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Risk Factor Analysis of Facet Fusion Following Cervical Lateral Mass Screw Fixation with a Minimum 1-Year Follow-up: Assessment of Maximal Insertional Screw Torque and Incidence of Loosening

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Abstract

Posterior stabilization is a common surgical procedure, which aims for rigid stabilization by facet fusion. Facet non-union has a potential risk of the screw loosening and malalignment. Although some authors have reported the influencing factors about screw loosening in the lumbar spine, there are few reports about the risk factor contributing to the facet non-union in the cervical spine. In all, 22 patients (78 facets and 122 screws) with degenerative cervical kyphosis or spondylolisthesis who underwent decompression and lateral mass screw (LMS) fixation were analyzed. Age, gender, smoking, bone mineral density (BMD), the degree of facet decortication with bone packing, and screw loosening were investigated as risk factors contributing to the facet non-union at each segmental fused level. Facet fusion rate was 85.9% (67/78 facets) and the incidence of loosening was 4.9% (6/122 screws, 4 patients). Insufficient facet decortication with bone packing is a significant risk factor of facet non-union ($p < 0.05$, odds ratio: 26.5). All six loosened screws were associated with bony non-union of the facet and were located in the uppermost or lowermost vertebrae. Comparing loosened screws and stable screws, the average maximal insertional screw torque (MIT) was 9.8 cNm and 39.5 cNm, respectively ($p < 0.05$). Additionally, the length of the stable screws was significantly longer versus the loosened screws ($p < 0.05$). Lower MIT and shorter screw length located near the ends of the lateral mass may predict loosening, which can lead to facet non-union. Sufficient facet decortication with bone packing is one of the important factors contributing to the facet fusion.

Keywords: cervical lateral mass screw fixation, maximal insertional screw torque, loosening, facet fusion, decortication

Introduction

Posterior stabilization with lateral mass screw (LMS) in the cervical spine is one of the common surgical procedures, which aim for rigid stabilization by facet fusion. Facet non-union has a potential risk of the screw loosening and malalignment.[1,2] Although some authors have reported the influencing factors about screw loosening in the lumbar spine, there are few report about the risk factor contributing to the facet non-union in the cervical spine. The objective of this article is to investigate the incidence of and risk factors for facet non-union of the LMS fixation in the cervical spine. Additionally, we aim to determine whether intraoperative LMS insertional screw torque correlates with facet fusion and maintained postoperative alignment.

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Materials and Methods

We reviewed data from 2011 to 2018 for 22 patients (78 facets and 122 screws) retrospectively. The inclusion criteria for the patients were as follows: 1) degenerative cervical spondylolisthesis, which was confirmed by functional radiograms, 2) degenerative cervical kyphosis, and 3) patients with at least 1-year postoperative computed tomography (CT). The exclusion criteria were as follows: 1) patients with different types of fusion applied on different levels, 2) patients with screws resulted in a breach or were revised during the procedure, and 3) patients with trauma. Age, gender, smoking, bone mineral density (BMD), the degree of facet decortication with bone packing, and screw loosening were investigated as risk factors contributing to the facet non-union at each segmental fused level. Additionally, we measured maximal insertional screw torque (MIT) intraoperatively in all patients and assessed insertional screw torque, BMD, number of fused levels, the position of screw, screw length and diameter, comparing loosened screws with stable screws. Institutional review board in our hospital approved this study (FHR 2019-14).

