Original Article
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The Feasibility of Translaminar Screws in the Subaxial Cervical Spine: Computed Tomography and Cadaveric Validation

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Background: The use of translaminar screws may serve as a viable salvage method for complicated cases. To our understanding, the study of the feasibility of translaminar screw insertion in the actual entire subaxial cervical spine has not been carried out yet. The purpose of this study was to report the feasibility of translaminar screw insertion in the entire subaxial cervical spine.

Methods: Eighteen cadaveric spines were harvested from C3 to C7 and 1-mm computed tomography (CT) scans and three-dimensional reconstructions were created to exclude any bony anomaly. Thirty anatomically intact segments were collected (C3, 2; C4, 3; C5, 3; C6, 8; and C7, 14), and randomly arranged. Twenty-one segments were physically separated at each vertebral level (group S), while 9 segments were not separated from the vertebral column and left in situ (group N–S). CT measurement of lamina thickness was done for both group S and group N–S, and manual measurement of various length and angle was done for group S only. Using the trajectory proposed by the previous studies, translaminar screws were placed at each level. Screw diameter was the same or 0.5 mm larger than the proposed diameter based on CT measurement. Post-insertion CT was performed. Cortical breakage was checked either visually or by CT.

Results: When 1° and 2° screws of the same size were used, medial cortex breakage was found 13% and 33% of the time, respectively. C7 was relatively safer than the other levels. With larger-sized screws, medial cortex breakage was found in 47% and 46% of 1° and 2° screws, respectively. There were no facet injuries due to the screws in group N–S.

Conclusions: Translaminar screw insertion in the subaxial cervical spine is feasible only when the lamina is thick enough to avoid any breakage that could lead to further complications. The authors do not recommend inserting translaminar screws in the subaxial cervical spine except in some salvage cases in the presence of a thick lamina.

Keywords: *Subaxial cervical spine, Translaminar screws, Feasibility, Cadaver, Validation*

Posterior subaxial cervical screw fixation is used to stabilize cervical spine fractures,[1)] as well as to promote posterior cervical fusion.[2)] Many fixation methods can be used such as lateral mass screws, pedicle screws, as well as translaminar screws. Among them, lateral mass screws are most widely used.[3)] Lateral mass screw fixation is considered relatively safe; however, some complications regarding the lateral mass screw technique have been reported.[4,5)] Cervical pedicle screws can be an alternative method,[6)] but

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may not be feasible if there is anatomic variation.[7,8)]

The use of translaminar screws may serve as a viable salvage method for complicated cases. It was first described for fixation in C2.[9)] Since then, a few studies were performed to expand their usage in the subaxial cervical spine,[10-12)] as well as the thoracolumbar spine.[13,14)] Additionally, there have been a few biomechanical studies that showed its favorable fixation strength.[15-18)] Recently, a feasibility study of inserting translaminar screws in the subaxial cervical spine was performed; however, it was not done on the actual spine.[19)] To our understanding, a study on the feasibility of translaminar screw insertion in the entire subaxial cervical spine has not been carried out yet.

METHODS

Approval from the institutional review board and informed consent from patients were not needed because it was a cadaveric study.

Eighteen cadaveric spines were obtained. In order to exclude any congenital bony anomalies or fractured vertebral segments during extraction from the bodies, 1-mm computed tomography (CT) scans and three-dimensional reconstruction were created. Because not all specimens were fully intact with full cervical segments from C3 to C7, missing segments were not included. There were no congenital bony anomalies. After excluding initially missing segments and fractured segments during extraction, total 30 anatomically intact segments were collected (C3, 2; C4, 3; C5, 3; C6, 8; and C7, 14), and they were randomly arranged. Using the trajectory proposed by the previous studies,[12)] as shown in Fig. 1, translaminar screws were simulated at each segment. CT measurements of thickness of lamina along the simulated trajectory were performed. On top of CT measurement of each lamina, we planned to measure various lengths and angles manually. In order to measure the thickness of each lamina manually, randomly selected 12 cadaveric spines were separated into each segment, and total 21 vertebral segments were collected and grouped under group S. In addition, in order to simulate the real situation, remaining 6 specimens were left in situ. The non-separated cadaveric spines were named as group N–S which included 9 segments.

