Longitudinal spinous-splitting laminoplasty with coral bone for the treatment of cervical adjacent segment degenerative disease: A 5-year follow-up study

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Research article

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Abstract

Background: To analyze the causes of cervical adjacent segment degenerative disease (ASDis), explore the surgical results of longitudinal spinous-splitting laminoplasty with coral bone (SLAC) during cervical reoperation, and accumulate data on reoperation with SLAC in a primary hospital.

Methods: We conducted a retrospective study. From 1998 to 2014, 52 patients underwent cervical reoperation for ASDis using SLAC at our hospital. Among them, 39 were treated with anterior cervical fusion and internal fixation in the first operation (anterior cervical corpectomy with fusion [ACCF], n=24; anterior cervical discectomy and fusion [ACDF], n=11; and cervical disc arthroplasty [CDA], n=4).

Results: In patients who underwent an anterior cervical approach in the first instance, ASDis was significantly higher in the C3/4 gap than in other gaps. In the ACCF group, the lateral radiograph of the cervical spine revealed that the distance between the anterior cervical plate and adjacent segment disc in15 cases (62.5%) was <5 mm, and five cases (12.8%) had internal fixation screws that broke into the annulus of the adjacent segment. After the first SLAC, ASDis occurred in C2/3 and C3/4 in four (30.8%) and eight cases (61.5%), respectively. Post-reoperation, all cases were follow-up for >5 (average, 6.2) years. Comparing pre-reoperation and last follow-up values, the mean Japanese Orthopedic Association score was 10.2±1.5 versus15.5±0.7 (P=0.03), neck disability index was 26.2 versus13.6 points (P=0.01), upper-limb visual analog scale (VAS) score was 6.1 versus2.6 points (P=0.04), and neck and shoulder VAS score was 6.6 versus 2.1 points (P=0.03).

Conclusions: ASDis was primarily caused by 1) a distance of <5 mm between the anterior cervical plate and adjacent segment disc and 2) the screw breaking through the adjacent segmental annulus. SLAC proved to be a simple technique, with clear local anatomy and satisfactory clinical results.

Background

Cervical surgery has been widely used in the treatment of cervical trauma, tumors, deformity, and degenerative diseases [1-7]. However, with the rapid development of new theories and new techniques in the field of cervical spine surgery, if spine surgeons are not aware of the various surgical techniques applied to the cervical vertebrae or if they are biased in their use of techniques, there is a greater likelihood that they will make poor choices and technical errors. In recent years, adjacent segment disease (ASD), which occurs after cervical spine surgery, has gained attention as an issue in the long-term care of patients [8-11]. Adjacent segment degeneration (ASDeg) (Figures 1A and 2A) is the simple degeneration of adjacent segments and includes disc degeneration, osteophyte formation, articular process hyperplasia, and spinal stenosis without clinical symptoms. Adjacent segment degenerative disease (ASDis) refers to a new radiculopathy or myelopathy at adjacent segments.

In this study, we summarize the cases of cervical spine reoperation due to ASDis in our hospital from January 1998 to January 2014. Appropriate cases underwent longitudinal spinous-splitting laminoplasty with coral bone (SLAC).This study aimed to explore the surgical results of SLAC and accumulate data on reoperation via SLAC in the primary hospital.

Methods

Patient information

This study included 52 patients (37 men and 15 women). The median age of the patients was 58.3 years (47–78 years).For the first procedure (Table 1), 11 patients underwent anterior cervical discectomy and fusion (ACDF), 24underwentanterior cervical corpectomy with fusion (ACCF), and four underwent cervical disc arthroplasty (CDA). The median interval between the first surgery and reoperation was 74 months (7–242 months). Thirteen patients underwent SLAC for the first surgery. The median interval between the first surgery and reoperation was 33 months (21–59 months). Before reoperation, there were 31 patients who suffered from neck and shoulder pain, 11 patients with upper limb pains/numbness/inability, and 10 patients with spinal cord compression symptoms.

Table 1. Preoperative information of reoperation patients undergoing anterior cervical surgery

	Total	ASDis section C3/4	Steel plate from adjacent segments <5mm	Internal fixation screw breaks through adjacent fiber ring	Compressed tissue accounts for >50% of spinal canal area
ACCF	24	16 (66.7%)	15 (62.5%)	3 (12.5%)	0
ACDF	11	5 (45.5%)	0	2 (18.2%)	0
CDA	4	2 (50.0%)	0	0	0
Total	39	23 (58.9%)		5 (12.8%)	0

ASDis, adjacent segment degenerative disease; ACCF, anterior cervical corpectomy with fusion; ACDF, anterior cervical discectomy and fusion; CDA, cervical disc arthroplasty

The inclusion criterion was the requirement for reoperation using SLAC. The exclusion criteria were unstable cervical vertebrae, internal fixation failure, non-union of the bone graft, cervical kyphosis deformity >10°, and intraspinal pressure of the adjacent segment accounting for >50% of the spinal canal cross-section.

The study was approved by the Ethics Committee of Beijing Jishuitan Hospital (approval number: 201905), and informed consent was waived due to the retrospective design of the study.

Observation indicators

(1) Japan Orthopaedic Society (JOA) score, neck disability index (NDI) score, and visual analog scale (VAS) score (upper limb/neck and shoulder).

(2) Cervical vertebrae lateral radiograph, which was defined as the distance between the anterior cervical plate and the adjacent segment at <5 mm (Figures 1B, 2B, and 3B), and the internal fixation screw breaking through the adjacent segmental annulus (Figure 1B).

