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Examination and Diagnosis

Clinical Cases in Implant Dentistry, First Edition. Edited by Nadeem Karimbux and Hans-Peter Weber.

Case 1

Clinical Examination

CASE STORY

A 39-year-old Caucasian male who had just moved in from another city presented to our clinic with a chief complaint of "I lost my lower molar tooth and I need a fixed replacement." Five months before this visit the patient had acute pain on mastication in tooth #30. Periodontal examination revealed a localized 7 mm pocket depth on the distal of tooth #30. The Slooth test was positive and there was severe pain on percussion of the lingual cusps. This led his previous dentist to suspect vertical root fracture of tooth #30. Exploratory flap surgery was performed, which revealed a fracture extending all the way to the middle of the root. The tooth was extracted in the same visit and the socket was grafted with bone allografts and covered with resorbable collagen membrane. When he presented to our clinic, it was 5 months since the time of extraction and ridge preservation. The patient reported that he was getting regular dental care, including periodontal maintenance, from his previous dentist.

LEARNING GOALS AND OBJECTIVES

- To be able to understand the necessary elements in the examination and documentation portion of dental implant therapy
- To be able to understand the several diagnostic tools available for comprehensive evaluation and implant treatment planning
- To understand the importance of systemic, periodontal, and esthetic evaluation in dental implant therapy

Medical History

The patient when presented was a well-controlled type II diabetic. His last glycated hemoglobin was 6.2, measured a month before his initial visit. He was taking metformin 1000 mg per day. Other than diabetes, the patient did not present with any other relevant medication condition, allergies, or any untoward incidents during his previous dental visits.

Review of Systems

- Vital signs
  - Blood pressure: 120/77 mmHg
  - Pulse rate: 76 beats/min (regular)
  - Respiration: 14 breaths/min

Social History

The patient did not smoke but he reported that he was a social consumer of alcohol.

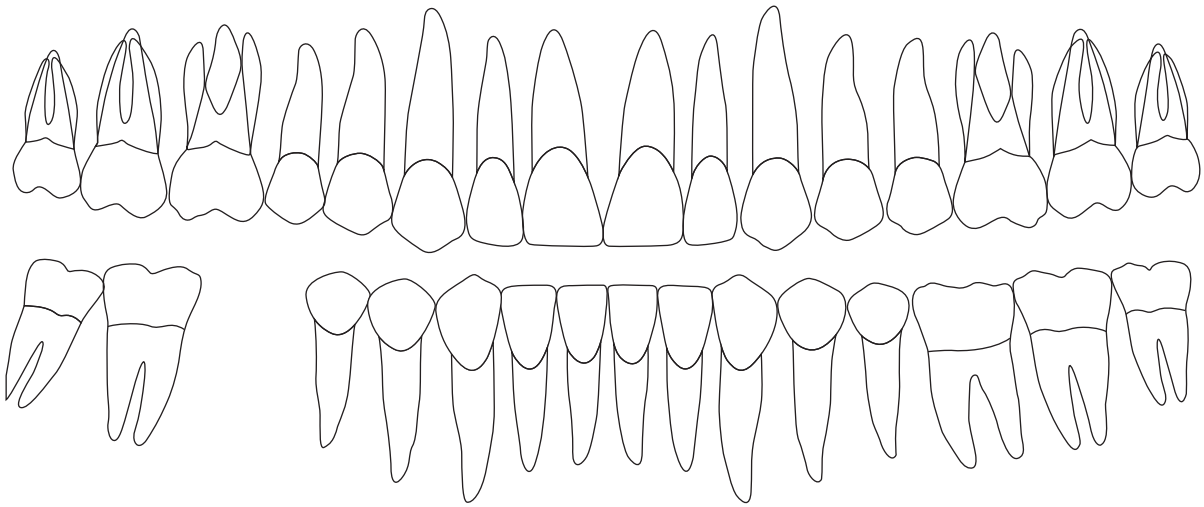
Extraoral Examination

No significant findings were noted. The patient had no masses or swelling, and the temporomandibular joint was within normal limits. No facial asymmetry was noted, and lymph nodes assessment yielded normal results.

Intraoral Examination

- Oral cancer screening was negative.
- Soft tissue exam, including his buccal mucosa, tongue, and floor of the mouth, was within normal limits.
- Periodontal examination revealed pocket depths in the range 2–3 mm (Figure 1).
- Color, contour, and consistency of gingiva was within normal limits, with localized erythema of marginal gingiva in the lingual of mandibular anterior areas.

Buccal	323	323	333	212	212	212	222	212	212	323	213	323	323	323	333	323
Palatal	333	323	333	222	323	213	212	212	212	212	223	212	313	323	333	323



Buccal	323	323	323	213	212	212	212	212	212	313	323	323	323	333	323
Lingual	323	323	333	322	323	213	212	212	212	212	323	312	323	323	323

Figure 1: Probing pocket depth measurements during the initial visit.

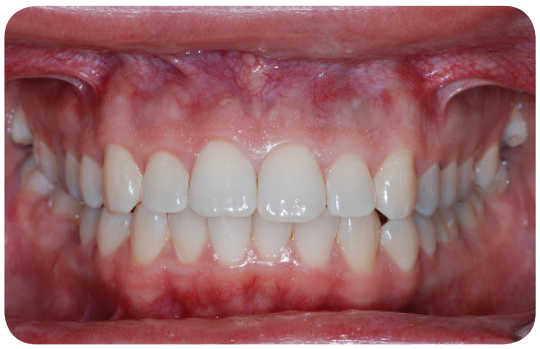


Figure 2: Initial presentation (facial view).

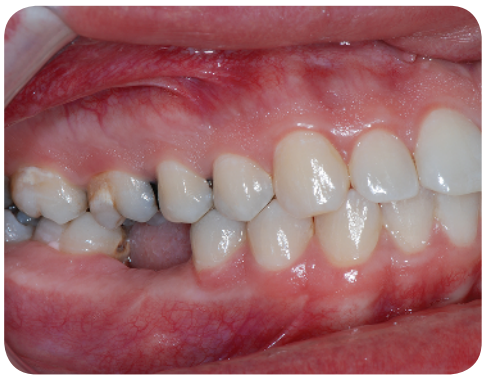


Figure 3: Initial presentation (right lateral view).

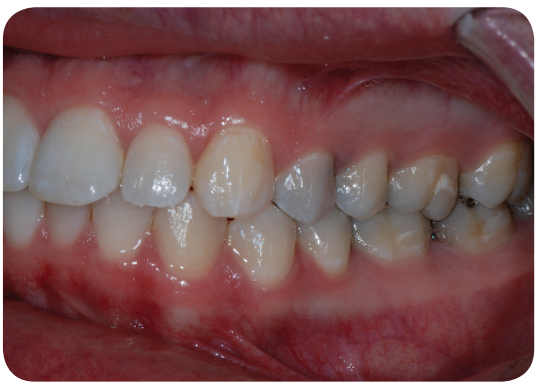


Figure 4: Initial presentation (left lateral view).

- Oral hygiene was good when he presented to the clinic (Figures 2, 3, and 4).
- Localized areas of dental plaque-induced gingival inflammation were noted.
- Slight supragingival calculus was noted in the mandibular lingual areas.
- Dental caries, both primary and recurrent, was noted in a few teeth.
- The ridge in the site #30 healed adequately, which revealed a slight buccal deficiency (Figure 5).

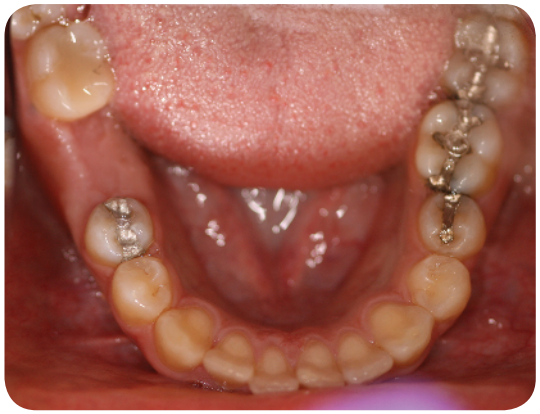


Figure 5: Initial presentation (occlusal view).

- On palpation, the ridge width was found to be adequate to place a standard diameter implant (to replace the molar tooth), without the need for additional bone grafting.
- No exaggerated lingual concavity was noted in the area.
- Normal thickness and width of keratinized mucosa was noted (Figure 3).
- No occlusal disharmony was noted, and there was adequate mesio-distal and apico-coronal space for the future implant crown (Figure 3).

Occlusion

There were no occlusal discrepancies or interferences noted (Figures 2, 3, and 4).

Radiographic Examination

A full mouth radiographic series was ordered. (See Figure 6 for patient's periapical radiograph of the area of interest before extraction of #30 and after extraction and ridge preservation.) The postextraction radiograph revealed radiographic bone fill of the #30 socket. The crestal bone level was well maintained. Normal bone levels in the adjacent teeth were noted. The inferior alveolar canal was not visible in any of the three radiographs.

Diagnosis

American Academy of Periodontology diagnosis of plaque-induced gingivitis with acquired mucogingival deformities and conditions on edentulous ridges was made.

Treatment Plan

The treatment plan for this patient consisted of disease control therapy that included oral prophylaxis and oral hygiene instructions to address gingival inflammation. This was followed by implant placement. After an adequate time for osseointegration (4 months), the implant was restored.

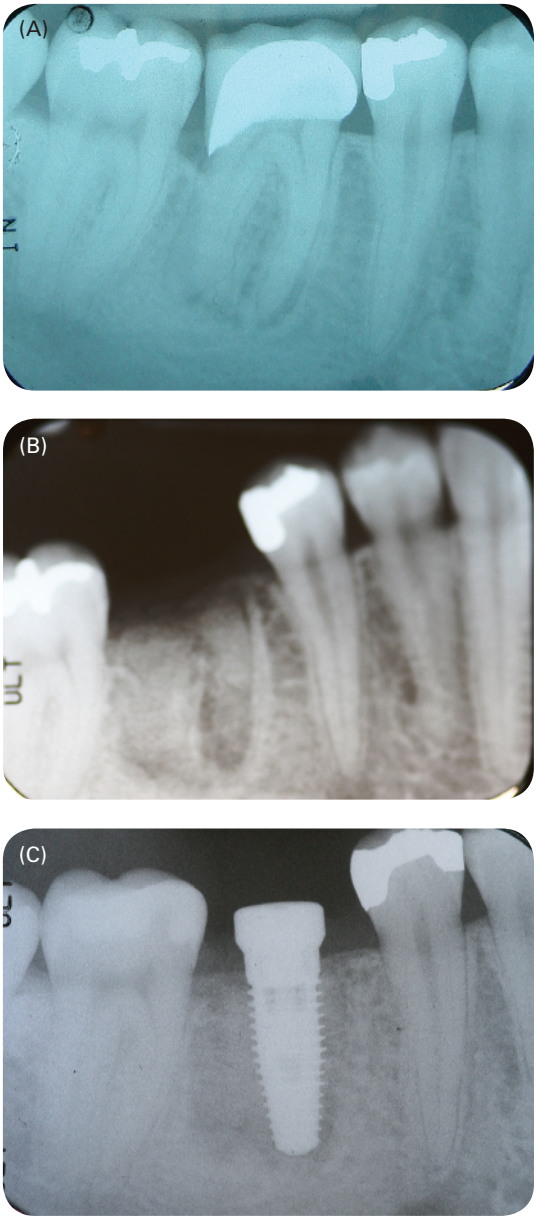


Figure 6: Periapical radiographs: (A) pre-extraction; (B) postextraction; (C) postimplant placement.

Examination and Documental Visit

The patient when presented to our clinic had already lost tooth #30, which had been extracted 5 months previously. The healing at the extraction site was found to be satisfactory. Systemically, the patient was a diabetic but with good glycemic control and was a nonsmoker. Periodontal examination revealed healthy periodontium with localized areas of mild gingivitis. His part dental history revealed that he was a compliant patient and was on a regular dental maintenance

schedule. Occlusal analysis revealed no occlusal disharmonies. These factors together made him a good candidate for dental implant therapy.

The site-specific clinical and radiographic evaluation revealed enough bucco-lingual width and mesiodistal and apico-coronal space for both the placement and the restoration of the implant. The inferior alveolar canal was not in the vicinity of the planned implant site. For these reasons, additional imaging analysis such as cone beam computed tomography (CBCT) was not planned. Impressions were taken during this initial visit that were utilized for doing diagnostic wax-up and for making a surgical guide. Extraoral and intraoral clinical photographs were taken during this visit for patient education and communication with the restoring dentist. Once the treatment plan was finalized, the patient was educated about the dental implant and the treatment sequence. This was followed by implant placement on a separate day using a surgical guide and a drilling sequence recommended by the implant manufacturer.

Self-Study Questions

(Answers located at the end of the case)

A. Why is systemic evaluation important in a dental implant patient?

B. Is the success rate of dental implants different in smoker versus nonsmoker?

C. How important is periodontal evaluation before planning for dental implants?

D. What are the site-specific assessments that need to be done prior to placing implants?

E. What are the components of esthetic evaluation for planning implants in the esthetic zone?

F. What are the anatomical landmarks that have to be examined carefully that may influence treatment execution?

G. What are the presurgical adjunctive evaluations required on a case-by-case basis?

H. How are ridge deformities classified?

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Answers to Self-Study Questions

A. There are several factors that influence the success rate of dental implants. Systemic factors are one among them and have a strong influence in the outcome of dental implants. Any systemic condition that has the influence to alter the bone turnover or wound healing process has to be carefully considered. It is clear from a well-conducted recent systematic review that smoking and radiotherapy (before or after implant placement) are associated with a higher (35% and 70% respectively) risk of implant failure [1]. With regard to other medical conditions, such as diabetes, it is becoming clearer that poor glycemic control is not an absolute contraindication for implant therapy provided that appropriate accommodation for delays in implant integration are considered [2]. Other commonly encountered systemic conditions that may modify the treatment plan include uncontrolled hypertension, intake of anticoagulants, patients on bisphosphonate therapy, or patients with psychiatric conditions. In select cases, getting clearance from the patient's physician is required. Therefore, it is extremely important that a thorough systemic evaluation be completed prior to planning for dental implants.

B. It has been shown that smoking affects periodontium by more than one mechanism [3]. Smoking was shown to negatively influence the oral microbial profile, suppress the immune system, and alter the microvascular environment, leading to disrupted healing [3]. Smokers have a two times higher risk for dental implant failure than nonsmokers do [1]. Apart from the lower success rate of implants in smokers, the incidence of peri-implantitis (a condition synonymous with periodontitis around natural tooth) is also shown to be high in smokers compared with nonsmokers [3,4]. Though smoking is not an absolute contraindication for dental implant therapy, explaining the higher risk for implant failure to the patients who are current smokers is the responsibility of the clinician.

C. Doing a thorough periodontal examination prior to implant therapy is as important as doing a systemic evaluation of the patient as this allows the clinician to obtain information on the patient's current periodontal disease status, oral hygiene status, and mucogingival parameters, such as the level of frenal attachments, width of keratinized mucosa, and vestibular depth. A moderate level of evidence suggests that patients with a history of periodontitis (especially the aggressive form of the disease) are at a higher risk for implant failure and marginal bone loss [5]. Poor oral hygiene is considered to be another important risk factor for dental implant failure [6]. Certain mucogingival conditions, such as low vestibule or high frenal attachments, may necessitate a soft tissue procedure in addition to implant placement. There is emerging evidence that lack of keratinized mucosa around dental implants is associated with more plaque buildup, inflammation, and mucosal recession [7]. Therefore, a thorough periodontal examination will guide the clinician to modify the treatment approach based on the periodontal findings.

D. For placing implants of standard diameter and length, having adequate bone volume both buccopalatally/-lingually and apico-coronally is a prerequisite. Therefore, site-specific examination, including evaluating for height and width of the bone, should be performed. This is accomplished by digital palpation of the area and by imaging techniques (described in question G). As a general rule, for a 4 mm diameter implant, at the level of the bone crest there should be at least 7 mm of mesiodistal space and buccolingual bone thickness to safely place the implant without encroaching on adjacent anatomical structures or without encountering bony dehiscence. It is a general guideline that there should be at least 1.5 mm distance between the implant and the adjacent tooth and 3 mm space between two implants placed adjacently. It is also important to make sure that there is sufficient distance from the proposed implant platform to the opposing teeth for restoring the implant with proper sized abutment and crown.

E. The esthetic analysis of an implant patient should include the following elements [8]:
- patient's smile line (high, medium, and low) and course of gingival line assessment;
- gingival phenotype (thick or thin) assessment;
- examination of tooth size and space distribution;
- examination of the shape of anatomical tooth crowns;
- examination of the length to width ratio of clinical crowns;
- examination of the hard and soft tissue anatomy of the site;
- interproximal bone heights (from radiographs);
- occlusal assessment (overjet and overbite).

F. In the maxilla, if the proposed implant site is in close vicinity to maxillary sinuses, nasal cavities, and the nasopalatine canal, those sites should be carefully evaluated to avoid encroaching on these structures while placing the implant. In the mandible, knowing the buccolingual and apico-coronal location of the inferior alveolar canal within the bony housing and the extent of lingual concavity of the mandible are important. This is usually accomplished by taking a CBCT of the area of interest. It is a general rule to maintain a safety distance of at least 2 mm between the implant and inferior alveolar canal (to account for radiographic distortions). In some instances, neurovascular bundles can be seen exiting lingual of the anterior mandible near the midline. Any trauma to these vessels may lead to severe hemorrhage in the sublingual area that can be life threatening.

G. Apart from a clinical oral examination that includes periodontal evaluation, in select cases adjunctive diagnostic assessments such as imaging, diagnostic wax-up, and clinical photographs are required to aid in diagnosis and/or treatment planning. Imaging typically includes periapical radiographs, bitewing radiographs, panoramic radiographs, or CBCT. CBCT is more advantageous than radiographs as it gives three-dimensional information of the proposed treatment site. It also allows the clinician to accurately determine the proximity of vital anatomic structures [9]. Doing a diagnostic wax-up allows the clinician to determine the need for additional implant site preparation, help with patient education, and for making surgical guides [10]. Clinical photographs are useful diagnostic aids, especially in anterior esthetic cases to document the patient's smile and also to discuss the case with peers.

H. There are several classifications that exist to categorize ridge deformities, but the most commonly used one is the classification proposed by Seibert in 1983 [11]. This classification was originally proposed in the context of soft tissue augmentation, but it has been adapted and is widely used in the context of implant site preparation.

The three classes of ridge deformities according to Seibert are:
class I – buccolingual/-palatal resorption;
class II – apico-coronal resorption;
class III – combination of buccolingual/-palatal and apico-coronal resorption.

Case 2

Medical Considerations

CASE STORY

A 70-year-old Caucasian male presented with a chief complaint of "I am missing my back teeth and I have difficulty in eating normally." The patient lost teeth #2–#5, #12–#15, #18, #19, #26, and #28–#31 several years ago due to severe periodontal disease. The third molars were impacted and removed at a very young age. The patient had a maxillary and mandibular interim partial denture fabricated before proceeding with a fixed solution, which he was wearing irregularly (Figures 1 and 2). The patient visited his dentist regularly for uninterrupted dental care to maintain the remaining teeth and reported that he brushed twice per day and flossed at least once a day. He had two class V composite restorations in teeth #20 and #21 buccally and a composite restoration in the incisal edge of #8.

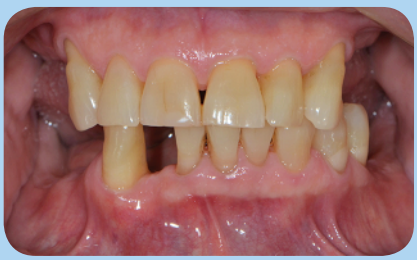

Figure 1: Pre-op presentation (facial view).

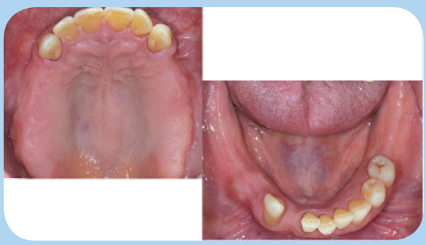

Figure 2: Pre-op presentation (occlusal view).

LEARNING GOALS AND OBJECTIVES

- To be able to understand which medical conditions may increase the risk of implant treatment failure or complications
- To understand the impact that medications might have on implant treatment
- To understand the absolute medical contraindications to dental implant treatment
- To understand that individualized medical control should be established prior to implant therapy

Medical History

At the time of treatment the patient presented with type II diabetes, controlled with medications (metformin). His last glycated hemoglobin (HbA1c) level was 6.7%, measured a few weeks before his initial exam. His fasting blood sugar was 120 mg/dL in the last physical exam. The patient was also hypertensive, controlled with medications (hydrochlorothiazide, doxazosin methylate, benazepril). In addition, he had hypercholesterolemia that was controlled with medication (simvastatin). Last, he suffered from a knee injury 4 years prior to his initial visit, which resulted in a blood clot formation that traveled to the lungs. The patient had surgery on his knee and has been taking Coumadin since then. The patient's last international normalized ratio (INR) was 2.3. The patient's body mass index was 33.9, which put him in the obese category. The patient denied having any known drug allergies.

