

The Evolution of External and Internal Implant–Abutment Connections: A Review

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Abstract

Key Words

Implant–abutment interface, external hexagon, internal hexagon, spline dental implant, morse taper implant.

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A study of the implant–abutment connection is of great importance because it is the primary determinant of the strength and stability of an implant-supported restoration, which, in turn, determines the restoration's prosthetic stability. Traditionally, Brånemark's external hexagon has been used, but significant complications, such as abutment screw loosening, rotational misfit at the implant–abutment interface, and microbial penetration have led to modification of the external hexagon and the development of internal implant–abutment connections. In this review, we describe various implant–abutment connections that have evolved over time from the traditional external hexagon.

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Introduction

The foundation of implant dentistry dates to the establishment of the Brånemark Protocol in the United States in the 1980s. Since then, implant dentistry has evolved continuously from the original protocol to include various techniques and applications (1,2). This evolution has been possible because numerous investigators have documented biological factors, surgical procedures, and restorative principles that influence the outcome of implant restorations, widening the application of implant dentistry from the restoration of a single tooth to the replacement of multiple missing teeth with predictable success (3,4). The mechanical principles governing implant restorations have also been defined clearly and are well understood (5,6). Improvement in restorative principles and better understanding of the perceived outcome of implant therapy have led to the development of the concept of restoration-driven implant dentistry (7).

The original Brånemark Protocol involved a two-stage surgical procedure and was designed to

restore a completely edentulous mandibular arch (8). The first step involved the placement of a titanium screw into viable bone, followed by an undisturbed healing period of at least 3 months. The next step involved exposure of the implant, attachment of a transmucosal element, and the connection of the implant to the prosthetic component of the restoration. In this protocol, the implant–abutment interface was an external hexagon with a 0.7-mm height that served as a torque transfer coupling device (fixture mount) during the initial placement of the implant into the bone and the subsequent connection of the transmucosal extension, which, when performed in sequence, could effectively restore a completely edentulous arch. Although the external hexagon served these purposes, it was not an effective anti-rotation device (9) and was not designed to withstand intraoral forces directed at the crowns (10). These properties are required when implants are used to restore partially edentulous arches or a

single missing tooth. Thus, implant manufacturers compensated for these limitations by changing the type of screw used (e.g. with regard to its geometry, height, and surface area), the precision of the fit over the hexagon, and the amount of torque used to secure the screw (11-13).

To overcome the inherent deficiencies of the external hexagon, a variety of implant–abutment connections have also been derived from the original design. The goals of new designs have been to improve connection stability throughout the placement and functional periods, and to simplify the armamentarium necessary for the clinician to complete the restoration. The implant–abutment interface determines joint strength and lateral and rotational stability (14), and joint stability is one of the most important parameters affecting the success of 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, with the aim of providing the clinician with an overview of commercially available implant–abutment connections.

Search strategy

The MEDLINE database was searched to identify relevant articles published between 1980 and 2011. Key words such as 'implant–abutment interface', 'external hexagon implant', 'internal hexagon implant', and 'Morse taper implant' were used alone and in combination to search the database. The 'related articles' option was also used. The reference lists of review articles and the most relevant papers were also searched. This electronic search was supplemented by manual searches of journals relevant to the field of implant dentistry, such as the *International Journal of Oral and Maxillofacial Implants*, the *Journal of Oral Implantology*, and *Clinical Oral Implants and Related Research*.

The implant–abutment interface

Implant–abutment connections may be internal or external; external connections feature a distinct projection external to the implant body (Fig. 1), whereas internal connections are recessed into the implant body (Fig. 2).

