Facet joint violation during pedicle screw insertion: a cadaveric study of the adult lumbosacral spine comparing the two pedicle screw insertion techniques

Kook Jin Chung · Seung Woo Suh · Keny Swapnil ·
Jae Hyuk Yang · Hae Ryong Song

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Abstract This article analyses the incidence of facet joint violation by pedicle screws inserted via the two most commonly used techniques, intersection and mamillary. Pedicle screws were inserted on each side of fresh-frozen human cadaveric specimen lumbosacral spines using the two techniques. All facet joints which were violated were found to be on the right side, where the mamillary process technique was employed. The incidence of facet joint violation was higher in the mamillary technique, which was statistically significant. The intersection technique appears to be safer than the mamillary with respect to violation of the adjacent superior facet joint.

Résumé Cet article analyse l'altération de la facette articulaire par la vis pédiculaire qui est habituellement introduite selon deux techniques, celle de l'intersection ou celle de la pénétration mamillaire. Les vis étaient insérées sur les deux côtés d'un spécimen lombo-sacré cadavérique. Toutes les facettes articulaires atteintes étaient du côté de l'introduction mamillaire. La technique de l'intersection apparaît la plus sûre.

Introduction

The pedicle screw system, which was first introduced in the 1950s by Boucher [1] and popularised by Roy-Camille et al. [15] in the 1960s, is a penetrating type of anchor with resistance and offers a secure vertebral grip that enables improved control of instrumented segments and rigid fixation [8]. Since then, there have been many studies mentioning the safety of pedicle screw insertion in relation to the osseous and neural elements of the spine. Though several entry points have been described in the literature for the insertion of pedicle screws, the two which have been the most widely used are the intersection technique and the mamillary process technique. Even though many studies about complications following transpedicular instrumentation have been reported [2, 11, 17, 20], the possibility of adjacent superior facet joint violation that may lead to instability, which can bring about adjacent segmental degeneration, has not been studied in detail. Only one clinical study outlined the possibility and incidence of adjacent superior facet joint violation [16], but did not encompass invasion of the facet joint according to the insertion techniques. This study was undertaken to compare and analyse the results in view of adjacent superior facet joint violation of the lumbosacral spine following the two most common pedicle screw insertion techniques.

Materials and methods

Fifteen fresh-frozen lumbosacral vertebrae (L1-S1) were harvested from adult human cadavers, aged between 30 to 50 years (nine males, seven female), whose medical records were reviewed to confirm they were free of metabolic or metastatic spine diseases. Before the procedure, all speci-

S. W. Suh (✉) · K. Swapnil · J. H. Yang · H. R. Song
Department of Orthopaedic Surgery, College of Medicine,
Guro Hospital, Institute of Scoliosis Research, Korea University,
80, Guro-Gu, Guro-dong,
Seoul, South Korea
e-mail: spine@korea.ac.kr

K. J. Chung
Department of Orthopaedic Surgery, College of Medicine,
Kangnam Sacred Heart Hospital, Hallym University,
Seoul, South Korea

