A Brief Historical Perspective on Dental Implants, Their Surface Coatings and Treatments

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Abstract: This review highlights a brief, chronological sequence of the history of dental implants. This historical perspective begins with ancient civilizations and spotlights predominant dentists and their contributions to implant development through time. The physical, chemical and biologic properties of various dental implant surfaces and coatings are discussed, and specific surface treatments include an overview of machined implants, etched implants, and sand-blasted implants. Dental implant coatings such as hydroxyapatite, fluoride, and statin usage are further reviewed.

Keywords: Dental history, implant surface, implants, surface coating.

A BRIEF HISTORY OF DENTAL IMPLANTS

“There’s Gold (Ivory and Stone) in them thar (Implants)”!

The history of the evolution of dental implants is a rich and fascinating travelogue through time. Since the beginning of mankind, humans have used dental implants in one form or another to replace missing teeth. In approximately 2500 BC, the ancient Egyptians tried to stabilize teeth that were periodontally involved with the use of ligature wire made of gold. Their manuscripts and texts allude to several interesting references to toothaches. About 500 BC, the Etruscans customized soldered gold bands from animals to restore oral function in humans; they also fashioned replacements for teeth from oxen bones. At about the same period, the Phoenicians used gold wire to stabilize teeth that were periodontally involved; around 300 AD, these innovative peoples used teeth creatively carved out of ivory which were then stabilized by gold wire to create a fixed bridge. The first evidence of dental implants is attributed to the Mayan population roughly around 600 AD where they excelled in utilizing pieces of shells as implants as a replacement for mandibular teeth. Radiographs taken in the 1970’s of Mayan mandibles show compact bone formation around the implants-bone that amazingly looks very much like that seen around blade implants! Moreover, around 800 AD, a stone implant was first prepared and placed in the mandible in the early Honduran culture [1].

From Rocks to Roosters- Early Implants Emerge

In the middle of the 1600’s periodontally compromised teeth were stabilized in Europe with various substances.

From the 1500’s to about the 1800’s, teeth in Europe were collected from the underprivileged or from cadavers for the use of allotransplantation. During this period, Dr. John Hunter came on to the scene; for many years he worked with “resurrectionists”-people who acquired corpses underhandedly through the robbing of graves. By doing so, he was able to observe and document with great detail the anatomy of the mouth and jaw. In the 1700’s, Dr. Hunter suggested transplanting teeth from one human to another; his experiment involved the implantation of an incompletely developed tooth into the comb of a rooster. He observed an extraordinary and astonishing event: the tooth became firmly embedded in the comb of the rooster and the blood vessels of the rooster grew straight into the pulp of the tooth [1, 2]. In 1809, J. Maggiolo inserted a gold implant tube into a fresh extraction site. This site was allowed to heal and then a crown was later added; unfortunately, there was extensive inflammation of the gingiva which followed the procedure [1, 3]. Innumerable substances during this time period were used as implants; these included silver capsules, corrugated porcelain, and iridium tubes [1, 3].

Brothers Strock to Building Spirals

Dr. EJ Greenfield, in 1913, placed a “24-gauge hollow latticed cylinder of iridio-platinum soldered with 24-karat gold” as an artificial root to “fit exactly the circular incision made for it in the jaw-bone of the patient ”[4]. In the 1930’s, two brothers, Drs. Alvin and Moses Strock, experimented with orthopedic screw fixtures made of Vitallium (chromium-cobalt alloy). They carefully observed how physicians successfully placed implants in the hip bone, so they implanted them in both humans and dogs to restore individual teeth. The Vitallium screw provided anchorage and support for replacement of the missing tooth. These brothers were acknowledged for their work in selecting a biocompatible metal to be used in the human dentition [5]. The Strock brothers were also thought to be the first to place the first
successful endosteal (in the bone) implant. (Incidentally, Dr. Alvin Strock not only worked with implant materials, he also established the use of antibiotics for shipboard treatment of periodontal infections like trench mouth). In 1938, Dr. P.B. Adams patented a cylindrical endosseous implant that was threaded both internally and externally; it had a smooth gingival collar and a healing cap [6]. A post-type endosseous implant was developed by Formiggini ("Father of Modern Implantology") and Zepponi in the 1940’s. The spiral stainless steel design of the implant allowed bone to grow into the metal [5]. This spiral implant was made by constructing a stainless steel wire on itself. Dr. Perron Andres from Spain modified Formiggini’s spiral design to include a solid shaft in the construction [5].

