Posterior Column Reconstruction of the Lumbar Spine Using En Bloc Resected Vertebral Arch in Spinal Tumor and Deformity Surgeries

Satoshi Kato, Noriaki Yokogawa, Takaki Shimizu, Motoya Kobayashi, Yohei Yamada, Satoshi Nagatani and Satoru Demura

Department of Orthopaedic Surgery, Graduate School of Medical Science, Kanazawa University, Kanazawa, Japan

Abstract:

Introduction: In high-grade spinal osteotomy involving large anterior column resection, restoration of the structural integrity of the posterior column at the osteotomy site can reduce postoperative instrumentation failure (IF). This study aimed to describe our technique of posterior strut bone grafting using an en bloc resected vertebral arch, which is useful for posterior column reconstruction after high-grade osteotomies during surgeries for spinal tumor and deformity in the lower lumbar spine.

Technical Note: Using a posterior approach, en bloc resection of the targeted vertebral arch was performed in accordance with the surgical technique for total en bloc spondylectomy (TES). The posterior elements in the upper and lower adjacent vertebrae were separated by a significant space after vertebral body resection followed by cage insertion in TES or anterior column osteotomy followed by correction in deformity surgery. To create a new posterior column, the en bloc resected vertebral arch was placed at 90° rotation to bridge the upper and lower vertebral arches. Using this technique, an abundant amount of bone chips made from the resected vertebral elements were placed over the en bloc resected posterior arch as an additional bone graft. The technique was used in three patients who underwent TES for spinal tumors and in one patient who underwent grade 4 osteotomy for adult spinal deformity in the lower lumbar spine. One year after surgery, computed tomography showed that the structural integrity of bony fusion was successfully achieved between the en bloc resected arch and the posterior elements of the adjacent vertebrae in all patients and showed no postoperative IFs.

Conclusions: This bone graft technique created new continuity of the posterior column after high-grade osteotomies in the lower lumbar spine. Bone fusion was achieved in the posterior elements to prevent IF after surgery.

Keywords:

lumbar spine, posterior column reconstruction, spinal tumor, spinal deformity, three-column osteotomy, total en bloc spondylectomy

Spine Surg Relat Res 2024; 8(5): 534-539

dx.doi.org/10.22603/ssrr.2024-0041

Introduction

Total en bloc spondylectomy (TES) was developed for the complete oncological resection of spinal tumors[1,2]. It provides excellent local control of the affected spine[3,4]. Owing to extended patient survival following TES[4,5], spinal reconstruction after TES is crucial for prolonged function and quality of life[4,6]. From a biomechanical point of view, TES presents a challenge for spinal reconstruction because the operation involves complete resection of the affected vertebra(e) and the surrounding musculoligamentous supportive tissues. There is a high incidence of instrumentation failure (IF) after TES (20%-40%)[7-11], especially in the lumbar spine[11].

For patients with severe back pain, disability, and a lower quality of life associated with adult spinal deformity (ASD)[12,13], it has been shown that surgery can improve symptoms than conservative treatment[12-14]. Therefore, there has been an increasing number of adults undergoing surgery[15]. For patients with severe ASD, high-grade spinal osteotomy involving anterior column resection is often employed to effectively improve spinal alignment, especially in the sagittal plane[14]. Spinal reconstruction after high-grade osteotomy for ASD is challenging. IF-related nonunion or

Corresponding author: Satoshi Kato, skato323@gmail.com

Received: February 11, 2024, Accepted: April 27, 2024, Advance Publication: June 10, 2024

