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Research Article

Contemporary Advances in Dental Implant Abutments

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ABSTRACT

Since the introduction of dental implants, implant designs have continuously evolved to meet both mechanical and biological requirements. Macro- and micro-design parameters, including implant length, diameter, body shape, and surface characteristics, directly influence intraoral success and prognosis. Thanks to advances in surface technologies, short implants can now be reliably used, improving osseointegration outcomes.

Alongside these developments, abutment design plays a decisive role in the success of implant-supported prostheses. Abutments are classified according to criteria such as the material used (titanium, zirconia, hybrid), manufacturing technique (prefabricated or customized), retention method (screw- or cement-retained), and implant–abutment connection type. Titanium remains the gold standard due to its mechanical strength and biocompatibility, whereas zirconia is increasingly favored in esthetic zones. However, the difference in hardness between zirconia and titanium may cause fractures or wear over time, which has led to the emergence of hybrid abutments that combine esthetic and mechanical advantages.

KEYWORDS

Dental implant abutments, Abutment technology, Prosthodontics.

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1. Introduction

Dental implants are a reliable treatment option for partially or fully edentulous patients, offering high survival rates and predictable outcomes [1,2].

Biomechanical factors—such as prosthetic loading, implant-abutment connection, bone quality, implant surface, and prosthesis design—are critical to implant success. Proper management of these factors is essential, with abutments playing a key role in linking the implant to the prosthesis [3].

Titanium's biocompatibility and osseointegration capabilities have contributed significantly to long-term implant success. Advances in implant design and surface treatments have further improved outcomes [4].

Selecting the appropriate abutment—considering material, shape, type, and connection—is vital for achieving functional, stable, and esthetic prosthetic restorations and ensuring patient satisfaction [5].

2. Dental Implants

An implant is an artificial device designed to restore the function or aesthetics of a missing part of the human body. The surgical placement of implants into living tissue is referred to as implantation. Dental implants are components that integrate with bone and are used for supporting crowns, bridges, facial prostheses, orthodontic anchorage, or removable dentures [6].

According to the Glossary of Prosthodontic Terms, a dental implant is defined as a prosthetic device made of alloplastic materials that is implanted into oral tissues beneath the mucosal and/or periosteal layer and on or within the bone, in order to provide retention and stability for fixed or removable dental prostheses, or as an object placed on or within the jawbone to support such prostheses [7].

3. Components of A Dental Implant

Most dental implant systems consist of two main components: the **implant fixture** and the **abutment**. These components are typically connected by tightening a screw to a specific torque value, depending on the chosen material and the design of the connection [8]. Dental implants were classified into **four distinct components instead of** two gears by Hunt et al. [9].

Implant Body

This is the portion of the implant that remains entirely within the bone. The implant body consists of three regions: the **crest module**, the **body**, and the **apex.** (Figure 1) The **crest module** is the part specifically designed to allow the connection of prosthetic components to the implants in two-piece implant systems [9].

Implant Collar

This is the part of the implant where the section embedded in bone ends and comes into contact with the soft tissue [9].

Connection Interface

This is the region where the implant body and the abutment join together.

Restorative Component: Referred to as the abutment [9].

4. Components Used in Implant Systems

Implant Body

This is the main part that is surgically placed into the jawbone. It is the component that directly interacts with the bone to achieve osseointegration and serves as the base to which parts like the healing abutment and abutment are screwed. In addition to titanium—which has proven biocompatibility—implant bodies can also be manufactured from other materials such as zirconia. Various surface treatments are applied to improve bone integration [10].

Healing Abutment

Healing abutments are commonly made of titanium and help to shape healthy gingival tissue around the future prosthesis, creating the appearance of the tooth emerging naturally from the gum. They are attached to the implant body during the second surgical stage using a cylindrical transmucosal screw. They are produced in different diameters and gingival heights [10].

Abutment Screw

A thin screw-shaped component that passes through the abutment and fits tightly into the implant body.

Abutment

This is the prosthetic component connected to the implant body via the abutment screw. Temporary or permanent prostheses are designed and fabricated based on the abutment. They are manufactured in different step heights according to the gingival height and in various angles based on the inclination of the implant body. Depending on the type of prosthesis to be produced, they may be made from materials such as titanium, zirconia, polyether ether ketone (PEEK), or gold.

Impression Copings

These components are used to transfer the position of the implant in the jaw to a model outside the mouth. During this transfer, an impression coping is used in combination with impression material and a tray. Different types of impression copings are produced for various implant-level impression techniques.

