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RESEARCH AND EDUCATION

Comparative study of torque resistance and microgaps between a combined Octatorx-cone connection and an internal hexagon implant-abutment connection

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ABSTRACT

Statement of problem. Although the implant-abutment connection may prevent crestal bone loss around dental implants, its failure often leads to treatment failure. Microgap and micromovement of the implant-abutment connection could be causes of bone resorption around dental implant neck.

Purpose. The purpose of this study was to compare torque resistance and microgaps between a new cone and index connection (Octatorx) and an internal hexagon implant-abutment connection (Internal hex).

Material and methods. Twenty Octatorx and 20 internal hexagon connections were attached with retaining screws at 30 Ncm. In a torsion resistance test, 10 of each type of connection were attached to a universal testing machine. Torque resistance with 90 degrees per minute rotation speed was recorded. For microgap measurement, each of 10 connections was embedded in clear acrylic resin. The blocks were cut longitudinally. Twenty specimens of each connection were evaluated. Twelve measurements of microgaps (6 on each side of specimen) were recorded under scanning electron microscopy.

Results. The average torsion resistance of Octatorx (203.6 ±17.4 Ncm) was significantly greater than that of the internal hexagon (146.4 ±16.1 Ncm, $P<.05$). For the microgap, there was a significant difference ($P=.001$) between the median values of Octatorx (1.19 μm) and the internal hexagon (3.80 μm).

Conclusions. In this study, the new connection, Octatorx, had a smaller microgap and greater torque resistance than the internal hexagon connection. (J Prosthet Dent 2015;■:■-■)

INTRODUCTION

The success of dental implant treatment has been well documented.[1-4] However, many key factors are involved in the success of dental implant treatment including, surface treatment of the dental implant, dental implant design, abutment design, and implant-abutment connections. One issue that might influence the success of dental implant treatment is early crestal bone loss. A meta-analysis study of marginal bone level changes around dental implants after 5 years in function by Laurell and Lundgren[5] showed that the pooled mean marginal bone level change of 3 implant systems were in the range of 0.24 to 0.75 mm. They concluded that the documentation of marginal bone level change should be mandatory because it is a key factor for the long-term success of implant treatment.[5] Oh et al[6] reviewed the possible causes of early implant bone loss. They concluded that the possible causes of early implant bone loss include surgical trauma, occlusal overload, microgap, periimplantitis, biologic width, implant crest model, and implant-abutment connection.

Surgical trauma is one of the factors that may influence periimplant bone loss during the healing period. This trauma results from overheating during the drilling

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Clinical Implications

The reduced microgap and greater torque resistance of Octatorx might prevent crestal bone loss and reduce the failure rate of implant treatment resulting from the failure of the implant-abutment connection rather than the internal hexagon connection.

of the bone, from periosteal flap elevation, or from excessive pressure during implant placement. Because the pattern of bone loss from surgical trauma is more likely to be vertical than horizontal, that loss is similar to the pattern of periimplant bone loss or saucerization. Steigenga et al[7] studied dental implant design and its relationship to long-term implant success. They also reported that surgical trauma was an important contributing factor in the process of early implant bone loss. Furthermore, they stated that occlusal overload could result in the loss of marginal bone or osseointegration. Occlusal overload can be caused by improper implant size or design, incorrect number of implants to support the restoration, excessively cantilevered pontics, excessive parafuctional forces, or improper restorations. A loosened screw is frequently the first sign of implant overload. Balancing and reducing occlusal contacts to the implant support area and the shortening or elimination of cantilevered pontics can reduce the excessive stress to the crestal bone. Oh et al[6] concluded that occlusal overload was likely a contributing factor to early crestal bone loss, but if traumatic occlusion is combined with inflammation, marginal bone loss rapidly progresses.

