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Significance of the Pars Interarticularis in the Cortical Bone Trajectory Screw Technique: An *In Vivo* Insertional Torque Study

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Study Design: Retrospective study.

Purpose: Cortical bone trajectory (CBT), a more medial-to-lateral and shorter path than the traditional one for spinal fusion, is thought to be effective for severely degenerated vertebrae because screws are primarily stabilized at the posterior elements. We evaluated the efficacy of this approach through *in vivo* insertional torque measurement.

Overview of Literature: There has been only one prior *in vivo* study on CBT insertional torque.

Methods: Between January 2013 and April 2014, a total of 22 patients underwent posterior lumbar fusion using the CBT technique. The maximum insertional torque, which covers the radial strength needed for insertion, was measured for 113 screws, 8 of which were inserted for L5 spondylolysis. The insertional torque for cases with (n=8) and without (n=31) spondylolysis of L5 were compared using one-way analysis of variance (ANOVA). To evaluate vertebral degeneration, we classified 53 vertebrae without spondylolysis by lumbar radiography using semiquantitative methods; the insertional torque for the 105 screws used was compared on the basis of this classification. Additionally, differences in insertional torque among cases grouped by age, sex, and lumbar level were evaluated for these 105 screws using ANOVA and the Tukey test.

Results: The mean insertional torque was significantly lower for patients with spondylolysis than for those without spondylolysis (4.25 vs. 8.24 in-lb). There were no statistical differences in insertional torque according to vertebral grading or level. The only significant difference in insertional torque between age and sex groups was in men <75 years and women ≥75 years (10 vs. 5.5 in-lb).

Conclusions: Although CBT should be used with great caution in patient with lysis who are ≥75 years, it is well suited for dealing with severely degenerated vertebrae because the pars interarticularis plays a very important role in the implementation of this technique.

Keywords: Cortical bone trajectory; Insertional torque; Spondylolysis; Pars interarticularis; Vertebral degeneration

Introduction

The cortical bone trajectory (CBT) technique, used with a pedicle screw, was first described by Santoni et al. [1] in 2009. The trajectory starts in the lateral part of the pars interarticularis and follows a caudocephalad and lateral path through the pedicle. We began using this method in our institution (Department of Neurosurgery, Osaka University Graduate School of Medicine) in 2012 for cases requiring thoracolumbar fusion. Compared with traditional

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methods of inserting a pedicle screw, CBT is thought to be more effective for initial fixation by maximizing contact between the screw and cortical bone. In addition, it may also be useful in dealing with severely degenerated vertebrae in patients with osteoporosis because the screws are primarily stabilized at the posterior elements and are not deeply inserted into the vertebral bodies.

However, there have been few evaluations with respect to stabilization of the CBT screw in cadaver or *in vivo* studies. Therefore, it has yet to be determined whether CBT is truly indicated for patients with osteoporosis. To the best of our knowledge, there has been only one prior *in vivo* study on CBT insertional torque [2]. This study was designed to investigate the efficacy of the CBT technique and appropriate structures for its use through the measurement of *in vivo* insertional torque.

Materials and Methods

This study was approved by our Institutional Ethics Committee (approval number 14168).

Between January 2013 and April 2014, a total of 22 consecutive patients, including 9 men (mean age, 61.0±15.7 years; range, 37–80 years) and 13 women (mean age, 62.3±14.6 years; range, 32–80 years) underwent posterior interbody or posterior lumbar fusion at our institution using the CBT technique for the treatment of lumbar degenerative spondylolisthesis, lumbar canal stenosis, or lumbar spondylolysis. In total, 114 screws were inserted into the lumbar spine. Among these, eight were inserted for cases with L5 spondylolysis.

CBT was performed under lateral fluoroscopy. We used the isthmus of the lamina as an anatomical landmark for entry [3]. Screws were placed 3 mm inside the isthmus and inserted in a cephalad and lateral direction. In cases with spondylolysis, the entry point for the screws was the rostral point of the defect in the pars interarticularis; the trajectory followed was the same as that in the CBT technique. In both cases, similar tapping was done. The screw diameter was 4.5 mm (Zodiac polyaxial screw, Alphatec Spine, Tokyo, Japan), the screw lengths were 25, 30, and 35 mm, and the pitch was 4 mm. The maximum insertional torque of the last two screw rotations was measured using an Inline dial indicator 584100 (Holmed Corporation, Franklin, USA) (Fig. 1). Its scale was modified by Alphatec Spine to measure 0–55 in-lb in increments of 1 in-lb.

The insertional torque of the 114 screws used in our study was also measured. One of them was incorrectly placed medially by more than half of its diameter; therefore, it was excluded from our study. The insertional torques in cases with (n=8) and without (n=31) spondylolysis of L5 were compared using one-way analysis of variance (ANOVA).

