THE INFLUENCE OF INSERTION TORQUE ON PEDICULAR SCREWS' PULLOUT RESISTANCE

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SUMMARY

Mechanical assays were performed in order to evaluate the effect of the insertion torque on the pullout resistance of pedicular screws. Thirty vertebrae of Landrace pigs were used in the study, with 5-mm screws being inserted into the vertebral pedicles. The pilot hole was drilled with 1.5, 3.8 and 4.5 mm burrs. Mechanical assays of implant pullout resistance were performed with a universal testing machine. An increase in the insertion torque of the screws was observed when a pilot hole with a smaller diameter than the inner diameter of the screw was drilled, and a reduction was observed when the diameter of the pilot hole was larger than the inner diameter of the screw. A statistically significant difference in the insertion torque values was observed. The pullout resistance of the implants increased when the pilot hole had a smaller diameter than the inner diameter of the screw and decreased when the pilot hole had a larger diameter than the inner diameter of the screw. A statistically significant difference in implant pullout resistance was observed only when the diameter of the pilot hole was larger than the inner diameter of the screw.

Keywords: *Spine. Bone screws, Biomechanics, Orthopedic fixation devices.*

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INTRODUCTION

The anchorage of pedicular screws inside the vertebra and their pullout resistance is related to the integrity and mineral density of the bone, to the design and kind of thread, to the preparation of the pilot hole and to insertion torque. All these variables influence a fixation system's stability and may affect the end outcome of the treatment when a vertebral fixation system fails(1-5).

The objective of this study was to assess the influence of insertion torque on pedicular screws' pullout resistance.

MATERIALS AND METHODS

Thirty vertebrae of Landrace breed swine with mean age of 90 days and approximate weight of 55Kg. The vertebrae on lumbar region (L1 - L6) and distal thoracic region (T13 - T14) were selected for the study.

The implant used in the study was the steel pedicular screw with 30 mm in length, 5 mm of outer diameter (thread diameter) and 3.8 mm of inner diameter (screw core diameter) (USS1-Synthes Screw) (Figure 1). The pilot hole was made using cutting drills.

The experimental model was based on the insertion of implants into the vertebral pedicle under direct view and orientation of the classical anatomical references. The drilling of the hole was made with drills, and the diameters of the holes were smaller (2.5 mm), similar (3.8 mm) or larger (4.5 mm) than screw's inner diameter. The screws were manually introduced into vertebral pedicles, with its insertion torque being measured by a torquimeter (Mackena). With the purpose of maintaining the drilling angle and of providing support and stability for the torquimeter, a fixed guide was built for screw insertion (Figure 2).

Three experimental groups were assigned according to each drilling diameter:

Group I – perforation with 2.5 mm drill.

Group II – perforation with 3.8 mm drill.

Group III – perforation with 4.8 mm drill.

Implants' pullout resistance was assessed by means of mechanical assays, using the Universal Assay Machine. The set constituted of the vertebra and the screw inserted into it was fixated to the bench vise, and the pullout strength applied through the proximal portion of the screw. A pre-load of 40 N with 30 seconds of accommodation time, followed by continuous and progressive load application at a speed of 10 mm/ minute.

Values for maximum pullout strength and maximum insertion torque resulting from the mechanical assays were statistically assessed, first with a parametric test, followed by ANOVA for comparing significant differences and, then, for obtaining the significant difference values, the Bonferroni's method was employed. A significance level of 5% ($p<0.05$) was adopted on the statistical tests performed.

