Dental Implantology

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Dental Implant Basics

- An implant system can be divided into an endosseous part, a transmucosal section, and a prosthodontic interface.
- A dental implant is the surgical component that interfaces mechanically and biologically with the bone to support a dental prosthesis.
- Most commonly used implants are screw root forms that are threaded into a prepared osteotomy, reliant on threads for initial stability via mechanical retention.
- Implant body can be divided into a crest module, body, and an apex (see Fig. 4.1).
- Implants can be designed with the neck of the implant supra-crestal (tissue level), crestal (bone level), or sub-crestal.
- Supra-crestal (soft tissue level) implants are favored to reduce marginal bone loss or saucerization around implants when compared to butt-joint bone level implants, by moving the neck above the bone and preventing bacterial colonization of the microgap. With the advent

For this section it is important to know the implant system *you use*. Know the sizes, drilling sequence, surface modification, thread distance, and abutments. It is not uncommon to be told by the examiners that there is no financial barrier to implant therapy in these cases. Make sure that you offer a defendable treatment plan based on how you would manage a case and not based on what you think the examiners want to hear.

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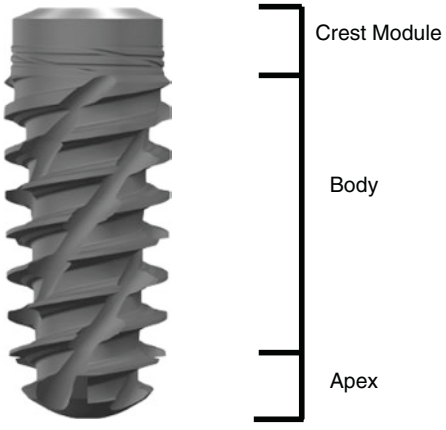

Fig. 4.1 Dental Implant. Straumann BLX Dental Implant. (Image Courtesy of Straumann)

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of platform switching, and internal conical connections, that can also be obtained with bone level or below the bone level implants.

Length

- Important for implant primary implant stability, and influences immediate loading. Once secondary implant stability has been achieved (osseointegration), length is not as important. (Side note: thread pitch, drilling sequence, and bone quality also play a great role in gaining stability prior to osseointegration) [1].
- Increases surface area of bone-implant interface.
- Most stress of implant at first 5 mm making diameter important in stress reduction.

Diameter

- Larger diameter implants increase the surface area of bone-implant interface.
- Disperses forces in poor bone, thereby reducing risk of overload.
- Reduces the magnitude of force to system when used as part of bridgework or cantilever.
- Increased diameter can allow for better emergence profile for larger crowns. In modern platform switch implants this is not the case, since the choice of prosthetic components is independent of the implant diameter.
- Increased diameter of crest module size decreases the risk of implant fracture and prosthetic component fracture.
- Concern for stress shielding from wide diameter implants leads to bone atrophy due to lack of strain transfer to the bone.
- Increased diameter implants require a larger drilling, thereby reducing bone thickness around the implant. There is a current trend to not use wide body implants (>5 mm diameter) in order to preserve more alveolar bone.
- Narrow (Reduced Diameter) implants are indicated in the anterior region of the maxilla or mandible. Narrow implants are more prone to implant fracture and internal connection damage, especially when placed in the posterior region. When placed in the posterior region, they shoud be splinted with other(s) implants. Modern alloys (TiZi) provide additional mechanical resistance to narrow implants, increasing survival rates.

Shape

Parallel wall:

- Provides increased surface area.

Tapered:

- Provides stability by creating pressure on cortical bone, which is good for poor bone quality sites.
- Allows compression in poor bone quality sites.
- Reduced apical width allows for placement in constricted sites.
- Reduced overall surface area increases with taper.

Implant Surface Modifications

- Hydroxyapatite (HA) – HA-coated implants are no longer used as the processing methods convert HA to tricalcium phosphate which is rapidly absorbed and is easily colonized with bacteria. Additionally, there have been problems with delamination of HA.
- Micro-rough surfaces 0.5–2.0 microns (minimally rough 0.5–1, intermediately rough 1.0–2.0, and rough 2.0–3.0 microns) create peaks and depressions in the implant to increase surface area. Roughened surfaces can be created by acid etching with such chemicals as sulfuric, hydrochloric, and hydrofluoric acids. Spraying the implant surfaces with titanium oxide, hydroxyapatite, and aluminum oxide is another option. Micro surface roughness causes an increased implant to bone surface area, clot retention, aids in earlier osseointegration, and leads to harder and stronger bone around implants by increasing mRNA expression of osteonectin and osteocalcin [2].
- Electrowetting – wettability of implants important to improve plasma protein adherence and mesenchymal cell adherence and differentiation. Many methods are available, but commonly fluoride and magnesium ions are used. Some manufacturers package implants in saline.

Crest Module

- Microthreads – preserves both bone and soft tissue around cervical portion of implant fixture by dissipating forces around crest. Can facilitate higher incidence of peri-implantitis

due to plaque retention if the implant is exposed to the oral cavity.
- Microgap – connection between implant and abutment.
- Anti-rotational component – platform of the crest module has an anti-rotational feature to retain prosthetic component. This can be a platform such as an external hex (external connection) or within the implant body itself (e.g., internal hex, Morse taper, octagon, internal grooves, or pins).
- External connection – connection to implant that is superior to coronal portion of implant creating a butt joint connection. Have higher prevalence of screw loosening, rotational misfit, and microbial penetration. Classic example is the External Hexagon connection.
- Internal connection – internal connection to implant, seen in most modern implants. Can have parallel walls (Internal Hexagon) or morse cone type (connical connection). Conical connection preferred vs. flat connection as it can disperse load and prevent microgap elongation on function with fluid invasion. Connical connections have Improved microbial seal, reduced screw loosening, increased joint strength, and increased platform switching abutment options.
- Platform switching – it is an horizontal offset between the implant connection and the cervical area of the abutment. This method can help to reduce crestal bone loss using a narrower restorative abutment compared to the crest module which leads to a more superior position of the epithelial attachment around the neck of the implant. This technique also medializes the implant abutment interface, which redirects stress from the crestal bone [3]. Inflammatory infiltrates are positioned away from the crestal bone leading to less bony destruction/loss [4, 5].

Materials
- Titanium is a metal that presents low-weight, high-strength/weight ratio, low modulus of elasticity, excellent corrosion resistance, excellent biocompatibility, and easy shaping and finishing.
- Most commonly used: Grade 4 pure titanium (cpTi), titanium-zirconium alloy, and titanium-6 aluminum-4 vanadium (Ti 6AL-4V).
- Biocompatibility due to surface dioxide layer that forms almost instantaneously upon exposure to air (2–10 nm by 1 second). Important role in corrosion resistance, biocompatibility, and osseointegration. This oxide layer is composed of titanium dioxide (TiO_2).
- Zirconia: Implants produced with zirconia are biocompatible, bioinert, radiopaque, and have a high resistance to corrosion flexion and fracture. They are typically considered "non-metallic" and are white in color.

Criteria for Implant Success
- Immobile when tested clinically.
- No radiographic evidence of peri-implant radiolucency.
- Vertical bone loss is less than 0.2 mm annually after the first year of service of implant.
- Implant performance is characterized by an absence of persistent or irreversible signs and symptoms of pain, infection, neuropathy, paresthesia, violation of mandibular canal.

(These aforementioned success criteria were based on radiography, clinical signs, and symptoms. There are other factors today that we would take into account to establish implant success. New parameters to take into account include esthetics, soft tissue integrity/appearance, patient satisfaction, and prosthodontic parameters) [6].

Important Numbers to Know About Implants
- Distance of 1.5 mm between implants and natural teeth to allow for lateral biologic width. Violation leads to bone loss around implants and adjacent structures.
- Normal bone loss is <1.5 mm for the first year and 0.2 mm per year after (These numbers do not take into account the prosthetic construct used. For example, an implant supported FPD where forces are evenly distributed may have less bone loss per implant in the entire construct. Platform switching has also lessened the microbial bioburden that contributes to overall bone loss).
- A minimum distance of 3 mm between two implants must be adhered as to maintain interproximal bone height which provides room for restorative components.
- Minimum Distance of 1 mm of bone between implant and buccal/lingual wall. In the aes-

thetic zone, 2 mm posterior to buccal wall is desired for emergence profile and to preserve the buccal bone.
- Minimum Distance of implant apex is 1 mm from nasal floor.
- Minimum Distance of implant apex is 2 mm above the inferior alveolar nerve.
- Implant body 5 mm in front of mental foramen.
- Head of bone level type implant should be 2–3 mm below gingival margin of planned crown to allow space for emergence profile.
- Each 0.25 mm increase in diameter yields a 10% increase in surface area.
- Classic integration timelines for smooth surface implants are 3 months for the mandible and 6 months for the maxillae. Modern implants surface treatments (SLA) can decrease time to as early as 6–8 weeks for conventional loading.
- Ensure that drills are sharp and use new drills often, especially for dense bone.
- Thermal necrosis during drilling occurs above temperatures of 47 °C. Keep RPM to 2000 or less and ensure pumping action during drilling to allow water to reach base of osteotomy.
- Minimal intra-arch space of 5 mm for cement retained and 8 mm for screw retained for single crowns. More inter-arch space may be needed for overdentures or fixed hybrid prosthetics.
- Minimal interarch clearance for a bar attachment is 12 mm.
- Implants in a growing child will lead to a submerged implant, that is more palatal/lingual, out of occlusion and deep into alveolus, secondary to facial and dentoalveolar growth adjacent to the implant. Implants should be placed after confirmation of growth cessation by following growth indices for 1 year such as hand-wrist or spine radiography. Some authors recommend a minimum age of 15 for females and 18 for males. Literature shows reports of adult patients with continous alveolar growth, leading to vertical defects around the implant area.
- Most implant drills have tapered tips of 0.5 mm beyond their established measurement.
- In comparison to a medical grade CT, cone beam computed tomography (CBCT) uses about 2% of radiation dose.
- 40–60% of expected bone loss occurs during the first 36 months after the tooth is extracted.
- Contact point to crest of bone with presence of papillae [7]:
  - 3 mm – 100%
  - 4 mm – 100%
  - 5 mm – 98%
  - 6 mm – 56%
  - 7 mm – 27%