Direct Impression Copings (Open Tray Transfer Copings)

These are screwed onto the implant body within the jawbone and are used in single-stage implant-level impressions. Also called open-tray impression copings, they are generally preferred when there are more than two implants or when implants are placed at steep angles. The parts of these copings that contact the tray are perforated; after the impression material sets, the screw is accessed through these perforations and loosened. They are longer than closed-tray copings to allow easy access through the tray.

Indirect Impression Copings (Closed Tray Copings)

These differ in design from open-tray copings and have fewer undercuts or surface grooves. They can be used in either one-step or two-step impression techniques. Unlike open-tray copings, the tray does not need to be perforated during impression taking. After the material sets, the coping is removed from the mouth, connected to an implant analog, and inserted into the corresponding negative space in the impression [10].

Snap Coping

This is an indirect impression coping developed to improve accuracy with closed trays. It has plastic caps with undercut areas that lock into the impression material. The top of the coping comes in various shapes [10].

Analog

A component designed to replicate the implant body. It mimics not the external shape but the connection portion of the implant. Impression copings are screwed onto this part, which remains embedded in the master model, allowing the intraoral implant position to be transferred accurately outside the mouth [10].

5. Abutments

According to the Glossary of Prosthodontic Terms, an **abutment** is defined as the part of a tooth, tooth root, or implant that serves to support and retain a prosthesis. In the context of implantology, the portion of the implant that extends into the oral cavity is referred to as the **abutment**. It is used to provide retention, ideal emergence profile, and support for implant-supported prostheses [11].

Abutments play a central role in both the **functional** and **esthetic** aspects of implant therapy. They have a direct influence on the long-term prognosis of implant-supported restorations. Abutments are divided into three sections: [12]

a. **Prosthesis-Connecting Section**

This is the portion of the abutment that connects to the prosthesis and can be modified to optimize the treatment outcome. Modifications depend on factors such as prosthesis size and shape, emergence profile, the form and height of interdental papillae, interocclusal space, desired embrasures, and the space required for the final crown material [12].

b. **Implant-Connecting Section**

This is the portion of the abutment that connects directly to the implant. This part should not be altered, as it is critical for ensuring the proper function and integration of the implant system [12].

c. **Transgingival Section**

This is the part of the abutment that extends above the implant platform and is surrounded by gingival tissue. Like the prosthesis-connecting section, it can be modified to optimize treatment outcomes. Changes are based on the desired emergence profile, the overall prosthetic plan, the thickness of the gingiva above the implant platform, and hygiene and maintenance goals [12]. (Figure 1).

Figure 1: Components of dental implants.

Classification of Abutments

There are many different classification systems. In general, they can be grouped into two main categories:

A. Temporary Abutments

These are made of titanium or plastic and can be prepared for the purpose of temporary restorations. Temporary restorations help shape and stabilize the soft tissues during the healing phase after surgery, and allow for the evaluation of aesthetic parameters before the definitive restoration. Many of these abutments are modified to create soft tissue contours in aesthetic areas. These abutments serve as a guide in defining the emergence profile, aesthetics, phonetic limits, and desired final restoration position [3].

a) Impression Abutments:

Impression abutments are divided into two types: those used for open tray and closed tray impressions. Open tray impression abutments are often referred to as “pick-up” or “direct copings”. Closed tray impression abutments are referred to as “transfer” or “indirect copings” [3].

b) Healing Abutments:

Healing abutments are used post-surgically to cover the implant body and prevent the ingrowth of soft or bone tissue into the implant. They also aid in gingival epithelialization and prevent the passage of oral fluids into the implant body. They can be used with either a one-stage or two-stage surgical protocol [3].

c) Modifiable Metal/Plastic Abutments:

These abutments, which can be made from titanium (metal), zirconia (ceramic), or PEEK (polyetheretherketone/acrylic), are used during the temporary restoration phase. They also help determine the final restoration’s form, color, soft tissue profile, and occlusion. They can be produced either in standard shapes or anatomically to match the patient’s natural gingival profile. These abutments can be modified either indirectly in the lab by a technician or directly in the mouth by a dentist [3].

B. Definitive Abutments

These are used for the final restoration and are permanently fixed in place. At this stage, the dentist may choose from a standard stock abutment, a castable custom abutment, or a computer-generated custom abutment. The choice depends on the clinical case, the clinician’s experience, and the patient’s preferences (Figure 2).