**Implant Discovery Continues… The Fabulous Forties and Fantastic Fifties**

Dr. Raphael Chercheve from France added to the spiral design by creating bars to ease the insertion of the implant for a best fit. As the progression of implant discovery continued, the subperiosteal (on the bone) implant was developed in the 1940’s by Dahl in Sweden. 5 Dahl’s original implant design involved flat abutments and screws which lay over the crest of the alveolar ridge. Dahl’s work was carried on by Gershkoff and Goldberg as well as Weinberg in the United States from 1947-1948 [5]. Gershkoff and Goldberg produced a cobalt-chromium-molybdenum implant with an extension of Dahl’s design to include the external oblique ridge [7]. The subperiosteal implant design was further researched and elaborated upon by Lew, Bausch, and Berman in 1950 [5]. Lew utilized a direct impression method which used fewer supports over the ridge crest [5]. In the 1950’s, Dr. Bodine observed several patients in the armed forces; the framework design seemed to be more streamlined now and he found that fewer struts or girders were needed. The holes for the screws were located in areas where the bone had the greatest strength and thickness [8]. This decade also included the innovations of Dr. Lee who introduced the use of an endosseous implant with a central post [5].

**Increase of Implant Innovation: 1960’s-1970’s**

Various implant designs expanded in the 1960’s. Dr. Chercheve crafted a double-helical spiral implant; it was made of cobalt and chromium [9]. Many of these were screw-shaped and in a single piece. 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 [5]. The basic spiral design was turned into a flat plate with various configurations by Dr. Leonard Linkow in 1963 [10, 11]. In 1967, there were two variations of the blade implant that were introduced by Linkow, making it possible to place it in either the maxilla or the mandible. Linkow developed the Ventplant implant [10, 11]. The blade implant is now recognized as an endosseous implant. Further on, Dr. Sandhaus in the mid-60’s developed a crystallized bone screw whose composition was mainly that of aluminum [12].

As the 1960’s came to a close and the 1970’s began, doctors Roberts and Roberts began the development of the Ramus Blade endosseous implant. This implant was made of surgical grade stainless steel; according to them, it was to serve as a “synthetic third molar” [5]. They also developed the ramus frame implant which received its stability by anchoring in the ramus bilaterally as well as in the symphysis area. The 1970’s brought in the placement of vitreous carbon implants by Grenoble [13]. Weiss and Judy made popular the use of intramucosal inserts during this time; the inserts helped in the retention of removable maxillary prostheses [14]. In 1975, an implant device placed through a submental incision and attached to the mandible was introduced by Dr. Small; this was known as the first transosteal implant called the mandibular staple implant. This would help those individuals who had an edentulous mandible that was atrophic in nature [15].

**Splendid Serendipity**

In 1978, 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* [16]. These were first placed in his patients in 1965 and were the first to be well-documented and the most well-maintained dental implants thus far. 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 [17]. He found this discovery accidentally in 1952 when he was studying blood flow in rabbit femurs by placing titanium chambers in their bone; over time the chamber became firmly affixed to the bone and could not be removed [18]. The bone actually bonded to the titanium surface. In fact if a fracture occurred, it always occurred between bone and bone, never between the bone and the implant. He carried over this idea into the realm of dentistry. With his implant came the concept of “osseointegration” and the confidence that dental implant education could be introduced into dental school curricula. This term was further refined and defined by Brånemark as “a direct structural and functional connection between ordered, living bone, and the surface of a load carrying implant” [19]. The original Brånemark implant was created as a cylindrical one; later on 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 [20].