Osseointegration

- Process of which there is a bone to alloplastic interface without the interposition of non-bone tissue, which is clinically asymptomatic and is maintained in bone during functional load (based on electron micrographic findings).
- Classic definition of osseointegration by Branemark: osseointegration is the direct, structural, and functional connection existing between ordered, living bone and the surface of a functionally loaded implant.
- Primary stability: mechanical stability achieved at the moment of implant placement. Depends on bone quality (density), shape of implant, and adequacy of surgical technique. Can be optimized when these three factors are considered and technique is adequate for existing type of bone and implant placed.
- Secondary stability: biological stability, achieved after bone healing (osseointegration). Influenced by bone quality, implant surface, overall health of patient, and loading protocols.
- Two mechanisms of osseointegration: (1) distance osteogenesis occurs from existing bone and blood supply and (2) contact osteogenesis (de novo bone formation) from osteogenic cells.

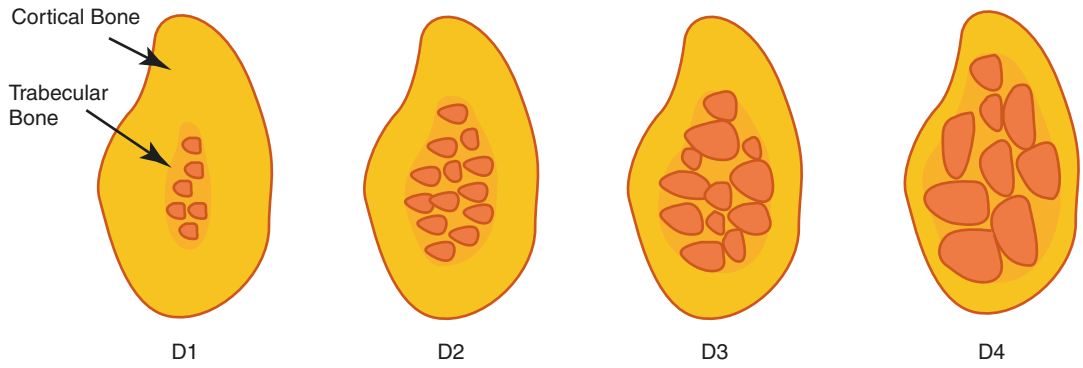
Bone Quality

- Implant survival is multifactorial but arch location plays a vital role. Most failures occur in softer bone.
- Bone density is directly correlated to bone strength.

- Lekholm and Zarb, in 1985, classified based on the ratio of cortical and cancellous bone using radiographs [8].
  - Type 1 bone is composed mostly of compact bone.
  - Type 2 is mostly a compact bone surrounded by a core of trabecular bone.
  - Type 3 is composed of thin layer of cortical bone surrounded mostly by trabecular bone.
  - Type 4 is composed of thin layer of cortical bone surrounded by a core of low-density trabecular bone.
- In 1998, Misch described bone densities in the edentulous maxilla and mandible based on macroscopic specimens based on cortical and trabecular bones. In 1999 Misch updated his classification to include bone density independent of region of jaw while taking into consideration Hounsfield units. Classes range from D1 to D4, with D1 being the most dense (see Fig. 4.2) [8].
- Misch classification: Bone elasticity increases from D1 to D4, leading to increased micro strain and implant mobility leading to failure. The cortical cancellous ratio decreases from D1 to D4.
- Crestal strain and stress transfer increase with decreasing bone density.
- As bone density decreases, it is prudent to treatment plan longer/wider implants with maximization of the number of implants and designs, which increase surface area.

Testing for Implant Stability

1. Insertion torque of an implant should ideally be 35 Ncm or more. Over Torquing >80 Ncm may impair implant healing.
2. Absence of clinical mobility with 500 g in any direction.



TYPE	Description	Location	Hounsfield CT
D1	Dense cortical bone	A. Mandible	>1250
D2	Thick cortical and course trabecular	A. Mandible P. Mandible A. Maxilla	850–1250
D3	Thin cortical compartment with dense trabecular	A. Maxillae P. Maxilla P. Mandible	350–850
D4	Fine trabecular, extremely thin cortical	P. Maxilla	150–350

Fig. 4.2 Misch bone density classification. (Modified from Torabinejad et al. [21])

3. Implant stability quotient (ISQ) – a resonance frequency analysis with a number between 1 and 100. High stability, >70 ISQ; medium stability, between 60 and 69 ISQ; and low stability, <60 ISQ.

Loading Protocols

1. Immediate loading – prosthesis is delivered up to 7 days after implant placement.
2. Early loading – prosthesis is delivered 6–12 weeks after implant placement. Some implant surfaces consider 8 weeks as conventional loading.
3. Conventional loading – prosthesis is delivered after osseointegration is achieved. Classic period is 3 months for mandible and 4–6 months for maxilla.

Pre-surgical Workup

CC/HPI: Patient's desires or concerns, prior prosthetic reconstructive efforts, expectations, how long has the patient been without teeth, and causes of tooth loss.

REMEMBER: the patients want teeth and not implants. Make sure that all surgical procedures follow a restoratively-driven plan, in order to ensure the best possible restorative outcome.

Medical History/Medication History/Surgical History

- Smoking – reduced success rate, about 6.5–20% lower than in nonsmokers [9].
- Diabetes – need longer healing times to reach stability [10, 11].
- Osteoporosis – studies have found similar rates of implant failure in patients suffering from osteoporosis vs patients with normal bone densities. Some weak evidence reduced bone healing and may consider longer healing times [12–14]. Higher risk for failure of bone grafting procedures in this patient population [15].
- Oral bisphosphonates – AAOMS recommends a drug holiday of 2 months, for patients taking oral bisphosphonates, prior to surgery. The bisphosphonate should be held until osseous healing has occurred [16].
- Avoid implants in patients using IV bisphosphonates or antiangiogenic drugs.
- IV bisphosphonates or antiangiogenic drugs for cancer.
- Denosumab – no studies to support discontinuation at this time [16].
- Radiation of the head and neck: consider HBO if necessary (>60 Gy); failure rates similar with the advent of newer radiation protocols [17].
- Parafunctional habit – consider wider diameter or stronger alloy implants. Judicious planning of designing load-sharing prosthetics, occlusal adjustments of prosthetics, and longer healing time for loading bearing bone formation may help counteract the destructive forces of parafunctional habits.
- TMD complaints –assess for placement and length of procedure.
- Debilitating disease – e.g., rheumatoid arthritis, scleroderma, or Parkinson's disease that may cause xerostomia due to medications and make dental care difficult to maintain. Consider home assistance and prosthetic type, fixed vs. removable.

Evaluation

- Head and neck exam as expected on all patients.
- Lip support/gingival display on repose and animation. Short upper lip, high smile line, or hyperanimation may reveal artificial teeth and flange.
- Width of remaining ridge. If edentulous a prosthesis with flange may be desirable vs. fixed crown and bridge to provide lip support and better esthetic outcome.
- Papillae position and gingival margins of adjacent teeth.
- Condition of the oral cavity and restorability of teeth to determine best prosthetic type.
- Palpation of muscles of mastication and observe for hypertrophy of masseter, concern for parafunctional habit. Assess for wear pattern of teeth, bruxism, or occlusal interferences.
- Occlusion – assess for angle classification, scissor bites, and cross bites and how these occlusions may affect implant success. May

create prosthesis design issues or cantilevers. May require orthognathic procedures.
- Inter-incisal opening ability to access site of implant.
- Periodontal health/oral hygiene. Periodontal probings to ensure healthy cervical margins of adjacent teeth. Higher failure rate in those with poor periodontal status and poor hygiene (should be controlled before dental implant placement).
- Gingival biotype: assess visibility of probe through gingival sulcus. Thick biotype associated with greater soft tissue stability, less recession, and is more resilient to oral flora.
- Keratinized tissue – 2 mm or more of keratinized gingivae reduces gingival inflammation, increases implant survivability, and reduces marginal bone loss.
- Interarch crown height space, ideal 8–12 mm for fixed restoration or 12 mm or more for bar connections.
- Ridge contour – bone loss may push prosthesis palatal/lingual if restored with implant which will lead to extensive ridge overlap or food trap. Bone grafting may be indicated.
- Articulated diagnostic models aid in planning with diagnostic wax-ups, stent fabrication, and easier measurements such as for prosthetic space.
- Photos of patient in repose, full smile, lateral views for implants in the aesthetic zone.