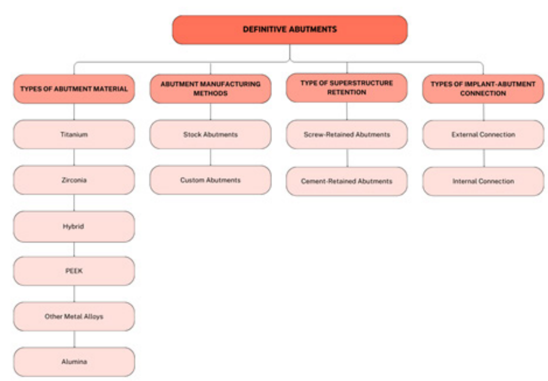

Figure 2: Classification of dental implant abutments.

6. Abutment Materials

Titanium

Titanium is considered the ideal material for dental implants. Due to its excellent biocompatibility, corrosion resistance, low molecular weight, and high tensile strength despite its low density, it is the most commonly used metal alloy in the production of implant abutments [13].

Thanks to its outstanding material stability, resistance to distortion, and proven success in long-term clinical studies, titanium was long regarded as the gold standard among abutment materials for implant-supported prostheses. However, with the growing emphasis on aesthetics in contemporary dentistry, titanium abutments have shown limitations—particularly in cases where the gingival biotype is thin or the implant is positioned buccally—due to the grayish hue they can impart to the surrounding mucosa [14].

Zirconia

Zirconium dioxide (zirconia) is a white crystalline oxide of zirconium, widely used as an alternative to titanium abutments due to its esthetics, machinability, high flexural strength (900–1200 MPa), fracture toughness (6 MPa·m^0.5), and biocompatibility [15]. Its low surface porosity and color similarity to natural teeth also enhance its clinical appeal [16].

A key drawback of zirconia abutments is wear at the implant-abutment interface, as zirconia's hardness can cause abrasion of the titanium components under functional load [17].

In cases with shallow implant placement and thin gingival biotype, zirconia abutments are preferred over titanium due to better esthetic outcomes, avoiding the gray shine-through effect [18].

Studies show both materials have similar tissue compatibility [17]. Rimondini, et al. [19] found no difference in bacterial adherence in vitro, but significantly less bacterial accumulation on zirconia *in vivo* [20]. Though titanium demonstrates higher fracture strength in vitro, modern zirconia abutments have improved mechanical properties and can now withstand masticatory forces well, making them suitable for both anterior and posterior use [17].

Hybrid Abutments

Despite their esthetic benefits, zirconia abutments have shown susceptibility to fractures—especially at the collar area—and can cause wear on titanium implant interfaces due to their greater hardness. To address these issues, hybrid abutments were developed, combining a titanium base for strength with a zirconia component for esthetics [21].

In these designs, the titanium portion connects to the implant, while the zirconia supragingival part supports the prosthesis. These are joined through various bonding methods, allowing for a unified structure. Ti-base systems further enable custom zirconia restorations to securely fit the titanium platform, combining durability with esthetics [21].

PEEK

PEEK abutments are prefabricated and widely used for provisional restorations. This semi-crystalline organic polymer, available in beige or white, offers good mechanical strength, chemical resistance, and favorable esthetic and biological properties. Its low elastic modulus reduces stress on the implant and cement interface during mastication [12]. However, studies show that titanium provides superior mechanical strength and marginal sealing [22]. Due to its resistance to heat, moisture, and organic debris, PEEK is considered ideal for temporary abutments [23].

Other Metal Alloys

Metal abutments are commonly used in implant-supported restorations for their excellent biomechanical strength and biocompatibility. Typically made from gold or titanium alloys, titanium has become the material of choice due to drawbacks associated with gold abutments [24].

Other alloys such as stainless steel, nickel-chromium, and cobalt-chromium have also been explored. However, using metals with similar electrochemical potentials poses a risk of galvanic corrosion, potentially causing pain due to corrosion and oxidation [23].

Alumina

To overcome esthetic limitations of titanium abutments, alumina abutments were introduced by Prestipino and Ingber in 1993. Manufactured using CAD/CAM technology from 99.5% pure dense cold-sintered alumina ceramic, these abutments possess enhanced optical properties, low corrosion rates, low thermal conductivity, and high biocompatibility. Despite proven excellent esthetic outcomes, their cylindrical shape requires intraoral adaptation, production is complex and time-consuming, and high failure rates limit their current clinical use. Therefore, alumina abutments are not widely preferred today [24].

