Prosthodontics and Implants: *From Xenodontics to Biodontics*

Abstract

To date, the restoration, repair, and replacement of lost and damaged teeth used metals and plastics, nonbiological materials. This type of dentistry has been referred to as "xenodontics." This article discusses the progress in developing a tissue-engineered tooth derived from stem cells. The use of biologically derived replacements for lost and missing teeth is called "biodontics." The technical difficulties that dentists had to overcome historically in restoring, replacing, and repairing lost and damaged teeth are reviewed. The inventiveness and creativity of our professional ancestors in using materials available to restore damaged teeth and to make artificial teeth and denture bases are discussed. This section concludes with the introduction of plastics for both the fabrication of prosthetic teeth and denture bases. The history of root implants is introduced, concluding with the use of titanium. This article concludes by noting that, for the most part, dental schools are just beginning to include implants or computer-aided design (CAD) and computer-aided manufacturing (CAM) into the curriculum and that this process should be accelerated to ensure our graduates are fully prepared to practice efficiently and successfully.

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Restoring, Replacing, and Repairing Lost and Damaged Teeth

The dental profession has taken on a difficult task: restore, replace, and repair lost and damaged teeth. For the task of restoring and repairing damaged tooth structure, the profession was fortunate because amalgam was discovered to be an almost ideal restorative material. Amalgam was easy to handle, could be carved to the likeness of the original tooth, and was inexpensive. However, its disadvantages included color, and its coefficient of expansion was different from that of enamel. By 1900, dentists were excavating decay from diseased teeth with GV Black's new electric drill and routinely and successfully replacing the lost tooth structure with amalgam.[1]

When it came to replacing a single tooth or 2 adjacent teeth, the profession also was reasonably fortunate. A reasonable facsimile of the natural tooth could be carved from bone and ivory, and when ivory was used, the color was not movie star quality but wasn't too bad, either. The artificial tooth or teeth could be attached to adjacent natural teeth using wire. These early appliances might not have functioned for more than a few years and often damaged the abutments, but they were more suitable than the alternative—a gap in the anterior dentition.[2]

However, the replacement of a complete dentition, either maxillary or mandibular, presented a challenge to dentists of the 1800s and early 1900s. Although a replacement dentition could be carved, there were problems in finding a scaffold or framework to anchor these prosthetic teeth to something that was comfortable to wear, stable to the forces of mastication, and nonirritating to the intraoral tissue. Until the introduction of plastics in the mid 20th century, the choices of scaffold framework material were limited to leather and wood.[3] In the 1700s in Paris, Pierre Fauchard was making dentures of wood, ivory, and bone.[4] At that time, many of the finer items such as furniture, wine, and clothing, were imported from Europe, and the principles of denture making were no exception; Fauchard's techniques were used by US dentists of the day. When touring the National Dental Museum in Baltimore, you learn that George Washington had a set of teeth that caused considerable pain, and, so we are told, he rarely wore them. Perhaps this explains why, in the many paintings of him on display, he is not smiling.

Dentists recognized that leather and wood needed to be replaced as a denture scaffold, and after the discovery of vulcanization by Goodyear in 1844, vulcanized denture bases were introduced.[5] One hundred years passed before a new material, plastics, became available, and prosthodontists rushed to try this new material. Plastics worked and remain in use today not only for the denture base, but for prosthetic teeth. With plastics, the prosthetic teeth are colored and shaded to make the replacement more acceptable for the patients. With the introduction of plastics, the dental profession had found a solution to the problem of replacing lost and missing teeth. Combined with amalgam for restoration, it appeared that dentists' responsibility to patients and the public was fulfilled.

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Replacement of Lost and Missing Teeth with Root Implants

Plastics and amalgams as the standards for replacement therapy were where things stood until the last decade of the 20th century when root implants were introduced into the US dental market. Interestingly, others had attempted implants long before that time. As early as the mid 1700s, Hunter experimented with the replacement of extracted human teeth. His meticulous notes record his efforts and the results of his studies in this area.[5]

After Hunter, dentists tried a variety of materials as anchors, all of which were screwed into the bone, and all of which were rejected. It was the discovery that titanium was biocompatible and would not be rejected that changed the way the dental profession thought about the replacement of lost and missing teeth.[6] Currently, dental implants are made of titanium, a metal with special qualities that make it useful for this purpose. Titanium develops a thin film on its surface that protects it from corrosion. It is resistant to acids, salt solutions, and oxygen, among other things. Titanium also is almost completely nonmagnetic and is extremely strong for its weight. Improvements to titanium implants include acid etch, plasma sprayed, acid etched and grit blasted, and hydroxyapatite coated.

