STUDY OF THE INFLUENCE OF THE TYPE OF PILOT HOLE PREPARATION AND TAPPING ON PEDICULAR SCREWS FIXATION

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SUMMARY

Mechanical assays were performed with screws of the USIS vertebral fixation system for the study of the influence of type of pilot hole preparation with probe or burr and tapping of the pilot hole pathway on pedicular screw pullout. The screws were inserted into wood, polyurethane and bovine bone test bodies. The pilot hole was prepared with probes and burrs of 3.5 mm. Three experimental groups were formed: I -drilling with a probe, II - drilling with a burr, and III – drilling with burr and tapping. After screw insertion into the test bodies, pullout assays were performed with a universal test machine. Increased screw pullout resistance was observed when the pilot hole was drilled with a probe, with a statistically significant difference compared to preparation with a burr and with a burr in combination with tapping. No difference in screw pullout resistance was observed with tapping of the pilot hole pathway.

Keywords: *Fracture fixation; Bone screws; Spine.*

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INTRODUCTION

The history of vertebral spine surgery is closely related to vertebral arthrodesis and fixation systems use. Vertebral fixation systems' mechanical functions performance is associated to its mechanical properties and to the anchorage of its supporting elements on vertebrae[1-4].

The anchorage of fixation systems on vertebrae is directly related to the mechanical properties of the interface between implants and bone tissue. Screws have been frequently used as anchorage elements for vertebral fixation systems and their mechanical properties are correlated to several factors, such as bone tissue's mineral density, the design and dimensions of its thread, its outer diameter, and pilot hole preparation[5,2,6,7].

Pilot holes are made for guiding and enabling screw insertion into the vertebra. Pilot hole preparation can be made by drills or probes, and their channel can be tapped[5,8] .

The need and the potential biomechanical advantages of the kind of pilot hole preparation and pathway tapping have been a controversial topic in literature addressing this matter, and this was the purpose of this study

The objective of the study was to examine the influence of pilot holes preparation, considering the use of drills, probes and pathway tapping, over pullout resistance of implants employed on spinal fixation, using different test bodies.

MATERIALS AND METHODS

For the present study, we used test bodies made of polyurethane, wood and bovine bone. Thickness of the test bodies was determined based on the difficulty to perform pullout tests on implants during a pilot study. Polyurethane test bodies were 27-mm thick, the wooden ones 13-mm, and bovine bone test bodies were 17-mm thick. The test body made of bovine bone was constituted of the central metaphyseal and femoral distal portions, which were prepared with the aid of a saw, removing the external cortical bone and shaping 17-mm thick spongy bone segments.

The implant used in this study was the USIS system's pedicular screw (Ulrich), of which outer diameter is 6 mm and inner diameter 3.5 mm (Figure 1). Screws were implanted on corresponding test bodies my making a 3.5-mm wide pilot hole, which corresponded to the inner diameter (core diameter) of the screw.

Once the pilot hole was built, the screw was inserted on test body, transfixing it and leaving exposed 1 cm of its distal end. Thus, the thread number of the screws inserted into the test bodies was constant, and the exposed distal end of the screw was used for applying load during mechanical assays addressing pullout resistance.

The experimental groups were constituted according to the way in which the pilot hole was prepared: group I - perforation with probe (3.5 mm), group II - perforation with 3.5-mm drill, and group III - perforation with 3.5-mm drill and pilot hole tapping.

The test bodies with corresponding implants were submitted to mechanical assays performed on a universal assay machine (EMIC® model, Brazil), attached to a computer and a 200-kgf load cell, for assessing implants' pullout resis-

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tance. The mechanical assay for assessing pullout resistance was performed by setting up an axial load along of screw's axis from its end, determining the maximum strength required for pullout. Figure 2 shows a graph generated by the computer attached to the universal assay machine and the values recorded during each test, a depiction on polyurethane test body and another one on bovine bone, respectively. Ten mechanical assays were performed on the groups using wooden and polyurethane test bodies and 15 assays were conducted on the bovine bone group. The results achieved were compared by means of statistical study, with variance analysis (ANOVA) being used and significance level of p≤ 0.05. Bonferroni's post hoc test was employed for comparing the different methods of preparing a pilot hole.

