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What is the Effect of Pedicle Screw Reinsertion Through the Same Trajectory on Pullout Strength?

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ABSTRACT

AIM: To investigate the pullout strength of a pedicle screw reinserted through the same trajectory

MATERIAL and METHODS: Fifty freshly frozen lamb L4 vertebrae were divided into the following five groups: Group 1, inserted with a 5-mm pedicle screw; Group 2, inserted with a 5-mm pedicle screw followed by the removal and reinsertion of the same screw after control; Group 3, inserted with a 5-mm pedicle screw followed by the removal and reinsertion of a 5.5-mm screw after control; Group 4, inserted with a 5.5-mm pedicle screw; and Group 5, inserted with a 5.5-mm pedicle screw followed by the removal and reinsertion of the same screw after control. Pedicle screws were inserted into the right pedicles, and axial pullout testing was performed at 5 mm/min. All data were recorded. A load-displacement curve was used to obtain the peak value of the pullout strength for all specimens.

RESULTS: The mean pullout strengths were 1086.22 N, 1043.32 N, 1039.18, 1199.10, and 1131.68 N for Groups 1–5, respectively. No significant difference was observed among all groups ($p>0.05$).

CONCLUSION: Perioperative reinsertion of the same screw or 0.5 larger in diameter through the same trajectory after the control of the screw trajectory did not affect the pullout strength of the screw.

KEYWORDS: Biomechanics, Lumbar vertebrae, Pedicle screw, Tensile Strength

INTRODUCTION

Transpedicular screw fixation has been widely used in spinal surgery in the last two decades. Screw breakage, bending, and loosening signify implant failures after spinal surgery (12,19,20). Many different screw insertion techniques have already been used by surgeons (5,8,12,19). Some surgeons use the tapped or untapped technique with or without fluoroscopy. Other surgeons use the freehand insertion technique with the pilot hole on the cortex of the pedicle (5,19). After inserting the pedicle screw, lateral and anteroposterior fluoroscopic controls are used to control the screw location. Once the surgeon identifies the screw location after fluoroscopic control, whether there is a suspicion, the screw is removed, and the pedicle wall is controlled by a probe. If the pedicle walls are intact, the screw is reinserted. If the walls are not intact, the screw trajectory must be changed. The pullout force is influenced by bone mineral density, insertional

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torque, thread, core diameter of the screw, and depth and diameter of the pilot hole. Studies showing the pullout force of the screw after the control and reinsertion of the same or thicker screw (in diameter) were limited (1,2,5,6,9,11,14,15). Therefore, this study aimed to investigate the pullout force of different screw diameters after their removal and reinsertion to prevent intraoperative pedicle screw loosening.

MATERIAL and METHODS

This study was conducted at the School of Medicine Health Science Institute Biomechanics Laboratory and approved by the ethics committee of the affiliated institution. Lamb spinal materials, which are similar to the in vivo model used in Smith's study, were used (22).

Specimen Preparation

Fifty freshly frozen lamb L4 vertebrae were selected from 50 specimens obtained from a meat-cutting institute in the municipality of Izmir. All specimens were stored at –35°C until the preparation and testing. The average lamb age was 12.6 ± 2.76 (10-15) months. The average weight of the lambs was 31.7 ± 3.14 (range 28–34) kg. The specimens were free of macroscopic and radiological diseases. Before biomechanical testing, all specimens were thawed at room temperature, and soft-tissue attachments were carefully dissected.

Screw Technical Data

An experienced spinal surgeon inserted a 5–5.5-mm diameter titanium self-tapping pedicle screws (Piron Spine, Izmir, Turkey) to the right pedicle of each specimen (30 mm in depth) at the same angle (Figure 1A). A digital torque adapter (Wisretec-WRG2-030, Shanghai, China) was used at the insertion stage of each screw, and the values were recorded (Figure 1B). Torque measurements were obtained for every screw insertion, as in Lorenz et al.'s study (18).

Biomechanical Setup

A special pullout test device was designed for this study. Our test setup was established to prevent the vertebrae pullout during axial screw pullout as shown in Figure 2. The axial compression-testing machine was used (AG-I 10 kN, Shimadzu, Japan) (Figure 3). Direct pullout strength was described using the ASTM-F-543-02 standard4. Pullout direction displacement was imposed at a constant rate of 5 mm/min until screw failure. Peak pullout strength was measured in newtons. The lamb spinal models underwent bone mineral density (BMD) testing and an indentation test (following all tests) to measure the bone quality at L4.

