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Dental Implant Material and Design

The glorious past and the road to a tremendous future

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It has been more than 30 years since the Toronto Osseointegration Conference, and over 50 years since the work of Professor Per-Ingvar Brånemark. In that time frame, we have seen an explosion in the field of dental implantology. Many facets of our knowledge-base and understanding of the field evolved during that time, as well as fundamental developments in material science. Our implant designs have evolved, our surface treatments have evolved, our surgical techniques and prosthetic protocols too have evolved, and so have the materials we use.

The original two-stage machined implants made of surgical commercially-pure titanium, used by the mavericks of implantology, are nearly extinct in the modern dental implant marketplace. Instead we are faced with a myriad of alloys, designs, connector geometries, all with substantial literature attesting to similar survival rates.

Thanks to evolution in materials, we now have a surge in ceramic implants that are made of increasingly stronger materials, and that feature new designs and material characteristics that simplify and enhance long-term outcomes in tooth replacement.

How do we choose? What is best and most successful? Where is the future of implant design and material heading? Is the age of metals in the mouth over?

In order to see the future, the best place to look is the past. History repeats itself and in dentistry, as in many other scientific pursuits, one needs to learn from that past.

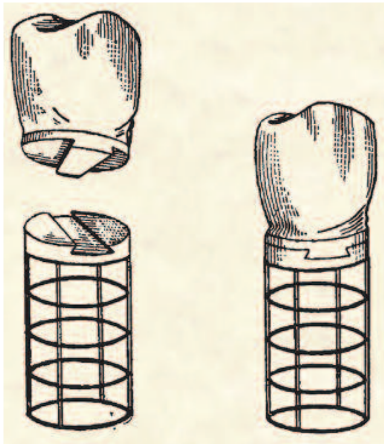

Figure 1: Greenfield Basket implant

Titanium Implants

The history of titanium in dentistry is familiar to us all. Many lessons were learned from past experiences, until one got to the success that Dr. Brånemark had reported.

The first documented metal dental implant was the Greenfield crib or basket implant system presented in 1913.[1] This iridioplatinum implant, restored with an attached gold crown, showed evidence of osseointegration and lasted for a number of years.[1]

Figure 2: Spiral implant

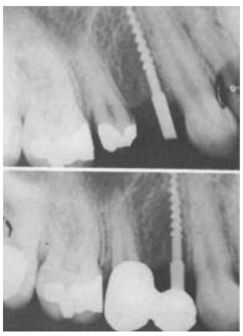

Figure 3: Pin implant

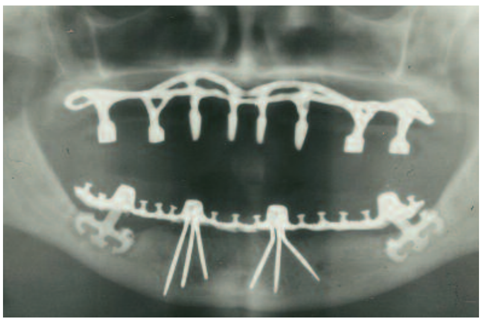

Figure 4: Panoramic radiograph of historic dental implants

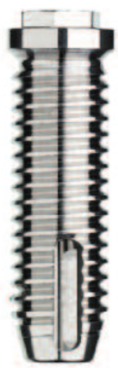

Figure 5: Original Brånemark implant

Figure 6: Exposed metal

Figure 7: Tissue recession around the implants in the anterior

Figure 7a: Fully edentulous tooth replacement – exposed metal

Figure 8: Sapphirre crystal implants

In the 1930's Drs. Alvin and Moses Strock, utilized orthopedic screw fixtures made of Vitallium (chromium-cobalt alloy). These early implants were inserted in both humans and dogs to restore individual teeth. The brothers were acknowledged for their work in selecting a biocompatible metal to be used in the human dentition.[2]

Formiggini and Zepponi developed a post-type endosseous implant in the 1940's. The spiral stainless steel design of the implant allowed bone to grow into the metal.[2] Dr. Perron Andres from Spain modified Formiggini's spiral design to include a solid shaft in the construction.[2] The design was successful and fused with the bone.