Radiography

- Overall use is to rule out pathology, assess bone quality, dental relationships, and proximity to vital structures.
- Periapical films – may use for initial evaluation, intraoperative assessment, and postoperative monitoring. However, periapical films lack reproducibility and it is often difficult to assess the proximity of vital structures (best indicated to observe crestal bone around adjacent teeth especially in the aesthetic zone).
- Orthopantogram – used as a generalized scout film that allows the visualization of vital structures, bone quality, and the presence of pathology. A major drawback is magnification. Vertical magnification is more uniform than horizontal magnification and can be overcome by radiographic markers of a known size.
- Cone Beam Computed tomography – allows for accurate assessment of distances to vital structures. Can view the height and width of ridge to plan for bone graft needs. Software allows for easier planning with dental implant database. Digital workflow improves collaboration and interaction with prosthodontic plan. Involves merging and superimposition of DICOM and STL files (created from intraoral or model scanning) data to create a fully guided stent for guided surgery. For the vast majority of implant cases, a CBCT is the indicated imaging modality.
- Hounsfield unit assessment gives objective measures of bone density in region and is based on medical CT imaging. CBCT imaging utilizes a gray value and is not directly correlated to Hounsfield units.

Implant Complications of Implant Placement

Failure to Integrate/Fibrous Connection Likely due to lack of primary stability, type IV bone, inadequate preparation of osteotomy (over-preparation of osteotomy, excessive torque when placing implants in type 1 bone, poor irrigation leading to bone necrosis and infection). Treatment is to remove the implant and assess the need for graft for future implant placement or if ridge allows preparing the site for a wider or longer implant. Soft tissues recession may require additional soft tissue graft or place implant in a secondary procedure.

Encroachment to IAN Canal Patient may express discomfort as though they experienced an electrical shock, or a rush of blood may come through the osteotomy site. Verify implant position with radiography (3D imaging preferred). The implant should be removed immediately if noted to encroach upon the nerve. In theory removal allows psychological therapy for the patient, pathway for escapement of debris and irritants, ease for future nerve repair, and takes pressure of the nerve (if not severed). No bone graft should be placed into the site. Steroid application to the injury site and high-dose steroids orally for a week may help reduce

neuropathy. NSAIDs such as ibuprofen 800 mg q 8 h for 3 weeks also have been recommended in the literature. The benefit of steroids and NSAIDs is questionable. Neurosensory testing is evaluated serially. If the patient has anesthesia/dysesthesia for 3 months or hypoesthesia for 4 months, then consider microneurosurgery. If no evidence of encroachment with patient complaining of a neurological disturbance, then one cannot rule out injection injury. Consider removing implant.

Sinus Penetration Implant penetration into maxillary sinus of 1–2 mm has been shown to be fully covered with sinus membrane and partially by bone in animal studies. No difference in stability is noted. Penetration of 3 mm or more showed exposure into the sinus cavity without any coverage.

Mandible Fracture Usually occurs late once implants are loaded but can also happen when placing implants in extremely atrophic mandibles. Recommended at least 6 mm in vertical height and width required for implant placement. If there is not enough bone stock, then a bone graft is indicated. Treatment follows basic trauma principles. Treatment of the edentulous mandible may require a large reconstruction plate with consideration for bone grafting.

Excessive Countersinking May cause excessive bone loss and difficulty with connections. May also result in loss of primary stability.

Peri-implantitis Infectious disease surrounding a load-bearing dental implant with features of bone loss and inflammation of the soft tissue. Associated with gram-negative anaerobes including *P. gingivalis, P. intermedia, and Aggregatibacter actinomycetemcomitans.* Symptoms include bleeding on probing, bone destruction, suppuration on probing, erythema, hyperplasia, probing depth >5 mm, mobility of implant, and swelling. Pain is normally only present in the setting of acute infection.

Adequate soft tissue management (plan to increase or maintain thick keratinized tissue around neck of implant) can reduce the chance for periimplantitis.

Treatments

1. Local debridement – exposure and cleaning with instrument softer than titanium. Consider rubber cup polisher with paste, plastic scalers, abrasive air powder treatment, and interdental brushes.
2. Decontamination – 40% citric acid with a pH of 1 for 60 seconds, chlorhexidine, tetracycline (50 mg/ml saline for 2 minutes), or application of local antibiotics (e.g.,tetracycline granules), Er:YAG or CO_2 laser or 3% H_2O_2.
3. Surgical – open flap combination of debridement and decontamination with allograft/autograft with membrane.
4. Removal of implant.

Sublingual Gland Injury/Sublingual Artery Palpate ridge or CBCT to visualize the sublingual fossa. Injury can be caused by perforation through the lingual cortical plate. Ranula or bleed can occur. Evaluate floor of mouth and be mindful of the airway. Sublingual artery bleed can be managed by exploration with cautery/ligation (Consider treatment in the hospital setting for airway protection). If ranula develops, consider removal of sublingual gland.

Bone Augmentation

Bone Grafting

- Heals by creeping substitution – a process by which osteoclasts resorb bone creating new vascular channels with osteoblastic bone formation resulting in new haversian systems. Laying down new bone and subsequent resorption of old bone.
- Osteogenic – transfer of osteocompetent cells for de novo bone formation, e.g., autografts.
- Osteoinduction – bone formation by stimulation of host mesenchymal cells to differentiate, e.g., allograft, bone morphogenic protein.
- Osteoconduction – providing scaffolding for new bone formation propagated by native bone. Does not contain proteins or cells, e.g., xenograft.

Bone Graft Materials

Autogenous – composed of tissue from the same person

- Osteogenic, osteoinductive, and osteoconductive.
- Gold standard.
- Disadvantage is a second surgical site.

Allogeneic – grafts taken from another individual of the same species but different genotype

- Osteoinductive and osteoconductive.
- Strict screening for infections, malignant neoplasm, degenerative bone disease, hepatitis B or C, STDs, autoimmune disease, or other diseases that may affect bone quality.
- Comes as a mineralized freeze-dried bone allograft (FDBA) or demineralized freeze-dried bone allograft (DFDBA). Both provide type 1 collagen which is the exclusive organic component of bone.
- Methods to decrease antigenicity – freeze-drying, irradiating, dry heating.

Xenograft – grafts taken from another species

- Osteoconductive.
- No organic component.
- Treated by sintering at 900 °C or high alkaline solution. Risk of prion transmission (e.g., bovine spongiform encephalopathy) is theoretical.
- Hydroxyapatite crystalline structure allows for ingrowth of vessels and migration of osteogenic cells.

Recombinant Human-Bone Morphogenetic Protein-2 (BMP)

- Part of transforming growth factor β superfamily.
- Recombinant DNA technology in Chinese ovarian hamster cells allows for transcription and collection of non-contaminated protein.
- Water soluble, requiring a collagen type 1 carrier (acellular collagen sponge) for slow release. Requires 15 minutes of absorption.
- Concentration of 1.5 mg/cc mixed with sterile water (do not substitute with normal saline as too hypertonic).
- Chemotactic for preosteoblasts and stem cells as well induces expression of VEGF by osteoblasts.
- Only on label use is currently for sinus augmentation or alveolar ridge reconstruction.
- Will have extensive edema due to influx of fluid and cells from the chemotactic and neovascularization activities of BMP.
- Allow healing of 6 months prior to implant placement.
- Contraindications: (1) pregnancy, (2) allergy to rhBMP or type I bovine collagen, (3) active infection at recipient site, (4) active or history of malignancy at site, and (5) skeletal immaturity.
- Postoperative steroids and icing of tissue may reduce the intensity of swelling.

Platelet-Rich Plasma (PRP)

- Platelet-derived growth factors act as a mitogen (encourages cell division) and encourage osteoid production and endothelial cell replication.
- PRP is a blood clot that is highly concentrated with platelets, about 1 million platelets/μL.
- Alpha granules in platelets secrete the growth factors that bind to transmembrane receptors to induce its effect, initiating a faster initial cellular response.
- Collection tube contains citrate dextrose as anticoagulant, which works by binding to calcium.
- The platelets are spun down either in two spins (separation spin followed with a concentration spin) or some manufacturers offer single spin units.
- Activated via the addition of $CaCl_2$ and thrombin.
- Utilized in soft and hard tissue grafting.

Platelet-Rich Fibrin (PRF)

- Platelet-rich fibrin (PRF) was developed as an improved formulation of the previously utilized platelet-rich plasma (PRP), to serve as a three-dimensional scaffold to biologically enhance healing.
- This new approach is based on the concepts that were introduced over a decade ago con-

sisting of a platelet concentrate without the use of anticoagulants.
- PRF is obtained simply by centrifugation without anticoagulants and is therefore strictly autologous.
- This fibrin matrix contains platelets and leukocytes as well as a variety of growth factors and cytokines including transforming growth factor-beta1 (TGF-β1), platelet-derived growth factor (PDGF), vascular endothelial growth factor (VEGF), interleukin (IL)-1β, IL-4, and IL-6.
- These factors act directly on promoting the proliferation and differentiation of osteoblasts, endothelial cells, chondrocytes, and various sources of fibroblasts.

Classification of Cawood and Howell

- Class 1: Dentate.
- Class 2: Immediately post-extraction.
- Class 3: Well-rounded ridge, adequate in height and width.
- Class 4: Knife-edged ridge, adequate in height and inadequate in width.
- Class 5: Flat ridge, inadequate in height and width.
- Class 6: Depressed ridge with varying degrees of basal bone loss that may be extensive but follows no predictable pattern.

