Chapter 1

Definition and History of Dental Implants

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Abstract

An implant is an artificial device placed in the body, typically expected to function in biological harmony with the body. These devices usually replace lost or damaged organs or tissues. The primary purpose of implants is to restore lost functions by replacing an organ or tissue, thereby regaining the system's functionality. Implants are widely used in various fields today.[1] They serve functions across a wide range, from dentistry to orthopedics, cosmetic surgery to neurological treatments.

1.Types of Implants

Dental Implants: The most common type of implant used in modern dentistry. Titanium screws are placed into the jawbone to treat tooth loss.[2] These implants, which fuse with the jawbone, offer aesthetic and functional solutions for many years.[3]

Orthopedic Implants: Implants used to treat bone or joint deformations.[4] They are usually preferred in the healing of fractures or joint deteriorations.

Cosmetic Implants: Implants made to address aesthetic concerns include applications such as breast implants, rhinoplasty, and facelifts.

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Neurological Implants: Implants targeting the nervous system, such as the brain and spinal cord, are used to treat neurological diseases.[5] Implants for treatment purposes are placed in Parkinson's, epilepsy, and spinal cord injuries.

Purpose of Implant Use:

The purpose of implant use is not limited to compensating for physical losses. It also aims to improve people's quality of life, correct functional disorders, relieve pain, and often achieve a more aesthetic appearance.

2.Development Process and Technological Advances of Implants

Developing Materials and Designs: The evolution of implant technologies has progressed in parallel with the development of materials used. The biocompatibility and durability of implant materials play a critical role in the success of treatment processes.

Use of Titanium: Until the mid-20th century, titanium was accepted as the first material compatible with bone. During this period, titanium attracted attention with its bone fusion capacity and became an ideal option for implants (Albrektsson et al., 1981).

Alternative Materials: Alternative materials such as zirconium have begun to be preferred, especially because they offer better aesthetic results.[6] Zirconium is frequently used for dental implants because it has a more natural appearance than metallic color tones.[7]

Innovations in Bioengineering: In recent years, advances in bioengineering, especially with biotechnology and nanotechnology applications, have opened new horizons in implant design. Nanotechnology enables the microscopic improvement of implant surfaces.[8] This enables faster bone integration and makes the implant more compatible with the body (Gallo et al., 2019).

3.Historical Development of Implants

Dental Implants in Ancient Times: Early Attempts:

The first dental implants date back to ancient civilizations.[9] In Egypt, in the years 2000-3000 BC, artificial teeth made of gold, silver, or stone were found placed in the jawbones found in ancient tombs (Anderson, 2004). Seashells are also among the trials carved into the jawbone (Tunalı, 2000). Although implants were not made with bone integration in the modern sense during this period, they were recorded as the first attempts to compensate for tooth loss. Archaeological findings show that there were similar applications in Egyptian, Roman, and Chinese civilizations (Jones & Smith, 2010). In the ancient Mayan culture, people used dental prostheses made of stone or other hard materials to prevent tooth loss.[10] These teeth were usually placed in the jawbone, but biological processes such as osseointegration were not used (Brown, 2015). In the 1930s, archaeological excavations in Honduras found a piece of jawbone with implants containing three pieces of shell carved into tooth shapes placed in the sockets of three missing lower incisors from the Mayan civilization. This is one of the oldest known examples of dental implants. Examinations also observed compact bone formation around two of them (SULLIVAN, 2001; Gaviria et al., 2014). In addition, initially, teeth were made from a wide variety of materials, such as ivory, bone, metals, and precious stones. It has also shown that early civilizations more than 2,000 years ago replaced missing teeth using carved stone, seashells, bones, and gold (Gaviria et al., 2014).[11]

18th and 19th Centuries: First Scientific Approaches

In the Middle Ages, dental implantation was performed using allografts (tissues from the same species) and xenografts (tissues from different species). However, these practices did not become widespread due to the risk of infectious diseases and related deaths (Gaviria et al., 2014; Sullivan, 2001).

Late 1800s

Modern dental practice began to emerge in the 18th century. However, the scientific foundations of dental implants began to be laid at the end of the 19th century. During this period, dental prostheses generally consisted of removable dentures or metal frames attached to tooth roots (Williams, 1998).

1840s

In the 1840s, dentist Edward Maynard performed one of the first successful dental implants. Maynard used metal implants placed in the jawbone instead of tooth roots. However, these implants were generally not strong enough and had problems with biological compatibility (Green & Taylor, 2003). In the 19th century, in 1891, teeth made using porcelain and gutta-percha were implanted by Znamenski (1891) and Hillischer (1891). Payne (1902) applied the procedure by filling gold-plated tin capsules with gutta-percha, and Greenfield (1913) placed endosseous implants consisting of hollow caged iridio-platinum cylinders. A grooved disc with an artificial tooth attached to it was located at the top of each cylinder. The trepan used for the surgery had a cylindrical shape. A circular socket was prepared in the jaw, leaving a core of bone on which the cylinder was placed. Greenfield hypothesized that the remaining core of bone in the implant site triggered the accumulation of new bone. The next 20 years did not see a major breakthrough in the field of implantology.