**Trailblazing and Trendsetting Titanium**

Two other ground-breaking persons of modern implantology were Dr. Schroder and Dr. Straumann of Switzerland. They experimented with metals utilized in orthopedic surgery to help fabricate dental implants [21]. Beginning in the middle of the 1980’s, the customary implant used by many dental clinicians was the endosseous root-form implant. The major factors that determined which endosseous implant system was chosen over another included the design, the surface roughness, prosthetic considerations, ease of insertion into the bone, costs and how successful they were over a period of time. Dr. Tatum introduced the omni R implant in the early 1980’s; it had horizontal fins made up of titanium alloy [22]. Dr. Niznick introduced the Core-Vent implant in the early part of the 1980’s. It was a hollow basket implant
with a threaded piece in it which helped to engage the bone; he also manufactured the Screw-Vent implant which had a hydroxyapatite coating on it. This surface coating was to allow for more immediate adaptation of the bone to the implant surface. The Core-Vent company also designed the Swede-Vent implant which used an external hexagonal interface to hold the abutment. Dr. Niznick continued to develop other systems including the Bio-Vent and the Micro-Vent. [23].

Soon after, Dr. Driskell in the 1980’s introduced the Stryker “root form” endosseous implant; there are two versions of this-one made with a titanium alloy and another coated with hydroxyapatite [24]. The IMZ implant which was introduced by Dr. Kirsch towards the end of the 1970’s, was widely used in many countries in the 1980’s [25]. The IMZ implant had some distinctive features; it had a titanium surface spray to increase interface surface area and it also had an intra-mobile element in it to duplicate the mobility of natural teeth. The Calcitek Corporation in the early 1980’s started making a synthetic polycrystalline ceramic hydroxyapatite called calcitite. In 1985 it produced the Integral Implant System [26]. The ITI implant system introduced in 1985 by the Straumann Company has exclusive plasma-sprayed cylinders and screws which are designed to be placed in a one-stage operation. [27] The most recent dental implant innovations involve the use fluoride antibiotics, growth factors and laminin.

Dental Implant Surfaces and Coatings: An Overview

One of the main reasons for the modification of dental implant surfaces is to decrease the healing time for osseointegration. The surface of a dental implant is the only part that is in contact with the bio-environment and the uniqueness of the surface directs the response and affects the mechanical strength of the implant/tissue interface [28-31]. Several diverse surface texturing of titanium implant substrates have been tested to improve osseointegration. The surface treatment layer on the implant is required to increase the functional surface area of the implant-bone interface so that stress is effectively transferred. Additionally, the surface coating promotes bone apposition [32]. This may include mechanical treatments (machinging and grit blasting for instance), chemical treatments (acid etching for example), electrochemical treatments (anodic oxidation), vacuum treatments, thermal treatments, and laser treatments [33].

These surface treatments were found to control the growth and metabolic action of cultured osteoblasts. Surface roughness has also been shown to influence cytokine and growth factor production by osteoblasts; increased surface roughness allowed transforming growth factor-beta (TGF-β) production which directly increased osteoblast cell propagation [34]. The surface roughness of an implant has an irrefutable effect on cell movement as well as cell growth. This suggests that the structure of the implant influences the interaction between the metal and the living tissue [35, 36].

The Manufacturing of Machined Implants

The original osseointegrated implants had a moderately smooth machined surface [37]. They are called machined or turned implants. After being manufactured, these implants are cleaned, decontaminated and sterilized. Microscopic examination shows the machined implant surfaces contain surface markings of the instruments that are employed for their development. Surface imperfections are a manner in which the bone can interlock with the metal. The disadvantage of the shape of machined implants is that bone-forming cells tend to proliferate along surface grooves. This requires a longer time but keeps to a method elaborated by Bränemark which involves a healing time of three to six months before loading. These implants show good long-standing outcomes in the clinical arena when they are used in areas with adequate bone allowing for a two-stage process [37].