Surgical methods

SLAC (C2-7)

1. After successful anesthesia, the patient was placed in the prone position so that the neck was in a slight flexion position and the position of the hands was maintained on either side of the body.
2. A midline incision was made after C2-C7, the skin and the soft tissue of the neck were cut subcutaneously, and the spinous process of C3-C7 was exposed. Cobb's periosteal stripper technique was used to push the paravertebral muscles away from the periosteum. The surgical hemostasis device was then used to stop the bleeding. The bilateral rotator muscles were cut on the spinous process with scissors, carefully protecting the cervical semi-spine muscles in C2 and C7. This exposed the C3-C7 lamina.
3. The C3 and C7 lamina and C2 ventral lamina were removed with a grinding drill, an ultrasonic bone knife, and a laminar rongeur. The ligamentumflavum between C6 and C7 was removed to expose the underlying dura mater. A catheter and T-saw were placed under the lamina, and the spinous processes of C4-C6 were sawn with the T-saw.
4. A hinged structure, like that of a door shaft, was made with a grinding drill on the inner side of the small C4-C6 joints on each side, until the depth of the contralateral cortex and the ventral cortex was preserved. The lamina was opened with tissue scissors and a small curette. The two sides were separated, and the ligamentumflavum was cut longitudinally to expose the underlying dura mater. The dura mater and pulsate were carefully observed (Figure 4).
5. Holes were drilled in the spinous process (Figure 5); the three coralline hydroxyapatite (CHA) implants ($10×20×10×10mm^3$; Beijing YHJ Science and Trade Co., Ltd., Beijing, China) (Figure 6) were fixed between the left and right sides of the C4-C6 spinous processes (with a width of about 2 cm) with two 10-lines (Figure 7).
6. The wound was washed with saline, and a negative pressure drainage tube was placed in the wound after the bleeding was stopped completely. The wound was sutured layer-by-layer, and the operation was completed.

7. At this point, the operation was deemed successful, and the patient returned to the ward after surgery.

Statistical analyses

Data were analyzed using the paired t-test and represented as mean ± standard deviation. Statistical analysis was performed using SPSS version 11.0 software (SPSS Inc., NC, USA).A value of $P<0.05$ was considered statistically significant.

Results

After the first anterior cervical surgery, rates of ASDis were significantly higher in C3/4 than in other gaps (66.7% in the ACCF group, 45.5% in the ACDF group, and 50.0% in the CDA group).In the ACCF group, 15 cases (62.5%) were identified from the lateral radiograph of the cervical spine in which the distance between the anterior cervical plate and the adjacent segment was <5 mm. Five cases (12.8%) had internal fixation screws that broke into the annulus of the adjacent segment.

There were 13 cases of first-time SLAC (Table 2), including four cases (30.8%) with ASDis occurring in C2/3 and eight cases (61.5%) with ASDis occurring in C3/4. After reoperation, all cases were followed up for more than 5 years, with an average follow-up period of 6.2 years. There were no cases of nerve damage or internal fixation failure. The mean JOA score of the 52 patients was 10.2±1.5before the reoperation and15.5±0.7at the last follow-up. There was a significant difference between the preoperative score and the follow-up score ($P=0.03$).The NDI score was significantly higher before the reoperation (26.2 points) compared to that at the last follow-up(13.6 points; $P=0.01$). The upper limb VAS score was significantly higher (6.1 points) before reoperation compared to the last follow-up (2.6 points)($P=0.04$). The neck and shoulder VAS score was significantly higher (6.6 points) before reoperation compared to the last follow-up (2.1 points)($P=0.03$).

Table 2. Preoperative information of reoperation patients undergoing first posterior neck surgery

	Nerve root symptoms	Spinal cord compression symptoms	ASDis section		Prominent tissue accounts for >50% of spinal canal area	Cervical instability
			C2/3	C3/4		
No.	8	5	4 (30.8%)	8 (61.5%)	0	0

ASDis, adjacent segment degenerative disease

Discussion

The evaluation of cervical spine surgery is based on the medical knowledge of the disease at the time, the developmental status of the internal fixation device, and the technical skill of the surgeon. The therapeutic goal of ASDis is to resolve the new spinal cord/neural root compression in adjacent segment degeneration and correct new malformations or instability, taking into account the stability of the reconstructed spine. The difficulty and risks of the second operation are much greater than those of the first. In addition, factors such as distrust of doctors may complicate communication between doctors and patients regarding reoperation. Moreover, patients' unrealistic expectations of surgery, the anxiety of patients and their families, and the financial struggles of families may also have an influence.

C3/4 is prone to ASDis

After the first anterior cervical surgery, ASDis was significantly higher in C3/4 than in other gaps. Our results suggest that C3/4 is prone to ASDis. Furthermore, of the 13 cases of first-time SLAC, eight cases (61.5%) occurred in the C3/4 region.

Yue et al. [12] and Ishihara et al. [13] found that ASDeg increased at a rate of 3–8% per year after 10 years of follow-up after ACDF. Hashimoto et al. [10] reported that after cervical fusion, the incidence of imaging ASDeg was 32.8%, and 1/4 to 1/3 of cases eventually developed into clinically symptomatic ASDis. Hilibrand et al. [14] showed that among patients undergoing ACDF, 25.6% develop ASDeg within 10 years after surgery. Hilibrand et al. [11] reported a 2.9% rate of reoperation in patients with ASDis development and no symptomatic improvement after receiving conservative treatment; however, other scholars believe that the incidence of ASDis requiring reoperation is higher than this. Zigler et al. [15] believe that the incidence of ASDeg after ACDF is as high as 54.7% and the rate of ASDis reoperation is as high as 11.6%. Buttermann et al. [3] found that 29% of patients with ASDis needed secondary surgery after 10 years of follow-up after ACDF. To explain the reasons for this, Ahn et al. [1] provided evidence that the anterior vertebral plate and ACDF increase the risk of ASDis and pointed out that this is consistent with the findings of randomized controlled trials conducted in the United States, in which the anterior vertebral plate fixation method and ACDF were used. In Europe and other countries, ACDF usually does not include the front side of the steel plate, only the cages. The original purpose of using a steel plate is to reduce the incidence of pseudarthrosis in the surgical segment, but a meta-analysis reported by Shriver et al. [16] showed that the risk of pseudarthrosis was low. Ji et al. [17] reported that there was evidence that the use of the anterior vertebral plate fixation method, together with ACDF of the two segments, increases the incidence of ASDis compared to the use of an ACDF without the anterior vertebral plate method. In another analysis aimed to uncover the reasons behind this, Park et al. [18] reviewed the lateral radiographs of 118 patients with anterior cervical fusion and found that the probability of adjacent disc degeneration increased in patients with a distance between the edge of the anterior vertebral plate and the adjacent disc of less than 5 mm. In a biomechanics study, Eck et al. [7] reported that the use of prevertebral plates may accelerate the motion of adjacent segments, leading to ASDis.