To evaluate vertebral degeneration, 53 vertebrae (excluding cases with spondylolysis) were classified based on lumbar radiographs using a semiquantitative method [4]. This is an quick and routine assessment of vertebral fractures [5] and correlates moderately well with quantitative morphometry [6]. Vertebrae were graded on visual inspection and without direct vertebral measurement as follows: (1) Normal (grade 0), (2) Mildly deformed (grade 1, approximately 20%–25% reduction in anterior, middle, and/or posterior height and a reduction in area of 10%–20%), (3) Moderately deformed (grade 2, approximately 25%–40% reduction in any height and a reduction in area of 20%–40%), (4) Severely deformed (grade 3, more than an approximate 40% reduction in any height and area).

There were 14 vertebrae of grade 0, 23 vertebrae of grade 1, and 16 vertebrae of grade 2; there were no grade 3 vertebrae in this study. The insertional torque of the 105 screws used for these 53 vertebrae was statistically compared using one-way ANOVA with the Tukey test.

To assess the relation among sex, age, and insertional torque, the 105 screws were classified into four groups based on patient age and sex: men <75 years (n=24), women <75 years (n=56), men ≥75 years (n=10), and women ≥75 years (n=15). According to a previous study [7] using a quantitative method, the prevalence of vertebral fracture in women rapidly increases in their 70s, reflecting lower bone density. To evaluate the same kind of sex- and age-related tendency in posterior elements, we chose 75 years, termed as late elderly in Japan, as the division criterion.

In addition, insertional torque and lumbar level (L1,

Fig. 1. Photograph of the torque measurement device.

n=2; L2, n=10; L3, n=22; L4, n=40; and L5, n=31) were evaluated for these 105 screws statistically using one-way ANOVA with the Tukey test.

1. Statistical analysis

Statistical analyses were performed using one-way ANOVA with or without the Tukey test. Statistical significance was defined as $p<0.05$. We used JMP pro ver. 11 (SAS Institute Japan, Tokyo, Japan) for statistical analysis.

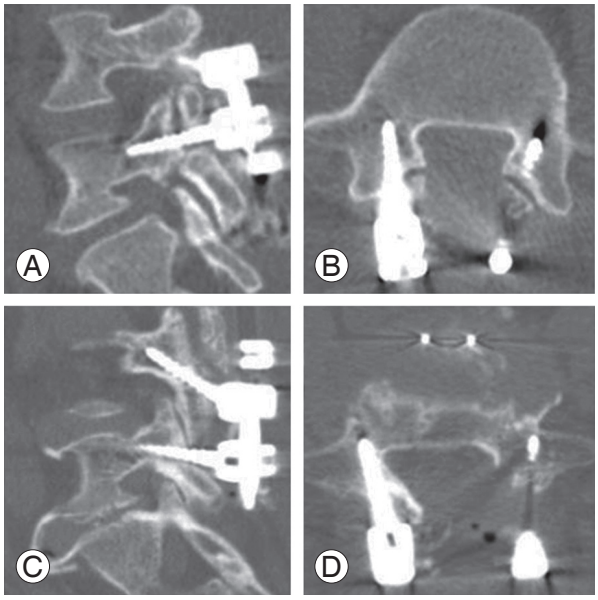

Fig. 2. Postoperative computed tomography demonstrating typical screw insertion in L5: sagittal view **(A)** and axial view **(B)** of L5 screws for a case with spondylolysis. Sagittal view **(C)** and axial view **(D)** for a case without spondylolysis.

Results

Typical cases with and without spondylolysis of L5 are shown in Fig. 2.

The mean maximum insertional torque in L5 for cases with spondylolysis was significantly lower than that for cases without spondylolysis (4.25±1.74 vs. 8.24±0.89 in-lb, respectively; $p=0.040$) (Fig. 3).

Among the four groups classified by sex and age, there was a significant difference only between insertional torque for men <75 years and women ≥75 years (10±1.03 vs. 5.5±1.31 in-lb, respectively; $p=0.038$) (Fig. 4).

The mean insertional torque by grade of vertebral de-

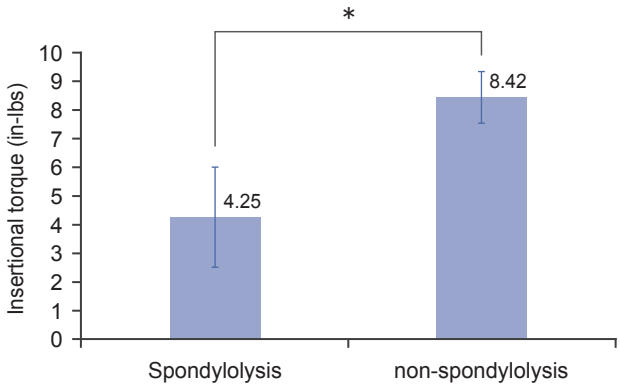

Fig. 3. The mean±SEM for maximum insertional torque in cases with and without spondylolysis in L5 ($p=0.040$). SEM, standard error of mean.