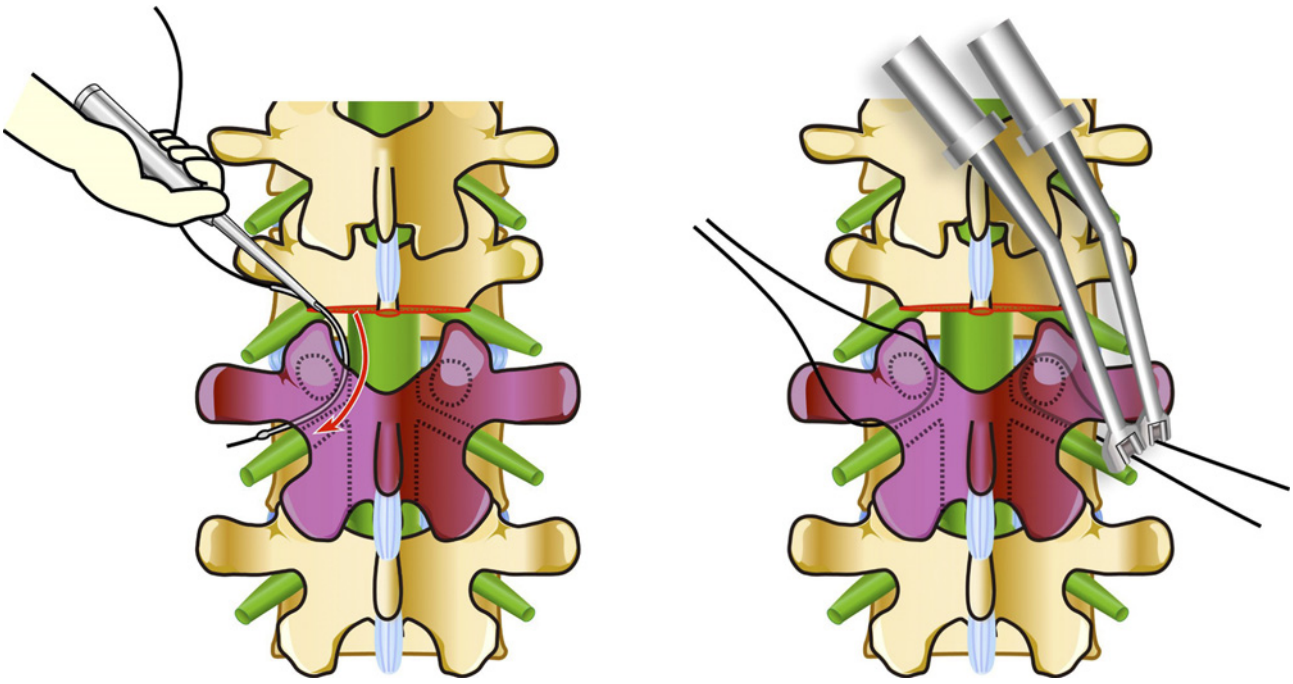

Figure 1. Operative schema of a pediculotomy using a T-saw.
A C-curved malleable T-saw guide is introduced from the spinal canal to the intervertebral foramen in a cephalocaudal direction (left). The pedicles are cut using a reciprocating motion of the T-saw through pulleys (right).

delayed union at the osteotomy site is of great concern, particularly in three-column osteotomies of the lumbar spine[16,17].

In these surgeries, restoration of the structural integrity of the posterior column at the osteotomy site can reduce postoperative IF. This study aims to describe our technique of posterior strut bone grafting using an en bloc resected vertebral arch, which is useful for posterior column reconstruction after TES for spinal tumor and high-grade osteotomy for ASD in the lower lumbar spine.

Technical Note

Description of the surgical technique

1. En bloc resection of the posterior arch

With the patient in prone position, a posterior midline approach was used to expose the posterior elements of the targeted and adjacent vertebrae. To expose the superior articular processes of the targeted vertebra, the spinous and inferior articular processes of the adjacent upper vertebra were osteotomized and removed by dissecting the attached soft tissues. To pass through a threadwire saw (T-saw)[1,2,18], a C-curved malleable T-saw guide was introduced from the spinal canal to the intervertebral foramen in a cephalocaudal direction (Fig. 1). After passing through the T-saw, it was clamped to T-saw holders at either end. The T-saw was placed beneath the superior articular and transverse processes using a specially designed T-saw manipulator while tension was maintained. During this procedure, a T-saw was wrapped around the pedicle and the pedicles were cut using the reciprocating motion of the T-saw through the pulleys (Fig. 1); this allowed the entire posterior elements of the spine, namely, the posterior arch, spinous process, superior and inferior articular processes, transverse process, and pedicle, to be removed in one piece.

