History of implantology from the aspect of osseointegration and mucointegration

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Summary: The tendency to replace lost teeth by implanting foreign material is as old as civilization itself. The accelerated development of implantology as a science started only in the middle of the last century. The essence of implantology is the process of osseointegration. The greatest merits for this phenomenon belong to prof. Per Ingvar Brenemark, who accidentally discovered the possibility of complete incorporation of a titanium implant into the surrounding bone. With the discovery of osseointegration and defining the conditions that enable it, the period of implantology development begins with the improvement of endosseous implantation into an efficient method of prosthetic rehabilitation, predictable outcome and extended lifespan of implants and dental restoration in function. Implantology initially aimed to improve the function and quality of life of partial and complete edentulism patients, and since the 1990s it has become prosthetically guided not only by functional but also by aesthetic principles. With the beginning of the 21st century, implantology is aimed at improving the appearance and stability of soft tissues, thus beginning the era of mucointegration.

Key words: history of implantology, osseointegration, mucointegration

INTRODUCTION

Although implantology as a science has flourished in recent decades, it should be remembered that the history of implantology stretches back to ancient times. Based on archaeological research, we find that 4,000 years ago, the Chinese used spikes of bamboo trees and implanted them in the jaw bone as a substitute for lost teeth. The ancient Egyptians, the Etruscans, and later the Phoenicians used noble metals, processed ox bones or ivory and implanted them in bone tissue. These innovative nations used gold wires to stabilize disassed teeth [1,2].

Hippocrates (5th century BC) wrote about the possibility of hardening artificial teeth using gold or silk thread to replicate the teeth removed, advising the practitioner not to "discard the teeth or teeth removed from the injured mandibula, but to return them to place, tying them to the remaining teeth with golden threads "[3]. The same recommendation was made by Aulus Cornelius Celsus (1st century BC) which in the journal “De Medicina” mentioned the possibility of replacing the missing tooth with a dental implant, taken from the kadaver, in those who lost a tooth for different reasons; however, he did not report whether such treatment was successful. However , it must be noted that the main purpose of these replacements was cosmetic , while the function of mastication was not much considered [3].

It is known that Mayans in the 7th century used various materials for aesthetic purposes, such as tirkes, quartz, serpentine, etc. and inserted carefully prepared spaces on the vestibular surfaces of mostly front teeth. Particularly interesting is the findings of Wilson Popenoe and his wife Dorothy during a survey of the Mayan civilization in Honduras, where they found a fragment of mandibula containing three replica teeth made of shellfish in alveolas. In studying this unusual find, expedition members initially assumed that the inserted elements were cosmetic treatments post-mortem, possibly as part of a complicated funeral ritual or religious practice [4].

Picture 1. The find of a 7th-century mandle of the Mayan civilization was found in Honduras. (Taken from http://www.implantmn.com/about-dental-implants/history-and-types-of-dental-implants/ for scientific purposes and not used for commercial purposes)

Radiographs of mandible in 1970. showed the formation of a bone around the implants that resembles what is seen around modern implants. This appears to have been the first authentic aloplastic material implanted in human tissue during life. Recent and exhaustive histological research on the behaviour of shell fragments in direct contact with bone tissue in experiments with animals has confirmed the principle of oseointegration between the two tissues [3,6,7].

Until the mid-19th century numerous attempts at replantation and dental transplantation were recorded, where the works of Pare, Dupont, Fauchard and others were not much advanced in the development of implantology. In the 19th and early 20th centuries, the founders of the Baltimore School, further Maggiolo, Bonville, Gram, Paine and others used various materials, platinum, lead, silver, gold, iridium, ceramics, and used cylinder-shaped implants, hollow screws, full screws, cylindrical nets, spirals, needles, etc.

Although these cases cannot be considered entirely successful, it must be noted that during this century, from Maggiolo to Paine, researchers have progressively tried, at least on a conceptual level, to use more and more inert materials, and this is in accordance with the development of the concept of implanting aloplastic implants with retentional morphology [6,7].

In 1938, Sweden's Gustav Dahl installed a subperiostal mandibular implant with four metal columns above the gums that were later anchored to the braces.It is important to note that after this attempt, the Swedish Dental Society asked him to immediately refrain from conducting the treatment, and the punishment was expelled from society at the very moment when the procedure appeared destined for success [8,9].

In Boston in 1939. the Strock brothers began testing of vitalium implants, chromium alloys, molibden and cobalt that they had already tested on dogs. The design of subperiosteal implants was further explored and developed by Lew, Baush and Berman in 1950. [8,9]. At a conference in Milan on 27 february 1947. Italy's Manlio Formiggini proposed a hollow spiral bolt made of stainless steel wire or tantal. The Designer called the method "direct endoalveolar implantation" and marked a definitive transition to an era of endoseal implants. Formigjni then presented several clinical cases and brought with him two patients who chewed without problems with fixed dentures [9]. The dental world has experienced a justifiable period of cautious skepticism towards endoseal implants and hopes instead to make the latest subperiosteal implant technique possible. As a result, failures (due to technical errors by formigni's first students) were taken into account more than success when it came to official verdicts [3, 8,9].

