Contents

Foreword ..... *ix*

Acknowledgments ..... *xi*

About the Author ..... *xii*

List of Contributors ..... *xiii*

About the Companion Website ..... *xiv*

1 Implants 101: History, Implant Design, Parts, and Pieces 1

2 Implant Therapy: Oral-Systemic Health, Medical History, and Risk Assessment 17

3 What Lies Beneath the Surface? Natural Teeth, Bone, and Implant Surgery 31

4 Setting the Stage: Adjunctive Surgical Procedures, Restorative Options, and Treatment Planning 53
With contributions by Dr. Robert Horowitz, Dr. Robert Schneider, and Dr. Maria L. Geisinger

5 How to Talk to Patients About Implant Dentistry: Risks, Benefits, and Alternatives 87

6 AIM for Implant Success: Assess, Identify, and Monitor 103

7 Implant Complications: Peri-Implant Disease, Biofilm, and Corrosion 117
With contributions by Dr. Maria L. Geisinger, Dr. Gerrarda O'Beirne, and Dr. Luciana Safioti

8 Biofilm-Focused Implant Home Care 141

9 Professional In-Office Implant Maintenance and Disease Treatment 169

Appendix: Terminology and Resources 211

Index 219

Foreword

Dental implants are a viable option for natural tooth replacement with predictable long-term survival rates. Implant survival alone is an inadequate predictor of success according to modern standards. Careful implant position, prosthetic design, and soft-tissue management can result in superior aesthetic and functional outcomes. Preservation of peri-implant soft tissues, optimal function and aesthetics, and implant survival has become the parameters that define success. As such, the partnership of the implant surgeon, restorative dentist, and dental hygienist is essential to preserve these outcomes.

The success of an implant-supported restoration is promoted by a prosthetically driven treatment plan. The days of placing implants *where the bone is*, without consideration for tooth position or the planned prosthesis, are long gone. Implant position is ideally determined by the position of the teeth and by the type of prosthesis to be planned. Moreover, the amount of vertical space required for the planned prosthesis must be assessed prior to implant placement. Modern technology facilitates this planning; CBCT machines allow accurate 3-D visualization of patients' anatomy, proposed implant positions, and the prosthesis. Surgical guides can be fabricated quickly and economically using 3-D printing or with CAD/CAM technology. Although this technology is used routinely in planning dental implants, it is critical that the implant surgeon utilizes this technology correctly for accurate implant placement, especially if an immediate prosthesis is planned. Moreover, meticulous surgical technique is vital for healing and implant survival.

Paying particular attention to prosthetic design will promote a favorable outcome. The number of implants, antero-posterior spread, implant-to-prosthesis ratios, lip support, the condition of the opposing arch, and functional requirements are considerations when planning an implant prosthesis. An important and sometimes overlooked consideration is the cleanability of the final prosthesis. Creating a prosthesis that harmonizes function, aesthetics, respect for biology, and cleanability should be the primary objective when planning and carrying out fixed and removable implant therapies. If tooth position, function, implant positions, and/or lip support results in a fixed prosthesis that is not conducive to proper and complete oral hygiene practices, a different prosthetic design must be considered.

The necessity for complete and responsible implant maintenance transcends the traditional goal of calculus removal. Oral biofilm is not only responsible for localized and generalized dental, periodontal, and implant disease but is also implicated in the exacerbation of many systemic conditions, including, but not limited to cardiovascular disease, metabolic imbalances, rheumatoid arthritis, and Alzheimer's disease. Complete biofilm disruption has

been shown to promote a favorable oral environment and to reduce the risk of the oral contribution to systemic disease. Technology is available to facilitate efficient and effective biofilm disruption in a way that is safe for dental implants. Conversely, there are instruments and medicaments that can be damaging to dental implant surfaces and prosthetic materials and can compromise longevity. The titanium surface on dental implants has been proven to be biocompatible and corrosion-resistant, but common preventive practices have been implicated in its degradation, including topical medicaments to prevent dental caries, a general or local acidic pH and instruments used to remove biofilm, plaque, and calculus. This dissolution, degradation or permanent deformation of the implant surface may contribute to peri-implant inflammation, bone loss or eventual loss of osseointegration.

Collaboration between the dentist and dental hygienist is fundamental to promote successful long-term implant outcomes. A restoration that is not only maintainable for the patient but also the dental hygienist will encourage health in the oral environment and peri-implant tissues. Dental hygienists that have a general understanding about implant restorations, dental materials, and appropriate preventive measures are invaluable. First, the dental hygienist can educate patients about available prostheses and assess the patient's motivation to pursue implant therapy. This can begin a fruitful discussion for the dentist and the patient. In addition, when dental hygienists understand dental materials and basic prosthetic design, they can select the appropriate armamentarium for maintenance appointments and properly educate patients to practice optimal at-home maintenance.

To provide safe and appropriate care for implant patients, attention to all of the points previously introduced is crucial. Collaboration between the dentist and dental hygienist will produce superior patient care and a satisfying clinical environment. The dental hygienist has a profound responsibility to be equipped with the knowledge, instruments, technology, and materials to successfully contribute to this collaboration. This text is a culmination of decades of research and will educate and ultimately empower the dental hygienist to provide exceptional care for patients considering, undergoing, or have completed implant therapy.

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Susan S. Wingrove.

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Susan Wingrove BS, RDH. International speaker, researcher, writer, consultant, and RDH Award of Distinction Recipient. Instrument co-designer of the Wingrove Titanium Implant Series, ACE probes, and Queen of Hearts instruments. Susan specializes in sorting through the science to develop protocols for healthy teeth, implants, and disease treatment. She does medical research on regenerative wound healing and dental research on biofilm-focused care for long-term disease prevention. Published author ACP Clinical Practice Guidelines Scientific Panel, Doctor Clinical Implant Maintenance White Papers, American and International journals on peri-implant therapy, regeneration, and advanced instrumentation. Resides in Missoula, Montana, USA and enjoys fly fishing, hiking, and snowshoeing.

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1 Implants 101: History, Implant Design, Parts, and Pieces

History, 1
Dental implant history timeline, 4
Implants, 6
  Implant design, 8
Orthodontic implants/temporary anchoring devices (TADs), 11
  Parts and pieces for implants, 12
Implant dentistry terminology, 14
Summary, 14
References, 15

Understand as hygienists a tidal wave of ailing or failing implants may be imminent. It is imperative that hygienists are trained in identifying and treating peri-implant mucosal inflammation that could affect overall body health (1).

—G. Nogueira-Filho, DDS, MDent, PhD

Dental hygienists must be ready and be prepared to take on this next, very important challenge in our profession! The 21st century is an important and critical time to be a hygienist. During this exciting time in dentistry, we as hygienists have a critical role in implant therapy. As a hygienist, your role will be to access patients for healthy periodontium prior to placement of implants, to monitor the tissue surrounding the implants, and to maintain the implants through safe, effective implant maintenance. Current studies reveal that infections in the periodontium occur in more than 50% of implants placed (2). Therefore, we as dental professionals will be faced with different dynamics, challenges, and complications.