Maxillary Sinus and Grafting

Anatomy

- Schneiderian membrane is 0.13–0.5 mm thick and is composed of respiratory epithelium.
- Paired sinuses with a mean size of 15 ml per sinus. Width ~2.5 cm; height ~3.75 cm.
- Sinus ostium is located in superior medial sinus wall (halfway in the A-P distance of the sinus just below the orbital floor). It is usually 25–35 mm above the antral floor. It opens up to the middle meatus via the infundibulum.
- Underwood's septa – fine bony projections from the floor of the maxillary sinus, which can cause two or more compartments and complications during sinus grafting. One septum is present in about 90% of patients.

Table 4.1 Sinus lift methods in relation to alveolar bone height

Technique consideration based on remaining alveolar ridge height (based on 10 mm length implant)	
≤4 mm	Lateral approach and delayed implant placement
>4 mm	Lateral approach/summer approach with simultaneous implant placement
6-8mm	Summer osteotome technique/internal lift (≤2 mm) with immediate implant placement
+10+	Placement of implant

- Vascular supply to maxillary sinus is from branches of the maxillary artery:
  1. Posterior superior dental artery
  2. Anterior superior dental arteries
  3. Greater palatine artery
  4. Lesser palatine arteries
  5. Lateral and posterior nasal branches of the sphenopalatine artery
- The venous flow occurs via the facial vein, the sphenopalatine vein, and the pterygoid plexus.

Preoperative Evaluation

- PMHx – recent upper respiratory tract infection, history of sinusitis or chronic sinus disease, sinus or nasal surgeries, otitis media, and smoking. Chronic steroid use may thin out membrane, making it more fragile during sinus procedures. Reduction of sinus volume may lead to worsening of sinus symptoms. Smoking has not been shown to reduce sinus lift viability, but does affect implants. If there is acute sinus issue, delay until resolves.
- Adequate inter-arch space.
- Adequate remaining alveolar bone (see Table 4.1).
- Discussion with restorative doctor for stent/surgical plan.
- For Summer's technique, Meniere's or Meniere's-like diseases are contraindications.
- CBCT/CT scan – rules out pathology and identifies remaining width and height of alveolar ridge, sinus topography including septae, air fluid levels, and presence of polyps.

- Antral pseudocyst/mucocele – should be removed/aspirated 6 months prior to lift and re-evaluated for recurrence. A relative contraindication.

Lateral Approach (Also Known as the Tatum's Technique)

1. Local anesthetic for hemostasis and insufflation.
2. Incision should be palatal to the alveolar ridge to reduce risk of postoperative fistula if no immediate implant is planned. A crestal flap should be utilized if an implant is planned at time of augmentation.
3. Ostectomy – thin out lateral sinus wall exposing sinus or window outline (quadrilateral ostectomy) to act as superior bony roof. The inferior extent should be 1 mm superior to the floor. Many surgeons now use piezosurgery to reduce perforation rate from 30% with conventional burs to about 7%.
4. Elevation of sinus membrane with piezosurgery with non-cutting blade along perimeter or sinus curettes. If patient is awake, asking them to inhale allows visualization of adherent membrane. Check for perforations.
5. Place graft material medially to ensure adequate bulk toward the medial aspect of the sinus cavity. In simultaneous implant placement, after lifting the sinus membrane and preparing the implants, a graft should be placed first, then implants, and then more graft material. Materials include autogenous (gold standard, good for larger grafts), allograft, xenograft, or alloplastic. Non-autogenous grafts have similar success rates, only a small percentage lower.
6. Placement of absorbable membrane at bony window.
7. Suture to watertight closure of flap.

Summer's Technique (Transalveolar, Vertical or Internal Approach)

1. Local anesthetic for hemostasis and insufflation.
2. Crestal incision to expose ridge.
3. Start osteotomy with 2 mm twist drill to 1 mm below sinus floor.
4. Guide pin placed and PA taken to ensure subsinus ideal position.
5. Osteotomies of different gauges are now malleted 2 mm higher than native bone using up to appropriate gauge of planned implant.
6. Test with Valsalva and hand mirror to evaluate sinus integrity.
7. Placement of autograft/allograft and work into sinus space created to dome sinus.
8. Placement of implant.
9. Repair incision with sutures.

Postoperative Management

- Sinus precautions: no nose blowing for 2 weeks, sneeze with mouth open, no pressure changes such as scuba diving and use of straws or wind instruments.
- Antibiotic with sinus coverage (e.g., amoxicillin 500 mg q 8 h × 7 days), oxymetazoline 0.05% q 12 h for 3 days, saline nasal spray PRN congestion, pseudoephedrine 30 mg q 6 h PRN congestion.
- Allow 6 months for graft consolidation.

Complications

Sinus Perforation If perforation is 2–3 mm, will likely self-repair by folding over or blood clot formation, consider collagen wound dressing. If perforation is 5–10 mm, consider bioabsorbable collagen membrane. If larger (10 mm >), assess possibility of using collagen membrane to completely cover graft. If not possible, abort surgery and return in 3 months. At this point, the sinus will be thicker in the area of the perforation.

Antral Septae Make two windows and treat as two compartments or osteotomize septum along sinus floor.

Bleeding Pack sinus with epinephrine-soaked gauze. Enlarge opening and attempt to visualize bleeder for cauterization. Clamping vessel may cause further damage and increased bleeding.

Infection/Acute Sinusitis Common sign is swelling over lateral window site with pain and localized tenderness. Antibiotic with respiratory flora coverage. If no spontaneous drainage, surgical drainage is indicated with consideration for graft removal.

Graft Exposure Gentle daily normal saline irrigation and chlorhexidine rinses.

Blockage Ostium Caused by overfill or migration of particles, infection, or inflammation. Assess extent of sinusitis with imaging. Place on steroids and antibiotics. If no improvement, consult with ENT.

Vertigo Usually resolves on its own. Attempt Epley maneuver. Anti-vertigo drugs like meclizine 50 mg PO BID for symptomatic treatment.

Harvesting Techniques of Autografts from Oral Cavity Sites (Please See Reconstruction Chapter for Other Bone Harvesting Techniques)

Autogenous bone grafts are contraindicated if metabolic bone disease, previous radiation treatment, local infection or pathology is present in donor site area.

Mandibular Symphysis

- Can be performed under local anesthesia.
- It is important to open recipient site first to ascertain appropriate graft size.
- Best to harvest lateral to midline, at least 5 mm below apex of canine. Can be done bilaterally, if larger graft is required. Preservation of anterior chin contour is recommended.
- Some authors recommend grafting the harvest site with allograft/xenograft to maintain chin contour.
- Allow 5 months for integration.
- Second graft can be taken no sooner than 10 months from initial harvest [18].

Mandibular Symphysis Surgical Approach

1. Infiltration of local with vasoconstrictor.
2. Incision from canine to canine, through mucosa 1 cm below mucogingival junction, then through mentalis muscle and periosteum.
3. Exposure of symphysis using periosteal elevator, do not completely remove the attached mentalis muscle.
4. Outline planned osteotomy with saw/bur of choice, ensuring to be 5 mm inferior to root tips and 5 mm from the inferior border, entering into cancellous layer. Preferred area to remove bone is below lateral incisor and canine, preserving the midline region.
5. Remove graft, a curved chisel or fine osteotome may aid in its harvest. May harvest additional cancellous bone with curettes.
6. For large grafts, place bone substitute to fill donor site.
7. Close in layers with 4-0 slow resorbing sutures deep and with 3-0 resorbable sutures for mucosa.
8. Pressure dressing over chin.

Ramus Graft

- Can be done under local anesthesia.
- Convenient to be done with third molar removal.
- Harvest the external oblique ridge. Provides mainly cortical bone with minimal marrow.
- Allow 5 months for integration.

Ramus Graft Surgical Technique

1. Local anesthetic with vasoconstrictor.
2. Open and prepare graft site to obtain graft size.
3. Sharp incision along the external oblique ridge from the level of the maxillary occlusal plane to the distal of the mandibular molar.
4. Periosteal elevator to reflect periosteum and temporalis tendon.
5. Outline graft site with saw/bur extending just into cancellous bone.
6. Make osteotomy using saw/bur, ending 5 mm distal to last molar in mandible.
7. Remove graft with periosteal or osteotome.
8. 3-0/4-0 resorbable suture to close. Collagen plug or dressing can be applied to area before closing.

Maxillary Tuberosity
- Older patients will have more fatty marrow.
- Ease of harvest and can be done under local anesthesia.
- Contraindicated if highly pneumatized sinus or sinus infection is present.
- Risk of sinus exposure if over aggressive harvesting.

Maxillary Tuberosity Technique
1. Local anesthetic to area.
2. 3-corner full thickness flap with a distal release.
3. Rongeur used to remove bone, or chisel to gain a thin segment of cancellous bone.
4. Close with 3-0 resorbable suture.

Complication of Block Grafts

Exposure of Block Graft Overall a poor prognosis, inform patient of this. Opening the wound and attempting to suture again will lead to increased microbiological load, large dehiscence, and possible flap necrosis. One protocol calls for chlorhexidine rinses for 4 weeks with debridement/reduction of the graft. Partial or complete survival of graft is low.

Screw Exposure Decreasing bone volume is expected up to 25%. The position of the screw will remain constant as the tissue collapse. Patient asked to keep screws clean with chlorhexidine mouth rinses and debridement with tooth brushing.

