

Biomechanical study of prosthetic interfaces: A literature review

Abstract / Implantology has improved its biological and mechanical characteristics. However, the big challenge nowadays is to offer esthetic rehabilitation treatment that is durable and, at the same time, enables maintenance of the surrounding structures, such as bone and mucosa, where this balance depends on several factors, including the type of prosthetic interface. The first implants were developed by superimposing external hexagonal interface, however, several reports have described clinical complications that resulted in loosening of screws, as well as fractures of implants and prosthetic components. To reduce these failures, mechanical connections — hexagonal, triangular, octagonal or conical — were developed with internal fitting. With the advent and the several options of prosthetic interfaces available for rehabilitation planning, greater knowledge about their biomechanical characteristics and longevity is required.

Keywords / Dental implants. Biomechanics. Prosthesis failure.

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INTRODUCTION

One of the major challenges of present Implantology is to obtain an implant-prosthesis connection system that meets biomechanical and esthetic needs, that is easy to handle, resists masticatory functional loads and has acceptable clinical performance. Due to the wide variety of implants and prosthetic interfaces, it is up to the clinician to choose the most suitable according to each treatment plan, taking into account the biomechanical characteristics of the dental implant system, his experience, personal preference and final costs to the patient.

After osseointegration of the implant, the prosthetic connection of choice is responsible for stabilizing the prosthesis and such stabilization is, in turn, responsible for implant and prosthetic treatment longevity.¹ The design of the prosthetic implant platform should: (1) facilitate the physiologic development of the gingival contour and, as a result, yield a natural look for the prosthetic crowns; (2) achieve acceptable final aesthetic results; (3) have clinical longevity; and (4) promote functional restorations that resemble natural teeth.²

Biological, aesthetic, functional and mechanical factors are among the risk factors involved in osseointegrating implants. Biological failures are complications that can lead to lack of osseointegration of implants and inflammation of the peri-implant mucosa. Non-osseointegration results in peri-implant mobility, pain and/or bone loss of multifactorial etiology. It may be a result of bacterial contamination, poor bone quality or quantity, traumatic surgery, excessive forces on the implant during osseointegration, among others. Inflammation of the mucosa surrounding the dental implants can result in mucositis and peri-implantitis. Mucositis occurs due to poor control of peri-implant plaque and when there is bone loss associated with pathogenic flora, a condition known as peri-implantitis.³ Functional failures are associated with phonation and lingual position, when the air passage between teeth /denture can create phonetic difficulties and implant-supported prostheses in the mandible or maxilla with infrastructure involving the tongue space can lead to discomfort.⁴

Determining the etiology of implant and prosthetic components fracture as well as their treatment

can be complex. The causes are divided into three categories:⁵ (1) defects in implant design or material; (2) prostheses without passive fit and (3) physiological or pathological masticatory overload. In implants with an external prosthetic interface, the screw often loosens before failures occur in the retention system, moreover, angular bone loss is frequently observed around the fractured implant. Mechanical failures have been associated with instability of the implant /prosthesis junction where, according to some authors, biomechanical complications may shorten the life of implant-supported prosthesis and dental implants. Most of these complications are observed in single restorations both in the anterior and posterior region.^{1,6} In this context, this literature review discusses the biomechanical characteristics of dental implants using external and internal prosthetic interfaces.

LITERATURE REVIEW

Implant with external prosthetic interface

In early 60's, Per-Ingvar Brånemark and colleagues began to develop a system of endosseous dental implant of which function and clinical longevity depended on "direct" anchorage to the bone known as osseointegration.⁷ This type of implant, from which the current dental implant systems derive, have two main components: an implant of cylindrical or conical shape made of commercially pure titanium, and a prosthetic component that supports the prosthesis. Over the years, rehabilitation with endosseous dental implants became a safe and fairly predictable treatment modality for partially or fully edentulous patients. The use of implant systems with external hexagon connections became popular and widely used in Implantology, perhaps, for being the precursor system of osseointegration and the most widespread type of implant, making it popular among dentists (Fig 1).

The following are among the advantages of this type of interface: the possibility of performing treatment at two surgical stages; the presence of an anti-rotational mechanism; reversibility and, especially, compatibility of insertion platforms of different brands. The main disadvantages include micro-movements due to the low height of the hexagon, or loosening or fracture of the

prosthetic screw (Fig 2); space between the implant and abutment enabling the percolation of fluid of microorganisms which, in turn, causes bone resorption around the cervical region of the implant (Fig 3). Clinical studies^{5,8-11} found that 30.7% to 49% of prosthetic screws tend to loosen in external interface implants.

