long as all areas of the examination are covered, other sequential examination steps are acceptable.

7.2 Tooth and Implant Count

The examination begins with identifying missing teeth and the current position of the patients remaining teeth and implants. This information becomes part of the patient's record.

7.3 Radiographs

A review of previous radiographs is the next step. It is important to have accurate right angle baseline films that were exposed just after the surgical placement of the implant and after the final prosthesis was placed. Subsequent films are measured against this baseline. These two-dimensional films are most useful in measuring mesial, distal, and apical bone loss. Right angle films (peri-apical or vertical bitewings) are strongly suggested where possible since these are the most accurate. The importance of this process was emphasized in recent joint publications by the American Academy of Periodontology (AAP) and the European Federation of Periodontology (EFP) [1].

Radiographic examination of peri-implant bone loss and pathology includes examination for potential crestal and apical pathology. Although the crestal bone level is frequently examined and classified for possible loss over time, the apical peri-implant bone should be examined as well. Again, right angle peri-apical radiographs should be exposed at appropriate time intervals as the most appropriate way to evaluate bone changes. If bitewing radiographs are used, vertical bitewings are preferred to horizontal bitewings because vertical films are more likely to expose the relation of the crestal bone to the coronal portion of the implant. Panoramic radiographs are not acceptable for accurately measuring bone level due to the distortion inherent in these radiographs.

Any progressive crestal loss of bone should be noted (Fig. 7.1a, b). In the early days of root form implantology, bone loss less than 2 mm within the first year was considered within normal limits, followed by less than 0.2 mm each consecutive year [2]. Advances in implant design, such as built-in platform switching and improvements in implant surface treatment, have led to a reduction in expected bone loss within the first year [3]. Percentage of bone loss compared to the length of the implant is also useful in recording the extent of bone loss and should be recorded for diagnosis and treatment planning [4].

Appropriate radiographs also allow evaluation of the prosthetic components which should also be examined. Any signs of small gaps in prosthetic connections should be noted (Fig. 7.2). The relationship of the abutment and prosthesis to the

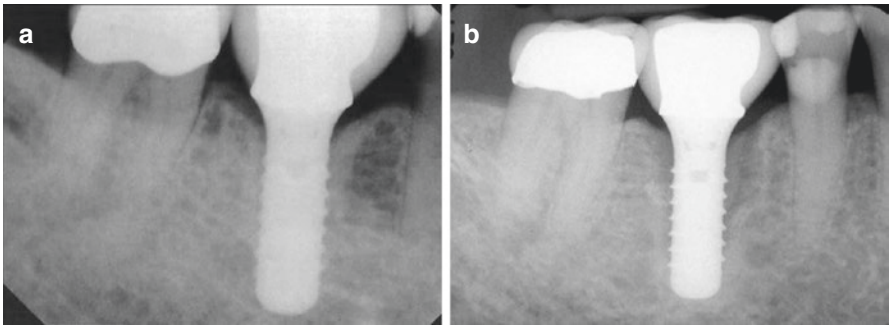

Fig. 7.1 (**a**) This radiograph was exposed 6 years before the one seen in (**b**). During that time, there was substantial bone loss both radiographically and clinically. The genesis of the bone loss was excess cement on the mesial surface of the implant

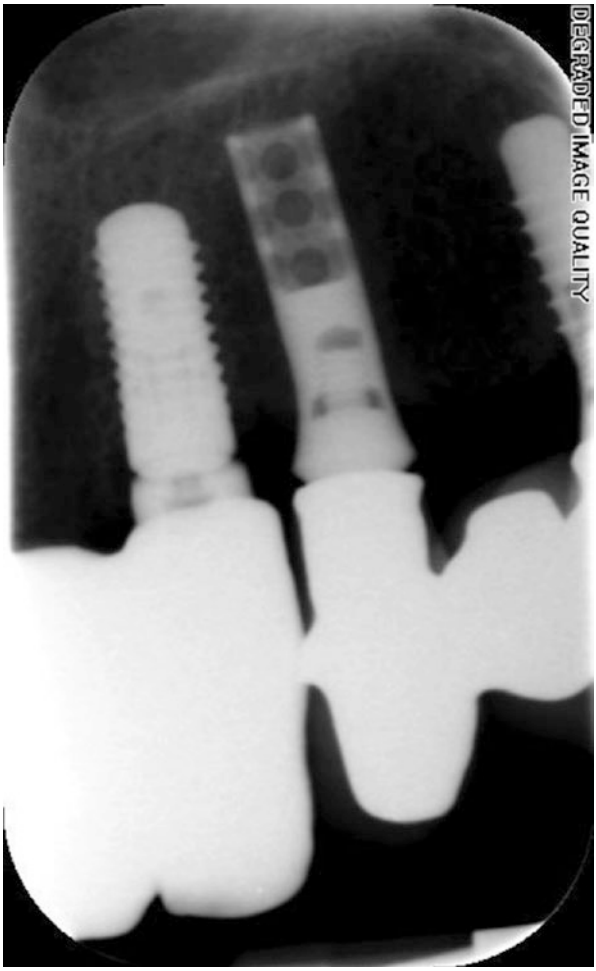

Fig. 7.2 This radiograph demonstrates an open margin between the superstructure and the abutment on these two implants. This can lead to retention of bacteria and subsequent inflammation of the surrounding soft tissues

surrounding area should be examined to make sure that they are contoured to maximize the patient's ability to clean around the implant (see Chap. 5).

7.4 Tooth Mobility/Implant Stability

Tooth mobility and implant stability are then evaluated. Both should be performed by using the non-working handle of two dental instruments. Alternating gentle pressure is placed on the facial and then lingual and any mobility of tooth or implant is recorded. As a general statement, any mobility of the implant or its prosthetic components should be addressed and corrected. Almost universally when the body of the implant is mobile, the implant has failed and should be removed.

7.5 Implant Restorations

Next, the prosthesis should be examined for stability and integrity. This is best performed manually by attempting to rotate or dislodge the prosthesis. Rotation found with cemented restorations usually indicates that the abutment has loosened. Similar mobility around a screw retained crown usually means that the screw has loosened. Both of these problems need to be addressed promptly. Each situation allows for ingress of bacteria between the prosthetic and implant interface and can lead to peri-implant disease. Additionally, the composite covering the access opening of screw retained crowns should be examined for an adequate seal.

Implant crowns should be checked for open contacts. Studies have shown a prevalence of 34–66% for open contacts on the mesial or distal of implants placed next to natural teeth [5]. This supports the superiority of a retrievable screw retained prosthesis that may be adjusted in the future if needed.

It is particularly important to evaluate cemented restorations both clinically and radiographically for evidence of excess cement. An explorer is an appropriate instrument for this evaluation. Inability to identify excess cement at the clinical level does not mean that cement could not be found in the surrounding tissues. In fact, studies by Wilson et al. indicate that microscopic cement particles are frequently found at the scanning electron microscope level around implants with cemented restorations suffering from peri-implant disease [6].

When excess deposits are suspected, advanced visualization techniques including a dental endoscope and the Dental Videoscope can be helpful in identifying and eliminating these excess cement deposits (see Chap. 11). Excess cement should be considered as a possible contributing factor to peri-implant diseases and should be included in diagnostic and treatment considerations [7].

7.6 Evaluation of the Peri-Implant Soft Tissues

The peri-implant soft tissues are evaluated next (Fig. 7.3). Any abnormal color, thickness of the tissue, soft tissue dehiscence, or absence of keratinized tissue

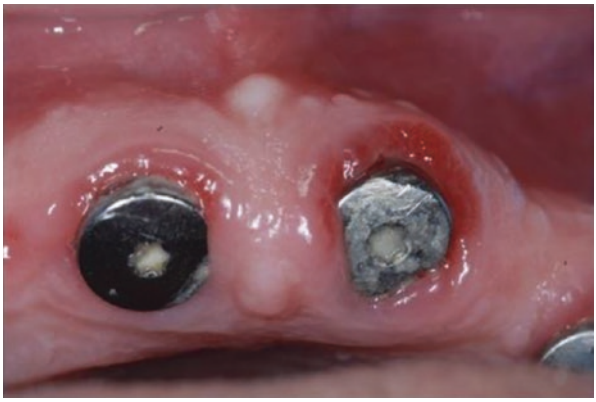

Fig. 7.3 The tissues around these healing abutments reveal plaque induced peri-implant mucositis. This is characterized clinically by the abnormal redness of the tissue

should be noted. Classically, a coral pink color of the gingiva is noted as a sign of health, with exceptions of racial melanin pigmentation. The tissues should be gently palpated for any evidence of purulence. This step is best performed by starting at the facial or lingual apex of the implant and applying gentle finger pressure coronally. Because of the dynamic connection between the soft tissue and the underlying bone, any disturbance or inflammation of the soft tissue may also affect the health of the supporting bone. While a debate continues about the need for keratinized gingiva around implants, several studies have indicated that reduced signs of inflammation and bone loss have been found around implants with at least 2 mm of keratinized tissue [8] and adequate tissue thickness of at least 2 mm [9].

7.7 Probing

Although probing around implants has been controversial in some circles, the publication of the 2017 guidelines published by AAP/EFP Consensus Conference indicates that routine probing around the implants is the standard of care [1]. However, this publication draws no conclusions on what comprises an appropriate probing depth. Their data indicates that probing is the most accurate way to diagnose the presence of inflammation around these fixtures. A more gentle pressure (15 Ncm) for probing has been recommended versus the 25 Ncm recommended for teeth, which may reduce false positives of bleeding on probing [10]. Bleeding on probing around implants with cemented restorations in a patient with good personal oral hygiene often indicates the presence of excess subgingival cement (Fig. 7.4). Ideally, the authors of this book advocate the use of a plastic periodontal probe that has flexibility and has less risk of damaging the implant surface or implant components. If a plastic probe is not available, a metal probe may be used with care. Bleeding upon probing (BOP) and probing depths should be recorded for future comparison.

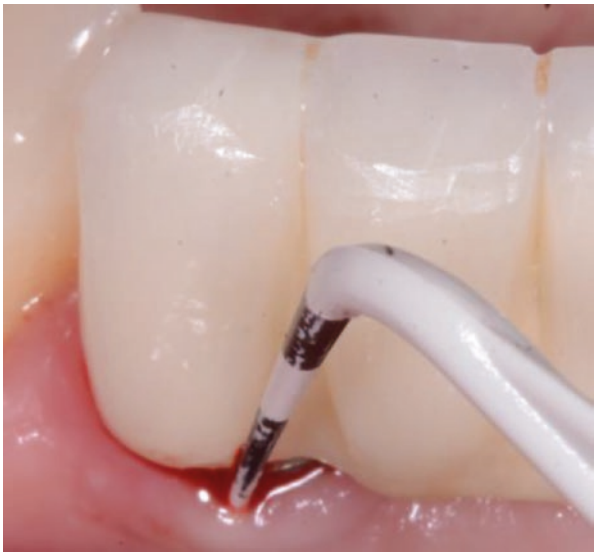

Fig. 7.4 The prosthesis overlying this implant was cemented. Approximately 4 years after cementation bleeding on probing was found. In a significant number of situations this is pathopneumoninc of excess subgingival dental cement

7.8 Occlusion

Next, occlusion should be examined, since excessive occlusal forces and occlusal interferences can cause implant or component fracture or contribute to peri-implant bone loss [11, 12]. For further details on the effects of occlusion on implant failure, see Chap. 9. This examination is performed with occlusal marking paper while guiding the patient through centric, lateral, and protrusive movements. For the details on occlusal evaluations for full arch prosthesis, see Chap. 8.

