Principles and Surgical Technique of Cervical Laminoplasty

Shigeru Hirabayashi, M.D., Ph.D.

Department of Medical Science

Teikyo University of Science

Tokyo, Japan

COI: HOYA CORPORATION


Photograph.pro

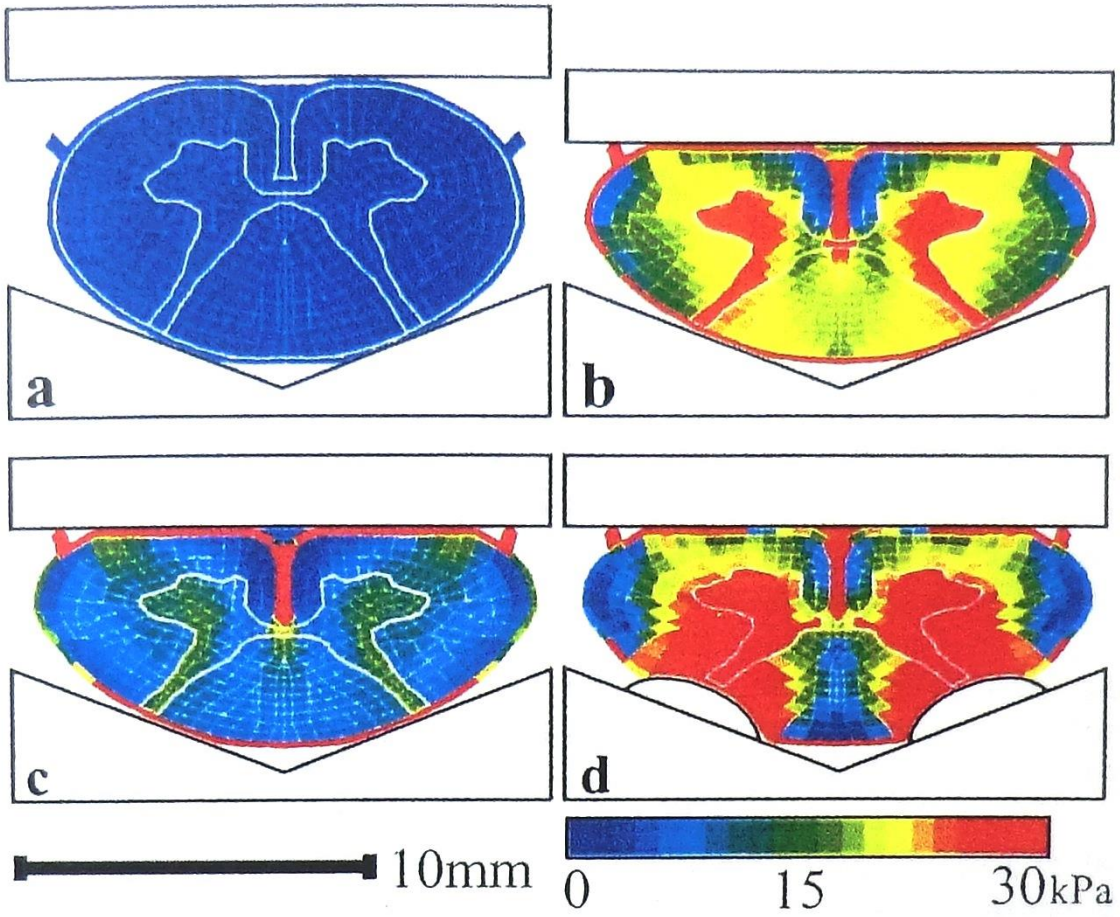
Laminoplasty is usually performed for patients with cervical myelopathy.

Cervical myelopathy is caused related to the narrow spinal canal.

Within the narrow spinal canal, the spinal cord is compressed
due to both static and dynamic stress mechanisms.

As a result, the spinal cord gradually becomes degenerated and atrophied.

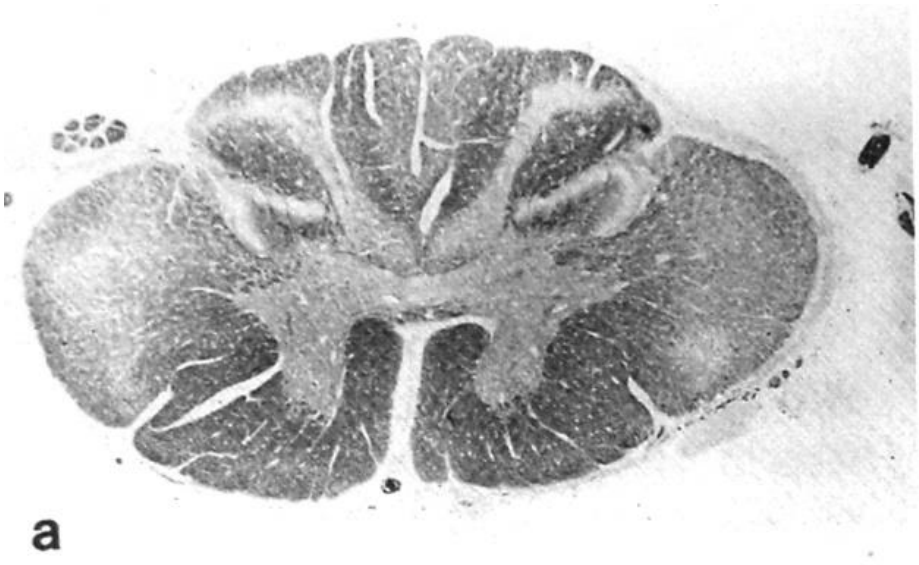
Biomechanism causing cervical myelopathy



a: before compression b: acute anterior compression
c: chronic anterior compression
d: chronic anterior compression combined with acute posterior compression

