IMPLANT ABUTMENT CONNECTIONS: A REVIEW

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INTRODUCTION

The concept of replacing missing teeth with artificial substitutes has been a part of dentistry for centuries now. Clinical research in oral implantology has led to advancements in the biomechanical aspects of implants, implant surface features and implant componentry thus widening the applications of implant dentistry from restoration of a single tooth to multiple missing teeth with predictable success.A **dental implant abutment** is formally defined as “that portion of a dental implant that serves to support and/or retain a prosthesis”. [1]

Crest module is that portion of implant fixture that provides connection to abutment and consists of a platform & anti rotation features.[2] The success of implant not only depends on osseointegration but also on prosthetic elements. Particularly, the connection between implant and abutment is a key junction because it is the primary determinant of long term stability and strength of implants which in turn determines the final outcome of implant therapy. The implant abutment interface ensures optimal load distribution along with lateral and anti rotational stability.Currently, there are some 20 different implant/ abutment interface geometric variations available.[3]

SEARCH STRATEGY:

An electronic search was performed of articles on Medline and Ebsco from September 1983 to February 2017. Keywords, such as implant abutment interface, external hexagon implants, internal hexagon implants, morse taper implants, spline dental implants, biomechanics etc were used alone or in combination to search the database. The option of ‘related articles’ was also used. Finally, a search was performed of the references of review articles and the most relevant papers following which everything was combined.

TYPES OF IMPLANT ABUTMENT INTERFACE:

The implant abutment interface can be categorized into the following types:[4]

1. **Whether or not there exists an extension of a geometric figure above the body of the implant:**
   External Hex: There is an extension above the implant surface.
   Internal Hex: the connection is recessed into the implant body.
2. **Depending on the space between the connecting parts:**
   Slip fit: slight space exists between the connecting parts, and the connection is passive.
   Friction Fit:no space exists between the components and the parts are literally forced together
3. **Angulation between the connecting parts:**
   Butt Joint: the connecting surfaces are at 90 degrees to one another.
   Bevel Joint: The connecting surfaces are at an angle internally or externally.
4. **According to the geometrical configuration:**
   a. Octagonal,
   b. Hexagonal,
   c. Conical,
   d. Cylinder hex and
   e. Spline, etc.

EXTERNAL HEXAGON

Historical background:

The history of implant dentistry dates back to 1980s with the development of the Branemark Protocol. The original protocol was a two-stage procedure. The first stage involved the placement of a titanium screw into the bone followed by a healing period of 3 months. Stage 2 involved the exposure of the implant and attachment of a transmucosal element. Here, the implant abutment connection used was an external hexagon of 0.7mm height.[5] It was an effective torque transfer coupling device. This implant system was developed for the restoration of a completely edentulous arch with multiple implant connected to one another with a metal bar.[2]

Since then implant dentistry has evolved continuously and has expanded its usage in the restoration of one or few missing teeth, maxillofacial prosthetics. The disadvantages of the Branemark external hex make it unsuitable for these applications. The original hex was not an effective antirotaional device.[6]

Abutment screw loosening was reported in about 6%- 48% of the cases.[7] Also, dynamic micromotion was reported with external hex of height 0.7mm.[8] To overcome these complications, various implant connections have evolved from it.

Modifications of External Hex:

The external hex is now available in heights of 0.7, 0.9, 1.0 and 1.2 mm and with flat-to-flat widths of 2.0, 2.4, 2.7, 3.0, 3.3 and 3.4 mm, depending on the implant platform.[2]Also, a variety of modifications of the external hexagon, such as the tapered hexagon, external octagon and the spline dental implantare now available. [9](Fig 1, Table 1)