7.9 Personal Oral Hygiene

Since bacterial plaque is a major factor in implant loss, an evaluation of the patient's personal oral hygiene is extremely important. It is important for the clinician to understand what type of personal oral hygiene regimen the patient uses on a daily basis. Any areas of deficient oral hygiene found during the examination should be pointed out to the patient and appropriate strategies for improved cleaning of these areas discussed and demonstrated. It is always important to re-emphasize the necessity for these procedures and their relationship to the longevity of the implant. See Chap. 10 for more information.

7.10 Setting Maintenance Intervals

Since many of the factors affecting implant loss are similar to those found around teeth, it is important that implant patients have routine maintenance. In general, the

more severe the periodontal involvement of any remaining teeth, the more frequently the patient should be seen for maintenance. Also, patients should be informed that a history of periodontitis is a risk factor for implant failures. Those individuals with less than adequate personal hygiene should be seen more frequently than those whose cleaning efforts eliminate clinical and radiographic signs of disease initiation and progression. See Chap. 10 more information.

7.11 Summary

Dental implants are affected by many of the same etiologic factors as teeth. Chief among these is inflammation secondary to bacterial infection and inappropriate pressure from the occlusion. This argues strongly for routine and regular maintenance of these fixtures. An examination during which the information normally gathered around teeth is also appropriate for dental implants. Baseline information can be used to track the health and stability of both implants and their surrounding tissues.

Implants should be examined clinically and radiographically on a routine basis. Implant maintenance and reinforcement of oral hygiene techniques are necessary to help prevent implant failure.

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Diagnosis of Peri-Implant Diseases

8

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Key Points

- Implant failure has been reported since they were introduced to dentistry.
- The history of implant failure is briefly discussed.
- International groups have recently clarified and defined various implant related diseases and failures.
- The technical descriptions of implant inflammation/diseases/failures are reviewed.
- Some of the difficulties in using the new classifications in clinical situations are reviewed.

8.1 Historic Perspectives

During the early stages of implant dentistry, implant failures were the rule rather than the exception. The early implants which were extraosseous or supraosseous rather than intraosseous provided initial stability, however due to the very extensive surgical procedures needed and size of the metallic frames frequently failed with the consequent sequela of additional bone loss. With the discovery of osseointegration, dental implants became more predictable and success rates increased dramatically. The fact that the surgical standards for placement of osseointegrated implants were very strict and the training required for the surgeons and restorative dentists was exquisite and case selection was restricted to fully edentulous patients may have contributed to the success obtained in the first decades of osseointegration. In many cases however implants failed due to failure to establish initial osseointegration but rather fibrointegration. In these cases, the implant would develop a soft tissue attachment rather than bone contact. The high survival rates of osseointegrated implants and patient satisfaction triggered the demand for this type of treatment in

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Peri-Implant Diseases and Conditions			
Peri-Implant Health	Peri-Implant Mucositis	Peri-Implantitis	Peri-Implant Soft Tissue and Hard Tissue Deficiencies

Fig. 8.1 Peri-implant disease classification. Consensus report of the 2017 World Workshop

the partially edentulous population. Since then, there has been an exponential increase for the demand for this type of treatment for patients totally or partially edentulous. The industry has developed different implant surfaces and designs, which have stimulated more rapid bone formation and implant stability. This therapy is now more accessible and at the same time more dental specialists and general dentists are involved in placing and restoring implants. Based on the success of currently available implants, some have the incorrect assumption that there is no contraindication for implant therapy. At the same time, the number of publications reporting complications has increased. Recent reports indicate that the prevalence of peri-implantitis is about 20%, which could be interpreted as if one of every 5 implants placed would have some biologic complication. Therefore it is imperative to detect the early signs of the disease. Several attempts have been made to try to classify inflammatory conditions around implants. The American Academy of Periodontology and the European Federation of Periodontology have recently developed a classification system, which will be discussed briefly in this chapter (Fig. 8.1).

8.2 Classification of Peri-Implant Diseases and Conditions

8.2.1 Peri-Implant Health

Peri-implant health requires the absence of clinical signs of inflammation, including no bleeding on probing. Around clinically healthy implants, the mucosa forms a tight seal around the trans-mucosal component of the implant itself, the abutment or the restoration. The soft tissue height around the implant following placement determines the initial probing depth. In most cases, the probing depth associated with peri-implant health should be ≤5.0 mm. As part of the definition, there should be no bone loss greater than the bone level changes which occurs after initial bone remodeling immediately following implant placement [1].

8.2.2 Peri-Implant Mucositis

There is a growing number of publications about complications around dental implants. However, most of them focus on the prevalence, diagnosis, and treatment of peri-implantitis due to the devastating effect of this condition. Therefore it is important to highlight the early stages of this condition, which is termed peri-implant mucositis (PI mucositis). The main clinical sign of this lesion is inflammation of the peri-implant mucosa characterized by bleeding on gentle probing (<0.25 Ncm) [2].

Thus, it is important to routinely probe around implants to be able to detect inflammation. The main risk factor for PI mucositis is bacterial biofilms. This appears to occur in a similar manner as the bacterial etiology of gingivitis. Experimentally, when plaque accumulates for 21 days around healthy implants, all implants developed erythema and edema as well as bleeding. Histologically, the inflammatory infiltrates have been found to be quite similar to those found in gingivitis [3, 4]. We can say with certainty that PI mucositis is reversible based on experiments performed to evaluate the time taken by the PI soft tissues to return to normal once the biofilms have been removed. In most cases it takes 21 days, however in some cases it can take slightly longer than 3 weeks [5]. Some factors such as age can also influence the severity of PI mucositis, for example older age. It has been shown that although there could be less plaque accumulation on implants, the peri-implant mucosa shows a stronger clinical response than gingiva. This phenomena may be associated with a less favorable "self-cleaning" implant restorations due to their reduced diameter compared to a natural root as well as various other technical features, making oral hygiene more difficult [6]. It is unknown if mucositis will progress to peri-implantitis in all cases due to our inability to test this in humans, however in patients with poor maintenance compliance it has been observed there is a higher risk of developing peri-implantitis, especially if there is bleeding on probing. It has been shown that for implants presenting bleeding on probing, there was a 24.1% chance of being diagnosed with peri-implantitis [7]. Also a significant association has been found between the number of bleeding sites around the implant and the average probing depths at peri-implant mucositis [8]. An important consideration is lack of bone loss beyond crestal bone level changes resulting from initial remodeling [1].

The major risk factors for mucositis are biofilm accumulation, poor oral hygiene, the design and composition of the implants and abutment components, the characteristics of the marginal soft tissues, and the presence of excess cement [9].

There are some reports about increased mucositis in patients with oral lichen planus [10], as well as in patients with allergic reactions to titanium [11], however more evidence is needed.

8.2.3 Peri-Implantitis

Peri-implantitis was defined by the 2017 Proceedings of the World Workshop as "a plaque-associated pathologic condition occurring in the tissue around dental implants, characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone." The authors stated that clinically, the inflammation around implants is manifested as erythema, edema, mucosal enlargement, bleeding on probing (67%) with or without suppuration (94%); with deeper probing depths (PD ≥6 mm at 59%) and bone loss radiographically with a combined supra and infra-osseous configuration, progressing circumferentially around implants and faster than around teeth [12]. In the absence of baseline radiographs and probing depths, radiographic bone level ≥3 mm and/or probing depths ≥6 mm in conjunction with profuse bleeding represents peri-implantitis [1].

8.2.4 Periapical Peri-Implantitis

Also known as retrograde peri-implantitis, periapical peri-implantitis is a condition in which the affected implants are commonly characterized by a periapical radiographic radiolucency with or without concomitant clinical signs of inflammation, such as redness, edema, fistula, and/or abscess formation. The reported prevalence of retrograde peri-implantitis is 0.26%, however typically it is associated with implants placed in close proximity to teeth affected by periapical lesions of endodontic origin with a prevalence of 7.8%. Therefore, endodontic evaluation of teeth adjacent to implant sites should be performed for primary prevention of periapical peri-implantitis [13].

8.2.5 Hard and Soft Tissue Implant Site Deficiencies

In this aspect of classification, the sequelae left after the teeth have been extracted, which could affect the implant sites are discussed. After teeth are lost, the alveolar ridges heal and the dimensions of the bone and soft tissues change. Large deficiencies are often associated with severe loss of periodontal support, traumatic dental extraction, endodontic infections, root fractures, thin buccal bone plates, poor tooth position, injury and pneumatization of the maxillary sinuses. Other factors affecting the ridge can be associated with medications.

After implant placement, some hard and soft tissue deficiencies can be caused by malpositioning of the implants, peri-implantitis, and mechanical overload. Also, changes of the bone after implant placement can be associated with lack of soft tissue thickness and/or lack of buccal bone, and esthetic complications can be associated with insufficient papilla height. Finally, another important variable is the natural migration of the teeth and the skeletal growth changes throughout the life of the individuals which could result in changes of the hard and soft structures around implants [14].

8.3 Conclusions

These guidelines for the classification of peri-implant conditions should help the clinician to identify early signs of peri-implant disease and to treat it or refer accordingly. These classifications also assist in appropriate communication among oral health professionals and third party providers.

8.4 Summary

Implant failures occur on a routine basis. The reader should become aware of the current classification of peri-implant health and diseases.

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Occlusion and Its Relation to Peri-Implant Diseases

9

Stephen Harrel

Key Points

- "Occlusal overload" on implants is poorly defined.
- Occlusal stress from temporary restorations can be associated with early implant loss
- Immediate and early loading of implants requires implant stability
- Implant failures can be associated with failure of the materials making up the implant or the prosthesis
- Occlusal contacts that place the stress in the long axis of the implant are considered ideal
- Bruxism is related to long-term implant failure and a night guard should be fabricated whenever there is any hint of parafunctional occlusal habits.

9.1 Introduction

The role that occlusion may play in the failure of implants is unclear. "Occlusal overload" may be mentioned in case reports of implant failures but there is very little definition of what characterizes an implant occlusal overload. Obviously it is possible that poorly designed occlusal contacts resulting in very heavy stresses can overcome the materials that make up the body of the implant or the prosthetic components that are placed on the implants. This type of overload will usually manifest as a fracture of the implant body, fracturing of abutments, sheering of retaining screws, or a loss of a portion of the crown. This type of failure is usually easily identifiable and similar types of failures occur in traditional non-implant dentistry. The role that occlusion may play in the failure of the osseointegration of the implant and the progression of bone loss around the implant is far less clear. This chapter will

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review what is currently known about the role of occlusion in implant failure and also what is known about avoiding implant problems associated with occlusion.