Ichihara K et al. *J Neurosurg (Spine3)* 99:278-285, 2003

Pathological changes of cervical myelopathy



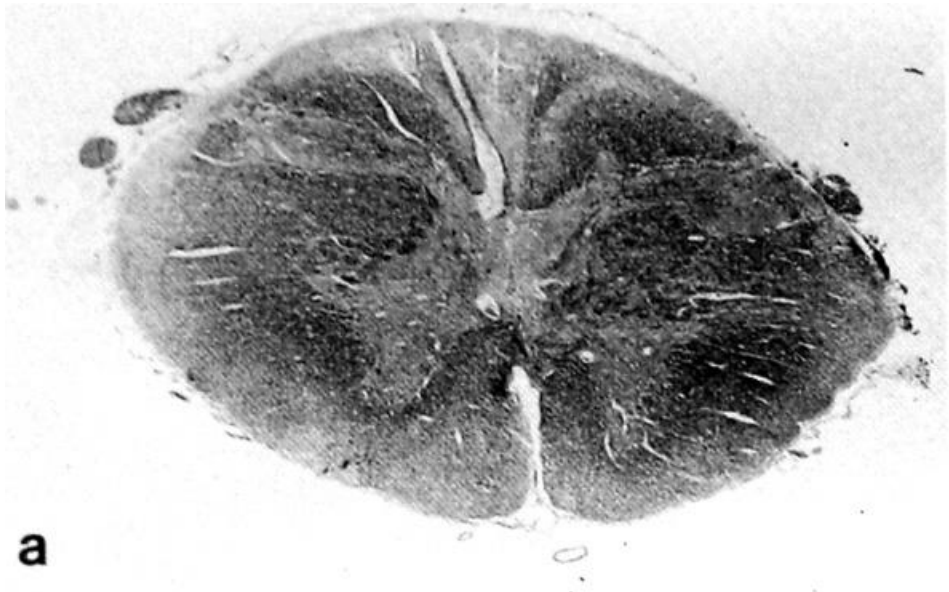
a: C3 segment

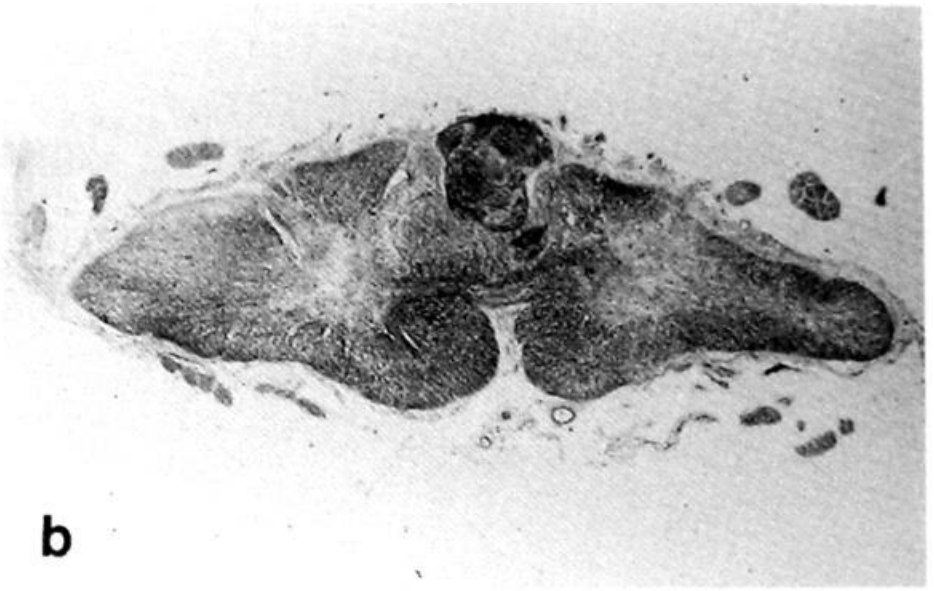
b: C5 segment

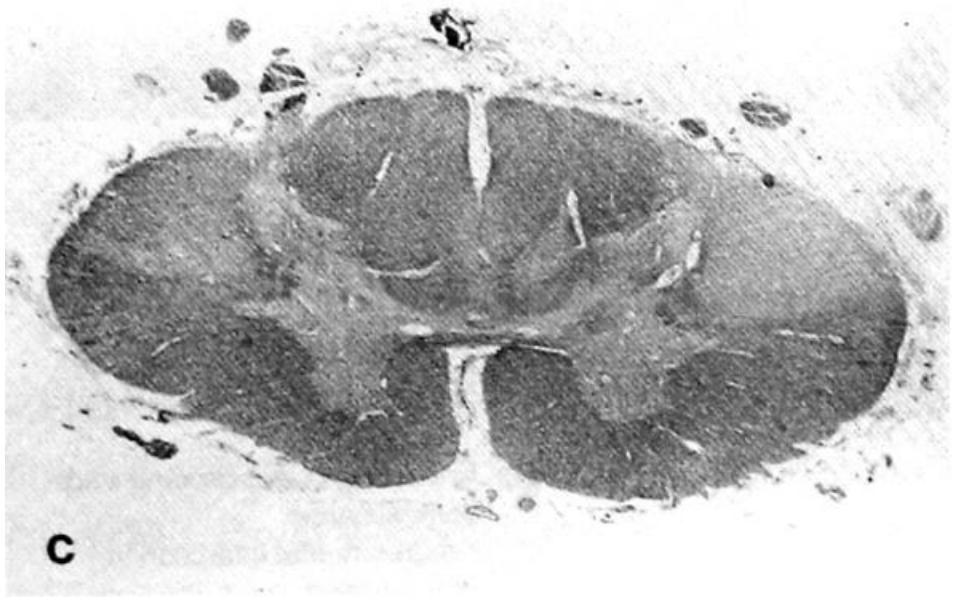
c: C8 segment

Wada E. et al. *NEW MOOK Orthopedic Surgery* No.6:12-21,1997

Pathological changes of cervical myelopathy







a: C2 segment

b: C6 segment

c: T1 segment

Wada E. et al. *NEW MOOK Orthopedic Surgery* No.6:12-21,1997

Two–type stress mechanisms causing myelopathy and the treatment for them

Dynamic mechanism ← Orthosis
Stabilization surgery

Static mechanism ← Decompression surgery

Laminectomy
Laminoplasty
Anterior decompression

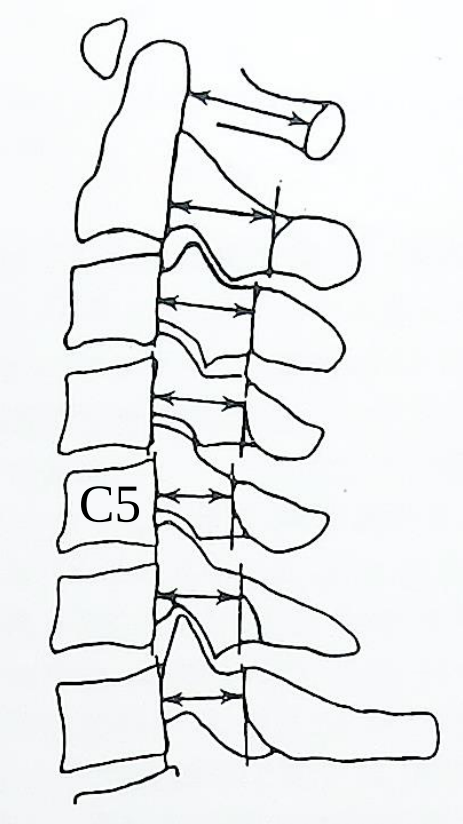
Why has laminoplasty been developed in Japan?

Narrower spinal canal in Japanese peoples

Higher prevalence rate of OPLL (ossification of the posterior longitudinal ligament) in Japanese peoples

Recognition of some disadvantages of laminectomy

Antero-posterior diameter of cervical spinal canal



At C5 level in Japanese peoples (mean)

Males: 16.1 ± 1.4 mm
Females: 15.2 ± 1.5 mm

(cf. 17.5 ± 5 mm in western peoples)

Patients with canal stenosis (mean − 2SD)

Males: ≦ 14 mm
Females: ≦ 13 mm

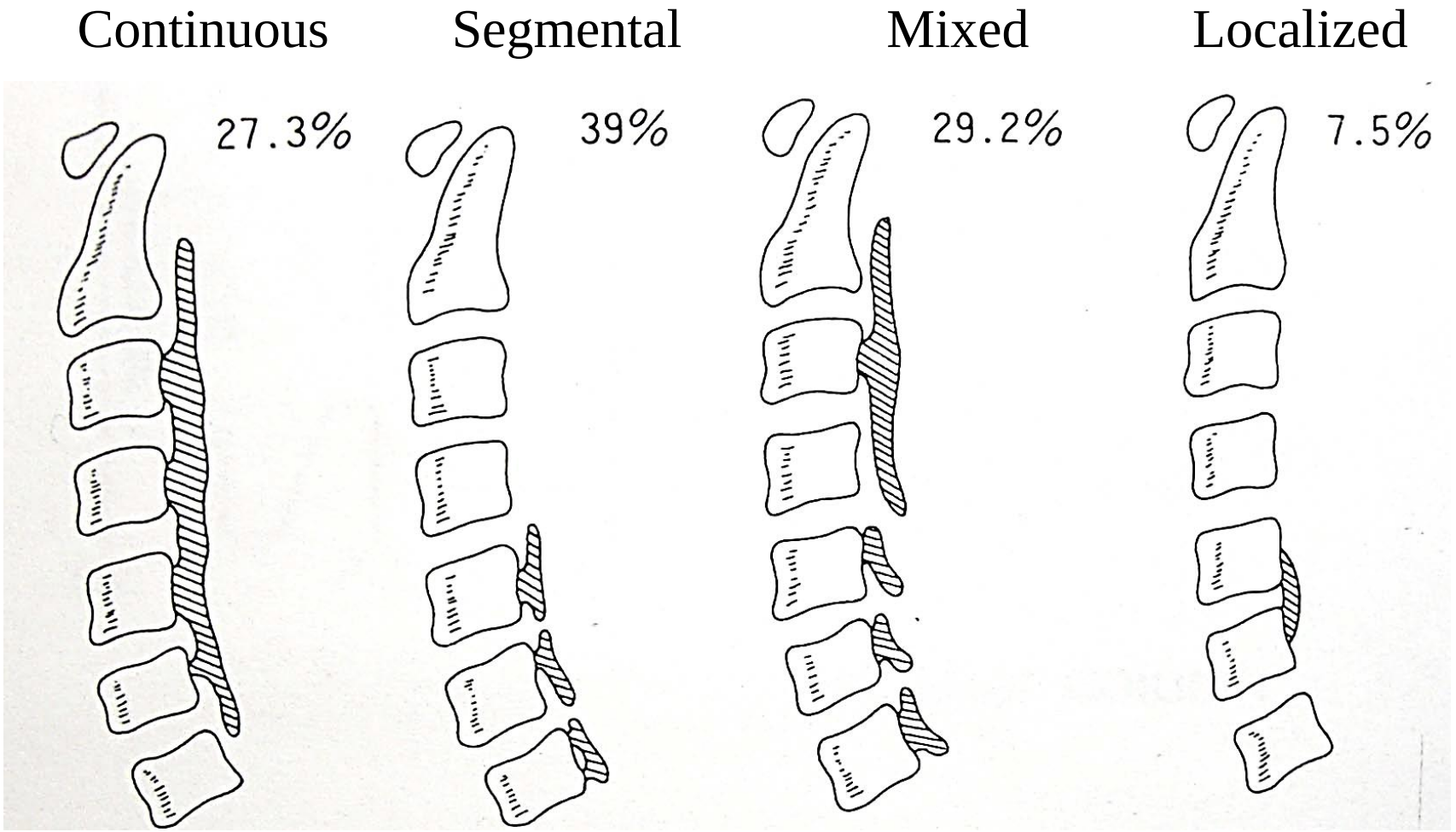
Higo M. *J.Jpn.Orthop.Associ*.61:455-465,1987