NEW DESIGN	FEATURES	COMPARISON WITH TRADITIONAL EXTERNAL HEX
TAPERED HEXAGON (Hex lock Innovation)	A 1.5 degree taper to the hex flat and a corresponding close- tolerance hexagonal abutment recess that is friction fitted onto the hex. It was first introduced by Swede-Vent TL (Paragon Implant Co, Encino, CA	Reduced freedom of rotation. So, less screw loosening. Due to friction fit added stability is there.
EXTERNAL OCTAGON	The external octagon is an eight-sided external implant- abutment connection. Commercially, it was first marketed as a 1-piece narrow diameter (3.3 and 3.5 mm) implant (ITI Narrow Neck) The tall, octagonal extension allowed for 45-degree rotation.	More number of positions to place the implant. Since the geometry is similar to circle less rotational resistance**.**
SPLINE DENTAL IMPLANT	The spline dental implantsystem was developed by Calcitek (Calcitek, Carlsbad, CA) in the year 1992. The implant consists of six spline teeth that project outward from the body of the implant and fit into six grooves between the projections from the corresponding abutment. The series of opposing parallel splines match integrally with the corresponding grooves of the opposite member.	Snug fit with excellent locational accuracy. Wider better than narrow**.**

Table 1: Modifications Of External Hex 4.9

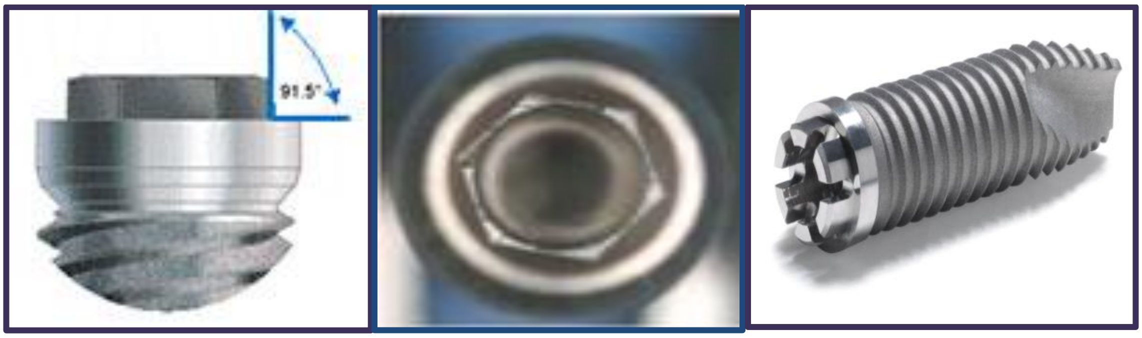


Figure 1 Tapered, octagon and spline External Hex

INTERNAL HEX CONNECTION:

Dr. Gerald A Niznick designed first form : 1.7mm deep hex below a 0.5mm wide 45 degree bevel.[10]

Advantages:

- Reduced vertical height which resulted in**Better esthetics**
- **Distribution of lateral loading** deep within the implant
- **Shielded abutment screw** that caused less abutment screw loosening
- Internal wall engagement: **less freedom of rotation**.
- Wall engagement with the implant that **buffers vibration**, the potential for a microbial seal
- Extensive flexibilty

The internal connection implants can be divided into the following groups:[4] (Figure 2)

1. Passive fit/slip fit joint

• 6-point internal hex:

– Center pulse-core vent/screw vent

– Friadent-Frialit-2

• 12-point internal hex

– 3i-osseotite certain

• 3-point internal tripod

– Alatech technologies, Camlog

– Nobel biocare/Replace select

• Internal octagon: Omniloc, Sulzer Calcitek

2. Friction fit

Locking taper/morse taper:

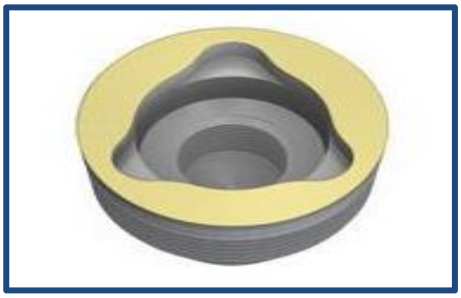
• 8 degree taper (ITI straumann, Avana, 3i TG, Ankylos)

• 11 degree taper (Astra)

• 1.5 degree tapered rounded channel (Bicon).

12 point internal hex

Internal Octagon



3 point internal tripod

Morse Taper

Figure 2: Types of internal connection

BIOMECHANICAL FACTORS AFFECTING IMPLANT ABUTMENT INTERFACE (EVIDENCE BASED DECISION MAKING)

1. STRESS DISTRIBUTION

a) Internal vs External

Chun et al [11]investigated the effect of 3 abutment types on the stress distribution in bone with inclined loads using finite element analysis. The abutment connections tested were single body, external hex and internal hex implant systems.

