Comparative Study between three different conections for dental implants: Internal Hexagon, External Hexagon and Morse Taper

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Abstract. *Since 1960 when the Swedish scientist Per-Ingvar Branemark, noticed that the titanium in contact with the bone tissue was easily integrated, the osseointegrated implant has became the best option for the existing oral rehabilitation. The search for an appropriate configuration led the appearance of implants with varied internal geometry and with different prosthetic connections, aiming to reduce the fatigue caused in the screw, biological gasket, patient's aesthetic, among others. The purpose of this study was to verify the mechanical resistance of the implant/abutment set with three prosthetic connection configurations: Internal hexagon, External hexagon and Morse Taper. Tests of torque were done also in the implants /installation drive set aiming to quantify the maximum torque supported by the implant compared with the values stipulated by the manufacturer.*

Keywords: *Dental implants; internal hexagon, external hexagon; morse taper; implant resistence; prosthetic connections.*

1. INTRODUCTION

The rehabilitation of edentulous patients was enormously benefited by the development and the improvement of the odontologic implants confectioned in titanium. Through them the straight anchorage between the implant and the bone tissue called osseointegration was successfully obtained (Adell et al., 1981). In ideal conditions, the implants can promote retention, stability and support of total or partial dental prosthesis, fixed or removable with comparable quality of the natural teeth (Buser et al., 1998, Bahat, 2000).

The osseointegration was defined by Branemark (1987) as the phenomenon of a straight and functional structural connection between the bone tissue and the surface of an implant in function (supporting load). Being the first study on bone microcirculation and vascularation realized in the University of Lünd in Sweden in 1952. The clinical success of the osseointegrated implants made a great increase of its use all over the world, the percentages of success reached 93 % for mandibular implants and 84 % for the maxillars in studies of 15 years of attendance carried out by Branemark (1985). Besides, the predictions of success are between 90 % and 100 %, independently of the implant type, the surface and the prosthesis drawing, according to the reports cases of Zargb (2005) and Suzuki (2007). The growing success, the introduction and the popularization of this system stimulated the appearance of several alternative systems of implants with geometry and varied prosthetic connections.

The implants with external hexagon connection (EH) developed by Branemark are the most used system nowadays. The great advantage of the EH system is the simplicity and previsibility acquired during years of favorable study cases. An important characteristic of the EH system is the great variety of prosthetic components that make easy the choice of the solution adapted for each case.

With the increase of the oral implants applicability for unit restorations, the connections started to develop an important part: to prevent the prosthesis rotation. It stimulated the manufactures to increase the torque values above the screw and promoted changes in the material. Besides, the components have been manufactured with more precision on the hexagon socket and have been created new interface pillar/implant design (Dantas et al., 2007).

With the several options of connections available on the market, it became necessary compare them in relation of the functional and mechanical performance. One of the objectives of this article is to establish a contribution in the mechanical behavior of these options.

2. LITERATURE REVIEW

The implants with external hexagon connection (EH) developed by Prof. Per-Ingvar Branemark, in the 60´s “Fig. 1”, are the most used until today. The great advantage of EH system is the simplicity and predictability acquired during the years with favorable study cases (Lenharo et al., 2007).An important characteristic of EH system is the big variety of prosthetic components that facilitate the choice of an appropriate solution for each case (Telles and Coelho, 2005).In this model of implant, the hexagon for positioning the prosthesis stays above the prosthetic platform, allowing the professional’s view in a direct way during the surgery.

The insertion of the external hexagon implants is done by a mount fixed on the hexagon that transmit the torque made by the engine and the implant’s drive (Soares et al., 2007).But, recently a new model of implant has been attached to the implant line of external hexagon, it is the implants with internal torque. This model was launched with the purpose of increasing the implant resistance to elevated torques, preserving the dimensions of the external hexagon for the adaptation of the prosthesis (Davi, 2006).