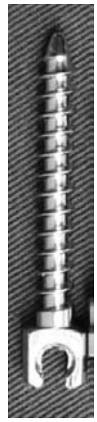

Figure 1 - *USIS (Ulrich) system screw with 6mm of outer diameter and 3.5 mm of inner diameter.*

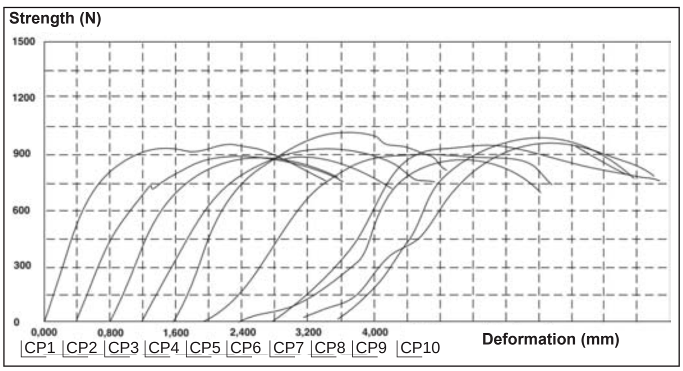

Figure 2 - *Graph generated by the computer attached to the universal assay machine and measurement values for each mechanical assay.*

	Average maximum strength (N)	Standard Deviation	Variation coefficient (%)	Number of tests performed
3.5-mm probe	*942.6	50.13	5.318	10
3.5-mm drill w/o tapping	848.2	81.28	9.583	10
3.5-mm drill with tapping	883.2	85.5	9.681	10

Table 1 - *Values for implants' maximum pullout strength on wooden test bodies.(*) Statistical difference from other values.*

	Average maximum strength (N)	Standard Deviation	Variation coefficient (%)	Number of tests performed
3.5-mm probe	*73.45	5.914	8.051	10
3.5-mm drill w/o tapping	63.96	1.517	2.372	10
3.5-mm drill with tapping	62.24	3.332	5.353	10

Table 2 - *Values for implants' maximum pullout strength on polyurethane test bodies.(*) Statistical difference from other values.*

	Average maximum strength (N)	Standard Deviation	Variation coefficient (%)	Number of tests performed
3.5-mm probe	*1134	243.0	21.43	15
3.5-mm drill w/o tapping	903.9	213.2	23.59	15
3.5-mm drill with tapping	857.3	254.7	29.71	15

Table 3 - *Values for implants' maximum pullout strength on bovine bone test bodies.(*) Statistical difference from other values.*

RESULTS

The measurements in mechanical assays, considering the average of implants' maximum pullout strength values on different test bodies, are represented on Tables 1, 2 and 3, and on Figures 3, 4 and 5.

In Group I (perforation with 3.5-mm probe), the averages for implants' maximum pullout strength values were 942.5 ± 50.13 (N) for wooden test bodies; 73.45 ± 5.914 (N) for polyurethane test bodies, and; 1134 ± 243 for test bodies made of bovine bone.

In group II (perforation with 3.5-mm drill), the average for implants' maximum pullout strength values were 848.2 ± 81.28 (N) for wooden test bodies; 63.96 ± 1.517 (N) for polyurethane test bodies, and; 903.9 ± 213.2 for test bodies made of bovine bone.

In group III (perforation with 3.5-mm drill followed by pilot hole tapping), the averages for implants' maximum pullout strength values were 883.2 ± 85.5 (N) for wooden test bodies; 62.24 ± 3.332 (N) for polyurethane test bodies, and; 857.3 ± 254.7 for test bodies made of bovine bone.

The comparison of values found for implants' pullout, considering the method of pilot hole preparation and the different test bodies (wood, polyurethane and bone) is represented by graphs (Figures 3, 4 and 5). In wooden test bodies, we found that the implants' maximum pullout strength was greater for group I (perforation with 3.5-mm probe) showing a statistical difference (p=0.03) between group II (perforation with 3.5-mm drill). Nevertheless, no statistical difference was seen between group I (perforation with 3.5-mm probe) and group III (perforation with 3.5-mm drill followed by tapping). Also, no statistical difference was found for values of group II and III.