Prevalence rate of cervical OPLL

Japan :	about 3% (1.8 - 4.1%)	1987 Ohtsuka, 1996 Shingyouchi, 1996 Sakou
China :	0.2 - 1.8%	1990 Ryu, 1994 Harata
Korea :	0.95%	1994 Harata
USA :	0.12%	1994 Harata
Germany :	0.10%	1994 Harata
Italy :	1.8%	1984 Terayama

It can be said that the prevalence rate of cervical OPLL is higher in Japan than the western countries.

Classification of the type of OPLL

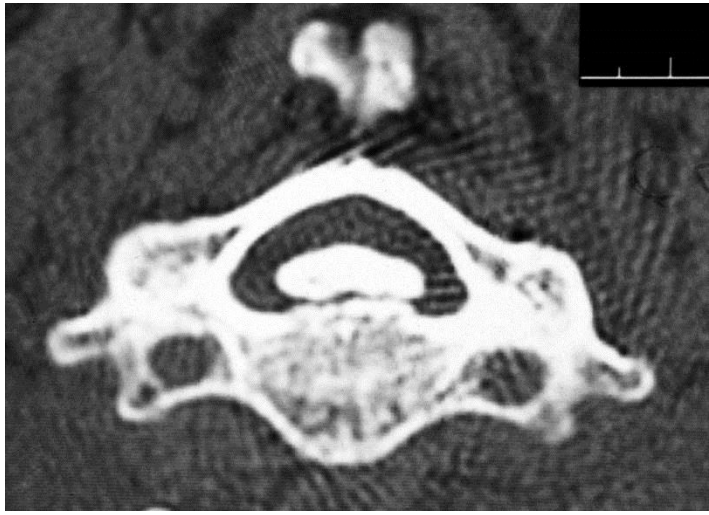


Seki H. et al *Seikeigeka* 25:704-710,1974

Cervical myelopathy due to OPLL

Tomography

MRI



CT

Disadvantages of laminectomy

1. Progression of kyphotic alignment of the cervical spine, especially in younger patients

   1987 Kurokawa

2. Progression of OPLL, probably because of traction force due to kyphotic-toward alignment change of the cervical spine

   1988 Hoshino, Hirabayashi

3. Invasion of scar tissues into the spinal canal, resulting in re-compression of the spinal cord

   2013 Taguchi

Principles of cervical laminoplasty

To decompress the spinal cord posteriorly for patients combined with:

spinal canal stenosis at multiple levels

anterior space occupying lesion at two or more levels

To preserve the posterior anatomical structures as much as possible

To steadily maintain the enlarged spinal canal

History of Laminoplasty

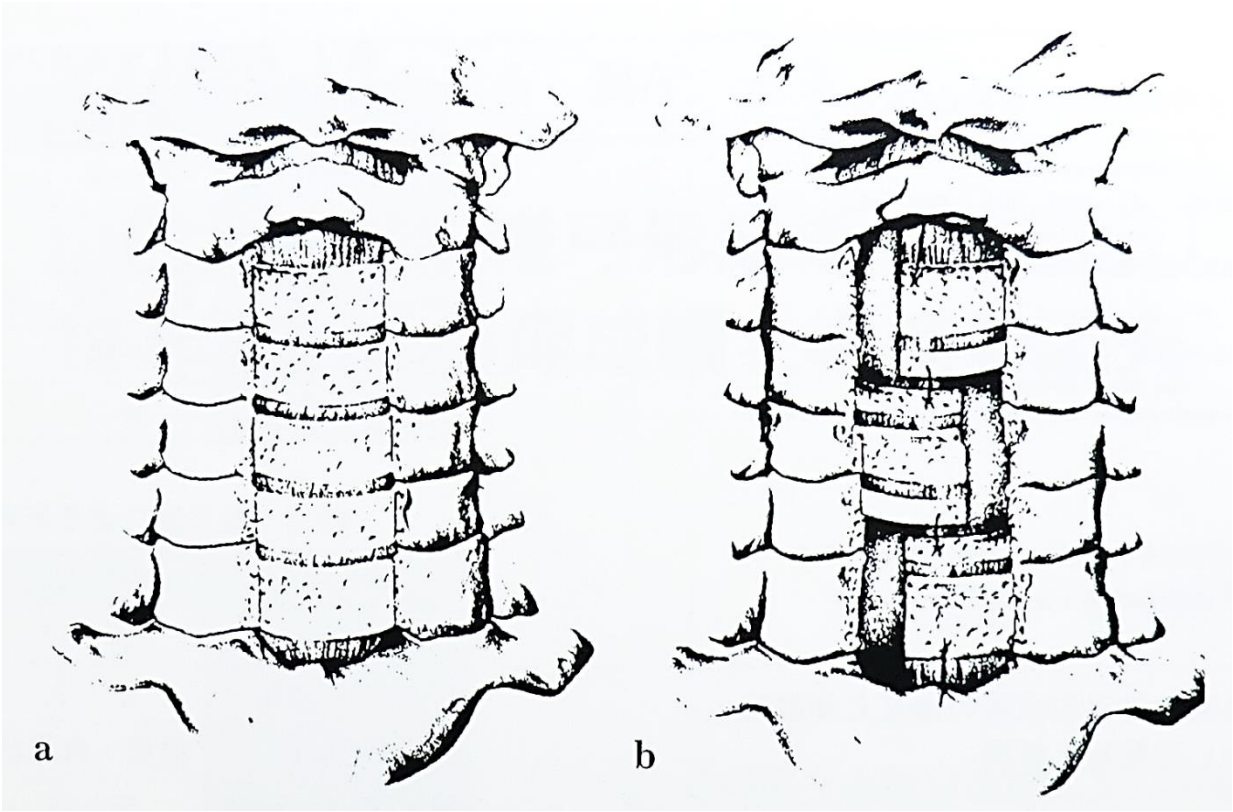
In 1973, the idea of cervical laminoplasty was first introduced by Oyama and co-workers by the name of “Expansive lamina-Z-plasty”.

Thereafter, various methods of cervical laminoplasty have been developed in Japan.

At present, they gradually become common around the world.

However, there remain some issues to be mentioned and resolved.

Expansive lamina-Z-plasty



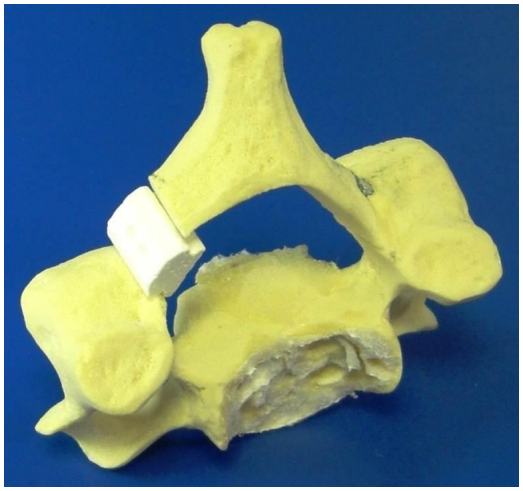
Tinned laminae are opened in a shape of zigzag, resulting in obtaining a wide spinal canal.