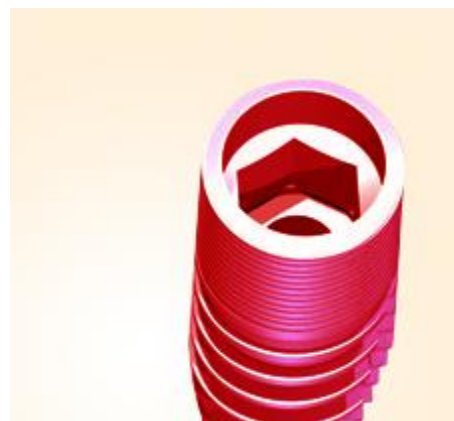


Figure 1. An external implant–abutment connection

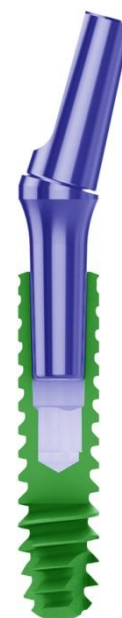


Figure 2. An internal implant–abutment connection

The connection can be characterised further as a slip-fit joint, where a slight space exists between the mating parts and the connection is passive, or as a friction-fit joint, where no space exists between the mating components and the parts are literally forced together.

The contact between mating surfaces is characterised further as a butt joint, which consists of two flat surfaces contacting one another at a right angle, or a bevel joint, where the surfaces are angled internally or externally. The joined surfaces may also incorporate a rotational resistance and indexing feature and/or lateral stabilising geometry. This geometry is further described as octagonal, hexagonal, conical, cylindrical hexagonal, or spline.

External implant–abutment connections

Brånemark's original implant–abutment connection was an external hexagon with a 0.7-mm height that acted as a coupler and torque transfer device. The original Brånemark Protocol was developed for the restoration of completely edentulous arches using a series of implants connected by a metal bar.⁸

The applications of implant dentistry have expanded from the original restoration of completely edentulous arches to the use of fixed partial dentures, single-tooth replacement, maxillofacial restoration, and a myriad of other applications limited only by the clinician's ingenuity and skill (15,16). Significant clinical complications of Brånemark's external hexagonal connection (9,17,18) make it unsuitable for these applications. Thus, the external hexagon has evolved, by necessity, into a prosthetic indexing and anti-rotational mechanism.

Since its introduction by Brånemark, the external hexagon has undergone a number of modifications and is now available in heights of 0.7, 0.9, 1.0, and 1.2 mm and with flat–flat widths of 2.0, 2.4, 2.7, 3.0, 3.3, and 3.4 mm, depending on the implant platform (8). Tapered hexagons, external octagons, and spline dental implants (19) are also now available.

Tapered hexagon

This design was developed with the aim of improving the fit between the implant and abutment by incorporating a 1.5° taper to the flat surface of the hexagon and a corresponding close-tolerance hexagonal abutment recess that is friction-fitted onto the hexagon. It was first introduced as the Swede-Vent TL by Paragon Implant Company (Encino, CA, USA). The manufacturer claimed that it greatly reduced the rotational freedom between the implant and the abutment, thereby reducing the incidence of screw loosening.

External octagon

The external octagonal implant–abutment connection was first marketed commercially as a one-piece implant with a narrow diameter (3.3 or 3.5-mm; ITI Narrow Neck; designed to replace the mandibular anterior teeth. The tall, octagonal extension allowed for 45° rotation. The manufacturer claimed that the implant had good lateral and rotational resistance and strength, but no relevant study supporting these claims is available.

Spline dental implant

The spline dental implant (19) system was developed in 1992 by Calcitek (Carlsbad, CA, USA). Six spline teeth project outward from the implant body and fit into six grooves between the projections from the corresponding abutment, providing a 'snug' fit between the implant and abutment and excellent locational accuracy.

Internal implant–abutment connections

Internal implant–abutment connections were developed to overcome the clinical complications associated with external connections (9,17,18). The goals of the new designs were to improve connection stability throughout the placement and functional periods, and to simplify the armamentarium necessary for the clinician to complete the restoration. One of the first internal hexagonal implants, the Core-Vent implant developed by Niznick in 1986, featured a 1.7-mm-deep hexagon below a 0.5-mm-wide 45° bevel (20,21). The design was demonstrated to distribute intraoral forces deep within the implant, thereby improving implant–abutment joint stability (20,21).

Internal connection implants can be subdivided into the following groups for the purpose of explanation.