Surgical technique

All procedures were performed with intraoperative C-arm digital fluoroscopic guidance. A 2-mm diameter pilot hole with trajectory directed at the superolateral mass quadrant was drilled using a high-speed burr at the mass entry, approximately 2-mm medial and cranial to the midpoint of the lateral mass prior to laminectomy. The trajectory was checked frequently and the length of screw was decided based on the length of tapper under intraoperative C-arm digital fluoroscopic guidance. The screws (SOLANAS; Globus Medical Inc., Methuen, MA, USA) were directed approximately 25° laterally and superiorly, parallel to the intervertebral facet (Magerl technique).[3] Unicortical screw fixation was performed in all patients to minimize the risk of neural or vascular injury. After inserting screws, facet decortication was performed by a 2-mm diameter diamond drill to the extent that it does not interfere with screws, confirming the direction of facet. Straight rod was used. After screw–rod fixation and decortication of the facets, locally harvested minced bone chips were packed into the facet joints to achieve biological fusion. Laminectomy for decompression and in situ fusion was performed in all patients. Three 1st operators with spinal surgery specialist license approved by Neurospinal Society of Japan performed the procedures.

Measuring maximum insertional screw torque

MIT was measured using an insertion torque driver (Globus Medical Inc., Methuen, MA, USA). We measured insertional screw torque when the screw shank was completely anchored into the entrance point. In cases where the LMS ran parallel to the bone without resistance, we recorded the insertional torque as 0 cNm.

Radiographic assessment

The incidence of screw loosening and the extent of facet union were assessed on CT at the final follow-up (minimum, 1 year). The criterion of the fusion of the facet joint was defined as a continuous, uninterrupted area of cancellous bone bridging the facet joint space or surface on CT (Fig. 1A). The screw was defined as loose when a radiolucency of 1 mm or wider was present at the bone–screw interface (Fig. 1B).[3,4] Radiographic assessments such as facet fusion and decortication with bone packing on CT were performed by five spinal surgeons. The degree of facet decortication with bone packing was classified into two groups based on CT findings at the postoperative 1 day; group A had adequate facet decortication with bone packing, group B had insufficient or poor facet decortication with bone packing despite the description of the operation record (Fig. 2). We measured BMD at the femoral head in all patients, using dual-energy X-ray absorptiometry because BMD measurements in the lumbar spine may be influenced by degenerative changes in facet joints, spur formation, and aortic calcification .

Statistical analysis

The statistical analysis was performed using JMP statistical software ver. 13 (SAS Institute Inc., Cary, NC, USA). The chi-square test was used for continuous and binary values. For nonparametric tests, Mann–Whitney U test, and Fisher's exact probability test were used. Logistic regression analysis was used for multivariate analysis. Significance of the obtained results was judged at the 5% level.

Results

Patients' demographic data are described in Table 1. Patients constituted 17 men and 5 women with an average age of 72 years (range, 47–83 years). Facet fusion rate was 85.9% (67/78 facets) and the incidence of loosening was 4.9% (6/122 screws, 4 patients) during an average of 27.6 months (range, 12.1–55.0 months). A summary of the risk factor contributing to the facet non-union was described (Table 2). Insufficient facet decortication with bone packing is a significant risk factor of facet non-union