RESULTS

Pedicular screws insertion torque behavior was inversely proportional to the perforation diameter against screw's inner diameter. An increased insertion torque was seen on screws as the pilot hole diameter was reduced over the screw's inner diameter, and a reduced insertion torque of the implants with the increased hole diameter. Implants'mean insertion torque for 2.5 mm perforation was 138.90 ± 21.44 N.m; 100.60 ± 21.05 N.m for 3.8mm, and 77.80 ± 18.46 N.m for 4.5mm perforations. In this Group, a statistical difference was found between insertion torque values and the different perforation diameters. ($p<0.05$). (Figure 2 and Table 1)

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Pedicular screws' pullout resistance was also inversely proportional to the pilot hole diameter. The mean maximum pullout strength was 1014.67±153.33 N for 2.5mm perforations; 996.97±107.43 N for 3.8mm perforations, and 862.61±141.17 N for 4.5mm perforations (Figure 3 and Table 2). No significant statistical difference was found between the values for 2.5 mm and 3.8 mm perforations. However, values for 4.5 mm perforation did show a statistical difference compared to those of the 3.8 mm perforations (Figure 3 and Table 2). The implants' insertion torque showed correlation with the implants' pullout resistance only for the values of perforations smaller than the inner diameter of the screw.

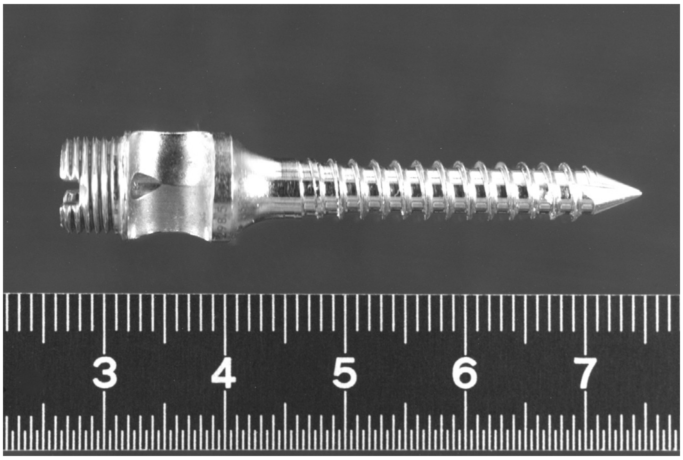

Figure 1 – *Photograph of the USS (Synthes) screw with 5mm of outer diameter and 3.8mm of inner diameter used on the mechanical assays.*

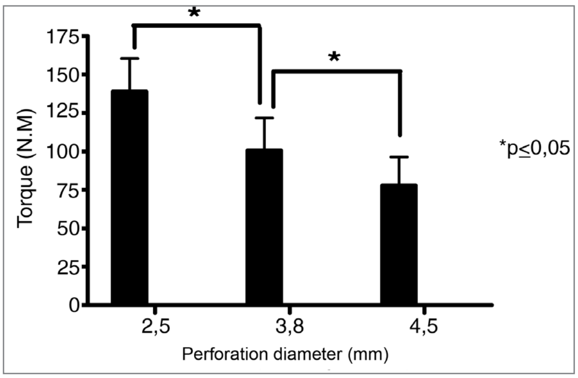

Figure 2 – *Graph illustrating the mean insertion torque value for screws with different pilot hole diameters. The asterisk (*) indicates a significant statistical difference between the groups.*

Torque(N.m)	2,5mm	3,8mm	4,5mm
	120	107	95
	118	85	42
	118	106	87
	140	146	72
	131	113	67
	126	92	82
	160	91	77
	184	72	112
	153	82	72
	139	112	72
Average	138,9	100,6	77,8
SD	21,44	21,05	18,46

Table 1- *Insertion torque values with different perforation diameters of the pilot hole (2.5mm; 3.8mm and 4.5mm). The individual values for each assay and the average + standard deviation of the values achieved in all assays performed are presented here.*

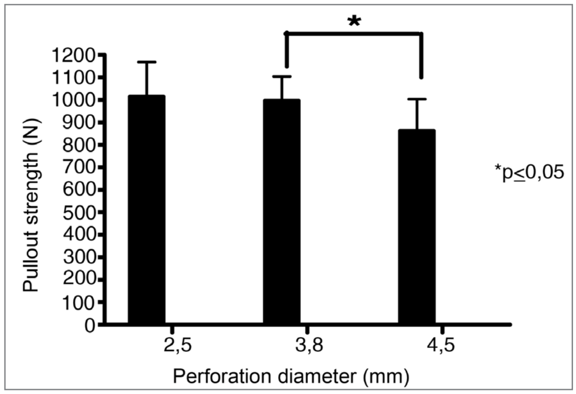

Figure 3 – *Graph illustrating the mean maximum pullout strength for implants with different pilot hole diameters. The asterisk (*) indicates a statistical difference between groups.*