9.2 Role of Occlusal Stress in Periodontal Disease

The fact that occlusion is often implicated in implant failure is probably based on the fact that occlusion has been associated with the progression of periodontal disease around natural teeth. While there are no clinical trials showing that occlusion is a factor in the progression of periodontal disease, there is substantial associational data showing that untreated occlusal discrepancies are associated with an increase in periodontal probing pocket depth around natural teeth. However, the data obtained from disease progression around natural teeth should not be applied to bone loss around implants. The supporting structure for an implant is completely different from the supporting structure for a natural tooth. Due to this, it is extremely unlikely that the same pathophysiologic factors are at play in periodontal disease and in peri-implant bone loss. The reader is strongly urged to not assume any kind of equivalency between the two disease processes.

9.3 Early Implant Failure

Occlusal forces often seem to be a factor in what is termed early implant failure. Early implant failure typically occurs very soon after the implant is placed surgically and often before the implant is placed into function with a restorative appliance. A classic example of this type of early failure can occur with the use of a temporary partial denture ("flipper") that comes into contact with the newly placed implant. In many cases, the movement of the saddle of the temporary partial on the implant healing screw or abutment contributes to the loosening of the implant and the failure of osseointegration of the implant. Because of the difficulty in fabricating a traditional removal temporary partial denture in a manner where no pressure is transmitted to the implant, these types of temporary partials are usually contraindicated following most implant placement. A removable partial denture such as an Essix type appliance or Snap-On-Smile (Den-Mat, Lompoc, CA, USA) is preferred when a partial denture is necessary to fulfill the patient's esthetic demands. Another option that will not place occlusal pressure on the newly placed implant is to temporarily bond the extracted tooth crown or a denture tooth to the adjacent teeth. With any temporary restoration, fixed or removable, care should be taken to not allow any contact with the implant.

9.4 Immediate and Early Loading of Implants

There is increasing use of what is termed immediate or early loading of implants where a temporary crown is placed at the time of implant placement or within several weeks of implant placement. Immediate loading of the implant refers to the placement of an abutment and temporary crown at the time the implant is surgically

placed or shortly after the implant is placed. Early loading is the placement of an abutment and temporary crown within a few weeks of implant placement. Misuse of these approaches can lead to implant failure. Several factors must be present before these techniques are used. The implant must have good stability at the time of placement. This occurs when there is dense bone at the implant site (type II bone) and the osteotomy has been performed without modification (the size of the osteotomy matches the size of the implant). The insertion torque should be greater than 25 N/cm with an abutment torque of 35 N/cm. If this level of stability is not obtained, immediate or early loading of the implant may be contraindicated. If implants that do no replace all of the teeth in an arch are loaded, the temporary crown must be placed in such a manner that there is no occlusal contact with the opposing teeth. A good practice is to fabricate the temporary crown so that it is 3–4 mm short of making occlusal contact. Even with this amount of space, most patients will be able to place some occlusal forces on the temporary crown during function. While immediate and early temporization of implants have many advantages in the form of soft tissue molding and patient satisfaction, these approaches should be avoided if there is any question of implant stability. No matter how much care is taken to avoid occlusal stress, occlusal pressure will always be placed on the implant when the patient functions and this in turn may lead to early implant failure. Wearing a maxillary full coverage hard acrylic night guard will reduce stresses during sleep.

9.5 Materials Failure

Excessive occlusal forces on the implant and prosthetic appliances can cause failure of either the implant itself or the prosthetic appliances attached to the implant. While fracture of a standard diameter titanium implant is relatively rare, this type of fracture can occur. Fractures were more frequent with early implants that had a "hollow body" design where the apical portion of the implant was not solid but was formed of thin metal around a hollow core. Fracture of the titanium where the solid portion of the implant transitioned to the hollow core was not uncommon. This would occur in patients with an apparently adequately designed occlusal relationship and while it can be said that these failures were caused by occlusal overload, it is more likely that these fractures were at least in part due to design failure of the implant. Failures with solid implants are frequently associated with the so-called reduced diameter implants. Traditional implant bodies are generally 3–5 mm in diameter. Implants with a diameter less than this are considered reduced diameter implants and have a greater tendency to fracture under load. While reduced diameter implants can be used successfully in certain cases, care must be taken to minimize the occlusal load on these implants. Splinting of reduced diameter implants may be indicated, especially when used in the posterior.

It is also possible for the prosthetic appliances placed on the implants to fracture or distort under occlusal stress. This can take the form of fractured abutments, fractured bridges, chipped porcelain, or broken retention screws. As with natural teeth, basic occlusal relationships should be maintained to minimize this type of damage. The design of occlusal patterns is discussed later in this chapter.

9.6 Peri-Implant Disease and Bone Loss Associated with Occlusion

There is very little literature about the role of occlusion in the progression of peri-implant disease. Graves has produced the only cross-sectional data that looks at the occlusal contacts on implant supported individual crowns and then correlated these contacts to the presence of peri-mucositis (inflammation around the implant) [1]. For this study, the occlusion was evaluated using the traditional methods of inked occlusal ribbon as well as the use of a computerized method of evaluating occlusal contacts (TekScan, South Boston, MA, USA). No correlation was found between any occlusal factors and the presence of peri-mucositis. In contrast to this, several reports following large numbers of implants over many years have associated the loss of implants with bruxism [2]. In these reports, it appears that the presence of bruxism was either self-reported by the patient or diagnosed from heavy wear facets on the teeth. Also, in most cases no mention is made as to whether the patients who were diagnosed as bruxers and who lost implants wore any type of occlusal guard. While it is certainly reasonable that heavy force on the implant from routine bruxism could play a role in peri-implant diseases, these uncontrolled case series are a weak source of information concerning implant loss.

There is a growing body of literature that associates the corrosion of the implant surface and the subsequent shedding of titanium particles with the failure of implants [3]. To date there is a single study showing that titanium particles are associated with failed implants [4]. In this study titanium particles were noted in the connective tissue surrounding the failed implants. Further, inflammatory cells were noted surrounding these embedded metal particles. While it has not been conclusively shown that these titanium particles are a factor in the loss of the implant, there is concern that these embedded metallic particles may play a role in peri-implant bone loss. It has been shown that when an implant is exposed to an acidic environment, such as plaque, corrosion occurs on the outer surface of the implant. Mechanical stressing of these corroded areas may then cause the particles of titanium to be shed and this may be a source of the inflammation seen in peri-implant diseases. Within this context, occlusal stresses on the implant may be a factor that causes the metal to separate from the implant body. In vitro studies have shown that repeated mechanical stresses, similar to occlusal loading, can cause corroded titanium surfaces to shed particles [5]. If the inflammation associated with shed titanium particles is a factor in bone loss around implants, then occlusion may be a factor in this disease process and may be part of why clinical observation has associated occlusal overload with implant failure. Research is currently ongoing in this area.

9.7 Occlusion in the Maintenance of Implants

Because the data on the role of occlusion in the loss of implants is sparse, the prevention of problems from occlusion must be couched in terms of good prosthetic practices learned in dentistry on natural teeth. A through occlusal evaluation of

centric and lateral movements as well as evaluating wear facets on the teeth should be performed prior to restoration of an implant. If significant occlusal discrepancies are present, the patient should have a pre-prosthetic occlusal adjustment performed on the existing dentition, natural or implant supported, so that when an implant is restored it will be possible to fabricate a restoration that has as few occlusal interferences as possible.

While not proven from a biological point of view, engineering principles dictate that a round metal rod support, such as an implant, is best able to withstand loading stress if the stress is placed parallel to the long axis of the metal support. It is logical that the implant would best be able to support occlusal stresses if the load is placed on an axis with the implant. In dental terms this would mean that occlusal forces should be placed to the greatest degree possible on the long axis of the implant (Figs. 9.1 and 9.2) This further means that torqueing forces should be avoided to the greatest extent possible. The following suggestions are based on the principle of axial loading of the implant as well as research on periodontally damaging contacts on natural teeth.

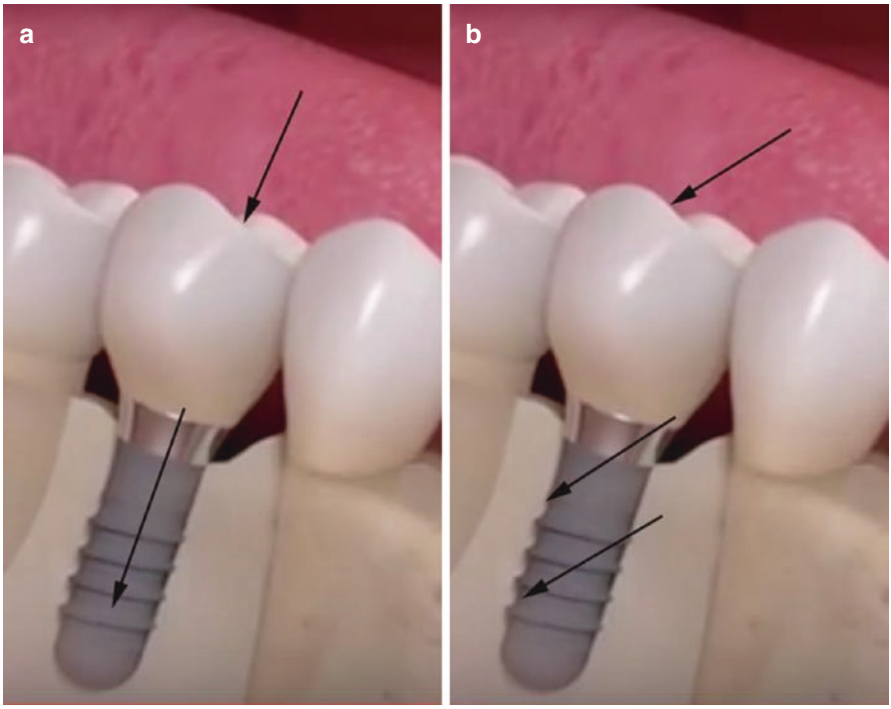

Fig. 9.1 Occlusal load on an isolated single implant crown. (**a**) Loading of an isolated single tooth implant with the occlusal stress on the long axis of the implant. This is considered to be the ideal loading pattern. (**b**) Loading of an isolated single tooth implant where the major occlusal force causes an off-axis torqueing/rotational force on the implant body and crown. This type of torqueing contact may place excess stress on the implant and may contribute to implant bone loss/failure