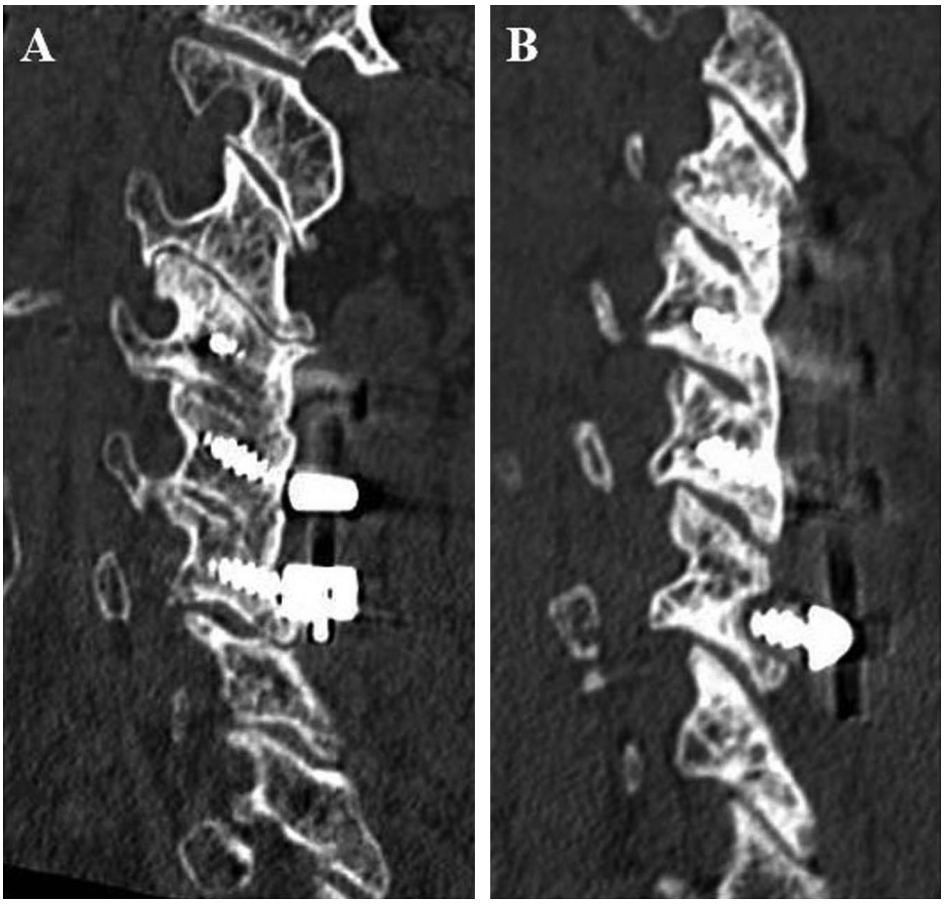

Fig. 1 (A) CT showing bony facet fusion at C4/5/6. (B) CT showing bony facet fusion at C3/4/5. Bony non-union of facet at C5/6 and a radiolucency of more than 1 mm around C6 screw are demonstrated. CT: computed tomography.

($p < 0.05$, odds ratio: 26.5). All six loosened screws were associated with bony non-union of the facet (Fig. 3). No patients experienced cervical malalignment secondary to screw back-out and loosening. A summary of the loosened and stable screws is given in Table 3. The average MIT was 39.5 cNm (range, 0–100 cNm) in the stable screws and 9.8 cNm (range, 0–22 cNm) in the loosened screws ($p < 0.05$). Loosened screws were in the uppermost vertebra in two patients with three screws and in the lowermost vertebra in two patients with three screws. None of the screws in the intermediate vertebrae loosened. Additionally, less number of fused levels and the length of the stable screws were significantly longer versus the loosened screws ($p < 0.05$). Although there was a slight correlation between MIT and BMD (Fig. 4), average BMD and screw diameter did not differ significantly between the loosened and stable screws ($p = 0.34$ and $p = 0.71$, respectively). Regarding the degree of facet decortication with bone packing, group A had higher facet fusion rate, even if uppermost or lowermost facets in multi-level fixation (Table 4).

Discussion

Spinal fusion is the most frequently performed surgery to treat spinal disorders. Although there are some issues such as adjacent segment disease left unsolved,[5] the ultimate aim of spinal fusion surgery is to achieve complete fusion at the fused level. In the systematic review Coe et al. reported, facet fusion rate of LMS was achieved in 97.0% of patients across nine studies ($n = 637$) with mean follow-up durations ranging from 9 to 45.6 months.[6] However, as the patient population is aging, screw loosening is becoming a common complication that can lead to facet non-union.

Previous biomechanical studies evaluated the safety and efficacy of unicortical versus bicortical LMS in the cervical spine.[7,8] Heller et al.[9] demonstrated that bicortical screw pullout force was 20% higher than that for unicortical screws; however, Seybold et al.[8] reported no statistically significant difference between the pullout force for unicortical and bicortical screws. Additionally, engaging the anterior cortex of the lateral mass is associated with a potential risk of injury to the cervical neurovascular structures. Cho et al.[10] reported

