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Implant fundamentals - A comprehensive review

[1]Arjun M R, [2]Anil Melath, [3]Subir K, [4]Paventhan Jolie Coeur,[5]Rathesha S, [6]Rida Javad.

[1-6]Mahe Institute of Dental Sciences & Hospital, Mahe.

Corresponding Author: Paventhan Jolie Coeur, Mahe Institute of Dental Sciences & Hospital, Mahe.

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Abstract

Dental implants have been used widely as a treatment option to replace missing teeth which can be a single tooth to full mouth rehabilitation. It is a permanent alternative to dentures which basically replaces the root and crown of the tooth using a biocompatible material such as metals and ceramics. With advancement in dentistry, the material available for dental implants are also improved. Therefore, it is necessary that every dental student, dentist should have a basic knowledge on implants.

Keywords: Dental Implants, Endosseous, Abutment.

Introduction

Dental implants are also known as oral or Endosseous implants which are basically a permanent tooth replacement treatment that offers a multitude of cosmetic health benefits. According to the glossary of prosthodontic terms nine; "The dental implants are defined as a prosthetic device made of alloplastic materials implanted into the oral tissues beneath the mucosal and/ or periosteal layer and on or within the bone to provide retention and support for a fixed or removable prosthesis. Success rate of an implant placement purely depends upon its integration to the surrounding tissues. Thus this review gives an idea on basics on implants". [1][2]

Components of a dental implant are;

1. Implant body/fixture - provides anchorage to the prepared tooth which is fixed onto the bone.
2. Healing screw/cap/gingival former - protects the main part of the implant from plaque and debris attachment and also promotes soft and hard tissue healing around the implant.
3. Abutment – part of the implant that gives support and retention which resembles a prepared tooth that is fixed to the body of implant. [1]

Osseointegration

The concept of osseointegration was introduced by **Brånemark** in 1952.

According to the glossary of prosthodontics terms nine: "The osseointegration is defined as apparent direct attachment or connection of osseous tissue to an inert, alloplastic material without intervening fibrous connective tissue". (or) simply the interface between alloplastic materials and bone.[2]

A successful osseointegration determines the stability and survival of an implant. Since it fuses with the surrounding bone it can also be known as functional ankylosis. Which primarily heals by primary healing procedure i.e, union occurs without intervening fibrous tissue or fibro cartilage. So, immediately after implant placement the clotted blood is replaced by granulation tissue and gradually covered by woven bone which then convert to form into a mature bone.[1][2][3]

So, osseointegration is basically a biological process where the bone integrates with the implant surface, securing it in place. It ensures stability and support for prosthetic teeth, allowing for natural chewing and speaking functions. This phenomenon enhances, dental implant success rates, longevity, and patient satisfaction with restored oral function and aesthetics.[3][16]

Development of design of implant

The evolution of dental implant design has progressed to enhance the integration of implants with the jawbone and ensure their stability. This advancement involves the utilization of materials like titanium, surface enhancement to promote bone adherence, and diverse implant shapes tailored to specific anatomical requirements. [4][5]

Porous coating (i.e., acid-etched, sand-blasted) can achieve more bone-to-implant contact than smooth Subcrestal surfaces. [7] Load transmission and resultant stress distribution is significant in determining the success or failure of an implant. Factors that influence the load transfer at the bone implant interface include the type of loading, material properties of the implant and prosthesis, implant geometry length, Diameter as well as shape implants surface structure, the nature of the bone-implant interface, quality and quantity of the surrounding bone. [4]

Most available dental implants designs have cylindrical or conical (root) thread shapes. The shape of a dental implant primarily influences its biomechanical fixation and function in bone tissue. Implant threads help in bone implant integration due to its macro porosity and increased surface area. The preferred biomaterial is titanium due to its biocompatibility and mechanical properties. Modifications like titanium with zirconia have shown to be mechanically stronger, this zirconia based titanium is claimed to be more biocompatible and stable with decreased production of toxins. Zirconia-based materials have been claimed as a biomaterial with a high chemical stability that avoids the release of toxic products to the surrounding tissues.[4][8][9]

Yttrium Tetragonal zirconia polycrystals (Y-TZP) stimulates osteoblasts during osseointegration and combines unique mechanical properties such as high fracture toughness, fatigue strength, high flexural strength, high corrosion resistance and radiopacity, and is more biocompatible than most alternatives.