Bone Mineral Density Measurement

BMD was quantitatively measured by dual-energy radiograph absorptiometry (Stratos dr 2D Gallargues-le-Montueux-France) using the anteroposterior view of the L1–L4 vertebrae (Figure 4) (23).

Experimental Setup

The freehand technique with a pilot hole to the pedicle cortex was used (width 4 mm, depth 3 mm). The vertebrae were randomly divided into the following five groups: Group 1, inserted with a 5-mm pedicle screw; Group 2, inserted with a 5-mm pedicle screw followed by the removal and reinsertion of the same screw after control; Group 3, inserted with a 5-mm pedicle screw followed by the removal and reinsertion of a 5.5-mm screw after control; Group 4, inserted with a 5.5-mm pedicle screw; and Group 5, inserted with a 5.5-mm pedicle screw followed by the removal and reinsertion of the same screw after control. The specimens were carefully inspected, and if pedicle-wall breakage was detected, the specimen was excluded from the study.

Statistical Analysis

The mean pullout force and standard deviation values for the five groups were calculated. The mean pullout strengths for each group were statistically analyzed with the Mann-Whitney U test; BMD and torque values were analyzed with the Kruskal–Wallis test (Statistical Package for the Social Sciences, v. 15.0; SPSS, Chicago, IL, USA). Statistical results with $p<0.05$ were accepted as significant.

RESULTS

Regarding the experimental results of the pullout tests, the mean and standard deviation values of the test groups are

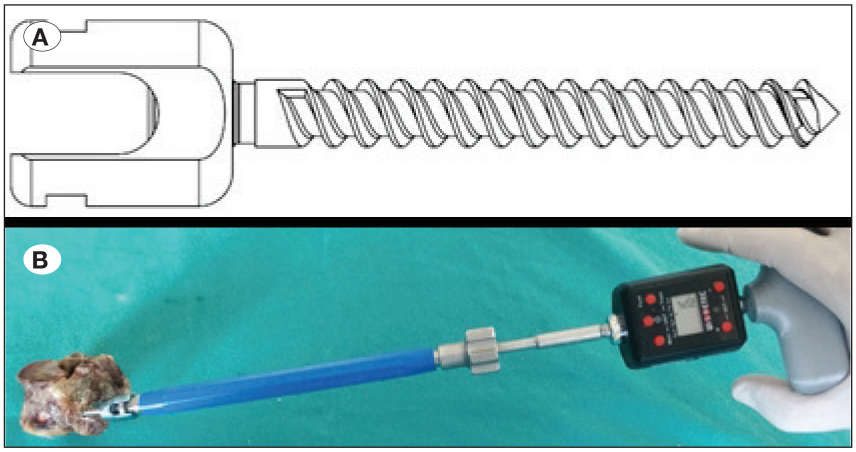

Figure 1: A) General view of the pedicle screw used (thread, inner and outer diameter are shown in the figure) (Piron İnc., Izmir, Turkey). **B)** Screw insertion with digital torque meter screwdriver.

shown in Tables I and II. Three, three, and two specimens in Groups 1, 4, and 5 were removed from the study due to pedicle bone fractures (Figure 5). The results for all groups are shown in the bar graph in Figure 6. For each specimen, a load-displacement curve was used to obtain the peak value of the pullout strength. The mean pullout strengths were 1086.22 N, 1043.32 N, 1039.18 N, 1199.10 N, and 1131.68 N for Groups 1–5, respectively.

In our study, no significant difference was found between groups of screw insertions recorded with a digital torque meter (p=0.999). No significant difference in the BMD of L4 vertebrae was observed between groups (p=0.765) (Table III).

No statistically significant difference was observed between Groups 1 and 2 (p=0.770) or between Groups 2 and 3 (p=1.000). Group 3 also had no statistically significant difference in pullout strength when compared to Groups 4 and 5 (p=0.172 and p=0.374, respectively). No significant differences in pullout strength were observed among all groups.

Figure 2: White arrow shows red mark for standard insertion of the screw.