2. Posterior bone grafting using the en bloc resected the posterior arch

After vertebral body resection followed by cage insertion in TES or anterior column osteotomy followed by correction in ASD surgery via a posterior approach, spinal reconstruction was performed using pedicle screws and rods. In this situation, the posterior elements in the upper and lower adjacent vertebrae had a significant space separating them. To create a new posterior column, the en bloc resected vertebral arch was placed at a 90° rotation to bridge the upper and lower vertebral arches (Fig. 2). Decortication was performed on the ventral side of the graft and the dorsal side of the recipient site. Thereafter, a large amount of chip bone made from the resected vertebral elements was placed over the en bloc resected arch as an additional bone graft (Fig. 2). In spine tumor surgery, when the vertebral arch had tumor involvement, the en bloc resected arch was frozen with liquid nitrogen (−196°C) for 20 min to kill tumor cells before usage in bone grafting[19,20]. Previous basic and clinical studies reported that the use of frozen autograft treated with liquid nitrogen was safe with no recurrent tumor that occurred within the graft even in the treatment for high-grade sarcomas[19,21,22].

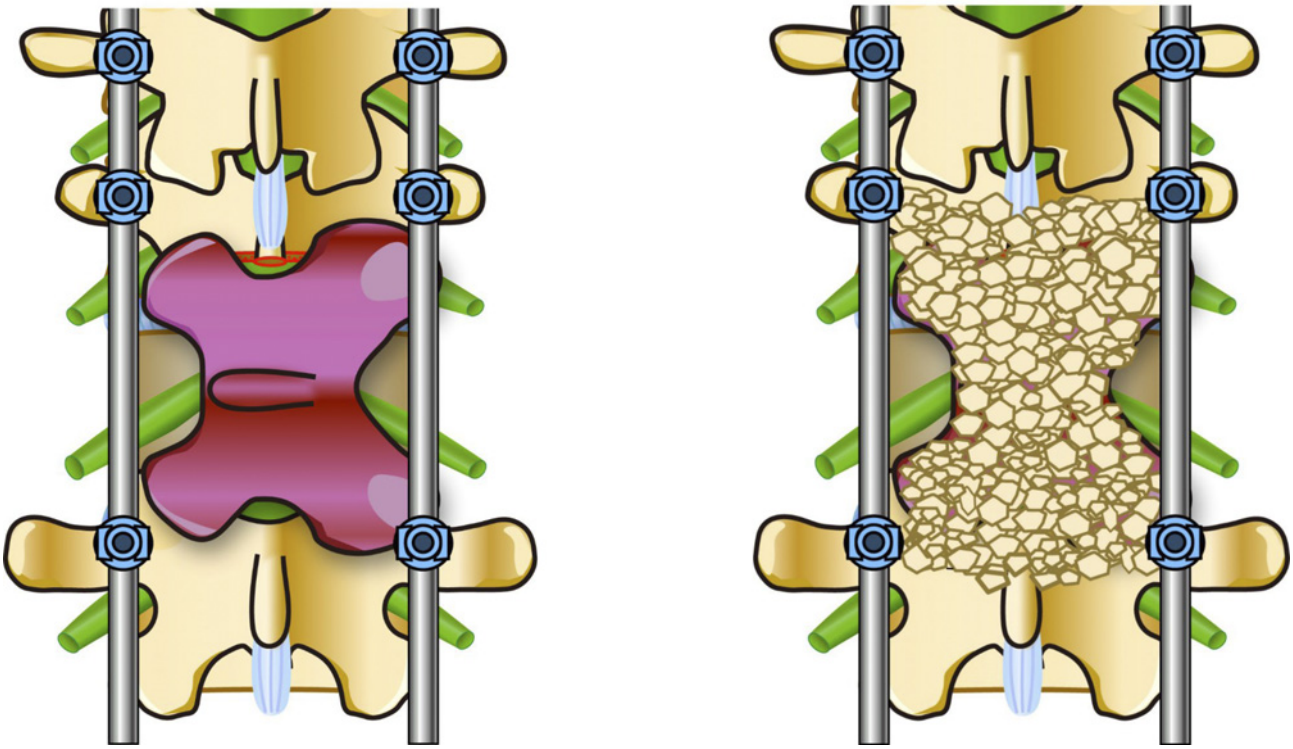

Figure 2. Operative schema of posterior column reconstruction using an en bloc resected posterior arch.
An en bloc resected vertebral arch is placed in a 90° rotation to bridge the upper and lower arches (left). Large volume of chip bones can be placed over the en bloc resected arch as additional bone grafts (right).