It was found that the internal hex implant system generated the lowest Von Mises Stresses for all loading conditions because of reduction in the bending effect by sliding in the tapered joints between the implant and the abutment.

Maeda et al [12]stated that almost the same force distribution pattern was found under vertical load in both systems.

Fixtures with external-hex showed an increase in strain at the cervical area under horizontal load, while in internal-hex fixtures the strain was at the fixture tip area.

Within limitations of the model study, it was suggested that fixtures with internal-hex showed widely spread force distribution down to the fixture tip compared with external hex ones.

Balik et al[13]investigated the strain distributions in 5 different implant-abutment connection systems under similar loading conditions. External hexagonal connection showed the highest strain values, and the internal hexagonal implant-abutment connection system showed the lowest strain values.

b) Internal connections Comparison

Saidin et al [14]analysed stress distribution at the connections of implants and four types of abutments: internal hexagonal, internal octagonal, internal conical and trilobe.

The internal hexagonal and octagonal abutments produced similar patterns of micromotion and stress distribution due to their regular polygonal design. The internal conical abutment produced the highest magnitude of micromotion, whereas the trilobe connection showed the lowest magnitude of micromotion due to its polygonal profile.

c) Conical vs Butt joints

Merz and Hunenbart[15]studies that conical abutment connections were superior mechanically and helped to explain their significantly better long-term stability in clinical applications.

Norton et al[16] stated that with respect to strength characteristics between conical and external hex butt joints, the conical joint is approximately 60% stronger.**Hansson**[17]found that the peak bone-implant interfacial shear stresses generated by the conical implant-abutment interface were less than those produced by the flat-top interface. The implant with the conical interface can resist a larger axial load than the implant with the flat-top interface.

Sutter et al [18] had shown that the conical angled design could reduce screw loosening by creating a friction lock. In addition, they found that the screw rotation is minimal in the morse taper integrated screwed-in thread abutment system when compared with the external hexagonal connection.

Levine et al [19]demonstrated that the external hexagonal connection system is more susceptible to screw loss than the solid conical abutment connection.

2) FATIGUE RESISTANCE

The design of the implant-to-abutment mating surface and the retentive properties of the screw joints affect the mechanical resistance of the implant-abutment complex.Fatigue is a progressive, localized and permanent structural damage that occurs in a material subjected to repeated or fluctuating strains.

Steinebrunner [20]concluded that implant systems with long internal tube-in-tube connections and cam–slot fixation showed advantages with regard to longevity and fracture strength compared with systems with shorter internal or external connection designs.

Rebeiro et al[21]evaluated fatigue resistance of 3 implant-abutment connections (external hexagon, internal hexagon and cone- in-cone) analyzing the prosthetic screw and determined their failure modes. The external hexagon interface presented better than the cone-in-cone and internal hexagon interfaces. There was no significant difference between the cone- in-cone and internal hex interfaces.

Khraisat et al[22]concluded that the fatigue strength and failure mode of the ITI system were significantly better ($P > .001$) than the Brånemark system.

3) CRESTAL BONE LOSS

The literature indicates that type of implant abutment connection influences the stresses and strains induced in peri implant crestal bone.

M.I. Lin et al[23] conducted a study which showed that the crestal bone change in 1st 6 months after loading were all within the success criteria proposed by **Albrektsson et al**[24]i. e. bone loss< 1.5mm in the first year. The mean changes were less than 1mm in first year for all implants.Crestal bone loss did not differ significantly. Slightly greater—60% for external hex and 52% for both internal octagon and internal Morse taper—during the healing phase (before occlusal loading) than during loading phases 1 and 2 (3 and 6 months after occlusal loading, respectively).

4) MICROLEAKAGE

Microgaps between the implant–abutment interface may cause microbial leakage. Bacterial leakage along the gaps and cavities as a consequence of poor adaptation of components in the two-part dental implants has been reported and suggested as a possible etiology of implant failure.

F.Gil et al[25]concluded that the external connection showed more microleakage (Micro gap of 1.22 microns) than the internal connections (micro gap of 0.97 microns).