Membrane Exposure Titanium membranes commonly exposed and are to be treated with chlorhexidine gel (0.5%) or rinses (0.12%). Membranes of e-PTFE need complete removal with graft as the membrane is quickly vegetated with microorganisms. Resorbable membranes will break down quickly with resorption of the bone.

Mobility of Graft During implant placement if graft moves after screw removal, the graft is not properly integrated. Remove covering soft tissue, provoke bleeding, and fragment should be resecured with screws and allowed to heal further for 4 months.

Ridge Expansion Techniques

Interpositional Graft/Sandwich Graft

Commonly used in esthetic zone, anterior maxillae, but can be used in any part of edentulous ridge.

- Also known as sandwich graft, as bone is "sandwiched" between basal and osteotomized bone.
- Blood supply is maintained by pedicle on lingual/palatal.
- Vertical bone height of 5 mm can be expected, limitation is stretch in pedicle.
- Bring tissue with the osteotomized bone.
- The final position of the bone tends to be more palatal/lingual.

Technique
1. Local with vasoconstrictor.
2. Elevate flap with a horizontal component in vestibule, vertical limits at papillae of adjacent papillae.
3. Divergent wall osteotomies to allow for a free path of advancement.
4. While holding graft in maximal expansion, place a fixation plate.
5. Graft around the gaps of the osteotomy with bone graft of choice.
6. Close wound with suture of choice.
7. Allow 6 months for healing prior to implant placement.

Ridge Split Technique
- More often used on the maxillae than mandible.
- Can gain from 3–6 mm of horizontal bone.
- Adequate bone height of 10 mm should be available on maxillae.
- In mandibular procedure, ideally more than 12 mm above canal.

- Must ensure ridge in favorable position and not too medial and without concavities.
- Minimum 3 mm of width.
- After ridge split, implant should be more facially positioned, likely require custom abutments when restoring.
- Tapered implants best to allow for increased expansion.
- Consider implant with less depth to threads.

Split Ridge for Maxillae Technique

1. Local anesthesia with vasoconstrictor.
2. Midcrestal gingival incision.
3. Minimal reflection of mucoperiosteal flap, no greater than 5 mm.
4. Use guide to mark implant position if immediate placement planned with 2.0 drill. If peak of bone present, it should be reduced.
5. Piezotome or saw used to make osteotomy, ensure angulation parallel with residual ridge for even splitting of bone. Ensure cut 2 mm away from adjacent teeth if present.
6. Spatula osteotome used for separation of cortical plates with gradually wider osteotomes/chisels to expand ridge. If difficult to expand, may make vertical osteotomies on facial bone at end of osteotomy to aid expansion.
7. Accomplish implant preparation with implant osteotomies (allow for more expansion) or implant drill if planned at this time.
8. Graft gap of osteotomy with bone graft of choice. Cortical graft may aid in keeping plates separated. Placement of collagen membrane to cover site.
9. Reapproximate tissues.
10. Allow 6 months for healing.

Technique for Mandible

1. Local anesthesia with vasoconstrictor.
2. Midcrestal incision and reflection of flap for complete buccal exposure.
3. Osteotomies to create an outline of the bone window into cancellous bone.
4. Close flap and allow 5 weeks of healing.
5. Re-expose a limited flap.
6. Spatula/chisel osteotomes used to carefully create greenstick fracture and expand ridge.
7. Graft site with bone substitute of choice and place membrane and close with sutures.
8. Implants can be placed 6 months after initial surgery or at time of expansion.

Complications

Facial Plate Fracture No implant placement. Graft gap and stabilize facial plate with plate and screws. Alternately, no expansion, secure fragment with plates, screw, or wire, and reattempt graft in 6 months.

Distraction Osteogenesis for Implant Site Development

- Based on "tension-stress," brings bone and tissue.
- Defects 6–9 mm in height are often indicated for distraction.
- Hard to control vector some doctors will wrap wire between adjacent teeth to aid in vector control or use surgical guides. Tendency for transport segment to rotate palatal/lingual.
- Lingual portion of osteotomies should be lingually convergent to prevent lingual tipping.
- With expansion of the bony segments, a "regenerate" is formed.
- This regenerate has four distinct zones:
  1. Fibrous tissue zone – located centrally and is organized type I collagen.
  2. Extended bone formation – located on both sides of the fibrous tissue zone. Mesenchymal and osteoblasts synthesize early bone spicules.
  3. Zone of bone remodeling – osteoblastic and osteoclastic activity causing bone remodeling.
  4. Zone of mature bone – located at the edges of the osteotomies.

Phases of Distraction

1. Surgical procedure – ensure divergent walls to allow passive movement. Location of incision should be in attached gingiva, if possible, to encourage gingival growth on distraction. 1 mm is allowed between roots to prevent injury in the osteotomy.

2. Latency period (3–7 days) – mobilizing the trasnport segment too early will cause the regenerate to be formed with high levels of fibrous tissue and low bone density.
3. Activation Period:
   – *Rate* – activation best at 0.7–1.3 mm per day (recommendation on most distractors 1 mm/day). High distraction rates (>2 mm/day) leads to impaired angiogenic response and fibrous bone. 0.5 mm/day carries risk for premature ossification and failure of distraction.
   – *Rhythm* – number of distractions per day. Increasing rhythm to several cycles a day reduces soft tissue trauma and patient comfort. A rate of 0.25 mm at 4 rotations a day, or 0.5 mm with 2 rotations a day, has shown to improve regenerate quality.
4. Consolidation (3 months) – keep device on until seeing radiographic evidence of bone healing. This may be longer in older patients. Can place implants at time of device removal.

Complications

Immobility of Transport Segment Incomplete osteotomy or poor osteotomy design that leads to blocking of transported segment. Treatment is to retrace osteotomies.

Loss of Distractor May be due to poor bone stock. Options are to replace distractor or consideration of bone graft and segment fixation with plate.

Tissue Dehiscence Slow rate of distraction, allowing for short period of tissue healing. Consider smoothing edges of segment if there are sharp areas.

Resorption of Transport Segment Due to interruption of blood supply that is most likely due to over reflection of tissue. Allow for prolonged latency period before further distraction.

Inadequate Vector of Transported Segment This can be avoided using extraoral devices or dental wiring to aid in vector guidance. May also consider other ridge augmentation techniques to overcome the malpositioned regenerate.

Zygomatic Implants

- Good for large maxillary ablative defects, traumatic defects, severely atrophic maxillae, cleft palate unrepaired defects, and patient's refusal for sinus augmentation.
- About 97% success rate [19].
- Zygomatic implants are available in 30–52.5 mm fixture lengths, 4 mm diameter in apical 2/3- and 5-mm diameter in the alveolar 1/3 (45° tilted connection to correct for angulation).
- Frequently enter oral cavity on palate side, reducing tongue space and disrupting palatal contour of prosthesis.
- As implants pass through sinus, sinusitis may compromise survival and should be addressed prior to placement. Patients are at a higher risk of postoperative sinus infections.
- Healing time is 3–4 months.
- Implant can be immediately loaded if a torque of >40 Ncm is acheived.
- Placement should be in the premolar region and into the mid portion of the zygomatic body.
- Intrasinus technique – create a lateral sinus window to push sinus membrane from implant; some clinicians elect to bone graft around implant and sinus cavity.
- Extra sinus technique – allows more crestal emergence, reducing sinus complications, increases tongue space allowing for decreased risk for altered speech and increase space for hygiene access. Major disadvantage is mid portion of implant is in direct contact with soft tissue, which may cause exposure and perforation.
- Require cross stabilization due to long moment arm of zygomatic implant.

Implant Prosthetics

Implant Attachments

Implant Bar Attachment

- Used for retention and support for an implant supported over denture.
- Can be fabricated using casting or milling (CAD-CAM) process.

Fig. 4.3 Implant bar attachments. (Reprinted with permission from Rutkowski [20])

- Material options: titanium, soldered gold, non-precious metal, zirconia.
- Bars constitute an excellent anchorage system that provides greater retention, enabling better force balance by its splinting effect and it can also correct severe lack of parallelism.
- The retention elements or clips are interchangeable and can be reactivated.
- The main disadvantages of bar attachments are the need for a large prosthetic space. There is an increased risk of mucositis and hyperplasia due to an inadequate oral hygiene under the bar.
- A minimum of 12–14 mm of vertical restorative space is required for a bar retained overdenture.
- Bars need to be parallel to the rotation axis, be straight, and be positioned 1–2 mm above the alveolar crest to aid in hygiene.
- There are some different bar designs such as Ackermann bar (spherical shape), Dolder bar (ovoid or "U" shape), and Hader bar (keyhole shape). Also, there are implant-supported milled bar overdentures. They are bars with precision attachments and rigid anchorage, made by casting, electroerosion, or CAD-CAM.
- Types: Hader bar, Dolder bar, Round bar, Free form milled bar, Paris bar, Wrap-around bar, Montreal bar, Hybrid bar (Fig. 4.3).

Locator Attachment

- The male part consists of an implant screw-metallic abutment and the female part of a metallic cap is lined with nylon of different colors depending on their retention capacity, which is anchored to the denture.
- These attachments do not need a large prosthetic space and they can correct non-parallel implants up to 40°.
- A reported minimum space requirement for implant-supported overdentures with locator attachments is 8.5 mm of vertical restorative space and 9 mm of horizontal space.

