ORIGINAL

Assessment of maximal insertional torque of cervical and thoracic screws during posterior spinal surgery

Takuya Mishiro[1], Koichi Sairyo[2], Akira Shinohara[3], Takashi Chikawa[4], Hirofumi Kosaka[1], and Akira Dezawa[5]

[1]*Department of Orthopaedic Surgery, Takamatsu Red Cross Hospital, Takamatsu, Japan,* [2]*Department of Orthopaedics, the Institute of Health Biosciences, the University of Tokushima, Tokushima, Japan,* [3]*Department of Orthopaedic Surgery, Jikei University Kashiwa Hospital, Kashiwa, Japan,* [4]*Department of Orthopaedic Surgery, Tokushima Municipal Hospital, Tokushima, Japan,* [5]*Department of Orthopaedic Surgery, Teikyo University Mizonokuchi Hospital, Kawasaki, Japan*

Abstract : Study Design : Multicenter intraoperative biomechanical analysis. Purpose : This study aimed to assess the maximal insertional torque (MIT) of lateral mass screw (LMS) and pedicle screw (PS) in the cervical or thoracic vertebrae during surgery. Methods : During posterior spinal fusion, cervical or thoracic multi-axial screws were placed at different cervical or thoracic levels and the MIT was recorded for each screw revolution using an analogue torque wrench. Screw number was as follows : 11 PS at C7, 134 LMS (C3-6) (Magerl technique, 70 ; Roy-Camille technique, 64), and 33 PS in the thoracic region. Results : Average MIT values (cNm) were as follows : for PS (diameter : 3.5 mm) at C7, 45.3 ± 21.9 in men and 60.0 ± 20.1 in women (p=0.28) ; for Magerl screws, 69.0 ± 20.5 in men and 58.6 ± 15.7 in women (p=0.13) ; and for Roy-Camille screws, 51.0 ± 17.9 in men and 42.4 ± 15.9 in women (p=0.52). The average MIT for Magerl screws was significantly higher than that for Roy-Camille screws in men and women (both p<0.01). Conclusions : Intraoperative insertional torque could be a good indicator to evaluate the purchase and help guide decisions on screw type and insertion technique. Further postoperative assessments with sequential X-rays are needed to reveal the significance of MIT during posterior spinal fusion. J. Med. Invest. 61 : 393-398, August, 2014

Keywords **:** *lateral mass screw, pedicle screw, insertional torque, Magerl technique, Roy-Camille technique*

INTRODUCTION

From 1970s, internal fixation procedures have been performed to correct instability of the spine. Recently developed posterior fixation procedures use either a lateral mass screw or a pedicle screw were useful for patients undergoing one-stage posterior decompression and stabilization of the spine. However, cervical pedicular fixation has been reported to afford superior biomechanical and clinical stability to the use of lateral mass screws (1, 2). But there are no reports mentioned a definite strength of screws to hold the spine intraoperatively. Roy-Camille *et al.* (3) described their technique for the first time in 1972, and many authors have also described technical variations aimed at reducing the

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Address correspondence and reprint requests to Koichi Sairyo, MD, PhD, Department of Orthopaedics, the Institute of Health Biosciences, the University of Tokushima, 3-18-15, Kuramoto, Tokushima 770-8503, Japan and Fax : +81-88-633-0178.

potential risk of neurovascular damage and improve biomechanical performance (4-7).

Abumi *et al.* (8) were the first to report on the successful clinical application of cervical pedicle screws in the treatment of traumatic lesions in the lower and middle subaxial spine, followed by the treatment of nontraumatic disorders. In posterior fixation for subaxial cervical fractures, initially screws were usually inserted into the lateral mass. In recent years, however, some papers have shown that PS fixation is biomechanically the most effective (2, 9, 10) and it is getting more and more popular with the development of navigation and fluoroscopic systems. Abumi *et al.* (11) also reported that the cervical pedicle screw system provides effective and safe fixation in cases of cervical traumatic disc herniation and that surgery can be performed safely through a single posterior approach without the need for additional anterior decompressive interventions. In addition, many authors have reported on the stiffness and pullout strength of lateral mass screws (LMS) or pedicle screws (PS) (2, 9, 10), but none have tested the insertional torque of LMS during surgery. The purpose of this study was to assess the maximal insertional torque (MIT) of screws (especially LMS) in the cervical or thoracic vertebrae during surgery.

