Short Communication

Fracture Resistance of the Implant-Abutment Connection in Implants with Internal Hex and Internal Conical Connections Under Oblique Compressive Loading: An In Vitro Study

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The objective of this study was to verify if differences in the design of internal hex (IH) and internal conical (IC) connection implant systems influence fracture resistance under oblique compressive forces. Twenty implant-abutment assemblies were utilized: 10 with IH connections and 10 with IC connections. Maximum deformation force for IC implants (90.58 ± 6.72 kgf) was statistically higher than that for IH implants (83.73 ± 4.94 kgf) (P = .0182). Fracture force for the IH implants was 79.86 ± 4.77 kgf. None of the IC implants fractured. The friction-locking mechanics and the solid design of the IC abutments provided greater resistance to deformation and fracture under oblique compressive loading when compared to the IH abutments. *Int J Prosthodont 2009;22:283–286.*

Internal hex connections were designed to increase the implant-abutment contact surface area in order to improve abutment stability. It has been shown that internal hex implants provide better force distribution when compared with external hex implants.[1] However, there is no frictional locking between the mating parts of the abutment and the implant and most of these forces are resisted by the screw preload.[1] If the preload is exceeded, the screw is prone to loosening or fracture.

Internal conical connections provide an intimate implant-abutment contact, which is meant to improve the mechanical stability of the abutment and avoid abutment loosening.[2] The fixation and stability of these systems are not functions of the screw; they are granted by the frictional resistance resulting from the contact between the conical mating parts of the abutment and the implant.[2] The good stability obtained by this system seems to provide a high resistance to bending forces at the implant-abutment interface.[3]

The objective of this study was to determine if the different design, dimensions, and mechanical properties of the abutments and implant-abutment connections of internal hex and internal conical connection systems influence fracture resistance under oblique compressive loads.

Materials and Methods

This study used two implant systems: Alvim II Plus (Neodent Implante Osseointegrável) with a 1.5-mm-high internal hex (IH) connection and Alvim CM (Neodent Implante Osseointegrável) with an 11.5-degree, 3.5-mm-high internal conical (IC) connection. The implants were 4.3 mm in diameter and 13 mm in length. The IH abutments were Universal Abutment II Plus (Neodent Implante Osseointegrável), a two-piece abutment with a fixation screw (Figs 1a and 1b). The IC abutments were Universal Abutment CM (Neodent Implante Osseointegrável), a one-piece solid abutment with an apical threaded portion (Fig 1c). Ten implant-abutment assemblies were used for each system (Figs 2a and 2b). Installation torques were 10 Ncm for the IH abutments and 20 Ncm for the IC abutments, according to manufacturer's instructions, as measured by a digital torque meter (TQ680, Instrutherm). Different preload values were due to the different types of threads in each system (ISO M1.60 mm for the IH system and ISO M1.80 mm for the IC system).

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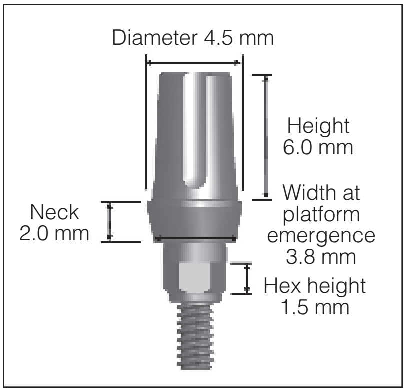


Fig 1a IH abutment and its dimensions.

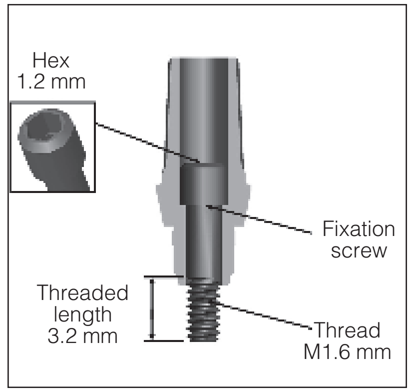


Fig 1b Longitudinal section of the IH abutment and its dimensions.