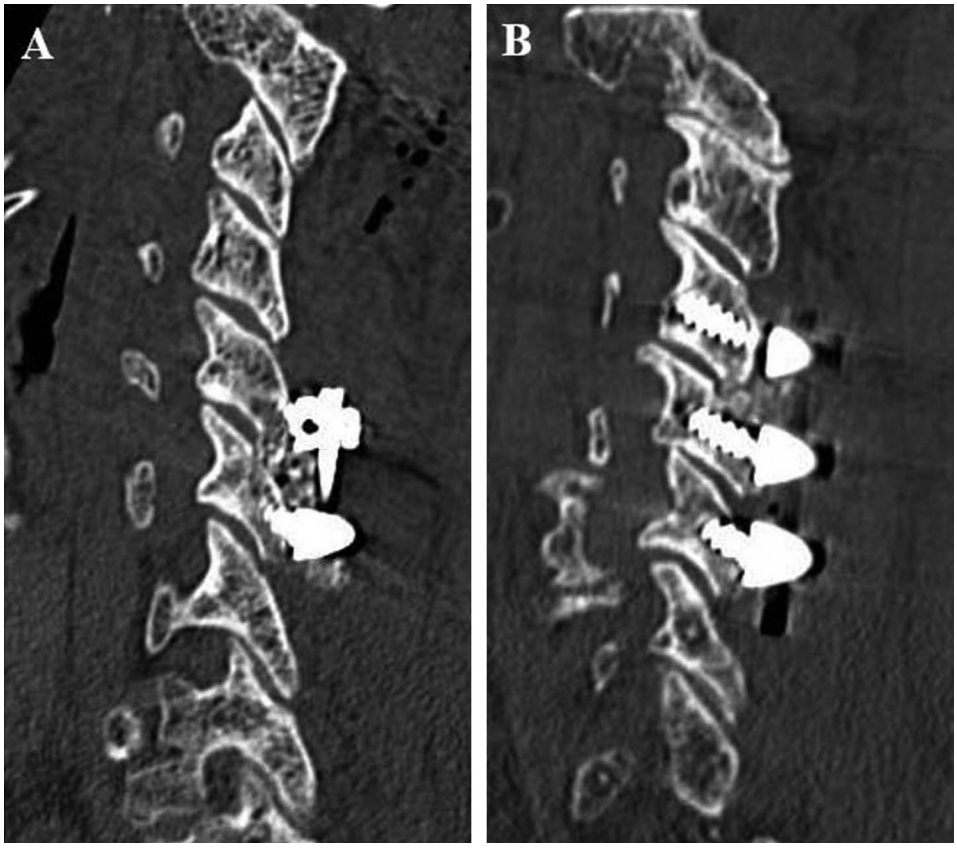

Fig. 2 (A) CT showing adequate facet decortication with bone packing was performed at C5/6 (group A). (B) CT showing group A at C4/5 and insufficient or poor facet decortication at C5/6 (group B). CT: computed tomography.

Table 1 Patients demographics

Characteristic	Value
Gender (male), no (%)	17 (77.3)
Age (y), mean ± SD	70.3 ± 9.1
Currently smoking, no (%)	4 (18.2)
BMD (g/cm^2), mean ± SD	0.77 ± 0.14
Number of fused levels, no (%)	
1	9 (40.9)
2	9 (40.9)
3	4 (18.2)
The number of facet non-union, no (%)	11 (14.1)
The classification of the degree of facet decortication with bone packing, no (%)	
Group A	63 (80.8)
Group B	15 (19.2)
The position of facet non-union	
Intermediate	1
Uppermost or lowermost	10
Loosening screw, no (/122 screws, %)	6 (4.9)

BMD: bone mineral density

Table 2 Prognostic factors for the occurrence of facet non-union

Explanatory variable	Odds ratio (95% confidence interval)	p value
Gender	0.16 (0.01–2.16)	0.13
Age	0.95 (0.88–1.02)	0.14
Currently smoking	0.4 (0.03–6.29)	0.52
Bone mineral density	0.93 (0.29–2.99)	0.17
Facet decortication with bone packing	26.3 (3.10–223.4)	<0.05

vertebral artery injury resulting in brain stem infarction after cervical lateral mass plating with bicortical screws. In the present study, we used unicortical screw purchase to eliminate neurovascular complications.