Table 1. Patient Characteristics.

Patient no./sex/age (year)	Diagnosis	Surgery (types of three-column osteotomy)	Perioperative complication	Postoperative period (month)	Bony fusion in the posterior spinal elements of the osteotomy level	IF
1/F/40	Giant cell tumor at L5	TES of L5	Temporary muscle weakness of the LEs	45	Achieved	None
2/F/50	Giant cell tumor at L5	TES of L5	Temporary muscle weakness of the LEs	30	Achieved	None
3/M/34	Solitary spinal metastasis at L4	TES of L4	Temporary muscle weakness of the LEs	26	Achieved	None
4/M/58	Adult spinal deformity associated with AS	Grade 4 osteotomy of L3 (PSO including a disc)	Temporary muscle weakness of the LEs	20	Achieved	None

M, male; F, female; AS, ankylosing spondylitis; TES, total en bloc spondylectomy; PSO, pedicle subtraction osteotomy; LE, lower extremity; IF, instrumentation failure

Clinical and radiological outcomes

Table 1 summarizes the clinical information of the four patients who were treated using this technique. Three patients underwent TES for spinal tumors in the lower lumbar spine (Fig. 3) and one patient underwent grade 4 osteotomy[23] for thoracolumbar kyphosis associated with ankylosing spondylitis. Computed tomography (CT) scans 1 year postoperatively showed that the structural integrity of bony fusion had been successfully achieved between the en bloc resected vertebral arch and the posterior elements of the adjacent vertebrae in all patients. All four patients had temporary mild muscle weakness in the lower extremities associated with massive dissection of the lumbar nerve roots and psoas muscles. However, all the patients fully recovered in the early postoperative period and did not experience any other postoperative complications, including IF or tumor recurrence.

Case presentation

The patient was a 40-year-old woman with an Enneking stage III giant cell tumor at the L5 level (number 1 in Table 1). A pathological fracture of the vertebral body with expansion of the tumor outside the vertebral body was observed (Fig. 3A, 3B). She underwent TES via a combined posteroanterior approach. After en bloc resection of the poste-