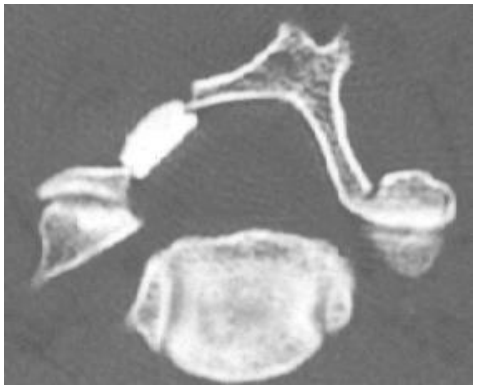
Taguchi T. et al *Spine and Spinal Cord* 26(11):1028-1032, 2013

The surgical methods are broadly divided into two types from the viewpoint of the site of osteotomy.

ODL

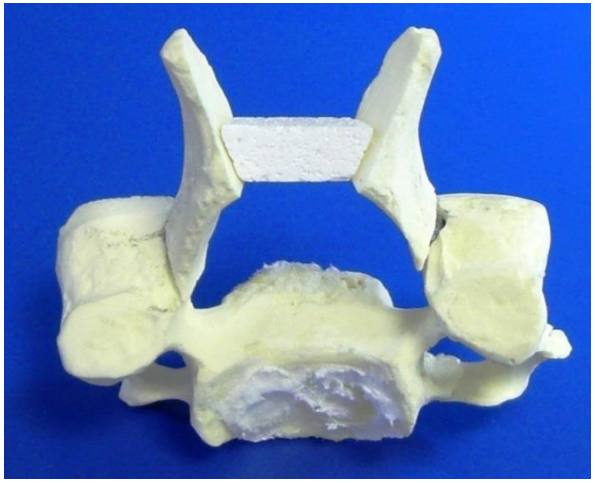
(Open-door laminoplasty)

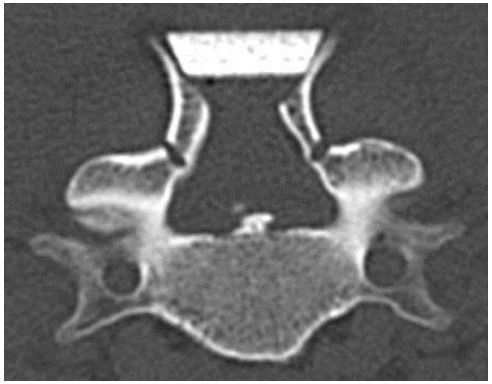




DDL

(Double-door laminoplasty)





Materials to maintain enlarged space

Thread

Autogenous bone (spinous process, iliac bone)

Hydroxyapatite spacer

Titanium plate and screws

Screw and wire

Silicon spring

Factors influencing postoperative clinical results

Ages of patients

Duration of clinical course

Preoperative neurological conditions, especially muscle atrophy

Preoperative systemic conditions, especially
osteoarthritis of the lower extremities, fracture of the spine, systemic neurological diseases, metabolic diseases, vascular diseases, etc.

Issues of this presentation

To show the surgical technique in DDL, because central splitting of the spinous process is technically demanding.

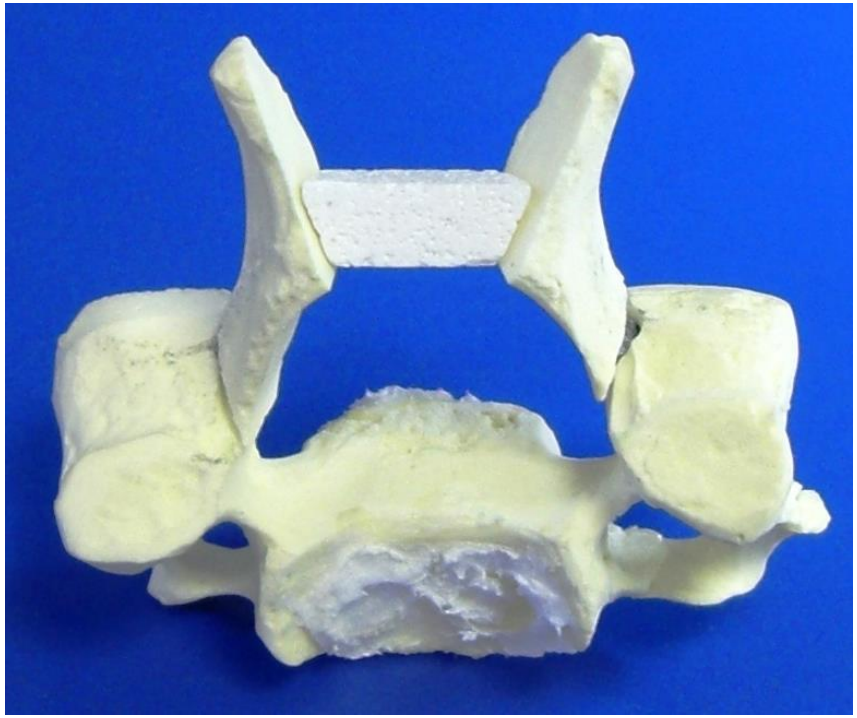
To compare the two methods: ODL and DDL

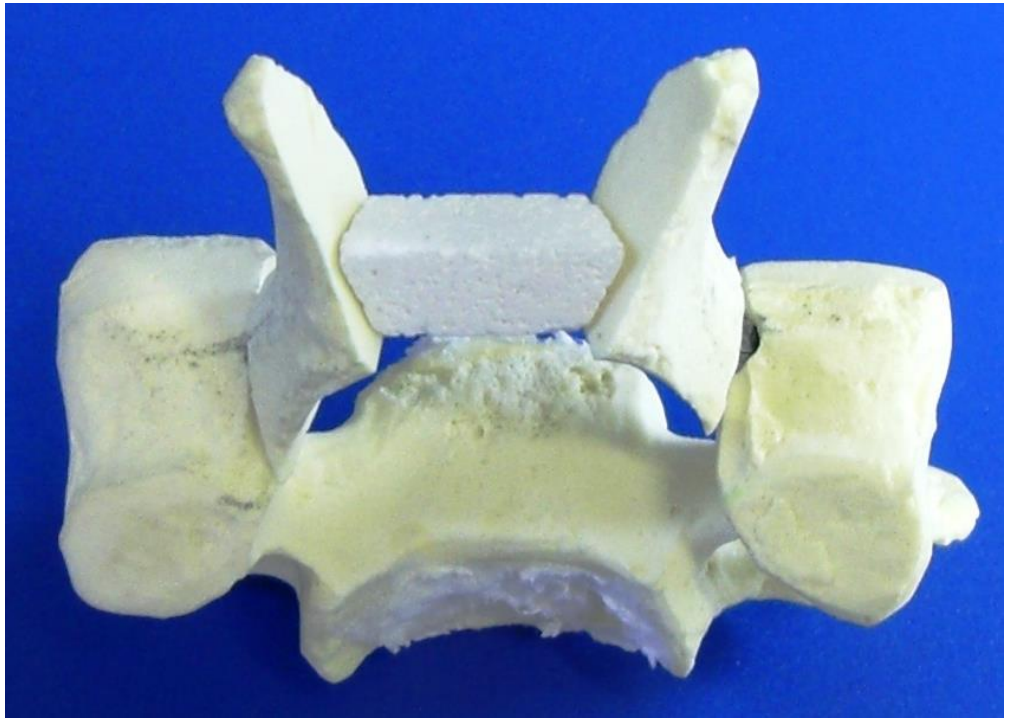
postoperative enlargement of the spinal canal
change of sagittal alignment of the cervical spine

From the anatomical study, to estimate the cause of postoperative C5 palsy, which sometimes occurs but its cause is even now unclear.