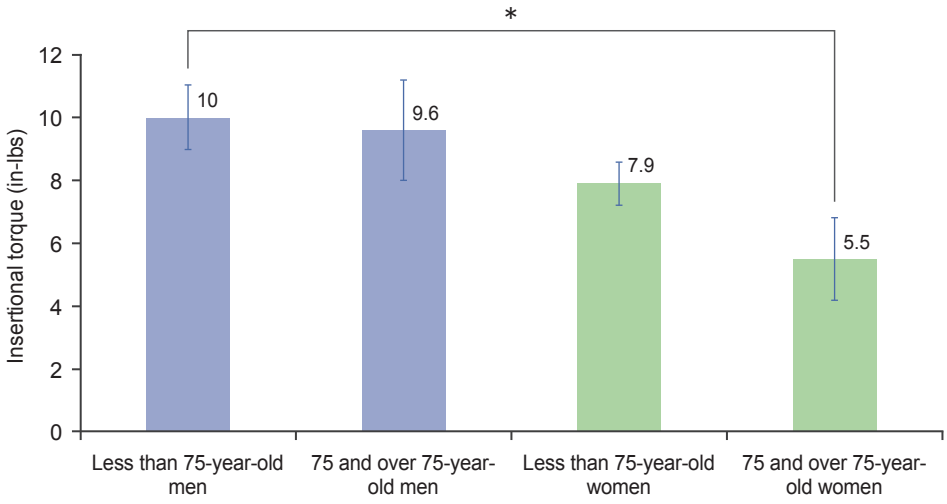

Fig. 4. The mean±SEM for maximum insertional torque by age and sex group. Significantly greater torque was used by men <75 years than women ≥75 years ($p=0.038$). SEM, standard error of mean.

generation is shown in Fig. 5. The mean insertional torque for grade 0, 1, and 2 vertebrae was 8.46±0.83, 8.58±0.73, and 7.31±0.76 in-lb, respectively. There was no statistical difference among them.

The mean insertional torque according to lumbar vertebral level is shown in Fig. 6. There were no statistical differences among them.

None of the patients in our study experienced surgical complications.

Discussion

Santoni et al. [1] designed the CBT technique to attach surgical screws to high-density bones in the posterior aspect of the spinal column, and they evaluated its efficacy in their human cadaver study. They demonstrated a 30% increase in uniaxial yield pullout load and equivalency in mixed loading for the CBT screw compared with that for traditional pedicle screws, which are inserted from the pedicle to the vertebral body and mainly anchored in the cancellous bone.

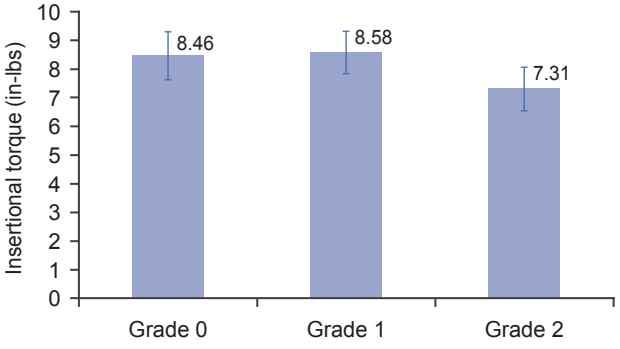

Fig. 5. The mean±SEM for maximum insertional torque classified by a semiquantitative method. The differences were not significant. SEM, standard error of mean.

According to Wakabayasi et al. [8], the traditional pedicle screw fixation is not recommended for osteoporotic vertebrae (grades 2 and 3 on their Jikei scale) because of the appearance of a clear zone, which means a limitation for the screws. Meanwhile, Santoni et al. [1] hypothesized that their new technique would work well for patients with poor trabecular bone quality.

Our study was designed to clarify the extent to which the utility of this new technique would be influenced by osteoporotic vertebrae and how widely it could be used. For this investigation, it was essential to grade the various degrees of vertebral degeneration. In addition, we used insertional torque to make an indirect evaluation of bone quality of posterior elements and the relation between this and vertebral degeneration.