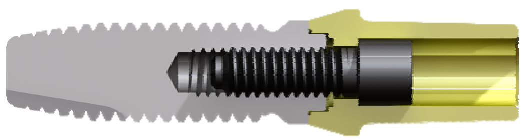

Figure 1 – implant/abutment set with external hexagon connection “section view”

The implants with internal hexagon connection (IH) “Fig 2” presents as principal advantage its high mechanical resistance. It has a big variety of prosthetic components that facilitate the choice of an appropriate solution for each case. Another characteristic of this system is the fact of having no mount. In this way, the transport and the installation of the implant are realized by the same drive model reducing the surgical time and the possibility of contamination. (Soares et al., 2007).This kind of implant gives more resistance to the torque during the implant insertion procedure on the surgical site, some authors asserts that it can increase the stability too (Arvindson et al., 1998).In this system the hexagon for the prosthesis positioning stays inside the implant, not allowing the professional’s view of the implant positioning in a direct way during the surgical procedure. This verification is done through the installation drive with a synchronized mark with the implant hexagon.

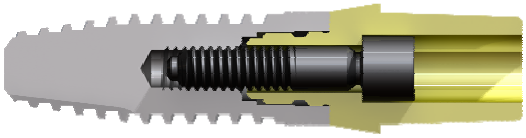

Figure 2 – implant/abutment set with internal hexagon connection “section view”

Another type of connection is the internal conical “Fig. 3”, also known as morse taper. The morse taper concept was developed by Sthepen A. Morse in 1864 and it is very much used in the mechanical area due to a high degree of resistance and precision. The internal conical connection has a great advantage the superior capacity to support cross loads because has a bigger contact area between the implant and the abutment, compared with the same macro-geometry implants (Mollersten et al., 1997). The drawing of the internal conical connection promotes a close adaptation between the pieces, acquiring a mechanical resistance similar of an one- body piece (Soares et al., 2007).Adapted to the implant lines since 1985 aiming reproducing as loyally as possible the prosthetic characteristics of the natural tooth with internal conical connection that presents more than twenty years of clinical cases (Dentsply, 2009) despite they have gained distinction in the national market in a little bit more than ten years.

According to studies by Arita (2006) no microgap (space between the abutment and the implant) exists between two components and it gives to an abutment a bigger resistance to the rotational movements. However, published results in recent studies shows that exists a space between the components of this type of connection causing also bacterial infiltration in the abutment/implant set (Mello, 2007). The internal conical connection also presents other characteristics like the reduction of concentration points of tension, especially on the retention screw, which function is limited to produce a final pressure adapted between the implant and the abutment. The results of studies on slackening of components with several connections showed that the slackening in the sets with internal conical connections is less than in the other connections sets (Oliveira, 2007).

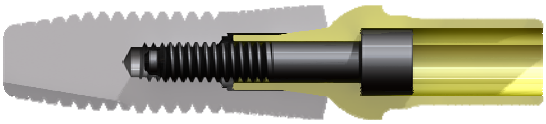

Figure 3 – implant/abutment set with internal conical “section view”

3. MATERIALS AND METHODS

Were tested 30 implants, ten implants with external hexagon connection (internal torque) "Fig 4 ", ten implants with internal hexagon connection" Fig 5 "and ten implants with internal conical connection" Fig 6 manufactured by the brazilian company SIN – Sistema de Implante (S.I.N. Implant System) , five samples of each implant were used in the tests of oblique load and others five in the tests of torque.