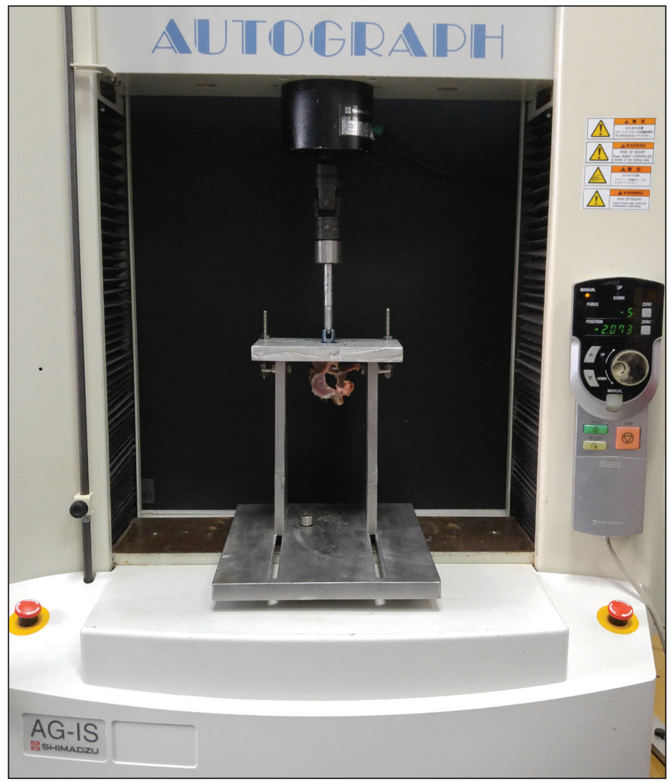

Figure 3: Pullout test setup using L4 ovine vertebrae (AG-I 10 kN, Shimadzu, Japan).

Table I: Experimental Results of Pullout Test (N)

Specimen	Group 1	Group 2	Group 3	Group 4	Group 5
1	x	930.78	878.75	x	x
2	1175.84	722.19	929.06	1580.16	1291.72
3	1167.19	718.91	1009.69	1120.16	1111.09
4	x	1503.28	1253.28	1014.53	1263.91
5	1326.09	1041.56	1195.94	1292.81	1051.88
6	812.19	626.41	479.53	x	x
7	1022.56	1305.47	1206.88	1048.59	1137.81
8	x	1335.63	1063.59	1325.31	1045.31
9	1064.22	898.59	1002.66	x	1008.75
10	1035.47	1350.47	1372.50	1012.17	1142.97

X: *Pedicle or bone fracture after the insertion of screw.*

Table II: Mean Pullout Standard Deviation Values of Test Groups

Groups	Mean pullout value (N)
Group 1	1086.22 ± 160.38
Group 2	1043.32 ± 311.95
Group 3	1039.18 ± 250.22
Group 4	1199.10 ± 211.27
Group 5	1131.68 ± 101.85

DISCUSSION

Various factors affect the pullout strength of a screw, such as a screw format (conical, cylindrical, or dual), inner and outer diameters, thread width, pitch length, BMD, insertional torque, and screw/bone interference. Cho et al. reported that larger outer diameter, smaller inner diameter, and shorter pitch increase bone screw interference, an important factor in pullout strength. They also demonstrated that a larger outer diameter is the most important factor for pullout strength in patients with osteoporosis (7). In our study, only the cylindrical

Table III: Mean Bone Mineral Density and Torque Value of Test Groups

Groups	BMD (gr/cm^2)	Torque (Nm) (Before reinsertion)	Torque (Nm)	P value
1	1.04 ± 0.16	-	1.31 ± 0.55	-
2	1.01 ± 0.15	1.30 ± 0.48	1.34 ± 0.52	0.798
3	1.02 ± 0.16	1.30 ± 0.53	1.31 ± 0.51	0.919
4	1.03 ± 0.18	-	1.36 ± 0.50	-
5	1.01 ± 0.16	1.33 ± 0.46	1.36 ± 0.49	0.461
Total	1.02 ± 0.16	-	1.33 ± 0.49	-