Strength (N)	2,5mm	3,8mm	4,5mm
	952,51	1049,45	706,41
	1173,51	987,08	662,35
	1241,31	1170,12	955,9
	1086,74	1187,07	927,42
	804,04	917,25	789,12
	1086,06	948,44	860,98
	1109,79	911,15	986,4
	1029,11	943,69	696,24
	845,39	871,15	978,27
	818,27	984,37	1063,01
Average	1014,67	996,97	862,61
SD	153,33	107,43	141,16

Table 2- *Maximum pullout strength of screws with different perforating diameters of the pilot hole (2.5mm; 3.8mm and 4.5mm). The individual values for each assay and the average + standard deviation of the values achieved in all assays performed are presented here*

DISCUSSION

Implants' pullout resistance is related with a number of factors, including the insertion torque[3,6-8]. The insertion torque has been represented by the equation: insertion torque = pullout resistance/1142 + 0.02 and its value expressed as Newtons. meter[2].

By building a pilot hole, the insertion torque is reduced, and the results found on mechanical assays performed are consistent with this statement[2]. With the increased diameter of the pilot hole, the insertion torque was reduced, with a statistical difference being seen between values. That phenomenon would be correlated with bone removal during pilot hole drilling, which would affect the anchorage of the implant. As the pilot hole's diameter increases, a larger amount of bone is removed, and a smaller amount of bone is available to be compacted around the implant, thus reducing the insertion torque.

The correlation between insertion torque and implants' pullout resistance has been presented as a controversial subject in literature reports addressing the matter, where reports exist on the correlation between insertion torque and pullout resistance[1,5,9-12] next to other reports not finding such correlation[13,14].

Screws' resistance to pullout is a complex phenomenon and dependant on a number of factors[2,15]. In mechanical assays with screws inserted into wooden, polyurethane and bovine bone bodies we found a correlation between pilot hole reduction and increased pullout resistance. However, in the present study, this correlation was not found in the assays with screws inserted into swine vertebral pedicles, and, probably, this fact is correlated with the participation of other variables acting on implants' pullout resistance.

In our study, we tried to establish a correlation between insertion torque and a given screw's pullout resistance using the diameter of the pilot hole compared to the inner diameter of the screw for establishing this correlation. It must be highlighted that, in other studies, this correlation was established for the assessment and comparison of different kinds of screws, which were inserted not taking the variable related to the pilot hole into account, valuing the individual characteristics of each implant[9,12,14].

The results of those assays evidenced the importance of a larger diameter of the pilot hole compared to the inner diameter of the screw for reducing insertion torque and screws' pullout resistance, showing a statistical difference of the results. This finding reinforces the need of selecting a pilot hole's diameter, showing that values above screw's inner diameter reduce its pullout resistance and compromise a fixation system's mechanical properties.

We couldn't establish a correlation between increased insertion torque and increased screws' pullout resistance based on the analysis of data drawn from the mechanical assays performed in this study. The required torque increase for compacting a spongy bone around a screw may explain the increased torque. However, the amount of compacted spongy bone was not enough to increase pullout resistance, or the limit of compacted bone depends at some extension on the size of a screw's thread, and cannot be infinitely increased by the reduction of the pilot hole's diameter. However, a larger pilot hole removes a larger amount of bone tissue, thus reducing the amount of compacted bone and an implant's insertion torque, accompanied by a reduced implant's pullout resistance.

CONCLUSION

Pedicular screws' insertion torque was shown to increase with the reduced diameter of the pilot hole compared to screw's inner diameter, and to reduce with a wider pilot hole.

A reduced pullout resistance was found for implants of which pilot holes were drilled with a wider diameter than the screw's inner diameter.

The insertion torque of the implants showed a correlation with pullout resistance only for perforation values smaller than the inner diameter of the screw.

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