Various implant designs expanded in the 1960's. Dr. Cherchieve crafted a double-helical spiral implant made of cobalt and chromium.[3] These were screw-shaped single-piece implants. The spiral shaft was further enhanced during this decade by Dr. Giordano Muratori by the addition of internal threading to the shaft of the implant.[2] The basic spiral design was turned into a flat plate with various configurations by Dr. Leonard Linkow in 1963[4,5] and by 1967, there were two variations of the blade implant and the subperiosteal design making it possible to place it in either the maxilla or the mandible.[4,5]

In the early 1970's, Dr. Roberts began the development of the Ramus Blade endosseous implant. This implant was made of surgical-grade stainless steel.[2]

All these materials saw a degree of success, as did the various designs. None of them withstood the test of time in a predictable manner. If was not until 1978, when Dr. P. Brånemark presented a two-stage threaded titanium root-form implant; he developed and tested a system using pure titanium screws which he termed fixtures.[6] These fixtures were first placed in his patients in 1965. Dr. Brånemark's first patient had severe deformities of the jaw and chin, congenitally-missing teeth and misaligned teeth. Four implants were inserted into the mandible. These implants integrated within a period of six months and remained in place for the next 40 years.[7] A careful implantation protocol was also introduced. The original Brånemark implant was created as a cylindrical one; later, tapered forms appeared. Many other types of implants were introduced after the Brånemark implant which included the ITI-sprayed implant, the Stryker implant, the IMZ implant and the Core-Vent implant.[11,12]

It took over 40 years of metal implantology for the "ideal" metal and implant design for the support of teeth to emerge. The success Dr. Brånemark had was attributed to the physical and chemical attributes of Titanium as well as a strict protocol for treating the

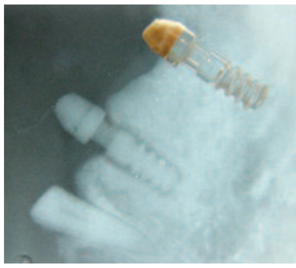

Figure 8a: Glass implant

Figure 9: Frialit ti AlO2 and coated

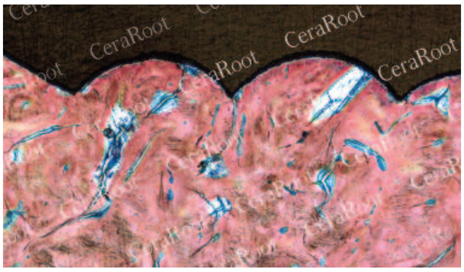

Figure 10: Ceraroot histology

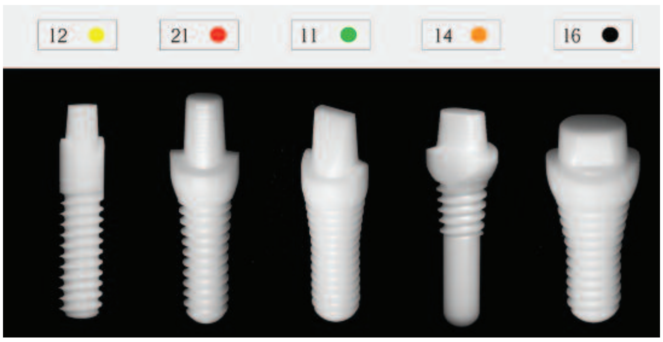

Figure 11: CeraRoot Ceramic Implant System

Figure 12: CeraRoot 14 and 16 replacing molar and premolar

Figure 13: CeraRoot placement

Figure 14: Lateral incisors Titanium vs. ceramic

Figure 15: Adjacent CeraRoot implants

completely edentulous patients.[8,9] These concepts of treating the completely edentulous were used in the 80's and beyond to attempt to restore the partially edentulous. This is where the profession found problems. Two-piece metal-made implants showed increasing amounts of tissue recession and bone disease that, although did not detrimentally affect outcomes in the completely edentulous, were disastrous in the highly demanding partially-edentulous patients. Poor performance in thin biotypes, lacking tissue contours and the prevalence of hard and soft tissue peri-implant disease, as well as prosthetic complications, meant that implant design had to change to solve these problems. A way to deal with those problems was altering the design of the implants. Abutment connection geometry, surface modifications, abutment materials are all attempts to overcome the challenges that present themselves in using two piece titanium implants in the partially edentulous patients.