Issue 1　Surgical technique

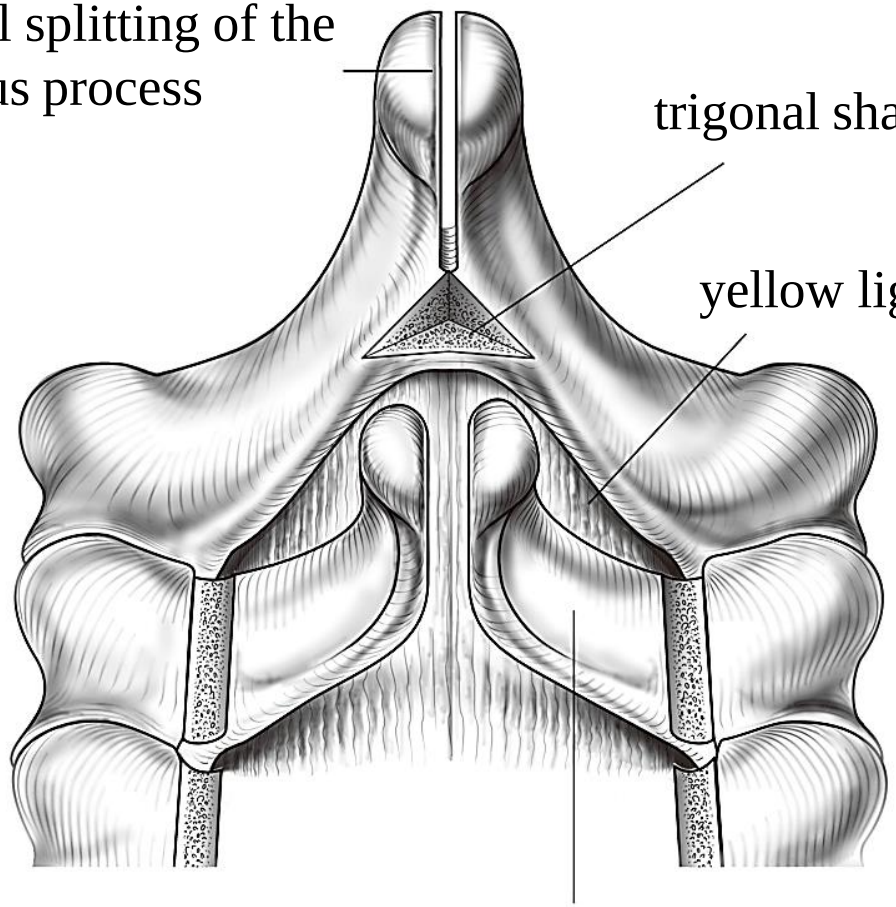
Double-door laminoplasty　(DDL)