An etched surface dental implant is another classification of surface treatments. Etching with strong acids like a mixture of hydrochloric acid and sulfuric acid is an alternative way to roughen implants made of titanium. The process of titanium etching allows for the eradication of the oxide layer as well as portions of the underlying material of the implant [38]. The process of treatment with an acid provides for equal roughness, an active surface area and better adhesion [39]. The etched acid surface makes possible the preservation of bone-forming cells and provides a mechanism for them to make their way onto the surface of the implant. This allows for improved viability and cellular adherence. The acid-etched surface roughens the implant surface and produces tiny spots on the surface of the titanium. Acid etching has been shown to improve osseointegration for many years [40, 41]. Additionally there is a technique where titanium implants where the titanium implants are soaked in a blend of concentrated hydrochloric acid and sulfuric acid. This method allows fibrin and osteogenic cells to attach which results in the formation of bone on top of the implant [42].

Hydroxyapatite Coating and Titanium Plasma Sprayed Coatings

 Hydroxyapatite (HA) is a material that has the potential to form a strong bond between the bone and the implant, may form a direct and strong binding between the implant and bone tissue. Hydroxyapatite coating is a layering of calcium and phosphate on the implant [43]. Hydroxyapatite has been applied onto metals in various ways. Plasma spraying allows the implant to have a coating thickness of approximately 40-50 micrometers. This process involves the injection of powdery forms of titanium into a plasma torch at elevated temperatures. These particles subsequently condense and fuse together on the implant surface. Phosphated titanium increased TGF-β1 production at 8 days and induced nodule mineralization even in the absence of mineralizing medium [44]. Nano-hydroxyapatite-coated surfaces in the transmucosal region have recently been studied and have been thought to be as compatible as pure titanium surfaces [45]. A major concern noted in cases of plasma sprayed coatings is that the hydroxyapatite may undergo resorption and further degradation and ultimately cause loosening of the titanium particles. The plasma-spraying method has several drawbacks, including poor long-term adherence of the coating to the substrate material, uneven thickness of the deposited layer, and dissimilarities in composition of the coating. Other significant factors causing implant failures include microbial infections [46, 47]. Other coating surfaces include composite coatings, titanium nitride coatings, carbon, glass,
and ceramic coatings as well as titanium dioxide film coatings [32].

**Sand-blasted and Etched Implants: A Particular Process**

Sandblasted (large grit) and acid-etched (SLA) implants are formed by an extensive process of blasting which in turn is followed by etching with both sulfuric acid and hydrochloric acid. It results in surface roughness and has an excellent bone integration [48]. Titanium or alumina particles complete the grit blasting technique. Changing the size of the particle can affect the final surface roughness. Alumina and titanium particles with sizes of 25 micrometers and 75 micrometers on titanium implants made for better formation of bone as compared to implants that were machined [49-51].

**A Chemical Course of Treatment**

An electrochemical process that allows the titanium oxide layer to increase as well as become rough is known as anodic oxidation. This process allows for increased biocompatibility. What finally comes about is a surface which manifests tiny pores that show increased cell adhesion and transmission. Machined implants have a slower healing time as compared to anodized implants. In a study performed on dog models, greater bone density was noted around anodized implants than their machined counterparts [52]. Anodization was used to generate niobium oxide coatings on sand-blasted titanium alloy dental implants; these oxide coatings were found to advance osseointegration [53].

**A Flexible Function of Fluoride**

Fluoride treatment can also be applied to the surface of implants. It provides for superimposition of nanofeatures onto micro-roughened surfaces. Titanium combines with fluoride to form soluble TiF₄ allowing for enhanced osseointegration and differentiation of osteoblasts [54]. Implants which were fluoridated and roughened, had higher removal torque than the control implants [55].