On polyurethane test bodies, we found that implants' maximum pullout strength was greater for group I (perforation with 3.5-mm probe) and a statistical difference (p<0.001) was found between group I and groups II and III, of which values did not present significant statistical differences.

On bovine bones test bodies, we also found that implants' maximum pullout strength was greater for group I (perforation with 3.5-mm probe) and a statistical difference (p=0.006) was found between group I and groups II and III, of which values did not present significant statistical differences.

The analysis of results shows that by performing a pilot hole with a drill of equal width to screw's inner diameter increased implants' pullout resistance when compared to the perforation made with a drill of similarly equal diameter to screw's inner width. The pilot hole pathway tapping built with a drill as wide as screw's inner diameter did not produce significant statistical change on implants' pullout resistance.

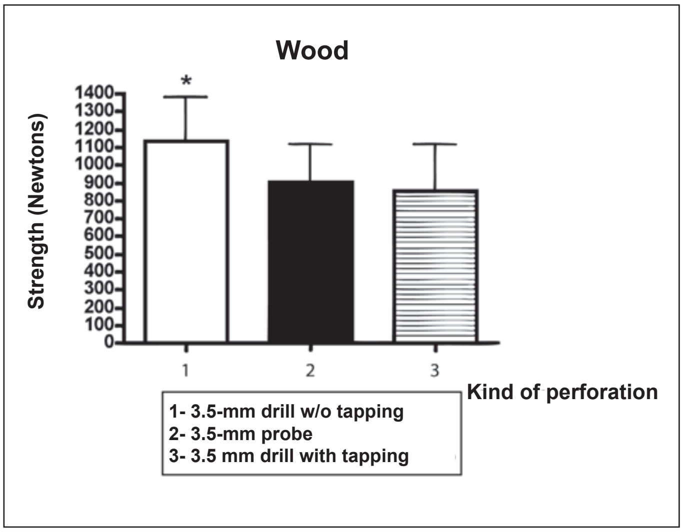

Figure 3 - *Average maximum pullout strength on wooden test bodies and the different perforations and pilot hole preparations.*

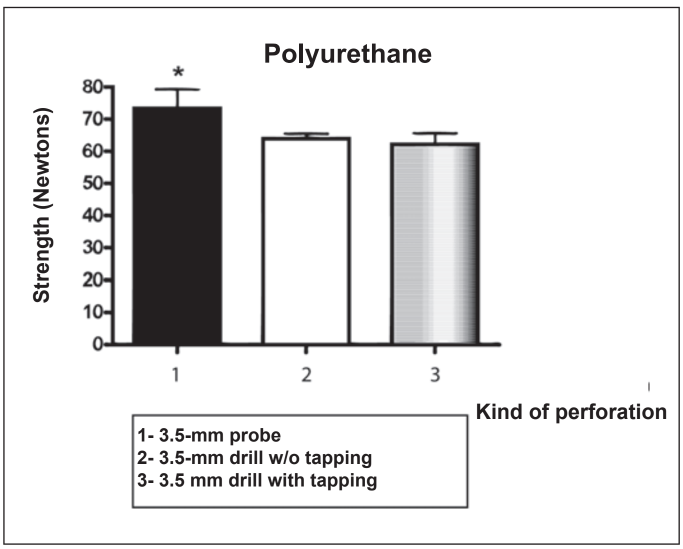

Figure 4 - *Average maximum pullout strength on polyurethane test bodies and the different perforations and pilot hole preparations.*