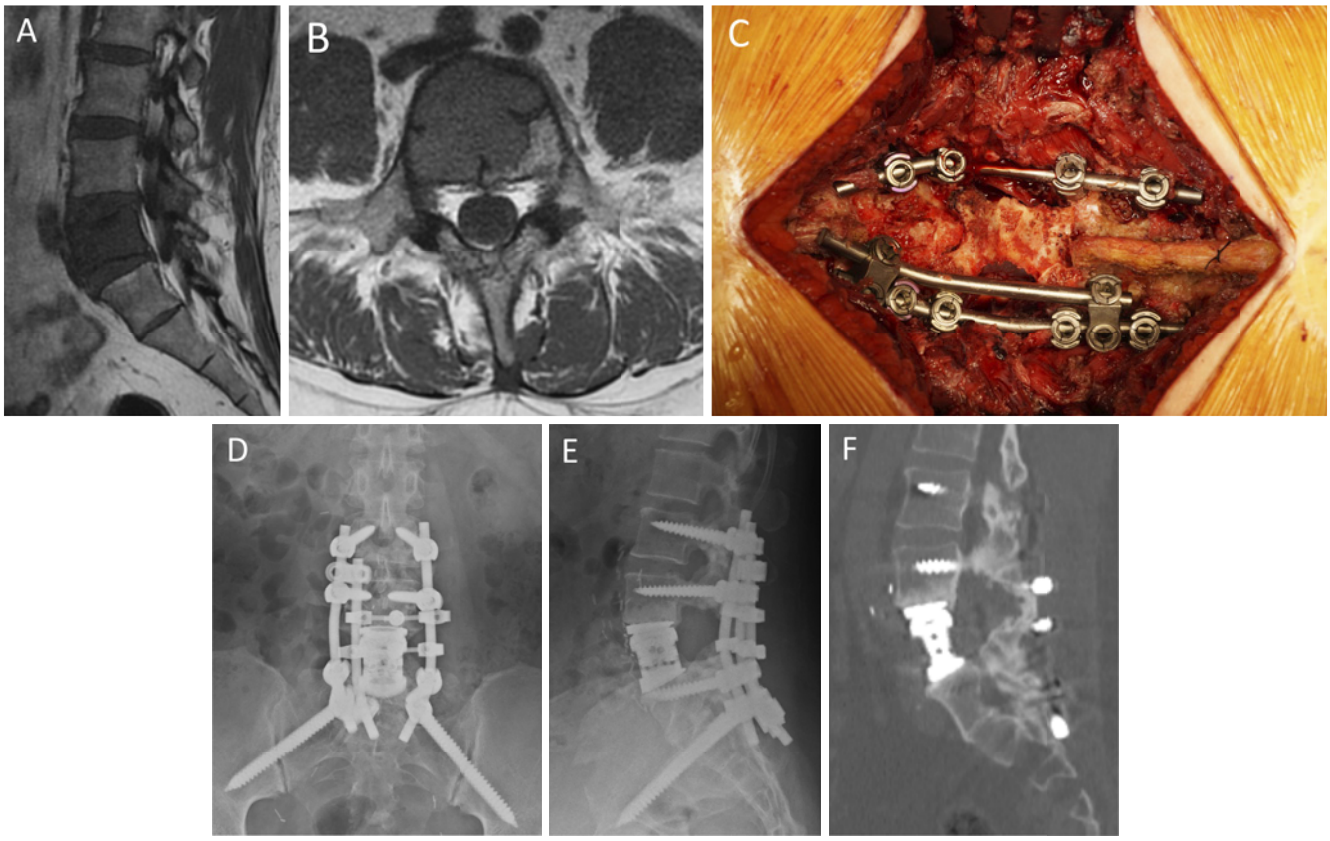

Figure 3. A representative case with a giant cell tumor at L5 undergoing total en bloc spondylectomy.
A) Preoperative sagittal T_1-weighted MRI showing the tumor in the L5 vertebral body. B) Preoperative axial T_1-weighted MRI showing that the tumor was partially expanded outside L5 vertebral body (Enneking stage III). C) Intraoperative photography showing that the 90° rotated posterior arch was secured between the spinous processes of L4 and the sacrum (the cranial side is on the right). D) Postoperative radiograph (frontal view) showing spinal reconstruction after TES. E) Postoperative radiograph (lateral view). F) Sagittal image of CT scan 1 year after surgery showing the structural integrity by a bony fusion of the grafted bone and adjacent laminae.

rior element of L5 and wide dissection of the tumor-affected vertebral body from the dura mater and nerve roots via a posterior approach, the en bloc resected arch of L5 was grafted in a 90° rotation to bridge the laminae of L4 and the sacrum. The 90° rotated arch was secured between the spinous processes of the L4 and sacrum (Fig. 3C). Using the anterior approach, the tumor-affected vertebral body was removed en bloc and an expandable cage was inserted and secured between the adjacent vertebral bodies (Fig. 3D, 3E). More than 3 years after surgery, she remained tumor-free and worked as a housewife without difficulty. Postoperative CT scans showed that the reconstructed spine was well-maintained with fusion of the grafted bone and adjacent laminae (Fig. 3F).

Discussion

In TES or high-grade osteotomy of the lower lumbar spine, the vertebral arches in the upper and lower adjacent vertebrae are usually separated by a significant space; this makes it challenging to perform posterior column reconstruction using bone chips, which are commonly used as bone graft materials. When bone fusion in the anterior column fails, a revision surgery is often required due to IF.

Mechanical stability and bony fusion at the osteotomy level using instrumentation or bone grafting techniques are topics of interest in TES[24] and ASD surgery[25-28]. Additional bone grafting in the anterior column[24] or a rigid construct using posterior multiple rods or bridging-rod technique[25-27] can increase the bone fusion rate in the anterior column and prevent IF. In surgeries using grade 3 osteotomy with partial wedge resection of the posterior vertebral body[23] and kyphosis correction, a new facet joint is sometimes created by reducing the inferior facet of the proximal level to the superior facet of the distal level, maintaining the integrity of the posterior column[28]. However, it is impossible to maintain the continuity of the posterior column in high-grade osteotomy surgeries[23] using grade 4 osteotomy with pedicle, partial body, and disc resection or grade 5 osteotomy with complete vertebral and disc resection, including TES for spinal tumors. In this situation, en bloc resection of the posterior arch can be used as a strut bone graft to create new continuity of the posterior column with the adjacent laminae and spinous processes. The concave parts between the superior and inferior articular processes fit the spinous processes of the adjacent levels sufficiently well to avoid movement with