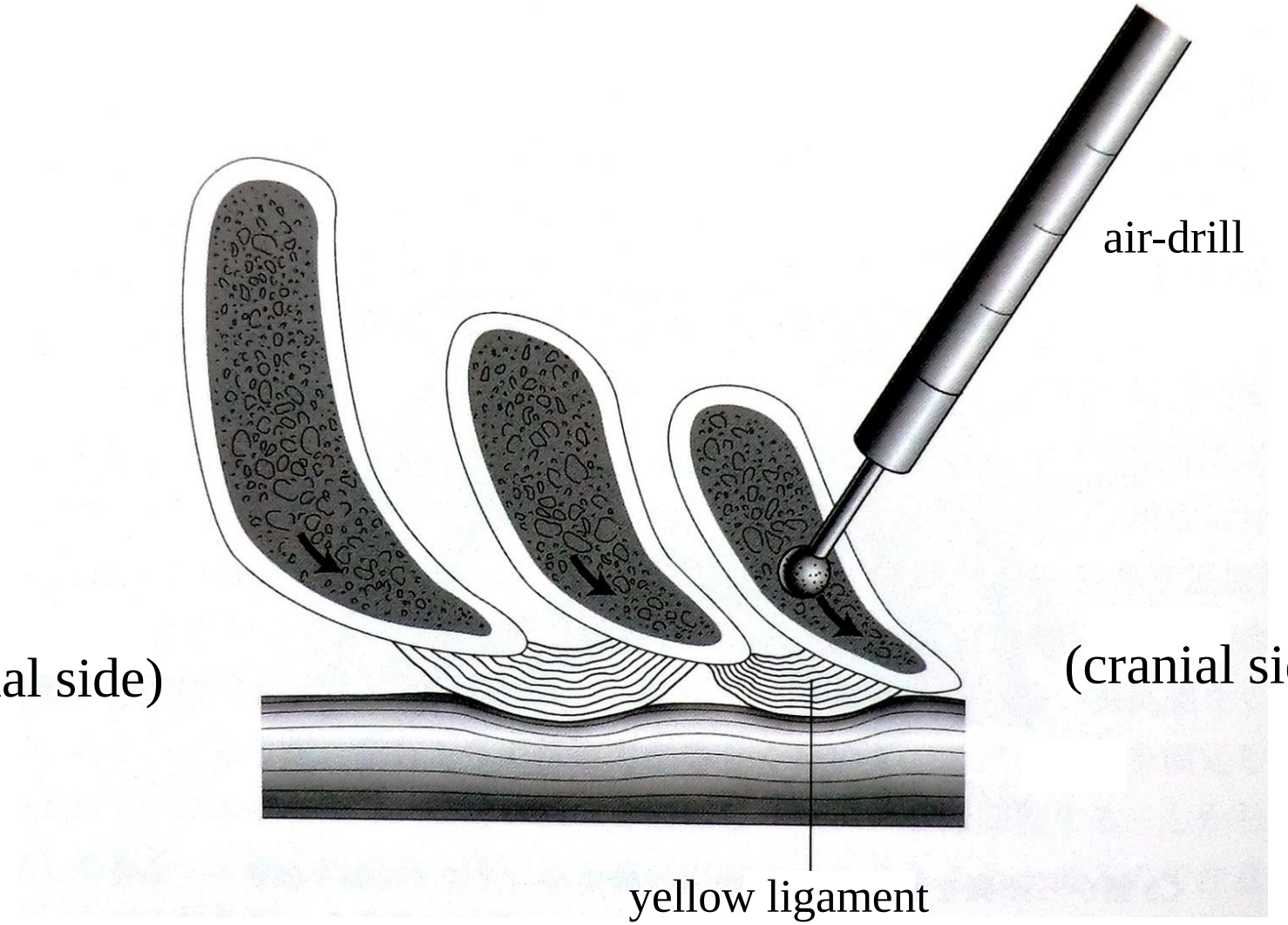
（views from the cranial side）

Trigonal shape osteotomy at the cranial base of the lamina

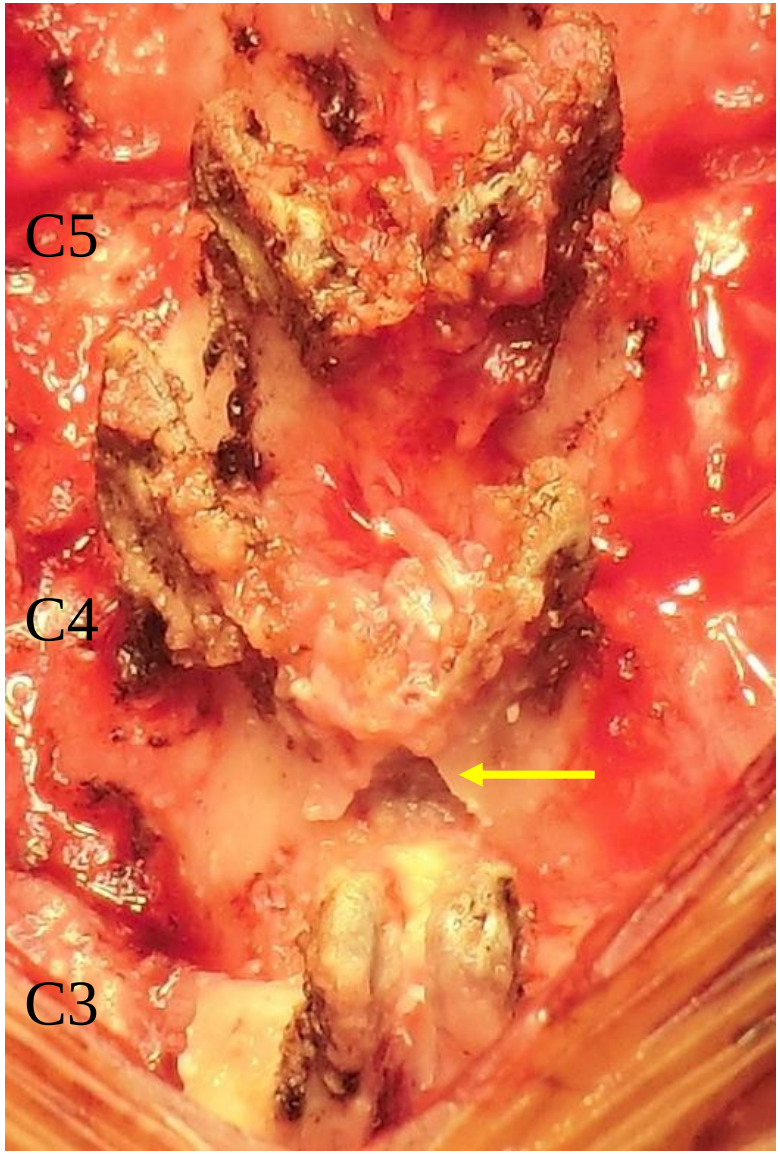


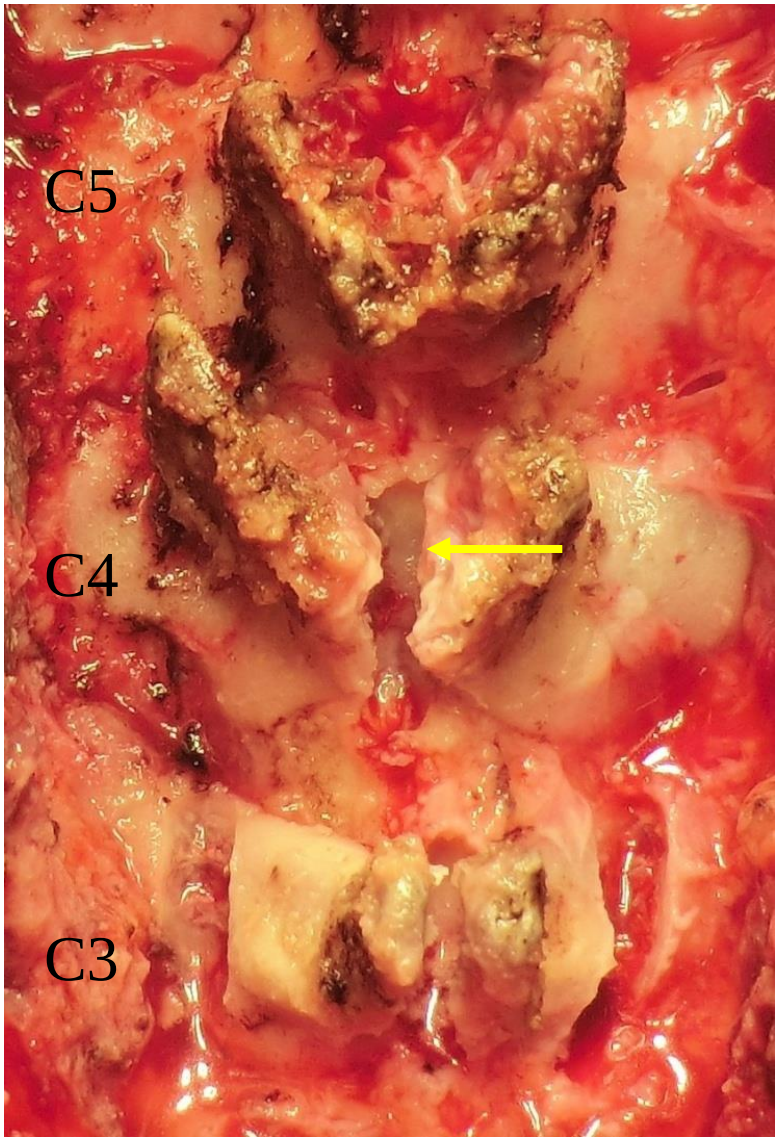
Hirabayashi S. *Spine & Spinal cord* 27:577-581, 2014

Central splitting from the caudal side of each spinous process



Hirabayashi S. *Spine & Spinal cord* 27:577-581, 2014





trigonal shape osteotomy at
the cranial base of the lamina

central splitting of the
spinous process

Important technical points in splitting spinous processes

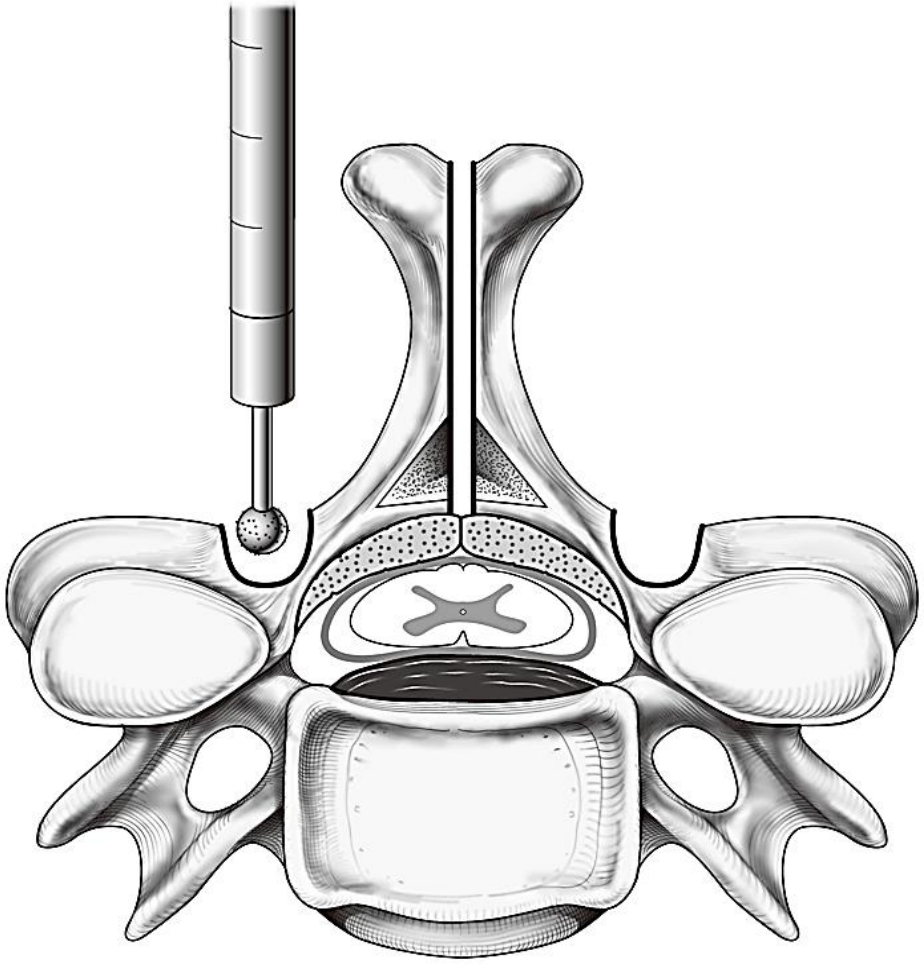
Lighting from the cranial side to obtain bright surgical field.

To attend the changes in color of the osteotomy site from red of cancellous bone, white of the inner cortex, and finally yellow of the yellow ligament and extradural fat tissue.

To attend the changes in sound and tactile sensation delivered from the air-drill at the time of complete osteotomy of the inner cortex of lamina.