Review of Systems

- Vital signs
  - Blood pressure: 135/70 mmHg
  - Pulse rate: 85 beats/min (regular)
  - Respiration: 16 breaths/min

Social History

The patient had no history of smoking or alcohol consumption at the time of treatment.

Extraoral Examination

There was no clinical pathology noted on extraoral examination. The patient had no masses or swelling. The temporomandibular joints were stable, functional, and comfortable. There was no facial asymmetry noted, and his lymph nodes were normal on palpation.

Intraoral Examination

- Oral cancer screening was negative.
- Soft tissue exam, including his tongue and floor of the mouth and fauces, showed no clinical pathology.
- Periodontal examination revealed pocket depths in the range 1–3 mm (Figure 3).
- Localized areas of slight gingival inflammation were noted.
- The color, size, shape, and consistency of the gingiva were normal. The keratinized tissue was firm and stippled.
- Generalized moderate with localized severe attachment loss and generalized recession were noted.
- An aberrant maxillary and mandibular bilateral labial frenum was also noted, which was extending also to the edentulous posterior areas.

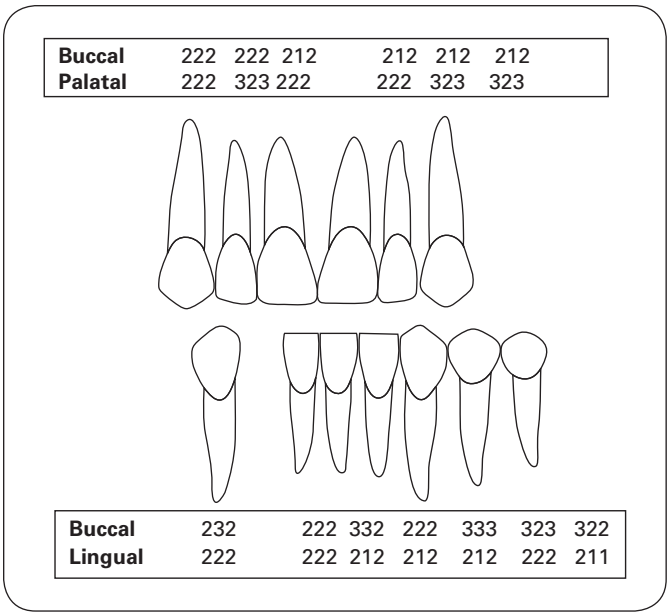

Figure 3: Periodontal chart. Probing pocket depth measurements during the initial visit.

- Localized plaque was found around the teeth, resulting in a plaque-free index of 90%.
- Evaluation of the alveolar ridge in the edentulous areas revealed both horizontal and vertical resorption of bone (Seibert class III).
- Class V composite restorations in teeth #20 and #21 buccally and a composite restoration in the incisal edge of #8 were also noted.

Occlusion

An overjet of 3.5 mm and overbite of 4 mm were noted. Angle's molar classification could not be determined due to loss of these teeth. Canine classification could only be determined on the left side, which was class II. Signs of secondary occlusal trauma (worn dentition, mobility, fremitus) were also noted. Functional analysis of the occlusion revealed anterior guidance during protrusion and canine guidance during lateral extrusion movements.

Radiographic Examination

A panoramic and a full mouth radiographic series was ordered (Figure 4). Radiographic examination revealed generalized moderate horizontal bone loss. There was also vertical loss of bone noted in the edentulous areas. A cone beam computed tomography scan was also ordered for better evaluation of the edentulous areas. The height of bone between the crestal bone and maxillary right sinus, in the position of the future implant, as indicated by the radiographic stent, was 4.95 mm and the height of bone between the crestal bone and maxillary left sinus was 8 mm. The height of bone between the

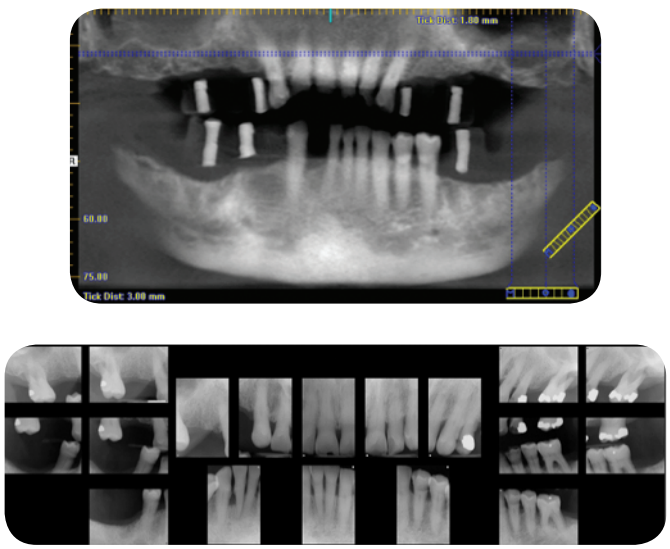

Figure 4: Panoramic and full mouth radiograph.

crestal bone and the inferior alveolar nerve canal was 12 mm bilaterally. The distance from the right mental foramen was 10 mm (Figure 5). The buccal–lingual width seemed adequate in all indicated positions for placement of dental implants.

A round, well-circumscribed radiopacity with well-defined borders was noted in the maxillary right sinus. The lesion occupied a big area of the right maxillary sinus space. Slight sinus membrane thickening was noted in the maxillary left sinus (Figure 5).

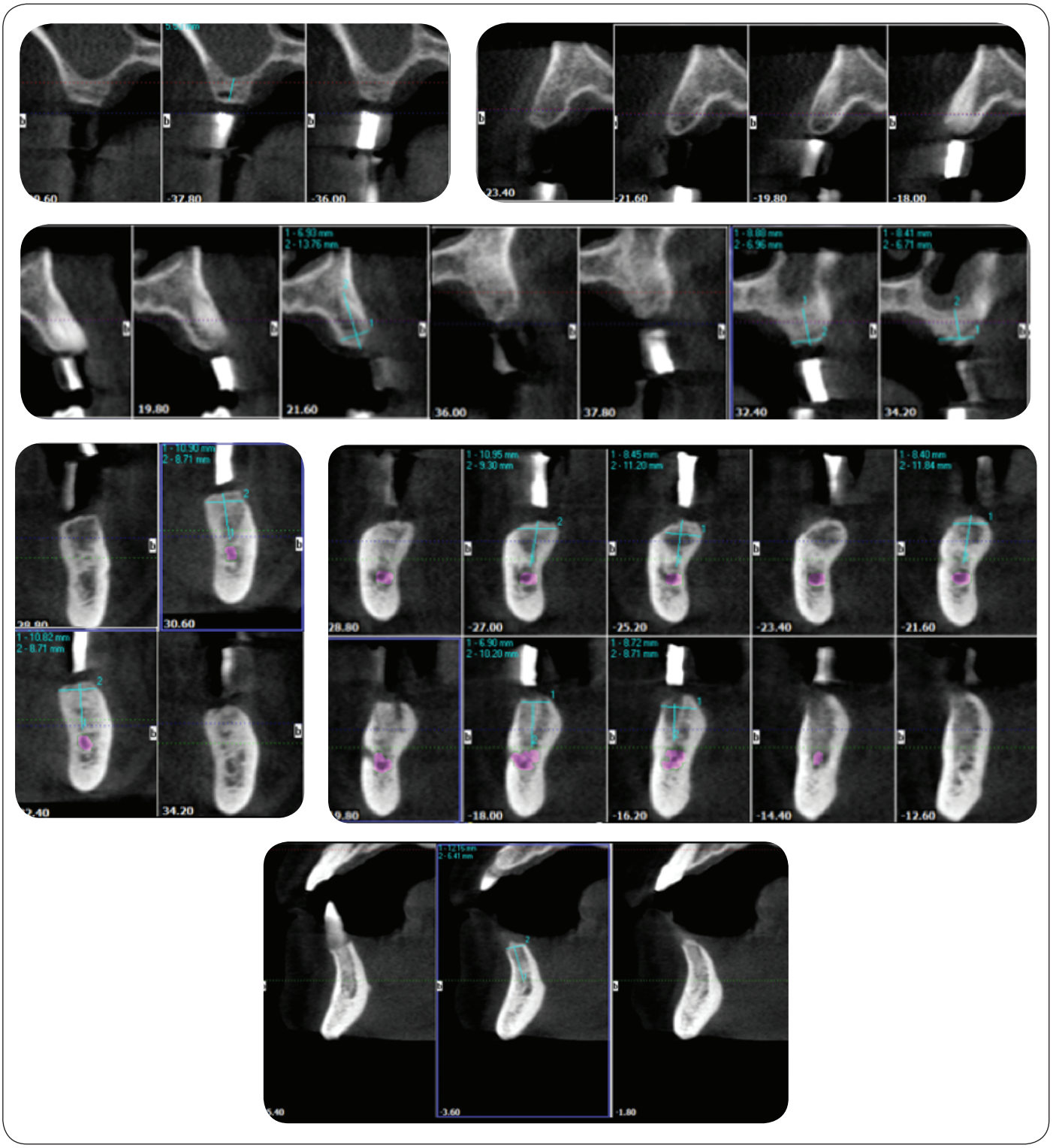

Figure 5: Cone beam computed tomography scan.

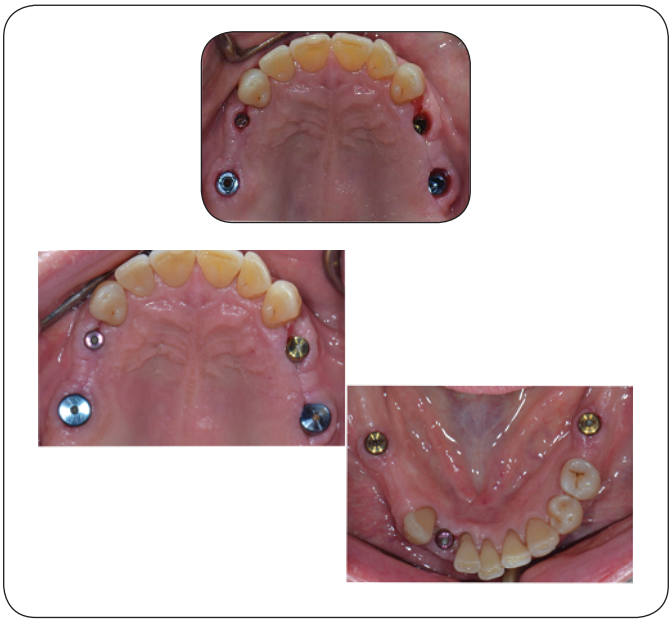

Figure 6: Implant placement.

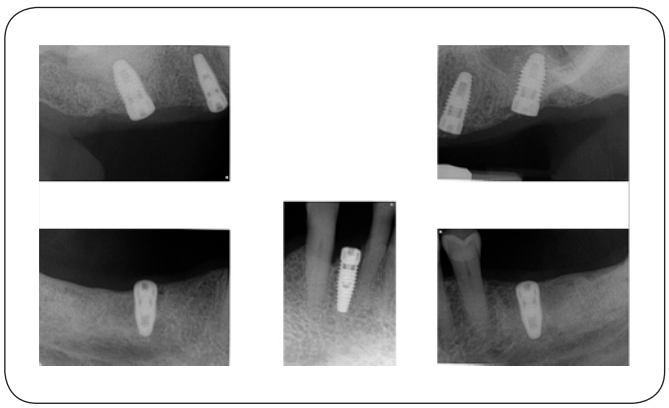

Figure 7: Implants placed.

Diagnosis

A diagnosis of generalized moderate and localized severe chronic periodontitis with mucogingival deformities and conditions around teeth (facial, lingual, and interproximal recession and aberrant frenum), mucogingival deformities and conditions on the edentulous ridges (horizontal and vertical ridge deficiency in all edentulous areas and aberrant frenum), and occlusal trauma (secondary) was made. Additional diagnosis of partial edentulism with Kennedy class I in the maxilla and Kennedy class I (mod 2) in the mandible was made.

Treatment Plan

Interdisciplinary consultation along with diagnostic casts and wax-up led to different treatment plan options. Financial limitations also played a role in the final decision. The treatment plan for this patient consisted of an initial phase therapy that included oral prophylaxis and oral hygiene instructions to address gingival inflammation. This was followed by implant placements #3 and #5 with external sinus elevation, implants #12 and #14 with internal sinus elevation, and implants in locations #19, #26, and #30 (Figures 6 and 7). After adequate time for osseointegration (6–8 months in the maxilla, 4 months in the mandible), the implants were restored.

Treatment

Prior to any treatment, primary care physician and ear, nose, and throat (ENT) consultations were obtained. The primary care physician recommended that the patient should stop warfarin treatment 5 days prior to surgery and start using Lovenox (low molecular weight heparin) until 24 h prior to surgery. The patient should restart warfarin and Lovenox 24 h after surgery until his INR ≥2.0, when Lovenox should be discontinued.

The ENT report stated that patient had a benign asymptomatic mucous retention cyst in the maxillary right sinus and a slight membrane thickening in the maxillary left sinus. Neither condition would interfere with the implant surgery or sinus elevation procedure. In the case of membrane perforation, though, the procedure should be stopped, no implants or bone grafts should be placed, and the patient should be referred to the ENT doctor for cyst removal and sinus treatment.

After the initial phase therapy, the patient presented for implant placement. Implant placement took place in three visits (Figures 6 and 7).

Implant placement and restoration will not be described in this chapter, since these topics will be addressed in later chapters.

Discussion

In this case, the primary concern was the patient's past and current medical history. The patient was being treated for several systemic diseased that he controlled with specific medication. These factors should be taken into consideration prior to any surgical implant treatment to minimize any possible complications and optimize implant therapy outcome.

In medically healthy patients, the success rates of some dental implant systems are reported to be between 90 and 95% at 10 years. Dental implants may fail, however, due to a lack of osseointegration during early

healing, or when in function due to breakage, or infection of the peri-implant tissues leading to loss of implant support. The long-term outcome of implant therapy can be affected by local factors or systemic diseases or other compromising factors. In fact, it has been suggested that some local and systemic factors could represent contraindications to dental implants treatment [1,2].

The impact of health risks on the outcome of implant therapy is unclear, since there are few if any randomized controlled trials evaluating health status as a risk indicator [1]. Certain conditions, such as uncontrolled diabetes, bleeding disorders, a weakened/suppressed immune system, or cognitive problems, which interfere with postoperative care, increase the risk of implant failure. There is still, however, a lack of high-quality substantiated evidence to confirm all the associations [1,2]. Therefore, proper patient selection is important to increase the likelihood of implant therapy success.

It is important to realize that the degree of disease control may be far more important than the nature of the systemic disorder itself, and individualized medical management should be obtained prior to implant therapy, since in many of these patients the quality of life and functional benefits of dental implants may outweigh any risks [1]. In patients with systemic conditions, it is critical to outweigh the cost–benefit considerations with the patient's quality of life and life expectancy, and it is very important to undertake the implant surgical procedures with strict asepsis, minimal trauma, and avoiding stress and excessive hemorrhage. Equally essential in these patients is to ensure proper maintenance therapy with optimal standards of oral hygiene, without smoking, and with avoidance of any other risk factors that may affect the outcome of dental implants [1,2].

Self-Study Questions

(Answers located at the end of the case)

A. What is the impact of systemic diseases and/or medications used to treat systemic diseases on the success of implant therapy?

B. What are the contraindications of dental implants in medically compromised patients?

C. Which medical/systemic diseases have a *high* risk associated with implant success and what is the level of association with lack of osseointegration, peri-implant bone loss, and/or implant failure?

D. Which medical/systemic diseases have a *significant* risk associated with implant success and what is the level of association with lack of osseointegration, peri-implant bone loss, and/or implant failure?

E. Which medical/systemic diseases have a *relative* risk associated with implant success and what is the level of association with lack of osseointegration, peri-implant bone loss, and/or implant failure?

F. Which other medical/systemic diseases have an *increased* risk associated with implant success and what is the level of association with lack of osseointegration, peri-implant bone loss, and/or implant failure?

G. Which medical/systemic conditions are considered to be absolute contraindications for implant therapy?

H. Which medication may affect osseointegration?

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Answers to Self-Study Questions

A. The achievement of osseointegration is a biological concept already adopted in implant dentistry [3]. The long-term maintenance of bone around an osseointegrated implant is paramount to clinical success, and peri-implant bone remodeling is important to long-term survival rates [4]. It is believed that several factors may affect peri-implant bone resorption: local, surgical, implant, post-restorative, and patient-related risk factors, which include systemic diseases, medications used to treat systemic diseases, genetic traits, chronic drug or alcohol consumption, and smoking status [4]. The widely accepted theory for physiologic bone loss is related to the formation of a peri-implant biologic distance and should be understood as a physiologic phenomenon. This is shaped by bone resorption that occurs to accommodate soft tissue structures, with a vertical extension measuring from 1.5 to 2 mm in the apical direction [5–9]. Later or additional bone loss is characterized by gradual

loss of marginal bone after osseointegration. Different levels of bone loss have been reported as acceptable [10]. One study reported that a gradual bone loss of 0.2 mm after the first year in function and ≤0.2 mm per year in subsequent years can be considered successful [11]. Another study tolerated 2 mm bone loss between the installation time and 5 years later [12]. However, another more recent study reported about 3 mm loss of bone apical to the abutment–implant interface after 5–20 years in function [13]. Although these studies [11–13] consider as acceptable bone loss up to 2 mm over the years, there is no consensus regarding this statement. Moreover, the relative importance of local and systemic factors to the development of alveolar bone loss around osseointegrated dental implants remains controversial [10].

The impact of health risks on the outcome of implant therapy is unclear, since there are a few randomized controlled trials evaluating health status as a risk indicator. In principle, only patients with an American Society of Anesthesiologists (ASA) physical status grade I (P1: a normal healthy patient) or II (P2: a patient with mild systemic disease) should qualify for an elective surgical procedure, such as dental implant placement, and the patient's surgical risks should be weighed against the potential benefits offered by the dental implants [1,14–16]. For very severe and acute medical problems (ASA physical status categories P3 to P6) calculating the risk of failure in affected subjects seems impossible because patients with such conditions hardly ever receive dental implants. A recent publication stated that elective dental treatment of patients classified as P4 or higher should ideally be postponed until the patient's medical condition has stabilized and improved to at least P3 [17].

Systemic diseases may affect oral tissues by increasing their susceptibility to other diseases or by interfering with healing. In addition, systemic conditions may be treated with medications or other therapies that potentially affect dental implants and the tissues carrying them [3]. There are different studies, mainly retrospective ones, that deal with the impact of medical/systemic factors and/or medications on the outcome osseointegrated implants, but the extrapolation of their results should be cautious, since it is not possible to collect much information from such studies if not much insight into the occurrence and nature of systemic disease is given [18,19]. Several authors have also identified diseases for which dental implants are not recommended, or are at least questionable, but it often remains unclear what type of evidence these statements are based on [20–23]. Therefore, it still remains a debated question whether some systemic factors/medications compromise the achievement of an intimate bone to implant interface and what their role is during the healing time [18,19].

B. A medically compromised patient can be described as one who has a distinctive physical or mental feature regarding people of the same age. In these sorts of patients there is a higher risk of interactions between their disease and the implant surgery, implying a higher medical risk [2]. A thorough and exhaustive medical examination will help not only to determine the specific measures that must be adopted for a medically compromised patient but also to carry out the estimation of the patient's risk. The system proposed by the ASA [16] to the dental patient is commonly used to define the patient's risk [23]. These classifications and the medical history allow the dentist to identify the systemic disease and the success rate expected in the medically compromised patient that is going to be rehabilitated with dental implants [2]. It seems like the medical control of the disease is more important than the disease itself. This evidence proves the need for carrying out personalized medical examinations [1].

To achieve and maintain successful osseointegration over time, which is the goal and outcome of successful implant treatment, indications and contraindications must be carefully balanced, Therefore, proper patient selection is the key issue in treatment planning [20]. Contraindications can be divided into local and systemic/medical. In a recent Consensus Conference [24] it was proposed to subdivide the general/medical risk factors into two groups:

- *Group 1 (very high risk).* Patient with serious systemic diseases (rheumatoid arthritis, osteomalacia, osteogenesis imperfecta), immunocompromised patients (HIV, immunosuppressive medications), drug

abusers (alcohol), and noncompliant patients (psychological and mental disorders).

- *Group 2 (significant risk).* Patients with irradiated bone (radiotherapy), severe diabetes (especially type 1), bleeding disorders/severe bleeding tendency (hemorrhagic diathesis, drug-induced anticoagulation), and heavy smoking habit.

Other authors have recommended certain patient groups or conditions as relative contraindications for dental implants [25]:

- children and adolescents
- epileptic patients
- severe bleeding tendency
- endocarditis risk
- osteoradionecrosis risk
- myocardial infarction risk.