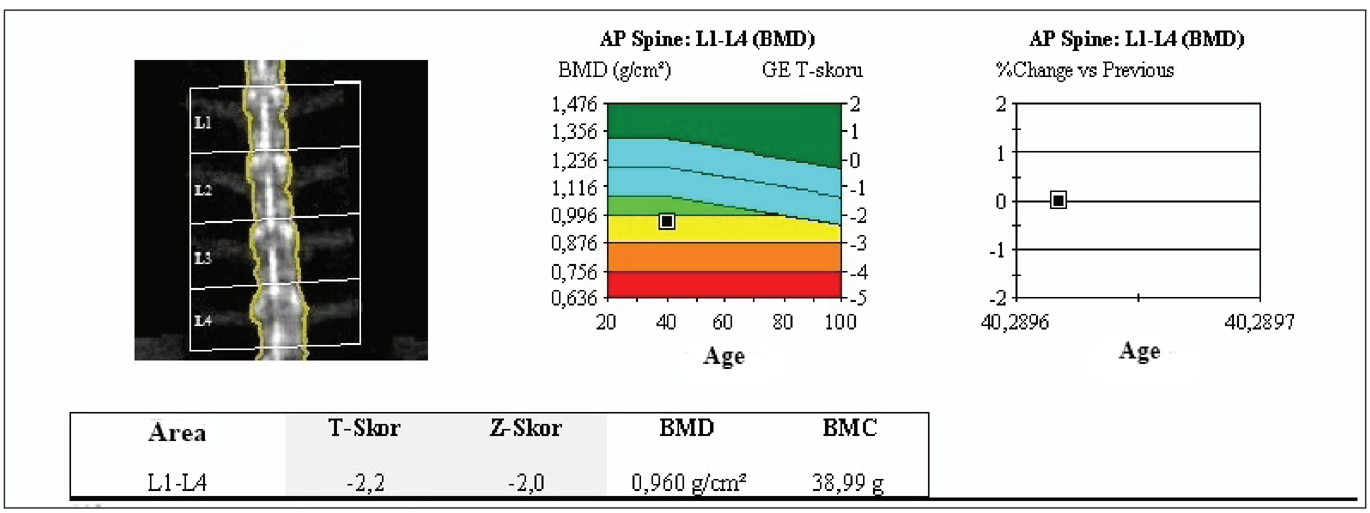

Figure 4: Measurement of bone mineral density (BMD) by dual-energy radiograph absorptiometry (DEXA).

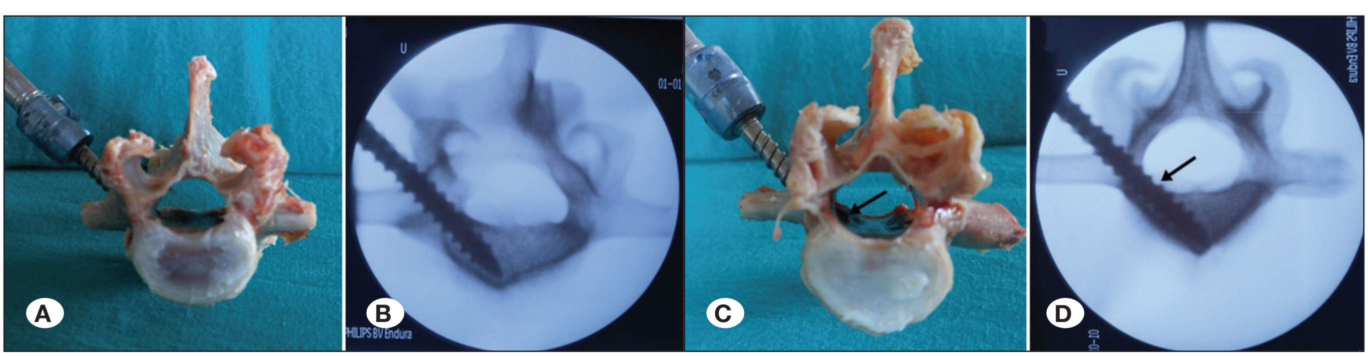

Figure 5: A) Vertebral pedicle was intact after screw insertion. **B)** Fluoroscopy showing an axial view of the screw trajectory. **C)** The image of a pedicle fracture after screw insertion. **D)** Fluoroscopy showing an axial view of the pedicle fracture.

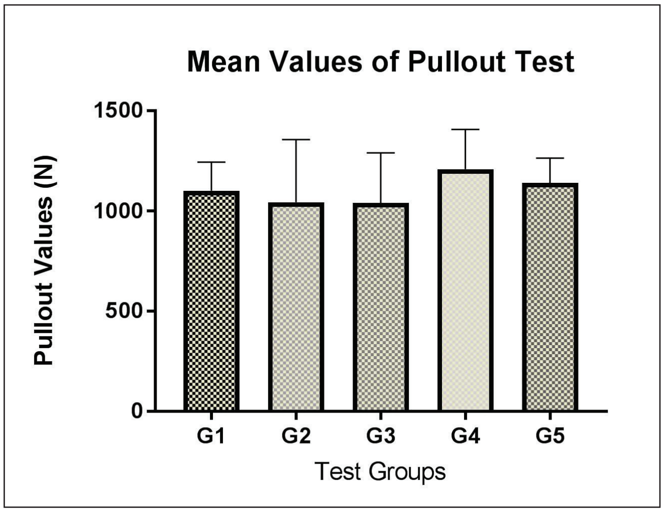

Figure 6: The mean pullout forces for each of the six screw insertion techniques were studied.

screw type was used, so that the screw type did not alter the results.