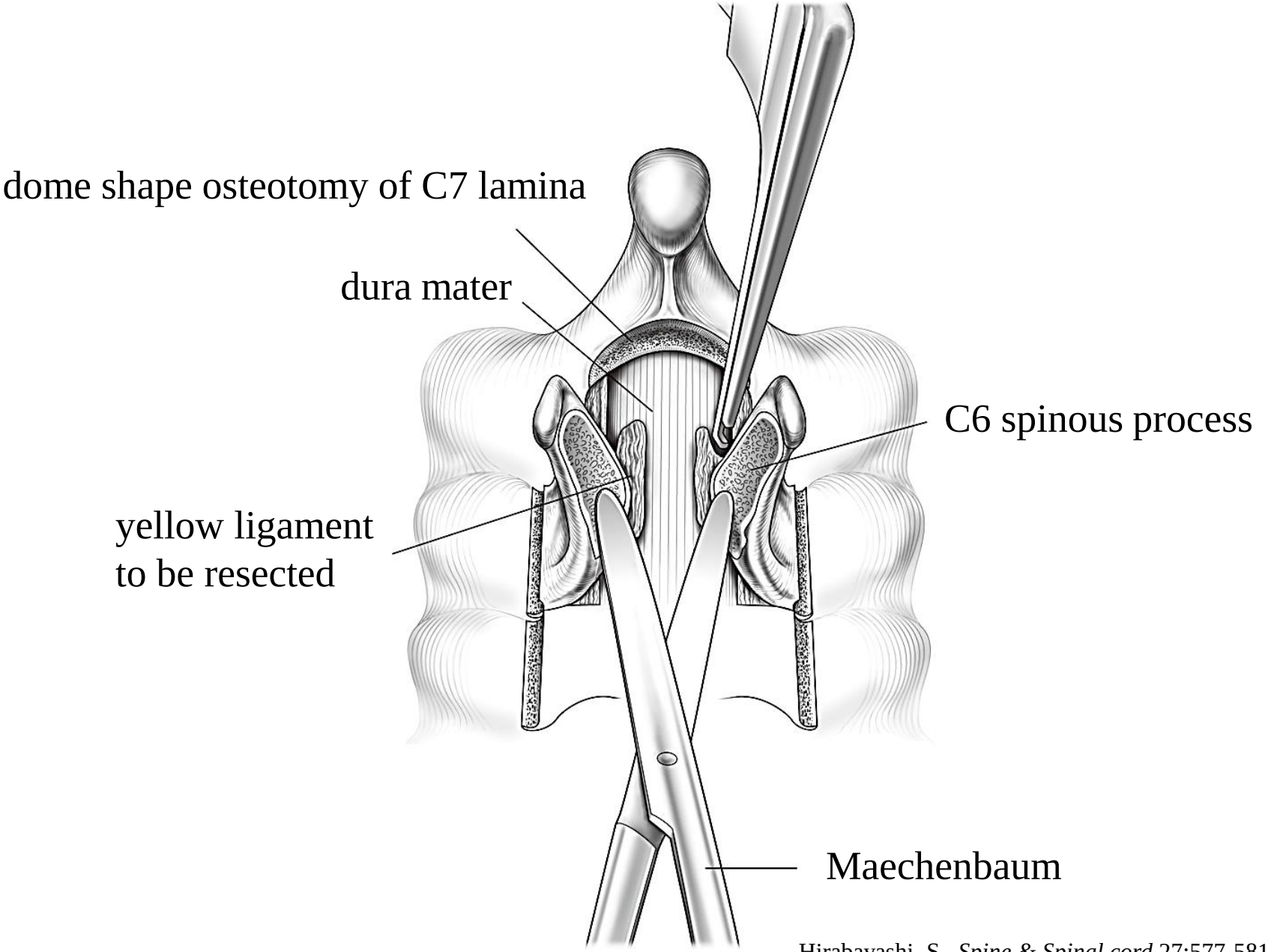
To often check the degree of osteotomy by touching with a probe.

Formation of lateral gutters



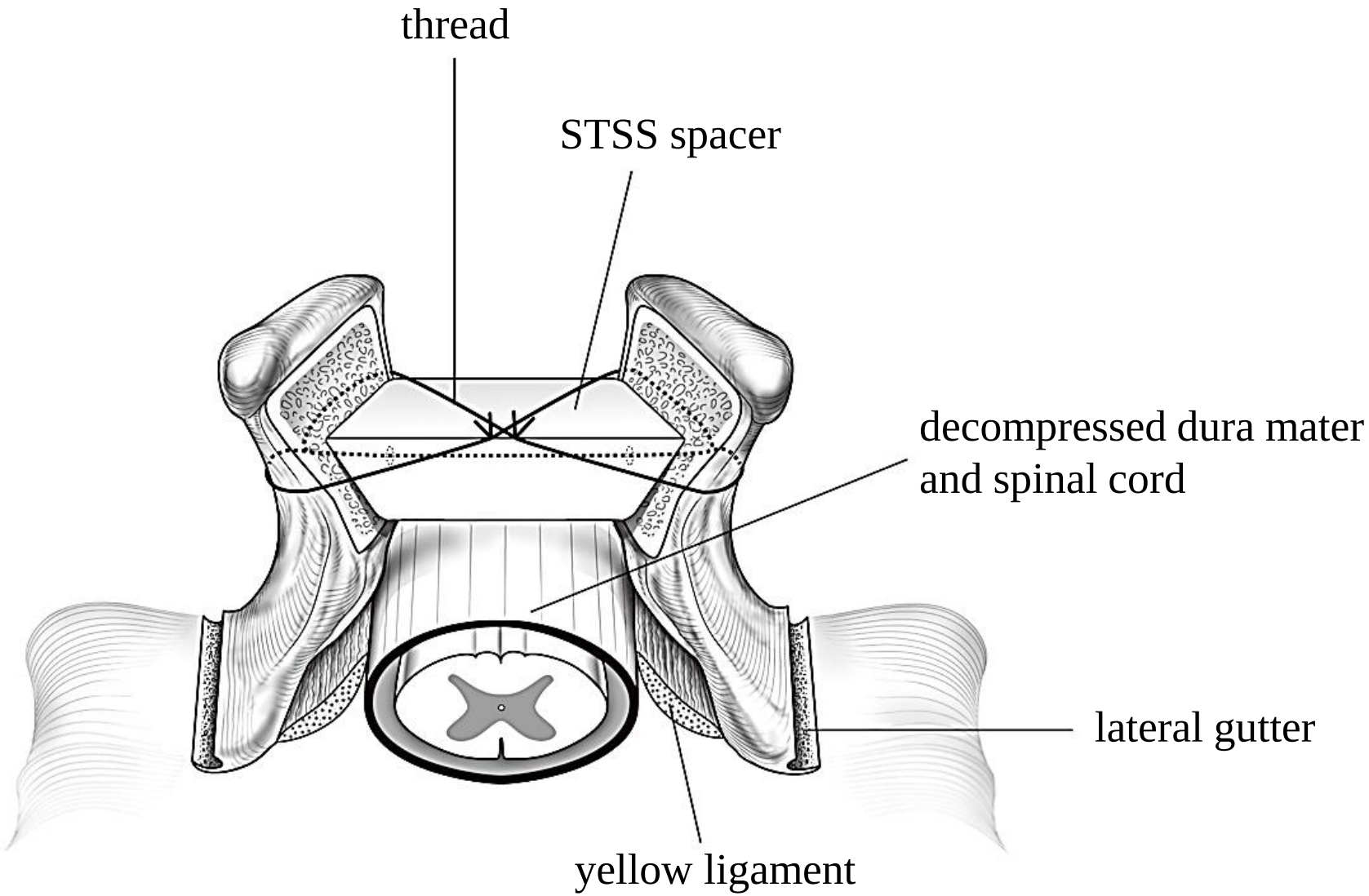
Hirabayashi S. *Spine & Spinal cord* 27:577-581, 2014