Most of the anterior cervical surgery cases in our hospital occurred below C4, and the results showed that ASDis was mostly located in the C3/4 segment and not in the gap below the surgical segment.

Matsumoto et al. [19] found through imaging studies that the C3/4 and C6/7 intervertebral space heights of the non-surgical segment in an anterior cervical fixation group indicated progressive spinal stenosis. Maiman et al. [20] showed that the pressure of theC4/5 intervertebral disc after C5/6 internal fixation was significantly higher than that of C5/6 after C4/5 internal fixation; thus, it was considered that the pressure increase of the upper intervertebral disc of the fixed segment was more obvious than that of the lower disc. Chang et al. [4] found the same result by studying cadaver specimens. The upper intervertebral space pressure was higher in the flexion/extension position. Chung et al. [5] conducted a biomechanical study and reported that the upper articular surface pressure of the adjacent segment was higher than that of the normal non-surgical group, and the pressure increased by 31.5%.

The basis for selecting SLAC as secondary surgery

ASDis was characterized by the presence of a screw and anterior plate in the vertebral body (Figures 1B, 2B, and3A, 3B). Even when the anterior plate and screw can be removed and reconstructed with ACDF, new screws still need to be inserted. Because the bone of the lower vertebral body is destroyed by the last screw, the holding force of the new screws will be significantly reduced, and internal fixation failure will occur.

In a meta-analysis article, although the JOA score and clinical symptom relief after ACDF were significantly better than after laminoplasty, the surgical technique and the rate of complications, such as cerebrospinal fluid leakage, internal fixation displacement, hematoma, and esophageal perforation [21-27] were higher with ACDF. Injury to the recurrent laryngeal nerve, postoperative dysphagia, and hoarseness were common [2,28]. Gok et al. [9] analyzed 30 cases of patients with cervical revision surgery, and the complication rate was 27%. Hannallah et al. [29] performed a statistical analysis of 1994 patients who underwent cervical spine surgery and the incidence of postoperative cerebrospinal fluid leakage was 1%, and the incidence of cerebrospinal fluid leakage during the revision surgery was 2.77 times that of the first surgery. Eichholz and Ryken [8] believe that some kinds of implantable barriers administered during surgery cannot prevent the formation of scar tissue.

Therefore, when there is a requirement for a second surgery for ASDis, although ACDF can be performed again, some cases may require a multi-segment ACDF. This makes the operation difficult as the anatomical level of scar tissue is unclear. Moreover, the technical skill level and operative experience of doctors in primary level hospitals may be limited. Using SLAC with indirect decompression, the risk is relatively low, the operation is simple, and the learning curve is low. Thus, the attending physician can complete the surgery independently.

We treated 52 patients with SLAC as the secondary surgery in our hospital, and the clinical results were satisfactory.

SLAC requires laminectomy and C2 laminoplasty-dome

In the 13 SLAC cases treated at our hospital, although the C2/3 and C3/4 segments of the intervertebral disc did not present with degeneration, protrusion, or spinal stenosis on imaging before the first operation, ASDis developed in 33 months (21–59 months) postoperatively. There were four cases (30.8%) of ASDis at C2/3 and eight cases (61.5%) of ASDis at C3/4. Increased contact and pressure during treatment or adjacent levels of facet joints may lead to micro-damage of the facet joint and eventually accelerate the degradation of the adjacent segment facet joint [30,31].

Therefore, we recommend (especially for patients older than 70 years) that SLAC should include C3 laminectomy and C2 dome laminoplasty to avoid a second operation onC2/3 or C3/4 for ASDis, even if the intervertebral discs of the C2/3 and C3/4 segments do not show degeneration, protrusion, or spinal stenosis before the initial surgery and there are no corresponding symptoms. Because of the high risk and difficulty of reoperation, it is necessary to cautiously consider its indications:

1. Residual or progressive compression confirmed on imaging, positive conservative treatment for 3 months (excluding myofascial pain) with no real improvement in the symptoms and signs, and detrimental effects on the work and life of the patients.
2. There are two “threshold values” for selecting ACDF or SLAC. Fujimori et al.[32], Denaro et al. [6], and Kim et al. [33] pointed out that when ossification of the posterior longitudinal ligament accounts for 50% of the cross-sectional area of the spinal canal, laminoplasty is less effective in relieving neurological symptoms than ACDF. Suda et al. [34] and Uchida et al. [35] reported that when cervical kyphosis is more than 10°, the effect of laminoplasty in relieving neurological symptoms is inferior to that of ACDF. Therefore, when the patient meets the two abovementioned criteria, posterior cervical SLAC can be considered for patients who are older, have other diseases, or unable to undergo anterior reoperation.
3. The social factors related to the patient, including mental status (presence of depression), age (presence of menopausal syndrome), marital emotional state, working status, economic status, and social identity must be considered. Patients often have high expectations and more negative emotions regarding revision surgery. Surgeons should communicate more with patients and their families, appropriately reduce the patient’s expectations of the efficacy of the surgery, and consider social and legal issues, such as possible medical litigation and medical compensation.

This study had several limitations. First, the retrospective design introduced a degree of uncertainty because of missing and erroneous data in the medical records, as well as the lack of clinical information. Second, the small sample size likely affected the strength of the statistical analysis of the demographic and radiologic parameters. Third, the follow-up period was relatively short.

Conclusions

In conclusion, the main causes of ASDis include a distance of <5 mm between the anterior cervical plate and the adjacent intervertebral disc, and the screw breaking through the adjacent segment of the annulus. In this study, we found that ASDis developed most commonly at the C3/4 level. We recommend that during reoperation, when cervical kyphosis is <10° and the intraspinal protrusions account for <50% of the spinal canal cross-sectional area, SLAC should be performed at the primary hospital. We suggest that this is a relatively simple technique, the local anatomy is clear, and the clinical results are satisfactory. Further studies with a larger sample size are required to corroborate our recommendations.