OSSEOINTEGRATION

Osseointegration as a concept is introduced by Per-Ingvar Branemark (1969), professor at the Institute of Applied Biotechnology, University of Gothenburg. He defined it as "a direct structural and functional connection between the living bone and the surface of the implant". He came to this phenomenon by accident. He observed microcirculation of the bone and the healing of the wounds through the titanium tube that he incorporated into the rabbit fibula. When he tried to remove the chamber after the experiment, he noticed that it had grown with bone tissue and could not be easily removed. That's when he discovered bone growth on the surface of the titanium chamber and good integration of bone implants. The phenomenon was called oseointegration [11,12,13,14]. Oseointegration is derived from the Greek word for bone "osteon", and Latin "integrare", which means to create a whole [11]. It was assumed that bone anchoring on the principle of feeling could work in humans, and the first toothless patients were treated in 1965 [11,12,13,14].

At the time, the osseointegration was not an accepted phenomenon. Although experiments on animals conducted in Branemark's laboratory made it clear that it was possible to anchor the bone on the condition that basic guidelines were observed, the scientific community was not convinced of the osseointegration because hystological evidence was absent. It wasn't until mid-1970, A. Schroeder, using a newly developed technique of cutting non-decalized bones and implants without separating anchored parts, showed that it was osseointegration. It was the first evidence of a direct conection of implants and bone. The original Branemark implant was created as a cylindrical; later, the conical shapes appeared [13,14,15]. Implant designs were breakthrought in the 1960s, and the basic spiral design was modified by Dr Leonard Linkow in 1963. the implant of the shape of the blade with the ability to place in maxillo and mandibul, which is now known as endooseal implantation [8,14].

In 1978, The Harvard Consensus Conference was held to establish a consensus on the use of implants at Harvard University, and the standard for a successful implant was whether the implant remained implanted and functional for five years. This standard may seem extremely short, but it illustrates what the expectations of implant treatment were at the time [8,16].

During the 1980s, Professor Zarb of the University of Toronto played a central role in holding the Toronto Conference on Oseointegration in Clinical Dentistry, where Branemark presented the results of his research over 30 years and clinical practice for nearly 20 years. With this conference as a turning point, the Branemark regime has expanded across North America. The typical Branemark regime during this period consisted of implanting four to six implants in the lower jaw and recommended a surgical two-stage technique that became widespread worldwide [8,16].

In the mid-1980s, a common implant used by many dentists was a root-shaped implant. The main factors that determined which implant system was selected relative to the other, included design, surface roughness, prosthetic considerations, simplicity of insertion into the bone, costs and success over a certain period of time [17].

After numerous clinical studies, the merits of Dr. Brennemark, Schroeder, Strauman, and especially Dr. Zarb in the 1980s expanded the indication area for the implantation of dental implants from the purely toothless and toothless jaws of patients. The results of successful oseointegration climb to more than 90 per cent, so implantology is also experiencing a commercial boom and is accepted as a valid therapeutic discipline [15,18,19].

This age is characterized by the emergence of new and modification of old designs as well as the emergence of new surgical techniques. The basis of this new philosophy consisted of oseointegration and a number of preconditions that need to be met in order for it to be achieved. Albrektsson et al. (1981) published educations about a number of factors to be taken for successful oseointegration. Oseointegration is a direct link between bone and implants, without inserted layers. However, it does not occur to 100 per cent - the development of bone and implant connections. Therefore, the definition of oseointegration is based on stability, not histological criteria, which reads "the process of achieving clinically asymptomatic rigid fixation of aloplastic material in the bone, during the functional load" [13.17]. Some scientists believe that only a biomechanical factor determines whether a fibrous capsule or bone will be created around the implant [13.18]. Contrary to this understanding, there is well-documented evidence of how the bone's response is quantitatively different depending on the type of biomaterials and the roughness of its surface [13,20]. The surface of the dental implant is the only part that is in contact with the biological environment, and the uniqueness of the surface directs the response and affects the mechanical strength of the contact of the implants / tissue [20,21]. One of the main reasons for modifying the surfaces of dental implants is the reduction of oseointegration time. This may include mechanical treatments (for example processing and sanding), chemical treatments (acid-etching), electrochemical treatments (anodyne oxidation), vacuum treatments, thermal and laser treatments. The surface layer on the implant is needed to increase the functional surface of the bone-implant touch so that stress is transmitted effectively. In addition, surface coating accelerates bone aposition. The latest innovations in dental implants include the use of fluoride, hydroxy-apathy, antibiotics, growth factors and laminna [20,21].