As a hygienist, the history of implant dentistry makes you aware that implants are not new, but have been evolving for decades. Patients may have concerns that implants are so new that not enough research or development has been done for them to feel comfortable with the procedure. With your knowledge of the history, design, and research done on implants you will be better able to talk with your patients and address these concerns. A fundamental understanding of key terms and statistics associated with implant dentistry will also be a valuable tool to add to your verbal skills when talking with patients about tooth replacement.

History

Believe it or not, the history of dental implants dates back to 600 AD with the ancient Mayans. Dr. and Mrs. Wilson Popenoe found the lower mandible of a young Mayan woman in Honduras in 1931 (Figure 1.1). She was missing some of her lower teeth and they had been replaced with the earliest example of the first dental implants, made from pieces of shell, shaped to resemble teeth. Scientists believe that

Peri-Implant Therapy for the Dental Hygienist, Second Edition. Susan S. Wingrove.

Companion website: www.wiley.com/go/wingrove/implant

these shells may have actually worked. Slots were made into the bone and the shells were pounded in like little wedges, without anesthesia!

Similar discoveries were made in Egypt, artifacts that date back to the 1700s. Ivory and the bones of animals were also sometimes used to replace missing teeth. It would be decades after these archeological discoveries before the modern world caught up with the Mayans' and Egyptians' dental technology.

In the late 18th and 19th centuries, the level of dental care went through many changes. Through the letters, journals, and accounts left by our first president, George Washington, we have a well-documented case history of his lifelong dental problems and the level of dental care available at that time. George Washington started losing his teeth at the age of 24 and by 1789, the year that Washington took his oath of office, he had only one of his original teeth left (Figure 1.2).

Figure 1.1 Discovery by Dr. and Mrs. Wilson Popenoe, Honduras, 1931. Reprinted with permission from Ring (20).

Dr. John Greenwood made a set of dentures for Washington made of hippopotamus ivory and eight real human teeth attached by brass screws. The denture, which was anchored on the one remaining tooth in Washington's mouth, has a hole that fits snugly around the one tooth. Dr. Greenwood was noted to be quite ahead of his time in his dental practice, extracting teeth, and utilizing them in the manufacture of dentures, but he also experimented with implantation.

Unfortunately for Dr. Greenwood, the 18th century's lack of antibiotics and any understanding of germ theory or antisepsis doomed any such experiments to failure. He did make President George Washington several sets of dentures, none made out of wood as often referred to. They were made from gold, ivory, lead,

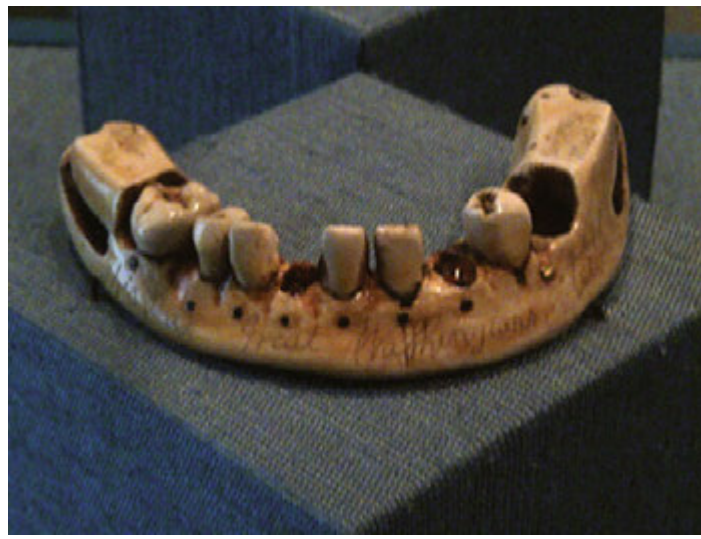


Figure 1.2 George Washington's lower denture. Courtesy of Rick Blanchette.

and human and animal teeth (horse and donkey teeth were common components), with springs to help them open and bolts to hold them together.

In the 18th century, researchers experimented with gold and other metal alloys including lead as implants. Dr. Maggiolo fabricated gold implants that were placed in sockets where teeth had recently been extracted and after a healing period attached a *donor* tooth. Dr. Harris, a physician, attempted the same procedure with a platinum post, both had poor results.

Dr. Edmunds in 1886 was the first in the United States to implant a porcelain crown mounted on a platinum disc and presented at the First District Dental Society of New York. Other metal alloys with porcelain crowns were experimented with, but these implants did not have a long-term success rate.

Dr. E.J. Greenfield, pioneer of the endosseous implant, provided many of the basic concepts of nascent field of implantology. He was known for his patented hollow-cylinder implants made of wire soldered with 24 karat gold. This hollow-basket design was a similar design that Straumann Implant Company from Switzerland adopted many years later. He presented his research and surgical technique in 1913, and although histological proof of bone-to-implant contact was not available at that time, he understood the clinical importance to what he called *primary stability or osseointegration*. His surgical techniques, stepwise use of drill diameters starting with round bur, were presented in 1913 and are still practiced today (3).

It was not until 1937 before the first relatively long-term implant success was noted. Dr. A.E. Strock used the metal alloy Vitallium®, placing a series of implants at Harvard University in animals and humans. He published a paper on the physiological effects of Vitallium in bone, with no postoperative complications or reactions noted, total toleration. These were the first relatively successful dental implants and certain types of implants are still cast in Vitallium today.

The turning point of implant dental history happened in the 1950s, when Professor Per-Ingvar Brånemark, an orthopedic surgeon, discovered that titanium components can bond irreversibly with living bone tissue. His team designed many studies on the healing effects of bone with one specific study on rabbits in which a titanium metal cylinder was screwed in a rabbit's thighbone. A several-month healing period and other experiments of the blood circulation in animals using a hollow titanium cylinder demonstrated that the titanium cylinder fused to the bone. Brånemark named this discovery osseointegration (the firm, direct, and lasting biological attachment of a metallic implant to vital bone with no intervening connective tissue) (Figure 1.3).

Brånemark's research and other colleagues from other disciplines evolved this theory of osseointegration along with the design of the *Brånemark titanium* screw

Figure 1.3 Professor Per-Ingvar Brånemark, an orthopedic surgeon. Courtesy of Nobel Biocare.

device with a number of specific surface treatments to enhance bioacceptance with bone. One of the key reasons that titanium was chosen by Brånemark is his relationship to Hans Emneus, an orthopedic surgeon, who studied different metals used for hip joint prostheses. His research indicated that a new metal, titanium, from Russia and used in nuclear industry, might be optimal. Brånemark used a sample from Russia and from there on, the best metal for implants has been pure titanium.