Abbreviations

ACCF: anterior cervical corpectomy with fusion

ACDF: anterior cervical discectomy and fusion

ASD: adjacent segment disease

ASDeg: adjacent segment degeneration

ASDis: adjacent segment degenerative disease

CDA: cervical disc arthroplasty

CHA: coralline hydroxyapatite

JOA: Japan Orthopaedic Society

MR: magnetic resonance

NDI: neck disability index

SLAC: spinous-splitting laminoplasty with coral bone

VAS: visual analog scale

Declarations

Ethics approval and consent to participate: The study was approved by the ethics committee of Beijing Jishuitan Hospital (approval number: 201905), and requirement for informed consent was waived due to the retrospective design of the study.

Consent for publication: Not applicable.

Availability of data and materials: All data generated or analysed during this study are included in this published article.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: WH and WT conducted the study, participated in data collection, and drafted the manuscript. MML performed statistical analysis and BH participated in its design. QLW helped in drafting the manuscript. All authors read and approved the final manuscript.

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Figures

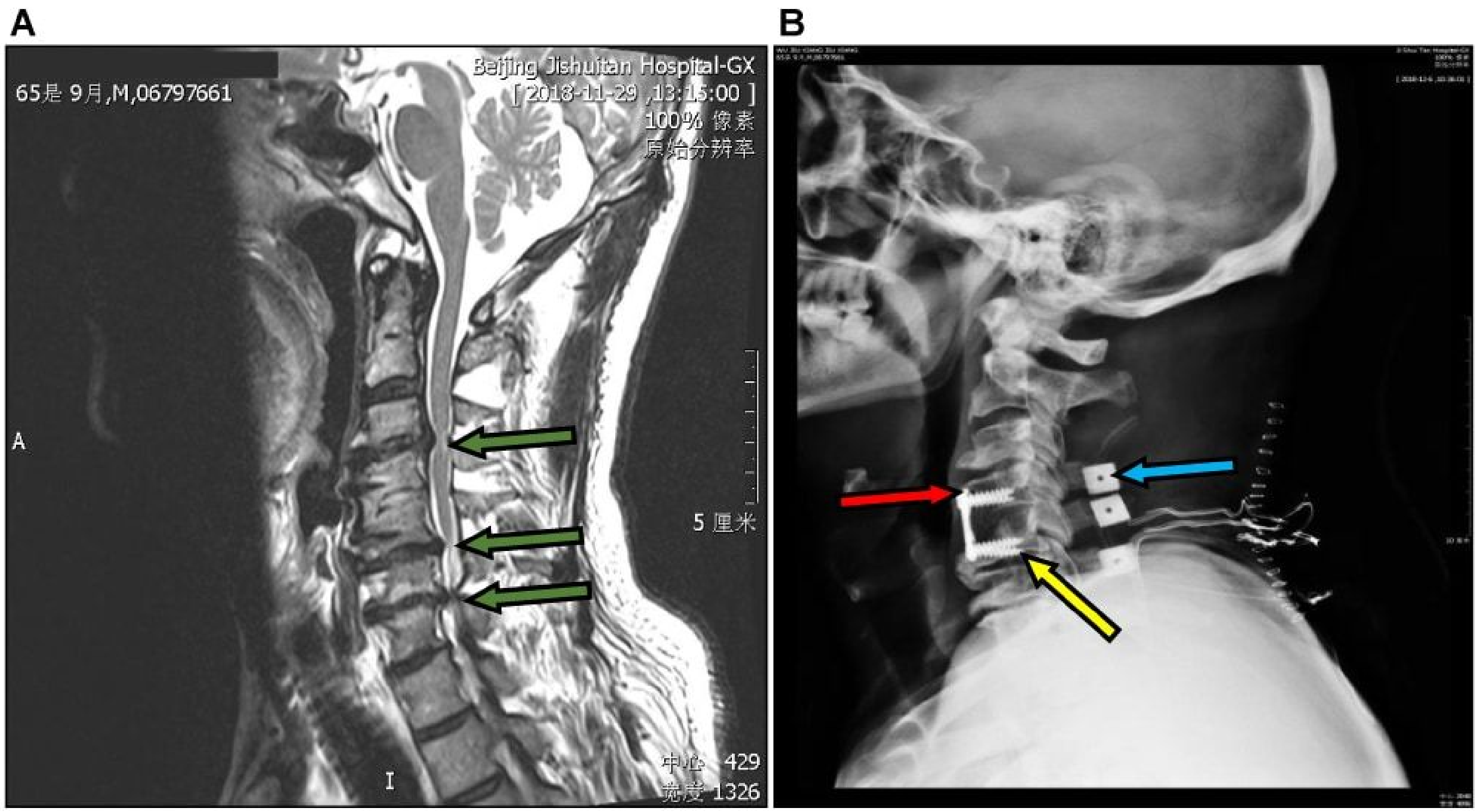

Figure 1

Preoperative and postoperative radiological imaging scans of a patient A) Cervical MR scan obtained after the first C4/5 ACDF. Postoperative ASDis: C3/4, C5/6-disc herniation, corresponding to the flat spinal cord compression (green arrow). B) Radiograph obtained after the reoperation (SLAC).The distance between the vertebral plate and the lower edge of the C3/4 intervertebral space is <5 mm (red arrow). The C5 vertebral body screw has broken through the C5 vertebral endplate and the C5/6 annulus (yellow arrow). The figure shows that there is an artificial bone (blue arrow) between each of the C4, C5, and C6 spinous processes.MR, magnetic resonance; ACDF, anterior cervical discectomy and fusion; ASDis, adjacent segment degenerative disease; SLAC, spinous-splitting laminoplasty with coral bone