METHODS

Between March 2012 and December 2012, the insertional torque of cervical and thoracic screws was measured intraoperatively in 24 consecutive patients (12 men and 12 women) at four institutions. Two institutions mainly used Magerl screws and the other two used Roy-Camille screws as LMS. Insertional torque was measured using an analogue torque wrench with an adapter for the Solanas system (Alphatec Spine, Carlsbad, CA). Two size of the wrench were prepared for the MIT below 100 cNm or above 100 cNm. When MIT was over 100 cNm, the big wrench was used. Minimum scale division of the wrench was 2 cNm (10-100 cNm) and 5 cNm (30-200 cNm). Reproducibility of the wrench was checked before every surgery with an industrial analogue torque wrench (Tohnichi Mfg. Co., Tokyo, Japan). The average age at the time of spinal fixation was 62.3 years (range, 48-79 years) in men and 61.1 years in women (range, 50-77 years). Spinal disorders were cervical spondylotic myelopathy (15 patients), ossification of the posterior longitudinal ligament (7 patients), and trauma (2 patients). During posterior spinal fusion, cervical or thoracic multiaxial screws were placed at various cervical or thoracic levels after drilling a 2.0-mm hole, and the MIT was recorded for each screw revolution using the analogue wrench when the screw just touched the vertebral cortex. The number of screws used was as follows : 11 PS at C7, 134 LMS at C7 (Magerl technique, 70 ; Roy-Camille technique, 64), and 33 PS in the thoracic region. In addition, LMS were used at C1 and laminar screws were used at C2 or C7, but these screws were excluded from analysis because of the low number used (Table 1). Screws with different diameters (3.5 and 4.0 mm) were used. All LMS and 10 thoracic PS were 3.5 mm screws. Twenty three thoracic PS were 4.0 mm screws.

Table 1. Summary of screw type and use in the present analysis

Screw type	No. of cases (men ; women)
Pedicle screw (PS) at C7	11 (6 ; 5)
Lateral mass screws	134
Magerl technique	70 (38 ; 32)
Roy-Camille technique	64 (38 ; 26)
Thoracic PS (ϕ 3.5 mm)	10 (0 ; 10)
Thoracic PS (ϕ 4.0 mm)	23 (4 ; 19)

Note : Additionally, lateral mass screws were used at C1 and laminar screws at C2 or C7, but these screws were excluded from analysis because of their low number (< 4).

RESULTS

The average MIT values (cNm) were as follows : for Magerl screws, 69.0 ± 20.5 in men and 58.6 ± 15.7 in women ($p=0.13$) ; for Roy-Camille screws, 51.0 ± 17.9 in men and 42.4 ± 15.9 in women ($p=0.52$) ; for thoracic PS with a diameter of 3.5 mm, 55.0 ± 11.6 in women (no data for men) ; for thoracic PS with a diameter of 4.0 mm, 64.8 ± 18.3 in men and 52.7 ± 9.5 in women ($p=0.18$) ; and for PS with a diameter of 3.5 mm at C7, 45.3 ± 21.9 in men and 60.0 ± 20.1 in women ($p=0.28$).

In the four LMS groups, the average MIT for Magerl screws in men was significantly higher than that for Roy-Camille screws in men and women (both $p< 0.01$; Fig. 1). The average MIT of Magerl screws in women was also significantly higher than that of Roy-Camille screws in women. No significant differences in MIT were noted between thoracic and C7 PS (Fig. 2). The average MIT for all LMS was

56.2 ± 20 cNm ; for 120 LMS (90%) it was 20-80 cNm and for 77 LMS (57%) it was 40-70 cNm (Fig. 3).