Early 20th Century

1930s

In the 1930s, the first attempts were made to use biocompatible metals such as titanium. However, the compatibility of implants with bone could not be achieved during this period, and success rates were low (Johnson, 2011).

1940s

The first titanium dental implants were made with the discovery of titanium metal, which would later become a very important material. However, the true potential of titanium implants was not understood until after the 1950s (Smith et al., 2017). It can be said that the history of modern dental implants began when Dr. Norman Goldberg, while in the army during World War II, began to try using metals used in other parts of the body in dental restorations. Later, in 1948, he and Dr. Aaron Gershkoff produced the first successful sub-periosteal implant (Gaviria et al., 2014). This laid the foundation of implant dentistry, as they pioneered the teaching of techniques in dental schools and dental associations around the world (Gaviria et al., 2014).

1950s, 1960s, and 1970s: First Clinical Applications and Development of Implant Design

One of the most important developments in dental implantology was the application of the first successful titanium dental implant to a patient by Swedish researcher Per-Ingvar Brånemark, who was an orthopedic surgeon (Gaviria et al., 2014). He placed implants in a 34-year-old human patient with missing teeth due to severe jaw and jaw deformities (Gaviria et al., 2014). Brånemark placed four titanium fixtures in the patient's mandible and, after a few months, used the fixtures as the basis for a fixed set of prosthetic teeth (Gaviria et al., 2014). This application later laid a foundation for the future use of titanium implants by achieving long-term successes (Brånemark, 1983). Brånemark's implants were the first dental implants to attach directly to the jawbone and remain stable for years.

Brånemark improved the design of implants, creating a safer and more effective system. Other researchers, inspired by Brånemark's findings, developed their own implant systems, and titanium implants slowly began to spread in dentistry (Adell et al., 1981). Brånemark's method was based on the principle of "complete osseointegration." Brånemark conducted numerous studies on animals and humans.

Linkow's blade and Sandhaus's ceramic bone screw were introduced as a new concept in 1970 (Linkow and Cherchève, 1970). After 1970, efforts increased to understand and eliminate the factors that caused dental implants to succeed or fail.

1980s: Spread of Implants and Technical Developments

Following Brånemark's discovery, dental implants began to become more common. During this period, many studies were conducted on implant techniques, surgical procedures, and healing processes (Zarb & Schmitt, 1996). By the late 1980s, the success of implants exceeded 90%, and titanium implants began to be widely used worldwide (Albrektsson et al., 1986).

During this period, studies were conducted on the aesthetic properties of dental implants. Especially in the front teeth, the harmony of the implant with the gums and the appearance with the natural tooth was an important focus. The surface properties of implants, surgical methods, and healing processes were further developed during this period (Buser et al., 1988).

1990s: Surface Modifications and Advanced Technologies

Significant advances were made in implant materials and designs. During this period, the modification of implant surfaces became one of the most important strategies to increase osseointegration. Surface roughness allowed the implant to adhere better to the bone and increased the biological compatibility of the implant (Schwartz et al., 1998).

Macro and Micro Surface Structures: Surface modifications enabled better integration of the implant with the bone. Micro-rough surfaces facilitated the adhesion of osteoblast cells to the implant surface, accelerating osseointegration (Albrektsson, 1993).

Ion Coatings and Biological Applications: Ion coating technologies and surface improvements with biological molecules are important factors that increase implant success. During this period, the impact of biotechnology on implant treatment greatly increased (Coelho et al., 1999).

2000s and Beyond: Digitalization and Personalized Implants

The 2000s witnessed great advances in dental implantology with the widespread adoption of digital technologies. Computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies enabled more precise placement of implants (Misch, 2015). At the same time, three-dimensional imaging techniques (CBCT) allowed more detailed analysis of bone structure and personalized implant planning (Sümbül et al., 2020).

2010s: Surface Modifications and Innovations in Biomaterials

In the 2010s, implant surface modifications became an important research area. Hydrophilic surfaces provided faster healing at the bone-implant interface (Albrektsson & Wennerberg, 2019). At the same time, zirconia implants were developed as an alternative to titanium alloys, offering new options in terms of aesthetics and biocompatibility (Pjetursson et al., 2018).

2020 and Beyond: Personalized and Biotechnological Approaches

Today, artificial intelligence-supported planning systems optimize patient-specific implant designs. In addition, thanks to biomaterial research, biofunctional coatings that accelerate bone regeneration and patient-specific implants produced by 3D printing are becoming widespread (Chrcanovic et al., 2021).

Aesthetic and Functional Developments

Zirconium implants have begun to be preferred as an aesthetic alternative to titanium implants. Zirconium has the capacity to better mimic tooth color and does not have a metallic color tone. This feature is a significant advantage, especially for patients who want a more natural appearance (Gallucci et al., 2014).

Current Implant Studies and Experimental Approaches

Implant technologies have made significant progress, particularly in terms of biomaterials, surface coating techniques, and innovations that enhance osseointegration. Recent research focuses on increasing the longevity and biocompatibility of implants.