"O" Ring or Ball Attachment

- Ball attachments are considered the simplest type of attachment for clinical application with tooth- or implant-supported overdentures.
- It has a screw-retained male abutment in the implant with a spherical shape on its occlusal portion and a prosthetic anchored female part that can be metallic or covered with nylon having a different retention range.
- These attachments do not need a great prosthetic space and they allow hinge and rotation dislodgements.

Magnetic Attachment

- They consist of one magnet attached to the denture and another to the implant. They constitute a simple and comfortable system for the patient as magnet attraction guides the denture insertion. On the other hand, they have a weaker lateral stability and retention in comparison with mechanical attachments as ball or bar devices.
- They are susceptible to corrosion by saliva, explaining why they are clinically less often used.

Screw-Retained Versus Cement-Retained Restorations (See Tables 4.2 and 4.3)

Anterior Posterior Spread (AP Spread)

- AP spread is defined as the distance between a line drawn between the distal sides of the posterior implants and a parallel line drawn

Table 4.2 Pros and cons of screw-retained restorations

Screw-retained restorations	
Pros	Cons
Ease of retrievability Low-profile retention Limited crown height space: Low-profile bar for overdentures Crown contour requirement Reduced moment loads No residual cement Splinting nonparallel implants As the screw is the weakest link, it can be designed as the point of failure to prevent mechanical overload	Risk of prosthetic screw loosening Fracture risk of prosthetic screws Device not sealed (bacterial growth) Passive casting requires much more accuracy Lack of axial occlusal loads Less aesthetic restorations Increased risk of porcelain fracture Access is often difficult Lack of progressive loading Increased cost Angulation problems, fixture determines screw access, which can lead to undesirable access hole position

Table 4.3 Pros and cons of cement-retained restorations

Cement-retained restorations	
Pros	Cons
Ease of splinting implants Better passive fit Easier correction of non-passive casting Progressive loading can be achieved Improved force direction of loads Optimal occlusal contacts Enhanced aesthetics Improved access to posterior regions Reduced fracture of components Reduced porcelain fracture More economical More aesthetic overall as no access hole	Risk of residual cement causing peri-implantitis and implant failure, especially if implant placed too deep into bone More difficult to retrieve if abutment becomes loose Need for more crown height space

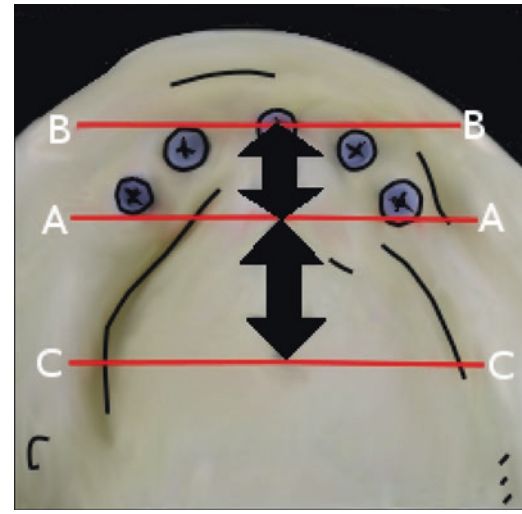


Fig. 4.4 AP spread. From line A to B is the A-P spread. Measure from line A to C, which is distal cantilever extension. (Courtesy of Erik Steenberg)

through the center of the most anterior implants (Fig. 4.4).

- The ideal AP spread is 1 cm when four or five implants have been placed.
- When the AP spread is 1 cm or more, Branemark and his colleagues concluded that the cantilever could be extended to, but not beyond, 20 mm or up to two times the AP spread.
- Others have recommended that the cantilever extension be limited to 1.5 times the AP spread. If the cantilever extension is excessive, the load delivered to the posterior implants is magnified and can lead to screw fractures and prosthesis or implant failure.
- It may be difficult to obtain implant arrangement with suitable AP spread in patients with square arch forms or significant anterior loop of the inferior alveolar nerve.
- In these patients, if a fixed prosthesis is desired, distal angling of the posterior implants may offer some theoretical biomechanical advantage. The distal angulation of the implants can be corrected with angled abutments (e.g., – tilted implant technique aka All-On-4®)

Restoration of Edentulous Maxillae and Mandible with Implant Prostheses

Implant-Assisted Overdentures

- The term implant-assisted prosthesis implies a system of shared support where implants provide retention and stability and the denture bearing areas providing support. Therefore, dentures must be extended properly to cover primary support areas with bilateral balanced occlusion.
- Implants should be positioned sufficiently anteriorly or else the denture will tip and rock around the implants during function.
- Several types of attachments have been used for implant-assisted overdentures.
- Selection is based on biomechanics, the quality of retention, stability and support provided, ease of fabrication, laboratory costs, the cost of maintenance, and the personal preference of the clinician.

Individual Attachment Systems

- Conventional ball-type attachment.
- Locator abutments.
- Mini-implants with O-ring attachments.
- Magnetic attachments.

Advantages
- Distribute occlusal forces in a favorable manner.
- Minimize risk of mechanical failures and implant loss secondary to implant overload.
- Exhibit less wear on the patrix and matrix of the system.
- Allow dentures to rotate freely.
- A high amount of implant divergence can be accommodated.
- Magnetic attachments do not lose retention over time.

Disadvantages
- Do not provide as much retention compared to bar-clip systems.
- Gradual loss of retention due to attachment fatigue and wear.
- Implants can be exposed to lateral torqueing forces.
- If implants are positioned improperly, it may be difficult to position denture teeth.
- High implant failure rates of mini-implants vs. conventional implants.
- Magnetic attachments do not provide as much retention as mechanical attachments.

Implant Connecting Bar-Clip Design
- Two implants splinted together with Hader-type bar can be used (Fig. 4.3).
- A Hader bar is round, allowing bar clips to freely rotate during occlusal function, resulting in less attachment fatigue of clips and wear of the bar compared to elliptical bar designs.
- The bar should be perpendicular to the midline and parallel to the plane of occlusion. ERA (extracoronal resilient attachment) may be added to the bar for increased retention.

Advantages
- Excellent support to resist incising forces.
- Implants share vertical and lateral forces.
- Superior retention and less maintenance compared to other systems.
- Provides better lip support compared to a fixed prosthesis.
- Can compensate for unfavorably positioned implants.

Disadvantages
- Added time and cost of fabrication.
- Harder to maintain oral hygiene.
- Tissue hypertrophy around implants and under the bar especially if the bar is designed to contact the underlying mucosa. This can lead to peri-implantitis.
- Implant-connecting bars are subject to wear and subsequent loss of retention of the denture.

Implant-Supported Overdentures

- With implant-supported overdentures, all of the forces of mastication are borne by implants.
- This can be achieved by fabricating implant-connecting bars with conventional or CAD/CAM methods.

- The prosthesis may be removable or fixed.
- The advantages/disadvantages of implant-supported removable prosthetics are as follows.

Advantages
- May be indicated when inferior alveolar nerve is exposed.
- Easier to maintain oral hygiene compared to a fixed prosthesis.
- Longer life span of the bar since there is no movement of denture base.

Disadvantages
- Requires placement of at least four implants in the mandible with at least 1 cm of AP spread to support posterior occlusal forces.
- The implant-connecting bars have to be bulkier and acrylic denture should be reinforced with metal substructure.
- Increased cost, time, and need for accuracy compared to implant-retained overdentures.

Implant-Supported Fixed Prosthesis

Advantages
- Psychological and psychosocial advantages of having a fixed prosthesis.
- Increased bite force.
- Patient prefers not having the palatal coverage in the denture.
- Improves phonetics, appreciation of temperature, and taste.

Disadvantages
- Needs five implants in the mandible or six in the maxilla, unless an All on 4®/tilted implant prosthesis is planned using angled implants.
- May require additional surgical procedures to augment alveolar ridge or maxillary sinus, or alveolectomy to provide interocclusal space.
- Significantly increases cost of prosthesis and need for accuracy.
- Sufficient interocclusal space is required to allow for fabrication of a rigid prosthesis and provide space beneath prosthesis to maintain oral hygiene.
- Challenge to maintain oral hygiene especially in elderly or debilitated patients.
- Esthetic limitations. Inability to provide adequate lip support due to insufficient denture flange.
- Needs sufficient AP spread to reduce distal cantilever or prosthesis.
- Unfavorably positioned implants can add significant cost and complexity to prosthesis.
- Complications include metal or zirconia framework fracture, fracture or delamination of veneering porcelain, separation of resin from metal framework, fracture and wear of denture teeth, fracture of implants and prosthetic screws.

Material Options
1. Hybrid prosthesis – denture teeth embedded in heat-cured acrylic resin supported by a rigid metal framework.
2. Metal-ceramic prosthesis – can be cast or milled. Acceptable aesthetics, tissue response is excellent, material is non-porous, little wear on occlusal surfaces. High cost.
3. Zirconia prosthesis – aesthetic, biocompatible. Produces less wear than porcelain surfaces; high strength, toughness, wear resistance, and acid resistance; minimal abrasiveness.