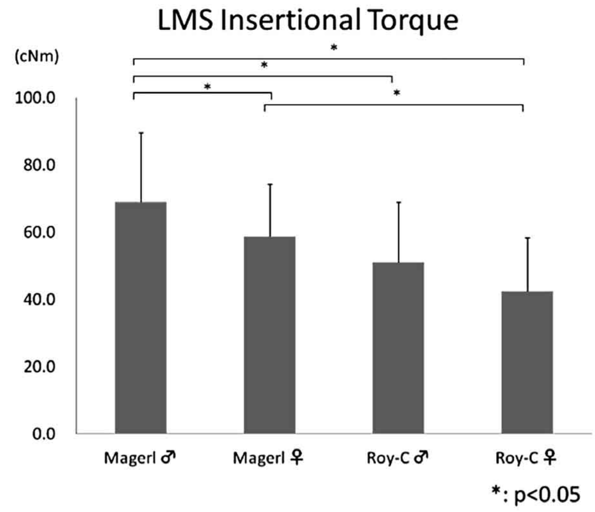

Fig. 1 LMS insertional torque

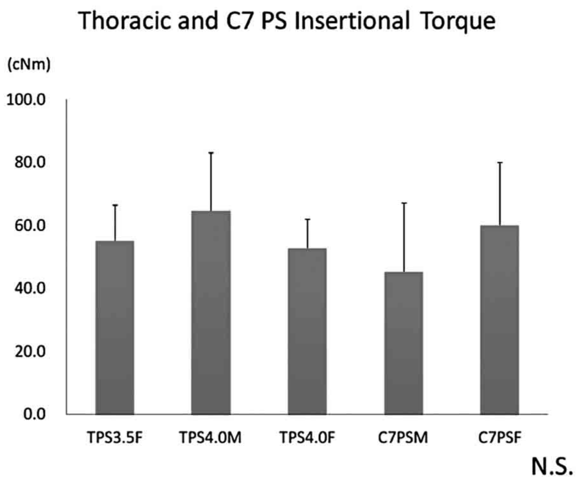

Fig. 2 Thoracic and C7 PS insertional torque

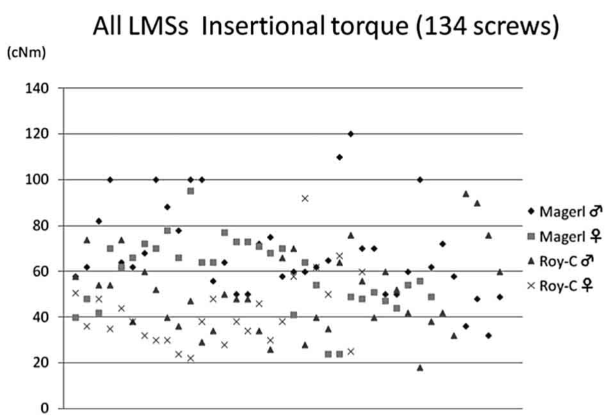

Fig. 3 Insertional torque of all 134 LMS screws

Clinical results

Complications : There are following possible complications associated with cervico-thoracic reconstruction surgery with screws : i.e. spinal cord injury, nerve root injury, C5 palsy, vertebral artery injury, hematoma, surgical site infection. In our current series of 178 screws from 24 cases, postoperative C5 palsy was observed in a female case with cervical kyphosis. But there were no screw related complications.

DISCUSSION

Various techniques are used to treat fractures of the cervical spine (3, 4, 12-14). Cervical screws have become popular and useful for cervical fusion in recent years, and several techniques of lateral mass screw placement have been developed. Each has its original entry point for screw insertion and screw trajectory. Roy-Camille *et al.* (3) recommended that the entry point for insertion should be located at the top of the lateral hill of the lateral mass, exactly at the midpoint. The entry point is then drilled with a 2-mm bit, perpendicular to the vertebral plane and 10 degrees lateral to the sagittal plane. Magerl *et al.* (4) recommended that the entry point should be slightly medial and cranial to the posterior center of the lateral mass and that the orientation of the screw should be 20-30 degrees lateral and parallel to the adjacent facet. Both techniques are leading procedures for posterior cervical fixation. In this series, we did not have any complications such as spinal cord injury, nerve root injury, or vertebral artery injury, indicating that our strategy of the screwing based on the both lateral mass screwing for the cervical spine would be safe. Barrey *et al.* (15) reported that Roy-Camille screws demonstrated greater pullout strength (23%) than Magerl screws at the C3-4 vertebral level, but no significant difference between the techniques was observed at the C5-6 vertebral level. Montesano *et al.* (7) found that the Magerl technique provided greater resistance and had a higher load to failure (585 N) than the Roy-Camille technique (152 N) ; however, only three spines per surgical technique were analyzed, and only one technique per spine was tested. The results obtained in a study of bovine cervical spines by Errico *et al.* (16) were similar to those of Montesano *et al.*, but the difference in pullout strength between the two techniques was considerably smaller (471