Other reported relative contraindications include adolescence, ageing, osteoporosis, smoking, diabetes, positive interleukin-1 genotype, HIV positivity, cardiovascular disease, hypothyroidism, and Crohn's disease [22].

In more recent studies, the following diseases and conditions were examined for their increased risk for dental implant treatment failure: scleroderma, Sjögren syndrome, neuropsychiatric disorders/Parkinson disease, lichen ruber planus/oral lichen planus, HIV infection, ectodermal dysplasia, long-term immunosuppression after organ transplantation, cardiovascular disease, Crohn's disease, diabetes, osteoporosis, oral bisphosphonate medication, and use of radiotherapy for the treatment of oral squamous cell carcinoma [3,26].

Suggested absolute contraindications for implant placement (severe and acute medical conditions for which implant therapy has always been considered a contraindication) include the following: acute infections, severe bronchitis, emphysema, severe anemia, uncontrolled diabetes, uncontrolled hypertension, abnormal liver function, nephritis, severe psychiatric disease, conditions with severe risk of hemorrhage, endocarditis, recent myocardial infarction and cerebrovascular accident, transplant or valvular prosthesis surgery, profound immunosuppression, active treatment of malignancy, drug abuse, and intravenous bisphosphonate use [1,15,23]. There is, however, little or no evidence to support most of these conditions [1].

Generally, though, the evidence level of implant failures in the medically compromised patient is limited due to the low number of controlled randomized studies [2]. Therefore, different reviews have tried to evaluate certain disease categories as possible contraindications to implant therapy and their evidence on implant treatment complications/failures. The existing evidence has been generally drawn from a wide range of sources, ranging from case reports to controlled cohort investigations, including both human and animal studies [1].

The implant outcome assessment has varied from histological and radiographic outcomes, to objective and subjective determinations of implant and treatment failure [1].

Contraindications are mainly based on both the risk of medical complications related to implant surgery (e.g., hemorrhage risk in patients with bleeding disorders) and the rate of dental implant success in medically compromised patients (e.g., in patients with head and neck cancer receiving radiotherapy) [1].

The medical risk factors will be analyzed according to the different classification systems (high risk, significant risk, relative risk, and other medical conditions) described earlier.

C.

- *Rheumatoid arthritis.* There are some retrospective series on dental implants outcomes involving females suffering from autoimmune rheumatoid arthritis with or without concomitant connective tissue diseases, and the authors conclude that a high implant and prosthodontic success rate can be anticipated in rheumatoid arthritis patients, but peri-implant marginal bone resorption and bleeding are more pronounced in those with concomitant connective tissue diseases [27,28].
- *Osteomalacia.* This is a defective mineralization of the organic bone matrix (i.e., collagen). The disorder is usually associated with vitamin D deficiency and alimentary deficiencies. The vitamin D deficiency reduces the intestinal uptake and the mobilization of calcium from the bone and thus results in hypocalcemia. This leads to an increased parathyroid hormone secretion, which in turn increases the clearance of phosphorus by the kidneys. The decrease in the concentration

of phosphorus in the bone fluids prevents a normal mineralization process. The radiologic characteristics of bone in osteomalacia are a thinning of the cortices and a decreased density of the trabecular part [19]. No reports could be found on the clinical relevance of osteomalacia for the outcome of oral implants. It could be that some osteomalacia patients have been categorized as patients with "poor bone quality," category IV bone, which has been clearly associated with a higher failure rate [29,30].

- *Immunocompromised patients (HIV, immunosuppressive medication).* There have been some studies (mainly animal models) that have shown that cyclosporin impairs peri-implant bone healing and implant osseointegration [31]. However, many patients receiving organ transplantation (mainly liver and kidney) with long-term cyclosporin therapy have had successful dental implant therapy [32–35]. Similarly, no significant problems after dento-alveolar surgery have been reported in HIV-positive patients [36,37]. In a recently published case–control series of HIV-positive patients receiving different regimens of highly active antiretroviral therapy, after assessing peri-implant health, the authors concluded that dental implants may represent a reasonable treatment option in HIV-positive patients, regardless of CD4 cell count, viral load levels, and type of antiretroviral therapy [38]. It seems that dental implants are well tolerated and have predictable short-term outcomes for HIV-infected individuals, but published evidence is limited and the predictability of the long-term success remains unknown. It would seem wise though to proceed with implant therapy when CD4 rates are high and the patient is on antiretroviral therapy. In general, there is no evidence that immune incompetence is a contraindication to dental implant therapy, but medical advice should be obtained before considering dental implant therapy, and strict anti-infective measures should be enforced when treating these patients [1,3].
- *Drug abusers (alcohol).* There is no reliable evidence that alcoholism is a contraindication to implants, but patients that consume alcohol may be at increased risk of complications. Negative effects of alcohol intake on bone density and osseointegration have been demonstrated in animal models [39,40]. In humans, there is evidence of increased peri-implant marginal bone loss and dental failures in patients with high levels of alcohol consumption [41,42]. Generally, it is worth considering before placing implants to alcohol consumers that alcoholism (a) is often associated with tobacco smoking (which itself may be considered as contraindication to implant therapy), (b) impairs liver function and may cause bleeding problems, (c) may cause osteoporosis (another relative contraindication to implant placement), (d) may impair the immune response, and (e) may impair nutrition, especially folate (vitamin B9) and vitamin B in general [1].

D.

- *Radiotherapy.* This can significantly affect dental implant outcomes mainly during the healing period [43]. Radiotherapy may induce obliterating endarteritis, and hence can predispose to osteoradionecrosis of the jaw [1]. Some studies involving implants placed in adult patients who have received radiotherapy reported lower success rates [44], but there are also several clinical studies demonstrating that dental implants can osseointegrate and remain functionally stable in patients who had received radiotherapy [45]. Other authors have reported successful dental implant outcomes but occurrence of late complications, such as bone loss and mucosal recession, possibly due to altered saliva flow and increased bacterial colonization [46]. Several case–control studies have shown evidence of improved outcomes in patients with history of radiotherapy and dental implants with the addition of hyperbaric oxygen therapy mainly through reduction in the occurrence of osteoradionecrosis and failing implants [47]. However, in a recent systematic review the authors were unable to find any strong evidence to either support or contradict the use of hyperbaric oxygen therapy for improving implant outcome, concluding that the use of hyperbaric treatment in patients undergoing implant treatment does not seem to provide significant benefits [48,49]. Radiotherapy could be responsible for the reduction in the success rate of dental implants when it is administered in doses

exceeding 50 Gy, as has already been proven for extraoral implants [23]. An animal case–control study with irradiated maxilla and mandible (24–120 Gy) showed a decrease of implant stability quotient values long term in irradiated bone when compared with nonirradiated bone [50].

To increase implant success in irradiated head and neck cancer patients, the following precautions should be considered [47]:

1. Implant surgery is best carried out >21 days before radiotherapy.
2. Total radiation dose should be <66 Gy if the risks of osteoradionecrosis are to be minimized or <50 Gy to reduce osseointegration failure – avoiding implant site/portals.
3. Hyperbaric oxygen should be given if >50 Gy radiation is used.
4. No implant surgery should be carried out during radiotherapy.
5. No implant surgery should be carried out during mucositis.
6. Deferral of implant placement for 9 months after radiotherapy.
7. Use implant-supported prostheses without any mucosal contact and avoidance of immediate loading.
8. Ensure strict asepsis during surgical procedure.
9. Consideration of antimicrobial prophylaxis.

- *Diabetes mellitus.* This is a metabolic disorder resulting in hyperglycemia caused by a defect in insulin secretion, impaired glucose tolerance, or both. Diabetes is the most prevalent endocrine disease, comprising the third highest cause of disability and morbidity in the Western world [51]. HbA1c is a measure of long-term glucose control. Normal level is 4.0–6.0%; good balance is 6.0–7.5%, fair is 7.6–8.9%, and poor balance is 9.0–20.0% [51].

It is well established that diabetic patients are more prone to healing complications, with usually delayed wound healing [2]. There are two major types of diabetes. Type 1 (previously termed "insulin dependent") is caused by an autoimmune reaction destroying the beta cells of the pancreas, leading to insufficient production of insulin. Type 2 (previously termed "noninsulin dependent") is viewed as a resistance to insulin in combination with an incapability to produce additional compensatory insulin [3].

Metabolic changes produced by diabetes are associated with the synthesis of the osteoblastic matrix induced by insulin. Variation in the differentiation of osteoblastic cells and hormones that regulate calcium metabolism produce homeostasis in the mineral bone tissue, an alteration in the level of bone matrix required to produce mature osteocytes that enhance the osseointegration of dental implants [2]. Epidemiological case–control studies carried out in animals show a variation in the bone density surrounding the implant in samples of noncontrolled diabetic patients [52,53]. Most studies reviewed confirm these experimental results. In a 3-year retrospective study, a higher frequency of implant failure was shown in diabetic patients (7.8%) than in healthy patients (6.8%) [54].

These data are also confirmed in recent thorough reviews [3,26]. Some other recent publications produce different results in spite of insisting on the higher risk of failure in diabetic patients [51,55]. Most case series, cohort studies, and systematic reviews support that dental implants in diabetics with good metabolic control have similar success rates when compared with matched healthy controls [51,56–58]. However, impaired implant integration has been reported in relation to hyperglycemic conditions in diabetic patients [59]. In a recent systematic review the authors concluded that poorly controlled diabetes negatively affects implant osseointegration [60]. This fact is consistent with the known effects of hyperglycemic states on impaired immunity, microvascular complications, and/or osteoporosis [1]. Generally, there is no evidence that diabetes is a contraindication to dental implant therapy, but as HbA1c may represent an independent factor correlated with postoperative complications and due to the known effects of hyperglycemic states on healing, medical advice and strict glycemic control before and after dental therapy are recommended [61]. Antimicrobial cover using penicillin, amoxicillin, clindamycin, or metronidazole should be provided during the implant surgery [62]. These patients should also quit smoking, optimize oral hygiene measures, and use antiseptic mouth

rinses to prevent the occurrence of periodontal and peri-implant infections [1].

In the light of the results, the total contraindication to placing dental implants in diabetic patients because of their higher frequency of failure due to the risk of infection [51] has been modified. If controlled diabetics receive an antibiotic prophylaxis protocol and aseptic techniques with chlorhexidine gluconate 0.12% during implant placement the failure rates are similar to those of healthy patients [54,62].

- *Bleeding disorders/severe bleeding tendency (hemorrhagic diathesis, drug-induced anticoagulation).* Even though hemorrhage can be a relatively common complication in dental placement there is no reliable evidence to suggest that bleeding disorders are a contraindication to the placement of implants: even hemophiliacs have successfully been treated with dental implants [63]. Any oral surgical procedure may lead to hemorrhage and blood loss, and if this bleeding reaches the facial spaces of the neck it can endanger the airway [1]. In patients with bleeding disorders, hemorrhage associated with implant surgeries is more common and can be prolonged particularly with warfarin or acenocoumarol [64]. In these patients, the current recommendation is to undertake the implant surgical procedure without modifying the anticoagulation, provided the INR is less than 3 or 3.5 [64]. There is evidence that anticoagulated patients (INR 2–4) that have not discontinued their anticoagulant medication do not have a significantly higher risk of postoperative bleeding, and topical hemostatic agents are effective in preventing postoperative bleeding [65]. Oral anticoagulant discontinuation is therefore not recommended for dentoalveolar surgery, such as implant placement, provided that this does not involve autogenous bone grafts, extensive flaps, or osteotomy preparations extending outside the bony envelope [1,66]. The bleeding risk is also low in patients treated with heparin [67]. Generally, there is no evidence that any bleeding disorders are an absolute contraindication to dental implant surgery, although these patients may be at risk of prolonged hemorrhage and blood loss, and medical advice should be taken first, especially in congenital bleeding disorders [1]. The primary care physician may decide any medication alteration or "bridging" the patient with low molecular weight heparin prior to implant placement in order to keep the INR at levels suitable for surgical treatment. The practitioner should take into consideration that the risks of altering or discontinuing use of the antiplatelet medications – increased risk of thromboembolism – far outweigh the low risk of hemorrhage, and medical advice is necessary prior to any treatment [68].

E.

- *Osteoporosis.* This is a common metabolic condition characterized by generalized reduction in bone mass and density with no other bone abnormality and an increased risk and/or incidence of fracture [3]. The World Health Organization has established diagnostic criteria for osteoporosis based on bone density measurements determined by peripheral dual-energy radiographic absorptiometry. A diagnosis of osteoporosis is made when the bone mineral density level T is at least 2.5 standard deviations below that in the mean young population ($T \leq 2.5$) [69]. The major concern about osteoporosis with respect to implant placement is the possibility that the disease modifies bone quality, formation, or healing to an extent that osseointegration is compromised [23]. When evaluating whether dental implants in osteoporotic patients have a different long-term outcome, even though failure rates have been reportedly higher in animal models [70] and patients [71,72], a systematic review revealed no association between systemic bone mineral density (BMD) status, mandibular BMD status, bone quality, and implant loss, concluding that the use of dental implants in osteoporosis patients is not contraindicated [73]. Another study found no relation between osteoporosis and peri-implantitis [74], and even patients with severe osteoporosis have been successfully rehabilitated with dental implant-supported prostheses [22,75]. The authors in a recent study concluded that taking into consideration the existing evidence, osteoporosis alone does not affect implant success [23]. A recent review, though, showed a weak association between osteoporosis and the risk of

implant failure [3]. It is recommended, therefore, to thoroughly evaluate and accurately analyze the bone quality prior to implant placement. A further potential complication in osteoporotic patients is the possible effect on bone turnover at the dental implants interface of systemic antiresorptive medication and the risk of developing bisphosphonate-related osteonecrosis of the jaw (BRONJ) [1].

- *Crohn's disease.* This is an idiopathic chronic inflammatory disorder of the gastrointestinal tract that may also involve the oral cavity. The disease process is characterized by recurrent exacerbations and remissions [76]. Crohn's disease has also been suggested as a relative contraindication for dental implants. It is associated with nutritional and immune defects, and hence it may impair dental success [72]. However, the literature regarding the performance of dental implants in patients with Crohn's disease is scarce and with a very low level of evidence [3]. In different prospective and retrospective studies it was shown that implants placed in Crohn's disease patients integrated successfully, with limited early implant failures in patients with Crohn's disease [72,77,78]. Owing to limited evidence, a final conclusion cannot be drawn, but caution is indicated when implants are planned in such patients. The circulating antigen–antibody complexes in Crohn's disease may lead to autoimmune inflammatory processes in several parts of the body, including the bone-to-implant interface during the healing phase. Factors associated with the disease, such as medication or malnutrition, may also play a role in regard to implant placement [2].
- *Cardiovascular disease.* Five forms of cardiovascular disease (hypertension, atherosclerosis, vascular stenosis, coronary artery disease, and congestive heart failure) may impair the healing process, which depends on oxygen supply delivered by a normal blood flow [23]. The cardiac systemic disease can endanger and reduce the amount of oxygen and nutrients in the osseous tissue, which may affect the osseointegration process of dental implants. Some authors even point out the relative contraindication of placing dental implants in patients with certain cardiac systemic disease due to their higher risk of developing infective endocarditis [3,23]. On the contrary, no correlation seems to exist between the lack of osseointegration of dental implants and patients with certain cardiac systemic disease, as concluded in a retrospective case study: similar implant failure rates were found in both the cardiovascular disease and control groups [79]. Despite causing physiological alterations, cardiovascular disease seems not to affect clinical implant success. Additionally, in two retrospective studies and one prospective study from the same center, the investigators also found no relation between early implant failure and cardiovascular disease, though patients with possibly noncontributory cardiovascular disease (such as angina, heart valve anomalies, and arrhythmia) were included [72,77,80]. The literature addressing dental implants and their success and failure rates in patients with cardiovascular disease is scarce. Further studies with implants in function are needed, but it appears that cardiovascular disease does not diminish initial implant survival. It is important, though, to understand that patients with cardiovascular disease often take medications for the disease control that may have an impact on implant treatment.
- *Smoking.* Smokers are categorized in ASA II physical status classification (mild systemic disease) [81]. Cigarette byproducts such as nicotine, carbon monoxide, and hydrogen cyanide incite toxic biological responses. Nicotine attenuates red blood cell, fibroblast, and macrophage proliferation, increases platelet adhesion, and induces vasoconstriction via the release of epinephrine; this leads to a lack of perfusion and compromised healing. Carbon monoxide competitively binds to hemoglobin and, thus, reduces tissue oxygenation. Hydrogen cyanide inhibits enzyme systems necessary for oxidative metabolism and cell transport. In addition, smoking promotes expression of inflammatory mediators (e.g., tumor necrosis factor and prostaglandin E2), and impairs polymorphonuclear neutrophil chemotaxis, phagocytosis, and oxidative burst mechanisms. It also increases matrix metalloproteinase production (e.g., collagenase and elastase) by polymorphonuclear neutrophils [23]. Several

investigations implicate tobacco use in implant failure. Several retrospective studies showed that smokers have a higher failure rate, which sometimes was as high as 2.5 times greater, compared with nonsmokers [82]. Significantly more implants in the maxilla failed in smokers than in current nonsmokers, leading to the maxilla having greater failure disparity between smokers and nonsmokers [83,84]. In an 8-year long, randomized, prospective clinical trial the researchers concluded that persistent tobacco use following implantation lessened the ability of bone or other periodontal tissues to adapt over time, thus compromising all stages of treatment after fixture uncovering. They suggested smoking cessation for all implant candidates [85]. Only a few studies conclude that smoking status does not influence implant success [86–88]. Two retrospective studies concluded that the consumption of tobacco is not a decisive factor in the loss of dental implants [72,89]. In another study it was observed that surface-modified implants may resist effects of smoking [90]. On the whole, smoking appears to reduce implant success in the maxilla, but smoking cessation prior to implant rehabilitation appears to improve results. Generally, many authors have associated the consumption of tobacco with the implant loss significantly [23,72,77]. The use of surface-modified fixtures may decrease the risk of failure in smokers, though evidence is preliminary [23].

F.

- *Ectodermal dysplasia.* This is a hereditary disease characterized by congenital dysplasia of one or more ectodermal structures. Common extra- and intraoral manifestations include defective hair follicles and eyebrows, frontal bossing, nasal bridge depression, protuberant lips, hypo- or anodontia, conical teeth, and generalized spacing [91]. There have been several case reports and case series for patients with ectodermal dysplasia treated with dental implants. Most series demonstrate an excellent implant success rate in adults with ectodermal dysplasia [92], although results reported in children and adolescents mainly when implants were placed in the maxilla or the symphyseal region of the anterior mandible have been less encouraging [93,94]. The most appropriate age for dental implant treatment in growing children remains controversial [95,96]. There are no controlled studies, though, to demonstrate any positive or negative effect of the disease on the implant treatment [3].
- *Lichen planus.* Oral lichen planus is a common T-cell-mediated autoimmune disease of unknown cause that affects stratified squamous epithelium virtually exclusively [97]. It has been suggested that dental implants are not ideal for patients with oral lichen planus because of the limited capacity of the epithelium involved to adhere to the titanium surface [20]. Case control and case reports have showed successful outcomes of implants placed in patients with oral lichen planus. Peri-implant mucositis and peri-implantitis seem to be slightly more frequent in patients with oral lichen planus than in controls, and desquamative gingivitis was associated with a higher rate of peri-implant mucositis [98]. Implant placement does not influence the disease manifestations, though [99]. Careful long-term monitoring of both lesions and dental implants is recommended [92]. With the available literature at present, oral lichen planus as a risk factor for implant surgery and long-term success cannot be properly assessed.
- *Scleroderma.* This is defined as a multisystem disorder characterized by inflammatory, vascular, and sclerotic changes of the skin and various internal organs, especially the lungs, the heart, and the gastrointestinal tract. Typical clinical features in the facial region include a masklike appearance, thinning of the lips, microstomia, radial perioral furrowing, sclerosis of the sublingual ligament, and indurations of the tongue [100]. The skin of the face and lips as well as the intraoral mucosa is tense, thereby hindering or complicating dental treatment. There are only case reports and case series with up to two patients with scleroderma and treated with dental implants in the literature [101–105]. According to a recent review, no further controlled studies for scleroderma were found and, therefore, the level of evidence for the efficacy of dental implants in such patients is low [3].
- *Neuropsychiatric disorders.* The literature with respect to implant placement in patients

with neuropsychiatric disorders is scarce and contradictory. Some case reports and case series have shown implant treatment to be successful in some patients with various degrees of both intellectual and physical disability, including cases of cerebral palsy, Down syndrome, psychiatric disorders, dementia, bulimia, Parkinson disease, and severe epilepsy [105–108]. However, poor oral hygiene, oral parafunctions such as bruxism, harmful habits such as repeated introduction of the fingers into the mouth, and behavioral problems are not uncommon in patients with neuropsychiatric diseases, and dental implants in such patients may lead to complications. Therefore, the success of oral rehabilitation depends fundamentally on appropriate patient selection, and adequate medical advice should be taken prior to implant therapy. It is important to keep in mind, though, that patients with diseases affecting motor skills can benefit from implant-retained overdentures. In contrast, full fixed prosthetic restorations over implants should be avoided because of the difficulty of effective cleaning [3].