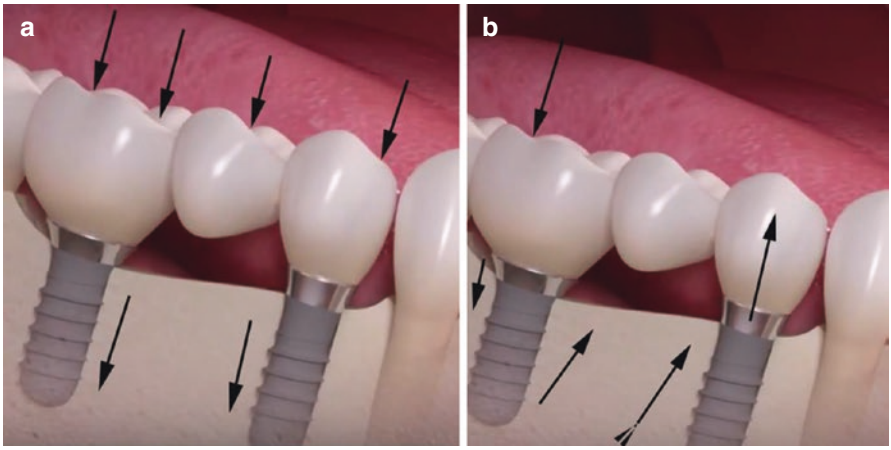

Fig. 9.2 Occlusal load on a multi-unit implant supported bridge. (**a**) Loading of a multi-unit bridge so that occlusal stress is on the long axis of the implants. Note that contacts on both abutment crowns and the pontic are on the same axis as the implants. This is considered to be the ideal loading pattern. (**b**) Loading of a multi-unit implant supported bridge where the major occlusal force is a premature contact on the distal abutment crown. This would be a "centric prematurity" where the patient would "hit high" and then "slide" to maximum occlusal contact. This type of contact places heavy stress at the initial contact and torques the entire bridge in a vertical and lateral motion. On natural teeth, this is the most damaging type of occlusal contact and it is assumed to be damaging to implant supported restorations

On posterior natural teeth lateral and protrusive stresses should be limited or avoided. Studies on natural teeth have shown that premature contacts in centric relation, balancing, and protrusive contacts on posterior teeth are the most damaging in terms of inducing deeper periodontal pockets [6]. Working contacts on posterior natural teeth are less damaging than balancing contacts but have been implicated in deepening pockets. Based on these observations on natural teeth, when possible, posterior implants should have only contacts in centric occlusion with no discrepancy between initial contact and full intercuspation. This is often described as the occlusion having no prematurities and no slide between initial contact (centric relation) and maximum contact (centric occlusion).

In the anterior portion of the mouth it is difficult to avoid protrusive contacts and the resulting torqueing motion of these contacts on the implant. In the anterior area care must be given to distribute protrusive forces over as large an area as possible and to avoid placing heavy stress on a single implant. In a situation where there are no strong natural teeth to carry some of the stress of protrusive movement or where it has been necessary to place only short or reduced diameter implants, consideration should be given to splinting so that stress is distributed as much as possible.

9.8 Bruxism

As bruxism is the only form of occlusal trauma that has a reported association with implant loss, bruxism should be addressed with all implant patients. The patient

should be asked if they have a history of bruxism and the potential role of bruxism in implant failure should be discussed. The existing occlusion should be evaluated carefully to determine if there is evidence of bruxism or other parafunctional habits such as clenching. Flat wear patterns on the occlusal surface, known as faceting, are an indication of possible past or present bruxism. If there is any hint of a bruxism habit either currently or in the past, the patient should be fitted with a maxillary hard acrylic full coverage occlusal appliance that acts as a night guard. While there is no proof of its necessity, some practitioners insist that all implant patients have a night guard fabricated after an implant is restored. The fabrication of a night guard for every implant patient may err to the side of over caution but parafunctional habits and specifically bruxism is one of the few occlusal patterns reported to have a direct association with implant failure. When viewed in this light, the use of an occlusal guard for all implant patients may be a warranted precaution.

9.9 Summary

Occlusal stress is frequently implicated as a factor in implant and implant prosthetic failure. However, there is little literature that supports occlusion as a causative factor in peri-implant diseases. Despite the lack of evidence of occlusion as a contributing factor, the occlusion on implant supported prosthesis should be carefully evaluated and occlusal stresses that have been shown to be detrimental on natural teeth should be minimized. Additionally, the design of the prosthetic devices should take into account the strength of the reaming natural detention, the number of implants to be loaded, the diameter of the implant, and the length of the implant in the bone. As with all restorative dentistry, the strength of the available support from teeth and implants should be a major factor in the type of prosthetic restoration placed and the stresses placed on the restoration should be guided by this underlying support.

Occlusal stress is frequently implicated in implant failure but there is little evidence beyond clinically based conjecture to support occlusion as a risk factor. Proper prosthetic techniques to insure stress on the long axis of the implant will minimize any potential damage caused by occlusal loading.

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A Typical Implant Maintenance Visit

10

Thomas G. Wilson Jr.

Key Points

- Most implant failures occur after bony integration
- In most cases, if the genesis of the problem can be discovered and treated in its early stages, the implant can survive
- The status of the implant health is best analyzed using a periodontal probe and right angle radiographs taken over time
- Appropriate treatment is determined by a proper diagnosis
- Peri-implant mucositis is best treated by personal oral hygiene and gentle porfessional cleaning with streile saline on a cotton pellet
- Peri-implantitis often requires surgical intervention and outcomes are not always predictable

Implants suffer from many of the problems associated with natural teeth. For this reason maintenance for these devices is advisable. This hypothesis has been substantiated in the literature [1–7]. This chapter will detail current approaches for maintenance for individuals with dental implants. Since the etiology of some peri-implant problems has been shown to resemble that seen around natural teeth, a typical maintenance visit for these individuals will be similar to a periodontal maintenance visit.

10.1 Medical and Dental History

A typical visit would start with an overview of the patient's medical history. This would include any changes in health, hospitalizations, and medications. The patient's blood pressure is taken and recorded. Any concerns or changes in the patient's dental or medical history are recorded.

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10.2 Extra- and Intra-oral Examination

An extraoral examination including evaluation of the temporomandibular joints and muscles of mastication along with a brief survey of the external features of the head and neck is performed. This is followed by a thorough examination of the intraoral tissues including the mucosal surfaces, evaluation of the tongue and oropharynx. The fact that the examination was performed along with any positive findings are recorded.

10.3 Tooth and Implant Mobility

Tooth and implant mobility are evaluated using bidigital mobility (Fig. 10.1) and opposing teeth are checked for fremitus (tooth movement in function) (Fig. 10.2). Restorations are evaluated for fractures, marginal integrity, and movement. The teeth are examined clinically for evidence of dental caries. The examination and any positive findings are recorded. Implant mobility without pain is usually indicative of a problem with the crown or abutment. Intense pain usually indicates implant failure.

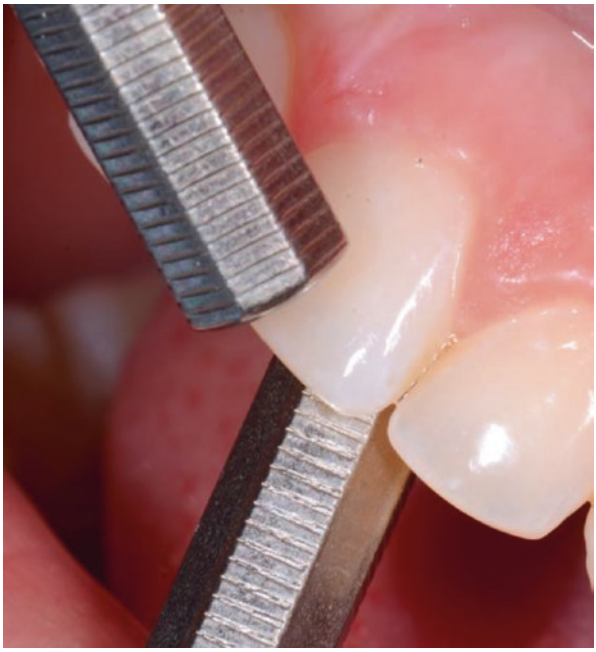

Fig. 10.1 The blunt ends of two instruments are used to determine tooth mobility (see Table 10.1)

Table 10.1 Classification of Bidigital Tooth Mobility

Class 0	Physiologic mobility; firm tooth
Class I	Slightly increased mobility
Class II	Definite to considerable increase in mobility, but no impairment of function
Class III	Extreme mobility; a loose tooth that would be uncomfortable in function (a plus sign can be used for intermediate values, e.g. 1^{+}). This approach obviously leads to a great deal of individual variation. However, some degree of reproducibility is possible within one's own office [8]

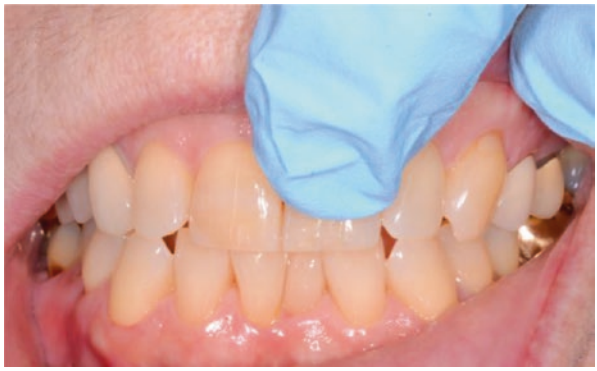

Fig. 10.2 Any tooth movement felt during function is fremitus

10.4 Probing

Probing is performed at 6 points around all remaining teeth and on up to 6 points around each implant depending on access (Fig. 10.3). Currently metal probes are suggested for natural teeth and flexible plastic probes with millimeter markers for implants.

It is especially important to check for bleeding upon probing around implants with cemented restorations. This is because cemented restorations in patients with good oral hygiene that exhibit bleeding upon on probing usually have excess cement in the surrounding tissues [9]. This excess cement has been shown to be strongly associated with peri-implant disease [10]. It is also important to record any deepened probing depths around teeth [11]. A diagnosis is now possible. Peri-implant mucositis is characterized by bleeding upon probing and tissue color changes. It is currently assumed to be caused by bacterial plaque. Peri-implantitis is the progressive loss of bone and seen on radiographs and/or with increased probing depths and associated with inflammation [12].

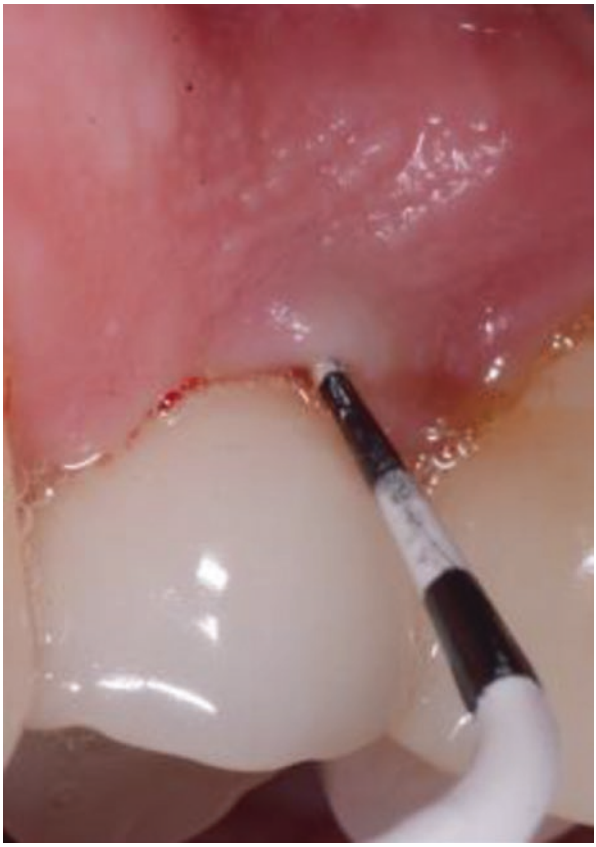

Fig. 10.3 A flexible plastic probe

10.5 Therapy

The use of any device that will create aerosols should be preceded by a 30-second rinse with chlorhexidine gluconate 0.12% (CHX). This reduces the cultivatable microflora within the oral cavity significantly, thus reducing the possible spread of these bacteria to both professionals and patients [13].

