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NEW TECHNIQUE FOR ADDITIONAL SUPPORT POINT TO IMPROVE THE STABILITY OF PEDICLE SCREW SYSTEMS

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ABSTRACT

Objective: Pedicle screw (PS) fixation for spine arthrodesis is a useful procedure for the treatment of spinal disorders. However, instrument failure often occurs, and PS loosening is the initial step of a range of complications. In order to prevent PS loosening, the author offers to open a hole in the middle of spinous process of vertebra and pass a cross link which connects rods with each other through that hole. The paper provides explanation of an operating technique, clinical impressions in the early and late postoperative period and any technical problems that may occur. The aim of this study is description of a new technique to prevent PS loosening and demonstration of application results.

Materials and Methods: The technique we propose has been applied for two years to 24 patients with idiopathic scoliosis, 4 patients with vertebral fracture and 4 patients with lumbar stenosis, all aged between 13 and 65.

Results: The modification can be easily conducted and takes no more than 2- 5 minutes. None of the patients had any unusual or pronounced pain in the shaft zone in early postoperative period and no movement restriction or any other clinical symptoms can be observed. None of the patients have had loosening or displacements of screws for two years.

Conclusion: The technique for support of spinous processes is efficient and easy which prevents PS loosening and creates no further complications. It does not thoroughly modify the principles of fixation and require any special instruments, therefore it can widely be used.

Key words: implant failure, loosening, pedicle screw fixation, pedicle screw loosening, spine surgery

Level of evidence: Retrospective clinical study, Level III

INTRODUCTION

In 1959, Boucher was the first to penetrate into the vertebral body through the pedicle, describe the possibility of fixation passage [5]. There have been no significant changes in the design of segmental pedicle systems since 1959 up to now. We should point out screws that pass through the main vertebral body and support spongious bone circular thread blades and rods that connect them with each other. Three factors are required to obtain successful and longstanding fixation: quite hard bone, non-releasable tightening metal elements which keep rods firm and above-construct strong scar if possible. Thus, there are three factors to keep the structure firm:

1. Spongious material of the vertebral body to be the only contact area of vertebrae and metal implant;

2. Tightening elements of regular metal screws and metal screws for fixation;

3. Transverse ties to reduce the rod movements when the patient moves and ensure once again metal - metal contact;

4. Above-construct scar that has a relatively low effect, prevents the construct from coming out of the bone and ensures the second metal — tissue contact.

Generally, the metal and the bone are always in conflict during metal implantation due to their different density, which results in atrophy in the bone because of metal pressure, and local osteoporosis can lead to the loosening and dislocation of pedicle screws in 3 - 6 months postoperatively. Clinically, this state reveals itself by pain, inflammation, purulence and the loss of correction in case of deformity and finally results in the appearance of the construct under the skin.

Pull-out may also occur with patients as a result of osteoporosis. The screws can also be displaced during the operation that may occur in cases when the unbalancing force is applied, the direction of force is parallel to screw, the transverse size of the screw is thinner than the width of the pedicle or when the screw fails to reach the anterior part of the body.

Taking all the above-mentioned into consideration, we offer to create the second contact and support point by forming a contact with another element of vertebra, apart from the contact of pedicle screw into spinal construct with the vertebral body. We propose to refuse to place the component earlier called DDT and later - Cross Link Shaft among the rods instead of the posterior process upon its resection and let it pass through the transverse hole opened in the middle of processus spinosus. Therefore, when fixing the rods by putting the shaft through the hole with a lying patient, the support of the construct on that hole and posterior process can reduce the patient's micro-motions in the sagittal plane and impede or eliminate the occurrence of atrophy, osteoporosis and Looser's zones as a result of pressure relief around the blade during the fixation of the construct and flexion motions while placing the patient vertically.

MATERIALS AND METHODS

The current retrospective study assesses the outcomes of a new technique which was performing as the application of Cross Link through spinous processes. The study was performed in the department of adult orthopedics in Azerbaijan Research Institute of Traumatology and Orthopedics.

