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Julio Cesar Gomez Garcia
Master of Science Student, Universidad Autonoma de Nuevo Leon, Facultad de Odontologia, Monterrey, Nuevo Leon, 64460 ZIP, Mexico

Norma Cruz Fierro
Profesor, Universidad Autonoma de Nuevo Leon, Facultad de Odontologia, Monterrey, Nuevo Leon, CP 64460, Mexico

Lizeth Edith Quintanilla Rodriguez
Profesor, Universidad Autonoma de Nuevo Leon, Facultad de Odontologia, Monterrey, Nuevo Leon, CP 64460, Mexico

Feliciano Chavez Gonzalez
Profesor, Universidad de Guadalajara, Departamento de Fisiologia, Guadalajara, Jalisco, 44600 ZIP, Mexico

Rosa Elia Arias Gomez
Profesor, Universidad de Guadalajara, Clinicas Odontologicas Integrales, Guadalajara, Jalisco, 44290 ZIP, Mexico

Irene Meester
Profesor, Universidad Autonoma de Nuevo Leon, Facultad de Odontologia, Monterrey, Nuevo Leon, CP 64460, Mexico

Maria Fernanda De Leon Gomez
Master of Science Student, Universidad Autonoma de Nuevo Leon, Facultad de Odontologia, Monterrey, Nuevo Leon, 64460 ZIP, Mexico

Juan Manuel Solis Soto
Profesor, Universidad Autonoma de Nuevo Leon, Facultad de Odontologia, Monterrey, Nuevo Leon, CP 64460, Mexico

Corresponding Author:
Luz Estrella Romero Oliva
Master of Science Student, Universidad Autonoma de Nuevo Leon, Facultad de Odontologia, Monterrey, Nuevo Leon, 64460 ZIP, Mexico

Implant-abutment connections: A literature review

Julio Cesar Gomez Garcia, Norma Cruz Fierro, Lizeth Edith Quintanilla Rodriguez, Feliciano Chavez Gonzalez, Rosa Elia Arias Gomez, Irene Meester, Maria Fernanda De Leon Gomez and Juan Manuel Solis Soto

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Abstract
Introduction: In recent years, different implant-abutment connections have been developed to achieve greater longevity, improving mechanical and biological failures in implant treatments.
Objective: To analyze the types of connections that are external, internal and Morse cone, and evaluate their biomechanics, the impact they have on the alveolar bone and microbial contamination.
Methodology: PubMed, SCOPUS and Google Scholar databases were reviwed to find recent articles published on implant-abutment connections with the following keywords "implant-abutment connection", "fixture-abutment connection", "implant-abutment interface", "External hexagon", "internal hexagon", "internal connection", "conometric connection".
Results: The external connection presents micromovement under lateral load and this can create a microgap at the implant-adhesive interface, causing future bone loss and bacterial accumulation inside the implant. As for the internal connection, it was found that it presents a smaller microgap, managing to maintain the crestal bone for a longer time and having a minimum bacterial proliferation inside the implant. The conical connection systems seem to have almost no microgap and therefore tend to have better adaptation and longevity of the peri-implant hard and soft tissues, in addition to a non-significant bacterial microleakage. It was found that the biomechanics of each type of connection are closely related to peri-implant bone loss and this is mainly developed by microbial contamination.
Conclusion: Further *in vivo* studies are needed to confirm which connection offers a better prognosis and longevity of the implant treatment performed.

Keywords: Implant-abutment connection, fixture-abutment connection, implant-abutment interface, external connection, internal connection, Morse cone

1. Introduction
It is important to analyze the types of implant connections at the time of implant selection in order to have an efficient, safe treatment with the least mechanical and biological failure in the long term [1]. Each implant system differs from the others by implant shape, materials, roughness, spirals, connection level, geometry etc. Regarding the connection geometry, the Branemark system suggested the external hexagon to simplify the implant insertion. Internal connections were developed to decrease micromovement at the connection level [2, 3]. Several studies investigated the biomechanical and clinical implications of different types of connections. The external connection; which was the first connection system adopted by modern implantology by Branemark, the internal connection; which tries to increase load absorption in lateral forces, and the conical connection; which works by blocking mechanical friction between the attachment wall and the implant [4, 5]. The types of connections are compared according to their degree of microleakage, resistance to displacement, evaluation of stress, response with the bone and soft tissues around the implant. In the implant-attachment connection types there is microleakage, which is developed due to micromovement, and may increase inflammation at the connection level resulting in marginal bone loss. It is important to know the benefits or disadvantages of the different types of connections [1, 6].
Analyzing all types of connections, their biomechanics, and their relationship to bone loss and microbial contamination is important, as it is critical to select the connection that demonstrates

longevity. Therefore, the aim of this article is to analyze the literature about the types of implant-attachment connections (external, internal, and Morse taper), the biomechanics, and their relationship to microbial contamination and crestal bone loss.