For separated segments in group S, manual measurement was performed. On the frontal plane, length of lamina and angle of lamina from the horizontal line were measured. On the axial plane, thickness of lamina and angle of lamina from the sagittal plane were measured.

After finishing CT and manual measurements, translaminar screws were placed along with simulated trajectory at each segment. Diameter of screws were determined by CT measurements of lamina thickness. Length of screws was determined by manual measurement of lamina length. In group S, each screw was inserted into each separated segment. In group N–S, each screw was inserted into each segment, while it was attached to the entire specimen. If the diameter chosen for the 2° screw was not feasible due to the 1° screw's specific trajectory, only the 1° screw was inserted, which was always placed to maximize bony purchase. Twelve from group S and 3 from Group N–S were chosen to receive the same diameter 1° and 2° screws. Nine from group S and 6 from group N–S received screws that were 0.5 mm larger in diameter. Larger diameter screws than the measured thickness were used to see if there was any plasticity of lamina as pedicle had.

After insertion of all screws, post-insertion CT scan was performed to measure the post-insertion thickness of lamina. The breakage of medial and lateral cortex was checked. For the vertebrae from group S, breakage of either the medial or lateral cortex was visually confirmed. For each vertebra from group N–S, breakage of the medial or lateral cortex was checked using CT scans.

RESULTS

Out of 21 segments in group S, 12 segments received 12 primary and 9 secondary screws with the same size as measured, and 9 segments received 9 primary and 8 secondary screws with 0.5 mm larger diameter than measured. Out of 9 segments in group N–S, 3 segments received 3 primary and 3 secondary screws with the same size as measured, and 6 segments received 6 primary and 3

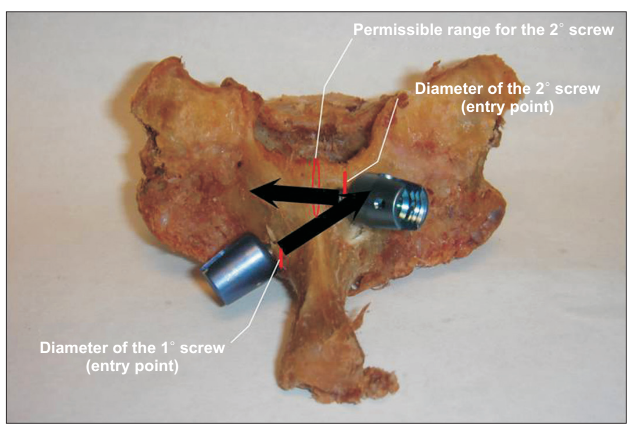

Fig. 1. The trajectory of translaminar screw insertion in the subaxial cervical spine.

secondary screws with 0.5 mm larger diameter than measured. For primary screws, medial cortical breakage was found in 1 with matched diameter screw and 4 with oversized screws in group S, 1 with matched diameter screw and 3 with oversized screws in group N–S. For secondary screws, medial cortical breakage was found in 2 with matched diameter screws and 4 with oversized screws in group S, 2 with matched diameter screws and 1 with oversized screws in group N–S. When 1° and 2° screws of the same size were used, medial cortex breakage was found in 2 out of 15 (13%) and in 4 out of 12 (33%) of the time, respectively, with C7 being relatively safer than the other levels. With larger sized screws, medial cortex breakage was found in 7 out of 15 (47%) and 5 out of 11 (46%) of 1° and 2° screws, respectively. There were no facet injuries due to the screws in group N–S. The percentage of medial cortical breakage was higher when the screw was larger than the measured lamina thickness. Cortical breakages are shown in Figs. 2, 3, and Table 1.