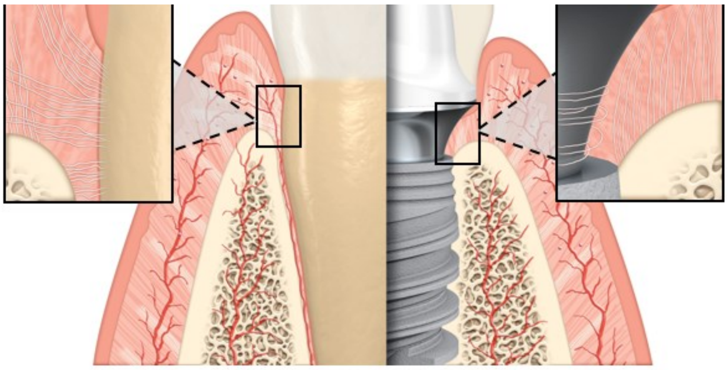
In the 1990s, the concept of prosthetics guided by surgery was replaced by the concept of prosthetic quided surgery and the focus of interest in oral implantology shifted from functional and aesthetic aspects. More or less, the imediate loading is replaced by delayed. Also, procedures of bone augmentation are being introduced to compensate for lost bone and put the implants in the correct position. So-called tissue engineering opens up completely new horizons in planning, but also in the performance of implant procedures [22].

Computer-designed production methods as well as computerized three-dimensional models are used to predict stress distribution characteristics in the implants around the bone. In recent clinical studies Blaschke and al. reported that dental implants made of zirconium are an adequate alternative to titanium dental implants. In addition to excellent aesthetic results, the authors conclude that zirconium implants enable a degree of oseointegration and soft tissue reaction that is better than titanium dental implants [23,24].

MUCOINTEGRATION

As it is known, the improvement of dental implants was done to enable optimal levels of osseointegration. However, there is another factor that is very important, the health of soft tissue. It is well known that for the health of the teeth, periodontal tissue is not only important because it stabilizes the teeth, it is a barrier between the oral cavity and the teeth. The role of soft tissue is quite similar when it comes to implants: contact between dense soft tissue and the surface of the abutment can act as a barrier to protecting and preserving the fundamental crestal bone. The anatomical characteristics of soft tissue and adjacent implants differ from soft tissue around natural dentation. Perpendicular collagen fibres known as Sharpey fibers bind natural teeth to cement, while collagen fibers tend to adher for the surface of the abutment in parallel or circular beads, which is a weaker combination. That's why the scientific community in recent years has been focused on improving the health of periimplant soft tissue, the health of the papilla around the implants, changing implant platforms, surfaces of abutments in order to better functionally adapt soft tissue. Mucogingival surgery (Pedicle grafts, gingival graft, free connective-tissue graft, etc.) can improve the appearance of periimplant contours [25,26,27].

Figure 2. A comparison of the characteristics of periodonte and periimplant soft tissue. Sharpey collagen fibers are attached to the cement of the root of the teeth in the perpendicular bead, while the perimplant fibers are oriented circumferentially or parallel to the surface of the abutment. (Taken from www.nobelbiocare.com/blog/science/why-abutment-surface-matters-for-soft-tissue-health/ for scientific purposes and not used for commercial purposes)



For long-term success, it is necessary to achieve soft tissue stability around implants. The introduction of "prosthetic-guided soft healing" in implant therapy aims to condition tissue before definitive prosthetic compensation, form an optimal emergence profile of the crown for achieving a gingive aesthetic and complication prevention. In this concept, temporary crowns or individualized abutments provide support to periimplantant tissues and papillas, existing or reconstructed during the implantation phase, ensuring positive gingive architecture without loss of volume and vestibular recession due to the collapse of soft tissues [22].

The surface of the implant is an important factor for long-term survival, but the role of the abutment surface has been least examined and has been the subject of today's researchers in recent years. As has been shown in numerous studies, smooth surface abutments do not facilitate mechanical cleaning, but they accumulate little plaque compared to those with rougher surfaces. Two factors are important for soft tissue connection: nanotography and surface chemistry [24,28,29,30,31,32]. Nanotopography of the abutment surface becomes increasingly important in explaining the connection between soft tissue. Surface's nanostructure is believed to play an important role in the interaction between cells and implants at the cellular and protein levels [33]. There are numerous methods for changing the nanotography of the abutment surface. One of them prefers the method of anodization, a process that involves immersing the abutment into electrolytic fluid using voltage. These changes in nanotography that lead to binding and proliferation of fibroblasts is an important step towards binding soft tissue [34,35]. The anode process is also important for surface chemistry and energy. Research shows that anodized surfaces have a lot of hydroxyl groups that correlates strongly and increases hydrophilicity or affinity surface for water, or blood [34,36]. It has also been shown that hydrophilic surface of abutment and priorities can help with adhesia, in support of soft tissue connection , which is functional and biological seal and barrier and prevention of microbial colonization [34,35,36,37,38].

