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IMPLANT DENTISTRY: FROM SEASHELLS TO TITANIUM

A history of the development of implantology | By Francis G. Serio, DMD, MS, MBA

Abstract

During the past 30 years implant dentistry has grown to become not only a reliable, predictable segment of the mainstream of dental care, but also one that offers a vastly improved quality of life for edentulous patients. This article provides a brief history of the development of implant dentistry, including a discussion of key pioneers of dental implantology, and focuses on clinical and technical applications and landmark clinical studies. Current technological advancements such as cone-beam computerized tomography and treatment planning software are also highlighted.

Learning Objectives

After reading this article, the reader should be able to:

- Engage in an overview discussion of the history of implant dentistry.
- Name several prominent innovators who were instrumental in the development of dental implantology.
- List key characteristics and features of today's implants.
- Discuss recent technological advances in both the diagnostic and treatment arenas of implant dentistry.

IN THE PAST 30 YEARS implant dentistry has evolved from a clinically interesting, sometimes successful, but not quite predictable treatment modality to where it is today—a predictable segment of the mainstream of dental care.

People have been trying to implant replacement teeth for millennia. According to Misch, implant dentistry is the second oldest dental discipline after exodontia.[1] In the second millennium B.C., the Chinese fashioned tooth replacements out of bamboo and drove them into the jawbones. Egyptians used precious metals to accomplish the same thing. There is evidence that Mayans and Incas used seashells as "implants" as many as 1,400 years ago. In the 19th century, dentists used gold, platinum, and other precious metals as implants in extraction sockets without success.

In the 20th century, researchers, dental technicians, and clinicians experimented with a variety of materials, including gold, cobalt chrome, zirconium dioxide, vitreous carbon, stainless steel, titanium, and other materials to find the holy grail of a biologically compatible, long-lasting dental implant. Implants came in any number of shapes, including conical, corkscrew, blades, and some designs that defied description.

Endosseous implants were placed in bone, transosseous implants were placed through bone, and subperiosteal implants were placed on bone underneath the oral mucosa. It was not for lack of imagination that implant dentistry did not come into its own until the late 20th century.

The modern era of implant dentistry began with the work of Brånemark, a Swedish orthopedic surgeon who was studying the healing and regenerative processes of bones in the rabbit. A serendipitous finding of his work showed that bone would grow up to his titanium healing chambers so that it was nearly impossible to remove these chambers for reuse. He termed this type of healing of bone in contact with the Educationtitanium by light microscopy as osseointegration.[2] Electron microscopic evaluation showed that there was a 20-nm gap between the bone and titanium in some places and direct contact in others, but for practical purposes there was union between the two.[3,4] He started experimenting with titanium implants in human subjects in 1965.[5] His group did many of the early landmark longitudinal studies that showed that root-form implants were a predictable modality upon which to construct either fixed or removable intraoral prostheses.[6]

> "There is evidence that Mayans and Incas used seashells as "implants" as many as 1,400 years ago."

The consistent characteristic of dental implants since the 1980s is that they have a conical root form. Almost everything else about implants has changed since that time. The original Brånemark root-form implants were of commercially pure titanium, then titanium alloy with a machined-threaded smooth surface and an external anti-rotation hex at the top of the implant. Other implants were press-fit where the implant fixture was tapped into place into a hole in the bone 0.3-mm to 0.5-mm narrower than the implant itself. Surface treatments also changed from smooth machined surfaces to those covered with hydroxyapatite, to the current standard of roughened surfaces to increase surface area and mechanical interlocking ability of implant to bone.

Today, implants are generally made of a titanium alloy but have a variety of thread patterns; typically internal anti-rotational features such as variations of the internal hex design that provides both a friction fit between the implant head and abutment as well as resistance to rotation of the abutment in the implant head, other anti-rotational features or a single-unit design of the implant and abutment; diameters, including "mini" implants, of 3-mm wide or narrower; roughened surface textures achieved by various means; polished collars; and abutment designs. The number of implant manufacturers seems to change daily, with some companies being absorbed by others and new players in the market touting certain distinguishable product features. Endosseous, root-form implants are available from many manufacturers in the United States, Europe, and Asia. What began as the Brånemark procedure, with rigid specifications for the implants themselves as well as a prescribed treatment protocol, has evolved into a cacophony of competing products, claims, and procedures. While Brånemark initially insisted on operating room conditions for implant placement, it has been shown that dental office aseptic technique is sufficient to minimize postoperative infections and does not affect success rates.[7,8]

One other area that has contributed to the explosion in implant dentistry is guided bone regeneration (GBR), the predictable restoration of lost alveolus or the growth of bone in sites such as the maxillary sinus where bone is normally not found.[9] Advances in regenerative therapy have opened the door for patients with severely atrophic ridges or localized osseous defects to enjoy the benefits of implant-retained restorations.