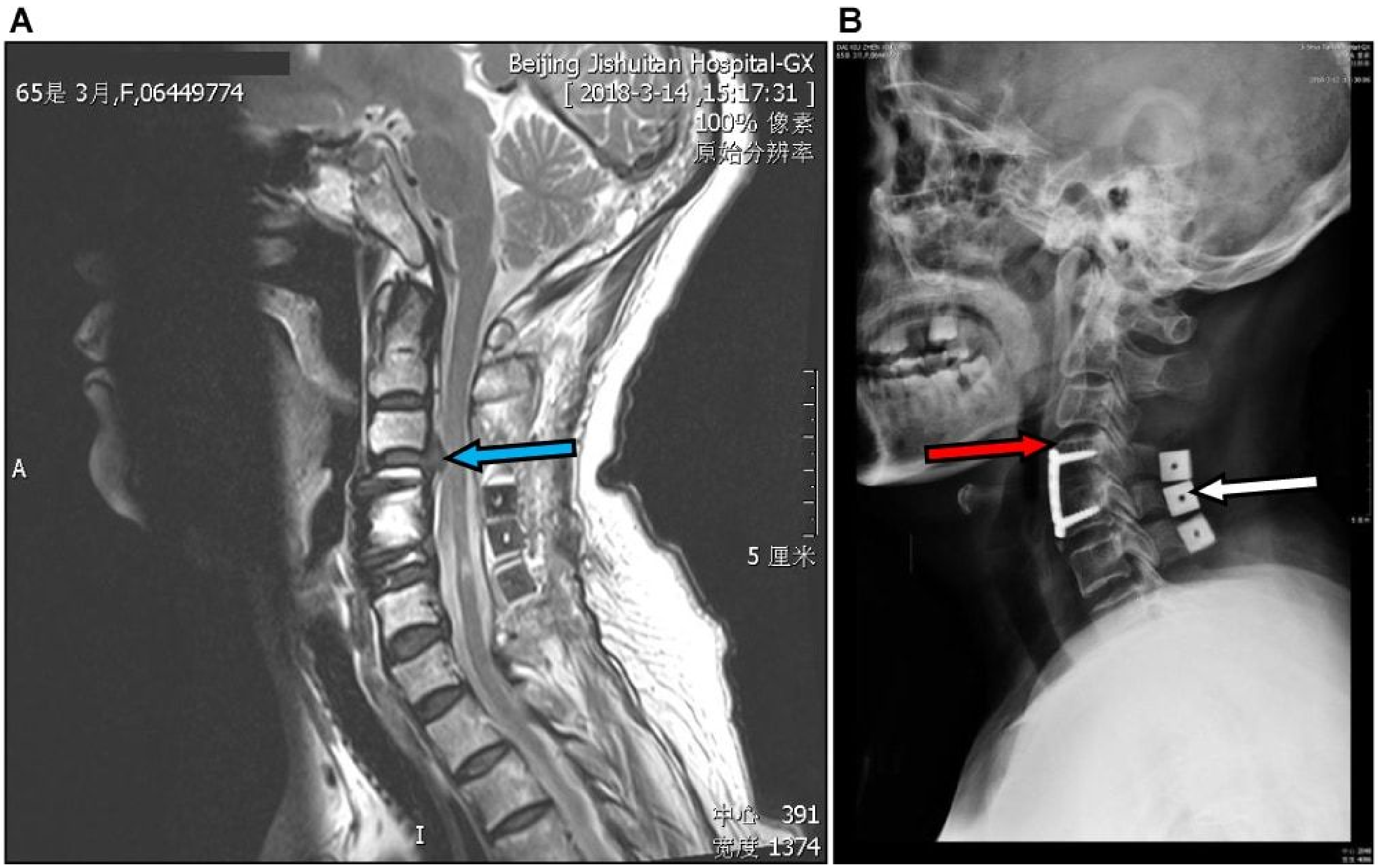

Figure 2

Preoperative and postoperative radiological imaging scans of a patient A) Postoperative cervical MR scan obtained after C4/5 ACDF. ASDis occurs in the C3/4, the disc protrudes to the spinal canal (blue arrow), and the spinal cord is compressed. B) The distance between the vertebrae plate and the lower edge of C3/4 intervertebral space is <5 mm (red arrow). Reoperation (SLAC). Lateral cervical radiograph: there is an artificial bone (white arrow) between the C4, C5, and C6 spinous processes. MR, magnetic resonance; ACDF, anterior cervical discectomy and fusion; ASDis, adjacent segment degenerative disease; SLAC, spinous-splitting laminoplasty with coral bone