In 1964, commercial-grade pure titanium was accepted as the material of choice for dental implants. Other bodies of medicine (i.e., joint replacements) had recognized the fact that the body does not recognize titanium as a foreign material, which results in higher success rate and fewer rejections. Eventually, the use of commercial pure titanium evolved into the use of titanium alloys ($TiAl_6V_4$ being the most commonly used) due to experimentation and improved durability.

In 1981, Dr. Per-Ingvar Brånemark published his findings covering all the data on the animal and human clinical trials: success rate, concept, and the design of endosteal root-form titanium implants most commonly placed today. In an effort to gain international support and collaboration, based on patient care with sound biological and clinical principles Brånemark founded the Association of Brånemark Osseointegration Centers (ABOC).

Brånemark identified the edentulous patient as an amputee, an oral invalid, to whom we should pay total respect and rehabilitation ambitions. He was also instrumental in identifying the mouth as a much more important part of the human body than medicine and controlling agencies had previously recognized. He coined the term *osseoperception*, "the dentate mouth communicates with the brain, possibly improving not only daily function but also being an important factor in restitution after intra-cranial vascular events" (P-I Brånemark, September 2005).

In the 21st century, technology and clinical awareness will take on more importance. The science and clinical advancements have made it possible for oral and maxillofacial surgeons, periodontists, and general dentists in the United States to double the number of implants performed per dentist between 1995 and 2002.

Dental implant history timeline

Ancient history: Mayans back in AD 600 had dental implants made from pieces of shell and ancient Egyptians used shells and ivory.

1700s: Lost teeth were often replaced with teeth from human donors. The process was mostly unsuccessful due to immune system reactions to the foreign material.

1800s: Researchers fabricated gold, platinum, and other metal alloys, including lead, into posts that were placed into the sockets of extracted teeth and donor teeth were attached after a healing period.

1886: Dr. Edmunds was the first in the United States to implant a porcelain crown mounted on a platinum disc and presented at the First District Dental Society of New York.

1913: Dr. E.J. Greenfield, pioneer of endosseous implant, provided many of the basic concepts of the nascent field of implantology. He was most known for his patented hollow-cylinder implants made of wires soldered with 24 karat gold and outlined surgical implant placement technique (Figure 1.4).

1939: Dr. A.E. Strock introduced the first biocompatible material, the metal alloy Vitallium, to place a series of implants at Harvard University in animals and humans. He is credited with the first relatively long-term successful dental implants.

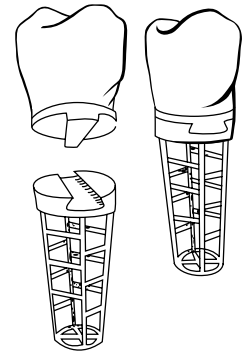


Figure 1.4 Dr. Greenfield's basket design. Greenfield (3).

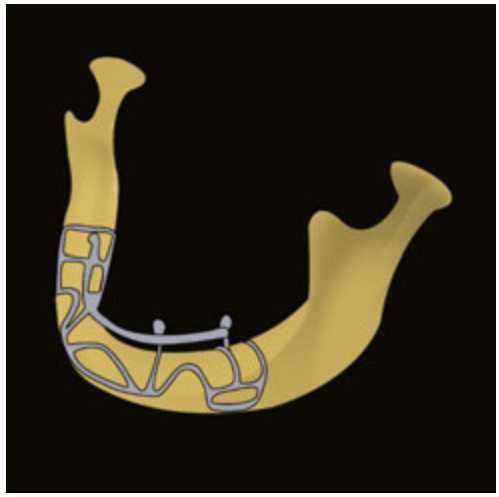


Figure 1.5 Dr. Dahl subperiosteal design.

1941: Dr. Gustav Dahl of Sweden is credited with the development of the **subperiosteal implant**, a metal framework that is surgically placed on top of the jawbone for completely edentulous patients (Figure 1.5).

1952: Professor Per-Ingvar Brånemark discovered that titanium components can bond irreversibly with living bone tissue and coined the term osseointegration.

1964: Commercial grade pure titanium, or commercial pure titanium, was accepted as material of choice for dental implants.

1967: Dr. Leonard Linkow of New York developed the blade implants and Doctors Ralph and Harold Roberts are also credited with the development of **endosteal implants** (Figure 1.6).

1968: Dr. Irwin Small developed the **transosteal dental implant** (Figure 1.7).

1969: Dr. Per-Ingvar Brånemark provided the proof of long-term success of titanium implants.

1981: Dr. Per-Ingvar Brånemark published his findings covering all the data on the animal and human clinical trials: success rate, concept, and the current design of **endosteal root-form titanium implants.**

1982: The Toronto Conference on Osseointegration in Clinical Dentistry created the first guidelines for what would be considered the standardization of successful implant dentistry.

1986: Implants received the endorsement of the American Dental Association (ADA).

1989: The Brånemark Osseointegration Center (BOC) in Gothenburg, Sweden, was founded. BOC's primary mission was to provide treatment for patients with severe oral, maxillofacial, and orthopedic impediments.

2002: An ADA survey showed that oral and maxillofacial surgeons, periodontists, and general dentists doubled the number of implants performed per dentist between 1995 and 2002.

Today: The Food and Drug Administration (FDA) regulates the oral and dental implants being placed, requiring implant companies to furnish data and controlled studies under medical devices to gain full approval.

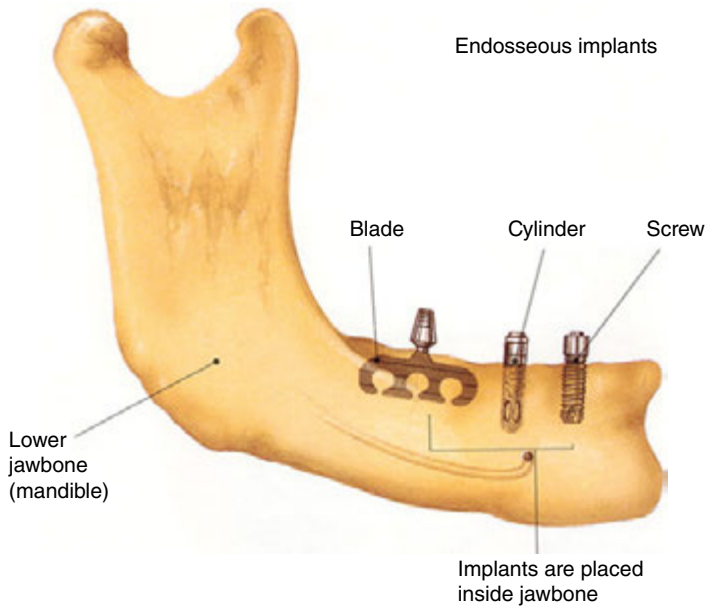


Figure 1.6 Endosteal design. Juodzbalys and Wang (21).