In this study, all facets were meticulously examined for the degree of fusion. According to our results, 11 facets did not achieve bony fusion, and 6 facets were associated with loosened screws. Although all patients underwent the same procedure, results for the remaining 5 facets might have been secondary to insufficient or

Table 3 The characteristics of the stable screws versus loosened screws

	Stable screws (n = 116)	Loosened screws (n = 6)	p value
BMD (g/cm^2)	0.87 ± 0.12	0.74 ± 0.11	0.34
The length of screw	13.2 ± 1.4	11.7 ± 1.5	p <0.05
The diameter of screw	3.52 ± 0.06	3.5 ± 0	0.71
Insertional screw torque (cNm)	39.5 ± 22.7	9.8 ± 7.3	p <0.05
C3	38.5 ± 20.2	14.3 ± 5.6	
C4	42.6 ± 20.7	(–)	
C5	39.0 ± 23.5	0	
C6	30.3 ± 9.9	8.0 ± 2.0	
Number of fused levels			p <0.05
1	36	0	
2	52	2	
3	28	4	
The position of screws			p <0.05
Intermediate	34	0	
Uppermost or lowermost	82	6	

BMD: bone mineral density

Table 4 The characteristics of group A versus group B

	Group A	Group B
The level of facets		
C3/4	26 (25/26, 96)	6 (2/6, 33)
C4/5	28 (26/28, 93)	6 (5/6, 83)
C5/6	9 (9/9, 100)	3 (0/3, 0)
Number of fused levels		
1	17 (17/17, 100)	1 (1/1, 100)
2	31 (29/31, 94)	5 (4/5, 80)
3	15 (14/15, 93)	9 (2/9, 22)
The position of facets		
Intermediate	22 (22/22, 100)	4 (3/4, 75)
Uppermost or lowermost	41 (38/41, 93)	11 (4/11, 36)

Values within brackets are expressed as the facet fusion rate (%). Single fused level is counted as intermediate facet and two fused levels are counted as uppermost or lowermost facets.

poor decortication with bone packing. When we compared stable and loosened screws, we found a statistically significant difference between screw length and MIT. Furthermore, all loosened screws were used in the uppermost or lowermost lateral mass with multi-level fusion, that is, short screws with low MIT to the end may be associated with screw loosening, resulting in non-union of fixed intervertebral joints. Zindrick et al.[11] stated that screw failure in cyclic toggling under caudocephalad-directed loads was caused by "a teeter–totter motion" of the screw, with the fulcrum or axis of rotation located within the pedicle, that is, screws inserted into the marginal segments have greater strength loading than those in the middle segment.

Previous studies assessed the relationship between screw torque values and stabilization in the lumbar spine.[12–16] Screw design,[4,17,18] metal quality,[19,20] screw diameter,[21] length,[22] tapping size,[23] insertion method,[24,25] and BMD[2,23] are reported factors affecting insertion torque, and it is generally accepted that larger outer diameter,[21] shorter pitch,[26] and longer screw length[22] increase the pullout strength. Although tapping torque could be a reliable guide for selecting pedicle screw size,[27] tapping decreases the pullout strength.[23] While some authors reported that insertional torque objectively predicted screw loosening and other related instrumentation failure,[28] others reported that loosening cannot always be predicted by