Application technique

When seeking for a place to put Cross Link after the implantation of pedicle screws and rods, we have to pay attention to whether the spinous processes are wide and thick. If the lowest instrumented Vertebra is L5, the level of its placement can be L4 or L5. Once the construct is for vertebral fracture and covers the short number of segments, it should be noted that pull-out cases mainly occur in vertebrae with straight, not angle-wise pedicles which covers the thoracolumbar region, namely the vertebrae above L3 [(3)].

When we cause the cross link pass the hole, we should not think of the osteoporotic vertebra, but bring pedicles closer to axial vertebrae where, according to the reference literature, potential screw loosening is higher. The second factor is that the spinous process' size. It is hardly likely that the cross link would break the hole in case of a wider process and such a case has never been observed by us. Upon the selection of the spinous process of the necessary vertebra, the middle and the lower part of the spinous process is perforated by a custom made perforating instrument and a hole is opened. When opening the hole, the base of the spinous process should be selected because it is thicker and stronger than the top. Also, the level of rods must be taken into consideration so that after the cross link has been passed through the opened hole we could reach it out placing on the rods to put it inside the hooks and fix. If the custom made perforating instrument is not available, the hole can be opened by high speed burr.

The perforating end of the instrument must be of a size to let the Cross Link pass the hole. Afterwards, the Cross Link is passed through the hole using regular Luer's forceps and put inside the hooks placing on the rods and the locks clinched. Then we check whether the posterior and anterior wall of the hole of spinous process is broken or not. If broken, the sizes of the broken part have to be considered, the cross link needn't to be removed if its upper part is covered by a big bone mass and the fracture occurs laterally, cross link must be removed and the manipulation is conducted in another process if fracture in the upper part occurs.

Cross Link simply fixes two rods together and bring their rotational movement to zero; here the spinous process is undergone to resection. The proposed technique is shown in Figure-1and here the shaft once again fixes two rods together, it is just placed by passing through the hole opened in the middle of the spinous process, that prevents not only the movement of the rods, but also the displacement of the screws backward (Figure-2).

We re-operated a scoliosis patient to treat pelvic tilt and another scoliosis patient to treat sagittal imbalance one year after postoperatively and examined the Cross Links inside the spinous processes. Cross Link passing through the spinous process is seen; the process is intact and unbroken. The clinches of the hooks are opened and the Cross Link is removed from the hole using Luer's forceps. We put the thread through the hole to prove that it is intact. We show that the hole is intact by passing the Cross link once again through it without hooks (Figure-2-8).