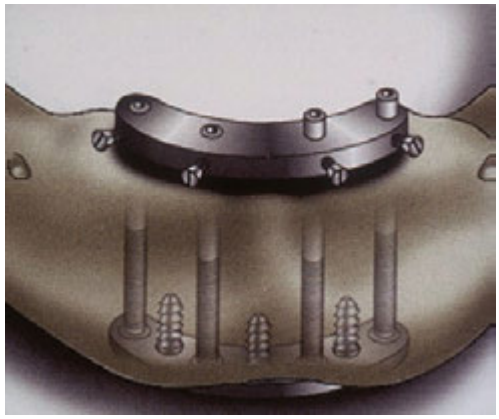


Figure 1.7 Transosteal design. Reprinted with permission from Zwemer (22) © 2008 Elsevier, Inc. All rights reserved.

Figure 1.8 Titanium and ceramic (zirconia) implant examples. Courtesy of Straumann.

Implants

Over the past 30 years, research has validated the success of osseointegrated implants as a viable alternative to fixed or removable prosthetic restorations (Figure 1.8) (4). Implant placement in the premolar and molar are 95% successful and are considered the first choice in tooth-replacement options (5, 6). This is supported by the dental literature for many implant systems in every area of the mouth (7). According to Michael Tischler

necessary for hygienists to know all the ins and outs of implant metals and designs, since the choice of implant to use will be in the hands of the surgeon. However, the biomechanics of implants or component parts of an implant are important to know and understand. The three main component parts of an implant are the implant body, with different designs, lengths, shapes, diameters, and surfaces; secondly, the abutment, which comes in many different types and materials, and even custom abutments are available, all screw directly into the implant to connect with the restoration/prosthesis. The final stage is the prosthesis; crown, bridge, fixed prosthesis, or removable overdenture (see Figure 1.17).

After the implant is placed into the bone, a cover screw or healing abutment (Figure 1.18) is placed directly into the implant to prevent bone and/or soft tissue from infiltrating the internal aspect of the implant during osseointegration. The healing abutment extends through the gingival tissue, forming the tissue contour/emergence profile to receive the final abutment and restoration (Figure 1.19).

At this time, well over half a million dental implants are being surgically placed annually. Implants are being properly planned and executed with success rates well over 90%. And yet, as rapidly as this

Figure 1.18 Examples of cover screws. Courtesy of BioHorizons.

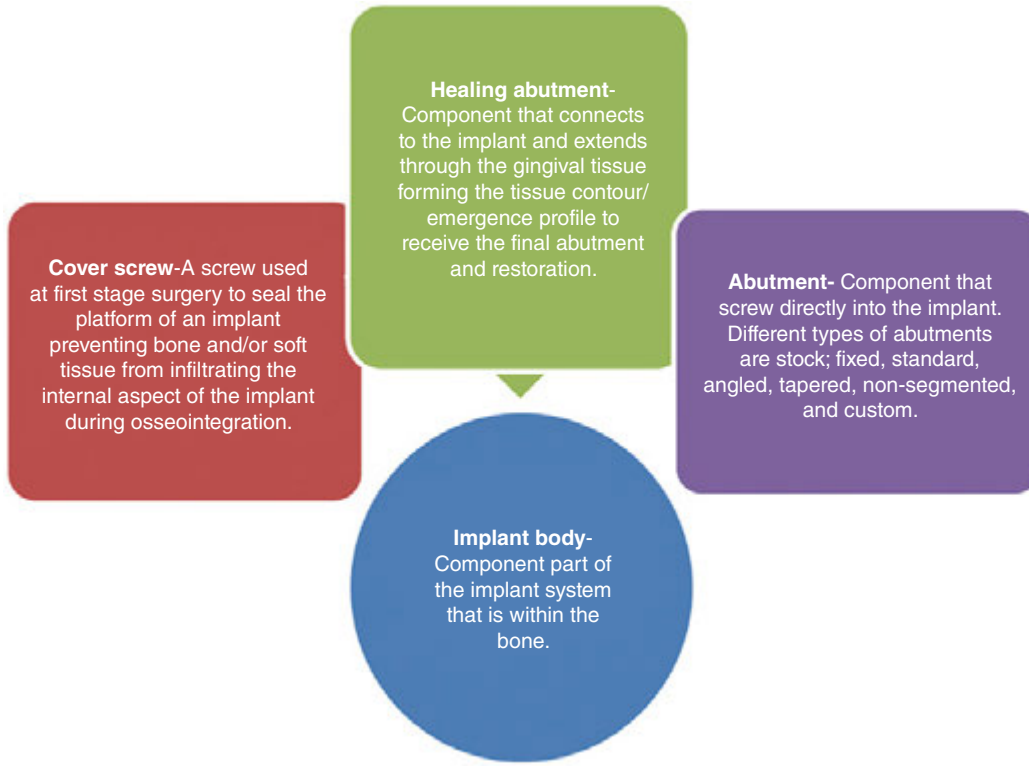


Figure 1.17 Parts and pieces.

Figure 1.19 Examples of abutments. Courtesy of BioHorizons.

field of dentistry is growing, the majority of potential dental implant patients are unaware that this treatment exists. To address this, dental hygienist can take the lead and talk with his or her patients about tooth replacement and implant dentistry. As hygienists, we need to ***plant the seeds*** with our patients that the technology exists today to better their quality of life. The knowledge of key implantology terms will allow hygienists the opportunity to talk with their patients about implants and these quality of life issues. See the Appendix for more implant dentistry terminology.

Implant dentistry terminology

Connecting bar: System between two or more implants to be utilized for stability for implant prosthesis.

Dental implant: A biocompatible device placed in the bone to replace the root lost, preserve the bone level, and support the prosthesis.

Dental implant abutment: The component part that screws directly into the implant to retain the crown, bridge, and/or overdenture prosthesis in place.

Implant thread: The screw-like component part of the body of the endosteal, root-form implant.

Osseointegration: The firm, direct, and lasting biological attachment of an implant to vital bone with no intervening connective tissue.

Peri-implant diseases: Collective term for inflammatory lesions that may affect the peri-implant area, mucositis, and peri-implantitis.

Peri-implant mucositis: A pathological condition occurring in the tissue around dental implants, inflammation similar to gingivitis, reversible, caused by bacteria, biofilm, or residue. Manifests in the form of redness and inflammation, in the peri-mucosa, with no additional bone loss.

Peri-implantitis: A pathological condition occurring in tissue around dental implants, characterized by inflammation in the peri-mucosa and progressive loss of supporting bone that can be irreversible.

Periosteum: Fibrous vascular membrane that fits tightly on the outer surface of the bone.

Permucosal seal: The tissue seal that separates the connective tissues from the outside environment around a dental implant.

Prosthesis: The removable or nonremovable restoration that attaches to the implant to replace the teeth.

TADs: Titanium mini-screws used primarily by Orthodontists in the facilitation of moving teeth or anchoring an orthodontic appliance.