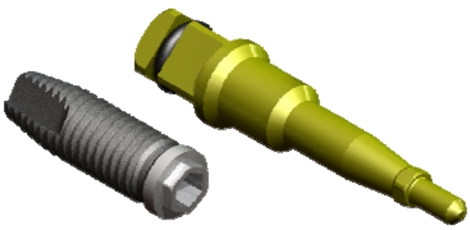

Figure 4 – Implant with external hexagon connection and its installation drive

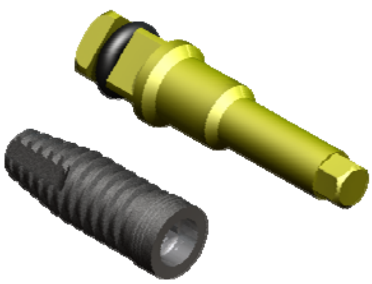

Figure 5 – Implant with internal hexagon connection and its installation drive

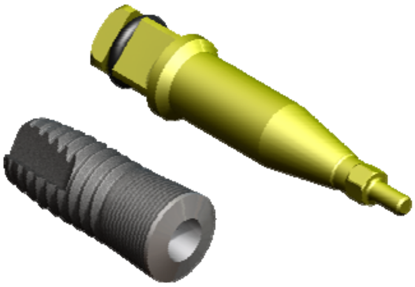

Figure 6 – Implant internal conical connection (IC) and its installation drive

In the oblique load tests were fixed above the implant a cemented abutment component with prosthetic height of 2.0mm “Fig. 7”. The fixation torque of this component was 20N.cm (value recommended by manufacturers to fix the component).

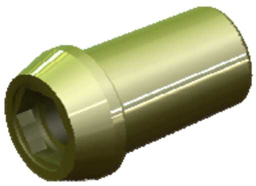

Figure 7 – cemented abutment

In the implant samples was used as raw material the commercially pure titanium grade IV, the chemical composition and main mechanical properties are shown in “Tab. 1”. The titanium is actually considered the best option for osseointegrated implant manufacturing due to its great acceptance by the organic bone. The high degree of biocompatibility is attributed in part to the stable layer of titanium oxide, which facilitates the adherence and deposition of extracellular matrix in bone-implant interface (Amarante and Lima, 2001).

Table 1 - Chemical composition and mechanical properties of commercially pure titanium grade 4 as NBRISO 5832-2 (2001).

N	C	H	Fe	O	Ti	Tensile Strength (MPa)	Yield Strength (Mpa)	Elongation (%)
0,03	0,10	0,0125	0,30	0,25	Balance	345	275	20

The raw material used in the confection of abutments and screws was the alloy of titanium grade V, the average chemical composition and main mechanical properties are shown in “Tab. 2”.

Table 2 - Chemical composition of titanium grade 5 as ASTM F136-2 (2008).

N	C	H	Fe	O	Al	V	Tensile Strength (MPa)	Yield Strength (Mpa)	Elongation (%)
0,02	0,02	0,002	0,10	0,02	0.40	0.15	860	795	10

The installation drives (mounts) were confectioned in stainless steel ABNT 420B “Tab. 3”, quenched and annealined, presenting final hardness of approximately 50HRC.

Table 3 – Chemical composition of stainless steel ABNT 420B according to NBR 5601[17]

C	Mn	Si	P	S	Cr
0,15 min	1,00	1,00	0,04	0,03	12,00 a 14,00

3.1. Mechanical tests

The resistance of the implants was valued through a oblique load test to 30 ° to simulate inclined loads with axial and cross components, besides representing a situation nearest to the real conditions of use of the product according to the standard ISO 14801(2007).

For comparison effect it references the values of the maximum load for the analysis of the results. Any material when submitted to an external force, by traction or compression, suffers modifications in its microstructure, these modifications can cause irreversible deformations or ,in certain cases, lead to the break of the material (Passos, 2006).

Up to certain level of applicable tension, the material works in the linear elastic regime, i.e. it follows the Hooke´s law and the linear specific deformation is proportional to the load applied. The proportionality can be observed in the right-lined passage of the diagram tension-deformation and the proportionality constant is called Young module or elasticity module (Silva Junior, 1972). Above a certain tension, the materials begun to warp plastically, in other words, permanent deformations occur. The point into which these permanent deformations start to be significant is called Yield Strength.