Implant of internal prosthetic interface

With the advent of internal prosthetic interfaces (hexagonal, triangular, octagonal and cone-screw), there was a better fit between connectors as a result of the interposition between the prosthetic abutment and the implant, which offers greater stability and anti-rotational effect. Additionally, increased strength

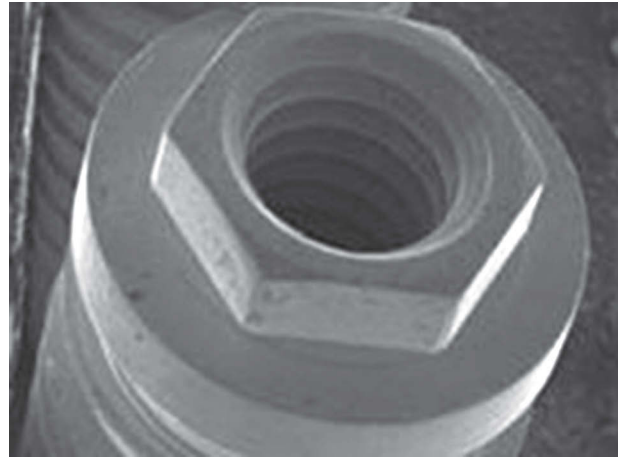


Figure 1: External hexagonal implant interface.

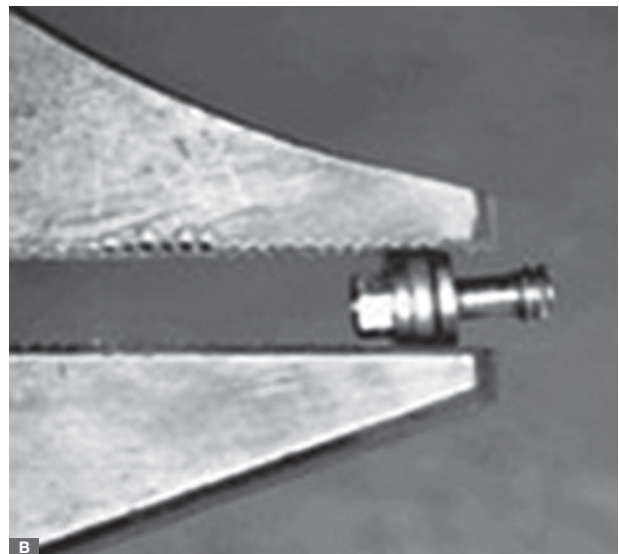
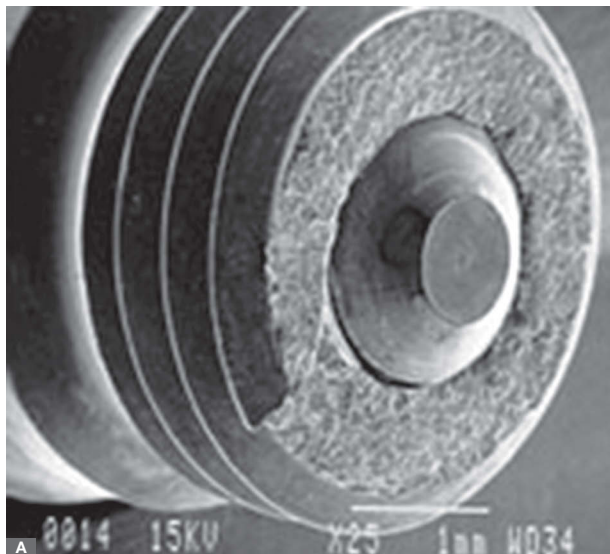


Figure 2: Implant fracture (A) and prosthetic abutment (B) (Source: Balshi,⁵ 1996).

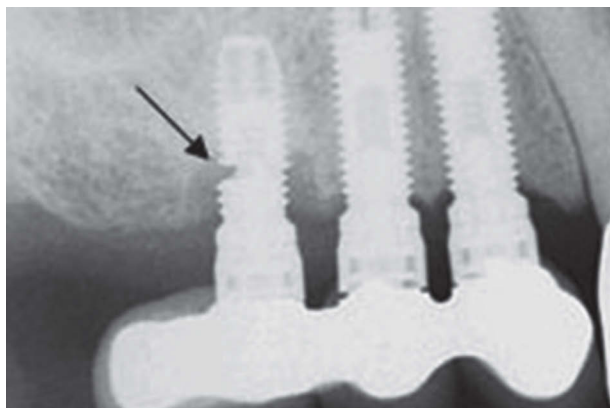


Figure 3: Bone loss around the implant platform and implant fracture (Source: Balshi,⁵ 1996).

and distribution of occlusal loads were also observed, making them more suitable for single restorations than external connections. The following are considered as disadvantages of implants of internal prosthetic interface: fragility of implant walls; difficulties in adjusting angle divergence between implants at the time of rehabilitation; and prosthetic screw loosening on the internal hexagonal connections^{4,12,13,14} (Fig 4).