2. Materials and Methods
Articles on the subject published through the PubMed, SCOPUS and Google Scholar databases were analyzed, with emphasis on the last 5 years. The quality of the articles was evaluated using guidelines, i.e., identification, review, choice and inclusion. The quality of the reviews was assessed using the measurement tool for evaluating systematic reviews. The search was performed using Boolean logical operators AND, OR and NOT. The search was performed using Boolean logical operators AND, OR and NOT; with the keywords: “implant-abutment connection”, “implant connections”, “fixture-abutment connection”, “implant-abutment interface”, “external connection”, “internal connection”, “Morse cone”. The keywords were used individually, as well as each of them related to each other.

3. Results and Discussion
3.1 External Connection
Most studies involving external connections show negative results towards this type of connection. Although a 5-year study evaluating internal and external connections recorded that no statistically significant differences were found in failures, complications or marginal bone level between both connections [7].

3.1.1 Biomechanical Behavior
Research involving external connections is extensive and mostly negative. One study showed that the external hex exhibits micromovement under lateral loading, creating a microgap at the implant-adhesive interface, leading to bacterial microleakage that can affect the long-term success of dental implants [8].

Several investigations have been developed analyzing the biomechanical behavior of external connections. External connections have higher micro stress values that are concentrated in the cervical region of the implants, also that they tend to concentrate stress on distal implants in implant-supported fixed prostheses [9]. In another evaluation of the influence of connection types on biomechanical behavior, it was observed that external connections had significantly higher bone stress [7]. In a study evaluating the incidence of technical complications in internal and external connections of metal and zirconia abutments, it was observed that external implant systems had a higher incidence of screw loosening, as a greater number of loose screws were reported than in internal connections [10].

Other study on the mechanical behavior of a multiple prosthesis joined by different implant connections, the external connection was the one that obtained the highest number of high intensity stripes, having positive results from a biomechanical point of view [11]. In a report of an 8-year evaluation of single implants with internal and external connection, no differences were found between the two types of implants in survival, fracture, screw loosening and peri-implant disease, which could imply greater positive results of the external connections [12].

3.1.2 Crestal Bone Loss
The interface in the implant-abutment connection is directly related to bone loss due to bacterial penetration and colonization, so the type of connection is closely related to bone loss [13]. In an evaluation of the different types of connections and their influence on biological behavior, the most frequent biological complication in external connection was dehiscence [14]. Although greater bone loss has been reported in external connections, we should be aware that peri-implant marginal bone change is caused by several factors, including bone and soft tissue architecture, occlusal loading, implant position, implant design and future inflammatory processes [15]. In order to evaluate possible causes of marginal bone loss in addition to the mismatch in the abutment-implant connection, a study was carried out in which it was shown that bone loss is more common in short abutments than in long ones, it is greater in grafted bone than in pristine bone, and smoking increases this loss. In terms of diameter, greater loss was seen in 5 mm implants than in 4.5 mm implants [16].

3.1.3 Microbial Contamination
In a microbiological evaluation of the implant-abutment interface in different connections after 5 years, it was shown that no design could avoid at 100% the microbiological leaks, although they can influence the levels of bacterial activity qualitatively and quantitatively, especially inside the implant connection, where the external connection was the one that showed the highest bacterial activity [17]. It is well known that degradation in the implant-abutment connection is produced by wear and corrosion processes, releasing ions, nanoparticles and microparticles that go to surrounding tissues causing peri-implant inflammation and resulting in bone loss in addition to loosening in the implant-abutment connection [18].

The analyzed literature assures us that this connection has several defects in the biomechanical behavior, besides having greater internal microbial contamination. Currently, external connections are no longer so popular due to the fact that new designs have achieved greater implant longevity.

3.2 Internal Connection
Internal connections are a very popular type of connection because they have mechanical, biological and esthetic advantages. In a comparative review between internal and external connection, it was concluded that the internal connection can be successfully indicated for fixed partial dentures and overdenture planning, since it presents high mechanical stability [19]. Its use in esthetic zone single implants is recommended since they share better in esthetic parameters [14]. In addition to the mentioned advantages, many studies have demonstrated that internal connections show a better prognosis in bone response and fewer problems of peri-implantitis or any other periodontal disease [20].

3.2.1 Biomechanical Behavior
In vertical load transfer, a study in which three load positions were applied to an implant-supported prosthesis with 4 implants, it was shown that internal connections have less stress at the connection level compared to external connections, demonstrating that internal connections have a lower degree of deformation [21]. An evaluation to compare the fracture resistance of narrow diameter abutments in chewing simulation with internal and external connections showed that internal connections present greater resistance to fracture in the abutments [22].