A microgap is a space between an implant fixture and an abutment surface. When the 2 components in a 2-piece implant are fitted together, microgaps are inevitable. Tsuge et al[8] stated that microgaps are a probable origin of microbial contamination. Microbial leakage may cause inflammation of periimplant tissue that might lead to crestal bone loss, which is a contributing cause for the early crestal bone loss that occurs during the healing period, independently of submerged or nonsubmerged implants. Zipprich et al[9] stated that one of the factors that influences the occurrence of microgap is the design of implant-abutment interfaces. When microbial contamination occurs, periimplantitis may develop. A study on bacterial colonization on internal surfaces of one dental implant system showed the flora consisted mainly of facultative and anaerobic streptococci and of gram-positive anaerobic rods such as *Propionibacterium*, *Eubacterium*, *Prevotella*, and *Porphyromonas* species.[10] Early crestal bone loss may be induced by such an environment, which is appropriate for anaerobic bacterial growth and which results in bone destruction. However, biologic width or a biologic seal around dental implants can act as a barrier to prevent bacterial invasion and food debris from entering into the implant-tissue interface.[11] This seal consists of an epithelial attachment and a connective tissue attachment. The direction of collagen fibers in the connective tissue attachment surrounding a dental implant is parallel to the implant surface, but perpendicular to the surfaces of natural teeth. Whereas the epithelial attachment in the natural tooth is composed of basal lamina and hemidesmosome, which is similar to that in the dental implant.[12] However, the reformation of biologic width may not be the only factor in the process of early bone loss.

Furthermore, implant-abutment connections have been considered as important for the success of dental implant treatment. During mastication, dental implant interacts with compressive force, which is parallel to the implant's long axis and shearing force, which is not perpendicular to the implant's long axis. Biomechanically, shearing force is important in the loosening of the implant-abutment connection, leading to the failure of the retaining screw from deformation or breakage. The micromovement of the implant-abutment connection is considered critical for dental implant success. Zipprich et al[9] defined the implant-abutment connections as follows: connection without self-inhibition (butt connection), connection with self-inhibition (cone connection), connection with a mandatory index, and combination of cone connection and index.

A connection without self-inhibition or butt connection is a common feature in implant-abutment connections. Two surfaces are pressed against each other, perpendicular to the implant axis. The butt connection can be classified as an external or internal joint. A common disadvantage of this connection is movement between the abutment and implant during nonaxial load application when the retaining screw is loosened. The largest possible microgap is established during the nonaxial loading by the length of the parallel-wall connection.[9] The connection with self-inhibition or cone connection is a connection between a cone and a conical keyhole. The cone is located in the abutment, while the conical keyhole is located inside the implant. The connection consists of surfaces pressed against each other, causing engagement and frictional connection at the implant-abutment interface, as the joining gap disappears because of the conical geometry and contact pressure. The advantages of this connection are self-retention and a zero-clearance locking mechanism, which can prevent microgap formation and reduce micromovement.[9] The third connection is a connection with a mandatory index. This connection needs a key and keyway to mount the implant and abutment together. Normally, triangular or polygonal designs of the indices have been used to prevent rotation between

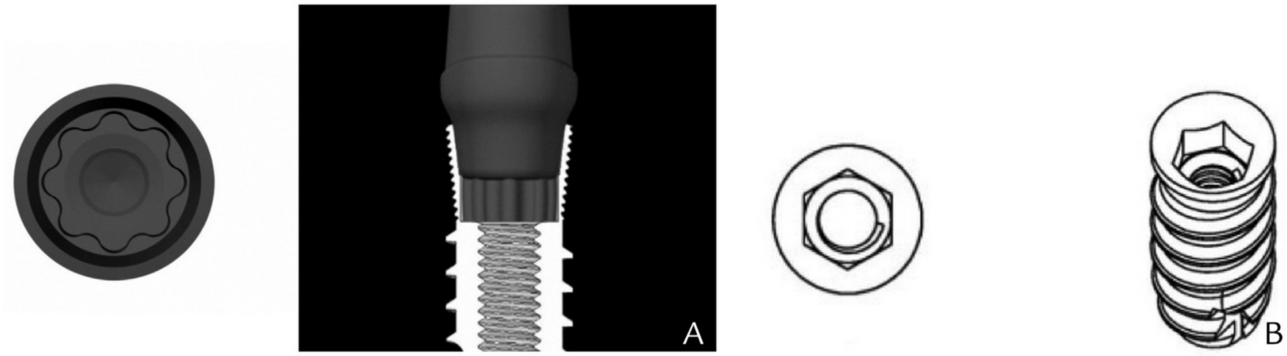

Figure 1. A, Cone connection combined with octalobular index (Octatorx). B, Butt connection with hexagon index (internal hexagon).