Like any treatment procedure, success depends on the diagnosis. The more the dentist can know about the location and area to house the implant, the greater the success rate. One of the most recent technologic advancements in the diagnostic area is the introduction of cone-beam computed tomography scanners. This diagnostic procedure provides information not previously available and with information from cone-beam scanners, patient selection and outcome can be improved.[7]

Biodontics: *The Future for Replacing Lost, Missing, and Damaged Teeth*

Biodontics is the practice of dentistry that promotes the repair, restoration, and replacement of dental, oral, and craniofacial structures using natural biological materials of cellular origin. Biodontics will replace xenodontics, the practice of dentistry that uses foreign materials (eg, metals and plastics) for this purpose.[8]

The materials of cellular origin are stem cells, not the controversial embryonic stem cells, but adult stem cells.[9] All adults have stem cells, which remain with us and get pressed into service when we need to regenerate something such as our liver. Stem cells have been isolated from exfoliated deciduous teeth, and it should be no surprise that entrepreneurs seeing an opportunity have formed companies to "bank" the stem cells for future medical and dental organ replacements.

Teeth made from stem cells are referred to as "tissue-engineered teeth." Although attaining this goal would be a biological triumph, it remains yet to be accomplished. Because metallic implants required at least several hundred years to become successful, and stem cells were only recently discovered, it should come as no surprise that presently, only a few years after the recognition of their potential use, scientists are still trying to make a structure.

Nevertheless, progress has been made toward creating tissue-engineered teeth. For example, investigators at Guy's Hospital in London and the Forsyth Institute in Boston, Massachusetts, have used stem cells in the bioengineering process.[10] One group used cell-seeded biodegradable scaffolds to generate tooth tissue including complex tooth crowns. To date, studies have been performed with rat and mouse stem cells; applications to humans are sure to follow.

This progress in so short a time is astounding considering that the sequence for the engineering of a tooth includes: (1) an increase in cell number; (2) the differentiation into multiple tissues including enamel, dentin, and cementum; (3) the assembly of the differentiated cells into the crown, pulp, and root of the tooth; and (4) the activation of the correct genes and subsequent biosynthesis of enamel proteins, dentin proteins, and cementum proteins of the finished tooth.[11] Of these steps, step 1 (the increase in cell number) occurs by mitosis, the continued cell division of the stem cell. Step 2 (differentiation) requires the exposure of the stem cells to "signals," which are compounds of biological origin that the scientist can synthesize and add to cells to induce differentiation. Step 3 (organ formation) often requires the use of a bioscaffold or framework that can be manufactured in the laboratory and used to guide the assembly of the differentiated cells.[12]

Dental Education and the Transition from Xenodontics to Biodontics

The spectacular success of technology in advancing xenodontic tooth replacement will not stop or even slow the emergence of the biodontic alternative, the replacement of lost teeth using biological components of cellular origin. At some future date, biodontics will replace xenodontics.

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However, a present concern is the slow acceptance rate of the advances in xenodontics in US dental schools. Implants came to US dentists from Europe decades ago and entered the market not through dental schools, but by the introduction to private dentists. Through a program of carefully controlled continuing education courses, dentists learned how to perform the implant procedure. Not surprisingly, this system produced a high success rate. Why the dental schools were not in the forefront of the implant revolution remains for the dental historian to discover. Also currently, implants are almost as common as amalgams, and why dental schools remain slow to introduce them into the curriculum should be addressed because neither dental schools nor state licensing boards require a competency in implantology as a requirement for graduation and licensure.

The slow acceptance of new technology in US dental schools is not unique to implants. Intraoral camera technology, originally introduced to US markets by Japanese manufacturers, is now common but received so much past resistance. Currently, there is a similar situation with the acceptance of the microscope for operative procedures. The use of this technology would ease the dentists' eye strain and improve their posture chairside.

Prosthetics departments in our dental schools face a similar situation with the success of CAD/CAM technology. Again, most dental schools do not offer CAD/CAM technology as part of their education either to dental students or residents. Of course, cost is a factor. But most discussions in dental schools usually return to the argument, "We have to teach the basics."

The inability, or unwillingness, of the US dental educational establishment to provide the latest and best in new diagnostics and treatments has not gone unnoticed by the marketplace. As a case in point, consider the opening of the new continuing education center in Scottsdale, Arizona. (Information available at: www.scottsdalecenter.com, accessed June 21, 2007.)

Those behind the design and implementation of this center recognized an opportunity: dentists are graduating without the necessary skills to practice dentistry as they would like, as their more established colleagues practice, and as their patients expect. These recent graduates flock to such centers for dental training.

The era of dental schools and their faculty determining or even controlling the education of a dentist is fading. Although xenodontics and biodontics will remain in equipoise for decades, it is the responsibility of the undergraduate dental educators to see that both are taught to ensure dentists provide the best oral health care for their patients. It should come as no surprise that the American Dental Education Association together with the American Dental Association have formed study groups and committees to address the issue of how best to include the advances in xenodontics and biodontics into the dental curriculum.

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