Next-Generation Biomaterials

Biomaterial research goes beyond titanium and its alloys, including new materials such as ceramics, polymers, and biocomposites. For example, hydroxyapatite coatings are an important biomaterial used to accelerate bone integration (Zhao et al., 2021). In addition, zirconia implants are increasingly preferred due to aesthetic concerns (Pjetursson et al., 2020).

Surface Modifications and Osseointegration

Surface modifications play a significant role in accelerating the osseointegration process. Techniques such as nano-level roughening, plasma spraying, and laser surface treatment enable bone cells to adhere better to the implant surface (Gittens et al., 2014). In particular, the addition of nanoparticles to the titanium surface increases the activity of bone cells (osteoblasts), providing faster healing (Luo et al., 2022).

Implants Produced with 3D Bioprinters

In recent years, 3D printing technology has revolutionized patient-specific implant design and production. Customizing titanium or bioceramic-based implants according to the patient's bone structure reduces failure rates (Schmidt et al., 2021). In addition, bone tissue engineering studies with bioprinting continue, which may pave the way for full biological implant production in the future.

Antibacterial and Smart Implants

Implant infections are a significant cause of failure. To overcome this problem, silver nanoparticle coatings are used to prevent bacterial colonization (Müller et al., 2023). In addition, some new studies aim to reduce the risk of infection by developing pH-sensitive implant coatings (Kumar et al., 2020).

Future Perspectives: Nanotechnology and Biomimetic Implants

In the future, dental implants will be developed with more biocompatible materials and more efficient healing processes. Nanotechnology will play a major role in improving implant surfaces and accelerating bone integration. In addition, biomimetic implants can provide higher success rates by mimicking the function and structure of natural teeth (Zhao et al., 2018).

Advanced Technologies

Today, advanced technologies in dental implants are being developed to shorten the osseointegration period, reduce the risk of infection, and increase the biological performance of the implant.

Historical Process

2000s: Cellular interactions were increased with nanotechnological surface modifications (Wennerberg & Albrektsson, 2009).

2010s: Laser technologies began to be used in precise surface modifications (Romero-Gavilán et al., 2015).

Today: Biomimetic approaches are used to make implant surfaces more biological by taking inspiration from nature (Hanawa, 2010).

Nanotechnology Applications

Nano-structured Coatings: Nano-sized hydroxyapatite or titanium dioxide coatings promote cell proliferation (Botticelli et al., 2011).

Nanotubes and Nanoparticles: Nanotubes applied to the titanium surface increase cell adhesion and strengthen the osteogenic cell response (Büttner et al., 2019).

Functional Nanoparticles: Silver or zinc oxide nanoparticles are used to impart antibacterial properties. These nanoparticles also provide controlled release of biomolecules that promote bone growth (Chrcanovic et al., 2017).

Laser Technologies

Femtosecond Lasers: Provides ultra-precise surface modification, creates microscopic roughness, and increases cellular interactions (Romero-Gavilán et al., 2015).

Laser Surface Hardening: Increases mechanical strength, improves wear resistance. Laser-created microchannels facilitate the adhesion of osteoblast cells to the implant surface.

Laser Surface Patterning: Used to create micro-patterns that promote cell adhesion. Laser-treated surfaces accelerate the healing process of tissues around the implant (Zhao et al., 2019).

Biomimetic Surface Modifications

Nature-Inspired Designs: Surface structures that mimic the bone matrix are developed. These structures allow cells to adhere better to the implant surface (Hanawa, 2010).

Hydrogel and Biopolymer Coatings: Creates cell-friendly, flexible surfaces. Biopolymer layers provide a stronger connection between bone tissue and the implant.

Biological Molecule Integration: Proteins and peptides that promote bone growth are attached to the surface, accelerating osseointegration.

Clinical Success Rates of Implants

The success of implant treatment depends on many factors. The main factors affecting the success rate include the patient's general health, the quality of the surgery, the quality of the implant, and the healing process.

Success Rates: Although the general success rate of implant treatment is over 90%, this rate may vary depending on the material used, the surgeon's experience, and the patient's health. In addition, personalized treatment plans should be created to increase the success rates of implants (Buser et al., 2017).

Complications and Early Failures: Although the failure rate of implants is generally low, complications can develop due to factors such as surgical error, infection, incorrect placement, or insufficient bone support. Therefore, appropriate patient selection and meticulous surgical techniques are required for successful implant treatment (Szalai et al., 2019).

Conclusion

Dental implants have made significant progress from scientific discoveries in the 1950s to the present and have revolutionized dentistry. The ability of titanium to integrate with bone has laid the foundation for implant treatment, and technological developments have made this treatment method more reliable, aesthetic, and functional. In the future, dental implants are expected to become even more perfect with biotechnological and digital advances. Dental implantology, which is an indispensable part of clinical dentistry today, is expected to reach 13 billion dollars in the global dental implant market in 2023. In addition, the survival rate of dental implants was reported to be over 90% (Lekholm, 1999).

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