- *Sjögren syndrome.* This is a chronic autoimmune disease affecting the exocrine glands, primarily the salivary and lacrimal glands. The most common symptoms are extreme tiredness, along with dry eyes (keratoconjunctivitis sicca) and dry mouth (xerostomia). Xerostomia can eventually lead to difficulty in swallowing, severe and progressive tooth decay, or oral infections. Currently, there is no cure for Sjögren syndrome, and treatment is mainly palliative [109,110]. Literature on implant treatment in patients with Sjögren syndrome is scarce. There are no controlled studies available; but there is one case series study, which showed an implant-based failure rate of 16.7% and patient-based failure rate of 50% [111].
- *Hypothyroidism.* Thyroid disorders affect bone metabolism. Thyroxine and, to a lesser extent, triiodothyronine regulate several homeostatic processes. In soft tissue and bone fractures, these hormones manage wound healing. Hypothyroidism decreases recruitment, maturation, and activity of bone cells, possibly by reducing circulating levels of insulin-like growth factor-1; this suppresses bone formation as well as resorption [23]. Fracture healing is therefore inhibited. It can be assumed, therefore, that hypothyroid states lead to greater failures in implant osseointegration. There are a few studies, though, on thyroid status and implant success rates where no correlation was found [80,112]. Thus, in a controlled patient, hypothyroidism fails to influence implant survival [23].

G.

- *Recent myocardial infarction or cerebrovascular accident or ischemic stroke.* When ischemia to the heart or the brain occurs, it generates necrosis and functional deficits. With intervention and a healing period of roughly 6–12 months after preliminary care, patient stability occurs. In the interim period and for 3–6 months after initial stability, it is necessary to avoid any stress, including surgical, that could trigger post-ischemia complications. Owing to the high risk of complications following a myocardial infarction or cerebrovascular accident, the dental provider must wait until preliminary stabilization. The patient may pursue elective dental care only if at least 6 months have passed since the ischemic incident and they obtain medical clearance. Additionally, the health-care professional must be aware of any anticoagulant or thrombolytic therapy administered and understand that the desire for oral implants does not necessarily justify interruption of a therapeutic INR [22].
- *Transplant or valvular prosthesis placement.* Repair of cardiac or vascular defects with autografts or particular materials often becomes completely encased in endocardium or endothelium within the first month, rendering them relatively impervious to bacterial seeding, increasing possible risks from exposure such as endocarditis or endarteritis. Especially prone to microbial infection, prosthetic valves restore function to those with progressive congestive heart failure, systemic emboli, or endocarditis [22,113]. Three forms of prosthetic valve exist: bioprostheses (porcine), mechanical valves, and homografts or autografts. All but the autograft fall subject to endocarditis, as well as regurgitation, stenosis, and degeneration. The prevalence of prosthetic valve endocarditis lingers around

1–3%, and the greatest risk occurs within the first 3 months [114]. By 6 months the prosthetic valve endocarditis rate drops to 0.4%. With prosthetic valve replacement, stability occurs at least 6 months to 1 year after cardiac surgery [113,114]. Avoidance of invasive periodontal procedures is mandatory in order to prevent bacteremia and possible subsequent valve loss. Depending on the type of valve used (mechanical or bioprosthesis), the patient requires different drug regimens (anticoagulants or plasma volume elevators, respectively) [113]. Additionally, premedication with antibiotics prior to any invasive surgical procedure may be required. Practitioners must take such medications into consideration prior to any implant treatment.

- *Conditions with severe risk of hemorrhage.* If proper hemostasis cannot occur, elective surgery must not take place. Uncontrolled hemorrhage stems from a multitude of conditions, including platelet and clotting factor disorders, but often originates from drug therapy. Patients taking oral anticoagulants (e.g., aspirin, warfarin, clopidogrel) for cardiovascular diseases must receive careful supervision of bleeding time and INR. Little risk of significant bleeding following dental surgical procedures in patients with a prothrombin time of 1.5–2 times is normal. The medical literature, however, proposes that a patient with an INR of 3 or less tolerates invasive oral therapies, including extractions or implant therapy [115]. If, for some reason, the INR must be kept higher, elective implant treatment is inappropriate [22]. A lack of platelets due to infection, idiopathic thrombocytopenia purpura, radiation therapy, myelosuppression, and leukemia may lead to bleeding issues during or after surgery as well. Mild thrombocytopenia, or platelet count 50,000–100,000/mm^3, may produce abnormal postoperative bleeding. Levels below 50,000/mm^3 lead to major postsurgical bleeding; spontaneous bleeding of mucous membranes occurs below 20,000 cells/mm^3 [116]. Such patients often require transfusion before surgery. For most dental patients, the hematocrit is crucial to outpatient care only when values drop to roughly 60% of low normal range. Patients who are to undergo sedation or general anesthesia require hemoglobin and hematocrit values within about 75–80% of normal [117].
- *Profound immunosuppression.* The ability to obtain an adequate immune response is crucial to wound healing. Oral surgery is typically contraindicated when the total white blood count falls below 1500–3000 cells/mm^3, as the patient becomes susceptible to infection and compromised repair or regeneration [118]. A normal absolute neutrophil count level lies between 3500 and 7000 cells/mm^3. A person with levels between 1000 and 2000 cells/mm^3 requires broad-spectrum antibiotic coverage [117]. Those with less than 1000 cells/mm^3 require immediate medical consultation and cannot receive dental implantation [22].
- *Active treatment of malignancy.* While needed to destroy rapidly dividing malignant cells, both ionizing radiation and chemotherapy disrupt host defense mechanisms and hematopoiesis. Because the patient on such regimens cannot mount an appropriate response to wounding from surgery, implantation is prohibited [22]. The total dose of ionizing radiation for cancer treatment ranges from 50 to 80 Gy. This is given in fractions of 1–10 Gy per week in order to maximize death of neoplastic cells and minimize injury to host cells. Four stages of biological interactions occur with radiation. Overall, the tissues and systems of the periodontium have intermediate radiosensitivity compared with those with more rapid turnover (marrow, skin, gastrointestinal cells). Typical head and neck radiation, however, makes the periodontal apparatus prone to injury. Osteocytes of outer lamellar and haversian bone in the direct path of ionizing radiation die, and blood vessels of the haversian canals may be obliterated. Mucositis and xerostomia, resulting from radiation damage to mucosa and salivary glands respectively, also contribute to a poor oral environment. Patency and hemopoietic potential of bone decrease. The posterior mandible in particular experiences osteoradionecrosis simply because it often lies adjacent to the radiation source. Additionally, it is less vascular, and contains less and larger trabeculae. Most studies that involve implant placement in irradiated bone reflect this. Additionally, active use of

cytotoxic anticancer drugs, which induce rapid granulocytopenia, followed by thrombocytopenia, may contraindicate implant rehabilitation [22]. There are, though, a very limited number of investigations on chemotherapeutic effects on implant survival. Case reports on subjects with dental implants who then undergo cancer chemotherapy show conflicting, though mostly adverse, results [119,120].

- *Severe psychiatric disorders.* In a patient unable to comprehend and anticipate dental treatment logically, it is best not to proceed with implant therapy. Several conditions have been identified as incompatible with implant placement. These include psychotic disorders (e.g., schizophrenia), severe character disorders (hysteroid and borderline personalities), dysmorphophobia, cerebral lesions, and presenile dementia, as well as alcohol and drug abuse [22]. There are no biological reasons for patients with most of the above disorders to lose implants (at least none that have been determined), but various case reports blame removal of osseointegrated fixtures on psychiatric factors [22].
- *Drug abuse.* Addictions to alcohol and other drugs lower resistance to disease, increase possibility of infection, retard healing aggravated by malnutrition, cause incoherence, and result in poor oral hygiene [121]. Alcohol abuse in particular induces hepatic disease and subsequent platelet disorders, hypertension, distress infarction, aneurysm, and insidious hemorrhage. A patient who abuses alcohol or drugs may suffer from an inability not only to recognize or accept realistic treatment outcomes but also to heal [22].

H. Some medications may cause complications during or after implant therapy or may have an impact on healing, early or late osseointegration, and possibly on implant failure.

- *Medications that cause gingival overgrowth.*
  - Antiepileptics (phenytoin). Phenytoin is an antiepileptic drug that is known to provoke gingival enlargement in the presence of plaque. Gingival overgrowth may also happen around transgingival/mucosal abutments in the presence of plaque accumulation. Resection of the enlarged soft tissue can be performed by gingivectomy (for limited overgrowths) or flap surgery (when larger volumes are involved). No data are available for oral implants in patients receiving phenytoin [19].
  - Antihypertensives (calcium channel blockers). Dihydropyridine calcium channel blockers for hypertension have gingival overgrowth as a common side effect. Data concerning the risk of gingival overgrowth in patients rehabilitated by means of implants are lacking [19].
  - Immunosuppressives (cyclosporin). Cyclosporin, and immunosuppressive medication usually given to patients with transplants, also has gingival enlargement as a common side effect. The gingival overgrowth does not appear to be plaque related. Cyclosporin has a more challenging effect on osseointegrated implants, namely its well-documented effect on accelerating bone turnover and provoking a negative bone balance [19,122].
- *Selective serotonin reuptake inhibitors (SSRIs).* These are the most widely used drugs for the treatment of depression and have been reported to interfere with bone metabolism, having a direct negative effect in bone formation by increasing osteoclast differentiation. As a result they reduce bone mass and bone mineral density and increase the risk of osteoporosis and bone fracture. In a recent cohort study, the authors' findings indicated that treatment with SSRIs is associated with an increased failure risk of osseointegrated implants, which might suggest a careful surgical treatment planning for SSRI users [123].
- *Bisphosphonates.* The bisphosphonates are drugs indicated in the prevention and treatment of illnesses associated with bony resorption (osteoporosis or Paget disease), bony metastasis of cancer, paraneoplastic syndromes, and multiple myeloma. They can be used orally or intravenously [2]. The risk in patients using bisphosphonates is well recognized, in terms of BRONJ [124–126]. The largest series of patients developing BRONJ following dental implants published to date involved 27 patients on bisphosphonates, taken either orally or intravenously (alendronate, zoledronic acid, and pamidronate). There was a mean duration of 16 months from implants placement until the

appearance of BRONJ [127]. In another series of BRONJ following dental implants, again involving patients on bisphosphonates either orally or intravenously, it has been suggested that posteriorly placed implants seem to be at higher risk of BRONJ development [128]. BRONJ is a real issue for patients treated with intravenous bisphosphonates, but the occurrence of BRONJ in patients receiving oral bisphosphonates medication is minimal [1]. The use of oral bisphosphonates at the time of implant placement and during healing does not seem to affect early implant success [129]. In 2007, the American Association of Oral and Maxillofacial Surgeons [130] produced guidelines for patients treated with oral bisphosphonates, based on the clinical situation of the patient and the length of treatment with the drug, indicating that greater caution prior and subsequent to surgery should be taken during 3 years after discontinuing bisphosphonate treatment. Two systematic reviews showed that the placement of dental implants in patients with chronic intake of oral bisphosphonates did not lead to BRONJ and did not influence short-term implant survival rates. The authors concluded that dental implants might be considered a safe procedure in patients taking oral bisphosphonates for <5 years [131] and that dental implants can osseointegrate and remain functionally stable in patients treated with bisphosphonates [132]. In summary, there is a consensus on contraindicating implants in cancer patients treated with intravenous bisphosphonates [131]. In patients with osteoporosis treated with bisphosphonates, they should be informed of the risk of possible implant loss as well as of the risk of suffering bony necrosis and a poor outcome from sinus lifts, and, therefore, adequate informed consent prior to dental implant surgery should be obtained [1].

- *Corticosteroid therapy.* Corticosteroid adverse effects include reduced bone density, increased epithelial fragility, and immunosuppression [64]. In consequence, the use of systemic glucocorticoids might compromise dental implant osseointegration and peri-implant healing. There is no evidence that corticosteroid therapy is a contraindication to dental implants, but it is important to consider that systemic corticosteroids can cause suppression of the hypothalamo–pituitary–adrenal axis and, therefore, standard recommendations for any oral surgery in patients on steroid therapy should be implemented [64]. The Medicines Control Agency still advises that patients who have finished a course of systemic corticosteroids of less than 3 weeks' duration and might be under stresses, such as trauma, surgery, or infection, and who are at risk of adrenal insufficiency receive systemic corticosteroid cover during these periods.

Conclusions

Patient selection is the critical factor for implant survival. In most cases an appropriate healing response allows for, if not ensures, success. Not all of those who desire implant rehabilitation, however, are candidates for surgery. Absolute medical contraindications exist and must be adhered to, lest the clinician contend with infection, implant failure, or even patient death. There are conditions that, if stabilized, do not seem to interfere perceptibly with repair. The careful practitioner understands the nature of a number of diseases, evaluates evidence regarding implant therapy in such patients, and picks their cases based on this knowledge. It is an informed choice that we make, and if we choose properly, then predictability results. A number of these relative contraindications to elective implant therapy exist. If controlled or isolated, the vast majority of diseases fail to affect conspicuously implant survival [22,23]. Not every patient who requires implant therapy initially qualifies for it; the good clinician possesses the ability to discriminate between candidates, make appropriate decisions, and instigate medical treatment as necessary.

Case 3

Implant Stability

CASE STORY
A 30-year-old Caucasian female with a dental history of trauma 14 years ago on tooth #9 presented with a chief complaint of crown mobility on tooth #9 for 6 months.

LEARNING GOALS AND OBJECTIVES
- To understand the key diagnostic factors for comprehensive implant therapy
- To understand tools to measure implant stability
- To understand important features for immediate implant placement in the esthetic zone

Past Dental History
The patient had a history of root canal therapy on teeth #9 and #10. These teeth were splinted by porcelain fused to a metal prosthesis. There was an uneven incisal alignment seen on tooth #9 with a maxillary anterior open bite (Figure 1).

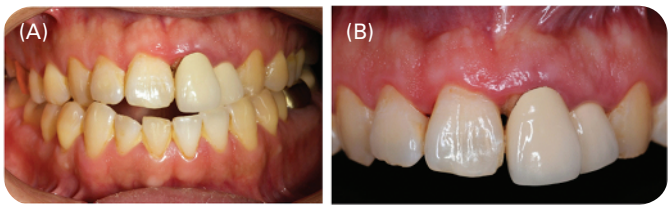


Figure 1: (A) Intraoral presentation and (B) close-up of tooth #9 (facial view).

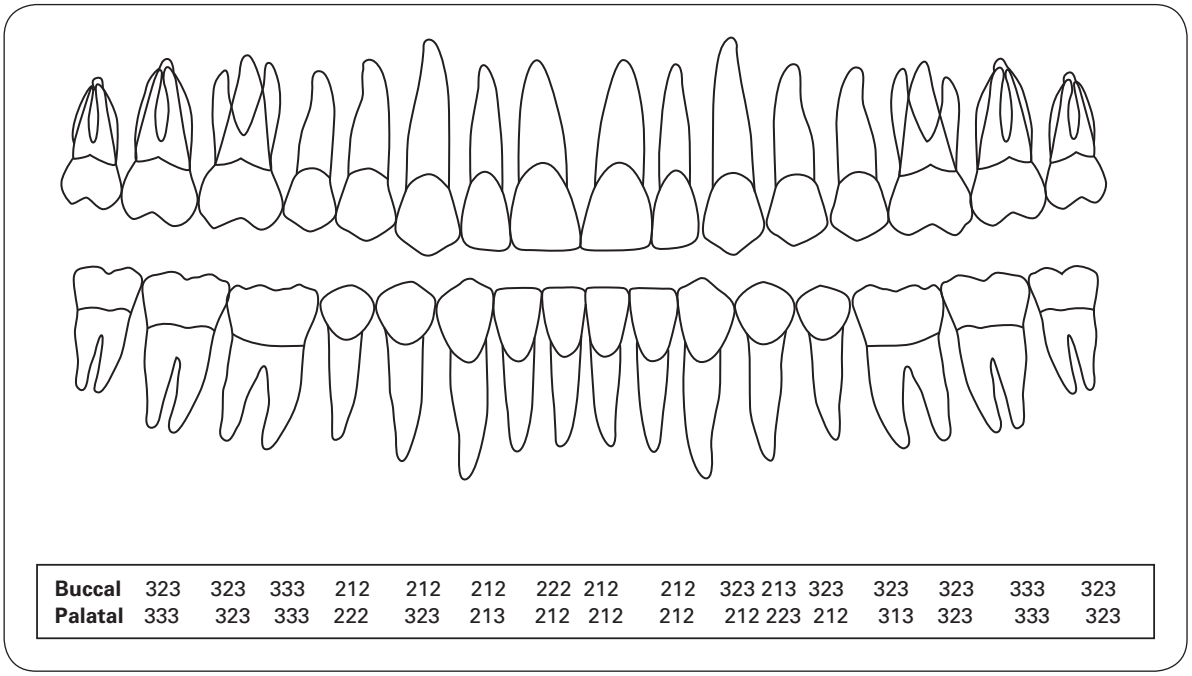
Medical History
There were no significant medical problems reported. However, the patient is a heavy smoker (10 per day). The patient's family is healthy without any reported medical problems.

Review of Systems
- Vital signs
  - Blood pressure: 110/72 mmHg
  - Pulse rate: 73 beats/min (regular)
  - Respiration: 15 breaths/min

Social History
The patient smokes and is a social consumer of alcohol. The patient was placed in a smoking cessation program.

Extraoral Examination
No significant findings were noted on extraoral examination. The patient had no masses or swellings and the temporomandibular joint was within normal limits. There was no facial asymmetry.

Intraoral Examination
- Soft tissue examination, including buccal mucosa, tongue, and floor of the mouth, was within normal limits.
- Oral hygiene was considered good, with an O'Leary plaque score of 22%.
- Slight calculus accumulation of lower anterior was found.
- Tooth #9 presented with crowding, uneven incisal alignment, and labioversion (Figure 1).
- Periodontal examination revealed probing depths in the range 2–3 mm (Figure 2).
- Loss of attachment and black triangle between teeth #7, #8, and #9 (Figure 1).



Buccal	323	323	333	212	212	212	222	212	212	323	213	323	323	323	333	323
Palatal	333	323	333	222	323	213	212	212	212	212	223	212	313	323	333	323

Figure 2: Maxillary probing pocket depth measurements during the initial visit.

- There was no primary or recurrent dental caries, and gingival inflammation was minimal.
- Localized erythema was noted on the margin of tooth #9.
- Normal thickness and width of keratinized mucosa noted.

Occlusion

The patient presented with a maxillary anterior open bite and group function.

Radiographic Examination

An initial panoramic radiograph (Figure 3) was ordered and subsequently a full mouth radiographic series was exposed. A cone beam computed tomography (CBCT) scan of the maxilla was also ordered. Buccal bone level and bone crestal height on the anterior maxilla were evaluated for proper diagnosis using CBCT scan selected images. Thin buccal bone was observed in the CBCT scan by three-dimensional reconstruction (Figures 4 and 5).

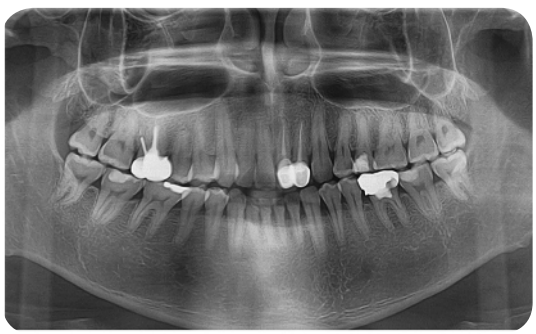


Figure 3: Panoramic radiograph.

Diagnosis

An American Academy of Periodontology diagnosis of plaque-induced gingivitis with traumatic, accidental, physical injury [1].

Treatment Plan

The treatment plan for this case included disease control therapy to effectively reduce gingival inflammation and surgical and prosthetic reconstruction of tooth #9.

Examination and Treatment Visits

The patient presented to our clinic with the chief complaint of tooth mobility. The medical and dental

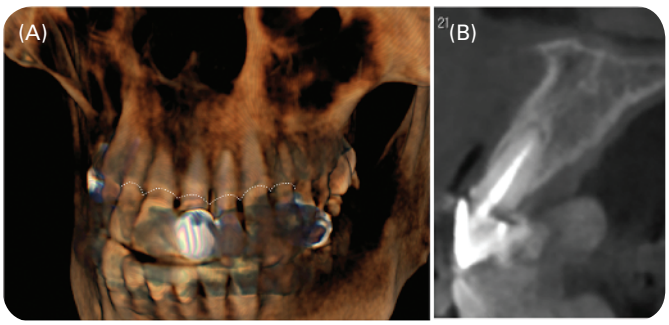


Figure 4: (A) CBCT reconstruction. (B) Sagittal view of the alveolar bone.