the abutment and dental implant. However, indices, or rotation locks, are usually designed with a clearance fit to facilitate the connection of implant and abutment. The use of rotation locks always results in rotational movement between 2 adjacent corners of the key and keyway.[9] The most frequent problems of the implant-abutment connection are micromovement of the connection, microgaps between implant and abutment, and breakage of the retaining screw. These lead to unsuccessful dental implant treatment.

The combined Octatorx-cone connection has been developed to overcome the weaknesses of the butt connection. This connection is a combination of the cone connection and special torx index. Normally, torx has been defined as a star-shaped "hexalobular" drive with 6 rounded points. It was designed to permit increased torque transferred from the driver to the bit compared with other drive systems. This torx is popular in the automotive and electronics industries because resistance to cam-out, extended bit life, and reduced operator fatigue minimizes the need to bear down on the drive tool to prevent cam-out as described in ISO 10664.[13] The Octatorx is a modified torx with star-shaped "octalobules," as shown in Figure 1. The advantages of the Octatorx are resistance to torsion, prevention of micromovement, and ease of placement of dental implants without a specific position index for the future prosthesis; for instance, the triangular index dental implant must be placed with the triangle tip buccally. When comparing the Octatorx with the internal hexagon connection, the contact of the hexagon is a spot connection while that of the torx is a surface connection, resulting in improved stress distribution and prevention of movement during function, especially from shear force.[9]

The cone connection is the upper part of the implant-abutment connection. The cone has its own tapered angle of approximately 6 degrees. To create the surface connection between the implant and abutment, there is a 200-μm shoulder at the lower part of the keyhole of the dental implant. When the abutment and implant are connected with appropriate torque, the abutment is seated on the shoulder and establishes the surface connection.

The purpose of the study was to compare the torsion resistance and microgaps of an internal hexagon implant-abutment and a combined Octatorx-cone connection.

MATERIAL AND METHODS

Ten commercial dental implants with internal hexagon implant-abutment connections and 10 commercial dental implants with Octatorx implant-abutment connections with a diameter of 3.75 mm and a length of 10 mm were used for the test. Both dental implant systems have been certified by the Community of Europe (CE marking; CE0197 and CE0123). A straight abutment was attached to the implant with a retaining screw with 30 Ncm of torque (Torq Control; Anthogyr). Each implant-abutment connection was attached to a universal testing machine (55 MT2-E3; Instron Corp). The torsional rotation speed was 90 degrees per minute. The universal testing machine was run until the connection failed. The torsional resistance was measured in Ncm. Statistical analysis using descriptive analysis and an unpaired *t* test (α=.05) was performed with software (SPSS v17.0; IBM Corp).

Ten implants of each connection type, internal hexagon connection and Octatorx-cone connection, were used for the microgap measurement. Each experimental implant was fixed perpendicularly in autopolymerized acrylic resin with its upper part exposed. Then a straight abutment was attached to the implant with a retaining screw with 30 Ncm of torque (Torq Control; Anthogyr). After that, the upper part of the implant with the abutment attached by the retaining screw was embedded in an acrylic resin block (2×2×2 cm). The resin blocks were longitudinally sectioned through the middle of the implant-abutment with a slow cutting instrument (IsoMet low speed saw, 11-1280-160; Buehler). Twenty specimens of each type of connection were tested. Then