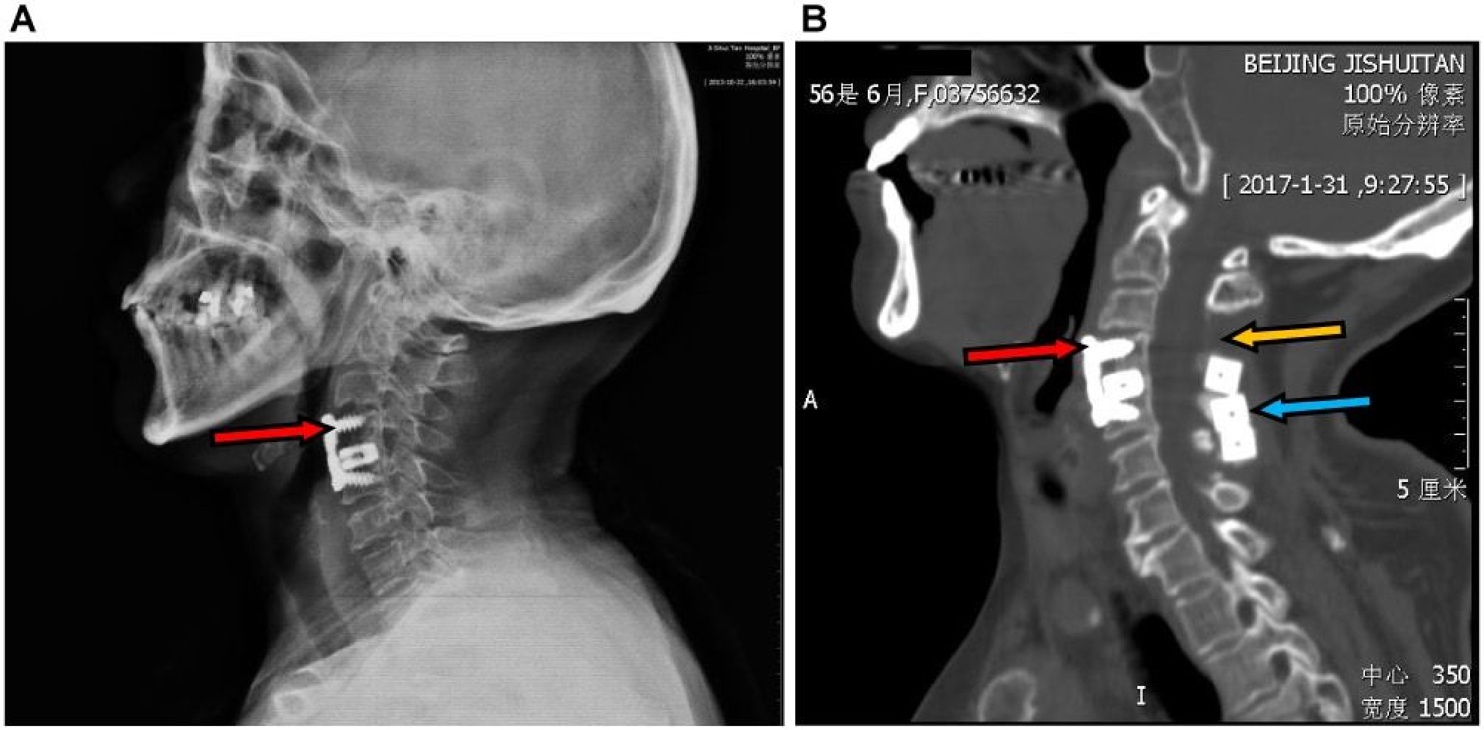

Figure 3

Preoperative and postoperative radiological imaging scans of a patient A) First postoperative cervical radiograph obtained after C4/5 ACDF. The distance between the vertebrae plate and the lower edge of C3/4 intervertebral space is <5 mm (red arrow). B) Reoperation (SLAC). Postoperative cervical CT: the distance between the vertebrae plate and the lower edge of the C3/4 intervertebral space is <5 mm (red arrow). C3 laminectomy (orange arrow); there is an artificial bone (blue arrow) between the C4, C5, and C6 spinous processes. ACDF, anterior cervical discectomy and fusion; SLAC, spinous-splitting laminoplasty with coral bone.

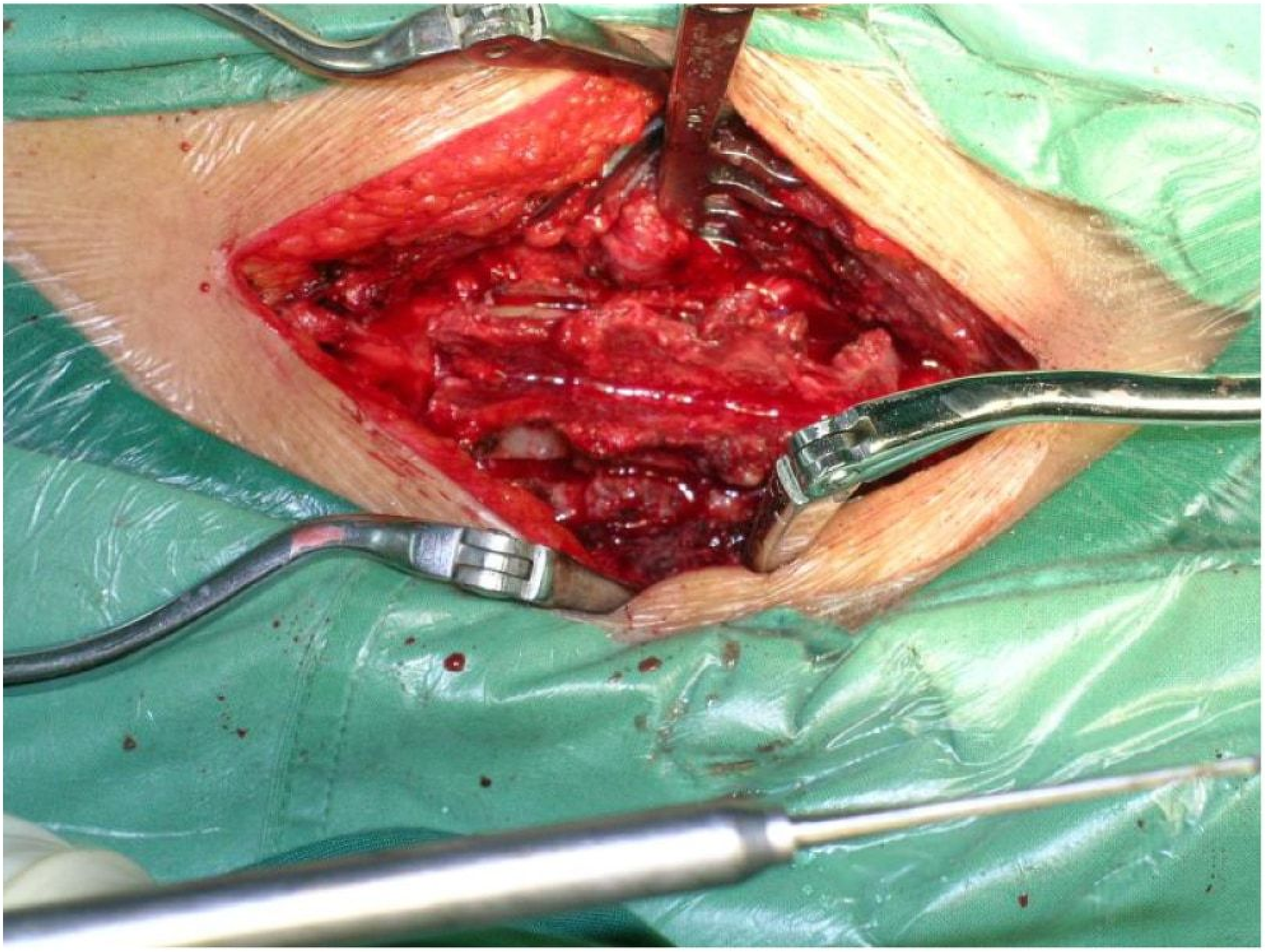

Figure 4

The spinous processes of C4-C6 are sawn The white arrow indicates the left half of the C6 processes. The yellow arrow indicates the left half of the C5 processes. The green arrow indicates the left half of the C4 processes.