7. Abutment Manufacturing Methods

Nowadays, abutments can be used as prefabricated components or can be custom-designed for individual patients. The fabrication of patient-specific abutments is typically achieved through conventional casting methods or CAD-CAM systems [25].

Stock Abutments

Stock abutments are generally prefabricated from titanium. They can be modified in the laboratory or intraorally to support a provisional crown, final crown, or bridge [12]. Abutments with different margin levels and collar heights are produced by manufacturers [24]. However, achieving an ideal emergence profile and esthetics with stock abutments is challenging. The correct implant positioning is crucial when using stock abutments. To address positional discrepancies, stock abutments are available in various angulations. Implant companies manufacture both straight and angled stock abutments. However, crowns supported by angled stock abutments do not provide an ideal emergence profile, which may complicate patients' oral hygiene maintenance [12].

- Cement-retained abutment: preferred for single or multi-unit restorations.
- Angled abutment: chosen when the implant or adjacent teeth are not parallel.
- Ti-base abutment: a system designed to facilitate the fabrication and attachment of the prosthetic crown onto the implant during dental implant treatment. Ti-base is a titanium platform that combines with the prosthetic crown and is directly seated

into the implant. This system assists in the secure and accurate connection of implant-supported crowns and bridges to the implant.

- Ball abutment: preferred for overdenture prostheses.
- Octa abutment: a screw-retained abutment used occlusally for fabricating screw-retained bridge prostheses.
- Milling abutment: a customizable, milled abutment tailored to the patient's gingival contours.
- Multi abutment: designed as a foundational infrastructure permitting the fabrication of all restorative options such as screw-retained crowns, bridges, hybrid prostheses, and bar attachments. It is also the primary abutment choice for immediate loading cases in the fabrication of provisional and definitive prostheses.
- Temporary abutment: used for the fabrication of provisional restorations.
- Solid abutment: a screwless abutment system usable for cement-retained crowns in both anterior and posterior regions. The solid abutment has a proprietary driver.
- Magnetic retainers: consist of a magnet attached to the implant and a corresponding metal component in the prosthesis; the retentive force arises from the magnet within the prosthesis, independent of the magnet's insertion path.
- Telescopic retainers: composed of a male part screwed into the implant and a female part within the prosthesis; retention is achieved by friction between the male and female components.
- Locator retainers: consist of a retentive component screwed into the implant at various heights and a metal housing in the prosthesis containing interchangeable nylon inserts of different retention strengths and colors. Suitable for cases with limited interocclusal space and implant angulations up to 40°. The Locator system includes abutments compatible with all implant diameters, metal housings with black plastic processing caps, and nylon inserts available in blue, pink, clear, red, orange, and green, each offering different retention levels.
- OD-secure attachment: corrects angulation discrepancies up to 30° between implants and can be used up to 50° angulation due to its design. The surfaces of OD Secure attachments are coated with wear-resistant titanium nitride.
- Locator R-Tx: tolerates implant angulations up to 60°. With a DuraTec Titanium Carbon Nitride coating, it is 32% harder and 62% more wear-resistant. The abutment features a narrower central cavity to reduce food and plaque accumulation and has a dual retention surface. Unlike standard Locators, the pink housing has horizontal grooves to improve prosthesis fixation.
- Optiloc: features a surface coated with ADLC (amorphous diamond-like carbon), which reduces attachment wear. The retentive ring is made from PEEK material. Allows implant angulations up to 40°. The matrix permits minimal prosthesis movement without detachment and always returns to its initial position, differing from other matrix systems.
- Locator F-Tx: an attachment system used for fixed full-arch restorations. Unlike traditional fixed restorations, it requires no cement or screws and seats passively. It is easily removable by the clinician but provides a fixed prosthesis for the patient, preserving esthetics, reducing cost, and improving patient comfort.
- CM-Loc: features no retention hole in the center of the abutment, improving cleanability. The retentive ring is made from wear-resistant Pekkton polymer. Allows implant angulations up to 60°.
- Novaloc: provides retention via a mechanical snap-lock system in the matrix. The titanium abutment surface is coated with diamond-like carbon for reinforcement, while the matrix is manufactured from PEEK. This coating and design allow tolerance of implant angulations up to 40° with reduced wear. The space occupied in the prosthesis is nearly identical to the Locator abutment. A non-integrated ring-shaped PEEK component fits over the abutment and is produced in different colors corresponding to retention strengths. The ring's opening allows flexibility during insertion and removal [26].