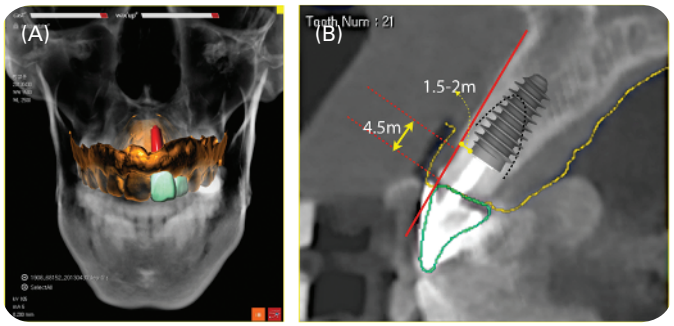


Figure 5: Virtual implant position plan: (A) facial view; (B) sagittal view.

histories were obtained. Systemically, the patient was healthy with the exception of being a smoker. The patient had a history of root canal therapy on tooth #9 and #10 and splinting by porcelain fused to a metal prosthesis. Periodontal examination revealed healthy periodontium with localized areas of mild gingivitis. Occlusal analysis revealed uneven incisal level alignment on tooth #9 with maxillary anterior open bite. These factors together made her a good candidate for dental implant therapy.

The patient had periodontal phase I treatment to resolve periodontal tissue inflammation. After a CBCT scan of the maxilla, a surgical stent was fabricated. The site-specific clinical and radiographic evaluation revealed enough buccolingual width and mesiodistal and apico-coronal space for both the placement and the restoration of the implant. Impressions were taken during this initial visit that were utilized for doing a diagnostic wax-up and creating a surgical guide. Immediately after the extraction of tooth #9 the implant was placed by using flapless surgery using the prefabricated surgical stent (Figure 6). Implant stability buccolingually and mesiodistally was measured using an Osstell device

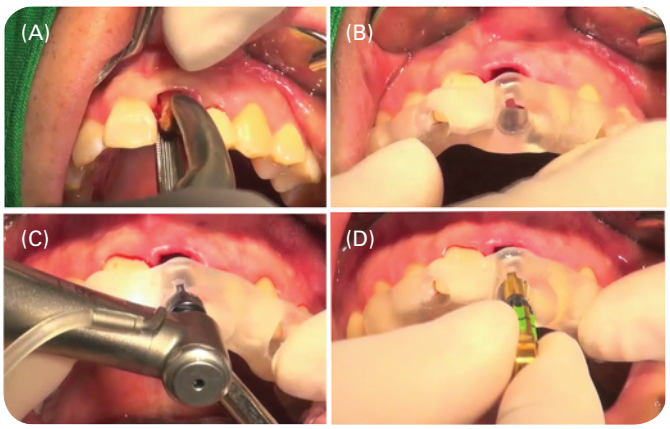


Figure 6: (A) Tooth #9 extraction. (B) Surgical stent placed. (C) Osteotomy. (D) Implant placement.

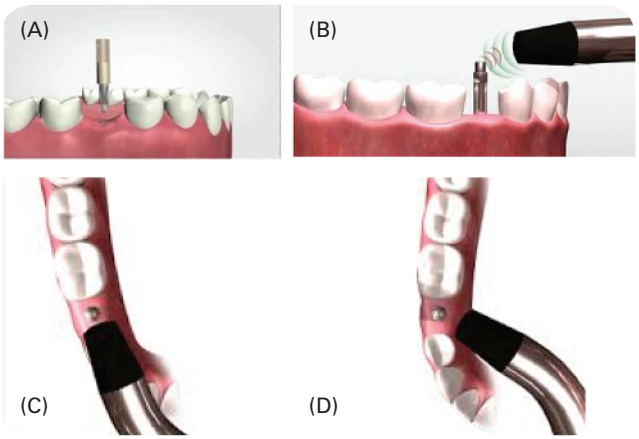


Figure 7: Schematic demonstration of implant stability measurement by Osstell device. (A) Attaching SmartPeg to implant; (B) transmission of magnetic pulses; (C) buccal and lingual measurements; (D) mesial and distal measurements.

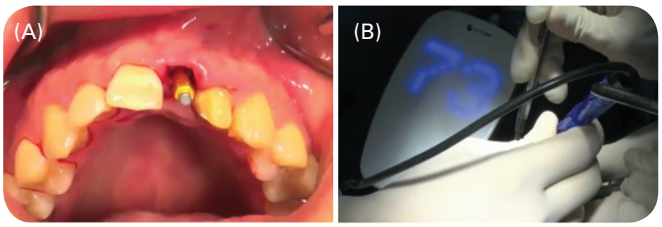


Figure 8: Clinical implant stability: (A) after SmartPeg placement; (B) Osstell measurements.

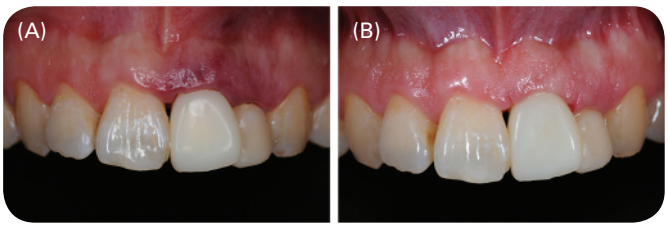


Figure 9: (A) Temporary crown postimplant placement. (B) At 2 weeks postimplant placement.

(Figures 7 and 8). A provisional crown was placed immediately after surgery without any occlusal contact. When the patient presented to the clinic, 2 weeks after extraction and implant placement, the peri-implant tissue was healthy (Figure 9). CBCT evaluation of the implant placement and its relationship with the buccal bone demonstrate optimal angulation (Figure 10). The final porcelain fused to zirconia restoration was delivered 8 weeks after implant placement (Figures 11 and 12).

Discussion

Dental implants have been widely used since the first development [2]. Implant placement has been advocated to be in sites that the bone is completely

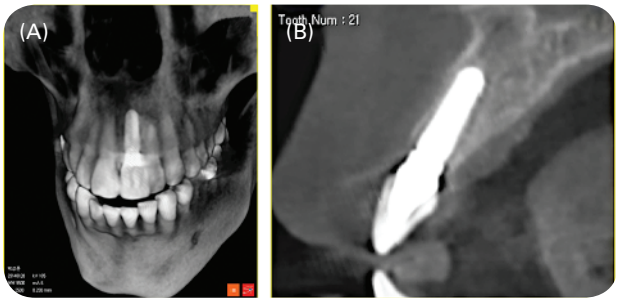


Figure 10: CBCT scan of new implant position: (A) facial view; (B) sagittal view.

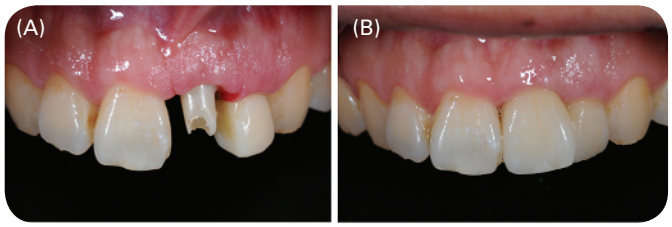


Figure 11: (A) Zirconia abutment. (B) Final crown.

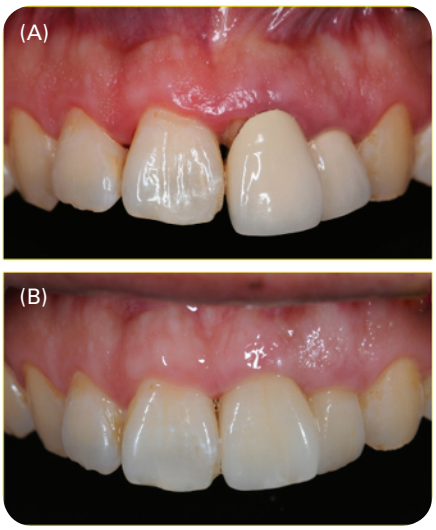


Figure 12: (A) Pre-extraction. (B) Postimplant placement (8 weeks).

healed and after placement there should be at least 3–6 months without any forces [3]. During implant–bone wound healing, forces may interfere with osteoprogenitor cells and proper bone formation. In fact, covering the implant was a strategy developed to prevent both infection and epithelial invasion, favoring osseointegration. The high clinical success rates of implant therapy have led to the indications of more demanding clinical situations, including immediate placement [4]. For both biologically and clinically successful implants, proper diagnosis is crucial to the final treatment outcome. Here, we describe proper techniques to diagnose the presurgical site and implant stability.

Site evaluation is a critical factor for the success of the short- and long-term success of the implant [5–7]. There are many factors that influence the surgical site, including soft tissue biotype and quantity, bone quality and shape, socket healing status, adjacent teeth periodontal tissue, presence of pathology, and esthetic considerations. In this patient, immediate placement was feasible because she presented with most of the key factors that favor a good outcome. It is important to point out that a thin gingival biotype can be a risk factor for future esthetics (Figure 13) of the implant because of buccal plate resorption and tissue recession [8–10]. If the buccal plate is lost and one tries to place an implant without grafting, the risks of recession and esthetic concerns after restoration are even higher. Thus, when the biotype is not thick and is highly scalloped, concomitant augmentation therapy is recommended. In addition, minimally invasive techniques are recommended to prevent trauma in both hard and soft tissues. In addition to surgical techniques, the surgical site requires optimal tissue quality and a quantity of soft and hard tissues without pathological lesions for implant placement [11].

Among all surgical factors that influence implant success, the most relevant and determining factor in the immediate implant scenario is primary stability. And this is imperative for immediate loading treatment options [7,12–14]. As reported in this clinical case, primary stability was achieved and evaluated by additional diagnostic techniques, including an Osstell device [15]. The concern for implant movement comes

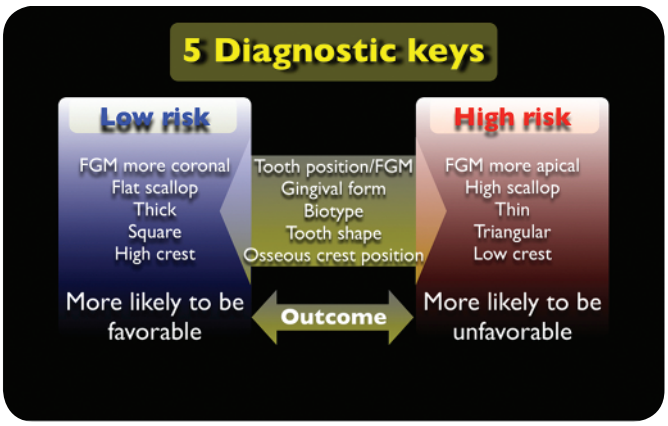


Figure 13: Diagnostic key factors (FGM: free gingival margin).

from the notion that micromovement has been shown to interfere with bone healing [16]. Connective tissue encapsulation was found in implants placed with poor initial stability. This has been illustrated by many studies demonstrating that micromotions of more than 100–150 µm influence the healing and even promote fibrous encapsulation [17,18]. Therefore, site-specific diagnosis and pre- and postimplant placement evaluation are tools predictive of osseointegration and implant success.

Self-Study Questions

(Answers located at the end of the case)

A. What are the key factors that contribute to immediate implant success?

B. How does immediate implant placement influence esthetic outcomes of the case?

C. What are the clinical methods to evaluate implant stability?

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Answers to Self-Study Questions

A. Several risk factors influence implant survival. Systemic and local factors influence the outcome of the therapy directly and indirectly. Immunocompromised patients and patients with uncontrolled diabetes and other systemic conditions can have poorer outcomes. Failures of endosseous implants were subdivided into early and late stages. In early failures there is an inability to establish implant-to-bone contact. Late failures are associated with plaque-induced inflammation and occlusal overloading. Early failures have been highly associated with hypertension, gastric problems, osteoporosis, diabetes type I and II, chemotherapy, and intake of medications. Heavy smoking should be considered a relative contraindication for immediate placement due to reduced peripheral blood circulation and proper tissue healing activation.

Local factors of the bone and soft tissue are important factors for implant success. Single tooth implants have high survival and low complications when compared with multiple implants. Bone quality and degree of resorption influences early and late ouctomes. In addition, presence of buccal plate, thick soft tissue biotype, optimal implant position and sites influence a successful therapy.

B. Immediate implant placement introduces a high risk of esthetic complications. Because of this, proper diagnosis and augmentation for soft and hard tissues is frequently necessary. Several clinical studies have shown that the facial mucosa is the main complication observed with immediate implants. To achieve a correct mucosal level on the facial aspect the implant needs to be positioned in a coronal–apical direction and the mucosa must be supported by a buccal plate that has sufficient height and thickness. Papilla height is also another important factor, and this can be affected by many factors, including tooth extraction technique, incision placement, the timing of implant placement, and adjacent hard tissue, soft tissue, and tooth relationships. Thus, an array of biological and surgical concepts influence treatment outcomes.

C. Implant stability can now be evaluated by many tests, such as reverse torque, bone implant contact, micromobility, and resonance frequency analysis (i.e., implant stability quotient or ISQ). Ostell devices were developed in 1999 by Integration Diagnostics Ltd (Sweden). This method allows the assessment of implant stability by measuring implant oscillation frequency on the bone. The ISQ ranges from 0 to 100. Implants with an ISQ of 70–85 are considered very stable (loading is acceptable), 65–70 as moderately stable (one-stage approach), and 60–65 as minimally stable (two-stage approach). Osstell devices can be used to assess primary stability, follow-up stability after surgery, and diagnosing detrimental actions of overloading in the early stages. The ISQ has been to shown to provide a standard and predictable method to assess biological changes in the bone–implant relationship.

Torque is the rotational friction between the implant and the bone and is normally measured in newton centimeters. Insertion torque describes the cutting friction of the tip of the implant in the bone as well as the friction between the implant surface in the bone. Seating torque is measured when the implant is fully inserted, while reverse torque is used to test the friction between the implant and the surrounding bone, but it has the risk of negatively influencing osseointegration.

Case 4

Oclussal/Anatomical Considerations

CASE STORY

A 60-year-old female presented for dental implant therapy in the maxillary left quadrant (sites #11–#14) and mandibular right quadrant (sites #29–#31). She was also missing tooth #18. The patient had lost her teeth in those areas due to failed restorations more than 5 years ago. She did not wish to restore the edentulous site #18 for the time being. She reported episodes of grinding and currently had a night guard, which according to her was worn down and needed to be replaced. The patient presented with a recent panoramic radiograph (Figure 1).

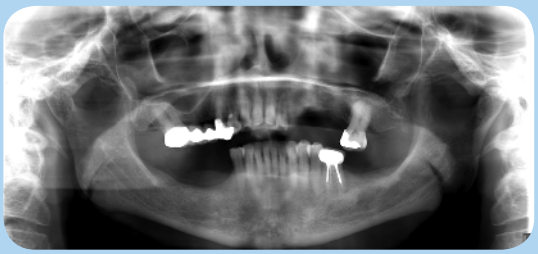


Figure 1: Initial panoramic radiograph.

LEARNING GOALS AND OBJECTIVES

- To determine the importance of a prosthetically driven implant placement and how it relates to the different anatomical landmarks
- To categorize and systematically analyze and evaluate the different anatomical landmarks
- To elucidate the pathologic conditions that may restrict implant placement
- To appreciate the importance of a team approach

Medical History

Not significant.

Social History

The patient did not smoke or drink alcohol at the time of treatment.

Extraoral Examination

No significant findings were noted. The patient did not have any masses, swellings, facial asymmetry, or lymphadenopathy. The temporomandibular joints (TMJs) were within normal limits.

Intraoral Clinical and Radiographic Examinations

See Figures 1, 2, 3, and 4.

- Class I maxillo-mandibular occlusal relationship, with normal vertical and horizontal bites.
- General assessment of TMJs within normal limits.
- Edentulous areas: #18, #11–#14, #29–#31.
- Residual alveolar ridge in the edentulous areas appeared atrophic.

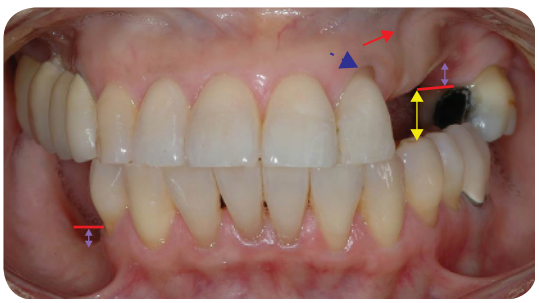


Figure 2: Frontal intraoral picture illustrating the reduced interocclusal distance for the maxillary left edentulous area (yellow double-headed arrow); buccal recession #10 (blue arrow); buccal frenum (red arrow); vertical bone loss (pink double-headed arrow). *Source*: image courtesy of Dr. Francesca Bonino.

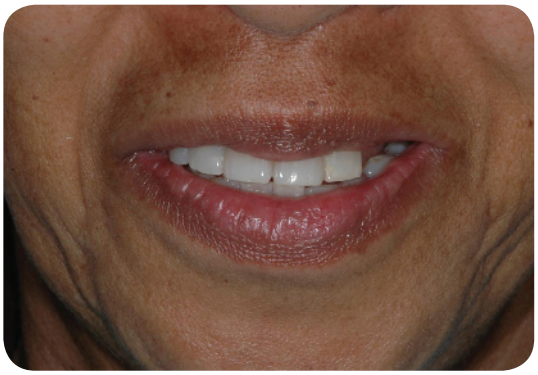


Figure 3: Smile picture. *Source*: image courtesy of Dr. Francesca Bonino.

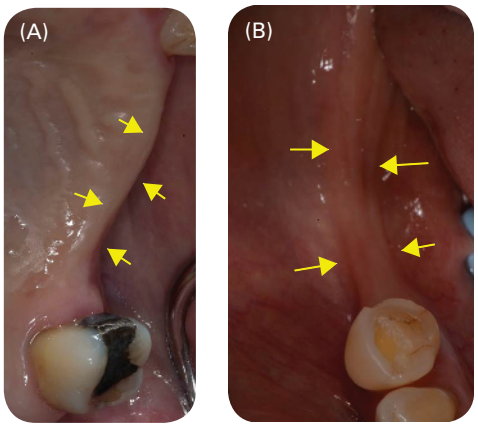


Figure 4: (A) Occlusal view of maxillary edentulous area illustrating atrophic residual alveolar ridge (arrows). (B) Occlusal view of mandibular site illustrating atrophic residual alveolar ridge (arrows). *Source*: images courtesy of Dr. Francesca Bonino.

- Soft tissue exam within normal limits.
- Low smile line.
- Periodontal examination revealed pocket depths in the range of 3–4 mm.
- Localized areas of gingivitis and a moderate oral hygiene were noted.
- The anterior teeth were triangular in form with a thin surrounding tissue biotype.
- A 2 mm buccal area of recession was noted on tooth #10.
- A 2.5 mm area of buccal recession was noted on tooth #28.
- Multiple restorations on existing teeth and periapical rarefying osteitis on tooth #19.
- Supra-eruption of tooth #15.
- The available mesiodistal space between #10 and #15 was 30 mm.
- The available space from distal of tooth #29 to the ascending mandibular ramus was 37 mm.

Implant Diagnosis and Treatment Plan

Upon evaluation of the patient's clinical and radiographic findings it was decided that the maxillary treatment plan should include placement of a single-unit implant retained crown in site #11 and an implant retained fixed partial denture (FPD) in sites #12–#14. The mandibular treatment plan should include placement of a three-unit FPD on implants #29–#31. A diagnostic wax-up of the desired size, anatomy, three-dimensional placement, and occlusion of the future restorations was done on the patient's mounted casts. A cone beam computed tomography (CBCT) scan was then performed with a radiographic stent in place (Figure 5) and the following detailed site analysis was completed. The radiographic stent was later converted into a stereolithographic surgical guide.

Detailed Site Analysis

Implant site analysis was performed intraorally, on mounted casts, and in CBCT images. Linear measurements were made using the CBCT measurement tool (Figure 6).

Site #11

- In the CBCT cross-sectional images, the density of trabeculae within cortical plates appeared within the range of normal. The density of trabeculae in cancellous bone appeared within the range of normal.
- In the CBCT cross-sectional images, the height of available alveolar ridge measured 19.68 mm and the width of the available ridge measured 4.08 mm.
- The apical area of tooth #10 was tipped distally, causing encroachment into the available space for dental implant #11 (red arrow, Figure 6A).
- The available bone height was limited by the floor of the nasal fossa or hard palate superiorly (Figure 6B).
- There was a pronounced labial concavity that would require careful angulation of the long axis of the implant to prevent perforation of the buccal cortical plate (yellow arrow, Figure 6A).