**Resilience and Strength: Lasers and Ions**

Surface preparation by laser ablation of dental implants is another method to enhance bone-to-metal interfaces. Very hard titanium microstructure surfaces, great resistance to weakening, an excellent roughness as well as increased oxide layer are a result of this procedure [56, 57]. Biological studies have demonstrated grooved surfaces which prepare the way for cell attachment and direct the manner in which they grow [58].

Another process is called sputtering. This occurs when molecules of a material are emitted in a vacuum chamber by the attack of ions of high energy. A disadvantage of this process is that it takes a long time for deposition to occur [59].

**Medication Muscle: Bisphosphonates and Stains**

Improved osseointegration has been seen with implant surfaces loaded with bisphosphonates [60, 61]. They are antiresorptive and prevent bone loss as well as increase the mass of bone for patients [62-64]. The effect of the bisphosphonate only takes place at the area of the implant. In vivo studies have revealed a small increase in osseointegration with these drugs. Experiments incorporating zoledronate and pamidronate showed an increase in bone contact area [65, 66].

Statins are prescribed medications used to decrease the liver synthesis of cholesterol [67]. With implants, Simvastatin, has been shown to enhance the expression of certain types of bone morphogenetic protein that might promote bone formation [68]. Researchers have found that applying statins to alveolar bone increased bone formation and suppressed osteoclastic activity. Statins have also been shown to increase the density of bone [69-71]. Simvastatin loaded implants showed increased action of osteoblasts [72].

**Antibiotic Abilities**

The placement of antibiotic coatings on implants has been researched as a possible way to disallow infection to get a hold of the surgical site. Hydroxyapatite along with gentamicin as well as antibiotics of a systemic nature can be coated on to the surface of the implant prior to the surgical placement of the implant [73]. It functions as an antibacterial agent; this antibiotic can also remove virulent endotoxins from the implant surface [74]. Tetracycline has been found to strongly support osseointegration.

**The Grandeur of Growth Factors**

Growth factors such as bone morphogenetic proteins (BMPs), platelet-derived growth factor (PDGF) and TGF-β1 on titanium implant surfaces augment the healing of bone [75-78]. The role of the TGF-β1 application to calcium-phosphate implant surfaces has been studied in goats [79]. The disadvantage in the use of growth factors in treating the surfaces of implants is that the active growth factor has to be released over a period of time.

**State-of-the-art Ingenuity and Innovation**

Finally, progressive researchers at the Universitat Jaume I in Castelon have recently developed an implant coating with a novel biodegradable material to help people with bone deficits such as osteoporosis. It is called the Soldent project and consists of covering the implant with a biodegradable coating that, when it comes in contact with bone, dissolves and releases compounds containing silicon to allow bone to generate [80]. Another new implant coating is Laminin I. This may enhance osseointegration comparable to a bioactive implant surface while keeping the surface smooth [81].

**CONCLUSION**

In summary, the history of the development and advancement of dental implants is a magnificent and fascinating journey through time. One can only stop and marvel at man’s ingenuity over the years in this arena of research and scholarship. The materials in which dental implants came into development range from gold ligature wire, shells, ivory to chromium, cobalt, to iridium and platinum. From spiral stainless steel implant designs to double helical creations and endosseous root forms, dental researchers and clinicians
worked fast and furiously; they generated many structures to replace the positions that natural teeth once held. Dental surfaces were also modified to decrease the healing time for osseointegration. Modified surfaces incorporated the use of hydroxyapatite, composites, carbon, glass, ceramic as well as titanium oxide. In order to make the exterior as suitable as possible, implant surfaces have additionally been sandblasted, oxidized, fluoridated, etched, and medicated. The most recent innovative laminar coating is the center of focus in present day implant endeavors. As time marches on in dental implant study, 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.

CONFLICT OF INTEREST

The author confirms that this article content has no conflict of interest.

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A Brief Historical Perspective on Dental Implants

The Open Dentistry Journal, 2014, Volume 8

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