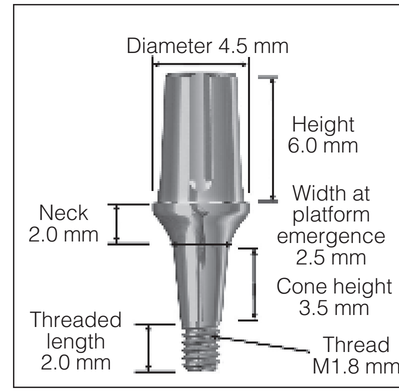


Fig 1c IC abutment and its dimensions.

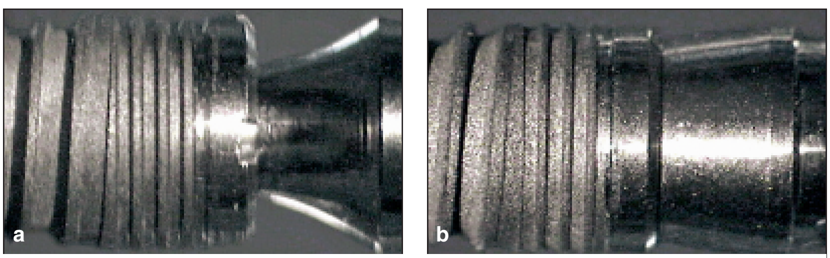


Fig 2a to 2c **(a)** Implant-abutment assembly for the IC system; **(b)** implant-abutment assembly for the IH system; **(c)** setup of the specimens placed on the universal testing machine for the 45-degree oblique compressive loading tests.

Table 1 Mean Values (Standard Deviations) for the Maximum Deformation Force and the Fracture Force of the Internal Hex and Internal Conical Connection Systems*

	Internal hex	Internal conical
Maximum deformation force	83.73 (4.94)[b]	90.58 (6.72)[a]
Fracture force	79.86 (4.77)	–

*Levels not connected by same letter are significantly different (P = .0182).

The implants were embedded in a 21.3-mm-diameter by 25.6-mm-high stainless steel cylinder. The embedded depth was 10 mm to simulate a 3-mm bone resorption.[4] Oblique compressive loading tests were made in a universal testing machine (DL-2000, EMIC). Loading was performed with the specimens positioned at a 45-degree angle, utilizing a 500 kgf load cell with 1 mm/min dislocation (Fig 2c). The loading point was at a distance of 11 mm from the cylinder surface (lever arm length). Two values were analyzed in each test: the maximum deformation force (MDF) and the fracture force (FF) of each implant-abutment assembly under 45-degree compressive loading. All results were analyzed using statistical software (JMP for Windows version 5.1, SAS Institute). MDF values were assessed using the Student t test ($P < .05$).

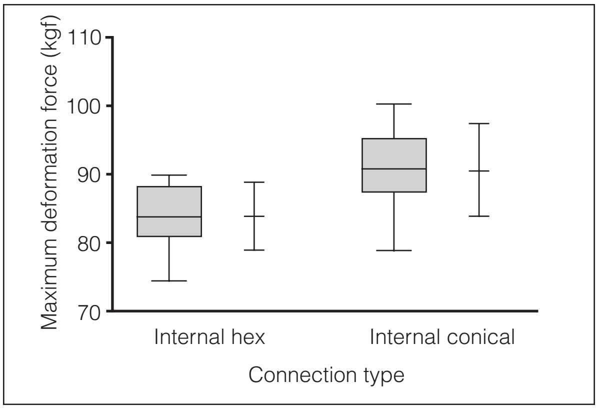
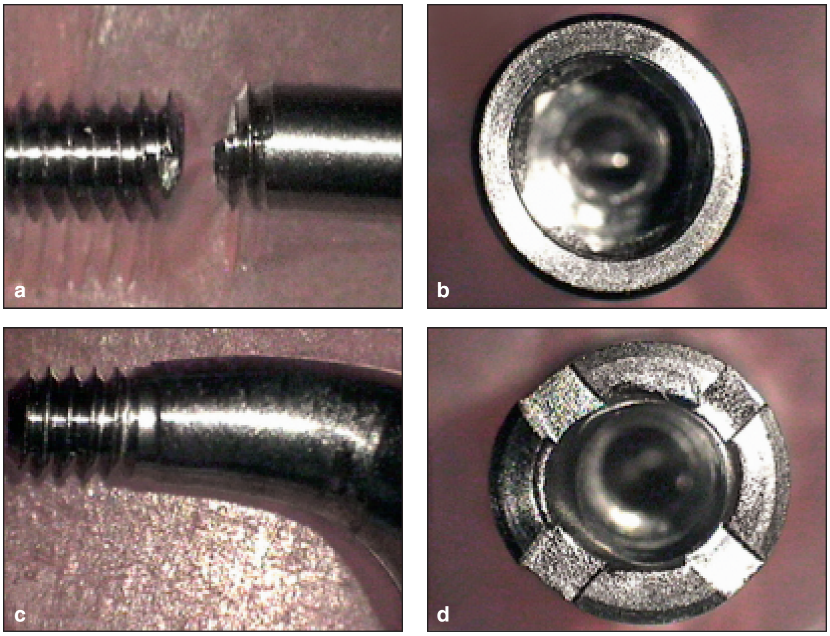