DISCUSSION

Neill Wright first described translaminar screws to avoid vertebral artery injury during pedicle or pars screw fixation in C2.[9] Since then, the efficacy and safety of translaminar screws in C2 have been reported.[20] Lehman et al.[15] preformed a biomechanical study and showed that there was a trend of higher pullout strength of translaminar screws compared to pars screws in C2, while pedicle screws have the strongest pullout strength. Reddy et al.[16] compared the motion after C2 pedicle screw-C3 lateral mass screw fixation and C2 translaminar screw-C3 lateral mass screw combination and showed favorable biomechanical properties in both constructs even though the pedicle screw construct permits less motion. More and more studies are showing that translaminar screws can be a good salvage technique.[21-23]

Recently, the studies have expanded to include the subaxial cervical spine[10-12] and thoracolumbar spine.[13,14] Hong et al.[18] performed a biomechanical study comparing transpedicular screws and translaminar screws in C7. The result showed that the translaminar screw still has favorable fixation power even if the pedicle screw has the strongest fixation, suggesting that translaminar screws can be a good alternative to pedicle screws in salvage cases. Hong et al.[10] also reported a series of cases where translaminar screws were inserted in the subaxial cervical spine. They inserted translaminar screws in the subaxial cervical spine of 11 patients, and the levels ranged from C3 to T1. Among these 11 patients, however, only 4 patients had true translaminar screws, all of which were placed at C7. The other 7 patients received mini screws to hold the lamina after laminoplasty; therefore, they were not true translaminar screws. More recently a feasibility study of inserting translaminar screws in the subaxial cervical spine was performed.[19] They concluded that translaminar in the subaxial cervical spine is safe especially if a unilateral screw is inserted. However, the study was performed on the CT of 50 patients, and no actual screws were inserted.

In a previous study, we proposed the trajectory of translaminar screws in the subaxial cervical spines.[12] In the study, we simulated the screw trajectories based on CT scans of cadaveric spines to maximize bony purchase. The proposed trajectory was as below: For the 1° translaminar screw, the entry point is the distance of the diameter of the desired screw superior to the inferior margin of lamina-spinous process junction. The trajectory should be targeted towards the most superomedial corner of lateral mass. For the 2° translaminar screw, the entry point is the

Fig. 2. Medial cortex breakage.

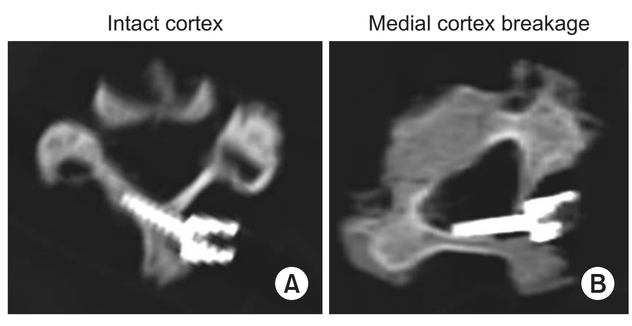

Fig. 3. Post-insertion computed tomography comparing an intact cortex (A) and medial cortex breakage (B).

Table 1. Pre- and Post-insertion Lamina Thickness, Screw Diameter, and Cortical Breakage