For metals that has gradual transition from plastic regime to the plastic one, the plastic deformation starts at the point which the tension-deformation curve stops being linear, being this point called proportionality limit. However, it is difficult to determine this point precisely. As consequence, was created a convention in which a straight line is built parallel to the elastic portion, passing by the 0,2 % of the total deformation. The corresponding tension to the intersection of this line with the tension-deformation curve is the Yield Strength. The magnitude of the Yield Strength is the resistance measure of a material to the plastic deformation and it can vary a lot, for example, between 35 MPa for an aluminum league of low resistance until 1400 MPa for a steel of high resistance.

During the plastic deformation, the necessary tension to continue deforming a metal increases up to a maximum point called of limit of resistance to the traction (or tension of break), in which the tension is the maximum in the tension-deformation curve of engineering. It corresponds to bigger tension that the material can hold; if this tension is applied and maintained, the result will be the fracture. Any deformation up to this point is uniform in the section. However, after this point, starts to form a stress, in which the whole subsequent deformation is bordered and it is in this region that will break. The tension corresponds to fracture is called Rupture limit.

So, it is possible to obtain the tension-deformation graphic (Fig 8), what varies according to the analyzed material. For example, the fragile materials, like ceramic and concrete, do not present a yield limit. Even the flexible materials, like the aluminum, do not present the yield limit well defined (Calister, 2002).

When in a sample, it is valued that the results of one or more replica are questionable; it is possible to use the proceeding of Chauvenet to reject or to maintain these results in the analysis of the sample. Such procedure specifies that a data must be rejected if the possibility to obtain the relative standard deviation is less than 1/2n. If many components are rejected, it is probable that the instrumentation is unsuitable or the studied process is extremely variable (Button, 2005).

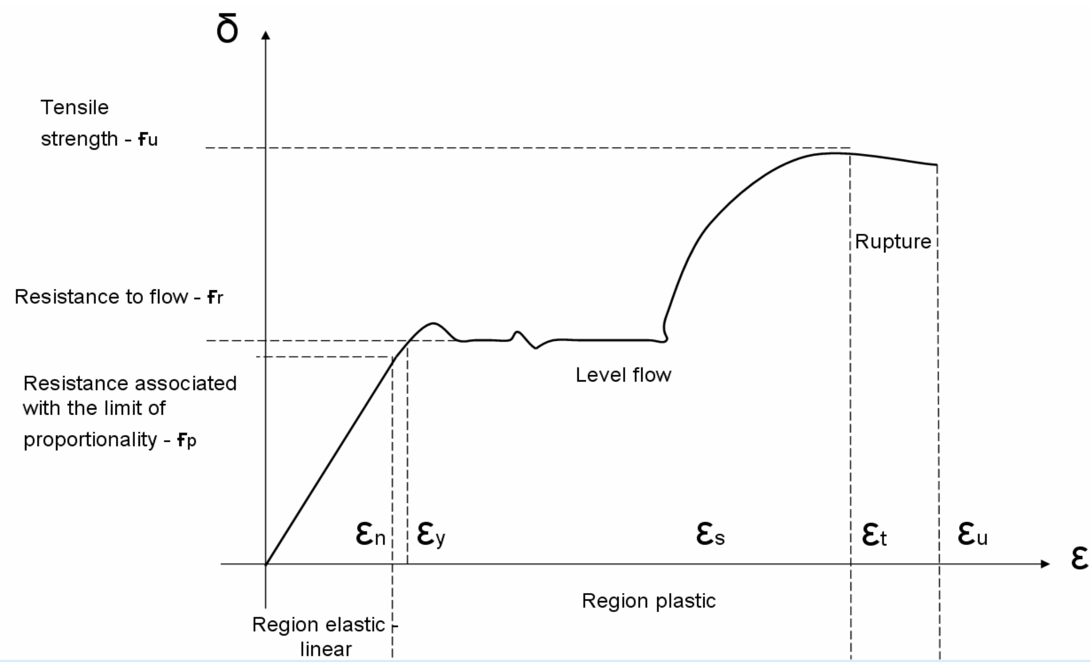

Figure 8 – Deformation-tensile diagram of the structural materials, scale deformed.