One of the most popular internal connections are hexagonal connections, and within these some can be found with certain modifications. In an investigation, a modified internal hex connection with a collar (to increase stability) was compared with a traditional internal hex connection, and it was shown that the internal hex connection with modification is more resistant to loosening or distortion [23]. Regarding the impact of torsional forces on the length of short implant abutments with different internal connections, it was shown that the octagonal internal connection had significantly lower seating in several clinical and laboratory stages compared to those with hexagonal shape [24].

3.2.2 Crestal Bone Loss

In a systematic review it was recorded that internal connections have a lower marginal bone loss compared to external connections, however, the implant-abutment connection did not influence implant survival. Therefore, it was concluded that internal connections should be preferred when there are risk factors that may contribute to greater marginal bone loss [25]. In a study where implants with internal connection were used, it was recorded that peri-implant bone loss is also influenced by the level of implant placement in relation to the bone crest (crestal or supracrestal), with greater loss in implants placed at the crestal level [26]. Both internal and external connections present high survival rates, although greater loss has been registered in implants with external connection than internal, there have been studies where no statistically significant differences were found between both connections, concluding that external connections are reliable in long term follow-ups as well as internal ones [27].

3.2.3 Microbial Contamination

In a study of two-piece implants with internal connection, it was recorded that this connection allows an implant-abutment precision of several microns. It was shown that the space between these structures opens and closes under occlusal forces, causing a pumping effect, resulting in contamination of the implant by bacteria and oral fluids, creating an inflammatory reaction. It was also observed that the use of antiseptics and other materials to seal the micro-gap can be useful to reduce the risk of contamination [28].

In another *in vitro* study, twenty implants with internal connection were used to try to reduce the bacterial load, and the use of a new antimicrobial coating of polysiloxane with chlorhexidine digluconate was evaluated, demonstrating that it is capable of inactivating the microbial species that penetrate the interior of the implant through the abutment-implant junction [29].

Comparative studies in biomechanical, biological and esthetic function show that internal connections are an evolution to the design of external connections. They are currently very popular in the market since they have significantly reduced the defects of external connections.

3.3 Morse Cone

The Morse taper is a modification of the internal connection, which has been reported to have a high survival and success rate. In a study of 117 implants, only two implants failed, resulting in a 1-year survival rate of 98.3% [30]. It has been demonstrated that in Morse taper connections there is less micro-gap and no micromovement thanks to the absence of screw in the abutment, decreasing the bacterial leakage between implants, where the percentage of leakage is so low in this type of connection compared to one-piece implants [31].

3.3.1 Biomechanical Behavior

Other studies with positive results were an evaluation of screw loosening, where conical connections showed better stability than internal connections after measuring the extraction torque before and after cyclic loading [32]. A negative point concerning the Morse taper was found when evaluating axial displacement in cemented prostheses, the Morse taper connection showed greater displacement than other connections, so it should be handled with caution [33].

3.3.2 Crestal Bone Loss

In a review of the literature on the Morse Taper, the results indicated that it has a lower incidence of peri-implantitis and bone loss at the abutment-implant level, and with the change of platform it has shown less inflammation and bone loss [34]. The choice of the type of connection influences masticatory overload, which is a cause of bone resorption. In evaluating different types of connections and their relationship to bone loss, it was concluded that the conical shape has a key positive role in the transfer of forces to the tissues [35]. In terms of peri-implant tissue preservation, the Morse taper connection is successful, although the soft tissue thickness of each individual must also be taken into account [36]. Peri-implant bone deterioration depends on the type of connection. An evaluation of clinical, radiographic, microbiological and biomechanical parameters showed that Morse taper connections show less bone loss compared to external connections [37].

3.3.3 Microbial Contamination

Several studies conclude that all connections present an amount of micro-gap and bacterial micro-leakage, although conical connection systems have been shown to have better results in addition to good load distribution [38]. The Morse taper is handled by several systems on the market. In an investigation comparing various systems, microgaps were detected in all units with no significant differences in dimension, so bacteria were observed in all units [39]. In an evaluation of bacterial leakage of 11 degree Morse taper compared to a butt connection, it was shown that the 11 degree Morse taper showed greater resistance to bacterial leakage, with significant differences [40]. It was found that both designs exhibited a similar risk of bacterial invasion into the microgap [41]. In a study where they used Morse taper connections to find out the effect of chlorhexidine in penetrating the implant-abutment interface, they concluded that 0.2% chlorhexidine solution had no significant effect in reducing bacteria, which would give minimal results in preventing contamination [41].

We found this to be an innovative design that proves to further decrease the micro-gap and therefore also bacterial leakage. There is no doubt that in the future new designs will be made decreasing more and more the mechanical and biological failures of implant connections.

4. Conclusions

The ideal connection should function as a one-piece implant avoiding the formation of a micro-gap at the implant-attachment interface. All connections presented an amount of microgap and bacterial microleakage, but the conical connection systems seem to have it in smaller amount presenting better adaptation in the peri-implant tissues. Further *in vivo* studies are needed to confirm which connection offers greater longevity in implant treatments.

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