Guided Surgery

- Guided surgery is the surgical placement of dental implants using site and patient specific surgical templates developed with software programs that combine DICOM (cone beam computed tomography (CBCT)) and STL files (intraoral or bench scanners) or scanned stone models.
- Allow for virtual treatment planning based on the anatomy of the patient and the prosthetic plan. Surgical templates incorporate drill keys and metal sleeves and allow for the precise preparation of the osteotomy sites and positioning of implants. Guided surgery can be static or dynamic (navigation). Static guided implant surgery is more widely used. Dynamic (navigation) requires a specific equipment for it.
- CBCT should be taken with partial separation of teeth.

- In fully edentulous patients, the surgical template is secured with anchor pins or bone screws inserted into bone adjacent to the implant sites.
- Will require newly relined or a well-fitting denture.
- In partially edentulous patients, the surgical template can be retained with either anchor pins or bone screws or by the residual dentition.
- Fully guided surgery provides complete control of implant positioning, depth, and angulation. However, the size of the drill sleeves makes their use difficult in partially edentulous patients and posterior teeth.
- Semi-guided surgery allows for accommodation of first or maybe second drill and allows control of only the initial osteotomy.
- Computer-guided planning allows the clinician to scrutinize the potential implant sites, select implants of suitable length and diameter, and position them to be compatible with the prosthetic design.
- Provides a prediction of stability around the implant based on Hounsfield units around implant.
- Prefabricated temporary crowns, custom healing abutments, and even final custom abutments can be fabricated in the lab.
- These software programs are particularly valuable in the esthetic zone to identify thin layers of bone overlying the labial surface of the implant that are at risk of resorption.

Advantages

- Visualization of the potential implant sites in three dimensions in relation to the prosthesis.
- Allows of precise implant positioning including extraction sockets.
- Reduced risk of encroaching upon adjacent vital structures.
- Allows for the fabrication of prostheses and abutments before surgery and immediate loading.
- Allows for flapless surgery.
- Allows for increased communication between restoring dentist and surgeon.

Disadvantages

- Increased cost.
- Lack of interocclusal space especially in the posterior region.
- Lack of flexibility during surgery.
- It is technically demanding.
- Radiation exposure from CBCT scans is a concern. Radiation dose varies between machines.
- Scatter from metallic restorations may reduce accuracy.
- Limited mouth opening and mesiodistal space are contraindications.

Implant Case #1

- *A 48-year-old female presents with consultation for reconstruction of her upper left maxillae. She is healthy without any medication or*

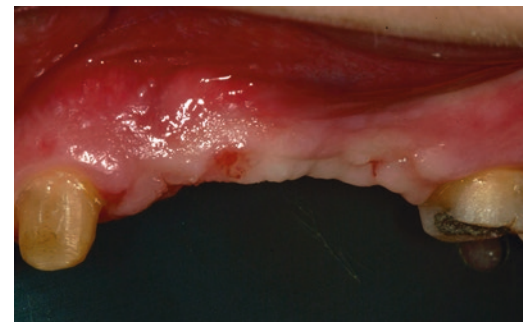


Fig. 4.5 Photo of case implant case #1. (Courtesy of Dr. Polido)

allergies. What do you see in the image focusing in the left maxilla? (Fig. 4.5)
I see a partially edentulous left maxillary ridge. It appears she is missing teeth 11 through 14. She has crowns placed on teeth 9 and 10. There is some gingival recession on tooth #10. Tooth #15 appears heavily restored. There is both height and width loss of the remaining ridge. There appears to be adequate keratinized gingivae.

- *What would you do next?*
  I would review how long the teeth have been missing and the mechanism. I would enquire about smoking and parafunctional habit history, what is her motivation for treatment, and how often does she have dental visits. I would inquire about her expectations on a prosthesis and whether she wants a fixed or removable solution, followed by a complete head and neck exam.
- *She has been missing these teeth for over 10 years. She had them extracted due to dental caries. She had worn a removable prosthesis but never liked it. She has always had difficulty chewing on her left side, but now she has the financial means to rehabilitate her maxilla. She is on a regular maintenance with her dentist every 6 months. She is a non-smoker and doesn't think she grinds or clenches. What specifically would you be looking for on a head and neck exam?*
  I would like to know the maximal incisal opening to gauge access to the surgical site. I would assess the interarch space, the width of the ridge and the amount of keratinized tissue to ensure implant long-term health. I would evaluate the gingival biotype diagnosed by probing into the sulcus of remaining teeth. I would also evaluate the overall health of the remaining dentition and whether there is any treatment work that would need to be completed, such as a dental prophylaxis or restorative treatment, prior to implant surgery.
- *What would you do next?*
  I would take a CBCT in my office and reformat for an orthopantogram.
- *What do you see* (Fig. 4.6)*?*
  A heavily restored dentition with a large spanning fixed prosthesis between teeth numbers 2 and 6. There is an implant at site #7. There is an edentulous maxillary ridge spanning from sites 11 through 14. There is sinus pneumatization of the upper left encroaching into the region of the second premolar. Tooth #19 has a slight overfill and leakage of material into the surrounding alveolus. Root canal therapy and full coverage restorations are noted on teeth 20 and 29. There are atrophic changes of the posterior mandible in the edentulous regions. There appears to be no intrabony pathology.
- *What next?*
  I would like to evaluate the cone beam slices of the edentulous left maxillary ridge.
- *What do you see in this image* (Fig. 4.7)*?*
  I see what appears to be a Cawood and Howell class III of the premolar region and class V of the molar region. The premolar region appears

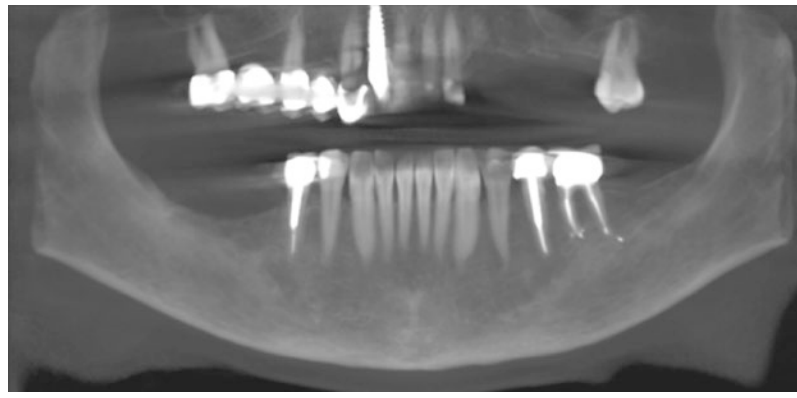


Fig. 4.6 Orthopantogram of implant case #1. (Courtesy of Dr. Robert Reti)

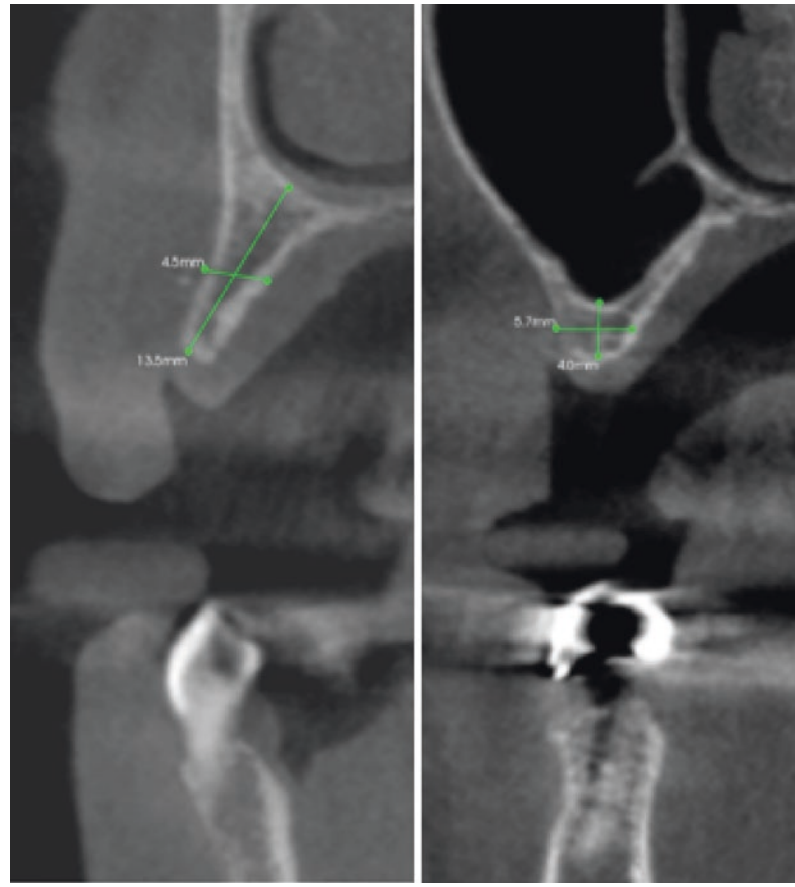


Fig. 4.7 CBCT of implant case #1

to have adequate height but a maximal width of 4.5 mm which would be inadequate for a regular diameter implant, which on average needs a minimum of 6 mm to allow a 1 mm buccal and lingual ridge. The molar site appears to have only 4 mm of height before the sinus cavity and just under 6 mm for width. Both sites are inadequate for a regular size implant placement.