mens were thawed for 6 h to room temperature. Para-vertebral anatomical structures were not violated, keeping the osteoligamentous structures intact during the preparation of the cadaveric spines. However, sacral ala, sacrotuberous, and sacrospinous ligaments were sacrificed to separate the sacrum from the rest of the pelvis. Before the instrumentation, all vertebrae were imaged with plain radiographs in the anteroposterior and lateral planes to document the osseous integrity of the vertebrae and computed tomography (CT) scans were also taken of all the specimens to document facet integrity and convergence angle of the pedicle at all the levels designated to be instrumented in the axial plane. Each specimen was mounted in a polyester resin cast with L3 vertebra placed most ventrally. Fixed head, 6.5-mm titanium pedicle screws (cylindrical) were inserted in all specimens through the mamillary technique on the right side and the intersection technique on the left side. All screws were inserted using a free hand technique. The specimens were randomly allocated into one of the three groups. The procedure was performed by three independent surgeons, i.e., a spine surgeon, a spine research fellow and a senior resident in orthopaedic surgery, who were blind to one another to minimise interpersonal variability in surgical experience. The pedicles on the left side of all specimens were inserted by the intersection technique and on the right side inserted through the mamillary process technique. An awl was used to perforate the posterior cortex and then a blunt pedicle feeler was introduced to locate the pedicle. All procedures were performed on both side of the specimens using the same technique as in vivo by three surgeons. After completing all procedures, CT scans were taken with thin (1-mm) sections on all the specimens to determine the violation of facet joints and to identify any inadvertent complications that may have occurred during the procedure. These results were analysed independently by a consultant radiologist and an experienced spine surgeon who were not involved in this experiment. Facet joint violation was recorded when the medial margin of the pedicle screw head was in line with or beyond medial border of superior articular process of the instrumented level. A total of 152 pedicles were inserted in 15 cadaveric specimens by the three surgeons. These included 77 pedicles instrumented by the intersection technique and 75 pedicles by the mamillary technique. The experienced spine surgeon inserted 52 pedicle screws in five specimens, which included 26 through the mamillary technique and 26 through the intersection technique. The spine research fellow inserted 45 in five specimens, which included 23 through the intersection technique and 22 the mamillary technique, and the senior resident in orthopaedic surgery inserted 55 in five cases, which included 28 through the intersection technique and 27 by the mamillary technique (Table 1).

Results

Convergence angle of pedicles was measured by CT scan executed prior to the experiment and a paired *t*-test was carried out to investigate facet tropism of all specimens to insert a pedicle screw. There was no statistically significant difference ($P=0.43$). Two observers reviewed the CT scans of all specimens that were instrumented. The first observer (observer 1), a consultant radiologist, noted that there were six facet joints violated out of the 152 (3.94%) top-level screws, all of which were on the side where the mamillary technique was performed. Facet joint violation was noted in two of 52 instrumented by the spine surgeon (3.84%), two of 55 (3.63%) instrumented by the spine research fellow and two of 45 (4.44%) instrumented by the senior resident. There was one in L2, 3, 4 at each level and three in L5. The second observer (observer 2), an experienced spine surgeon, noted that there were seven facet joint violations (4.6%) top level screws, all of which were on the side where the mamillary technique was performed. Out of these seven pedicle screws found to be in violation, six corresponded with the same levels as observer one interpreted. The second observer found another screw at L5, which was instrumented by the spine research fellow, to be violating the joint (Table 2). The surgeon's experience did not affect the results of facet joint violation interpreted by both observers 1 and 2 ($P=0.778$, 0.422 Cochran-Mantel-Haenszel). The incidence of facet joint violation was higher in the mamillary process technique than in the intersection technique, which was statistically significant ($P=0.003$ Cochran-Mantel-Haenszel). This incidence was also analysed according to the instrumented level, upper lumbar (from L1 to L3) and lower lumbar (from L4 to S1) area. The incidence of facet joint violation on both sides was not statistically significant with respect to the instrumented level ($P=0.558$, 0.376 Cochran-Mantel-Haenszel). During this experiment there were two complications. One was a pedicle fracture on the specimen instrumented by the orthopaedic resident and the other was a facet fracture by the spine research fellow.

Table 1 Distribution of pedicle screws (IS intersection technique, MM mamillary process technique)

Level	IS	MM	Total
L1	9	8	17
L2	14	14	28
L3	15	15	30
L4	15	15	30
L5	15	15	30
S1	8	9	17
Total	76	76	152

Table 2 Details of facet joint violation

	L1		L2		L3		L4		L5		S1		Total	
	IS	MM	IS	MM	IS	MM	IS	MM	IS	MM	IS	MM	IS	MM
Observer 1	0	0	0	1	0	1	0	1	0	3	0	0	0	6
Observer 2	0	0	0	1	0	1	0	2	0	3	0	0	0	7