N for Roy-Camille technique vs 607 N for Magerl technique). Similarly, our results revealed that the MIT for Magerl screws in men was higher than that of Roy-Camille screws, and was in fact the highest among all assessed (Fig. 1). Heller *et al.* (17) found that the screw pullout force of bicortical screws was 20% higher than that of unicortical screws. The use of bicortical screws engenders a greater risk of injury to local anatomical structures, but this may be an acceptable compromise in the cephalad and caudad regions of the cervical spine, where the placement of screws is relatively weak. On the other hand, there are some reports that cervical PS should be stronger than LMS, however, cervical PS may carry the risk of pedicle perforation. Ito *et al.* (2) compared the pullout strength of PS and found that 45 (6.7%) penetrated the cortical bone, but only 2 (0.3%) caused nerve root damage. They also found that C4 screws had the highest incidence of penetrating the cortex. In this series, they found that the mean pullout strength of the PS was nearly 4 times greater than that of the LMS (762 N vs 191 N, respectively). A study on postmortem tissue by Jeanneret *et al.* (18) suggested that C5 pedicle screws have the highest incidence of penetrating the cortex, followed by C3 and C4 screws, while C6 and C7 screws have the lowest incidence. Karaikovic *et al.* (19) reported that the most penetration occurred at C3-C5. The small size of the C3-C5 pedicles and medullary cavities makes it difficult to insert PS, which are likely to penetrate the cortex and enter the spinal canal, risking damage to the vertebral artery or spinal cord. This is the reason why many surgeons would rather place LMS at C3-C5. In addition, many surgeons have reported a safer and steadier method for reducing the potential risk of neurovascular damage to the cervical spine (20-23). Nakashima *et al.* (20) reported an incidence of PS misplacement of 19.5% (76 screws) ; 60 screws (15.4%) were classified as Grade I and 16 (4.1%) as Grade II malpositions. Three included complications directly attributable to screw insertion in 5 patients (nerve root injury by PS in 3 patients and vertebral artery injury in 2 patients). This degree of screw misplacement is similar to the 30% reported by Kast *et al.* (24).

The greater strength of PS fixation over LMS fixation demonstrated in the laboratory does not seem to be evident in the clinical setting. There have been numerous reports of LMS fixation providing equivalent or superior results in terms of maintaining alignment and the absence of hardware failure. LMS are relatively easy to place and have a significantly lower complication rate in terms of neurovascular damage (25, 26). Consequently, knowing the clinical differences between cervical PS and LMS is very important. PSs in this paper were used for only thoracic spine or C7. Basically those data could not compare with LMSs for mid-cervical spine. And thoracic pedicles were larger than that of cervical spine. The diameter of Solanas screw system was also limited for thoracic spine.

Our results are preliminary, and the clinical significance of MIT during surgery will becomeclearer through the assessment of radiographic findings over the long term. Intraoperative MIT insertional torque could be one of the best indicators for evaluating the purchase of screws. If intraoperative insertional torque is very low, we can change the size of the screw and use a different trajectory, or use additional implants.

CONCLUSION

This study was a preliminary intraoperative biomechanical assessment to check the screwpurchase. The average MIT for Magerl screws in men was 69.0±20.5 cNm and was the highest of all screw types used in this series. In the four LMS groups, the average MIT for Magerl screws in men was significantly higher than that for Roy-Camille screws in both sexes, and was significantly higher in women than Roy-Camille screws in women. Intraoperative insertional torque appears to be a good indicator to evaluate screw purchase and help guide decisions on screw type and insertion technique.

Further postoperative assessments with sequential X-rays are needed to reveal the significance of MIT during surgery for posterior spinal fusion.

CONFLICT OF INTERESTS

None of the authors has any conflicts of interest to declare.

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