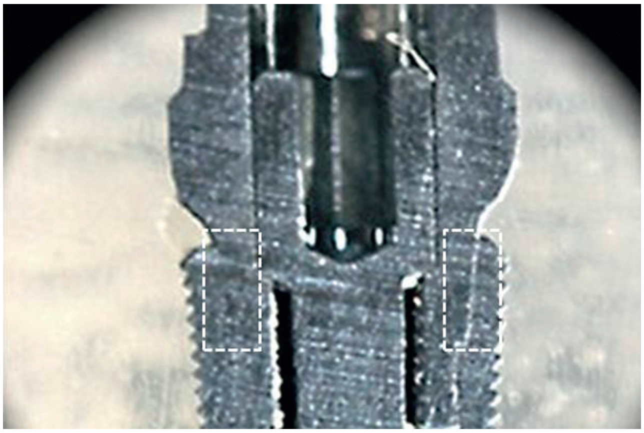

Figure 2. Upper part of implant-abutment connection.

6 measurements of microgaps of each specimen (3 on upper right area and 3 on upper left area as shown in Figure 2) were selected from 20 measurements (10 measurements from each side). Each measurement was performed under a scanning electron microscope (JSM-5600; JEOL) at ×2000. Because the results were not normally distributed, the mean microgap of each implant was determined, and the median value of each type of connection was reported and compared between groups with nonparametric Mann Whitney U tests (α=.05).

RESULTS

The average maximum torque of the Octatorx (203.6 ±17.4 Ncm) was significantly higher (P<.05) than that of the internal hexagon (146.4 ±16.1 Ncm).

Two specimens of internal hexagon and 4 specimens of Octatorx were excluded from the study because the specimens were not in the appropriate position after the cutting procedure. Then 108 (9 internal hexagon implants, Figure 3A) and 96 (8 Octatorx implants, Figure 3B) measurements were obtained. The median microgap of Octatorx was 1.19 µm, whereas that of the internal hexagon was 3.80 µm. A significant difference between groups was found and is presented in Figure 4 (P=.001).

DISCUSSION

The technical factors influencing the success of dental implant treatment are implant fixture design, surface modification, abutment design, and the implant fixture-abutment connection. The success criteria of dental implant treatment have been established.[14] The most important success or survival criterion for dental implant treatment is the functioning of the dental implant in the oral cavity, especially for mastication despite the existence of bone loss during the functional period.

There are 2 main causes of failure of dental implant treatment: the loss of osseointegration, which leads to the loss of the dental implant and prosthesis, and the failure of dental implant components, including the breakage of the dental implant itself or the failure of the connection between the dental implant and abutment.[4] The bone loss around dental implants has been considered as periimplantitis and crestal bone loss during dental implant function in the oral cavity. The crestal bone loss always occurs in the first year after prosthesis loading.[6] Albrektsson et al[14] and Smith and Zarb[15] have proposed criteria for implant success, including that crestal bone loss occurring during the first year should be less than 2 mm and less than 0.2 mm annually. Actual periimplantitis leads to critical bone loss around the dental implant and failure of osseointegration. A literature review by Oh et al[6] reported that the reformation of biologic width around dental implants, micrograps if placed at or below the bone crest, occlusal overload, and implant crest module may be the most likely causes of early implant bone loss.

Thus, the connection between the implant and abutment plays an important role in crestal bone loss around dental implants. Until now, the precise causes of this crestal bone loss have not been proved. However,