Clinical Applications

The development of predictable implantretained prostheses has been a boon to the edentulous patient with a severely atrophic

mandible. In the past, these patients had been sentenced to a life of ill-fitting, painful mandibular removable complete dentures with no hope of functional improvement. With advances in both the implants themselves and GBR allowing for the placement of implants in areas with otherwise insufficient bone for implant support, many of these patients can confidently wear a removable or fixed prosthesis in comfort with good masticatory function. Retention of the removable prosthesis may be accomplished with snap-type locators between the implant and tissue side of the denture or with a custom cast bar with clips in the underside of the denture.[10] In cases where the patient has enough resources and bone, a fixed prosthesis may be screwed or cemented to the implant abutments.

While restoration of the completely edentulous mouth is perhaps the most dramatic development, the use of implant-retained prostheses for single or multiple tooth replacement has also matured. Young patients with congenitally missing maxillary lateral incisors who have finished growing can now have a fixed restoration without involving the adjacent teeth. For those patients who must have a tooth removed, placement of an implant, either at the time of extraction or after ridge preservation bone-grafting procedures, allows for the maintenance of the bone volume of the alveolus and then fabrication of an all-ceramic or ceramo-metal restoration. Implant-supported fixed bridges allow patients to restore their dentition without resorting to sometimes uncomfortable and unstable removable appliances. Implants have also been used as temporary anchorage for orthodontic care and in extraoral sites for the anchorage and stabilization of maxillofacial prostheses. Narrow-diameter or so-called "mini" implants have been used as transitional fixtures during implant-retained rehabilitations.11

Landmark Clinical Studies

Many of the landmark studies that support modern implant dentistry emanated from the work of Brånemark and his colleagues in Göteburg, Sweden. His initial report in 1969 outlined the proof of principle for the use of titanium for dental implants.[5] Subsequent papers outlined successes in both animals and humans. Initial protocols for both placement and restoration of implants were developed. The first long-term study of success of the Brånemark approach was published in 1981 by Adell, et al.[12] They demonstrated a greater than 90% success rate of implants in the mandibular symphysis region over a 15-year period. These results have been replicated by many other studies.[6,13,14] Similar long-term results have been published for restoration of the partially edentulous patient.[15-17] In 1985, Brånemark, Zarb, and Albrektsson published their seminal work outlining the principles and scientific evidence supporting osseointegration and the restoration of implants in the edentulous patient.[2] Criteria for success, including absence of persistent signs and symptoms of pathology; implant immobility; no continuous peri-implant radiolucency; and negligible progressive bone loss have been published.[18] Other considerations for success include the location of the implant, quality of bone, type of restoration and occlusion, presence or absence of periodontal disease, and systemic factors such as smoking or uncontrolled diabetes.[19]

New Technological Developments

There have been several recent technological advances in both the diagnostic and treatment arenas of implant dentistry. Initially, clinicians had difficulty determining the 3-dimensional (3-D) bone volume available for implant placement using conventional 2-dimensional (2-D) radiographic techniques and clinical examination alone. The third dimension is critical in determining ridge width, the location of the mandibular canal and mental foramen in the lateral plane, angulation of the remaining bone, and the configuration of the maxillary sinus.

The initial theory that a 3-D object could be reconstructed from an infinite set of 2-D projections obtained at various angles around an object was presented by Radon in 1917.[20] The first computerized tomography (CT) scanner was developed by Sir Godfrey Hounsfield in 1967, with the first commercial CT scanner becoming available in 1972. These CT scanners needed to make multiple flat plane scans in the object area in order to collect enough raw data for conversion to a usable 3-D image. For many years, dental implant patients were referred to medical imaging centers for a CT scan. Films would then be provided to the clinician for treatment planning purposes, or copies of the electronic files would be used with rudimentary implant diagnostic software. In the past decade cone-beam computerized tomography (cone-beam CT) exploded onto the dental scene. The technological development of a fan beam of radiation utilizing a 2-D detector permitted enough raw data to be collected by a single rotation of the gantry through the region of interest. This decreased both the time for the scan and radiation exposure. The advent and increasing availability of 3-D cone-beam CT and 3-D digital panoramic imaging machines in dental schools and private practices has made obtaining these images easier, more timely, and less costly.[21] Images may be easily manipulated to accurately measure critical anatomic distances such as the distance from the crest of the ridge to the top of the mandibular canal in the posterior region both in the panoramic and cross-sectional views. Newer 3-D panoramic x-ray machines, which include cone-beam volumetric tomography, can control the volume of the examined area to minimize radiation dosage to the patient and have brought this technology to more dental practices. The increasing use of cone-beam CT imaging has also allowed for the discovery of other lesions of the head and neck not visible by older imaging techniques. The dentist performing the 3-D imaging or a designated radiologist to interpret the images is responsible for all of the findings on these images, not just in the areas

> “Predictable implant dentistry has taken its rightful place in the armamentarium of modern dentistry.”

being examined for the placement of implants. Sophisticated treatment planning software can construct 3-D models and stents designed for exact implant placement to enhance the implant planning and placement processes. In addition to these third-party imaging softwares, many newer machines integrate dental implant planning into the machine's software package. Digitally guided surgery is now routinely used, particularly when multiple implants must be placed and a complex restoration is required.[22,23] Surgical stents and provisional restorations may be fabricated from the digital information provided by the images as processed through the software—truly CAD/ CAM coming to implant dentistry.