Polishing with a rubber cup is then performed on the natural teeth and on the implant prostheses. Calculus removal, both supra and subgingival, is then performed around the natural dentition. Calculus on subgingival surfaces of implants has not been observed using endoscopy or the videoscope.

10.6 Diagnosis Peri-Implant Mucositis-Treatment Option 1

The titanium oxide layer on implants is necessary to achieve osseointegration. This layer is very thin and easily removed. Once this layer is removed during maintenance procedures, it may not reform. Peri-implant mucositis is frequently seen [14].

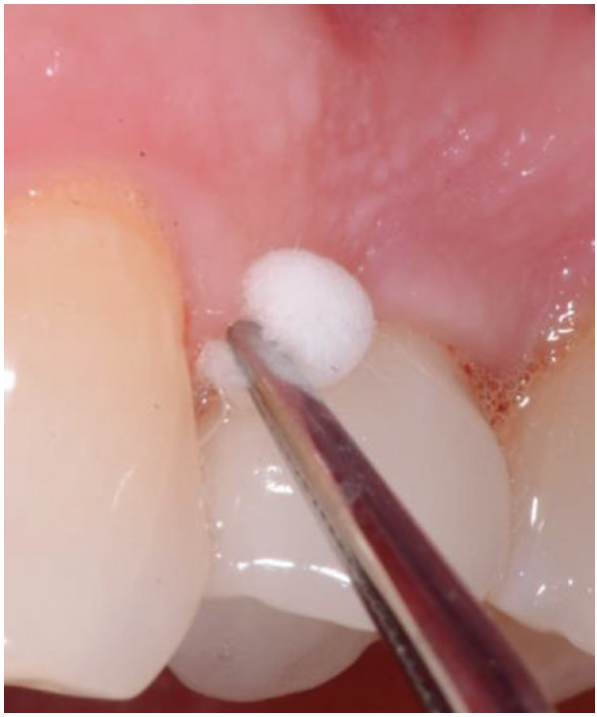

Fig. 10.4 A cotton pellet soaked in saline is used to gently clean the surface of the implant

If one accepts that the TiO layer will not always reform in vivo following maintenance therapy (see Chap. 6), then every attempt must be made to not disturb the implant surface. Therefore when the diagnosis of peri-implant mucositis is made, a cotton pellet dipped in normal saline solution is suggested for removal of bacteria on the subgingival portions of the implant (Fig. 10.4). The rationale for this approach is detailed in Chap. 11. It emphasizes attempts to remove bacteria while leaving the residual titanium oxide layer as intact as possible. When supragingival calculus is present on exposed implant surfaces it can be removed with a sharp curette. A curette is suggested because a recent study demonstrated that use of other mechanical devices will result in removal of titanium particles from surface of implant [15]. A sweep of the implant sulcus is made using a curette (normally metallic) with the blade turned toward the sulcus wall (Fig. 10.5). The purpose of this sweep is to remove particles of cement, titanium and microbial deposits that may have accumulated in the soft tissue.

In cases of mucositis, the patient's oral hygiene is reinforced and CHX rinses (BID) are prescribed. The area is re-evaluated in 1 month. If the patient's oral hygiene is good and bleeding upon probing is found at this second visit, it is highly probable that foreign bodies are present in the surrounding soft tissues. If the prosthesis is cemented the foreign body will most likely be excess cement, or in some cases titanium. In these cases surgical removal of the soft tissues immediately surrounding the implant is often indicated to facilitate removal of imbedded foreign

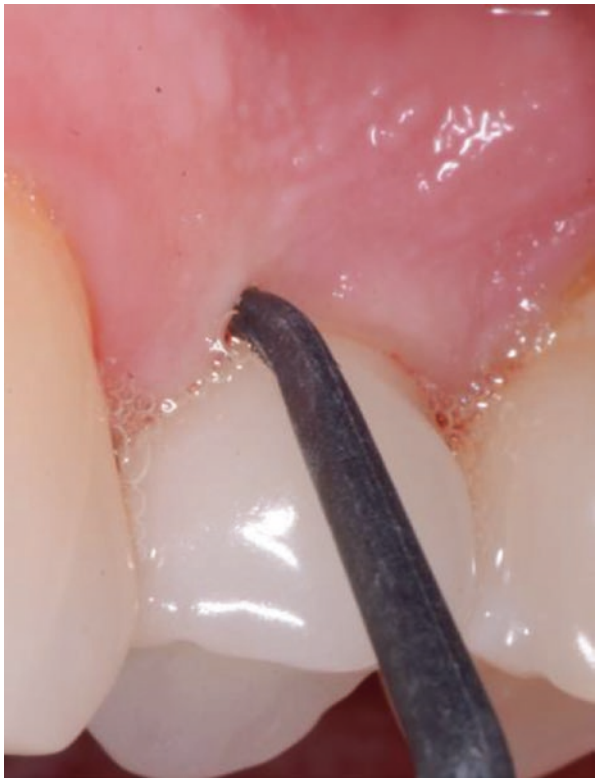

Fig. 10.5 A curette turned toward the sulcus wall is sued to remove debris

bodies. It is suggested that these particles be removed after elevating a flap. This flap is used to give visual access to the implant surface and to allow removal of the cement. The removal of cement on the implant surface should be accomplished with a sharp metallic curette and every attempt should be made to avoid damaging the implant surface. In our practice this approach is aided by the use of either the dental endoscope or in most cases the dental videoscope (see Chap. 11). Every attempt should be made to remove the surrounding soft tissues. This is because these tissues have been shown to contain remnants of cement and titanium surrounded by inflammation cells. Referral to a specialist should be considered. It should be noted that regaining health of the peri-implant tissues is delayed compared with those with gingivitis [16].

10.7 Diagnosis Peri-Implant Mucositis-Treatment Option 2

Many believe that the TiO surface will reform in vivo, or that reformation is not important, and that thorough cleaning of the implant surface is required to remove any adherent foreign material. Various instruments have suggested for this purpose including plastic, stainless steel, titanium, and gold-tipped scalers. Ultrasonic tips

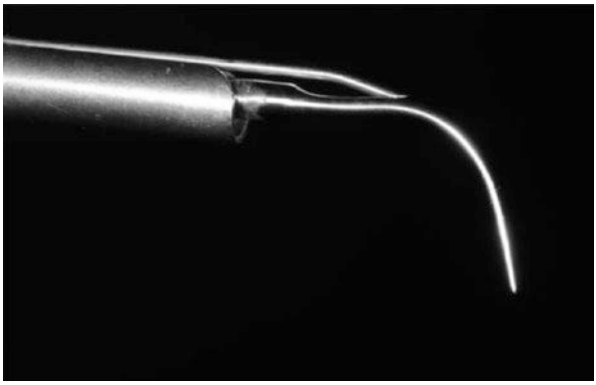

Fig. 10.6 Some prefer metallic instruments to "detoxify" the implant in spite of the damage inflected on the surface [15]

have also been used with traditional, plastic-coated, and metallic alloy tips (Fig. 10.6). Polishing paste, air-power abrasives and glycine power have been suggested (for a review see [7]). It is this author's contention that all of these methods remove the TiO layer, resulting in a possible lack of biocompatibility of the implant surface, especially when closed (nonsurgical) methods are used. This hypothesis is currently being debated.

10.8 Diagnosis of Peri-Implantitis

When progressive bone loss associated with clinical signs of inflammation is seen, steps should be taken to halt, and hopefully reverse, the process. Referral to individuals with experience treating these problems is strongly suggested (see Chap. 11).

10.9 Occlusion

The effect of occlusion on the peri-implant disease is controversial. It is well documented that excessive occlusal forces can result in fracture of implant crowns, screws, and in some cases the implants themselves. As a result, it is suggested that the effect of bite forces be evaluated periodically (see Chap. 9). Excessive bite forces can result from improper occlusal relationships and especially from bruxing. Clinical signs of these forces can be evident by fracture of the overlying restoration, loose or broken occlusal screws and fractured or mobile implants. Some patients develop TM joint symptoms while others exhibit fremitus or cold sensitivity of teeth in the arch opposing the implants. Because of the potential for harm from excessive bite forces, the author feels that in most cases fabrication of a maxillary hard acrylic full coverage night guard is appropriate. This is especially true for those individuals who brux.

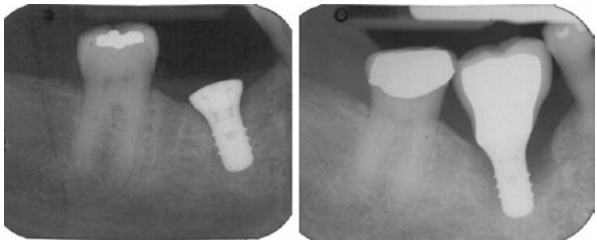

Fig. 10.7 Right angled peri-apical radiographs taken 11 years part

10.10 Radiographs

Right angle radiographs, either peri-apicals or vertical bitewings, should be taken at appropriate intervals. For patients with no clinical signs of inflammation or increases in probing depths this could be every 5 years. For those individuals showing signs of peri-implant disease more frequent radiographs are appropriate (Fig. 10.7).

10.11 Behavioral Changes and Oral Hygiene

Behavioral changes are addressed next. These include reducing or eliminating systemic modifiers of periodontal and peri-implant diseases including smoking, diabetes, thyroid, and parathyroid disorders and other systemic diseases or habits that might have negative effects on the tissues surrounding these devices.

The patient's oral hygiene is then evaluated and appropriate changes suggested. A soft manual or electric toothbrush should be used for a minimum of two minutes at a 45-degree angle to the gingival margin. Interproximal cleaning aids, such as floss and/or interproximal brushes, should be used as appropriate, depending on the size of the interproximal space. In areas where the gingival margin of the implant is apical to the adjacent teeth, a sulcular cleaning aid, such as a Sulcabrush, end tuft brush or implant care brush, may be helpful. The positive effect on health resulting from good personal oral hygiene cannot be overemphasized.

10.12 Maintenance Intervals

Setting patient maintenance intervals for partially dentate patients should be related to the periodontal status and the status of the peri-implant tissues [17, 18]. In general this would mean that an individual with a healthy periodontium and peri-implant tissues would be seen for maintenance at yearly intervals. One study concluded that compliance to suggested maintenance intervals was better for implant patients than those who suffered from periodontitis [19]. Those with gingivitis (or peri-implant mucositis not associated with excess cement) are usually seen approximately every 6 months, while those who have periodontitis will be seen more frequently [20]. Individuals with periodontitis who maintain regular maintenance visits as well as high levels of personal oral hygiene have

been shown to have minimal bone loss around their implants [21, 22]. The implant maintenance schedule should be set by disease profile not by the calendar.

In summary, maintenance for individuals with dental implants can be critical to the survival of these devices.