Group	Primary screw						Secondary screw						Comment
	Preinsertion lamina thickness (mm)	Cancellous thickness (mm)	Postinsertion lamina thickness (mm)	Screw diameter (mm)	Medial cortex breakage	Lateral cortex breakage	Preinsertion lamina thickness (mm)	Cancellous thickness (mm)	Postinsertion lamina thickness (mm)	Screw diameter (mm)	Medial cortex breakage	Lateral cortex breakage	
Group S				Size matched						Size matched			
1-C7	4.5	1.06	4.37	3.5	No	No	3.5	0.06	5.63	3.5	No	No	Both screws in, lamina intact
3-C7	4.83	2.29	5.33	4	No	No	4.47	2.29	6.02	4	No	No	Both screws in, lamina intact
4-C3	4.06	2	3.95	3.5	No	Yes	×	×	×	×	×	×	Only primary screw in, slight 1-mm diameter puncture lateral cortex
4-C7	6.25	2.33	5.84	3.5	No	No	4.46	2.18	4.58	3.5	Yes	No	Both screws in, secondary screw medial cortex puncture
5-C7	4.47	1.11	4.04	3.5	No	No	4.09	1.45	3.16	3.5	Yes	No	Both screws in, secondary screw medial cortex puncture
6-C7	5.33	3.23	6.58	4	No	No	5.82	3.26	6.55	4	No	No	Both screws in, lamina intact
7-C7	4.6	2.92	3.95	3.5	No	No	4.36	2.34	4.1	3.5	No	No	Both screws in, lamina intact
11-C7	4.3	0.3	5.82	4	No	No	5.02	2.96	5.78	3.5	No	No	Both screws in, lamina intact
8-C7	4.37	2.37	5.86	3.5	No	No	5.48	1.92	5.18	3.5	No	No	Both screws in, lamina intact
9-C3	4.71	1.49	6.74	3.5	No	No	×	×	×	×	×	×	Only primary screw in, lamina intact
9-C4	3.59	1.89	3.47	3.5	Yes	No	×	×	×	×	×	×	Only primary screw in, lamina too thin, medial cortex breakage
9-C7	4.14	2.3	4.32	3.5	No	No	4.28	0.78	4.99	3.5	No	No	Both screws in, lamina intact
				Oversized						Oversized			
1-C6	4.14	1.04	3.98	3.5	Yes	No	4.01	0.91	3.97	3.5	Yes	No	Both screws in, both medial cortex breakage
3-C6	3.56	0.24	3.84	3.5	Yes	No	4.55	1.23	4.17	3.5	No	No	Both screws in, primary medial cortex breakage
4-C4	4.55	1.53	3.82	3.5	Yes	No	3.92	2.12	3.56	3.5	Yes	No	Both screws in, both medial cortex breakage
1-C5	4.8	2.6	4.64	3.5	No	No	×	×	×	×	×	×	Only primary screw in, lamina intact

Table 1. Continued

Group	Primary screw						Secondary screw						Comment
	Preinsertion lamina thickness (mm)	Cancellous thickness (mm)	Postinsertion lamina thickness (mm)	Screw diameter (mm)	Medial cortex breakage	Lateral cortex breakage	Preinsertion lamina thickness (mm)	Cancellous thickness (mm)	Postinsertion lamina thickness (mm)	Screw diameter (mm)	Medial cortex breakage	Lateral cortex breakage	
6-C6	4.57	2.73	5.84	3.5	No	No	3.86	2	4.65	3.5	Yes	No	Both screws in, medial cortex breakage for secondary screw
7-C6	3.49	2.03	4.09	3.5	No	Yes	4.19	1.03	4.34	3.5	No	Yes	Both screws in, both primary and secondary lateral cortex breakage
8-C6	5	1.76	5.93	3.5	Yes	No	4.22	2.36	3.02	3.5	Yes	No	Both screws in, both medial cortex breakage
9-C6	3.99	0.51	4.03	3.5	No	Yes	3.5	1.76	5.01	3.5	No	No	Both screws in, primary lateral cortex breakage
10-C7	4.1	1.1	5.19	3.5	No	No	5.06	2.46	4.03	3.5	No	No	Both screws in, lamina intact
Group N-S				Size matched						Size matched			
13-C7	4.17	2.05	4.83	3.5	No	No	4.14	1.9	4.25	3.5	No	Yes	Both screws in, secondary screw lateral cortex breakage on CT
14-C7	5.71	3.15	3.47	3.5	No	No	5.29	3.03	3.3	3.5	Yes	No	Both screws in, secondary screw medial cortex breakage on CT
18-C7	6	2.98	4.71	4	Yes	No	5.44	2.5	4.61	4	Yes	No	Both screws in, both screw medial cortex breakage on CT
				Oversized						Oversized			
15-C6	3.35	0.27	4.51	4	No	No	4.35	1.79	4.76	4	No	No	Both screws in, lamina intact on CT
18-C6	2.55	0.97	4.18	4	Yes	No	4.65	3.05	4.43	4	Yes	No	Both screws in, both screw medial cortex breakage on CT
15-C4	4.35	2.21	4.11	4	Yes	No	×	×	×	×	×	×	Only primary screw in, possible medial cortex breakage on CT
15-C5	3.29	1.91	3.39	4	Yes	No	×	×	×	×	×	×	Only primary screw in, medial cortex breakage on CT
15-C7	5.52	1.32	7.03	3.5	No	No	6.21	3.91	7.31	3.5	No	No	Both screws in, lamina intact on CT
17-C5	4.49	2.67	3.26	4	No	Yes	×	×	×	×	×	×	Only primary screw in, lateral cortex breakage on CT