New technologies, both mechanical and biological, have improved the maintenance of the alveolar ridge during tooth extraction and the regenerative possibilities for regaining lost bone. Piezoelectric surgical units may be used to facilitate the atraumatic removal of teeth. While this seems to be an oxymoron, piezo surgical tips can be used in the periodontal ligament space to sever the connection of tooth to bone to allow the tooth to be removed with minimal bone damage. The continuing advancement in the use of growth factors and bone proteins, including recombinant bone morphogenetic proteins, has improved the clinician's ability to provide bone for accurate implant placement.

Quality of Life

Not surprisingly, there are many anecdotal reports and clinical studies that conclude that the quality of life for dental implant patients has significantly improved. Mandibular complete denture stability, maintenance of intact teeth, improved function and esthetics, and greater confidence and self-esteem are all cited as positive factors related to implant dentistry.[24,25] Patients are willing to spend up to three times more for implant-supported dentures compared to conventional dentures.[26] While implant-supported restorations have been a benefit to many, they are not a panacea free of all complications or failure. As more dentists with varying backgrounds and skills place and restore more implants, especially in compromised areas, the rate of implant success will fall. Some of these data will never be published as the complications occur in the silence of private offices. One caveat has been the use of dental implants in dependent patients, those who cannot take full responsibility for their oral care and may then be susceptible to peri-implant disease. [27]

Conclusion

Implant dentistry has come a long way over the past 30 years. As we enter the second decade of the century, you will see more and more exciting advances in implants and dental technology as a whole. Predictable implant dentistry has taken its rightful place in the armamentarium of modern dentistry.

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Q1.) Endosseous implants are placed:

A.) in bone.
B.) through bone.
C.) on bone underneath the oral mucosa.
D.) underneath bone.

Q2.) Transosseous implants are placed:

A.) in bone.
B.) through bone.
C.) on bone underneath the oral mucosa.
D.) underneath bone.

Q3.) Subperiosteal implants are placed:

A.) in bone.
B.) through bone.
C.) on bone underneath the oral mucosa.
D.) underneath bone.

Q4.) The consistent characteristic of dental implants since the 1980s is that they:

A.) have a conical root form.
B.) require screw retention.
C.) form a new periodontal ligament.
D.) will not accumulate a biofilm on their surface.

Q5.) The original Brånemark root-form implants were manufactured from:

A.) gold.
B.) platinum.
C.) commercially pure titanium.
D.) zirconium.

Q6.) While Brånemark initially insisted on operating room conditions for implant placement, it has been shown that dental office aseptic technique is sufficient to:

A.) allow for epithelial ingrowth around the implant.
B.) recruit red blood cells after implant placement.
C.) minimize postoperative pain.
D.) minimize postoperative infections.

Q7.) The growth of bone in sites such as the maxillary sinus where bone is normally not found is known as:

A.) bone deficiency.
B.) guided bone regeneration (GBR).
C.) osteoporosis.
D.) none of the above.

Q8.) Adell et al demonstrated a greater than 90% success rate of implants in the mandibular symphysis region over a:

A.) 5-year period.
B.) 10-year period.
C.) 15-year period.
D.) 20-year period.

Q9.) In 1985, Brånemark, Zarb, and Albrektsson published their seminal work outlining the principles and scientific evidence supporting:

A.) immediate implant loading.
B.) osseointegration and the restoration of implants in the edentulous patient.
C.) barrier effectiveness postoperatively.
D.) mini-implant use in orthodontic anchoring.

Q10.) Criteria for osseointegration success includes:

A.) absence of persistent signs and symptoms of pathology.
B.) implant immobility.
C.) no continuous peri-implant radiolucency.
D.) all of the above.

Q11.) The first commercial CT scanner become available in:

A.) 1970.
B.) 1972.
C.) 1974.
D.) 1980.

Q12.) Newer 3-D panoramic x-ray machines, which include cone-beam volumetric tomography, can control the volume of the examined area to:

A.) integrate dental implant planning.
B.) minimize radiation dosage to the patient.
C.) facilitate manipulation of images.
D.) improve regenerative possibilities.

Q13.) What may be used to facilitate the atraumatic removal of teeth?

A.) Piezoelectric surgical units
B.) cone-beam CT scans
C.) antiseptic rinse before extraction
D.) curved scalpel blades

Q14.) Positive factors related to implant dentistryinclude:

A.) mandibular complete denture stability.
B.) maintenance of intact teeth.
C.) improved function and esthetics.
D.) all of the above.

Q15.) As more dentists with varying backgrounds and skills place and restore more implants, especially in compromised areas:

A.) the cost of implants will decrease.
B.) the cost of implants will increase.
C.) the rate of implant success will fall.
D.) the number of implant systems will decrease.

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