Discussion

The pedicle screw system, which was first introduced in the 1950s by Boucher [1], and then adopted by many authors, including Roy-Camille and co-workers [9, 15, 18], has contributed to the development of the concept of transpedicular instrumentation. After pedicle screw fixation became widely accepted and popular, the incidence of spinal fusion using transpedicular instrumentation has increased tremendously over the past two decades [3, 6, 9, 14, 15, 18, 21]. Spinal fusion using pedicle screws has many advantages over other internal fixators in biomechanical properties, fusion rate, early mobilisation and versatility [7]. But, pedicle screw fixation has its own risks, so that spinal fixation using pedicle screws is technically demanding [2, 5, 7, 10, 12, 13] and many reports have been published about complications following transpedicular instrumentation [2, 4, 6, 17, 20]. Facet joint violation by pedicle screw at the proximal adjacent segment is one of these complications. The transpedicular instrumentation technique must leave the facet joints adjacent to the top screw level intact. If not, an abnormal, alternate path of loading is established which makes the adjacent segment worse [7, 19, 21, 22]. Accelerated degeneration of the adjacent segment is a factor of postoperative back pain which makes the operative results poor. There have been many efforts to prevent facet joint violation and several techniques have been described for localisation of the entry point to the pedicle screw insertion. Out of these, the intersection and mamillary process technique have been the most popular. The intersection technique involves dropping a line from the lateral aspect of the facet joint, which intersects a line that bisects the transverse processes at a spot overlying the pedicle. The mamillary process technique is based on a small prominence at the base of the transverse process. Usually the mamillary process is more lateral than the intersection technique starting point and hence a different angle must be used for entering the pedicle from these two points, which may be decided by a preoperative CT scan. Because of this variation in trajectories, there are practical difficulties when pedicle screws are inserted. In spite of the intricate anatomy around the facet joint and a difficult pathway reaching to the pedicle using a sound technique, there is only one study in the literature

which documents the incidence of adjacent superior facet violation following the pedicle screw insertion. Shah et al. [16] reported that facet joint violation following pedicle screw insertion is more than 20% in terms of the number of involved top-level screws and just more than 30% in terms of the number of patients. However, we think that our study is the first which compares the adjacent superior facet joint violation followed by the two most common techniques used today for pedicle screw insertion. In this study it was noted that the mamillary process technique has a high incidence of adjacent facet violation during pedicle screw insertion. This appears to be independent of the surgeon's experience or surgical skill, as was noted in this study, where all the three surgeons with different levels of experience and skill had the same number of facet joints violated. Hence, in spite of great caution during surgery, facet joint violation by the mamillary technique appears to be inevitable. The complications that occurred during this procedure were in the specimens which were instrumented by the spine research fellow and the orthopaedic resident, which shows that there is a definite "learning curve" effect as regards the accuracy of insertion of pedicle screws. There was an interobserver agreement regarding the number of facets violated by all three surgeons. However, this study has a small sample size as regards to the number of pedicles instrumented, hence it is not possible to predict the incidence of violation by the mamillary technique. Therefore it will be inappropriate to comment as to which of these two techniques should be preferred. In spite of this fact, the number of facets violated by the mamillary technique was significantly higher than by the intersection technique, which resulted in none of the adjacent superior facets being violated during this study. It would be of considerable interest to see whether future studies can corroborate our findings and determine the exact incidence of joint violation using each of these techniques. It would also be of great interest if any future study were able to identify and document the variation in anatomy of the facet joints or other factors, like degenerative facet joints, which make them liable to injury by the mamillary process technique. If these 'at risk' facets can be identified, inadvertent facet joint injury could be avoided by using the intersection technique. In conclusion, this study has documented that there is a higher incidence of adjacent

superior facet joint violation following transpedicular instrumentation using the mamillary process technique. So, we suggest that the intersection technique is a safer pathway that can reduce the incidence of facet joint violation and, thus acquire a better result in the case of debilitating degenerative lumbar diseases requiring spinal fusion.

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