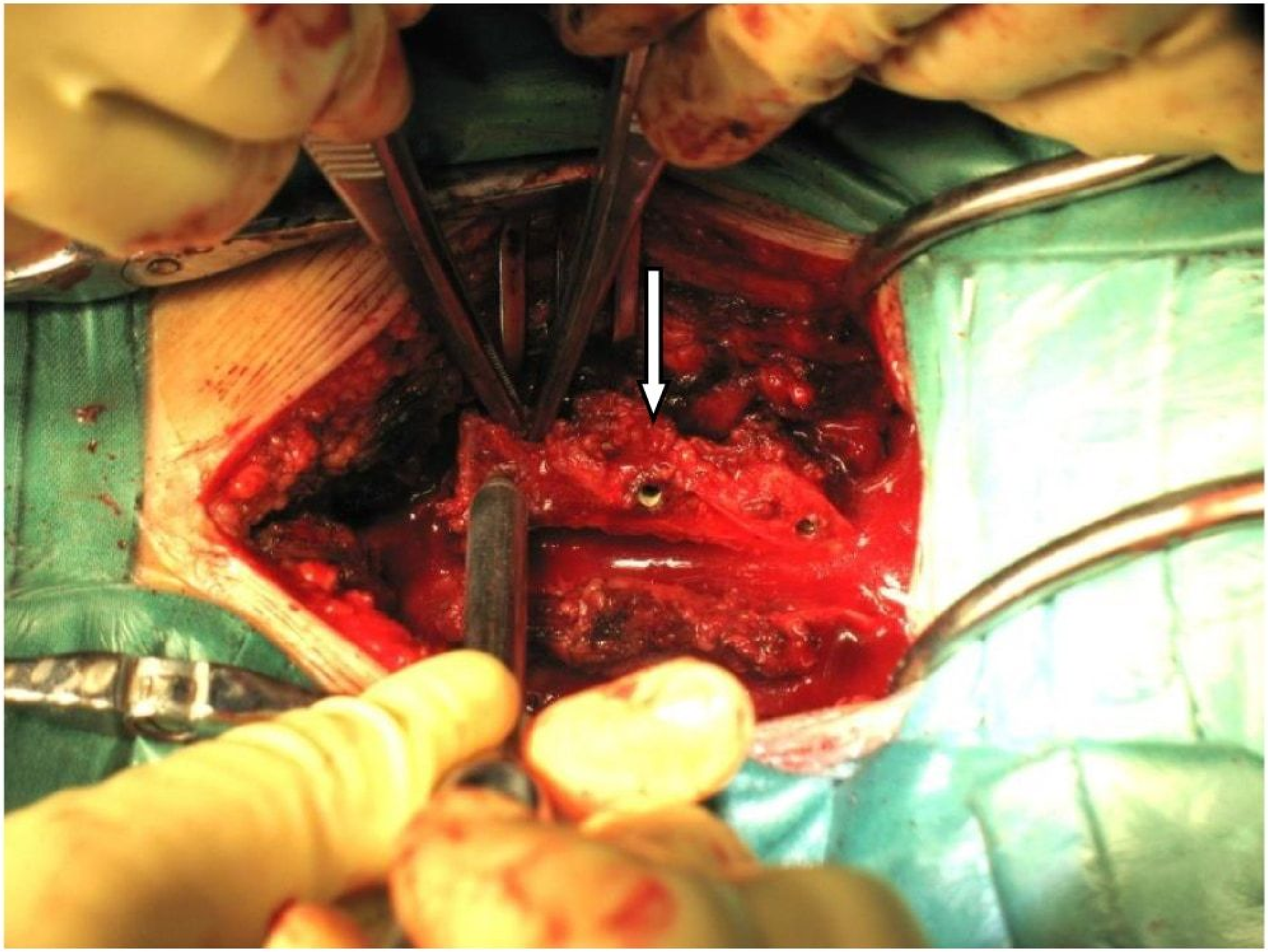

Figure 5

Holes are drilled in the spinous process. The white arrow shows the hole in the C5 processes.