3.1.1 Tests of compression (Obliqued load)

The mechanical oblique load tests were done in the universal test machine EMIC DL 10000 (EMIC – Equipments and Test Systems Ltda, Paraná, Brazil) with capacity of 10000N on the dependences of CCDM (Characterizations and Material Development Center). The implants were fixed according to the schematic (Fig 9) presented on standard ISO 14801. The important parameters used in the compression tests are presented in Table 4.

Table 4 – Parameters used in the tests

Number of samples	5 of each model
Temperature	Environment
Speed Test	5 mm/min
Distance – "L"	9,0mm
Load Cell	5000N
Equipment Test	EMIC DL 10000

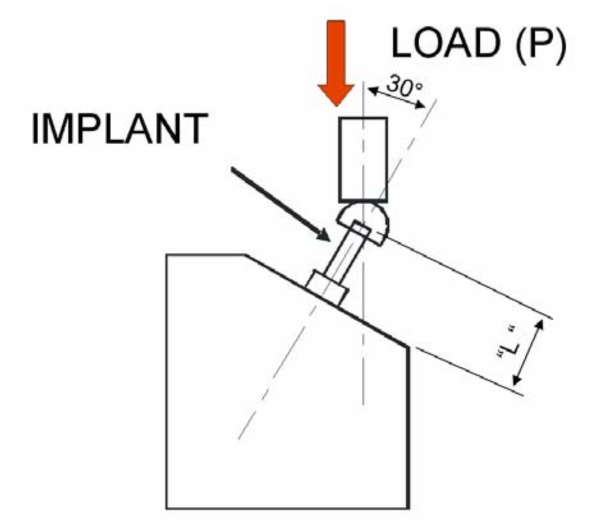

Figure 9 – Schematic and device of the compression test.

3.1.2 Torsion tests

The mechanical tests were done on the dependences of CCDM (Characterizations and Material Development Center) and aim to quantify the yield torque supported by the implant/installation drive set. The implants were fixed according to the schematic (Fig 10). For comparison effect it references the values of the yield torque for the analysis of the results. The important parameters used in the torsion tests are presented in Table 5.

Table 5 – Parameters used in the tests

Number of samples	5 of each model
Temperature	26,2°C
Speed Test	2 RPM
Exposed Length – "L"	2,29mm
Exposed Thread Wires	2 wires
Equipment Test	Termomec Ortho

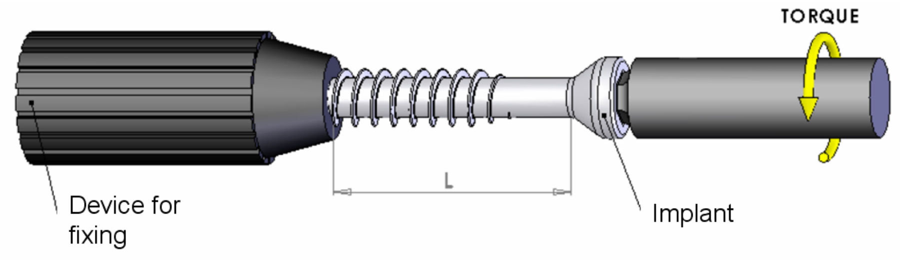

Figure 10 - Schematic of the torsion test.

4. RESULTS

The table 6 presents the results of the maximum load supported by the implants External Hexagon, Internal Hexagon and Internal Conical in the tests of oblique load. The results of the “Sample 5-EH” and “1-IC” were discarded after statistical analysis by the proceeding of Chauvenet.

Table 6 – Results of compression tests on implants

Samples	External Hexagon (EH)	Internal Hexagon (IH)	Internal Conical (IC)
1	1040,20	1402,00	---------
2	1030,50	1103,10	986,26
3	1058,20	1340,70	971,73
4	1131,50	1245,50	1019,50
5	---------	1235,50	1075,50
Average	1065,10	1265,36	1013,00
Standard Deviation	45,73	113,97	47,00

The implants with internal hexagon connection (IH) were those that presented bigger values of resistance – average 1265,36N. The multiple comparison of averages through the test of tukey (Campos, 1983) shows that the average resistance of this group is statistically the same ($p = 0,19847$) the average of the group EH is differently ($p = 0,01155$) than the average of the group IC.