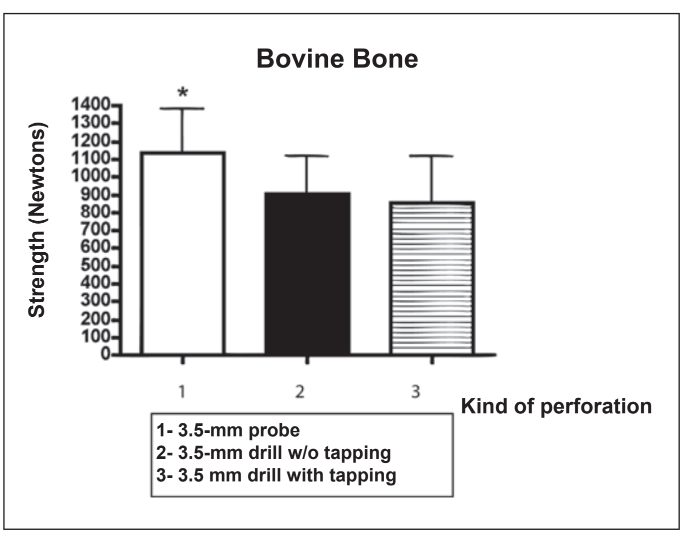

Figure 5 - *Average maximum pullout strength on bovine bone test bodies and the different perforations and pilot hole preparations.*

DISCUSSION

Inserting screws into vertebrae is a commonly employed technical step, which is largely important for spinal surgeries, because screw's anchorage on vertebrae is the ground for fixation system's biomechanical function performance[4,5,8,9]. The insertion technique, pilot hole preparation, screw design and mineral integrity and density of a bone tissue influence screw's fixation degree on bone tissue, and, thus, the stability of a fixation system and the end result of the treatment[8,10-12].

Pilot hole building is associated to a number of variables, especially its diameter, preparation, and pathway tapping[6,10,12-16]. Building a pilot hole allows for a previous guidance and determination of a screw's pathway and length, which, due to the importance of vascular and nervous structures associated to vertebral anatomy, improve safety of a surgical procedure[6,11].

Screw resistance at flexion moments is related to its inner diameter, while its pullout resistance is related to its outer diameter, thread diameter, depth and design[5, 6,8,15,16]. Pullout resistance is proportional to the bone volume between screw's threads[5,8, 15-17].

We noticed in our assays that the use of a probe for building a pilot hole increased screws' pullout resistance compared to the use of drills to build it. The use of probes would cause compression and compaction of spongy vertebral bone around the implant, increasing its pullout resistance. Building a pilot hole with drills cause bone tissue removal, reducing screw's pullout resistance. Spongy tissue integrity affects the insertion torque versus pullout resistance ratio[6,14-16,18] . However, the influence of the pilot hole preparation was not reported by Daftari et al.[14] and George[19], who did not find differences on implants' pullout resistance when preparing a pilot hole with drills or probes.

Pilot hole's pathway tapping has been described as a factor reducing screws' pullout resistance[5,6,14,19]. However, we didn't find differences on tapping over implants' pullout resistance in assays conducted on the different test bodies, which are consistent to reports by Ronderos et al.[20]. Tapping has been described as being associated to implants' pullout resistance and to disadvantageous use on soft materials, resulting in reduced pullout resistance due to the structural changes it causes on spongy vertebral bone[5]. Carmouche et al.[13] reported implants' pullout resistance reduction with the tapping of a pilot hole pathway in lumbar osteoporotic vertebrae. The test bodies used in this study did not simulate osteoporosis, which could explain why a negative effect of the pilot hole pathway tapping was not found. There are reports suggesting that tapping would reduce implants' pullout resistance on osteoporotic bones, but this would be less relevant on normal bones[5,12,21,20].

The assay model we used in this study was designed to simply simulate the strength required for pulling out implants, and, although it does not reproduce physiological conditions of strength applied on fixation systems, it allows for a reliable comparison and evaluation of the parameters studied. Implants' pullout resistance is a complex and multifactorial phenomenon, and it is associated to several factors, such as screw design, kind and diameter of screw's thread, bone density and biological responses (re-absorption and remodeling) that occur on a bone adjacent to the implant[5,12, 17,19,22].

CONCLUSIONS

Preparing a pilot hole with probes increased screw's pullout resistance in all mechanical assays performed on wooden, polyurethane and bovine bone test bodies, compared to the values found with the use of drills for preparing a pilot hole. Tapping a pilot hole's pathway using drills did not change pullout resistance levels of implants used in this mechanical pullout assay.