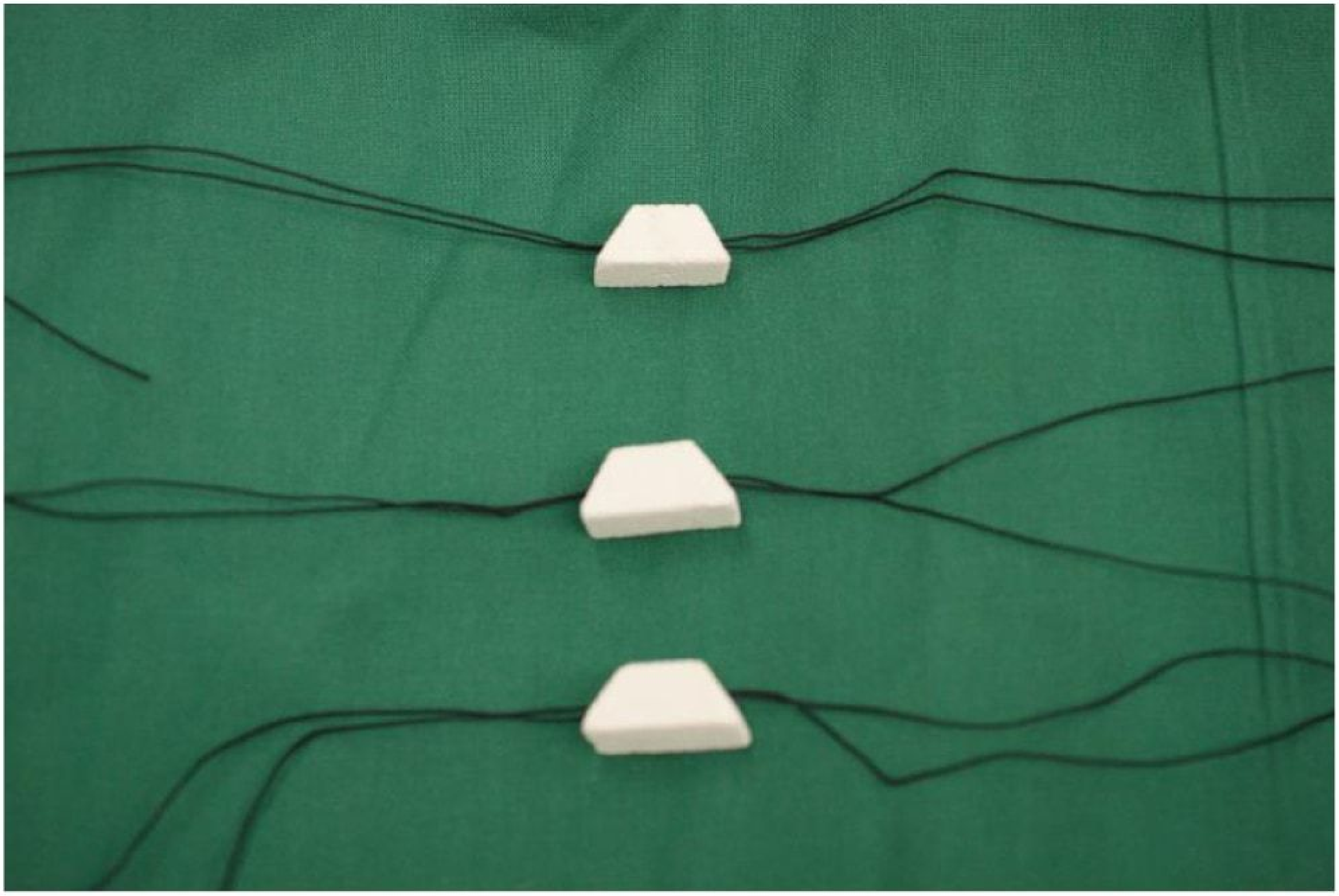

Figure 6

Coralline hydroxyapatite (CHA) implant (10 × 20 × 10 × 10 mm) with two lines

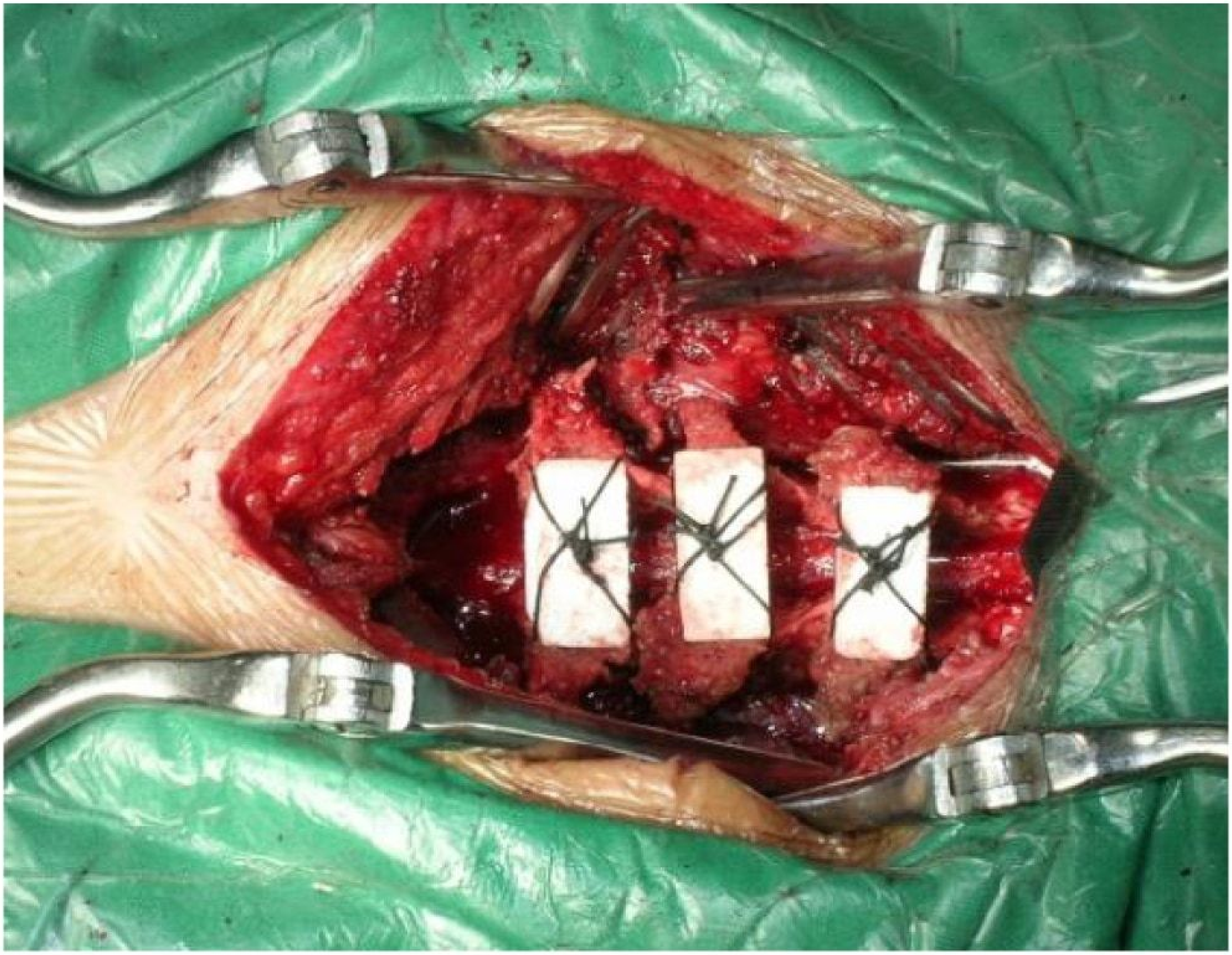

Figure 7

Coralline hydroxyapatite (CHA) implants are fixed between the left and right sides of the C4-C6 spinous processes (with a width of about 2 cm).