The implants with external hexagon connection presented intermediary values of resistance – average 1065,10N. The multiple comparison of averages through the test of tukey shows that the average of resistance of this group does not differ statistically ($p = 0,95392$)of the average of the group IC.

The implants with internal conical connection were those that presented less values of resistance – average 1013N.

The table 7 presents the results of yield torque supported by the implants External Hexagon, Internal Hexagon, and Internal Conical in the tests of torsion.

Table 7 – Results of torsion tests on implants – Yield Torque (N.cm)

Samples	External Hexagon (EH)	Internal Hexagon (IH)	Internal Conical (IC)
1	221,00	286,00	195,00
2	241,00	299,00	202,00
3	117,00	281,00	194,00
4	245,00	300,00	195,00
5	213,00	300,00	197,00
Average	207,40	293,20	196,60
Standard Deviation	52,28	9,04	3,21

The implants with internal hexagon connection (IH) were those that presented bigger values of resistance to the torque – average 293,20N.cm. The multiple comparison of averages through the test of Tukey[1] shows that the average resistance of this group is statistically different ($p = 0,0023$) to the average of the group EH and differently ($p = 0,0010$) from the average of the group IC.

The implants with connection extern hexagon presented intermediary values of resistance to the torque – average 207,40N.cm. The multiple comparison of averages through the test of Tukey shows that the average of resistance of this group does not differ statistically ($p = 0,8452$) from the average of the group IC.

5. DISCUSSION

The results obtained in the tests of oblique load are related to the resistance of the abutment / implant set and the following factors can interfere in these values:

5.1 Diameter of the fixation screw:

The fixation screw diameter of the prosthetic component does not follow a standard for each type of connection, so the criterion of choice of the best model is of the manufacturer. The screws of the tested implants have the following dimensions.

- External Hexagon: Screw M2,0 (external diameter of 2,0mm);
- Internal Hexagon: Screw M1,8 (external diameter of 1,8mm);
- Internal Conical M1,6 (external diameter of 1,6mm);

The screws for implant EH have 23,45 % more of resistant area when compared with the screws for implant IH and 56,25 % more of resistant area when compared with the screws for implants IC.

The screws for implants IH have 26,56 % more of resistant area when compared with the screws for implants IC.

5.2 Resistance of the abutment / implant set:

The resistance of the abutment / implant set also can be influenced by the resistant area of the implant in its cervical portion or by the thickness of wall between the implant external and internal geometry. This geometry / thickness also do not follow standardization and each manufacturer and / or prosthetic connection presents a different form. The analyzed implants geometry presents itself as:

- External Hexagon: diameter of the platform with 4,1mm and minimum thickness of wall of 0.90mm.
- Internal Hexagon: diameter of the platform with 4,5mm and minimum thickness of wall of 0,75mm.
- Internal Conical: diameter of the platform with 4,5mm and minimum thickness of wall of 0.90mm.

5.3 Contact area between abutment and implant:

The resistance of the abutment / implant set also can be influenced by the contact area between the implant and the abutment. This interface also interferes in the distribution of force for the implant. The analyzed implants presents as:

- External Hexagon: contact area with 5,960mm^2 between the abutment faces and the implant;
- Internal Hexagon: contact area with 8,670mm^2 between the abutment faces and the implant;
- Internal Conical: contact area with 18,075mm^2 between the abutment faces and the implant;

The results obtained in the torsion tests are related to the resistance of the implant / installation drive set and the following factors can interfere in these values:

5.4 Resistance of the implant / installation drive set:

The resistance of the implant / installation drive set can be influenced by the resistant area of the implant in its cervical portion or by the thickness of wall between the external and internal geometry of the implant where the torque is applied. This geometry / thickness also do not follow standardization and each manufacturer and / or prosthetic connection presents a different form. The analyzed implants geometry presents itself as:

- External Hexagon: diameter of the platform with 4,1mm and minimum thickness of wall where the torque is applied of 1,05mm.
- Internal Hexagon: diameter of the platform with 4,5mm and minimum thickness of wall of 1,00mm.
- Internal Conical: diameter of the platform with 4,5mm and minimum thickness of wall of 1,25mm.