Passive fit/slip-fit joint (space exists between mating components)

- 1) Six-point internal hexagon
 - a) Core-Vent, / Screw vent, Centerpulse Dental Inc.
 - b) Frialit-2, Dentsply Friadent
- 2) 12-point internal hexagon
 - a) Osseotite CERTAIN, 3i Implant Innovations, Inc.

3) Internal tripod

- a) CAMLOG, Altatec Technologies
- b) Replace Select, Nobel Biocare

4) Internal octagon

- a) Omniloc, Sulzer Calcitek Inc.

Friction fit (no space between mating components)

- 5) Locking taper/Morse taper
 - a) 8° taper (ITI Straumann, Avana, 3i TG, Ankylos)
 - b) 11° taper (Astra)
 - c) 1.5° tapered rounded channel (Bicon).

Six-point internal hexagon

This design is the most common type of commercially available internal implant–abutment connection. It consists of a hexagon recessed into the body of the implant. Because the internal geometry is hexagonal, the abutment can fit over the implant at every 60° of rotation, but not at an intermediate angle. Thus, abutment positioning is possible at six different implant positions.

This type of implant–abutment connection is available commercially from several manufacturers. Centerpulse Dental Inc. offers screw-vent implants with a 1.2-mm-long internal connection. This tapered implant has evolved from the original core-vent implant and has a hollow basket design. The manufacturer claims that this new design simplifies insertion and increases initial stability in soft bone when used according to a patented surgical protocol, in which the tapered implant is inserted into a straight socket.

An internal hexagonal connection (Frialit-2) is also available commercially from Dentsply Friadent. The manufacturers claim that the Frialit-2 system combines the advantages of a cylindrical implant and an internal connection. The cylindrical connection is claimed to provide lateral load resistance, resistance to joint opening, protection of the abutment screw, and high strength, and the internal hexagonal connection is claimed to provide 60° indexing and rotational resistance.

12-point internal hexagon

The 12-point internal hexagonal design, also marketed by some manufacturers as an offset hexagonal design, provides the greatest freedom during abutment placement over the implant. The 12-point double internal hexagon provides an opportunity to place the abutment on the implant at every 30° of rotation, and is thus useful when using angled abutments. It provides a greater opportunity to correct off-axis angulation of the abutment with respect to the implant. One such implant, the Osseotite CERTAIN, is marketed by 3i Implant Innovations, Inc., (Palm Beach Gardens, FL, USA).

Internal tripod

This type of implant–abutment connection has a triangular internal geometry. A major disadvantage of this system is that it allows for abutment positioning over the implant only at 120° of rotation. This type of implant–abutment connection was introduced by Nobel Biocare as the Replace Select tri-channel implant system. It is available in four diameters (3.5, 4.3, 5, and 6 mm) and is colour-coded for ease of identification. It is

claimed to provide a precise fit of the abutment over the implant and to have excellent lateral stability.

The CAMLOG implant system (Altatec Technologies), is an internal tripod implant–abutment connection. The length of the internal connection is 5.4 mm. It is claimed to have a 'tube in tube effect' that provides an accurate, mechanically secure implant–abutment connection with anti-rotational stability.

Internal octagon

The internal octagonal implant system allows for implant positioning over the abutment at every 45° of rotation. The internal octagonal connection was introduced as the Omniloc system by Sulzer Calcitek Inc.. The octagonal connection has thin walls, a 0–6-mm length, and a small diameter that create a geometric profile similar to that of a circle, offering minimal rotational and lateral resistance during function. Because of these disadvantages, it is no longer marketed.

Friction fit (Morse taper implants)

The Morse taper implant–abutment connection features a tapered projection from the abutment that fits into a tapered recess in the implant (Fig. 3). The implant–abutment interface is formed by a cold-welded friction-fit joint, which is necessary to eliminate rotation at the implant–abutment interface and subsequent abutment screw loosening (6).



Figure 3. A Morse taper implant–abutment connection

The original concept of the Morse taper implant included two tapers (2° and 4°) and was designed to provide a precise fit without self-locking threads.