Fig 3 Maximum deformation force values for the internal hex and the internal conical systems.



Figs 4a to 4d **(a)** Neck fracture of the IH screw, close to the unthreaded portion after oblique compressive loading test; **(b)** permanent deformation of the IH implant platform; **(c)** aspect of the IC abutment after the oblique compressive loading test with permanent deformation in the neck of the abutment and no fractures; **(d)** permanent deformation of the IC implant platform.

Results

The MDF and FF values for each implant-abutment assembly were recorded and mean values and standard deviations are shown in Table 1. For all specimens, MDF occurred during the plastic deformation phase; after MDF was surpassed, either component fractures occurred (IH system) or a considerable decrease of the resistance force caused by continued implant-component deformation occurred (IC system). The highest MDF values were obtained by the IC system (90.58 ± 6.72 kgf) followed by the IH system (83.73 ± 4.94 kgf) (Fig 3). The Student *t* test revealed a significant difference ($P = .0182$) between the two systems. Only the IH assemblies fractured and had their FF recorded (79.86 ± 4.77 kgf). Optical micrographs showed that the fractures on the IH abutments always occurred in the fixation screws and permanent deformations occurred in the implant platforms. The IC abutments showed permanent deformations in the neck. There were also permanent deformations in the implant platforms of the IC abutments; no fractures were detected in the abutments or implants (Figs 4a to 4d).

Discussion

All IH implants used in this study showed fractures in the fixation screw, while the IC implants showed no fractures. Both systems employed different mechanical principles of function.[5] In the IH configuration, the axial preload of the abutment screw was a primary factor for stability of the connection and the screw alone secured the abutment. There was no form lock or positive locking by the internal hex, which did not absorb any lateral loading.[5] Therefore, when oblique forces were applied to the implant-abutment assemblies during the tests, the yield point of the assemblies was basically the yield point of the screws. In IC connections, form lock and friction were the primary principles. Lateral loading was mainly resisted by the tapered interface, which prevented fractures of the abutments.

Normal chewing forces have been reported in the literature, ranging between 30 and 50 kgf in posterior regions. For all specimens tested, plastic deformations started to occur under oblique compressive loads of over 80 kgf. Thus, both systems presented an adequate resistance, which indicates that under normal occlusal conditions, both would present a successful clinical performance.

MDF can be used as a parameter value of the oblique load each system is capable of resisting before destructive events occur. Although MDF values were statistically different between the systems, these differences were not high enough to be considered clinically significant. If these systems were subjected to excessive oblique compressive forces surpassing their MDFs, screw fractures would probably occur in the IH abutments, while permanent deformations would be more likely to happen on the neck of the IC abutments. Either way, both systems would possibly show permanent deformations on the implant platform, resulting in failure of the treatment. These findings reinforce the importance of careful planning and refined occlusal adjustments, avoiding excessive oblique loads. Further studies are necessary to compare the fatigue resistance of both systems under dynamic cyclic loading in order to provide more accurate data concerning their long-term fracture resistance.

Conclusion

Under the conditions of this in vitro investigation, the results indicate that the friction-locking mechanics and solid design of the one-piece abutments of the IC connection system provided greater deformation and fracture resistance to the implant-abutment assembly under oblique compressive loading when compared to the IH connection system. Further in vitro and clinical investigations are needed to evaluate the fatigue resistance of these systems under long-term dynamic cyclic loading.

Acknowledgment

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Erratum

In IJP issue 2, 2009, in the article by Zitzmann et al, Figure 2g should appear as follows. The online version of this paper has been corrected. The publisher regrets this error.