Summary

The 21st century is an important and critical time to be a hygienist! History has shown us that implants are not new and

3 What Lies Beneath the Surface? Natural Teeth, Bone, and Implant Surgery

Natural teeth versus implants, 31
Bone: it is all about the bone!, 33
  Four classifications of bone, 35
  Frequently asked questions, 35
  Bone loss overview, 36
Bone regeneration, 37
  Regenerative procedures, 40
  Procedures to prevent bone resorption, 42
  Post-regenerative procedures home care, 43
Implant surgery, 43
  Endosteal dental implant surgery, 44
  Post-surgery implant home care, 46
Specialized implant placement, 46
  Subperiosteal dental implant placement, 46
  Transosteal dental implants placement, 47
  Zygomatic dental implants, 48
  Implant supported fixed final prosthesis dental implant procedure, 48
Summary, 50
References, 50

As dental hygienists we sculpt root anatomy while being blindfolded. The goal is not to alter the root surface, but to uncover the pre-existing root anatomy which lies beneath.

—Catherine Fairfield, RDH

As hygienists, uncovering the underlying anatomy is critical to understanding how to access, monitor, and maintain implants. Being able to visualize the physical characteristics of natural roots and implants, as well as the differences between different types of bone and tissue surrounding implants, will allow hygienists to effectively maintain implants. As well as, a fundamental knowledge of the biomechanics and component parts of an implant and the many varied restorative options.

Natural teeth versus implants

The physical differences between natural teeth and implants are often compared to the roots of teeth. Replacing the root of a tooth helps to maintain the bone in the maxillary and inferior dental arch. There are differences that start with the surface of a natural tooth (i.e., cementum) and the implant surface of titanium alloy or ceramic (zirconia), rough, porous, or smooth. No cementum or periodontal ligament (PDL) are the main differences. Both natural teeth and implants have a sulcus, junctional epithelium, supracrestal fibers, and bone. The supracrestal fibers are different. In natural teeth, they are in a pattern of attachment and implants with an adherence. The natural teeth are held in, primarily, with the tissue attachment and the PDL and implants mainly by bone. Figure 3.1 shows how the implant attaches to bone.

Peri-Implant Therapy for the Dental Hygienist, Second Edition. Susan S. Wingrove.

Companion website: www.wiley.com/go/wingrove/implant

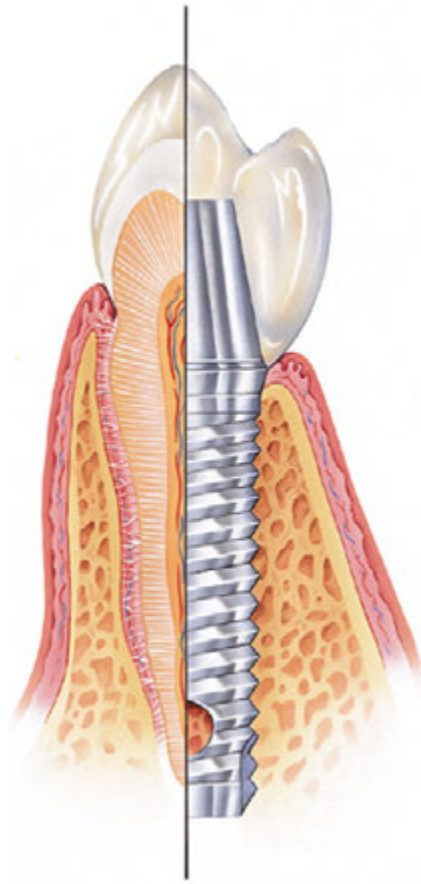


Figure 3.1 How an implant attaches to bone. Courtesy of Keystone Dental.

One of the key physical differences between a natural tooth/root and an implant is that implants are not susceptible to decay. This is one reason implants are a very good restorative choice for patients with controlled diabetes, xerostomia, or autoimmune disease patients. Xerostomia patients who suffer from decreased saliva go from an increase in decay to broken teeth and eventually dentures without much success. If an implant is placed when the first tooth is lost, this cycle can be broken and the quality of life for these patients greatly improved. Autoimmune diseases (i.e., AIDS, asthma, arthritis, or lupus) where the patient's immune system is not functioning properly can be helped by implant therapy which does not rely on the host response to stay healthy.

The mobility of a natural tooth can cause a loss of attachment, periodontal disease, or trauma that can be reversed. The natural tooth can also test positive or negative for mobility due to periodontal disease or occlusion. Implant mobility is caused by occlusion, trauma, or infection, but with a much more negative result, often the loss of osseointegration which means the loss of the implant. Since an implant is held in by the bone with no periodontal ligament (PDL), such as a cement post in the ground, if it becomes mobile there is a good chance the implant will fail. The good news is that in most cases it can be replaced with a new implant.

The attachment of the tissue that surrounds the natural tooth and implants is where the bigger differences lie. The attachment of the gingival tissues to the neck of the implant is distinct from the attachment to natural teeth. Both the natural tooth and the implant have junctional epithelium (hemidesmosomes and basal lamina) and sulcular epithelium but implants have no evidence of Sharpey's fibers between an implant or implant abutment and bone.

The junctional epithelium of a natural tooth attaches to the tooth coronal to the bone up to 2 mm and has a sulcular epithelium of 2–7 mm with a definite connective tissue attachment. The implant has only an adhesion attachment of connective tissue with a junctional epithelium up to 1.5 mm. It runs parallel and circular to the fixture with a sulcular epithelium of 0.5–1.0 mm, but these do not insert into the implant surface. Making this attachment much more fragile and susceptible to damage by trauma and/or infection. This tissue–implant interface is known as the ***perimucosal seal***. The perimucosal seal is the tissue barrier that prevents microorganisms and other inflammatory agents from the oral cavity from entering the tissues that surround the implant. It contains the

Table 3.1 Comparison between natural dentition/tissue and dental implants.

Structure	Natural Dentition	Implant
Attachment	Cementum, periodontal ligament, and bone	Bone (osseointegration)
Tissue: junctional epithelium, sulcular epithelium and connective tissue (CT)	**Junctional epithelium:** Attaches to the tooth coronal to the bone up to 2 mm **Sulcular epithelium:** 0.2–0.7 mm **CT:** Has attachment	**Junctional epithelium:** Run parallel and circular to the fixture up to 1.5 mm, do not attach **Sulcular epithelium:** 0.5–1.0 mm **CT:** Adhesion, no attachment
Vascularity and bleeding on probing (BOP)	**Vascularity:** Greater **BOP:** Reliable Supraperiosteal and periodontal ligament	**Vascularity:** Less **BOP:** Less reliable Periosteal only
Decay	Decay is possible	Do not decay
Infection	Yes, gingivitis and periodontitis	Yes, mucositis and peri-implantitis
Mobility	Yes, caused by loss of attachment, periodontal disease, or trauma. Reversible	Yes, caused by peri-implant disease, occlusion, or trauma. Not reversible

sulcular epithelium, and its presence is important for the longevity and success of the implants (see Table 3.1).