Furthermore, several studies have shown that zirconium oxide reduces bacterial adhesion and biofilm accumulation, thus reducing the risk of inflammatory reactions in the adjacent peri-implant tissues.

The progressive refinement of dental implant design, leveraging advancements in materials, biomechanics, and digital technology, enhances patient outcomes, comfort and longevity. [7][9]

The design of an implant encompasses its three-dimensional structure, encompassing all its constituent elements and characteristics.[7] During function, dental implants experience different magnitudes and directions of force.[5] Since implants are responsible for transferring occlusal loads to the surrounding biological tissues, functional design objectives should focus on effectively managing biomechanical loads to enhance the function of the implant-supported prosthesis. Therefore, the primary objective of functional design is to optimize the function of the implant-supported prosthesis by managing biomechanical loads.[8] Most of the commercially available designs of dental implants are threaded with cylindrical or conical (root) shapes[9] The shape of a dental implant primarily affects its biomechanical fixation and function in the bone tissue.[8]

Implant threads not only increase the surface area for direct bone-implant integration but also play a crucial role in significantly enhancing the long-term stability of a dental implant.[9]Cylinder or press-fit implants offer advantages such as friction-fit insertion, reducing the risk of pressure necrosis from excessive insertion pressure. They eliminate the need for bone tapping and may come with the cover screw pre-installed since no rotational force is necessary during insertion, making them the simplest to insert among implant types,there are reports of implant failure due to fatigue overload.[8].

While cylinder or press-fit implants may offer easier insertion, their design can lead to higher bone turnover rates and potentially lower bone-implant contact percentages. This increased bone turnover can contribute to a higher risk of overload failure over time, emphasizing the importance of careful consideration of implant design and placement techniques to mitigate such risks.[9]

In recent years, researchers have developed tantalum-based implants with highly porous surfaces, such as the Trabecular Metal Zimmer® Dental Implant System. These implants mimic the structure of trabecular bone, aiming to enhance bone ingrowth and ongrowth properties by maximizing the surface interface with bone tissue. This innovation represents a significant advancement in dental implant technology, offering improved osseointegration and potentially enhancing long-term implant success rates.[10][11]

Commercially pure titanium is still the preferred biomaterial for manufacturing dental implants due to its excellent biocompatibility and favorable mechanical properties. [12]

Modifications such as alloying titanium with metals like zirconium can lead to mechanically stronger implants. While this can enable the use of smaller diameter and shorter implants, the primary motivation behind these modifications seems to be enhancing the implant's mechanical properties rather than directly improving the implant-bone response. However, stronger implants can still indirectly benefit the implant-bone response by providing better stability and support for osseointegration. [14]

Osseodensification

It is a simply means that dental implant technique that compacts bone rather than drilling, promoting bone density and enhancing implant stability and osseointegration for better outcomes. [15]

The primary stability during implant placement stands out as one of the most critical factors influencing the success of implant therapy. Key factors that contribute to enhancing implant primary stability include bone density, surgical protocol, and the type and geometry of the implant threads. Primary stability is achieved through the mechanical friction between the external surface of the implant and the walls of the osteotomy. The peak insertion torque is directly correlated with implant primary stability and host bone density. High insertion torque can significantly enhance the initial bone-to-implant contact percentage. [15]16]

Osseodensification (OD) is an innovative technique for biomechanically preparing bone during dental implant placement. This method involves minimal plastic deformation of the bone through rolling and sliding contact, facilitated by a specially designed densifying bur. The bur is fluted in a way that allows it to densify the bone with minimal heat generation. [16][18][21]