REFERENCES

1. Chen SI, Lin RM, Chang CH. Biomechanical investigation of pedicle screw-vertebrae complex: a finite element approach using bonded and contact interface conditions. Med Eng Phys. 2003; 25:275-82.
2. Edwards CC, Garfin SR, Melkerson MN, Mishra NK, Winter RB, Yuan HA. Symposium: lumbar spine fixation--the pedicle screw controversy. Contemp Orthop. 1994; 29:439-54.
3. Simmons JW, Andersson GB, Russell GS, Hadjipavlou AG. A prospective study of 342 patients using transpedicular fixation instrumentation for lumbosacral spine arthrodesis. J Spinal Disord. 1998; 11:367-74.
4. Defino HL, Vendrame JR. Role of cortical and cancellous bone of the vertebral pedicle in implant fixation. Eur Spine. J 2001; 10:325-33.
5. Benzel E. Biomechanics of spine stabilization. New York: Thieme, 2001.
6. Öktenoglu B, Ferreira L, Andalkar B, Özer A, Sario¨glu A, Benzel E. Effects of hole preparation on screw pullout resistance and insertional torque: a biomechanical study. J Neurosurg. 2006; 94:91-6.
7. Van Ooterwyck K, Duyck J, Vander S, Van der Perre G, De Cooman M, Lievens S.,et al. I. The influence of bone mechanical properties and implant fixation upon bone loading around implants. Clin Oral Impl Res. 1998; 9:407-18.
8. Brownwe D, Jupiter J, Levine A, Trafton P. Skeletal Trauma. Philadelphia: Saunders; 1998.
9. Wagner H. Die Einbettung von Metallschrauben im Knochen und die Heilungsvorgänge des Knochengewebes unter dem Einfluss der stabilen Osteosynthese. Langenbecks Arch Klin Chir. 1963; 305:28-40.
10. Abrahão F, Shimano A, Defino H. Estudo da influência da técnica de preparação dos pedículos vertebrais na resistência ao arrancamento dos implantes. COLUNA/COLUMNA. 2003; 2:111-7.
11. Boos N, Webb JK. Pedicle screw fixation in spinal disorders: a European view. Eur Spine J. 1997; 6:2-18.
12. Brantley AG, Mayfield JK, Koeneman JB, Clark KR. The effects of pedicle screw fit. An in vitro study. Spine. 1994; 19:1752-8.
13. Carmouche JJ, Molinari RW, Gerlinger T, Devine J, Patience T. Effects of pilot hole preparation technique on pedicle screw fixation in different regions of the osteoporotic thoracic and lumbar spine. J Neurosurg Spine. 2005; 3:364-70.
14. Daftari TK, Horton WC, Hutton WC. Correlations between screw hole preparation, torque of insertion, and pullout strength for spinal screws. J Spinal Disord. 1994; 7:139-45.
15. Skinner R, Maybee J, Transfeldt E, Venter R, Chalmers W. Experimental pullout testing and comparison of variables in transpedicular screw fixation. A biomechanical study. Spine. 1990; 15:195-201.
16. Smith SA, Abitbol JJ, Carlson GD, Anderson DR, Taggart KW, et al. The effects of depth of penetration, screw orientation, and bone density on sacral screw fixation. Spine. 1993;18:1006-10.
17. Schtzker J, Horne J. The reaction of cortical bone to compression by screw threads. Clin Orthop Relat Res. 1975; (111):263-5.
18. Kwok AW, Finkelstein JA, Woodside T, Hearn TC, Hu RW. Insertional torque and pull-out strengths of conical and cylindrical pedicle screws in cadaveric bone. Spine. 1996; 21:2429-34.
19. George DC, Krag MH, Johnson CC, Van Hal ME, Haugh LD, Grobler LJ. Hole preparation techniques for transpedicle screws. Effect on pull-out strength from human cadaveric vertebrae. Spine. 1991; 16:181-4.
20. Ronderos JF, Jacobowitz R, Sonntag VK, Crawford NR, Dickman CA. Comparative pull-out strength of tapped and untapped pilot holes for bicortical anterior cervical screws. Spine. 1997; 22:167-70.
21. Phillips J, Rahn B. Comparison of compression and torque measurements of self- tapping and pre-tapped screw. Plas Reconstr Surg. 1989; 83:447-56.
22. Koranyi E, Bowman C, Knecht C. Holding power of orthopedic crews in bone. Clin Orthop Relat Res. 1970; (72):283-6.