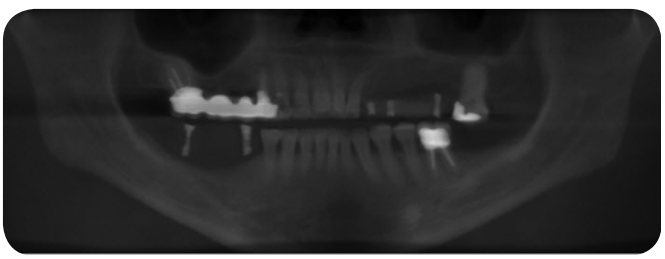


Figure 5: Reconstructed panoramic radiograph from CBCT with radiographic stent in place.

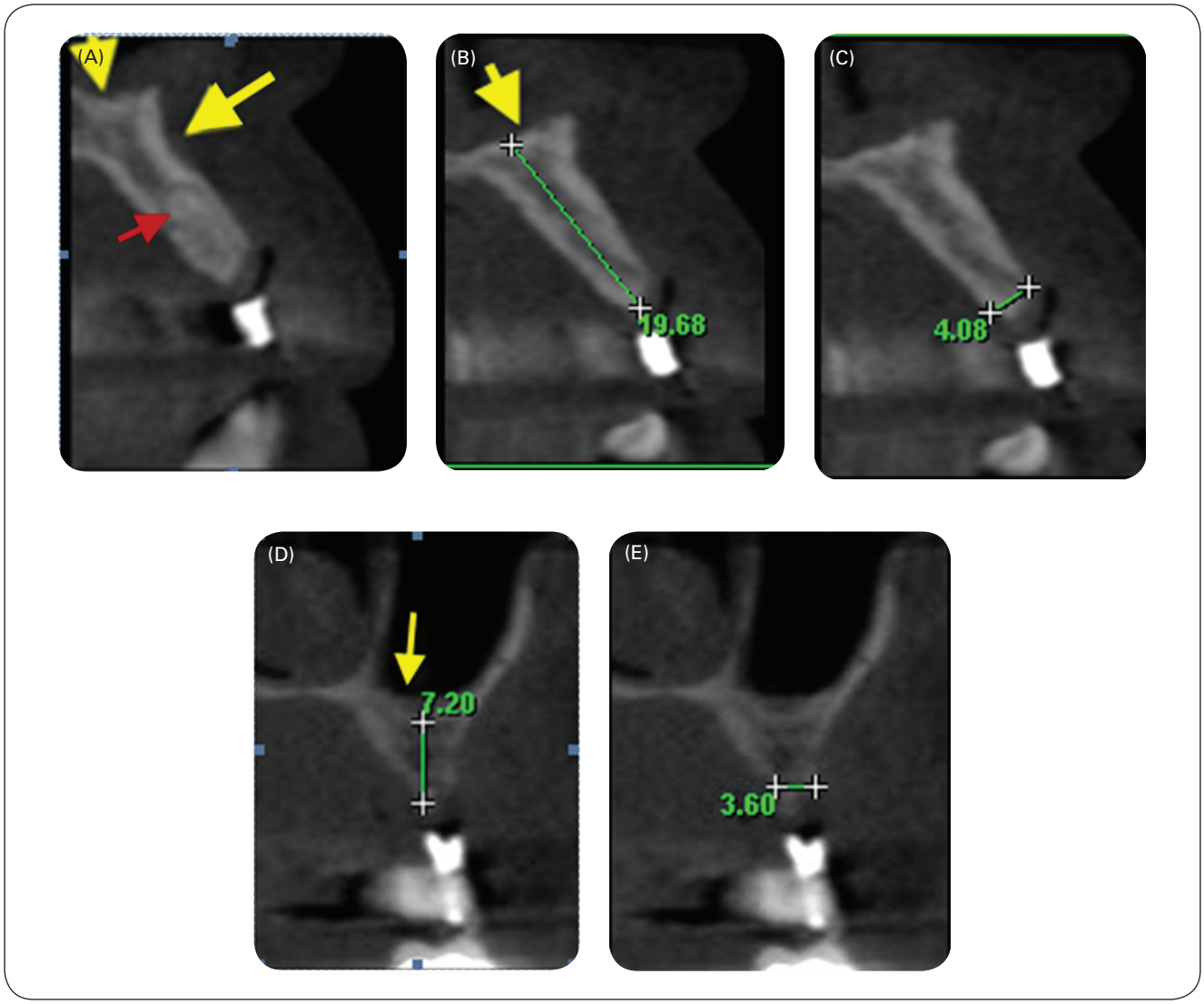


Figure 6: (A) Cross-sectional CBCT image showing the area of missing #11 illustrating the floor of the nasal fossa (arrowhead) and the labial concavity (yellow arrow) and the root of #10 (red arrow). (B) Cross-sectional CBCT image illustrating the height of available bone in area #11 limited superiorly by the floor of the nasal fossa (arrow). (C) Cross-sectional CBCT image illustrating the width of available bone in area #11. (D) Cross-sectional CBCT image illustrating the height of available bone in area #14 limited superiorly by the floor of left maxillary sinus (arrow). (E) Cross-sectional CBCT image illustrating the width of available bone in area #14.

- The available buccal keratinized soft tissue width was 4 mm.
- The available interocclusal space was 8.5 mm.

Site #12

- In CBCT cross-sectional images, the density of trabeculae within cortical plates appeared within the range of normal. The density of trabeculae in cancellous bone appeared within the range of normal.
- In CBCT cross-sectional images, the height of available alveolar ridge measured 18.01 mm and the width of the available ridge measured 2.34 mm; the ridge appeared narrow buccolingually due to atrophy.
- There was a low lateral frenulum attachment.
- Clinically, the available buccal keratinized soft tissue width measured 6 mm.
- Clinically, the available interocclusal space measured 8.0 mm.

Site #14

- In CBCT cross-sectional images, the density of trabeculae within cortical plates appeared reduced.

The density of trabeculae in cancellous bone appeared within the range of normal.

- The available bone height was limited by the floor of maxillary sinus superiorly (Figure 6D).
- In CBCT cross-sectional images, the height of available alveolar ridge measured 7.20 mm and the width of the available ridge measured 3.60 mm (Figure 6D and E).
- Mild soft tissue thickening was noted in the left maxillary sinus consistent with mucositis superior to the site of implant placement (Figure 6D and E).
- Clinically, the available buccal keratinized soft tissue width measured 4 mm.
- Clinically, the available Inter-occlusal space was 15 mm.

Site #29

- In CBCT cross-sectional images, the mental foramen was located approximately 6.50 mm distal and inferior to the marker.
- In CBCT cross-sectional images, the available bone height was limited inferiorly by the anterior extension of the inferior alveolar nerve (IAN) canal (Figure 7).
- In CBCT cross-sectional images, the available height of alveolar ridge measured 15.79 mm and the width of the available ridge measured 5.03 mm (Figure 7).
- Clinically, the available buccal keratinized soft tissue width measured 3.5 mm.
- Clinically, the available interocclusal space measured 10 mm.

Site #31

- The available bone height was limited inferiorly by the IAN (Figure 8).

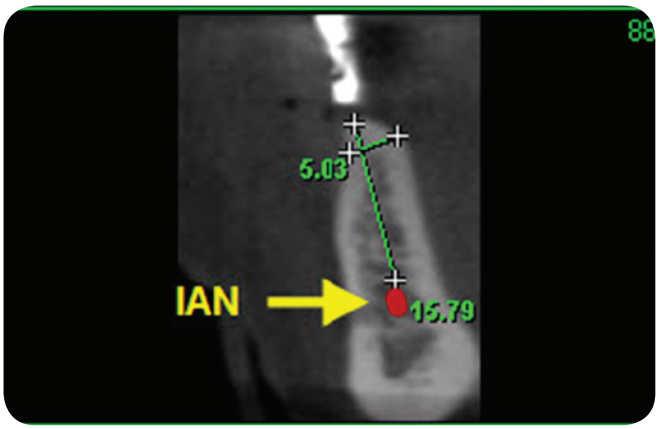


Figure 7: Cross-sectional CBCT image of area #29 illustrating the height of available bone above the IAN (red dot) and the width of available bone at the crest.

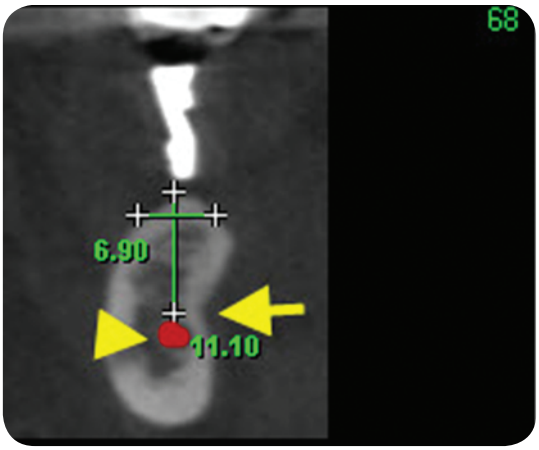


Figure 8: Cross-sectional CBCT image of area #31 illustrating the height of available bone above the IAN (red dot, arrowhead) and the width of available bone at the crest. The arrow indicates the submandibular salivary gland fossa.

- In CBCT cross-sectional images, the available height of alveolar ridge measured 11.10 mm and the width of the available ridge measured 6.90 mm.
- Clinically, the available buccal keratinized soft tissue width measured 3 mm.
- Clinically, the available interocclusal space measured 11.50 mm.

Treatment

The treatment for this patient was initiated with oral prophylaxis and oral hygiene instructions to reduce existing gingivitis.

Maxillary Arch

Owing to the limited buccolingual width in the edentulous area, it was decided to perform a hard tissue augmentation prior to implant placement (Figure 9). After the healing phase, one narrow and one regular-size implant was placed in sites #11 and #13 respectively, and a large-size implant was placed in site #14 with the guidance of the surgical stent (Figure 10). All implants were placed with a slight lingual orientation in order to allow for screw-retained restorations. Care was taken during the placement of implant #11 to avoid the distally tilted root of tooth #10. Owing to the patient's thin tissue biotype, the existing recession on tooth #10, and the low frenulum attachment in the area of #11 and #12, special care was taken to place the implants more lingually in order to maximize the amount of residual buccal plate and keratinized tissue. Both implants were also placed slightly deeper (approximately 3 mm apical to the CEJ of tooth #10) in order to avoid exposing the metal

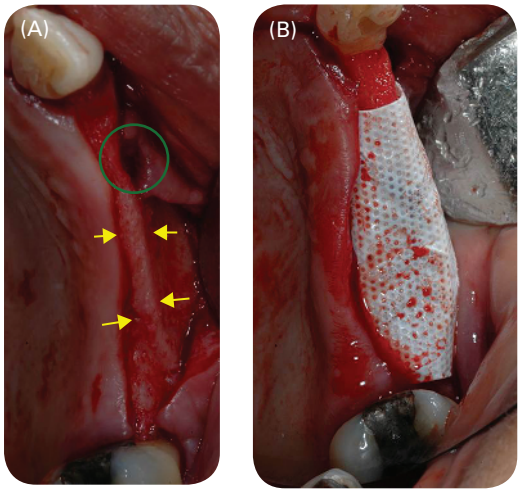


Figure 9: Intraoperative photographs illustrating (A) the maxillary residual ridge (arrows) and the labial concavity in the area of missing #11 (green circle) and (B) the ridge augmentation procedure for the maxillary site. *Source:* images courtesy of Dr. Francesca Bonino.

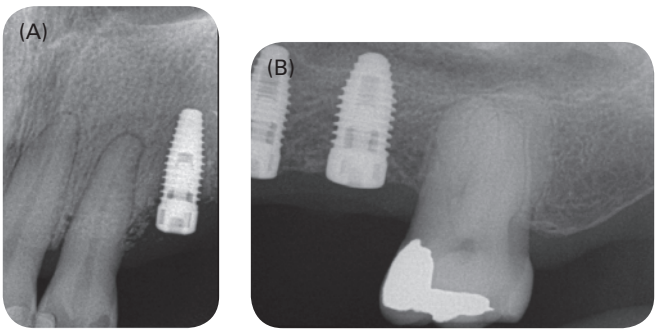


Figure 10: Periapical radiograph illustrating (A) the narrow-sized implant placed in area #11 and (B) the regular-sized implant placed in area #13 and large-sized implant placed in area #14.

abutment margin during the final restoration. The patient's thin biotype makes her prone to that risk. An internal sinus lift was performed concomitantly with the implant placement of #14 in order to overcome the issue of limited bone height in that area. Care was taken to place implants #12 and #14 in a parallel orientation to one another, to support the future FPD.

Following osseointegration, temporary implant retained restorations were recommended in order to shape the peri-implant and pontic soft tissues to the desired level. After a couple of weeks of the temporaries in function, a single-unit porcelain-fused-to-metal crown was placed on #11, and a screw-retained three-unit FPD was placed on implants #12–#14. The occlusal surfaces of the restorations on #12–#14 were made in metal without porcelain coverage due to the patient's bruxing habit.

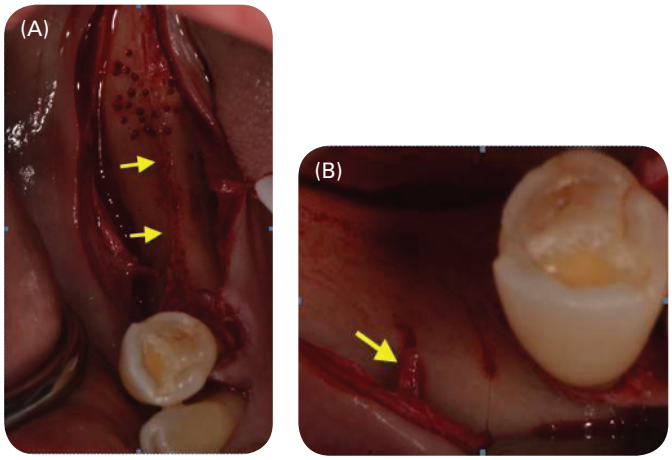


Figure 11: (A) Intraoperative view of the atrophic mandibular residual alveolar ridge (arrows). (B) Reflection of flap and exposure of mental foramen (arrow). *Source:* images courtesy of Dr. Francesca Bonino.

Mandibular Arch

A hard tissue augmentation was performed prior to implant placement of #29 and #30 (Figure 11), due to the reduced buccolingual width in the edentulous area of #29 and #30 (Figure 12). The flap was reflected to expose the mental foramen surgically, permitting its visualization (Figure 11B). After healing was established, with the guidance of the surgical stent a regular-size implant was placed in site #29 and a wide-size implant was placed in site #30 (Figure 13). Care was taken to place implants #19 and #30 in a parallel orientation to one another, to support the future FPD.

Both implants were placed so as to allow a screw-retained restoration. Following osseointegration, a temporary implant-retained FPD was fabricated to shape the peri-implant and pontic soft tissues to the desired level. After a couple of weeks of the temporary bridge in function, a three-unit FPD was delivered. Again, a metal occlusal surface of the FPD was suggested due to the patient's bruxing habit.

A new hard acrylic night guard was delivered to the patient at the end of the treatment.

Discussion

Placement of a short implant (<10 mm) instead of a standard-length implant would have eliminated the need

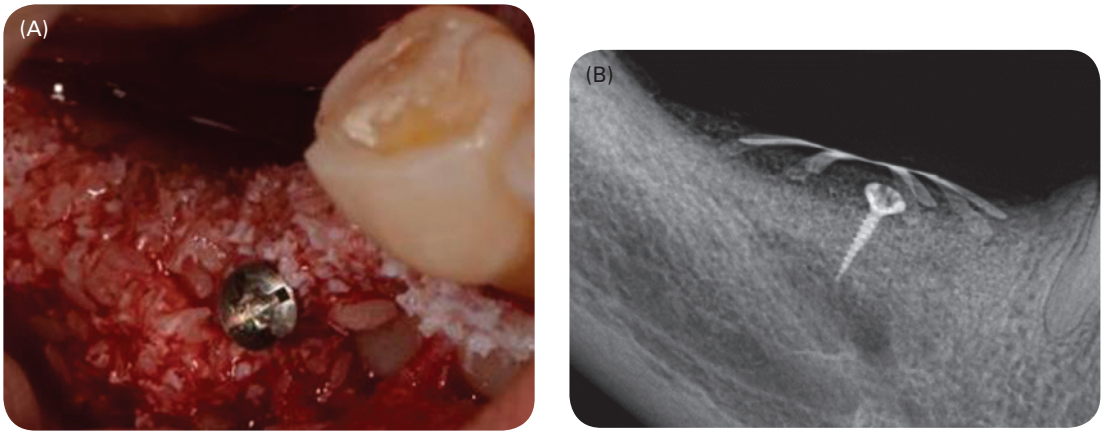
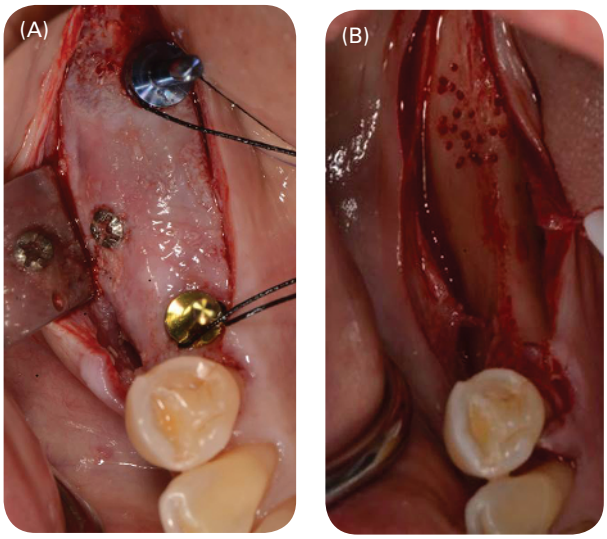


Figure 12: (A) Clinical photograph illustrating ridge augmentation procedure for mandibular site. *Source:* image courtesy of Dr. Francesca Bonino. (B) Postsurgical periapical radiograph illustrating the graft in place.



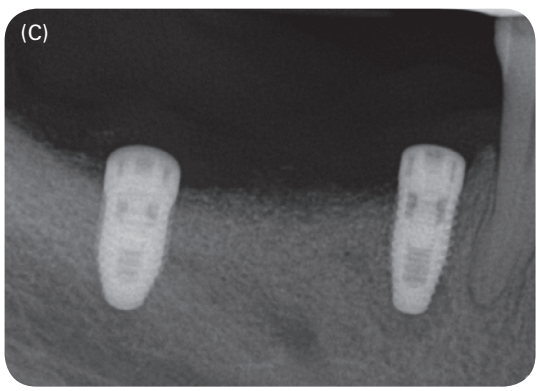


Figure 13: Clinical photographs illustrating (A) mandibular implants placements and (B) mandibular implant site healing. *Source:* images courtesy of Dr. Francesca Bonino. (C) Periapical radiograph illustrating mandibular implants in place.

for the internal sinus lift procedure. Research supports the use of short implants if prosthetic and occlusal considerations are respected [1].

Even though this patient had a low smile line, the thin tissue biotype placed her in a high-risk category for esthetic concerns [2,3]. Careful planning and placement of the anterior maxillary teeth (including the premolars) was crucial. If a soft tissue graft was necessary, the ideal timing would be during the temporary restorations stage. The temporary crowns would then be relined and reshaped to follow the new soft tissue contour and allow its maturation prior to the placement of the final restorations. To help categorize the difficulty level of a given treatment, in 1999 the Swiss Society of Oral Implantology proposed a system for classifying implant patients from a surgical and prosthetic standpoint. In the SAC classification system, S represents simple, A advanced, and C complex treatment procedures. In the surgical classification, all esthetic indications have been placed in either the A or C category, acknowledging the clinical challenges faced in the anterior maxilla and the frequent need for bone augmentation procedures [4].

Adjacent implant placement, such as areas 13 and 14 in the case presented herein, challenges the treatment team's ability to place dental implants in a position that allows for subgingival shoulder location and an ideal emergence profile while maximizing the osseous crest height and consequently papillary appearance [2].

Effective communication between the clinician and the patient is very important. After the evaluation of the clinical and radiographic findings, a separate consultation appointment is arranged to present the different treatment options to the patient along with the predictable treatment alternatives. This will help the patients understand the extent of the limitations and present them with the available options to reconstruct their mouth. In this way, treatment plans may be formulated to the patient's best advantage and will allow for treatment outcomes to be more predictable and successful [5].

Self-Study Questions

(Answers located at the end of the case)

A. What is the importance of a prosthetically driven implant placement and how does it relate to the different anatomical landmarks?

B. How can we categorize and systematically analyze and evaluate the different anatomical landmarks?

C. What pathologic conditions may restrict implant placement?

D. How important is a team approach?

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Answers to Self-Study Questions

A. The overall success of implant placement and restoration depends on careful patient selection and a comprehensive treatment plan. If the patient is indeed a candidate for implant therapy, a systematic protocol should be followed to assess the site-specific considerations. This chapter goes over some of the most frequently encountered anatomic structures that clinicians need to be attentive to when treatment planning an implant procedure.