stabilization using spinal instrumentation (Fig. 2, 3C). Spinal shortening in TES or kyphosis correction in ASD surgery decreases the gap between the posterior arches of the upper and lower adjacent vertebrae. In this case, the width of the en bloc resected arch was sufficient for bridging the gap. Using this technique, a significant amount of chip bone is placed over the en bloc resected arch as an additional bone graft to promote bony fusion in the posterior column (Fig. 2). Structural integrity of bony fusion was successfully achieved between the en bloc resected arch and the laminae of the adjacent vertebrae in all our patients using the technique, and there was no IF in the postoperative period.

However, the surgical technique has some limitations. In surgeries using grade 6 osteotomy with multiple vertebral resection[23], this technique cannot be applied due to the wider gap between the vertebral arches in the upper and lower adjacent vertebrae. In the thoracic and upper lumbar spines, the morphology of the posterior arch is not suitable for this technique because the concave parts between the superior and inferior articular processes are not developed. This technique is not recommended at the spinal cord level because displacement of the large strut bone can cause severe spinal cord compression. In TES for spinal tumors, the en bloc resected arch should be treated with liquid nitrogen to kill the tumor cells when the tumor involves the vertebral arch. Using this technique, the treatment can interfere with bone fusion in the posterior column. Previous studies reported that bone union of the bone treated with liquid nitrogen, although delayed, was achieved under sufficient stability with instrumentation[29,30]. Despite these limitations, the technique is feasible for most surgeons and is effective in preventing IF during these surgeries.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Sources of Funding: None

Author Contributions: Satoshi Kato designed the study. Satoshi Kato and Satoru Demura performed the surgery. Satoshi Kato, Noriaki Yokogawa, Takaki Shimizu, Motoya Kobayashi, Yohei Yamada, and Satoshi Nagatani gathered the data. Satoshi Kato wrote and prepared the manuscript. Satoru Demura supervised the study. All authors have read, reviewed, and approved the article.

Ethical Approval: IRB approval was not necessary for this technical note, which is being considered equivalent to a case report. This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was waived by the ethics committee due to the retrospective study design.

Informed Consent: Informed consent for publication was obtained from all participants.