Demir et al. demonstrated that a larger core diameter increases the torsional strength of pedicle screws and that the pullout strength reduces with decreased thread depth (9,10). Polly et al. found that insertional torque was significantly decreased during the pedicle screw back-out and reinsertion. They also suggested that a larger screw diameter should be used after the control (21). In our study, no significant difference was observed between the 5-mm and 5.5-mm screws, as no significant difference was observed between Groups 2 and 3.

Some studies have reported that the complete insertion of a conical screw and drawing it out at 180° decreases the pullout strength (8,17). Lill et al. compared cylindrical and conical screws on bovine vertebrae and found a significant decrease in pullout strength of the conical screw when backing out at 180° after insertion (17). Although cylindrical screws were used, the pullout strength was not decreased by removing and reinserting the screw after control.

Kang et al. used a 5.5-mm titanium polyaxial pedicle screw on freshly frozen human thoracic vertebral levels to measure the pullout strength of the screw. They reinserted the same screw using the previous pilot hole and trajectory after removal and significantly decreased the insertional torque but no significant decrease in pullout strength (14). Instead of the same screw we used (5.5 mm in diameter) in our study, no significant decrease was observed in the pullout strength.

No significant difference in pullout strength was observed after reinserting the pedicle screws through the same trajectory in the lamb vertebrae. However, Defino et al. found that pedicle screw reinsertion through the same trajectory in polyurethane, polyethylene, wood, and cancellous bone blocks significantly decreased the insertional torque and pullout strength (8).

Lehman et al. demonstrated that a straightforward technique, in which the pedicle screw is inserted parallel to the superior endplate, increases the pullout strength (16). In our study, the freehand technique was used, wherein the pedicle screw follows the natural trajectory of the pedicle.

Brasilience et al. showed that medially misplaced screws (perforating the medial cortex) had larger mean pullout strengths when compared to well-placed pedicle screws (4). In our study, if the pedicle wall was broken, the specimen was excluded from the study to prevent misleading results. Since no significant difference was observed between groups, Groups 2 and 3 had no pedicle-wall breakage during screw insertion and more advantages over other groups.

A tap is an instrument widely used by spinal surgeons to create a thread to the inner surface of the bone, creating a line for the screw. Undertapping is a technique in which the tap has smaller inner and outer diameters than the screw. Bohl et al. found that the pullout strength in undertapping was greater than that in normal tapping (2). Helgeson et al. reported that tapping insertional torque perioperatively is an important factor in pullout strength and optimal screw-size selection (13), whereas Chatzistergos et al. found that tapping the pilot hole results in lower pullout strength when compared to undertapping or insertion of a small-diameter screw before using self-tapping pedicle screws (5).

Chin and Gibson found that the risk of a pedicle-wall breach was 1.6% after undertapping followed by screw placement (6). In our study, pedicle walls were intact after reinserting a screw of 0.5 mm larger than the hole (Group 3). However, more specimens should be evaluated to determine the correct percentage of the pedicle-wall breach.

Bostan et al. showed that the use of screws 0.5 mm larger in diameter during the pedicle screw revision did not provide satisfactory pullout strength (3). In our study, no significant difference was observed in pullout strength between the reinsertion of the same screw or one that was 0.5 mm larger in diameter after control.

The insertional torque measurement of the specimens also played a role in the pullout strength, an important limitation for our study. The freehand technique was used for screw placement. Future studies should include screws 1 mm larger in diameter and other insertion techniques. More prospective and laboratory studies should be conducted on new screw formats, thread width, and pitch length to increase the screw pullout strength in the future.

CONCLUSION

Perioperative reinsertion of the same pedicle screw or 0.5 mm larger in diameter through the same trajectory after the control of the screw trajectory did not affect the pullout strength of the screw.

AUTHORSHIP CONTRIBUTION

Study conception and design: OK, CK

Data collection: SO, IU, BH

Analysis and interpretation of results: BH, MA

Draft manuscript preparation: OK, CK

Critical revision of the article: AK, HEA

Other (study supervision, fundings, materials, etc...): HEA

All authors (OK, CK, SO, IU, BH, MA, HEA, AK) reviewed the results and approved the final version of the manuscript.

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