- *Focusing on the premolar region, what are some options to create adequate width?*
  Options would include a veneer bone graft, split ridge procedure, cancellous graft, or a tunnel graft procedure.
- *What would you want to do and why?*
  I would offer a split ridge procedure as it is a procedure I am comfortable with and has good success in my hands. As well, it could potentially allow for immediate implant placement saving the patient healing time and reduced morbidity from a second graft site.
- *Describe how you would complete a split ridge procedure?*
  After infiltration with local anesthetic, I would make a sharp crestal incision down to the bone. I would carefully reflect a minimal flap to visualize the crestal bone. Using a piezotome I would make a corticotomy down to cancellous bone, staying 2 mm away from adjacent teeth not to disrupt them. I would carefully expand the bone with flat chisel osteotomes, keeping a dual finger guidance to help direct the slow careful expansion and mold the buccal bone. When appropriately expanded I would attempt to place my implants by under-preparing the apical portion of the osteotomy. I would graft around the implants and into the gap between the plates with a mixture of 1:1 allograft:xenograft. I would then place a resorbable membrane to contain the graft and close with 3-0 non-resorbable suture.

- *What implant system would you use and why?*
  I would use a tapered implant system. I would not want a system with a large aggressive thread pattern that would compromise the bone. The less aggressive threads would allow some further expansion upon placement. I would use a tapered implant, as it would aid in grasping the remaining apical bone that would be limited.
- *Your patient who has undergone a sinus floor elevation using the Summer's technique calls in 2 days after the procedure complaining of dealing with dizzy spells every morning. What do you want to know?*
  Inquire about constitutional symptoms (fever, chills, nausea, or cold-/flu-like symptoms), ear ache, or tinnitus. Has she ever experienced this before and if so has she ever been worked up for these symptoms? (rule in/out idiopathic endolymphatic hydrops?) Are the symptoms brought upon when she first wakes up from bed form a supine to upright position? How long do they last? Does she experience any nystagmus with these dizzy spells?
- *This has never happened before. She has no flu-like symptoms. She usually experiences a self-limiting dizzy spell from about 30 seconds when she gets up from bed. Her husband notes her eyes tend to shake when this happens. What next?*
  Benign paroxysmal positional vertigo is a known complication of sinus floor elevation and would be my working diagnosis. I would attempt to control her symptoms with antihistamines such as meclizine. I would reassure her that this likely would self-correct. If symptoms continue for a prolonged period, I would refer her to an ENT colleague for workup and canalith repositioning procedure (Epley maneuver).

Implant Case #2

- *A 78-year-old male presents with complaint of ill-fitting dentures. He takes simvastatin for hypercholesterolemia and an 81 mg ASA. His dentist has asked him to consult you for dental implants to help retain his denture. What would you like to do next?*
  I would perform a history and physical with some focused questions. Has he had a history of cancer? Use of any antiresorptive medications like bisphosphonates? Does he smoke? How long has he been missing his teeth for? What is his restorative goal and what motivates him to come in now? Is he having pain or discomfort when he wears his dentures?
- *He has no history of cancers or use of antiresorptive medications. He did smoke 1 pack per day in the past but had quit after his time in the service. He blames his edentulism due to "soft teeth" that runs in his family. His denture will not stay in any more even with denture adhesive. He reports recent pain with mastication. He complains of occasional "pins and needles" sensation in his lower lip and this is limiting his diet. What next?*
  I would like to do a head and neck exam. I would focus on if there is any keratinized tissue that remains. I would evaluate for the attachment of the genioglossus. I would press along the ridge to see if I can recreate the paresthesia. With his history of smoking, I would like to identify any concerning lesions.
- *There is no keratinized tissue remaining and no lesions appreciated. When you apply digital pressure on the mid mandible, it elicits a painful response from the patient. Would you like any imaging?*
  Yes, I would like a CBCT as I can use it for accurate measurements and can reformat it into an orthopantogram.
- *Ok, what do you see?* (Fig. 4.8)
  I see a severely resorbed mandible with ditching of the cortical bone. No fractures are appreciated or pathological changes.
- *How would you classify this mandible?*
  Cawood type 6.
- *Are there any other grading systems for edentulous mandibles?*
  Yes, there is the Luhr classification system that takes into account residual bone height. Class I, mild atrophy with a height between 15 and 20 mm. Class II, moderate atrophy with a height between 10 and 15 mm. Class III, severe atrophy with a height of less than 10 mm.

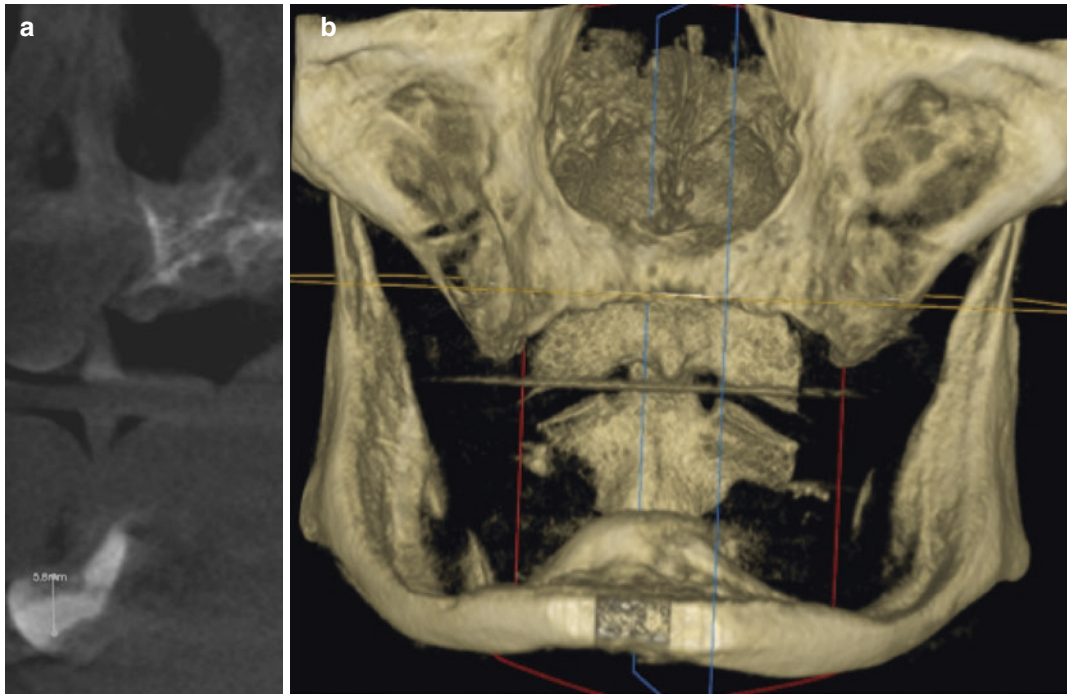


Fig. 4.8 (**a**) CBCT sagittal view of implant case #2. (**b**) 3D reformat of implant case #2. (Image Courtesy of Dr. Robert Reti)

- *What would your treatment plan be?*
  I would offer a "Tent Pole Procedure" with 6 implants.
- *Can you describe how you would do that briefly?*
  Ensuring no paralysis and with nerve monitoring. I would inject the tissue with anesthetic. I would outline a submental incision, not in the submental crease but 5 mm behind this to allow for the forward position of the tissue after grafting. I would carefully dissect down to the mandible in a layered fashion. I would dissect the buccal and occlusal tissues to the trigone regions along the mandible. I would identify the mental foramina on both sides. I would place my first two wide-bodied 15 mm in length implants, 5 mm in front of the identified mental foramina emergence. I would space the remaining implants evenly between the two distal implants. I would place cover screws at this time. I would protect the surgical site with saline-soaked gauze and harvest a posterior iliac graft. I would then return to the neck and graft around the implants and into the trigone regions. I would close in a layered fashion.
- *What would your postoperative instructions be?*
  I would recommend a soft diet for 3 months. No denture could be worn for the first 2 weeks. For the graft harvest, bed rest for the first 24 hours, assisted ambulation for the first week, and no physical activity for 6 weeks.
- *Patient complains of swelling on the floor of the mouth. Exam shows the tongue is slightly elevated, but no respiratory distress. This is the CT scan. What do you think is going on?* (Fig. 4.9)
  It appears the implant has perforated the lingual cortex. The implant may have damaged the sublingual gland causing what appears to be a possible plunging ranula. Damage to the muscle or vessel may have caused a bleed or hematoma in the area.
- *You aspirate the area and it comes out a clear thick fluid? What is your treatment?*

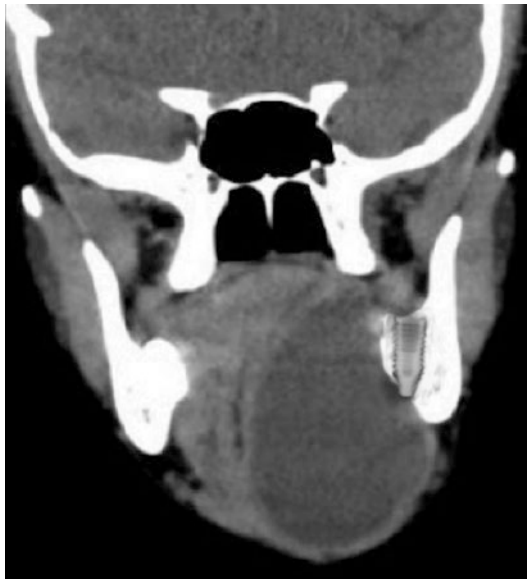


Fig. 4.9 Complication of implant case #2. (Image Courtesy of Erik Steenberg)

I would remove the implant and perform a transcervical removal of the ranula and the damaged gland.

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