Proper anatomic site evaluation along with restorative-driven planning will optimize final results. This involves a visualization of the emergence and position of the definitive implant-supported restoration. This is not only important for the planning of the ideal placement of the future implant, but can also aid in the diagnosis of hard and soft tissue deficiencies prior to implant placement

Articulated diagnostic casts will allow for the evaluation of the residual ridge, remaining dentition, existing occlusion, and available space in the edentulous site to receive the implant. The use of diagnostic wax-ups and templates for determination of anatomic comfort and danger zones is crucial in the initial planning process. This diagnostic wax-up will help with the determination of the number and position of the teeth to be replaced, implant location, angulation, relation to the remaining teeth, and the occlusal relationship with the opposing dentition. A resin template can be prepared from the finished diagnostic wax-up to serve as a radiographic and surgical template [6,7].

B. Identification and keeping clear of critical anatomical structures are key factors in the successful outcome and longevity of dental implants.

Anatomic structures to be taken into consideration with respect to implant placement can be classified into general and site-specific categories (Table 1).

Table 1: Classification of Anatomical Landmarks into General and Specific Categories

General	Site specific
Bone density	*Maxilla*
Mesiodistal interdental space	• Maxillary sinus/floor of maxillary sinus
Width of residual alveolar ridge	• Premaxilla–labial concavity
Height of residual alveolar ridge	• Floor of nasal fossa
Angulation of adjacent teeth	• Nasopalatine canal
Interocclusal space	• Palatine foramen and vessels
Occlusal forces	*Mandible*
Soft tissue biotype and smile analysis	• Inferior alveolar canal and mental foramen
	• Anterior extension of the inferior alveolar canal
	• Interforaminal area
	• Lingual canal
	• Submandibular salivary gland fossa
	• Sublingual fossa

General

- *Bone density.* This is a prime determinant in treatment planning, from implant design, to surgical approach, healing time, temporization, and loading protocol for the finalized restoration. Four types of mineralized bone have been described by Lekholm and Zarb based on its radiographic appearance and the resistance to drilling: type 1 bone, in which almost the entire bone is composed of homogenous compact bone; type 2 bone, in which a thick layer of compact bone surrounds a core of dense trabecular bone; type 3 bone, in which a thin layer of cortical bone surrounds a core of dense trabecular bone; and type 4 bone, characterized as a thin layer of cortical

bone surrounding a core of low-density trabecular bone of poor strength [8]. These differences in bone quality can be associated with different areas of anatomy in the upper and lower jaw. Mandible is generally more densely corticated than maxilla, and both jaws tend to decrease in their cortical thickness and increase in their trabecular porosity posteriorly.

A balance between the cortical and trabecular bone is desired. Too much cortical bone can delay osseointegration, while an excess of trabecular bone may limit the primary stability of the implants as well as its early stability in the bone [9].

- *Mesiodistal interdental space.* Adequate mesiodistal space must be present to provide a restoration that mimics natural tooth contours. It gives an indication of the number of implants that can be ideally placed. This has to be correlated with the buccolingual width of the bone, diagnostic wax-up of the future restoration, and the angulation of the crowns and ro ots of adjacent teeth (see later). Excesses or deficiencies in these areas must be previously addressed through the use of orthodontics, enameloplasty, or restorative materials prior to implant placement [5].

  The following recommendations should be used when selecting implant size and evaluating mesiodistal space for implant placement [10]:
  - the implant should be at least 1.5 mm away from the adjacent teeth;
  - the implant should be at least 3 mm away from an adjacent implant.

  Placement of the implant too close to the adjacent tooth can cause resorption of the interproximal alveolar crest to the level of that on the implant. With this loss of the interproximal crest height comes a reduction in the papillary height. This will also result in poor embrasure form and emergence profile, both of which will result in a restoration with a long contact zone and nonideal clinical results.
- *Width of residual alveolar ridge.* One of the first things to be assessed is buccolingual ridge anatomy, including whether there is sufficient crest width and the presence or absence of facial bone atrophy, and/or lingual undercuts. Deficient alveolar crest width and/or buccal bone resorption require a bone augmentation procedure so that the implant can be positioned in an accurate buccolingual orientation. Presence of bony undercuts may cause perforation of the bone. Clinical bone mapping and different three-dimensional radiographic techniques, such as computed tomography and CBCT, can assist in diagnosing deficiencies in this dimension [11].

  The minimum required residual bone width for stability of soft tissues following osteotomy and implant placement should be ≥1 mm. This is critical on the facial side since any bone resorption and ensuing change in the position of the gingival margin will be extremely unesthetic [3].
- *Height of residual alveolar ridge.* The apico-coronal dimension or height of the available bone is measured from the crest of the edentulous ridge to the anatomical landmarks that limit the placement of the implant. The assessment of implant length should allow adequate safety and distance from vital anatomic structures, particularly as many drills are designed to prepare the implant site slightly longer than the chosen implant. There should be at least 2 mm of bone between the apical end of the implant and neurovascular structures [5].

  Patients with excess tissue height require attention as well. Bone present in excessive amounts is not a conducive clinical situation to place implants as it could create occlusal plane interferences in the completed restoration. In some cases, bone or soft tissue scalloping procedures will be required to allow placement of the implant shoulder in a position that ensures a harmonious gingival contour along with the adjacent teeth/implants and result in a favorable crown/root ratio and appropriate occlusal scheme [9,12].

  These landmarks can be outlined accurately in cross-sectional slices of CBCT to indicate the amount of available height of bone. Clinical situations with reduced vertical bone on adjacent teeth are challenging, because there are currently no surgical techniques available to predictably regain lost crest height. In an attempt to regain this lost tissue, orthodontic tooth extrusion techniques have been proposed [13,14]. In addition, short dental implants have shown predictable results when placed in a reduced ridge height, as long as

occlusal forces are evenly distributed and lateral forces and parafunctions are controlled [1].

- *Angulation of adjacent teeth.* The inclination of the adjacent crown or root is a key parameter to avoid interference from a convergent structure during surgical placement. A panoramic or periapical radiograph can offer a basic clue to interroot space. Migration and tipping of teeth adjacent to an edentulous space will often compromise mesiodistal distance available for implant placement.
- *Interocclusal space.* This is the distance from the occlusal plane (posterior) or incisal edge (anterior) to the crest of the alveolar ridge of the arch in question This space will influence the type of prosthesis (cement or screw retained), material choices, and surgical technique that will be used.

  A satisfactory restorative outcome is obtained only if adequate crown height space is available. The ideal vertical dimensions of each region are 3 mm for the soft tissue, 5 mm for the abutment height, and 2 mm for the occlusal metal or porcelain. Screw-retained restorations generally require less crown height space compared with cement-retained prostheses, since they can screw directly onto the implant body [13].

  The consequences of inadequate crown height space include a decrease in abutment height, inadequate bulk of restorative material for strength, and esthetics, leading to prosthetic complications and poor hygiene conditions due to inadequate emergence profiles.
- *Occlusal forces.* Masticatory forces developed by a patient restored with implant-supported restorations are equivalent to those of natural dentition. Implants can tolerate much better axial loads as opposed to lateral forces [15]. Also, owing to the lack of proprioception that is found in the periodontal ligament surrounding natural teeth, implant-supported restorations are more susceptible to occlusal overloading than natural teeth are. Consequently, it is important to understand the factors contributing to the anticipated load on the implant. Patients with occlusal wear or abfraction-type defects due to clenching or bruxism should be identified since the parafunctional habits will affect the long-term predictability of the implant [13].
- *Soft tissue analysis.* An evaluation of the soft tissue at the future implant site should determine the amount of attached keratinized tissue, thickness of the fibrous connective tissue, and the harmony or disharmony of the gingival scallop.

  Tissue biotypes are classified as thick and thin. Thick and keratinized tissue is more favorable, easier to manipulate, and provides a more predictable esthetic outcome, compared with thin tissue, which is more likely to go through recession [2]. A thin biotype with a highly scalloped gingival architecture is often linked with triangular teeth when compared with a thick biotype featuring blunted contours of the papillae, and is often associated with square and bold teeth [3].

  Characteristics of the soft tissue biotype will play a vital role in planning for final shoulder position of the implant.

  A patient with the combination of a high lip line and a thin biotype is extremely difficult to treat and should be considered an anatomic risk. Tissue deficiencies often require bone augmentation procedures such as the guided bone regeneration technique, which uses a simultaneous or staged approach to regenerate adequate volumes of bone to allow for implant placement.

Site specific

Maxilla

- *Maxillary sinus.* The amount of residual ridge available in the posterior maxilla for implant placement is limited by the floor of the maxillary sinus. Accurate identification of this structure and its extent on radiographs, including the locations of septae, is important in estimating the available bone volume to prevent iatrogenic perforation of the sinus floor. This has been found to be a potential cause for implant failure in the posterior maxilla [9]. When performing a sinus lift procedure one should also try to anticipate the location of the posterior superior alveolar artery, which can be visualized in a CBCT scan, to prevent unnecessary bleeding during implant placement.
- *Premaxilla.* This zone is also known as the traumatic zone/esthetic zone. It consists of the alveolar ridge of the premaxilla and eight

anterior teeth: four incisors, two canines, and two first premolars. Implant therapy in the anterior maxilla is challenging for the clinician because of the esthetic demands of patients and difficult preexisting anatomy, such as development of labial concavity subsequent to tooth loss. This may lead to difficulty in implant placement in a prosthetically favorable position and may necessitate bone augmentation [5].

- *Floor of nasal fossa.* The amount of residual ridge available in the anterior maxilla for implant placement is limited by the floor of the nasal fossa. Accurate identification of this structure and its extent on radiographs is important in estimating the available bone volume to prevent iatrogenic perforation of the nasal floor. This has been found to be a potential cause for implant failure in the anterior maxilla.
- *Nasopalatine canal.* The location of the nasopalatine canal dictates the placement of a dental implant in the area of the maxillary central incisors. The nasopalatine canal contains the nasopalatine nerve, the descending branch of the nasopalatine artery, and fibrous connective tissue and is located in the middle of the palate, with the inferior end of the canal opening posterior to the maxillary central incisors. The knowledge and identification of the location of this canal is crucial to avoid perforating it. Any contact of dental implant with neural tissue could result in failure of osseointegration and may lead to prolonged neurological clinical signs and symptoms [10]. Limited volume CBCT imaging has been proposed to be of benefit to determine the location and morphology of the nasopalatine canal in all three planes before dental implant surgery.
- *Palatine foramen and vessels.* The area of greater and lesser palatine foramen is often a donor site for harvesting soft tissue grafts as this is the area where the thickest tissue may be found [16]. When harvesting the graft it is necessary to avoid the neurovascular bundle that enters the palate through these foramina. The location of the greater and lesser palatine foramen should be evaluated with respect to the proposed surgical site in CBCT images to avoid injury to the neurovascular bundle.

Mandible

- *Inferior alveolar (mandibular) canal (IAN) and mental foramen.* The most important anatomical consideration while placing an implant in the posterior is the location of the inferior alveolar canal, which contains the neurovascular bundles. Iatrogenic injury of the vital structures like the IAN and inferior alveolar artery can result in loss or alteration of sensation, pain, or excessive bleeding following implant placement.

  The IAN leaves the mandibular canal through the mental foramen in the buccal cortical plate as the mental nerve. Within the canal, the nerve is about 3 mm in diameter, and its course varies. It can run with a gentle curve toward the mental foramen, or it can have an ascending or descending pathway.

  Buccolingual location of the IAN can be classified into three types: type 1 canal (70% cases), located close to the lingual cortical plate of the mandibular ramus and body; type 2 canal (15%), located in the middle of the mandibular ramus posterior to the second molar; type 3 canal (15%), located near the middle of the ramus and body. The apico-coronal location of the mandibular canal has also been classified radiographically into high – within 2 mm of the apices of the first and second molars – intermediate, and low [5].

  Several methods are used to localize the IAN during treatment planning. These include traditional panoramic radiography, three-dimensional computed tomography or CBCT, and direct surgical exposure. The limitations and deficiencies of panoramic and periapical radiography for accurate location of the inferior alveolar canal and its variations are well documented in the literature [17,18].

  A *bifid IAN canal* has been reported to occur very infrequently. Despite the rare occurrence of the bifid IAN canal, the clinician must be on the lookout for these cases when planning for dental implants.
- *The anterior loop/extension of inferior alveolar canal.* The anterior loop refers to the anterior extension of the inferior alveolar nerve anterior to the mental foramen. Care must be taken to avoid this injury by careful identification in available images. If the anterior loop is not easily discernible on available images, then it is best to surgically visualize the area prior to placing a dental implant.

- *The lingual canal.* Located in the middle of the mandible, it carries neurovascular channels. This structure can be readily visualized in cross-sectional CBCT images of the midline area of mandible. Care must be taken to avoid perforation of the canal during implant placement, which may lead to neuropathic pain.
- *Interforaminal zone.* This zone comprises of the area of the anterior mandibular alveolar ridge between mental foramen on each side.
- *Submandibular salivary gland fossa.* Also known as the lingual concavity, the submandibular gland fossa is located below the mylohyoid ridge of the posterior mandible. The extent and morphology of the fossa may have variations that may restrict placement of dental implants with desired angulations. Assessment of this anatomy in three dimensions is crucial to avoid perforation of the dental implant through the gland leading to complications [19].
- *Sulingual fossa.* The sublingual fossa located on the lingual aspect of the anterior mandible also complicates instrumentation for implant placement by presenting as an extreme concavity. The concavity could result in lingual perforation during implant placement. Although undercuts can be palpated during an intraoral examination, the thickness of the soft tissue can mask the severity of the undercut. A CBCT scan can provide an accurate view of the lingual osseous architecture and help avoid dangerous hemorrhage in the presence of extreme sublingual undercuts [19].

C. In addition to assessment of restricting anatomical structures, the potential implant sites need to be assessed to rule out any disease that may compromise and complicate the outcome of the dental implant therapy. Commonly occurring local diseases, such as chronic odontogenic inflammatory lesions, may complicate healing of the surgical site. Local changes in normal bone architecture (as seen in fibro-osseous conditions like periapical cemento-osseous dysplasia, enostosis, or idiopathic osteosclerosis) and systemic conditions (such as osteoporosis) should be taken into consideration prior to implant placement. Thorough clinical assessment as well as assessment of all available radiographic images is necessary to rule out pathology. In the event of surgical removal of a pathologic lesion in a given implant site, care must be taken to initiate the process of implant placement after healing and remodeling of the surgical defect to ensure the availability of sufficient healthy bone for osseointegration with implants. Hard and/or soft tissue grafts may be required prior to successful implant placement in some of those cases.

D. In order to successfully meet the challenges of esthetic implant dentistry in daily practice, a team approach is beneficial and highly recommended. The team includes an implant surgeon, a restorative clinician, an oral and maxillofacial radiologist, and a dental technician. In special situations, an orthodontist can also supplement the team [13,14].

There is a learning curve associated with placing and restoring dental implants. The implant should be placed in an optimal position to effectively support its overlying prosthesis and surrounding soft and hard tissues, but also in a position that does not violate neighboring anatomic structures.

Case 5

Radiographic Interpretation and Diagnosis

CASE STORY

A 78-year-old Asian male presented with a chief complaint of, "I want to get implants." The patient had missing teeth in upper posterior areas and found it difficult to chew his food.

LEARNING GOALS AND OBJECTIVES

- To understand basic imaging principles as applicable to dental implant treatment
- To learn about types of available imaging modalities for preoperative, intraoperative, and postoperative implant imaging
- To understand and apply the appropriate imaging technique dependent on the stage of dental implant treatment
- To learn about radiation protection and selection criteria
- Learn to identify anatomic landmarks and abnormalities in radiographs critical for successful outcome of dental implant treatment

Medical History

History of myocardial infarction 6 years ago with subsequent placement of stents, hypertension, hypothyroidism, and macrocytic anemia. The patient reported to be on metoprolol, aspirin, Lipitor, Diovan, Levoxyl, and B12 injections.

Review of Systems

- Vital signs
  - Blood pressure: 107/65 mmHg
  - Pulse rate: 53 beats/min
  - Respiration: 14 breaths/min

Social History

The patient did not drink alcohol and did not smoke.

Extraoral and Intraoral Examination

No significant findings, no swellings, lymphadenopathy, assymetries, ulcerations, or exophytic lesions were present.

Occlusion

No occlusal discrepancies or interferences present.

Radiographic Examination

A panoramic radiograph (Figure 1) was obtained for initial screening. The endodontically treated tooth #5 presented with radiographic signs indicating chronic periapical inflammation.

A preoperative cone beam computed tomography (CBCT) scan with a radiographic stent was prescribed after extraction and healing to assess the edentulous areas for prospective dental implants. The radiographic stent had markers in the regions corresponding to teeth #3 and #5. The findings in the CBCT scan included disuse alveolar atrophy in the edentulous

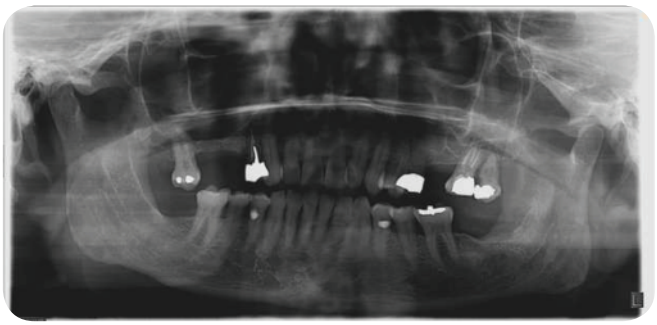

Figure 1: A panoramic radiograph for initial assessment of overall dentition and specifically edentulous areas in the right posterior maxilla.

region corresponding to the first molar. Figures 2, 3 and 4 present approximate height and width of available alveolar bone along with the edentulous saddle length for implant treatment planning. The floor of the maxillary sinus was intact. However, there was mucosal thickening, consistent with maxillary sinus mucositis. The morphology and quality of residual alveolar ridge (RAR) in area #3 could be described as Seibert class I and Lekholm and Zarb type IV. The morphology of the RAR in the edentulous region corresponding to the first premolar was within normal limits, and quality could be described as type II with a thick cortical outline surrounding a core of dense cancellous bone.

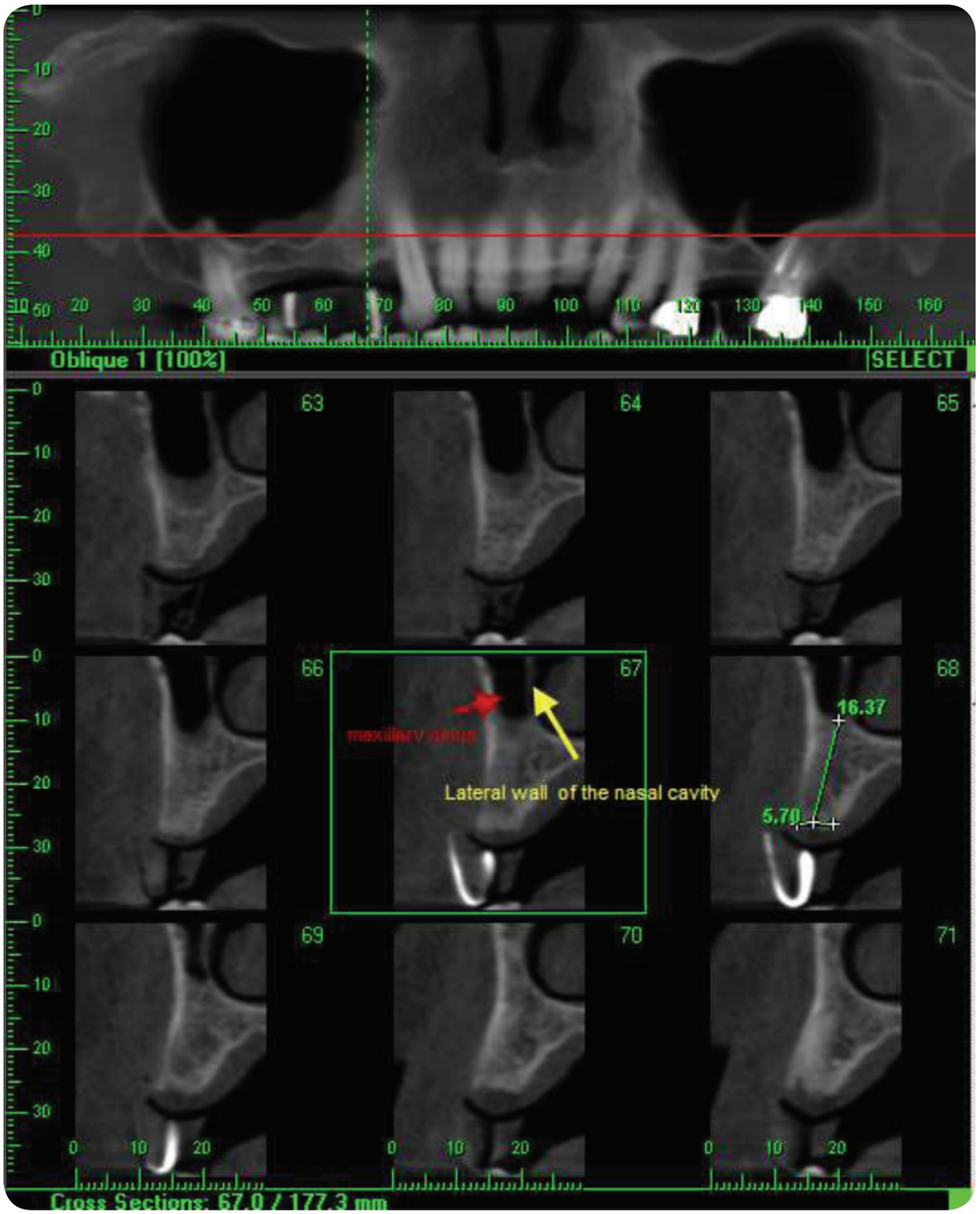

Figure 2: Cross-sectional and panoramic views from the preoperative CBCT scan of the maxilla with radiographic stent with a marker in edentulous area #5, showing cross-sectional morphology of the alveolar process, including width, height, and location of anatomic structures such as floor of the maxillary sinus and lateral wall of the nasal cavity.