Figure 3: Various types of stock abutments.

Custom Abutment

In certain clinical situations, dentists may require custom abutments for implant-supported prosthetic restorations. The main reasons for this necessity include insufficient esthetic outcomes, suboptimal implant angulation, the inability to achieve an ideal emergence profile, and the formation of inaccessible areas that compromise oral hygiene maintenance [27].

Custom abutment fabrication is a costly laboratory procedure that must be carried out with precision [28]. Methods used for the production of custom abutments include milling, casting, and CAD/CAM systems [25].

- **Milling:** Custom abutments can be produced by milling preformed titanium blocks. In such cases, the implant-connecting portion and screw of the abutment are provided as prefabricated components, while the transmucosal portion is supplied as a block by the implant manufacturer. After computer-aided design (CAD) procedures are completed, the intraoral portion of the abutment is milled from this block using a computer-aided manufacturing (CAM) unit. Both metal and ceramic abutments can be fabricated using CAD/CAM technology [24].

- **Casting:** This method involves conventional wax modeling, casting, trimming, and finishing procedures [29]. Cast custom abutments consist of a standard metal base and a plastic component placed on top of this base, which is shaped and adjusted in height according to the patient using carving or wax addition techniques. Compared to prefabricated abutments, cast custom abutments are more advantageous in terms of esthetics, soft tissue support, and achieving ideal crown contours. Rather than being cylindrical in form, they mimic the morphology of the missing tooth. However, the primary disadvantages of cast custom abutments are the time-consuming and costly laboratory procedures involved. Moreover, they tend to have inferior fit at the abutment/implant interface when compared to stock abutments [30].

- **CAD/CAM:** In this technique, virtual abutment design is performed using patient-specific data obtained via an optical scanner and processed with CAD software. The virtually designed abutment is then digitally transferred to a CAM milling unit, where it is fabricated from the selected abutment material [31]. CAD/CAM technology allows the use of various materials such as titanium, alumina, lithium disilicate, and zirconia in the production of implant abutments [35]. Unlike prefabricated abutments, CAD/CAM-fabricated abutments enable the creation of specific maximum and minimum thicknesses where required, the establishment of a natural gingival emergence profile following soft tissue conditioning during the healing phase, and the correction of abutment angulation without compromising the material's strength [33].

8. Abutments Based on the Type of Retention

Implant-supported fixed prosthetic superstructures can be attached to implant abutments either through cementation or screw-retained systems. The selection of the retention method is influenced by factors such as interocclusal space, the condition of periodontal tissues, occlusion, esthetic demands, and economic considerations [34].

Screw-Retained Abutments

In screw-retained systems, the prosthetic superstructure is secured to the abutment with a prosthetic screw. These systems are favored in cases with limited interocclusal space (as little as 4 mm), multi-unit restorations, to prevent cement-related complications, facilitate soft tissue shaping in esthetic zones, and allow easy removal for hygiene or repairs. Abutments are typically occlusally or transversely screw-retained. In occlusal designs, the screw access is on the occlusal surface and must not disrupt occlusion. Regular monitoring is advised, as unbalanced forces may cause screw deformation [12].

Advantages of Screw-Retained Abutments:
Screw-retained abutments provide easy retrievability for managing implant–abutment complications and improve retention in cases with short clinical crowns. Their removability allows for reassessment, while the absence of a cement interface minimizes bacterial colonization, reducing risks of decementation and peri-implantitis [35].

Disadvantages of Screw-Retained Abutments:
Achieving and maintaining a passive fit for the prosthetic superstructure can be challenging, with risks of fit loss during tightening. Mechanical complications such as screw loosening or fracture are common. Esthetics may be compromised by visible screw access holes, and occlusal morphology can be affected due to screw channel placement. Limited interocclusal space and narrow occlusal tables increase the risk of porcelain fracture, particularly in posterior regions where restricted mouth opening complicates the procedure and raises the risk of accidental component swallowing [35].

Cement-Retained Abutments

Cement-retained systems are widely used in implant-supported restorations, where the prosthetic superstructure is cemented onto the abutment, similar to tooth-supported restorations. They are preferred for short-span cases, improved occlusal control, and to correct implant angulation.

The main disadvantage is the difficulty in removing excess cement, especially with deeply placed implants. Residual cement can cause biological complications such as peri-implant mucositis and peri-implantitis [36]. Wilson et al. reported residual cement in 81% of cases with peri-implant issues.