Many studies [9-11] have reported that the insertional torque of pedicle screws was highly correlated with pullout strength. Meanwhile, other studies describe screw loosening primarily caused by cyclic caudocephalad toggling at the bone-screw interface [12]; insertional torque cannot predict screw loosening [13]. However, pullout strength and screw toggling cannot be evaluated *in vivo*; therefore, the evaluation of insertional torque is thought to predict a patient's postoperative clinical and radiological course. Insertional torque is caused by frictional resistance between the screw threads and bones as well as radial compression of the trabeculae [9,14]. It can also be influenced by multiple other factors, such as screw length, pitch, thread, and shaft design and diameter as well as

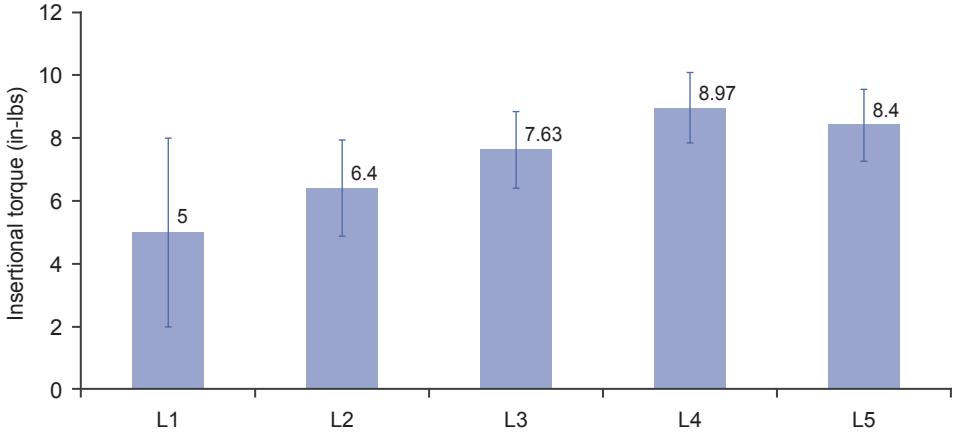

Fig. 6. The mean±SEM for maximum insertional torque according to vertebral level. The differences were not significant. SEM, standard error of mean.

bone mineral density (BMD) and surgical technique.

The *in vivo* insertional torque of CBT screws was first reported by Matsukawa et al. [2]. According to them, there was a significant difference between their mean maximum insertional torque (2.49±0.99 Nm=22.09±8.78 in-lb) and that of traditional screws (1.24±0.54 Nm=11.00±4.79 in-lb). They used SOLERA Spinal System screws with a diameter of 5.5 mm, pitch of 2 mm, and length ranging from 30 to 35 mm. Their differential method of torque measurement and the larger size of screws with short pitches might explain their higher insertional torque than that observed in our study.

From an anatomical point of view, CBT screws are thought to be primarily stabilized at the cortex and trabecula of the neural arch, the middle or lateral side of the pedicle cortex, and the cortex of the vertebral edge. In spondylolysis, or a defect of the pars interarticularis, there is thus a partial lack of the cortex and trabecula in the neural arch. In our study, the insertional torque in cases with spondylolysis was significantly lower than that in those without spondylolysis. These observations highlight the importance of the cortex and trabecula of the pars interarticularis as an entry point for the CBT technique.

Some studies have reported a correlation between osteoporosis and the insertional torque of the traditional technique. Ozawa et al. [15] reported that there was a negative relation between the insertional torque of the lumbar traditional pedicle screw and the grade of osteoporosis, although they showed no significant relation between insertional torque and screw loosening or clinical outcome. Lee et al. [16] found that the insertional torque of the traditional pedicle screw had a positive correlation with BMD.

On the other hand, Matsukawa et al. [2] demonstrated that although positive linear correlations between maximum insertional torque and BMD were found in both techniques, the correlation coefficient of traditional screws was higher than that of the CBT screws.

Considering the relevance of these findings, the study performed by Giambini et al. [17] is very important. Through the study of 36 women aged ≥50 years, they first showed that BMD of the neural arch trabecula was maintained regardless of the presence of a vertebral compression fracture. Therefore, compared with traditional screws, the insertional torque of CBT screws is thought to be less influenced by vertebral or femoral neck BMD.

In our study, instead of measuring vertebral BMD, we evaluated the relationship between the grade of vertebral degeneration and insertional torque. In addition, there was no statistical difference in the insertional torque, suggesting that BMD of the neural arch may be fairly maintained regardless of lumbar vertebral degeneration.

Our study demonstrated that late elderly women had significantly lower insertional torque than men <75 years. Because we could not clarify the reason for this finding, assessment of BMD in the neural arch according to sex and age may be needed, and it might be particularly important for this new technique.

Further studies will need to evaluate the relation between insertional torque and postoperative stability. However, our study highlights the importance of the pars interarticularis in the CBT technique because it does not appear to be affected by the lumber level or vertebral degeneration.

Conclusions

CBT is an efficient technique for the treatment of patients with osteoporosis and could therefore be used widely. However, in elderly women and patients with spondylolysis, careful consideration is advisable if potential complications are to be avoided.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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