CT: computed tomography.
*Oversized screws. †Cortical breakage for oversized. ‡Cortical breakage for size matched.

distance of the diameter of the desired screw below the superior margin of the lamina-spinous process junction, and the target is the most superolateral corner of the lateral mass, which is typically horizontal. The study of the feasibility of actual translaminar screw insertion in the entire subaxial cervical spine had not been carried out then.

In this study, we inserted the actual translaminar screws in the subaxial cervical cadaveric spine according to the proposed trajectory. Among 18 cadaveric spines from C3 to C7, 30 anatomically intact segments were collected and randomly arranged. Twenty-one segments were physically separated at each vertebral level (group S), while 9 segments were not separated from the vertebral column and left in situ (group N–S). CT measurements along the simulated trajectory were used to determine the screw diameter to be utilized. Twelve from group S and 3 from group N–S were chosen to receive the same diameter 1° and 2° screw. Nine from group S and 6 from group N–S received screws that were 0.5 mm larger in diameter. The reason we chose to insert bigger sized screws than the proposed trajectory and original screw diameter in some specimen was because we also wanted to see the plasticity of the lamina in the subaxial cervical spine. Contrast to pedicle, however, lamina did not show such a plasticity.

For the vertebrae from group S, breakage of either the medial or lateral cortex was visually confirmed. For each vertebra from group N–S, breakage of the medial or lateral cortex was checked using CT scans. Surprisingly, we found 13% of medial cortex breakage by 1° screws and 33% by 2° screws when the same size screws were used as were predetermined using CT measurements and proposed trajectories. C7 was relatively safer than the other levels. With larger sized screws than the proposed trajectory and original screw diameter, medial cortex breakage was found in 47% and 46% of 1° and 2° screws, respectively. The results obviously seem to be unacceptable in the clinical field.

One of the limitation of our study is that we did not measure the amount of canal encroachment as we simply measured presence or absence of breakage of lamina at medial or lateral cortex. Therefore, our finding will not be directly correlated with the neural safety once the cortical breakage happens. However, especially medial cortical breakage is certainly a concern of operating surgeons. The example of cortical breakage shown in Figs. 2 and 3 were definitely concerning. In addition, cortical breakage will decrease the fixation power as well. In order to find any biomechanical effect of cortical breakage on fixation power of translaminar screws in the cervical spine, subsequent biomechanical studies will be needed.

In conclusion, translaminar screw insertion in the subaxial cervical spine is feasible only when the lamina is thick enough (e.g., C7) to avoid any breakage that could lead to further complications. Otherwise, it is extremely dangerous; therefore, we do not recommend inserting translaminar screws in the subaxial cervical spine except in some salvage cases in the presence of a thick lamina. Preoperative CT scans are mandatory to measure the thickness of the lamina.

CONFLICT OF INTEREST

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

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