Implant depth significantly affects cement removal; *in vitro* studies show that margins placed ≥2 mm subgingivally hinder complete cement removal [37]. Thus, implant depth must be considered when choosing retention type.

A key factor for restoration success is achieving a passive fit, which reduces mechanical stress. Cement-retained systems are more likely to achieve this due to the cement layer, but cement dissolution remains a common issue, potentially leading to microleakage and biological failure [3].

Advantages of Cement-Retained Abutments:

Cement-retained restorations facilitate easier achievement of ideal occlusal morphology and emergence profile, even with suboptimally positioned implants, due to the cement space that aids passive fit. They demonstrate greater resistance to screw loosening or fracture and allow for simpler occlusal adjustments. Additionally, forces are more evenly distributed, enabling restoration of non-parallel implants with a natural tooth-like appearance.

Disadvantages of Cement-Retained Abutments:

Cement-retained restorations require cutting and replacement of the prosthesis in cases of implant or screw complications. Subgingival cement extrusion during cementation can be difficult to remove, and optimal retention demands a minimum vertical space of 7 mm between the implant and opposing dentition.

9. Types of Implant-Abutment Connection

Hex Connection: A hexagonal (hex) connection is a non-rotational, anti-rotational design that includes a positioning index on the implant platform. This feature guides the abutment into the correct orientation during placement. The internal or external hex connection helps prevent rotational movement between the abutment and implant, providing stability especially in single-unit restorations.

Non-Hex Connection: Non-hex (rotational) connections lack an anti-rotational feature such as a hexagonal indexing structure. Since these designs do not contain a positional guide, the abutment can rotate within the implant interface. They are generally used in cases where rotational stability is not a critical requirement, such as in multi-unit restorations where splinting provides additional support.

The interface that unites the implant and the abutment is referred to as the implant–abutment connection. This connection is one of the most critical elements influencing the long-term prognosis of dental implants in the oral environment [15]. It plays a vital role in preventing both biological and mechanical complications. Since the introduction of dental implants, various implant–abutment connection designs have been developed and introduced into clinical practice [38].

As the implant–abutment interface must withstand maximum and repetitive masticatory forces, as well as resist bacterial microleakage, it is considered one of the weakest points in endosseous dental implant systems [39].

The selection of an implant–abutment connection design is often based on the clinician's individual experience and preference. However, the design may influence bone remodeling around the implant after functional loading. Currently, screw-retained connection systems, in which the abutment is secured to the implant with a fixation screw, are most commonly used [40]. (Figure 4).

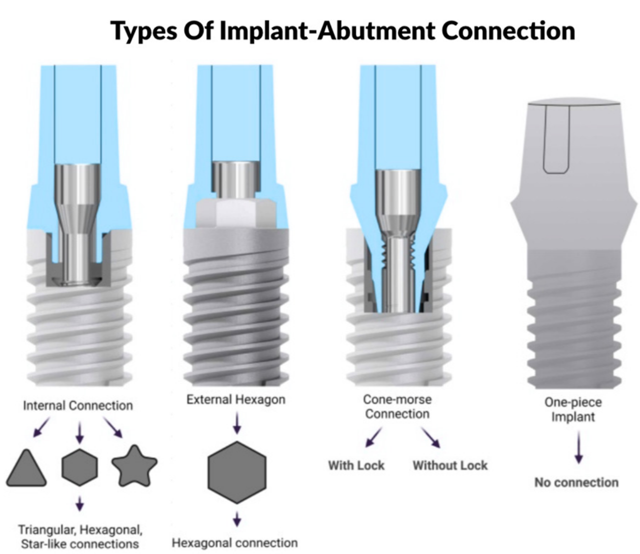

Figure 4: Types of dental implant and abutment connection.

External Connection

In external connection designs, the part of the abutment that connects to the implant surrounds the implant body from the outside. To prevent rotational movement, the implant's connection portion is designed in hexagonal or octagonal geometry. The junction between the implant and the abutment occurs above the marginal bone level [41].

Advantages of this design include the availability of long-term clinical follow-up data, compatibility with numerous implant systems, and the abundance of literature addressing potential complications due to its widespread use. It is particularly suitable for the two-stage surgical protocol originally described by Brånemark, as it facilitates the second-stage surgery and the connection of healing abutments. External connections also offer easy impression procedures, simple adjustments during the prosthetic phase, and compatibility with various prosthetic options [41].

However, this connection design has certain disadvantages, including a higher incidence of screw loosening, insufficient microbial seal, poor resistance to micromovements and lateral forces, and limited esthetic outcomes. Consequently, alternative connection designs have been developed over time to overcome these limitations [41].