Steinebrunner [26]evaluated microbial leakage in 5 different types of implants. Branemark, Frialit-2, Camlog, Replace Select, Screw Vent.All specimens showed bacterial leakage.

S. Harder et al[27]investigated the tightness against endotoxins of 2 implant systems(Astra Tech and Ankylos) On an average Astra implants showed a higher tightness than Ankylos implants.

Nascimento et al[28] concluded that Morse cone–connection implants showed the lowest bacterial counts when compared with internal and external connection implants under both loaded and unloaded conditions, with no significant differences between them.

5) PLATFORM SWITCHING

The nature of saucerization varies according to implant type (one-stage or two-stage) and abutment connection type. PLS refers to the use of a smaller diameter abutment on a larger diameter implant collar. This type of connection shifts the perimeter of the implant—abutment junction (IAJ) inward toward the central axis of the implant. **Lazzara and Porter**[29]reported that a concept of platform switching could bring the inflammatory cells infiltration, which would reduce the peri-implant crestal bone change. It requires that the abutment –implant microgap be placed away from the implant shoulder and closer toward the axis thus mesializing the inflammatory zone away from the crestal bone.Subsequent studies have supported the advantages of platform- switching designs.

6) EFFECT OF ABUTMENT MATERIAL

Earlier the abutments were made of titanium until the recent introduction of ceramic abutments. The problems with titanium abutments are the micro gap, consecutive fatigue and wear at the interface.

Yuzugullu et al[30]assessed the implant-abutment interfaces after the dynamic loading of titanium, alumina, and zirconia abutments. After the dynamic loading, there was no significant difference between the aluminum oxide, zirconium oxide, and titanium abutment groups regarding the micro gap.

Another study by **Yuong Jo et al**[31]evaluated the influence of abutment materials on the stability of the implant-abutment joint in internal conical connection type implant systems using abutments fabricated with commercially pure grade 3 titanium (group T3), commercially pure grade 4 titanium (group T4), or Ti-6Al-4V (group TA). Provided that biological risks can be excluded, it would be recommendable to use abutment materials with high strength and low frictional coefficients to improve the mechanical stability of the implant-abutment interface.

MORSE TAPER CONNECTIONS:

Mangano et al [32]studied the survival rate and clinical, radiographic and prosthetic success of 1,920 Morse taper connection implants: results after 4 years of functional loading

Success Rate	96.61%
Survival rate	97.56%
Prosthetic complications	0.65%

DISCUSSION

Dental implants have been widely accepted as a predictable and reliable tool for dental rehabilitation ranging from replacement of a single tooth to complete dentition. This calls for a detailed study of implant biomechanics in which implant abutment connection plays a crucial role. It is the primary determinant of strength and stability of an implant-supported prosthesis, which in turn dictates the success rate of implants.The implant abutment connection can be either an internal or external. The distinctive factor that separates the two groups is the presence or absence of a geometric feature that extends above the coronal surface of the implant.

The foundation of implant dentistry dates to the formulation of the Brånemark Protocol in the United States in the 1980s. Since then, implant dentistry has evolved continuously. The original design was an external hexagon connection of 0.7mm in height. However it was not an effective anti rotational device and could not withstand occlusal forces. This has led to the evolution of new designs like internal hexagon, internal octagon, conical etc. to improve the joint stability, which is one of the most important goals in implant therapy.

Several implant–abutment connection designs are now available, and the clinician faces the challenge of choosing an appropriate implant system and connection design. This literature review discusses the evolution of various implant–abutment connections, from the traditional external hexagonal implant to Morse taper implants, to provide the clinician with an overview of commercially available implant–abutment connections.

CONCLUSION

The implant–abutment interface determines the lateral and rotational stability of the implant-abutment joint, which in turn determines the prosthetic stability of the implant- supported restoration. Internal connections have better prosthesis retention and consequently higher stability, which decrease the stress on the cervical region of the implants and retention screws. Conical implant–abutment interface in combination with retention elements at the implant neck reduce the amount of micromotion. All types of prosthetic platforms can provide high success rate of the implant treatment by following a strict criteria of their indication and limitation. Therefore, a reverse planning of implant treatment is strongly indicated to reduce implant overload.

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