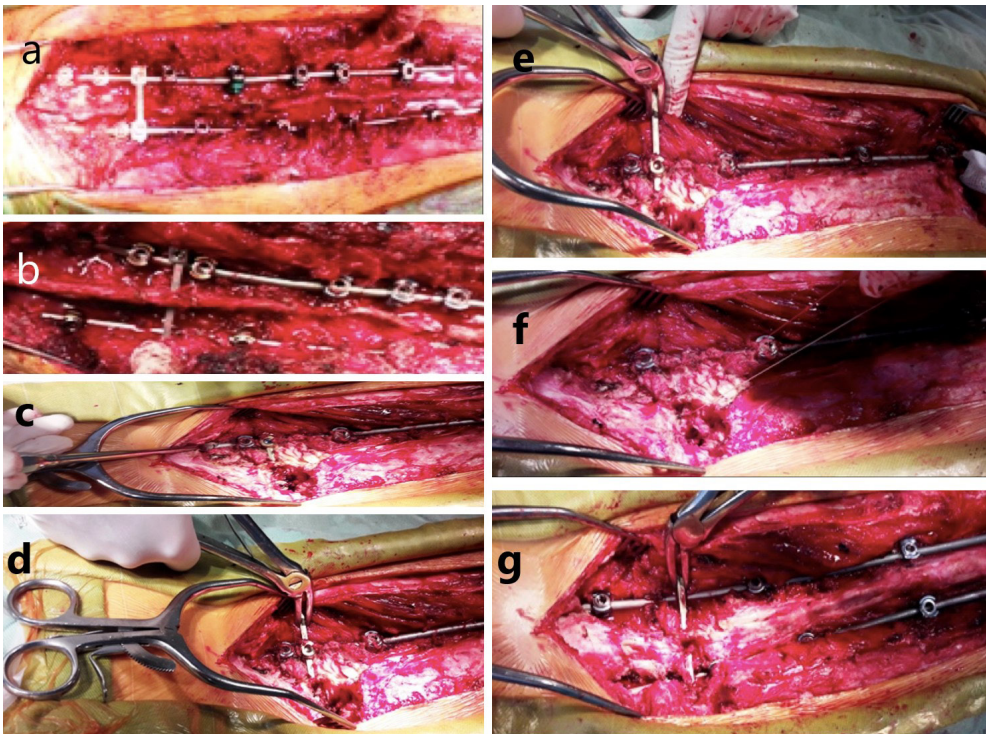

Figure-1. (a) Stabilization of cross-link between the rods, **(b)** cross-link passing through the hole of the spinous process, **(c)** postoperative figure of proposed method, **(d)** hook screws are opened and the cross-link removed, **(e)** removal of the cross-link, **(f)** intact spinous process hole, the thread is pushed through the hole to prove it, **(g)** the shaft is repeatedly pushed through the hole to prove that it is intact.

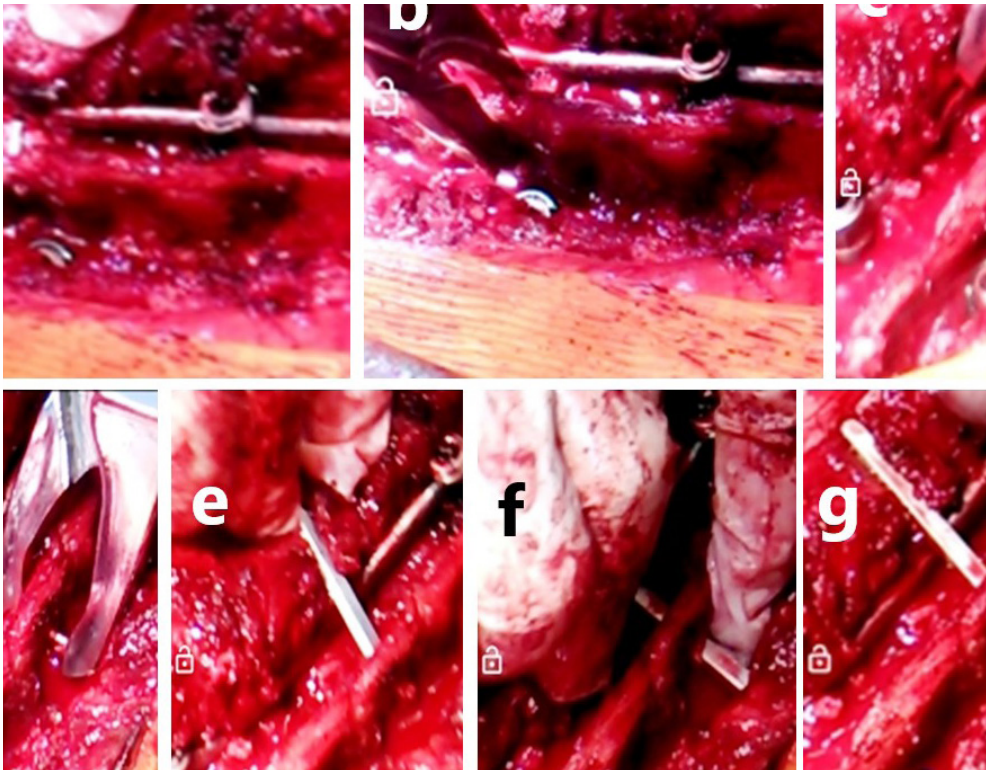

Figure-2. (**a-g**) Technique cross-link rod in to the spinous process with close-up view.