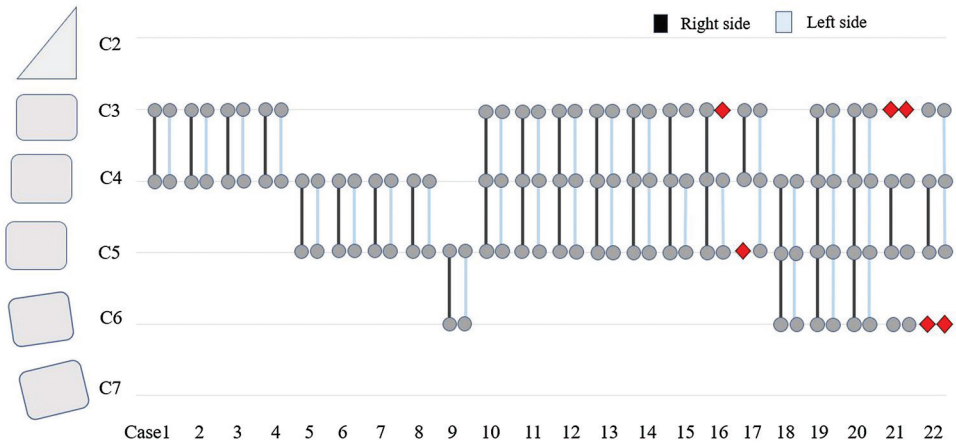

Fig. 3 Summary of the loosened screws and facet fusion. Loosened screws were described as a rhombus. Blank areas indicate bony non-union.

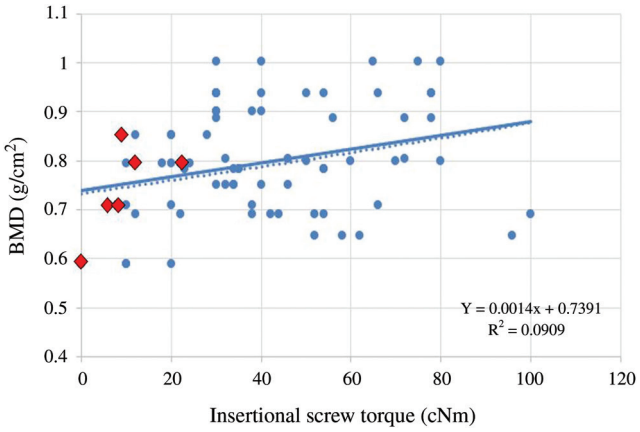

Fig. 4 Correlation between BMD and insertional screw torque, which showed a slight correlation between insertional screw torque and BMD. A loosened screw is described as a rhombus. BMD: bone mineral density.

insertional torque, clinically.[2] Screw loosening caused by cyclic bending or rotatory stresses at the bone–screw interface is thought to result in loss of correction or non-union after spinal surgery.[29]

Insertional screw torque is caused by frictional resistance between the screw threads and bone as well as radial compression of the trabeculae. It can also be influenced by multiple factors. In the current study, we focused on the MIT especially. If there is poor MIT in the uppermost or lowermost vertebra, the screw might still need to go in, resulting in bicortical purchase. Also, the extension of fused levels to C2 or C7 level using laminar screw or pedicle screw might be one of choices to acquire firmer anchors. Additionally, additional cross-linked devices and extension of external fixation such as with a neck collar might be considered to achieve facet fusion or prevent implantation failure.

The present study has several limitations. First, this study was retrospective and consisted of a small number of patients, which leads to the limited statistical power. Second, as for screw diameter, the difference of the average screw diameter was too small, resulting in no statistical significance. Spinal surgeons often experience that a screw with larger diameter has more pullout strength. Third, the decision-making for treatment was biased. It is unclear how many vertebral segments should be fixed for cervical kyphosis or cervical spondylolisthesis. Also, we could not clarify whether loose screws were present from the time of fixation or whether loosening occurred at an undetermined time after fixation. Fourth, there were some confounders which affected loosening. As for the construct length, the equivalent insertional torque in short segment fusions may not correlate to an increased risk of screw pullout compared to multi-segment fusions. However, we believe the current article provides important information regarding loosening in LMS fixation.

Conclusion

Lower MIT and shorter screw length located near the ends of the lateral mass may predict loosening, which can lead to facet non-union. Sufficient facet decortication with bone packing is one of the important factors contributing to the facet fusion.

Conflicts of Interest Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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