The Morse Taper internal interface is based on the mechanical principle of “cone in a cone”, which provides great contact friction between the surfaces and is often used in Engineering and Health Sciences. This connection system was developed by Stephen Ambrose Morse in 1864. The Morse Taper system was introduced in Implantology in 1985 by Thomas D. Driskell, by the Bicon™ Company in the United States. Some authors^{15,16} have studied its biomechanical behavior. The prosthetic component / implant junction is achieved by means of a compressive force that is applied to the abutment, intruding it into the implant where stability of the whole system is achieved by friction, also known as a cold weld (a mechanical property defined as an increase in the loosening torque in relation to the tightening torque).

Since 1997, the Brazilian Technical Standards Association (ABNT) regulates connections and mechanical equipment, including those using the Morse Taper system, under Normative Instruction 1119 which states that to be considered a Morse Taper, the sum of the internal angles of the components must be less than 3.014° of divergence.¹⁷ Thus, the system of conical dental implants presenting prosthetic interface angles smaller than 3.014° are considered “real” Morse Taper systems which do not use screws to support the prosthetic retention (Fig 5). Conical prosthetic interface implants with angulation greater than 3.014° are considered cone-screw, as they need a screw for prosthesis retention^{17,18} (Fig 6).

Morse Taper implant systems are known as self-locking because they use exclusively frictional retention to give stability and prosthetic retention. They are represented by Bicon Dental Implants System™ (Boston, USA); Leone™ (Italy); Mac™ (Italy), Axiom™ (France) and Sistema Friccional Biológico KOPP® (Curitiba, Brazil), with the latter having 2.54° conicity between its walls and the inner cone with 3 mm in length, both of which lead to the retention frictional effect of the prosthetic component (Fig 7).



Figure 4: Internal hexagonal implant interface (Source: Kim et al,¹⁴ 2011).

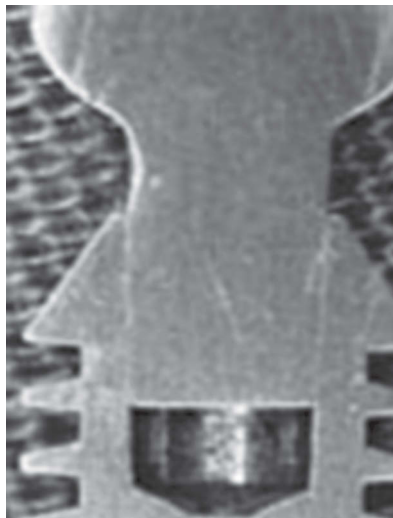


Figure 5: Implant of conical prosthetic interface – Morse Taper (Source: Urdaneta and Marincola,¹⁶ 2007).

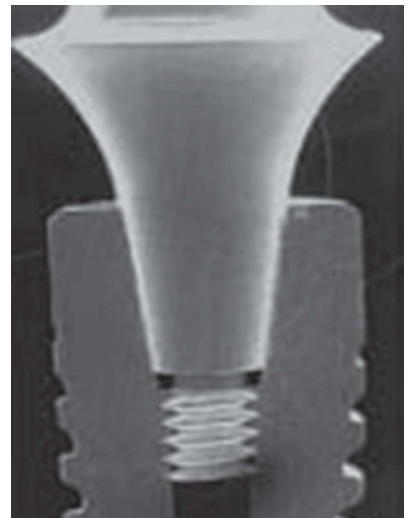


Figure 6: Implant of conical prosthetic interface – cone-screw (Source: Nentwig,¹¹ 2004).

The systems of internal conical connection, cone-screw and Morse Taper have shown better clinical performance. These interfaces favor the positioning of the abutments, offer greater stability and anti-rotational effect, provide greater strength and distribution of occlusal loads. Several authors^{2,14,19,20,21} assessed cone-screw implants and concluded that loosening was between 3.6% to 14%. Little attention has been given to the Morse Taper system in relation to other types of connections.

However, among the studies carried out to investigate the topic, most of them report resistance to loosening of prosthetic components,²²⁻²⁵ transmission of micro-movements of the implant / abutment connection in trials with finite elements and clinical studies covering mechanical complications.^{16,26,27} Table 1 presents some prospective and retrospective clinical studies assessing the duration of single prosthetic rehabilitation using external interfaces, cone-screw and Morse Taper implants.



Figure 7: Trademarks of implants of conical prosthetic interface - Morse Taper.

Table 1: Comparison of clinical studies focusing on dental implants with external/internal prosthetic interfaces: cone-screw and Morse Taper.