10.13 Summary

Implants should be maintained on a regular schedule. Treatment of peri-implant diseases is controversial at this time and the practitioner should approach treatment carefully. Incorrect treatment of early peri-implant disease may contribute to later implant complications.

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Advanced Therapeutics

11

Stephen Harrel and Jeffrey Pope

Key Points

- When bone loss is present around an implant advanced diagnosis and treatment are necessary.
- Excess cement is a known cause of peri-implant problems and should be ruled out as a first step.
- If cement is present, it should be removed with a curette, not an ultrasonic scaler. Surgical access with videoscope visualization is frequently necessary.
- Surgical treatment that is not aimed at regeneration is similar to osseous surgery around natural teeth. It is predictable but yields unaesthetic results.
- Regeneration of bone and re-osseointegration of the implant is somewhat unpredictable and the surgical methods that should be used are controversial.

11.1 Introduction

Peri-implant problems typically present with inflammation and bleeding on probing. If there is no evidence of bone loss, we refer to these implants as having peri-implant mucositis. Peri-implant mucositis should be treated as conservatively as possible (see Chap. 10). When deepening pockets and progressive bone loss are present and associated with clinical signs of inflammation, this is referred to as peri-implantitis. Conservative treatments such as scaling, local antibiotics, and systemic antibiotics are rarely effective in halting or reversing the progression of bone loss

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and ongoing bone loss may lead to the loss of the implant. The treatment of peri-implantitis and its associated bone loss is controversial and no generally accepted treatments are recognized. The specific treatment performed should be tailored to the clinical conditions presented. This chapter will discuss the various treatments, which we perform in the presence of peri-implant disease and some of the factors we take into consideration for the use of the different treatment approaches.

11.2 Cemented Restorations vs. Screw-Retained Restorations

Before embarking on treatment of the implant, the prosthesis should be closely evaluated. Loose components or a prosthesis that does not allow for cleaning of the peri-implant tissue should first be ruled out as a contributing factor. If the prosthesis appears to be acceptable, the next step is to determine if the prosthesis is cemented or screw-retained. There is evidence that excess cement is a major factor in peri-implant problems [1]. If the prosthesis is cement-retained, a detailed examination should be performed to determine if excess cement is present.

Rarely can excess cement be seen on radiographs. This is only possible if the excess cement is relatively large, present on the mesial or distal aspect, and radiopaque (Fig. 11.1). Many of the cements used to retain implant-supported crowns are not radiopaque which make radiographs of limited usefulness in determining if excess cement is present. If excess cement is visible on the radiograph, a cause of the peri-implant problem is relatively obvious. If cement is not visible in the radiograph, this does not rule out the presence of cement and further diagnostic steps are necessary.

If the clinician can detect the presence of cement tactually with a periodontal probe or explorer, it may be possible to remove the cement with a curette. The use of an ultrasonic scaler is contraindicated as this may spread small particles of

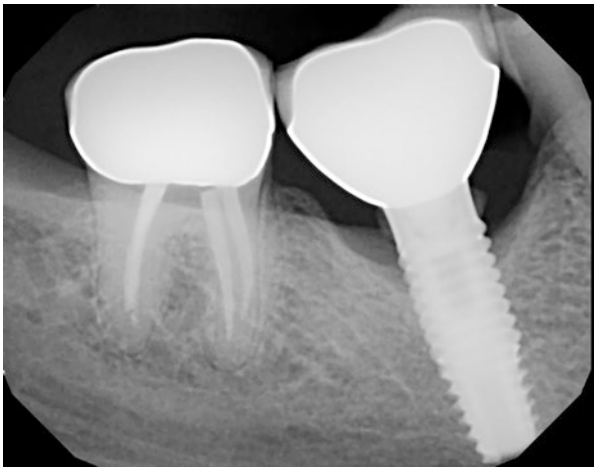

Fig. 11.1 Excess radiopaque cement is present on the mesial and distal aspect of the implant and is associated with bone loss around the implant. Non-radiopaque cement would not be visible on a radiograph

bacterial-contaminated cement into the peri-implant tissue. Particles of cement in the surrounding soft tissues have been associated with foreign body inflammation and with failed implants [2]. Every effort should be made to remove the cement as an intact mass. The clinician should bear in mind that even microscopic amounts of excess cement have been associated with peri-implant problems. The detection of a very small amount of cement with a periodontal probe is nearly impossible. Clinicians may require the use of advanced visualization techniques (dental endoscope and dental videoscope) to help detect and remove small particles of cement.

11.3 Dental Endoscope

The glass fiber endoscope was designed for non-surgical evaluation and treatment of an intact periodontal sulcus. The instrument consists of a 0.9 mm fiber optic bundle that is placed in a sterile single-use sheath containing a focusing lens (Fig. 11.2). The assembled instrument is less than 2mm in diameter and can be placed in the sulcus of a tooth or implant, possibly without anesthesia. The endoscope gives a picture of the implant and sulcus on an external monitor. The implant can be inspected for cement or other abnormalities such as a fracture. If cement is detected on the implant, abutment, or crown, it may be possible to remove it with a curette and endoscopic visualization. The advantage of the endoscope is that it can be used non-surgically and, if possible, the cement can be removed without surgical access. There are several problems that are routinely encountered with the use of the endoscope. One of these is the difficulty interpreting the image on the monitor. Because a glass fiber optic bundle is used with an external camera, the image on the monitor is often blurry and difficult to interpret (Fig. 11.3). This problem is compounded by the fact that a constant stream of water is used to keep the lens of the endoscope free of debris. The water in the sulcus along with floating debris can also limit vision. This has discouraged many from using the endoscope and the availability of this instrumentation is limited. Another concern is that the removal of the excess cement may be difficult to perform without surgical access. In other words, the endoscope may allow you to see the cement but the cement may require surgical access to remove. Nonetheless, in many instances when the endoscope is available it may be the preferred first-step approach in the evaluation and treatment of excess, cement-associated, peri-implant disease due to its simplicity and minimal morbidity.

11.4 When Should Surgery Be Performed?

In cases of progressive bony degeneration around implants or in cases where excess cement cannot be removed with endoscope assisted scaling, surgical access to the implant becomes necessary. There is mounting evidence that if a peri-implant problem does not respond to non-surgical therapy (i.e. gentle debridement of the sulcus, antibiotics and chlorhexidine rinses), further attempts to arrest the disease without surgical

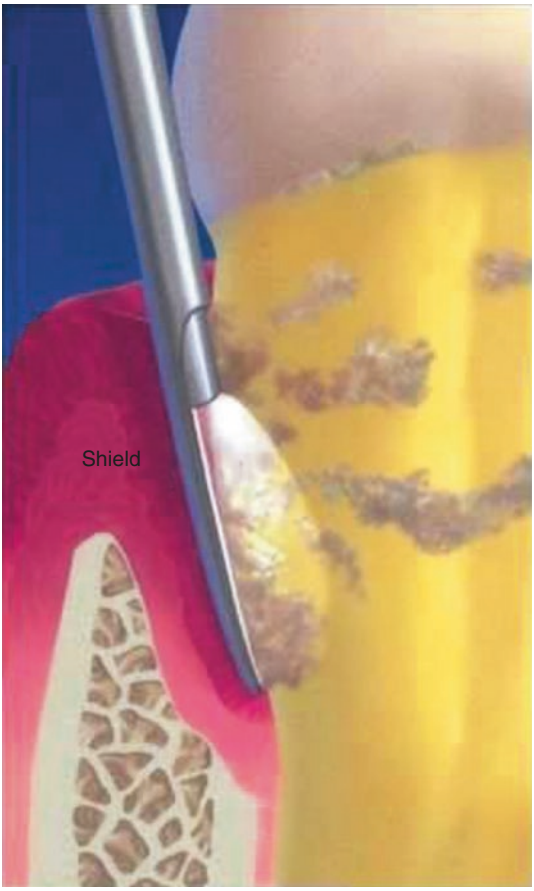

Fig. 11.2 The dental endoscope inserted into an intact sulcus (non-surgically) of a periodontal pocket. (Courtesy Dr. John Kwan and Zest Dental Solutions)

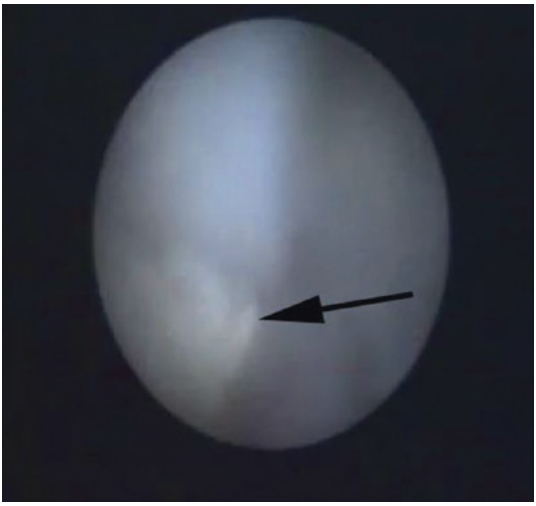

Fig. 11.3 Excess cement on an implant (arrow) as viewed with an endoscope

intervention will not be beneficial (see Chap. 10). It is our opinion that if peri-implant bone loss is present and if there is evidence of progression of the bone loss, repeated non-surgical treatment will not be beneficial and surgical treatment is indicated. If the treating clinician is not familiar with and comfortable in performing the procedures described, referral of the patient is indicated as soon as continuing bone loss is noted.

If it is determined that a surgical approach is indicated, either to remove cement and/or treat bone loss from an unknown cause, the clinician needs to be aware of the different surgical approaches that are currently being used. Surgical procedures that are not designed to regenerate bone and not re-osseointegrate the implant in the areas of bone loss are relatively straightforward and are frequently successful. Surgical procedures designed to regrow bone and attempt to re-osseointegrate the implant vary widely, and all have limited and varied success. If the reader plans to perform surgical therapy, they should stay current on this rapidly changing area of implant therapy.

11.5 Non-Regenerative Therapy

Surgical treatment that is not aimed at regeneration takes the form of a procedure termed implantoplasty, or a less aggressive procedure, which positions the soft tissue to a more apical level around the implant. Both procedures are similar with the only exception being the treatment of the implant surface itself. The bone loss around the implant is accessed with relatively large incisions, similar to what would be used for an open flap debridement around a tooth (Fig. 11.4).