Bone: it is all about the bone!

In implant dentistry, the most important factor is bone: quality, quantity, and density influence successful outcomes. The volume density of bone matrix in cortical (outer layer) bone is approximately 80–90 and 20–25% in cancellous (inner layer) bone (1, 2). Bone is composed of cortical and cancellous bone, and intertwined between these two parts is a lattice network of trabecular that is the reservoir for active bone metabolism (see Figure 3.2). The bone structure is continuously repairing and remodeling to keep its form and function.

Dental hygienists need to have a clear understanding of bone quality and density. Be able to explain this to patient in terms of how much time will it take for the patient to complete his or her implant treatment.

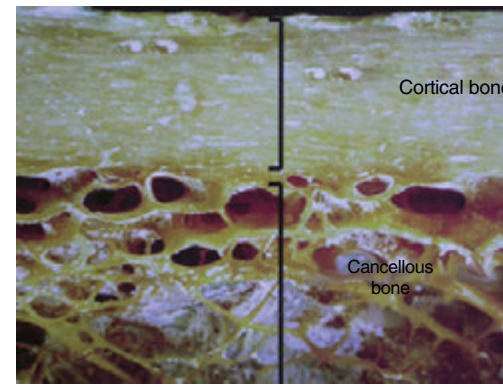
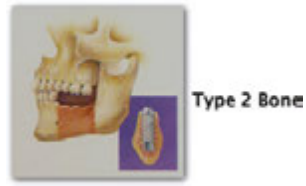
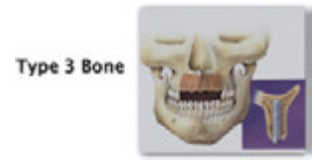
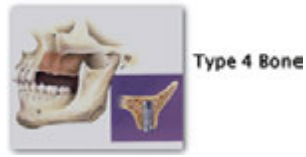


Figure 3.2 Cortical and cancellous bone. Courtesy of Keystone Dental.

To help the patient understand the expense associated with possible added procedures to have the necessary bone for successful treatment results. Research clearly states that *the strength of the bone is directly related to the density of the bone* (3, 4). Also, *the quality and density is directly related to the type of implant* the dental professional will choose to place, the healing time needed for the

Table 3.2 Bone classification (5).

Bone Type	Example
Type One Very compact, dense cortical bone 3–4 months of healing time Compares to oak/hard maple	 **Anterior mandible**
Type Two Porous, compact cortical bone 4–6 months of healing Compares to spruce/white pine	 **Posterior mandible**
Type Three Coarse, trabecularless cortical bone Usually a 6-month healing time Compares to balsa wood	 **Anterior maxilla**
Type Four Fine, trabecularminimal cortical bone 6–8 months of healing time Compares to Styrofoam	 **Posterior maxilla**

Figures courtesy of Keystone Dental.

patient, and success rate for the implant. Actual healing times may vary based on the patient's ability to remodel bone and his or her overall health.

For learning purposes and for a visual image to present bone types of the oral cavity to a patients, (see Table 3.2). Bone classifications are identified in four distinct bone types: *woven, lamellar, bundle, and composite*. Woven bone is rapidly replaced by mature, stress-bearing bone. Lamellar bone is the main component of mature cortical and trabecular bone. Bundle bone generally is found adjacent to the PDL with characteristics of ligaments and tendon attachments. Composite bone is a variation of fine cancellous compaction (osteons) or coarse cancellous compaction (whorling bone) (6). The literature points out that there are different surgical protocols for different bone types that affect healing and treatment planning (4–10). There are exceptions to the rule in location and type of bone for patients, but for an initial conversation with the patient, this classification is ideal.

Four classifications of bone

The hygienist needs a fundamental understanding of each type of bone and to be able to relate to the patient a tactile sense of the density of the bone in relation to where the implant will be placed (5). Each bone type can be compared to a type of wood to help the patient understand, visualize, and be able to relate to the surgeon's recommendation for healing time.

The bone is classified according to structure, composition, density, and volume with four types of bone referred to as types 1–4 or D1–D4 (the reference is the same; only the terminology is different). To further define this, the types are as follows:

1. **Type One Bone** is found in the anterior mandible, composed of dense cortical bone that has minimal trabecular spaces, making it the densest type of bone. The healing time is approximately 3–4 months. This varies based on multiple factors and is generally monitored by the surgeon. This bone density is compared to oak or hard maple wood.
2. **Type Two Bone**, generally found in the posterior mandible, is described as porous cortical or course trabecular. The cortical bone density is found in the superior and inferior borders and the trabecular in the center of the posterior mandible. The healing time is approximately 4–6 months based on amount of cortical bone present and monitored by surgeon. This bone density is compared to spruce wood or white pine.
3. **Type Three Bone**, found primarily in the anterior maxilla, is less dense crestal cortical bone than type one or type two while the remaining bone is quite trabecular. This translates into a more fragile type of bone, sometimes requiring more healing time and in which progressive loading of implants may be treatment planned. Progressive loading is the gradual increase in the application of load or forces on the final restoration and ultimately the implant monitored by the surgeon. The bone density is compared to balsa wood and healing time is approximately 6 months.
4. **Type Four Bone** is found in the posterior maxilla, consisting of minimal crestal cortical bone thickness with the remainder being very trabecular. This means this is the poorest quality of bone, with the highest implant failure rate, and for which progressive loading is strongly considered. Healing time is approximately 6–8 months and the bone density is compared to Styrofoam.

Hygienist Tip:

What the location, density, and quality of bone means to patients: "When and how fast can I get my implant/restoration?" Hygienists learn how to answer the most frequently asked questions and have the discussion with patients on WHY it is worth the wait for implants, it's all about the bone!

Frequently asked questions

Why is bone density or type so important?
The type of bone is critical in implant therapy. It is directly related to implant placement, implant selection, and the length of healing time for osseointegration.

A hygienist must know this for treatment planning and to be able to explain to the patient the different ***types or densities*** of bone in relation to healing time and restoration selection options.

What is the tooth relationship to type of bone?
Basel bone forms with or without teeth or implants. Alveolar bone forms because of teeth and residual bone is alveolar bone that has been resorbed.

What happens if teeth are lost and not replaced?

If teeth are lost and not replaced, atrophy and bone loss becomes apparent to facial aesthetics. This is commonly recognized as premature aging, increased wrinkles, jowl development, and loss of function.

Bone loss overview

Emphasize these points with patients when having the conversation on why bone is important. The width of bone decreases 25% in the first year after a tooth is lost or extracted and the bone height decreases 4 mm in the first year (11, 12). In the first 2–3 years after an extraction, 40–60% of the ridge width can be lost (13) and the overall bone can continue to be resorbed 0.5–1% yearly for the patient's life (14).