5.5 Contact Area between the implant hexagon and the drive:

The resistance of the implant / installation drive set also can be influenced by the contact area between the implant hexagon and the installation drive. As big as the contact area is, better is the force dissipation during the installation. The analyzed implants, drivers and the dimensions present itself as (Fig 11)::

- External Hexagon: Dimension of the hexagon for a 2,00mm torque, contact area between the implant and the installation drive of 9,66mm^2.
- Internal Hexagon: Dimension of the hexagon for a 2,50mm torque, contact area between the implant and the installation drive of 15,12mm^2.
- Internal Conical: Dimension of the hexagon for a 2,00mm torque, contact area between the implant and the installation drive of 9,66mm^2.

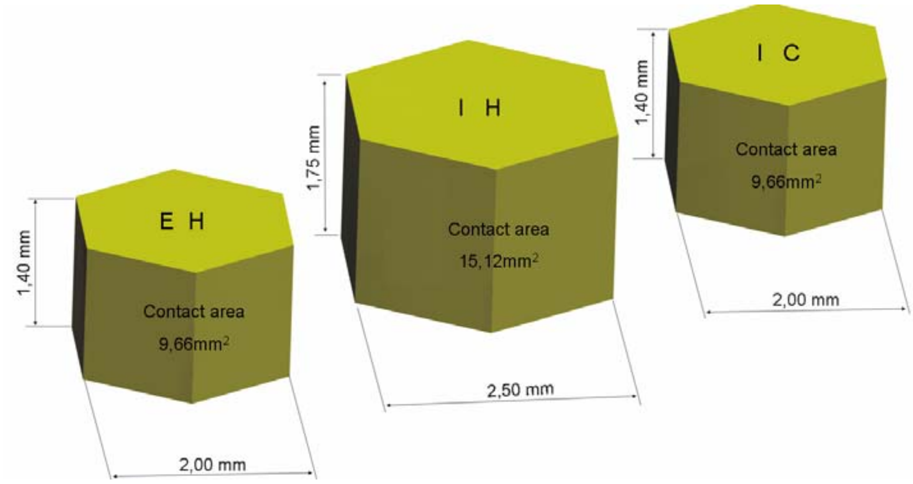

Figure 11 – Contact Areas between the drive and the implant

5. CONCLUSION

- In the conditions used in this study the implants with internal hexagon connection the level of resistance to oblique load is statistically similar to the implants of external hexagon.
- In the conditions used in this study the implants with internal hexagon connection presented higher level of resistance to oblique load in comparison to the internal conical implants.
- In the conditions used in this study the level of resistance to oblique load of the external hexagon implants and internal conical are similar.
- All the three models of connections present high resistance to the oblique load.
- In the conditions used in this study the implants with internal hexagon connection presented level of resistance to the yield torque statistically different when compared to the implants of external hexagon and internal conical.
- In the conditions used in this study the level of resistance to the insertion torque is similar for extern and internal conical implants.
- All the three models of connections present high resistance to the yield torque once the maximum torque for insertion recommended by the manufacturer is 80N.cm for all the models.

6. ACKNOWLEDGMENTS

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8. RESPONSIBILITY NOTICE

The authors Michel Aislan Dantas Soares, Vinicius Augusto Pereira, André Zaninetti dos Santos, Ariel Lenharo and Nelis Evangelista Luiz are the only responsible for the printed material included in this paper.