The granulation tissue is removed and the bony architecture is evaluated. If the bone loss is uneven, then the bone is reshaped to a contour that will allow for placing the soft tissue at a more apical level around the implant. This allows the soft tissues to be positioned so that they rest on the modified bony contours, similar to the apical positioning of soft tissue following osseous surgery for periodontal disease. With implantoplasty, the exposed threads and rough surface of the implant are ground off and the exposed titanium smoothed to allow for better cleansability and

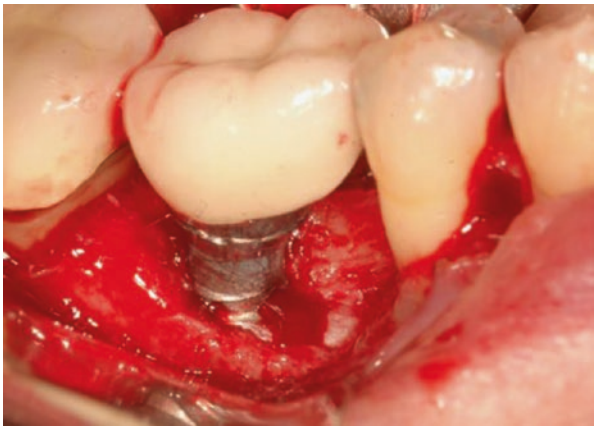

Fig. 11.4 A traditional (full flap) access of the peri-implant osseous damage to allow for non-regenerative treatment in the form of debridement and/or implantoplasty

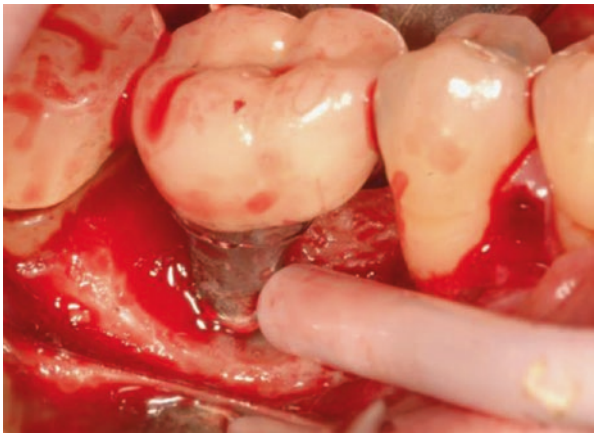

Fig. 11.5 The implant shown in Fig. 11.4 after implantoplasy. Note that the threads have been removed and the implant body smoothed. Also note that the surgical site has been scrupulously irrigated and suctioned to remove all visible titanium particles produced during the smoothing of the implant

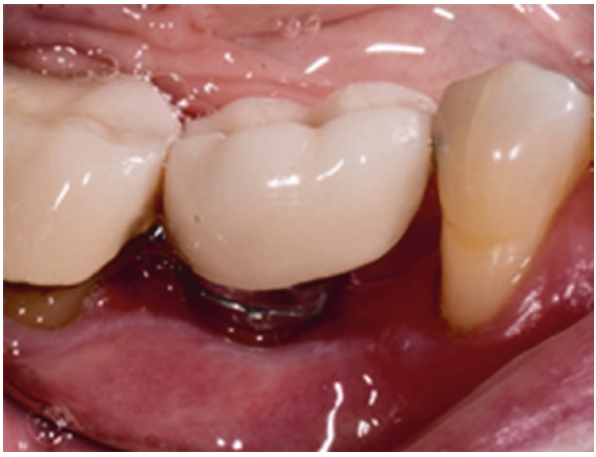

Fig. 11.6 The surgical site shown in Figs. 11.4 and 11.5 at five years post-operative. Note that the tissue has been apically positioned and a relatively large amount of space is present apical to the body of the crown. While this implantoplasty procedure with apical tissue positioning was successful in arresting the progression of the bone loss, it would be considered "un-esthetic" if it were performed in the anterior region

less irritation of the surrounding soft tissues (Fig. 11.5). In a more conservative approach, the exposed threads are left intact. Leaving the threads intact minimizes the contamination of the tissue with titanium particles but creates a very difficult surface for the patient to clean. Apically positioning the flap in combination with implantoplasty is the most predictable surgical procedure for preventing further bony loss around the implant [3]. However, the esthetic problems and patient dissatisfaction following this approach limit its usefulness (Fig. 11.6).

11.6 Regenerative Therapy: Full Flap Access

If the decision is made to attempt regeneration around the implant, two flap approaches may be utilized—full sized traditional (large) flaps or videoscope-assisted minimally invasive access. Most published reports have used a relatively

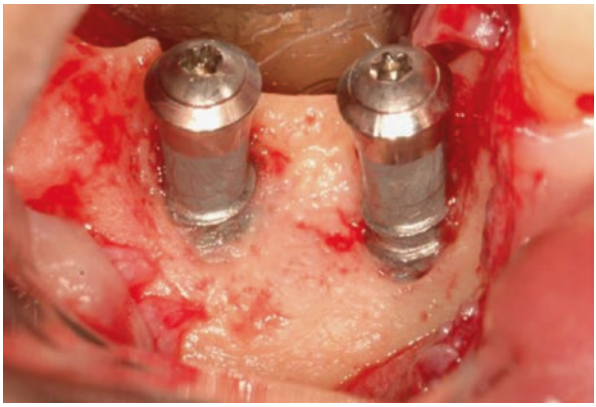

Fig. 11.7 A traditional (full flap) approach for regeneration of bone damage around implants. Note that the large flap is extended beyond the implants in a mesial-distal and an apical direction

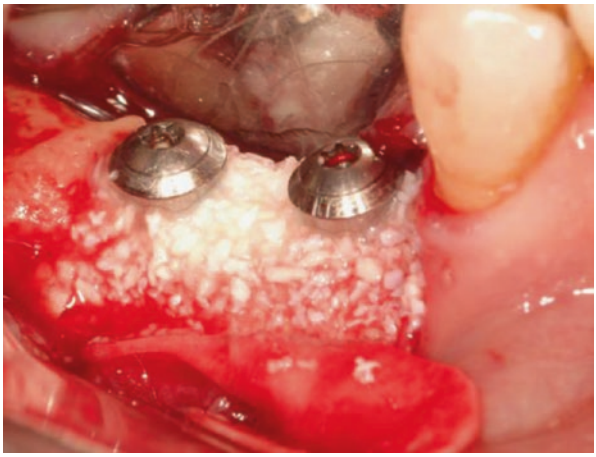

Fig. 11.8 After debriding the area of bone loss and disinfecting the implant surfaces, regenerative material, in this case DFDBA and enamel matrix derivatives, have been placed around the implants

large full flap approach. This is used for visualization and allows for various medicaments and the placement of various membranes. Typically, the implant will be exposed using flaps that are 15–20 mm or longer on both the buccal and lingual aspect (Fig. 11.7). The granulation tissue is removed and the bone evaluated. The implant is typically cleaned with a variety of instruments and medicaments. The instruments frequently used are ultrasonic scalers, plastic or metal scalers, air polishing with silica, or air polishing with glycine powder. The medicaments used may be chlorhexidine, hydrogen peroxide, citric acid, or tetracycline paste. All medicaments and instruments are used for the purpose of "decontaminating" the implant surface. Multiple studies have shown that various approaches can yield a bacteria free surface [4]. After decontamination, various bone grafting materials are placed in contact with the implant (Fig. 11.8). The bone can be mixed with biologic materials such as enamel matrix derivatives (Emdogain-Straumann), bone morphogenetic protein (Infuse—Medtronic), or recombinant platelet-derived growth factor (Gem 21—Lynch Biologics) to stimulate bone regeneration. The bone can then be covered

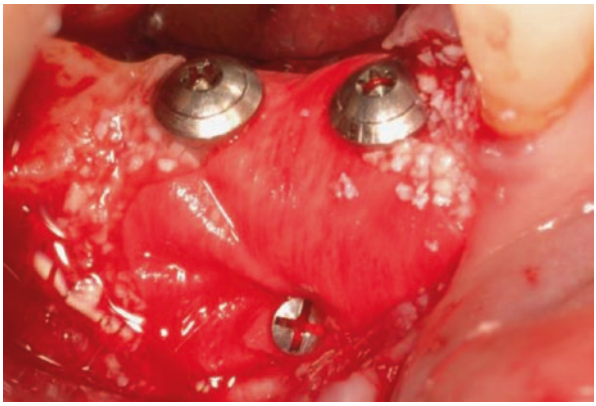

Fig. 11.9 A collagen membrane has been placed to stabilize the bone graft and cover the regenerative material. The membrane has been adapted around the implants and fixed in place apically with a retention screw

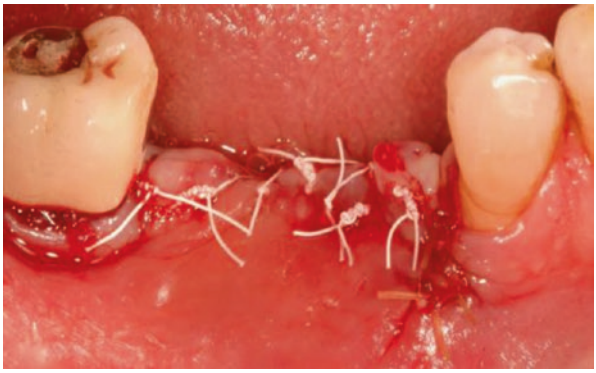

Fig. 11.10 The flap is closed in a coronal position as opposed to the apical position used with implantoplasty. The coronal position is aimed at both covering the regenerative materials (bone graft and membrane) as well as attempting to retain the gingival tissue at the pre-surgical level for esthetics and patient comfort

by a membrane to stabilize the bone graft (Fig. 11.9). The soft tissue is placed as close as possible to the pre-surgical level (Fig. 11.10). Some reports have shown moderate success with these approaches [5]. However, all mechanical methods and medicaments reported will remove the titanium oxide layer from the implant. The reformation of this layer after removal may not occur. Without this layer, it is questionable whether true re-osseointegration can occur.

11.7 Regenerative Therapy: Videoscope-Assisted Minimally Invasive Access

With the advent of a dental videoscope designed for use in periodontal surgery (Videoscope-Assisted Minimally Invasive surgery or VMIS) (Fig. 11.11), bone loss around teeth and implants can be accessed through much smaller incisions than in the past. Excellent results have been reported in regeneration around natural teeth using this approach [6]. These positive results are at least in part attributed to

Fig. 11.11 Dental videoscope (MicroSight, Q-Optics) used for videoscope assisted minimally invasive surgery on natural teeth and implants

maintaining the blood supply to the bone and soft tissue. Using small incisions around implants should, in theory, yield the same advantage as minimally invasive, regenerative treatment of teeth. When the VMIS approach is used to treat implants, a small flap of 4–6 mm is made only in the area of bone loss (Fig. 11.12). The tissue is slightly retracted using split thickness incisions so that a small retractor that is part of the videoscope can be inserted into the surgical site. This gives good visualization of areas of bone loss without large incisions (Fig. 11.13). At this point it is recommended that a thin section of tissue, usually 1–1.5 mm thick, be removed (Fig. 11.14). This is done to remove any titanium corrosion particles or cement particles that may have become embedded in the soft tissue. In this manner, a "fresh" tissue margin is placed over the bone graft and implant. The section of tissue removed routinely contains microscopic fragments of foreign material such as cement or titanium that are surrounded by inflammatory cells. These foreign particles are centers of inflammation, which may contribute to the failure of regenerative therapy. No scaling or harsh medicaments of any kind are used on the exposed roughened implant surface. Instead, after the granulation tissue is carefully removed, the exposed roughened implant surface is gently burnished with gauze soaked in a sterile saline solution (Fig. 11.15). This has been shown to remove most bacteria and to do less damage to the titanium oxide layer than more acidic medicaments [7]. The defect is typically grafted with human freeze-dried bone mixed with enamel matrix derivatives (Fig. 11.15). If human bone is not available, animal-derived bone can be used. With this minimally invasive approach, no membrane is necessary because the structural integrity and blood supply of the soft tissue have been maintained and will stabilize the bone graft. The videoscope-assisted minimally invasive approach is our preferred method for bone regeneration around implants.