Internal Connection

Although modifications made to external connection designs have helped reduce screw-loosening problems, issues related to esthetics and microbial sealing remained unresolved. Therefore, a new concept was developed—not merely by altering the existing abutment, but by redesigning the connection system entirely [35]. Internal connection designs were thus introduced to address the complications encountered with external connections and to establish a more stable implant–abutment interface [21].

In internal connections, the abutment fits within the body of the implant, rather than surrounding it externally. Today, numerous variations of internal connection geometries exist among implant manufacturers, including conical, hexagonal, and triangular designs with various angulations. Among the most widely used internal connection types are the internal hex connection and the Morse taper [21].

Compared to external designs, internal connections provide several advantages: lower rates of screw loosening, improved esthetics, enhanced microbial sealing, stronger mechanical retention, and a wider range of platform switching options [21].

- **Internal Hexagon Connection**

The internal hexagon connection was developed as an improvement over the external hexagon design, particularly to enhance load absorption under lateral forces. This design has significantly reduced mechanical and biological complications such as screw loosening, fractures, and marginal bone loss. In the internal hexagon system, the hexagonal unit extends within the implant body [42]. The increased connection depth within the implant body allows for a more homogeneous distribution of mechanical stresses. As a result, forces are not only distributed at the crestal level, but also along the implant walls and throughout the surrounding bone.

Internal hexagon connections increase the contact area between the implant and the abutment, allowing for improved load distribution and enhanced stability. This design has been shown to provide excellent functional and esthetic outcomes due to the high level of stability achieved in both the peri-implant soft and hard tissues, and its greater resistance to mechanical failure [41].

The advantages of internal hexagon systems include easier engagement between the implant and abutment, making the connection process more straightforward. This design is well-suited for one-stage implant procedures. The increased contact surface area at the implant–abutment interface provides enhanced stability and superior anti-rotational properties. Since the center of rotation is located closer to the marginal bone, the system exhibits better resistance against lateral forces. Additionally, internal hexagon connections allow for more balanced stress distribution throughout the implant structure, which reduces the risk of mechanical failure. This system can be effectively used in single-tooth restorations due to its strong connection and functional reliability [41].

The disadvantages of internal hexagon systems primarily relate to the implant's structural design. The lateral walls of the implant may become thinner near the connection region, which could compromise the implant's mechanical strength. Furthermore, correcting angulation discrepancies between adjacent implants can be more difficult with this system compared to other connection types. These limitations may pose challenges during complex restorative procedures, particularly in cases requiring precise prosthetic alignment [41].

- **Conical Connection**

In a conical connection, the male component with a tapered shape fits into a female socket with an identical taper angle. In this type of connection, the two components are mechanically locked through frictional engagement between the abutment wall and the implant. These connections may or may not include a fixation screw. However, in all cases, the stability and integrity of the conical implant–abutment assembly are primarily dependent on the friction generated between the contacting surfaces. Although it has been demonstrated that this mechanical friction provides sufficient strength, various implant manufacturers have incorporated screw-retained systems and anti-rotational features into their connection designs.

In vitro studies have shown that most conical connection systems allow for a better seating of the abutment within the implant under static forces, yet fail to eliminate the microgap entirely—even if it measures less than 10 μm. Other studies have reported minimal abutment movement and microgap formation under axial and oblique loading, while still exhibiting good resistance to torque loss and screw loosening. External and traditional internal connections have been found to be more susceptible to micromovements under rotational loads. Therefore, to minimize bacterial microleakage, conical abutments should be favored over other connection systems.

Marginal bone loss has been observed across all implant systems and surgical protocols; however, conical abutments appear to offer superior stability in both soft and hard peri-implant tissues. Although the implant–abutment connection geometry is a key factor influencing the mechanical and biological outcomes of prosthetic restorations, it cannot be considered the sole determinant. In clinical situations where the preservation of bone level is critical—such as immediate implant placement in the esthetic zone, especially in patients with a thin gingival biotype—internal conical implants should be used, particularly if zirconia abutments are selected. This is due to their superior capacity to maintain peri-implant tissue stability.

Morse taper is widely utilized in oral implantology due to the multiple advantages offered by the intimate contact between the implant and abutment. Recently, many implant manufacturers have developed systems incorporating internal conical implants. Among conical connection designs, the Morse taper is considered the most stable. It follows a "cone within a cone" concept. When two precisely manufactured cones are tightly engaged, they create stability through a "friction lock." This not only enhances the mechanical stability between the inner walls of the implant body and the abutment but also improves the sealing capability of the interface between the two components.