RESULTS

The technique we propose has been applied for 2014-2018 to 24 patients with idiopathic scoliosis, 4 patients with vertebral fracture and 4 patients with lumbar stenosis, all aged 13-65. The modification we propose can be easily conducted technically and takes no more than 2-5 minutes. None of the patients had any unusual pain or pronounced pain in the Cross Link zone in the early postoperative period. No movement restriction was applied. Any complication was not observed postoperatively. None of the patients had loosening or displacements of screws for two years. We think that the technology does not thoroughly modify the principles of fixation and require any special instruments and skills to be applied, so it can widely be used easily.

DISCUSSION

The implant loosening and displacement may occur with patients during the implantation of pedicle screw systems. Thus, in 2014 Abul Kasim and Ohlin examined 1666 pedicle screw displacement with 81 patients suffering from idiopathic scoliosis by low dose CT within two years and published the results. In 26 (32 %) patients there were signs of loosening of one or more screws, a maximum 3 screws. In males there were signs of loosening in 57 % and in females 27 %. One patient with a loosened L-4 screw had neurological deficit. Out of 26 patients with evidence of loosening, 5 patients reported displacement in lumbar region [(2)].

In 2014 Mavrogenis et al considered that loosening occurs due to the stiffness of rods proposed to use rods made from the polyetheretherketone (PEEK) and applied it practically [(12)]. As PEEK is more elastic and tolerant to body tissues it has a wide potential to be used in future. Kang et al also spread an information on the use of Polymethylmethacrylate cement to keep the screws more stable in osteoporotic patients [(8)].

In 2016 Leichtle et al. compared the use of solid pedicle screw, solid pedicle screw augmented with high-viscosity cement and fenestrated screw with cement by special pulling mechanisms in a total of 54 osteoporotic human cadavers. As a result, solid pedicle screws with high-viscosity cement provided comparable screw stability in pull-out testing to that of more expensive fenestrated screws, and the use of 1 mL in the thoracic and 3 mL in the lumbar spine was recommended [(1,4,9)]. Leitner et al attributed pedicle screw loosening to chronic infection [(10)]. Ohe M. et al give information on the use of pedicle screws with a thin hydroxyapatite surface coating in patients with osteoporosis [(11,14)]. Drummond's biomechanical analyses prove that the subspinous region is 117 % thicker and firmer than sublaminar region in the thoracic vertebrae and 73 % in the lumbar vertebrae [(6)]. In 2018 Fu J et al. are reported to apply new-designed high-priced expandable pedicle screws to a total of 27 patients in order to solve the problem in osteoporotic patients and manage to do it partially[(7)].

In 2018, Mizuno T. et al have tested a cross-link model and a cross-rod model for stability and proved the cross-link model to be more stable than the cross-rod one [(13,15)]. Authors says that surgery with pedicle screw instrumentation does not provide sufficient torsional stability. This leads to pseudoarthrosis, loosening of the pedicle screws and ultimately, implant failure. They use 6-axis material testing machine. As the specimen models, they prepared an intact model, a damaged model, a cross-rod model and a crosslink model. They measured the range of motion during the bending and rotation tests. In 2017 Wang Z et al. made a biomechanical study of double level pedicle screw construct with or without crosslink in an unstable model [(16)]. Ten cadaveric lumbar spines [(13-15)] of boars were used and 7 models were prepared by the sequential damage and spinal instrumentation of each specimen. Bending stiffness was measured in flexion, extension, lateral bending and axial rotation for each model using 6 –axis material tester under torgue of 0 to ±3Nm. In conclusion they said that contaminant use of CLs significantly increased axial rotational stiffness, even though stiffness in flexion, extension and lateral bending was not increased. In addition, stiffness in axial rotation significantly improved with the use of 2 crosslinks instead of single CL, and stiffness was unchanged by position and orientation of CL.

CONCLUSION

The cross-link technique we propose creates an additional support point for the pedicle screw system, but the number of cross-links passed through spinous processes can be increased individually, subject to pathology and bone density. Therefore, screw loosening mainly occurs posteriorly and the direction of the pedicle, the thickness and length of the screw, occurrence of chronic infection, osteoporosis, the number and level of instrumented segments are important. Cross-link technique helps to reduce screw movements in every directions and increase the stability of screws, and may prevent pain and greater complications relating to loosening in the early and late postoperative period.

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