8° Morse taper implants

In dentistry, the concept of the Morse taper or cone-screw tapered connection was first used by the ITI group (Switzerland) (22). The rationale was that a tapered connection would yield a mechanically stable, sound, and self-locking interface. It basically creates a friction lock similar to the Morse taper used generally in mechanical engineering and related industries.

A further modification of the ITI-Straumann implant design is the Synocta design. Although the original implant design allowed for a precise fit between the implant and the abutment, it did not allow for rotation of the abutment over the implant or fit at a different angulation. Wiskott & Belser supplemented the Morse taper connection by introducing an internal hexagon at its centre, thereby enabling abutment repositioning and the precise transfer of the implant position to the master cast. As a result, only one transfer system and one analogue are required.

A new implant introduced by Osteo-Ti known as the Combi implant, has a mechanism for accurate positioning and friction fit similar to that of the Synocta design, and combines the features of an internal hexagonal implant and a Morse taper implant. Other manufacturers marketing 8° Morse taper implants are Avana, 3i TG, and Ankylos.

11.5° Morse taper implant

This implant is marketed by Astra Tech. The fixture and abutment are strongly connected at an 11.5° angle by a conical seal design, which seals the connection and decreases micro-movement and microleakage. The implant has a micro-threaded conical neck and a TiO₂-blasted surface. Microthreads on the fixture top prevent the concentration of stress around the alveolar ridge crest and reduce marginal bone loss.

1.5° Morse taper implant

This true Morse taper implant is available from Bicon Implants. The Bicon locking taper abutment has no screw, but like a screw-retained abutment, it relies on friction to keep it intact. Assembly is achieved by driving the 1.5° Morse taper into the matching socket in the implant, which generates a high clamping force between abutment and implant. The high friction force is the result of relative slip between the two friction surfaces occurring at high contact pressure. This results in the breakdown of

surface oxide layers, causing cold welding at the implant–abutment interface.

Discussion

This review describes changes in implant–abutment connections, from Brånemark's 0.7-mm-high traditional external hexagon and its various modifications to the development of Morse taper implant–abutment connections. The external hexagonal connection, which served as a coupling and torque transfer device in Brånemark's Protocol, was adequate to restore a completely edentulous arch with a series of implants connected by a metal bar⁶. With better understanding of the concept of osseointegration and the development and refinement of surgical protocols in implant dentistry, the horizons of implant dentistry applications have broadened.

Dental implants are now used in a myriad of applications, from the restoration of a completely or partially edentulous arch to single tooth replacement and the use of fixed bridges (18,19). With these ever-increasing applications, the requirements of implant–abutment connections have also increased; they must now serve anti-rotational and prosthetic indexing functions⁸. These functions are most important in the restoration of single posterior teeth by implants because they are the most difficult to retain (23).

Thus, Brånemark's external hexagonal implant–abutment connection required modification to prevent complications, such as abutment screw loosening and fracture, which occurred commonly when the external hexagon was used in single-tooth implant restorations. Various manufacturers have developed design modifications, including the increased height and flat–flat width of the mating surfaces of the implant–abutment connection (8). The tapered hexagon and spline dental implant (19) have also been developed in attempts to overcome the limitations of Brånemark's external hexagon.

The search for a new implant–abutment connection design that overcomes the limitations of the external hexagon has resulted in the development of the internal hexagonal design, which has been modified further into the internal tripod, 12-point internal hexagon, and internal octagon. The basic clinical significance of these various implant–abutment connections is the freedom of abutment positioning over the implant, which is maximal for the 12-point internal hexagon and minimal for the internal tripod.

This review describes various commercially available implant–abutment connections, highlights the manufacturers' claims, and supports them with

published data, where available. With this review, we aim to help the clinician to make an informed decision as to which implant system and implant–abutment interface to use.

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. This review describes the evolution of various implant–abutment connections and seeks to inform the clinician regarding the various characteristics associated with external and internal designs. It also enlightens the clinician about the clinical applications of contemporary implant designs.

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