Ceramic Implants

Ceramics were first introduced into dental implantology as coatings onto metal-based endosseous implants in an effort to improve osseointegration. Materials such as hydroxyapatite(HA), tricalcium phosphate (TCP) and fluorapatite (FA) have all been used as coatings to enhance the biological response of bone.[13,14,15] These coatings proved not entirely successful as the bond with the metal substructure was not predictable.

Dr. Sandhaus in the mid-60's developed a crystallized bone implant whose composition was mainly aluminum oxides.[16] The 1970's brought in the placement of vitreous carbon implants by Grenoble[17], both showed poor results due to the brittle nature of the material.

In 1975 Schulte and Heimke introduced the Tubingen implant made of high-purity alumina ceramic.[18] The two-piece wide design was fraught with mechanical problems of material fracture (alumina oxide is a brittle material) and superstructure failure caused by the cemented restorative metal pins. However, what was observed was that a failure to integrate, resulted in neither acute nor chronic peri-implant osteomyelitis. Tissue reacted better to these ceramic materials than it did to metals.

McKinney, Koth, and Steflik's group have conducted numerous studies on the single-crystal sapphire endosseous dental implant, Bioceram®, in the early 1980's.[19] However, these had a poor survival rate and, although some survived for 15 plus years, the implants had barely a 50% survival rate.

In 1987 the Sigma implant (Sandhause, Incermed) was introduced as the first Zirconia dental implant system.[20]

Since then, about 15 different Zirconia dental implant systems have been introduced to the market with many more coming. The material has proven to osseointegrate, have high fracture-resistance, be very tissue-friendly and be able to solve many challenges of the partially-edentulous, that have previously been extremely difficult to manage with two-piece titanium.

In 2003 a system designed to be the ideal tooth replacement was introduced. The CeraRoot (Oral Iceberg, Granoliers, Spain) implant system encompassed the "Tooth Replacement Concept" with a system employing five unique tooth root shapes (with an additional two shapes introduced in 2015) designed to replace the root and trans-gingival part of the tooth with a one-piece y-TZP dental implant.

The evolution of ceramics in implant dentistry has spanned the course of nearly 40 years, with early learning leading to better and better solutions. Much like the pioneers of titanium, we have finally arrived at a material that is well suited for replacement of teeth.

The history of dental implants is a glorious voyage. Clinicians used materials ranging from coral sea-shells, ivory, chromium-cobalt, to iridium and platinum and stainless steel. Implant designs started as wires and spirals, evolving to blades and helical one-piece creations; and finally to endosseous two-piece titanium root forms. As time marches on in the dental implant research, the materials, forms, and surface coatings have been refined and restructured to allow the consumer the very best in tooth replacement choices for their present and future needs.

The late Dr. Brånemark famously commented that "no one should have to die with their teeth in a glass of water beside their bed". The titanium standard, as the foundation for treatment of the completely edentulous, highly-disabled patients, is unchallenged at this time. Today's pioneers take this mantra further. No one should have to compromise the aesthetic and biologic longevity of their smile for the sake of a strong, healthy, and functional mouth.

Thanks to the continued evolution of our field, patients no longer have to bear the consequences of metals in their mouths, loosening screws, abutment fractures or high rates of peri-implant disease. We now have materials and implant designs that more naturally mimic teeth and, as such, ceramic tooth replacement is becoming a viable and accepted treatment option for the partially-edentulous, or soon-to-be partially-edentulous patient. ■

About the author

Dr. Dan Hagi *received his dental training at the University of Toronto and now maintains a multidisciplinary implant and rehabilitative practice in Thornhill, Ontario. He is an associate Fellow of the American Academy of Implant Dentistry(AAID), a Fellow of the International Congress of Oral Implantology(ICOI), a Fellow of the Academy of General Dentistry(AGD) and the Misch International Implant Institute. His private practice focuses on metal free, minimally invasive rehabilitation and aesthetic smile design. His focus on ceramic materials has led him to gain valuable experience in the utilization of Zirconium Oxide materials as a restorative material as well as the use of Zirconium Oxide dental implants. He is a lecturer and mentor as well as a consultant on emerging metal-free materials and techniques.*

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If C.P. titanium or a titanium alloy has more than 85% titanium content it will form a titanium biocompatable titanium oxide surface layer or veneer that encloses the other metals preventing them from contacting the bone.[56]