When there are missing teeth involved, bone and tissue degrade over time, losing their function. If a tooth is extracted and left to heal on its own, it will repair, but with tissue regenerating faster than bone causing a sunk-in effect, (see Figure 3.3).

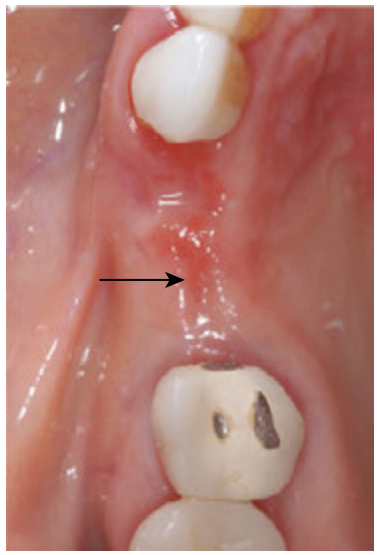


Figure 3.3 Ridge width lost (bone) with traditional extraction, no socket preservation. Courtesy of Dr. Kevin Frawley.

Resorption and remodeling of the alveolar bone occurs after teeth are lost due to periodontal disease, trauma, or tooth extraction (15, 16). If regenerative procedures such as socket preservation are done at the time of extraction, the bone will regenerate and keep its structure.

What happens if bone loss continues? As the jawbone continues to resorb or melt away, the patient returns for relines on his or her dentures to keep them in place and to accommodate for the remodeling of the jawbone. If this bone loss detoriates to severe levels, the patient may not even be able to wear dentures because the destruction of the jaw bone puts pressure on the nerve bundle with the denture, causing the patient pain, (see Figure 3.4).

To prevent bone loss and maintain the bone in the jaw for both natural teeth and implants, the bone needs to be stimulated. The teeth transmit force to the surrounding bone every time they come together in occlusion. Implants can maintain this by stimulation to the bone when occluded on. Also, by being placed into the bone like the roots of a natural tooth they can even increase bone density and preserves facial structure.

Hygienist Tip:

Learn how to explain this concept to patients with an understanding of Wolff's Law, developed by Julius Wolff in the 19th century (see Box 3.1). He states that ***"bone in a healthy person or animal will adapt to the loads it is placed under"*** (17).

After implant placement, the implant is loaded by placing a restoration or prosthesis. The bone will then remodel itself and become stronger (see Box 3.1). The converse is true that if the loading on the bone decreases due to loss of an existing tooth, the bone will weaken due to lack of stimulus for the remodeling that is required to maintain bone mass (18), (see Figure 3.5). *Bone needs to be stimulated!*

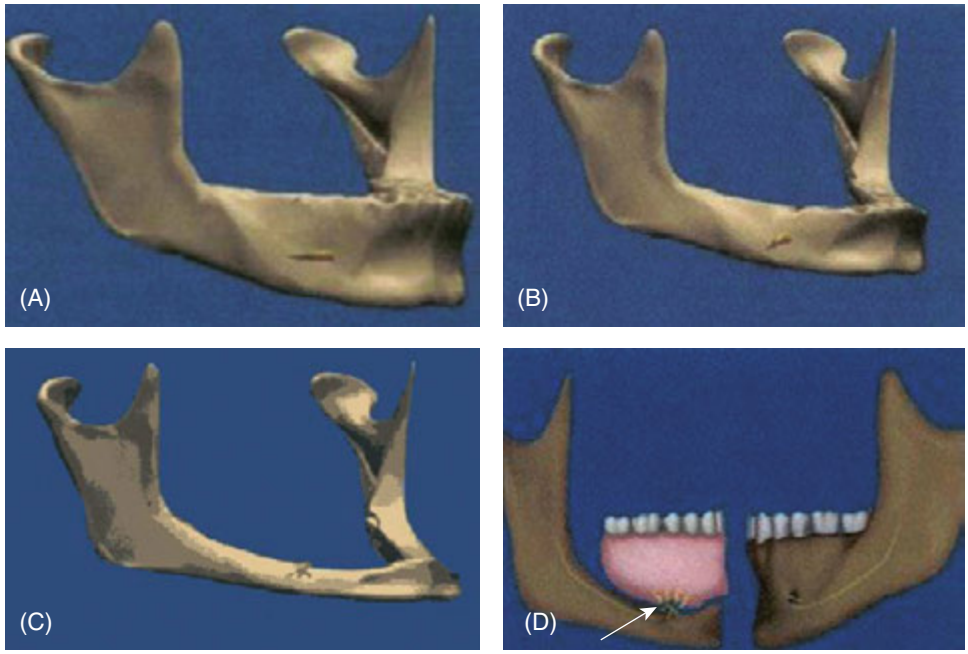


Figure 3.4 *What happens when bone loss continues?* Patient eventually will not be able to wear denture. Courtesy of Keystone Dental.

Box 3.1 Wolff's Law

Keys Points of Wolff's Law

- Bone must be stimulated to be maintained.
- Teeth transmit force to surrounding bone when in occlusion.
- Lack of stimulation or occlusion results in bone loss or resorption.
- An implant best replicates a natural tooth by replacing the root and crown.
- Implants maintain and increase bone density, preserving facial structure.

Figure 3.5 Bone needs to be stimulated (Wolff's Law). Courtesy of Keystone Dental.

Bone regeneration

Techniques and products are also available today to regenerate lost bone and tissue. To understand the principles of regenerative tissue engineered products and how they can promote healing, hygienists need to refer back to their sciences (i.e., histology), to their knowledge of how the cells work.

It starts with an understanding of the principles behind regeneration and

Table 3.3 The principles behind regeneration.

Type of Healing	Definition	Example
Osteogenesis *(cells)*	Osteogenic materials that contain living cells within the graft that contribute to bone formation and remodeling.	Autografts Autloglous and allogeneic stem cell materials
Osteoinduction *(signals)*	Osteoinductive graft materials contain signaling growth factors and/or biologics that stimulate the chemotaxis, differentiation, and division of cells for that then form new tissues in regeneration.	Allograft materials (contain BMP) Autlologous blood concentrates (PRP, PRF) Enamel matrix derivatives (EMD) Recombinant Human Platelet-rich growth factor (rhPRGF) Recombinant Human Bone Morphogenic Protein (rhBMP) Recombinant Human Fibroblast Growth Factor (rhFGF)
Osteoconduction *(scaffolds)*	Osteogenic materials that serve as an inert scaffold that allows angiogenesis and guides native cell population of the graft material. Space maintenance and occlusion of soft tissue cells can be achieved through the use of cell-occlusive membranes to separate graft materials from overlying soft tissues.	Autografts, Allografts Xenografts Alloplasts

osseointegration of implants into the bone. To grasp the full picture, refer to Table 3.3 to understand how bone remodels. Outlined are the types of healing that you need for regeneration. ***Osteogenesis (cells***), the osteogenic materials that contain living cells within the graft that contribute to bone formation and remodeling. ***Osteoinduction (signals),*** the grafting materials that contain signaling growth factors and/or biologics that stimulate the chemotaxis, differentiation, and division of cells form new regenerative tissues. ***Osteoconduction (scaffolds),*** are osteogenic materials that serve as an inert scaffold that allows angiogenesis and guides native cell population of the graft material. Space maintenance and occlusion of soft tissue cells can be achieved through the use of cell-occlusive membranes to separate graft materials from overlying soft tissues.