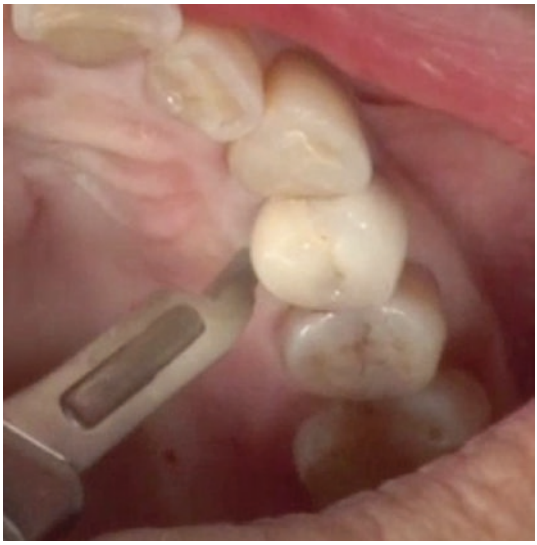

Fig. 11.12 A sulcular incision is made around the implant in the area of bone loss. A split thickness incision is extended to the line angles of the adjacent teeth

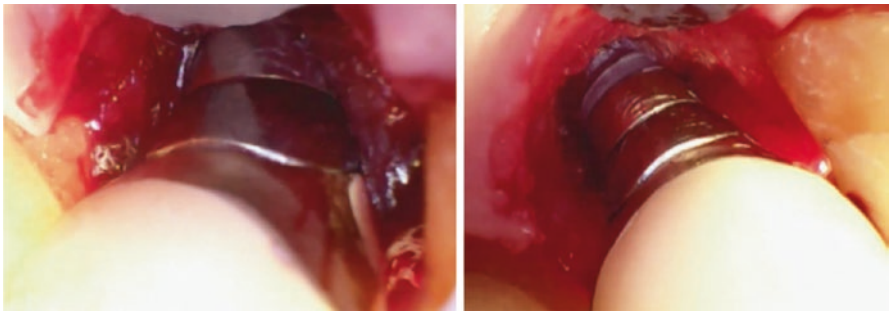

Fig. 11.13 (**a**) Initial videoscope view of the implant shown in Fig. 11.12. Note the excess cement at the right crown margin. This is removed with hand instruments. Ultrasonic instrumentation is avoided. (**b**) View of the implant after removal of cement and granulation tissue. Note the bone loss on the palatal aspect of the implant

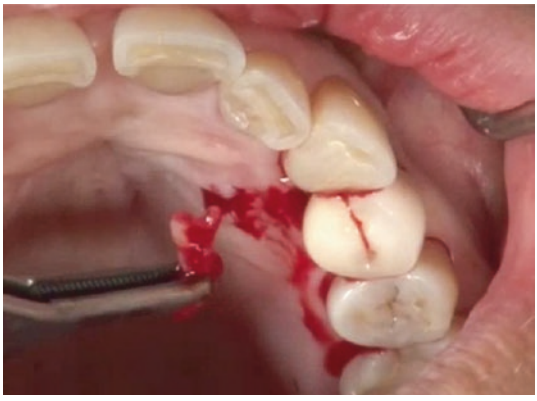

Fig. 11.14 A thin section of tissue is removed from the area immediately adjacent to the implant bone loss. This tissue routinely contains embedded foreign material, such as cement and/or titanium particles, surrounded by inflammatory cells

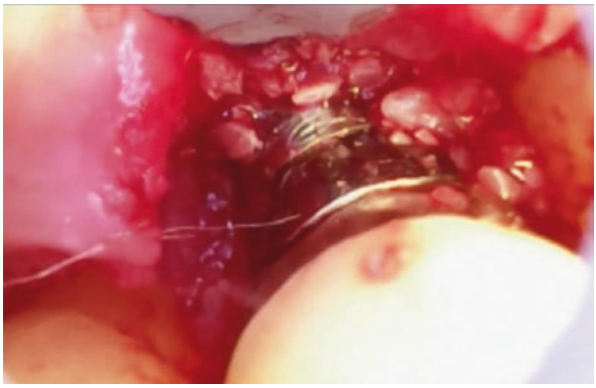

Fig. 11.15 Human freeze-dried bone mixed with enamel matrix derivatives (Emdogain, Straumann USA) is placed in the area of bone loss around the implant and the tissue is sutured closed with simple vertical mattress sutures in the papilla areas

11.8 How Should You Treat a Failing Implant?

A basic question facing the treating clinician is whether to maintain an implant exhibiting bone loss for as long as possible with the almost assured outcome that it will eventually be lost, or should you perform surgical treatment in an attempt to regrow bone and re-osseointegrate the implant. With the exception of the removal of excess cement, there is not currently a universally accepted answer. We know that the removal of excess cement often seems to stop or reverse bone loss around an implant and that this is best done surgically. It is recommended that the diagnosis and treatment of excess cement be pursued vigorously. Surgical permanent exposure of the implant with or without implantoplasty is relatively predictable but the patient must be fully informed of the unaesthetic and often difficult-to-clean outcome. The decision to attempt regeneration of lost bone and re-osseointegration is less obvious and should be decided on a case-by-case basis with the patient being fully informed of a potentially negative outcome.

11.9 Titanium Oxide Layer: Does It Spontaneously Reform?

In the regenerative surgical approaches described, the importance of the titanium oxide layer on the implant has been mentioned. It appears that the presence of titanium oxide is necessary for osseointegration [8]. It is also apparent that vigorous cleaning of the implant surface with mechanical or chemical treatment will remove the titanium oxide layer [7]. A yet unanswered question is whether the oxide layer will spontaneously reform in a clinical situation. Titanium oxide forms on titanium alloys when they are exposed to oxygen in controlled in vitro (laboratory) conditions. Clearly this might be possible in a clinical situation when the implant is cleaned and then exposed to atmospheric oxygen and/or water. However, there is some question that spontaneous regeneration (repassification) of the titanium oxide layer will occur during clinical treatment. At this time, the debate is ongoing. If it is questionable that the titanium oxide layer will reform during clinical procedures

then, based on this, great efforts should be made to maintain the titanium oxide layer that still exists on the implant. This question is a major one in determining if the various, relatively harsh methods recommended by some authors to "decontaminate" the implant are advisable or if the implant should be treated with great gentleness. We are of the opinion that the remaining titanium oxide layer should be retained to the greatest extent possible. Based on this, we currently recommend against the use of mechanical or ultrasonic debridement of the implant surface and against the use of strong disinfection solutions (e.g., citric acid and tetracycline). Time and further research will be necessary to answer this question.

11.10 Summary

When bone loss has occurred, advanced treatment is necessary. Multiple rounds of "conservative" treatments such as debridement or antibiotic therapy have been shown to be ineffective. For surgical treatment a decision must be made whether to use a regenerative or non-regenerative approach.

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Future Directions

12

Stephen Harrel

Key Points

- Near term improvements of implants will likely be accomplished by modifications of the surface of today's titanium implants.
- Research into ceramic implants is underway but the history of fractures in past ceramic implants makes their future questionable.
- Until the exact nature of "osseointegration" is clarified, it is unlikely that the prevention and treatment of peri-implant diseases will become predictable and successful.
- A structurally supported "biologic" implant is the most likely long-term future for implant improvement.

12.1 Near Term Improvements

In the short term we will likely see continued improvements of titanium implants that are similar to the implants currently in routine use. This means that the most frequently used implant will probably remain some form of machined titanium screw with various surface modifications that will osseointegrate with the bone. The improvements to implants will likely be incremental rather than a major shift in implant design. These incremental changes may take the form of changes to the surface of the implant with the goal of more rapid osseointegration and the ability to place a prosthesis sooner. The changes that are currently discussed are usually surface coatings such as antibacterial substances, changes in the roughened surface of the implant via laser etching, and a myriad of other possible changes. A recent review looked at possible approaches for modifying implant surfaces currently being explored [1].

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12.2 Need for Clarification of the Failure of Osseointegration

While some of the implant surface changes currently being explored will undoubtedly improve the functionality and ease of use of implants, until the actual mechanism for the failure of osseointegration is clarified, it is unlikely that there will be a marked reduction in implant failure from peri-implant disease. Currently the nature of osseointegration is controversial. Branemark et al. felt that there was a mechanical lock between the implant and the bony surface [2]. A more recent theory that is being considered views osseointegration as a type of foreign body response where the bone "walls off" the titanium surface so that the body can tolerate its presence [3]. Until the nature of osseointegration is clarified it is unlikely that there will be a marked improvement in preventing or treating failing implants. There is some indication that the induction of peri-implantitis is associated with corrosion of the titanium implant surface, which in turn breaks down the balance of the "foreign body" response. While this potential mechanism is unproven, there is a growing sentiment that titanium is not the ideal material for an implant.

12.3 Long-Term Improvements

There is little question that in the future the dental implant will be fabricated from a material other than titanium. There is current research on implants fabricated from zirconium. Historically, implants with ceramic surfaces such as vitreous carbon and hydroxyapatite have been well tolerated by the bone and tend to rapidly become clinically stable [4]. However, to date ceramic implants of all types have suffered from a high incidence of mechanical failure due to fracture. While it has not been studied in detail, it appears that zirconium implants may have this same failing. The authors feel that it is questionable that a ceramic will be the material of future implants.

The possibility of growing a new tooth in the laboratory using the patient's own stem cells is often held out as the long-term answer for the replacement of teeth. However, there are many factors beyond mechanical stability and biocompatibility that stand in the way of making this approach a clinically viable option. The human tooth is made up of multiple tissues that are nourished by an internal blood supply that will be extremely difficult to reproduce in a laboratory. Beyond these problems is the anatomy of human teeth, which have complex forms varying widely from anterior teeth to molars. While the potential for placing some form of tooth bud in an area of missing teeth that will eventually form a new tooth similar to the tooth that was lost maybe a possibility in the future, current technology is far from obtaining this goal.

In the authors' opinion, a more likely interim "biologic" implant will be a man-made scaffolding, possibly printed to fit the specific anatomic and structural needs of the patient, on which some form of cell structure from the patient is grown in the laboratory. The envisioned implant will then be inserted into a prepared opening in the patient's bone, similar to what is done for today's titanium implants, but the

bond between the implanted structure and the bone will be a biologic bonding. While this approach is only a vision at this point, a "biologic" implant with structural integrity seems an achievable possibility. Hopefully we can move beyond titanium implants to a more biologically based implant in the foreseeable future. Just as today's less than perfect but highly functional titanium implant was considered an unobtainable dream 60 years ago, the next major improvement in implant/tooth replacement is difficult for us to foresee today. Nonetheless, there is little question that a radically new approach will occur and it will be a major improvement in compatibility and functionality for dentistry and our patients.

12.4 Summary

The future of implant technology is unknown. Modification of the titanium surface will probably occur in the near term but until the nature of osseointegration is better understood, it is unlikely that an ideal implant surface will be manufactured.

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