However, not all Morse taper connections are identical. The taper angle and the contact length of the cone vary and are determined by each manufacturer. The taper angle of a Morse connection is selected based on the mechanical properties of the materials used. For instance, titanium-based structures exhibit an optimal relationship between the contact surface angle and the coefficient of friction [41].

Another key advantage of the Morse taper connection is that the force required to disengage the components is greater than the force needed to engage them. Furthermore, the retention between components does not rely on abutment screw threads. Instead, screw threads are used merely to position the components in order to establish the Morse taper connection [21].

There is a notable reduction in the size of the microgap at the implant–abutment interface in Morse taper designs, thereby reducing biofilm accumulation. When placed at the supracrestal level, Morse taper implants are associated with a lower incidence of peri-implantitis and decreased marginal bone resorption. A biological width forms both apically and laterally relative to the lateral platform of the abutment and implant. The smaller diameter of the abutment relative to the implant body results in increased peri-implant soft tissue thickness. The Morse system also offers excellent torque stabilization between the implant and the screw. The Morse taper design minimizes micromovements during occlusal load distribution. Compared to other implant–abutment configurations, the Morse taper eliminates the need for additional screw-retention mechanisms. It enhances the preservation of peri-implant bone, stabilizes soft tissues more effectively, and is well-suited for edentulous spaces with reduced mesio-distal width. Additionally, it offers superior support for the health of surrounding hard and soft tissues [41].

10. Application of Platform Switching

Preservation of the peri-implant soft and hard tissues and ensuring their long-term stability are primary objectives in clinical implantology. Over the years, modifications in the implant–abutment connection have been explored to prevent marginal bone loss. The concept of platform switching was first introduced by Lazzara and Porter, who observed minimal vertical bone loss around implants restored with abutments of smaller diameter than the implant platform on radiographic examination. Platform switching emerged in 1991 from studies involving 5.0 mm diameter implants restored with narrower prosthetic components of 4.0 mm diameter, where minimal or no bone resorption was noted. At that time, compatible wide-diameter abutments had not yet been developed; thus, the use of narrower abutments was preferred. Clinical follow-ups reported no significant bone loss around implants employing this technique [41].

This incidental finding laid the foundation for the platform switching concept—a novel approach aimed at preventing peri-implant tissue loss. The fundamental principle of this concept involves using an abutment with a smaller diameter than the implant platform.

Recent systematic reviews have demonstrated that the platform switching approach more effectively preserves the cortical bone surrounding implants. Therefore, it is considered to offer a significant advantage in reducing marginal bone loss [41].

For successful application of this concept, the peri-implant soft tissue thickness should be approximately 3 mm. Another important indication for platform switching is the use of short implants. Since platform-switched short implants preserve peri-implant bone, they yield more favorable outcomes in cases with limited bone height, potentially avoiding the need for advanced surgical procedures.

The platform switching concept offers several biological and mechanical advantages based on the diameter discrepancy at the implant–abutment interface. This configuration limits the infiltration of inflammatory cells accumulating at the connection interface by confining them within the angled connection zone, thereby preventing the apical spread of inflammation towards the bone tissue. Additionally, the horizontal step created by the smaller diameter abutment provides an extra area for biological attachment, supporting soft tissue integration. Furthermore, this design reduces the risk of bone resorption associated with microgaps at the implant–abutment interface [41].

11. Conclusion

In the contemporary development of dental implants, abutment design plays a decisive role in the success of implant-supported prostheses. While prefabricated abutments are preferred for their cost-effectiveness and ease of use, patient-specific CAD/CAM-fabricated abutments have demonstrated superior outcomes in complex cases and where higher esthetic demands exist. These custom abutments provide optimal biological compatibility, esthetic appearance, and mechanical stability tailored to the individual patient.

Implant–abutment connection systems have also evolved. The initially used external hexagonal connections proved insufficient; hence, internal connection designs—particularly internal hexagonal and Morse taper systems—are now more widely employed. These systems reduce micro-leakage, enhance stability, and offer esthetic benefits.

In summary, the primary goal of contemporary implant-supported prosthetic design is to achieve durable and functional outcomes by optimizing esthetics, biological compatibility, and mechanical strength. In this context, abutment selection and design play a critical role in the overall success of implant therapy.

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