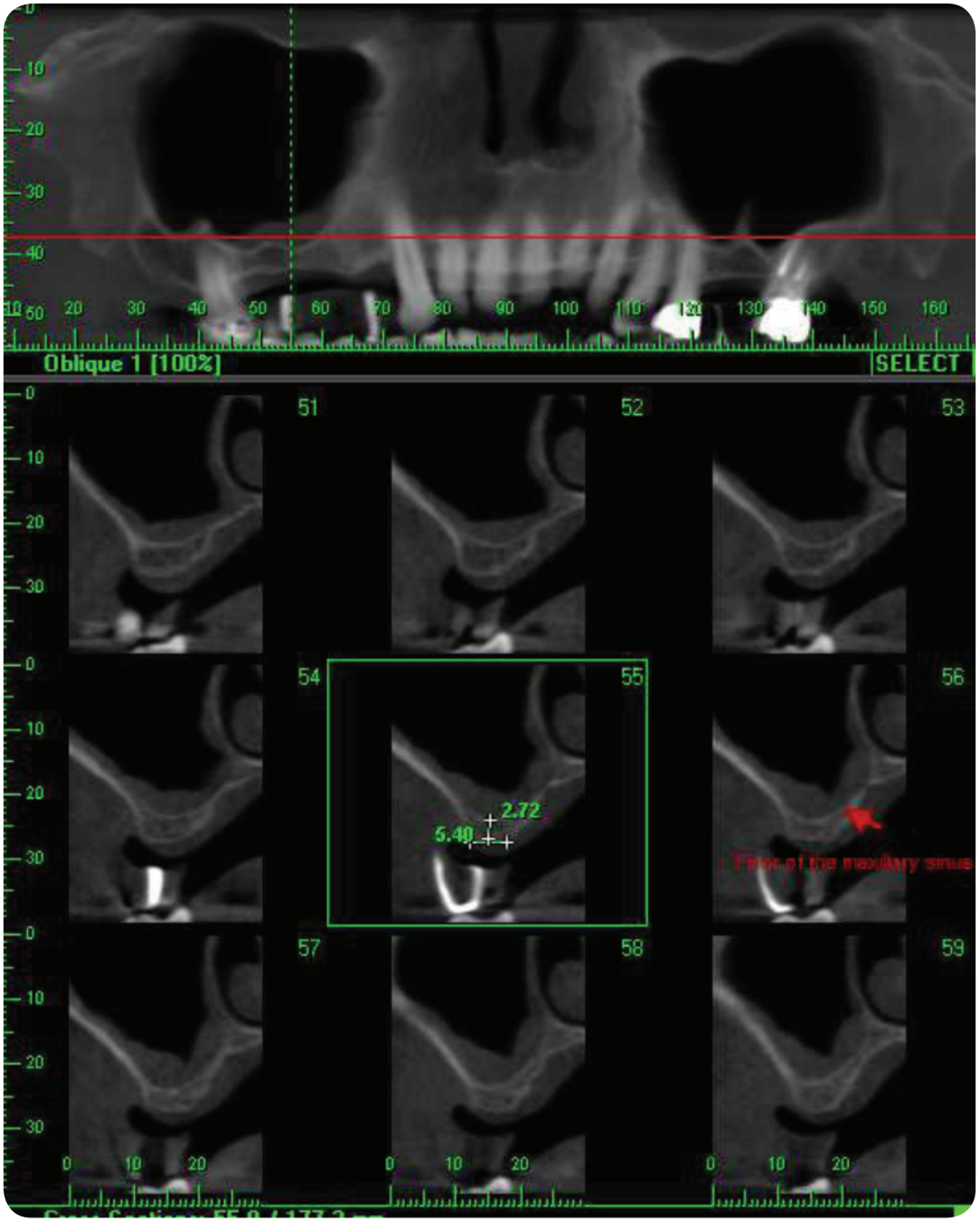

Figure 3: Cross-sectional and panoramic views from the preoperative CBCT scan of the maxilla with radiographic stent with a marker in edentulous area #3, showing cross-sectional morphology of the alveolar process, including width, height, and location of the floor of the maxillary sinus, along with maxillary sinus mucositis.

An external sinus lift procedure was done. A CBCT scan was obtained 2 months after the sinus lift procedure, for evaluation of the osseous graft in the region (Figure 5). This was followed by surgical placement of endosteal implant eight weeks later. A post-operative periapical radiograph (Figure 6) was taken after implant placement, that shows the location and oreintation of the implants in 2-dimension.

Radiographic Diagnosis

Diagnostic radiography is a critical aspect of implant therapy and can impact the outcomes of treatment. Today's sophisticated advanced imaging modalities make it possible to visualize and predict the final outcome of treatment in three dimensions. The aim of this case is to provide information on the imaging modalities for implant dentistry as it relates to the

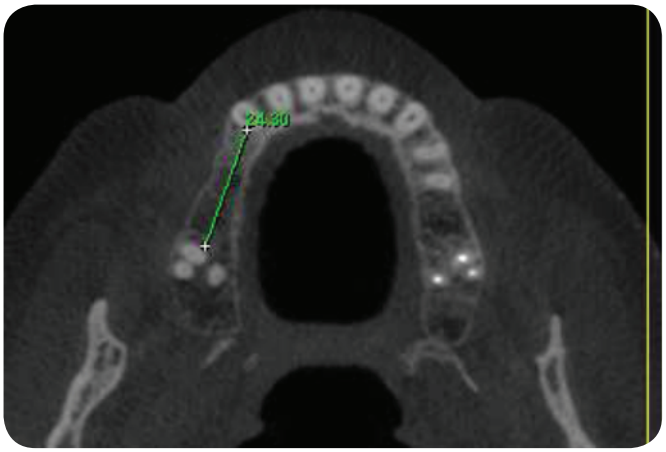

Figure 4: Axial image from the preoperative CBCT scan of the maxilla showing edentulous saddle length in the axial view.

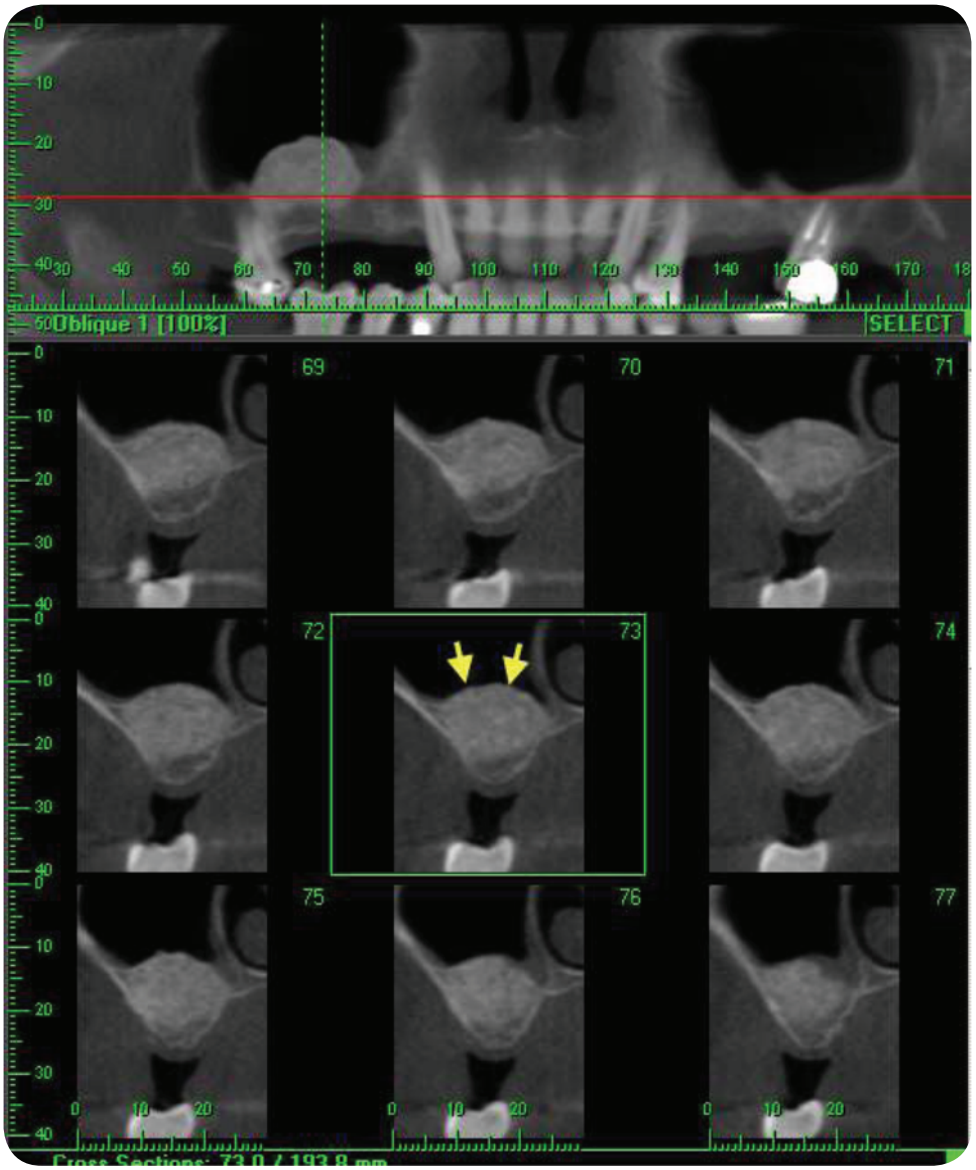

Figure 5: Cross-sectional and panoramic view from the CBCT scan taken after external sinus lift procedure showing the osseointegration of the osseous graft in the right posterior maxilla in edentulous area #3.

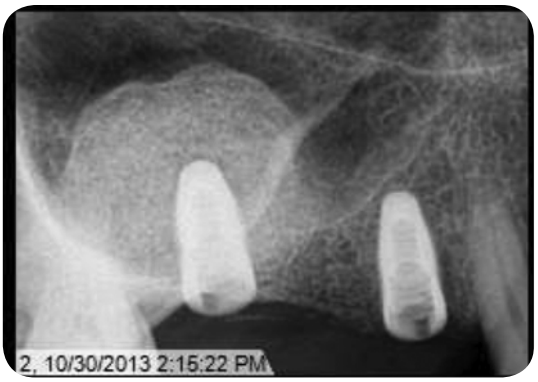

Figure 6: Postoperative periapical radiograph showing the two endosseous implants in the right posterior maxilla.

presurgical, surgical, and restorative components of implant therapy. Basic principles of radiography, which also apply to imaging for implant evaluation, include:

- Appropriate training in imaging technique, including patient positioning, radiograph beam alignment, and receptor position to minimize distortion and improve precision and anatomic accuracy.
- The use of a radiographic stent with radiographic markers for implant sites during imaging.
- Imaging of the proposed implant site, including those areas that could be affected by implant placement.
- Diagnostic quality images with optimum density and contrast, free of artifacts.
- Competence in interpretation of the acquired images.

Imaging Modalities for Implant Diagnosis and Evaluation

1. Intraoral periapical radiography
2. Panoramic radiography
3. CBCT.

A good imaging protocol is critical to produce diagnostic quality images with the least amount of patient radiation dose. This is in alignment with the as low as reasonably achievable (ALARA) principle of radiation protection as per the recommendations of the National Council on Radiation Protection [1,2]. The main advantage of CBCT imaging over intraoral and panoramic radiography is that it provides three-dimensional data of the imaged volume. The range of effective doses for different CBCT devices is published to be between 52 and 1025 μSv depending on the CBCT equipment and the imaging protocol used. This range is equivalent to 4–77 digital panoramic radiographs or 5–103 days of per capita background radiation dose in the USA. In comparison, conventional head computed tomography imparts a much larger radiation dose, with a dose range of 1400–2100 μSv [3]. When choosing a particular imaging protocol, the clinician must be aware of the effect of the technical parameters on image quality and patient dose. Reduction in patient radiation dose in CBCT imaging can be achieved by collimating the beam and using thyroid and cervical spine shielding.

Technical Parameters of Cone Beam Computed Tomography Imaging Protocol

Field of View

The ability to collimate the radiographic beam to fit the size of the region of interest (ROI) results in patient dose reduction along with improved image quality as a result of reduced scatter radiation. The dimensions of the scan volume are primarily dictated by the detector size, shape, beam projection geometry, and the ability to collimate the beam. The ROI should be the primary consideration when selecting the field of view (FOV). The beam may be collimated based on individual diagnostic needs and extend beyond the implant site and include the maxillary sinus or apposing arch. The smaller the FOV, the better the spatial resolution. A scout image taken prior to the acquisition of CBCT helps establish the accuracy of patient positioning within the FOV. This prevents unnecessary reexposure due to faulty positioning [4].

Voxel Size

The CBCT scan data is recorded and displayed as a matrix of individual blocks called voxels (volume elements). The smaller the FOV, the better the spatial resolution and smaller the voxel size. The factors controlling the voxel size in CBCT are radiographic tube focal spot size, radiographic beam projection geometry, and matrix/pixel size of the solid-state image detector [4].

Scan Time

It is desirable to reduce CBCT scan times to as short as possible to reduce motion artifacts due to patient movement. Metallic and beam hardening artifacts can result due to interaction of the radiographic beam with metallic hardware in the mouth, including dental restorations and implants. These artifacts are inherent to the technique and may obscure fine detail in the images [4].

Recommendations for Radiography for Implant Diagnosis and Management

Initial Examination

The purpose of the initial examination is the overall assessment of dentition and osseous structures, planning of location and type of proposed implant, and chronology of different treatment phases. Conventional imaging, such as periapical, bitewing, and panoramic radiographs, would be appropriate for initial examination.

Preoperative Site-Specific Imaging

CBCT is the imaging modality of choice for preoperative site specific assessment. Cross-sectional imaging is a critical component of implant site development especially when sinus augmentation or bone grafting is necessary [5]. The clinical advantage of utilizing CBCT for presurgical imaging can be enhanced by the use of a radiographic stent that will help relate the anatomic location of the proposed implant to surrounding anatomic structures. During imaging, the patient wears a radiographic stent, which is a clear acrylic stent with embedded radiopaque reference markers that indicate the proposed implant sites. This technique provides a precise reference of the location of the proposed implants. The best radiographic markers are nonmetallic, typically made of gutta-percha or composite resin to prevent metallic streaking artifacts. This radiographic stent could further serve as a surgical guide for the angulation of the implant placement. The preoperative site-specific imaging would aid in assessment of RAR characteristics, anatomic and pathologic considerations, and prosthetic considerations.

Residual Alveolar Ridge Characteristics

CBCT imaging allows the assessment of both quality and quantity of the RAR. These characteristics can be determined by vertical height, horizontal width, edentulous saddle length, and thickness and density of the cancellous and cortical bone. There are various methods that classify the quantity and quality of RAR. According to Seibert's classification [6,7], deficiency of RAR can be divided into three categories:

- class I, describing buccolingual loss of contour with normal apico-coronal ridge height;
- class II, describing apico-coronal loss of contour with normal bucco-lingual ridge width;
- class III, a combined loss in apico-coronal and buccolingual dimensions.

Lekholm and Zarb [8] described the quality of RAR as

- type I, homogenous cortical bone;
- type II, a thick layer of cortical bone surrounding a core of dense cancellous bone;
- type III, a thin layer of cortical bone surrounding a core of dense cancellous bone;
- type IV, a thin layer of cortical bone surrounding a core of low density cancellous bone.

A thorough assessment of all of these quality and quantity characteristics requires the use of cross-sectional images.

Anatomic and Pathologic Considerations

- Anatomic considerations in maxillary implant placement:
  - *Floor of the maxillary sinus and nasal cavity.* The available height of RAR for implant placement in the maxilla extends between the crest of the alveolar ridge and the floor of the maxillary sinus or nasal fossa. Assessment of the sinus and nasal cavity floor is necessary to prevent violation of these structures during implant placement or bone augmentation procedures.
  - *Nasopalatine canal and foramen.* This anatomic landmark is located in the maxillary midline. The morphology and course of the nasopalatine canal should be taken into consideration before placement of anterior maxillary implants. Violation of this structure may result in neurosensory loss, postoperative hemorrhage, or lack of osseointegration, leading to implant failure.
- Anatomic considerations in mandibular implant placement:
  - *Inferior alveolar nerve (IAN) canal and mental foramen.* The location and the course of the inferior alveolar canal are very critical for implant placement. There may be normal anatomic variations in the course of the nerve buccolingually, varying caliber or absence of distinct cortical boundaries that may negatively impact the outcome of implant therapy. Other common variations include extension of the nerve anteriorly, such as anterior loop, bifid IAN, or accessory foramen. The mental foramen is the opening of the IAN on the buccal mandibular cortical plate in the premolar region. Anatomic structures to avoid in the anterior mandible are the lingual foramen and lingual canal, in addition to larger caliber neurovascular channels.
  - *Submandibular and sublingual depressions.* These are concavities on the lingual aspect of the

mandible in the posterior and anterior mandible respectively. Improper angulation of the long axes of the implant may lead to perforation of the lingual cortical plate and result in injury to the salivary gland and vasculature.

- *Labial concavity.* The anterior maxillary region, also known as the esthetic zone, may present with a labial concavity due to alveolar atrophy due to prolonged edentulism. This may require bone augmentation for successful treatment outcome with regard to esthetics and function. Improper vertical angulation of an implant may result in perforation of the buccal cortical plate.

Prosthetic Considerations

A prosthetically driven treatment plan in addition to anatomic and surgical considerations is essential to optimize final results of dental implant therapy. Articulated diagnostic casts are used to assess the residual ridge, remaining dentition, existing occlusion, and visualization of the ideal implant-supported restoration. A radiographic template prepared from this information is crucial for necessary modification of angulation of the proposed endosseous implant in order to allow subsequent functional loading of the prosthesis. Thus, cross-sectional imaging in the form of CBCT is vital in correlating the anatomical limitations and the desired angulation of an implant to the desired prosthetic outcome.

Intraoperative Imaging

Some instances may warrant imaging during the implant placement procedure, to either confirm correct placement of implant or to locate a lost implant. This can be achieved through intraoral or panoramic or CBCT imaging.

Postoperative Imaging

Postoperative imaging may be used to assess the bone–implant interface and the alveolar height around the implant. However, periodic imaging in asymptomatic patients is unnecessary. This may be achieved through periapical, panoramic, or CBCT imaging. One of the drawbacks of CBCT is the beam hardening and streaking artifacts due to metallic implant fixtures that may obscure subtle changes in the peri-implant bone. Panoramic and periapical radiography may prove beneficial in this regard. In case of clinically symptomatic implants, peri-implant radiographic changes, such as a radiolucency along the implant outline and crestal bone loss, may implicate a failing implant [9]. Clinical correlation would substantiate this diagnosis. Cross-sectional imaging may be necessary for planning retrieval of a failing implant.

Self-Study Questions

(Answers located at the end of the case)

A. What is the imaging modality of choice for evaluation of a single implant site in the region of tooth #25, prior to extraction of the tooth?

B. After extraction of tooth #25, a CBCT scan is prescribed for pre-implant site assessment. What are the technical considerations while planning the CBCT procedure?

C. What is the imaging modality of choice for evaluation of a complex implant case with multiple potential implant sites?

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Answers to Self-Study Questions

A. The best imaging modality for evaluating a single potential implant site, prior to extraction of the tooth is with a periapical or panoramic radiograph.

B. The best imaging modality of choice for pre-implant site assessment is CBCT with radiographic stent. For a single-site cross-sectional evaluation a smaller FOV and a smaller voxel size must be chosen that includes the ROI with regions just adjacent to the implant site and opposing tooth. This limited FOV scan is in compliance with the ALARA principle.

C. If imaging is required for evaluation of multiple potential implant sites, CBCT would be the imaging modality of choice. The vertical height of the FOV can be adjusted to include one jaw, both jaws, or a larger area including the temporomandibular joints.