Osseodensification (OD), a bone-preserving technique, was developed by Huwais in 2013. It involves the use of specially designed burs (Densah™ burs) that aid in bone densification while preparing an osteotomy. [20][21]These burs offer the advantages of osteotomes by combining speed with enhanced tactile control of the drills during osteotomy. Standard drills remove bone during implant osteotomy, whereas osteotomes often induce fractures in the trabeculae, which require a longer remodeling time and result in delayed secondary implant stability. Densah burs enable bone preservation and condensation through compaction autografting during osteotomy preparation. This process increases bone density in the peri-implant areas and enhances the mechanical stability of the implant. [19][20]

In contrast to traditional osteotomy, Osseodensification (OD) doesn't excavate bone; instead, it simultaneously compacts and autografts the particulate bone outward to create the osteotomy. This process preserves vital bone tissue. This is accomplished using specialized densifying burs . When the specialized drill is operated at high speed in an anticlockwise direction with steady external irrigation (Densifying Mode), dense compact bone tissue is formed along the osteotomy walls. The pumping motion (in and out movement) generates rate-dependent stress to induce rate-dependent strain, allowing saline solution pumping to gently pressurize the bone walls. This combination enhances bone plasticity and promotes bone expansion. [21]

Various abutment and implant connections in dental implantology

Internal Hex Connection: This connection features a hexagonal interface on both the implant fixture and the abutment. [14] It provides stability and resistance to rotational forces, allowing for precise alignment during restoration placement. The internal hex design is widely used and has been a standard in implant dentistry for many years.[11][12][13]

External Hex Connection: In this type of connection, the hexagonal interface is located on the exterior of the implant fixture. The abutment has a corresponding hexagonal extension that fits onto the implant. While it was commonly used in the past, the external hex connection has become less prevalent due to concerns about stress distribution and potential complications. [9][13][14]

Internal Octagon Connection: Similar to the internal hex, the internal octagon connection features an octagonal interface on both the implant fixture and the abutment. This design aims to provide greater resistance to rotational forces compared to the hexagonal interface, enhancing stability and long-term success.[13][17]

Morse Taper Connection: The Morse taper connection involves a tapered interface between the implant fixture and the abutment. As the abutment is seated into the implant, the taper creates a frictional fit, ensuring stability and minimizing micro-movement between the components. This connection offers excellent mechanical stability and sealing against bacterial infiltration.[12][15]

Conical Connection: The conical connection is similar to the Morse taper but features a more pronounced tapering interface between the implant and abutment. This design enhances the precision of the fit and provides superior stability, minimizing the risk of component loosening or displacement.[12][15]

Tri-Lobe Connection: In this connection type, both the implant fixture and the abutment feature three lobes that interlock when assembled. This design provides rotational stability and prevents rotational forces from affecting the implant-abutment interface. The tri-lobe connection is designed to enhance the longevity and reliability of implant restorations.[14][17]

Platform-Switching Connection: Platform-switching involves using an implant fixture with a smaller diameter platform than the diameter of the abutment. This creates a horizontal offset between the implant platform and the abutment, which can help preserve bone levels and soft tissue contours around the implant site. Platform-switching is often used to minimize bone resorption and improve esthetic outcomes.[12]

Mosa Connection: The Mosa connection utilizes a friction-fit mechanism where the abutment fits into the implant body without any specific interlocking features. This design relies on the precise machining of the implant and abutment components to create a stable connection. The Mosa connection aims to provide stability and sealing against bacterial infiltration, similar to other internal connections.[12][13][14][15]

Peri-implant tissue response to bacterial insult and peri implant diseases

Common complications of dental implants include peri – implantitis (inflammation around the implant), implant failures, infections, nerve damage, and bone loss.