References	Study	Implant system	Interface	Follow-up (years)	Success/Duration	Screw/abutment loosening
Jemt ⁹	R	Brånemark	EH	1	98.1%	30.7%
Jemt et al ¹⁰	R	Brånemark	EH	1	98.6%	20.8% a 49%
Levine et al ¹⁹	R	ITI	CS	0.5	97.7%	3.6% a 8.7%
Brägger et al ²⁰	R	ITI	CS	4 to 5	-	6.8%
Mericske-Stern et al ²¹	R	ITI	CS	8	99.1%	14%
Muftu, Chapman ²⁷	P	Bicon	MT	4	93.51%	0.74%
Mangano, Bartolucci ²⁶	P	Mac	MT	3.5	-	1.25%
Mangano et al ²³	P	Leone	MT	1 to 4	98.4%	0.66%
Mangano et al ²⁴	P	Leone	MT	6	97.5 a 99.5%	0.37%
Mangano et al ²⁵	P	Leone	MT	5	98%	0%

(EH = external hexagon; CS= cone-screw; MT = Morse Taper); Study (R = retrospective and P = prospective).

Morse Taper implants have some advantages: simple prosthesis fabrication technique, as a result of the absence of a screw connecting the implant to the prosthetic system; a prosthetic component (solid pin) that can be customized and prepared as if it were a tooth ready to receive a conventional cemented prosthesis or an aesthetic material, making it a crown-pin-anchored prosthesis.^{16,28} The cervical profile of the prosthetic component is smaller than the implant platform (switching), which allows the prosthetic emergence profile to be customized similarly to the dental element, thus providing better gingival aesthetic on the emergence profile of the prosthesis.²⁹ According to some authors,²⁹ the major biomechanical advantage of implants with platform switching configuration in dental implants include reduced stress at the cervical level of the implant, which results in better distribution of masticatory forces to the bone tissue. A prospective study²⁸ assessed bone crest height around dental implants with platform switching, and revealed significantly less bone loss when compared to implants of standard configuration, characterizing less bone remodeling on the implants (Fig 8).

Other authors³⁰ evidenced a decrease in the infiltration of microorganisms in the implant-abutment interface, which reduces unpleasant odor and potential bone remodeling around the implant platform. Although masticatory forces generate occlusal movements of flexion and traction, which may negatively influence the retention of the



Figure 8: Bone remodeling around EH implant (arrow) and less bone remodeling with platform switching (Source: Fickl et al,³¹ 2010).

abutment, the occlusal compressive force acts in the direction of insertion of the prosthetic abutment, favoring self-activation in conical interface implants.¹²

DISCUSSION

Unscrewing and fracturing of prosthetic components are generally attributed to occlusal overload and malpositioned prosthetic abutments, with most of these complications being found in the systems with external connection. The internal conical connection system has a lower incidence of these problems, since they are based in an implant/abutment junction with pressure within the implants, which gives them the status of a more secure connection.¹³

Wear, loosening and fracture of prosthetic screws are the most frequent mechanical failure of implant-supported prostheses of external prosthetic interface. Loosening of screws can vary from 30.7% to 49% in maxillary or mandibular dentures, being more significant in the maxilla.^{9,10} Most patients have prosthetic screws loosened before the occurrence of fracture.⁵ Other authors⁸ report that the length of the external hexagon may influence the strength and stability of the implant connector interface. Thus, external hexagon of greater length showed better resistance to mechanical stress and improved mechanical stability of dental implants.

In a retrospective study¹⁹ where 174 ITI cone-screw implants were installed (Straumann™) for single reconstruction of teeth, it was found an incidence of 8.7% in loosening of prosthetic screws and only 3.6% of occurrence in loosening of conical solid abutments. Another study¹¹ assessed the installation of 5439 Ankylos cone-screw implants (Friadent™) and revealed that 943 implants were inserted in areas of single tooth loss. About six years later, during post-treatment follow-up, there were 13 cases of failure, and a success rate of 98.7%. In a follow-up clinical study investigating 233 single dental implants with Ankylos cone-screw prosthetic interface (Friadent™) and a 5-year control, loosening was observed in 1.3% of abutments.²

Some authors¹⁶ conducted clinical evaluations and reported that implants with conical interface decreased the problem of loosening of prosthetic components

and proved satisfactorily high performance over time, reaching 99% of success within 10 years for single tooth restorations. Others,²³ evaluated 307 Morse Taper implants for single rehabilitation in a follow-up period of 4 years and observed two cases of abutment loosening (0.66%) with a survival rate of 98.4%. In prospective studies^{23,24} with Morse Taper implants used for a period of 5 to 6 years, the loosening of prosthetic components was 0.37%.

CONCLUSION

External connection implants have their historical value and indicative of implant supported prosthetic planning, especially in fixed prostheses, however, studies have proved the need to review some concepts regarding the biomechanical flaws and instability of peri-implant tissues. Conical prosthetic interface systems meet the needs for obtaining a balance between biological and mechanical characteristics of dental implants.

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