There is a clear need for the abutment surface to remain clean and intact before use, in order to achieve a protective layer through use. Atmospheric elements can be upgraded to the surface of the abutment even though it is in sterile packaging. These deposits tend to have adverse effects on surface energy that are correlated with hydrophilicity and the representation of hydroxyl groups [39,40].

When one of the world's leading implant companies, Nobel Biocare, presented the newest surface of the Xeal abutment and together with Ti-ultra implant surface marked the beginning of an era of mucointegration. A smooth, non-porous, nanostructural, anodized surface has surface chemistry and topography that is designed to achieve soft tissue connection. Through Xeal and T-ultra Nobel biocare, it applies the anodization process to the entire implant system, from the abatment to the implant apex. That same year, they promoted the "on 1" concept, which involves an interstructure,on- 1 base, which is placed on an implant in the surgical implant phase and remains in that position during prosthetic restoration, which minimizes soft tissue trauma. The platform is therefore transferred from bone level to soft tissue level. Although this surface of abutment is on the market in 2019, it is already the subject of a two-year clinical study that showed a statistically significant increase in the height of keratinized soft tissue compared to machined abutments [29,41,42]. In addition to functional benefit, its golden hue (the result of the anodyne process) is useful in supporting natural appearance in the transmucosal zone, which can be particularly relevant in cases where thin mucous or mucosal recession is present. To ensure the condition of intactness, abutments are delivered with a protective layer that dissolves after contact with the liquid, i.e. blood. This dry packaging technology stores the surfaces of the abutment hydrophilic and surface chemistry and protects it from contamination with hydrocarbon [43].

DEVELOPMENT OF IMPLANT THOUGHT IN SERBIA

With the discovery of osseointegration begins the accelerated development of implantology in the world and in our country. This is the period when the first attempts to implantation in Serbia are made. Back in 1963 Dr. Tavcar, Dr. Škokljev and Dr. Spaić at the VMA made the first attempts to implantation two subperiostal implants in the toothless lower jaw, but after three years they were extracted. After the implant failure, skepticism reigned until 1977. The year that Dr. Skundric, Dr. Spaić and Dr. Skokljev implanted "pre-prepared wedges of a special alloy" in the form of tripods, which in the form of tripods are attached to the bone of alveolar continuation in the area of the canine and the first molar mutual. At the tips of the pegs are temporary crowns of palopont filled with silica. Encouraged by the success of the implant procedure, various implants of foreign authors, especially leafy, needle, screw-implants, are starting to apply in the VMA. Thanks to Professors Perovic and Kosovcevic above all, implantology begins to be studied in studies at the Faculty of Dentistry in Belgrade. Soon after, in 1981 the VMA installed the first one-piece circular leaf implant in the lower jaw [44]. Like Branemark, Schroeder, Straumann and Zarb, Dr. Skundric in Serbia is parallelly developing the B.C.T. home production implant system created as a product of years of application of different systems and acquired experience. Within the B.C.T system, this innovative scientist has also incorporated a part, a mesostructure that irresistibly resembles what 30 years later one of the leading implant houses, Nobel Biocare, will promote through its concept, on-1, which marked the beginning of an era of mucointegration.

CONCLUSION

Oseointegration is one of the most critical aspects of implant success. The history of developing and improving dental implants is a magnificent and fascinating time travel. In this field of research and learning it is only possible to stop and admire man's inventiveness over the years. Materials from which dental implants were made range from gold ligature wire, clams, ivory to chromium, cobalt, to iridium and platinum. From the spiral designs of stainless steel implants to double spiral creations and endoseal root shapes, dental researchers and clinicians worked fast and hard, creating many structures to replace positions that once had natural teeth. Dental surfaces have also been modified to reduce oseointegration time. Modified surfaces include the use of hydroxyapatites, composites, carbon, glass, ceramics and titanium oxide. To make the exterior as convenient as possible, the surfaces of the implants are further sanded, oxidated, fluorised, acid-etched and modified. The latest innovative coatings are the focus of today's implant research.

Although the importance of the surface of the implant is generally known, the surface of the abutment is subjected to far less intense research. Dense soft tissue contact with the surface of the abutment can act as a barrier that protects and preserves the subcrestal bone needed to achieve healthy integration and long-term success of dental implants.

This was the driving factor in the development of the Xeal abutment surface. To optimize the process of mucointegration, it is important to understand the surface characteristics of abutment, especially surface chemistry and nanostructure. Still the loss of implants due to periimplantitis is a growing problem each year, so in future aspects it should be given greater importance to soft tissue health around implants.

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