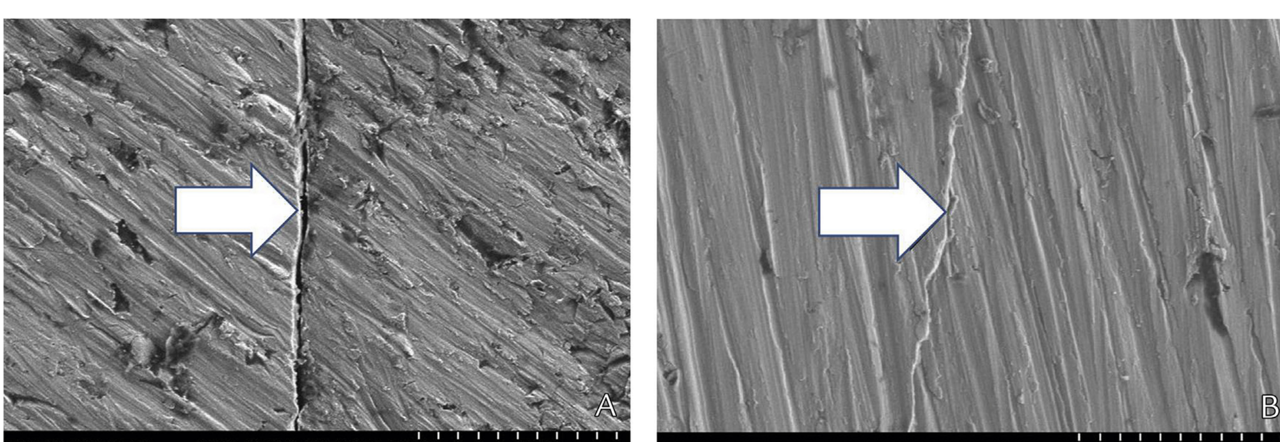

Figure 3. A, Microgap of conventional hexagon connection (×2000). B, Microgap of Octatorx connection (×2000).

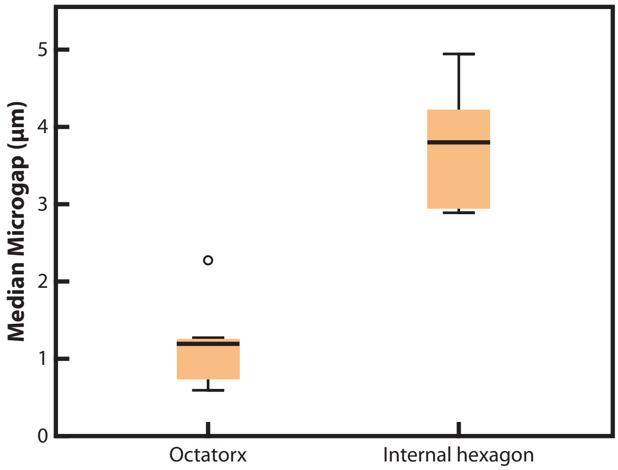

Figure 4. Median microgaps of implant-abutment connections.

Zipprich et al[9] and Cumbo et al[16] attributed the prevention of crestal bone loss around dental implants to the design of the implant-abutment connection. The combined connection of a mandatory index and a cone connection has been introduced and used in implant dentistry. The Octatorx is a newly developed connection with the main purposes of reducing the microgap and micromovement and of providing an appropriate situation for the reformation of biologic width, so called platform switching.[16]

The connection described in this study was designed to prevent crestal bone loss around dental implants and to prevent micromovement. The combination of an octalobule mandatory index and a cone connection was machined and tested following the standard testing procedure for dental implants with ISO 10451.[17] The results show that the torsion resistance was strengthened up to 30% when compared with the internal hexagonal index connection ($P<.05$), and the microgap decreased significantly when compared with the internal hexagonal connection ($P<.05$). Zipprich et al[9] suggested that the lobular connection design produces less micromovement than the polygonal design. The Octatorx design seems to have less micromovement than does the polygonal mandatory index. A finite element analysis study by Yamanishi et al[18] showed that implants with a conical implant-abutment connection may effectively control occlusal overloading on the labial bone and abutment micromovement. However, further clinical study of implant-abutment connections must be performed to clarify the relevance of the relationship between implant-abutment connections and crestal bone loss around dental implants.

CONCLUSIONS

The Octatorx abutment connection has significantly better torsion strength and a smaller microgap than the internal hexagonal mandatory connection ($P<.05$). This connection may prevent the crestal bone loss around dental implants that occurs with polygonal and butt joint connections. However, a well-designed, randomized, clinical trial should be conducted to gather scientific evidence.

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