References

1. Tomita K, Kawahara N, Baba H, et al. Total en bloc spondylectomy for solitary spinal metastases. Int Orthop. 1994;18(5):291-8.
2. Tomita K, Kawahara N, Baba H, et al. Total en bloc spondylectomy. A new surgical technique for primary malignant vertebral tumors. Spine. 1997;22(3):324-33.
3. Tomita K, Kawahara N, Murakami H, et al. Total en bloc spondylectomy for spinal tumors: improvement of the technique and its associated basic background. J Orthop Sci. 2006;11(1):3-12.
4. Kato S, Murakami H, Demura S, et al. More than 10-year follow-up after total en bloc spondylectomy for spinal tumors. Ann Surg Oncol. 2014;21(4):1330-6.
5. Kato S, Demura S, Shinmura K, et al. Surgical metastasectomy in the spine: a review article. Oncologist. 2021;26(10):e1833-43.
6. Kato S, Murakami H, Demura S, et al. Patient-reported outcome and quality of life after total en bloc spondylectomy for a primary spinal tumour. Bone Joint J. 2014;96-B(12):1693-8.
7. Matsumoto M, Watanabe K, Tsuji T, et al. Late instrumentation failure after total en bloc spondylectomy. J Neurosurg Spine. 2011;15(3):320-7.
8. Yoshioka K, Murakami H, Demura S, et al. Risk factors of instrumentation failure after multilevel total en bloc spondylectomy. Spine Surg Relat Res. 2017;1(1):31-9.
9. Park S-J, Lee C-S, Chang B-S, et al. Rod fracture and related factors after total en bloc spondylectomy. Spine J. 2019;19(10):1613-9.
10. Li Z, Wei F, Liu Z, et al. Risk factors for instrumentation failure after total en bloc spondylectomy of thoracic and lumbar spine tumors using titanium mesh cage for anterior reconstruction. World Neurosurg. 2020;135:e106-15.
11. Shimizu T, Kato S, Demura S, et al. Characteristics and risk factors of instrumentation failure following total en bloc spondylectomy. Bone Joint J. 2023;105-B(2):172-9.
12. Dagdia L, Kokabu T, Ito M. Classification of adult spinal deformity: review of current concepts and future directions. Spine Surg Relat Res. 2019;3(1):17-26.
13. Hasegawa K, Dubousset JF. Cone of economy with the chain of balance-historical perspective and proof of concept. Spine Surg Relat Res. 2022;6(4):337-49.
14. Matsuyama Y. Surgical treatment for adult spinal deformity: conceptual approach and surgical strategy. Spine Surg Relat Res. 2017;1(2):56-60.
15. Sing DC, Khanna R, Shaw JD, et al. Increasing rates of surgical management of multilevel spinal curvature in elderly patients. Spine Deform. 2016;4(5):365-72.
16. McDonnell JM, Evans SR, Ahern DP, et al. Risk factors for distal junctional failure in long-construct instrumentation for adult spinal deformity. Eur Spine J. 2022;31(12):3654-61.
17. Yasuda T, Yamato Y, Hasegawa T, et al. Revision surgery due to proximal junctional failure and rod fracture in adult deformity surgery at a single institution in Japan. Spine Surg Relat Res. 2022;6(5):497-502.
18. Tomita K, Kawahara N. The threadwire saw: a new device for cutting bone. J Bone Joint Surg Am. 1996;78(12):1915-7.
19. Tsuchiya H, Wan SL, Sakayama K, et al. Reconstruction using an autograft containing tumour treated by liquid nitrogen. J Bone Joint Surg Br. 2005;87(2):218-25.
20. Murakami H, Kato S, Demura S, et al. Novel reconstruction technique using a frozen tumor-bearing vertebra from a total en bloc sponydylectomy for spinal tumors. Orthopedics. 2013;36(8):605-7.
21. Yamamoto N, Tsuchiya H, Tomita K. Effects of liquid nitrogen treatment on the proliferation of osteosarcoma and the biome-

chanical properties of normal bone. J Orthop Sci. 2003;8(3):374-80.
22. Igarashi K, Yamamoto N, Shirai T, et al. The long-term outcome following the use of frozen autograft treated with liquid nitrogen in the management of bone and soft-tissue sarcomas. Bone Joint J. 2014;96-B(4):555-61.
23. Schwab F, Blondel B, Chay E, et al. The comprehensive anatomical spinal osteotomy classification. Neurosurgery. 2014;74(1):112-20.
24. Shinmura K, Demura S, Kato S, et al. A modified spinal reconstruction method reduces instrumentation failure in total en bloc spondylectomy for spinal tumors. Spine Surg Relat Res. 2023;7(1):60-5.
25. Jager ZS, İnceoğlu S, Palmer D, et al. Preventing instrumentation failure in three-column spinal osteotomy: biomechanical analysis of rod configuration. Spine Deform. 2016;4(1):3-9.
26. Krishnan A, Raj A, Meena U, et al. RCC (reinforced criss-cross construct): an easy and effective multi-rod thoraco-lumbar posterior reconstruction technique. Spine Deform. 2022;10(5):1203-8.
27. Hyun SJ, Lenke LG, Kim YC, et al. Comparison of standard 2-rod constructs to multiple-rod constructs for fixation across 3-column spinal osteotomies. Spine. 2014;39(22):1899-904.
28. Lewis SJ, Mohanty C, Gazendam AM, et al. Posterior column reconstruction improves fusion rates at the level of osteotomy in three-column posterior-based osteotomies. Eur Spine J. 2018;27(3):636-43.
29. Shinmura K, Murakami H, Demura S, et al. A histological examination of spinal reconstruction using a frozen bone autograft. PLOS ONE. 2018;13(1):e0191679.
30. Shinmura K, Kato S, Demura S, et al. Revision surgery for instrumentation failure after total en bloc spondylectomy: a retrospective case series. BMC Musculoskelet Disord. 2020;21(1):591.