Even though implants have a high success rate, there are also reported instances of implant failures. The implant might experience failure before functioning due to a lack of integration with peri-implant tissue during the healing stage. This failure is termed as early failure. Integration loss and failure of the implant may occur in later stages, ranging from months to even years after its initial placement and this termed as late failure. [18][21]

Complications affecting peri-implant tissue are reported, linked to the inflammatory response provoked by bacteria forming a biofilm on the implant surface. It happens when the equilibrium between the host's defense mechanisms and the bacterial presence tilts in favor of the bacteria.[20] The tissue reaction might be confined to the peri-implant soft tissues (mucosa) or could also spread to involve the peri-implant bone, resulting in its resorption. The combined tissue reactions to bacterial insult are commonly referred to as peri-implant diseases and they are categorized as either peri-implant mucositis or peri-implantitis. [18][19][20]

Peri-implant mucositis is similar to gingivitis, an inflammation involving only the immediate soft tissue. When this condition progresses to involve the bone, it results in peri-implantitis. From a clinical standpoint, peri-implant mucositis is identified by bleeding upon gentle probing.[22] It is a treatable condition, and the harm it causes is reversible. Peri-implantitis resembles chronic periodontitis in natural teeth, although some differences do exist.[20].For instance, crestal bone loss in peri-implantitis occurs circumferentially around the affected implant, unlike the bone resorption seen in chronic periodontitis. In chronic periodontitis the lesion is self limiting due to the connective capsule around it but this is absent in peri implantitis due to which the spread is seen apically and laterally.[22] It's important to note that dental implants may fail due to these diseases if left untreated, as they lead to bone resorption, eventually resulting in mobility and failure of the affected implant.[19][21]

In conclusion, while dental implants offer significant benefits, complications such as peri- implantitis and implant failure emphasize the need for careful patient selection, meticulous surgical technique. And ongoing postoperative care to ensure optimal outcomes.[18][22]

Digital technology in implant dentistry

Implant dentistry undergoes a digital revolution, transforming precision, efficiency, and patient care through innovative digital technologies. [31]In implant dentistry, the evolution towards digital technologies is evident through the increased utilization of CAD/CAM systems, cone beam CT scans, and digital impressions.[26][28][23]

CBCT

Cone Beam Computed Tomography (CBCT) plays a critical role in dental implant placement. It provides detailed 3-D images of oral structures, enabling precise evaluation of bone quality, density, and proximity to vital anatomical structures such as nerves and sinuses.[26][28]This comprehensive assessment enhances treatment planning accuracy, guiding optimal implant positioning and reducing surgical complications.[26][27]

Optical Scanning

Such as intraoral scanners, assists in implant placement by creating precise digital impressions of the patient's oral anatomy. [29][30]These scans offer detailed information on tooth morphology, soft tissue contours, and adjacent teeth alignment.[29][30]. This data aids in designing custom abutments and restorations ensuring optimal fit, aesthetics, and function of dental implants. Additionally, optical scanning eliminates the need for messy traditional impressions, improving patient comfort and streamlining the treatment process.

Role of 3D printing technology in surgical guide fabrication

Guided tissue regeneration (GTR) involves using barrier membranes to direct the growth of new bone and soft tissue around implants[29][30] .This technique is crucial in achieving successful implant placement, particularly in cases where there is insufficient bone volume or compromised soft tissue quality.[33][34][36] By utilizing 3D printing technology, custom surgical guides can be fabricated with precision based on digital scans of the patient's anatomy.[23][24][25]

These guides serve as template during surgery, dictating the exact positioning and angulations of dental implants, by following the pre-planned path delineated by the surgical guide, dentists can ensure accurate implant placement, which is vital or long-term success. Additionally, the use of 3D printing allows for the creation of patient-specific guides that are tailored to each individual's unique oral anatomy.[30][32][35]

The integration of GTR and 3D printing technology offers several benefits. Firstly, it enhances surgical precision by providing a roadmap for implant placement, reducing the likelihood of errors or complications during surgery.[36] Secondly, it streamlines the treatment process by allowing for efficient pre-surgical planning and preparation. Thirdly, it improves patient outcomes by promoting optimal tissue healing and regeneration around the implant site, leading to better aesthetic and functional results.[33][34][35]

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