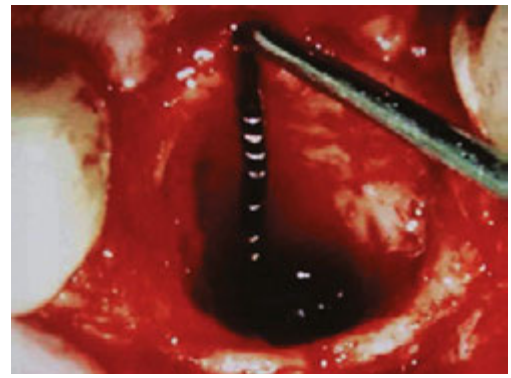


Figure 3.6 Blood clot is essential to healing. Courtesy of Dr. Kevin Frawley.

There are a number of steps to bone regeneration starting with the blood clot, essential to the healing process, (see Figure 3.6). Granulation tissue is formed, blood vessels migrating through the defect,

and the precursor cells migrate to the site from the marrow spaces of the adjacent bone. The regenerative procedure and/or product can be added to help the body perform this task more effectively for optimal results.

The normal wound healing sequence is hemostasis and inflammation, followed by proliferation of the cells, and finally maturation and remodeling. So, you have bleeding in the inflammatory stage, then connective tissue regenerates (proliferation), and finally bone remodels. ***If regenerative procedures and products are not used, the body generally heals with secondary intent in the form of scar tissue or scarring.***

The bone quality and quantity needs to be adequate or placement of an implant is not possible. Bone augmentation procedures are used with bioabsorbable (do not need to be removed) or nonresorbable (have to be removed) barrier membranes and bone grafting products or bone substitutes to enhance regeneration (19, 20). The regenerative products include mineralized/demineralized cadaver bone particulates, membranes, and growth factors; examples of these are listed, (see Figure 3.7 and Table 3.3).

Bone grafts are used to correct a defect and are categorized in four types: autografts, allografts, xenografts, and alloplasts. They can be used alone or in combination based on the osteogenic, osteoinductive, or osteoconductive principles (21); (see Table 3.3). Autografts are derived from patient's own bone from a donor site to the area to be grafted. Allografts are bone harvested from same species (i.e., human cadaver bone). The main concern of allografts is the risk of disease transmission, but this is all but eliminated with the current processes used to sterilize the cadaver bone (22, 23).

The use of xenografts goes back, as far as, 1889 and refers to bone grafts derived from another species (i.e., from an animal: bovine [cow], and equine [horse]). They are biocompatible, osteoconductive, and resorb over time ***replaced with the patient's own natural bone*** (24–26). Alloplasts are synthetic bone derivatives, are osteoconductive, but are not osteogenic or osteoinductive.

Figure 3.7 Examples of regenerative products. (A) Osteogenesis cells, OSSIF-i™ Particulate Allograft Bone Particulate Surgical Esthetics. (B) Osteoinductive growth factor, Straumann® Emdogain® Enamel Matrix Derivative. (C) Osteoconduction scaffold, GUIDOR Alloplast Bioresorbable Matrix Barrier.

The use of bone particulates (autograft) is the gold standard for treatment of implant-related bone defects (21, 27). Allografts with the use of bone particulates derived from the same species (human donor bone) are used in forms of putty, gel, and collagen sponges. They also have a high success rate,

eliminating the need for the morbidity associated with the donor site and many times eliminate the need for a second surgery (27). For more information on bone grafting options (see Chapter 4).

The growth factors and/ or biologics on the market are Allograft materials that contain blood morphogenic protein (BMP). Autologous blood concentrates; platelet-rich plasma (PRP) that is derived from the patient's whole human blood and processed through gradient density centrifugation. Platelet-rich fibrin (PRF) is also derived from the patient's whole human blood, centrifuged and then isolated proteins from the blood plasma are used to spray onto the implant body to accelerate osseointegration.

Also available are; Enamel matrix derivatives (EMD), a unique mixture of natural proteins. Once applied, these proteins form a matrix that can induce biological processes and may stimulate certain cells involved in the healing action of soft and hard tissues (28), (i.e., Emdogain® by Straumann). As well as, embryonic stem cells that are derived from early stage embryos and amniotic stem cells from donated placenta-derived products. These stem cell biologics are able to differentiate into various tissue types such as skin and bone with very promising study results (21, 27). Recombinant Human Platelet-rich growth factor (rhPRGF), Recombinant Human Bone Morphogenic Protein (rhBMP), and Recombinant Human Fibroblast Growth Factor (rhFGF) are also examples of osteoinductive growth factors (see Table 3.3).

Regenerative procedures

Regenerative procedures are often referred to as *guided bone regeneration* (GBR) or *guided tissue regeneration* (GTR). These procedures use the regenerative products especially the membranes that are designed to keep the unwanted cells out by creating a barrier, protecting the blood clot to allow for regeneration. The most common GBR procedures include socket preservation, implant defects (dehiscence or fenestration), and sinus and ridge bone augmentation.

Socket preservation procedure involves placing graft particulates and/or a scaffold in a tooth socket done at the time of extraction to preserve the alveolar ridge. If socket preservation is not done, the bone resorbs and is lost, as well as the alveolar ridge does not retain its original shape. Socket preservation is often done to prepare for an implant to be placed, however, it should be done after every extraction to preserve the bone and maintains the facial bone structure for the patient (see Figure 3.8).

If an implant treatment is planned to be placed, it is ideal to do a bone augmentation procedure at the time of extraction. A bone augmentation can be done at a later date, but at a much higher cost to the patient as well as with an additional surgical procedure. The key point to understand is that socket preservation differs for ridge augmentation; socket preservation is done before the bone structure is lost at the time of extraction and ridge augmentation is a procedure to bring back the lost bone and rebuild the ridge height and width. Socket preservation following tooth extraction is now becoming a standard of care. As a hygienist, record on the patient's record if the patient declines socket preservation, be sure to record it as an option presented to the patient at time of treatment planning an extraction, including any wisdom teeth extractions.

Implant defects (dehiscence or fenestration) are defined as the ***gap*** between the socket wall of less than 2 mm and the implant. A dehiscence is a defect that extends to the bone crest. A fenestration is a defect that does not extend to the bone crest, leaving an isolated buccal or lingual area of an implant exposed to the oral