Decompression of the spinal canal



Hirabayashi S. *Spine & Spinal cord* 27:577-581, 2014

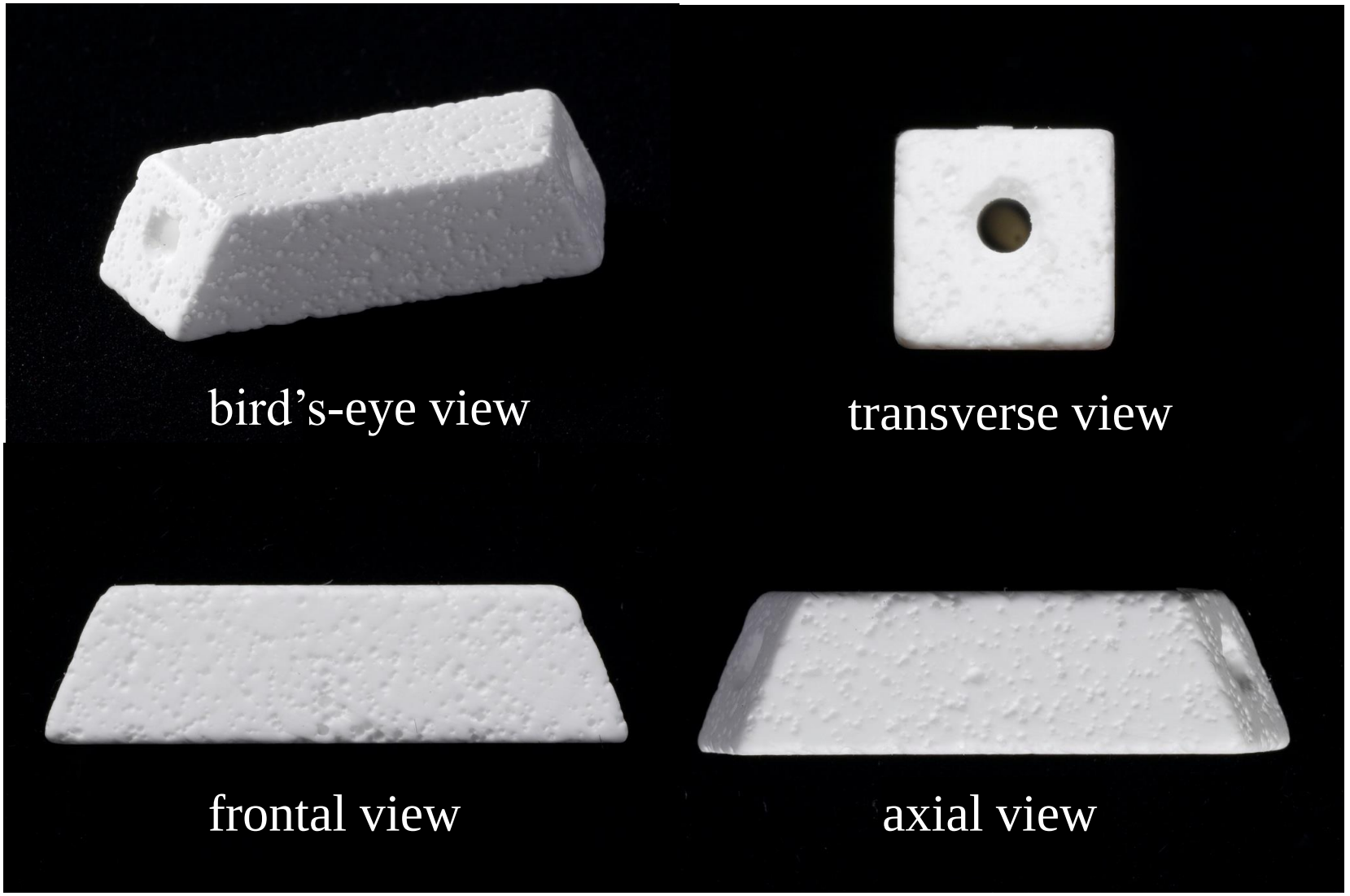
Fixation of STSS spacer



(view from the cranial side)

Hirabayashi S. *Spine & Spinal cord* 27:577-581, 2014

STSS spacer



Features of STSS spacer

Both the axial and frontal sections are trapezoidal.

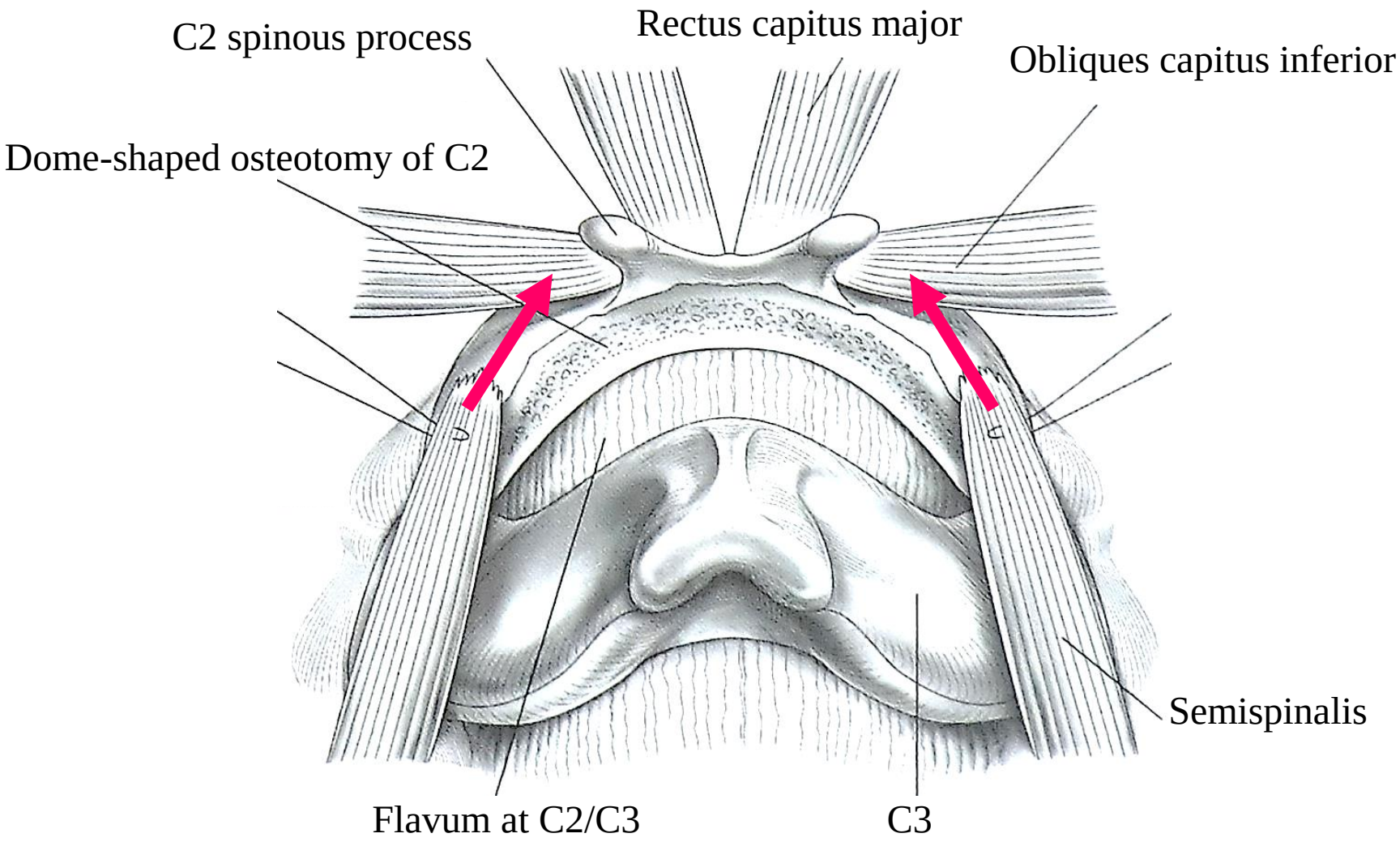
The shape of contact surface to the split spinous process is parallelogram, resulting in obtaing a wider area.

Well adapted to the widened space because of the same shape.

During the fixation to the split spinous process, a spacer rotates slightly in the sagittal plane, resulting in more firmly stabilized parallel to each spinous process.

(view from the cranial side)

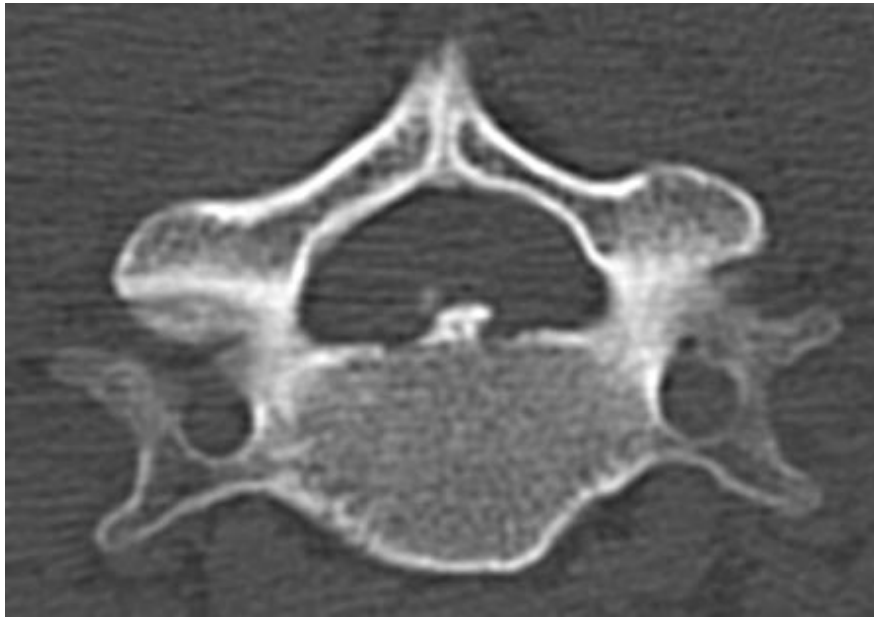
Restoration of tension of the Semispinalis muscles

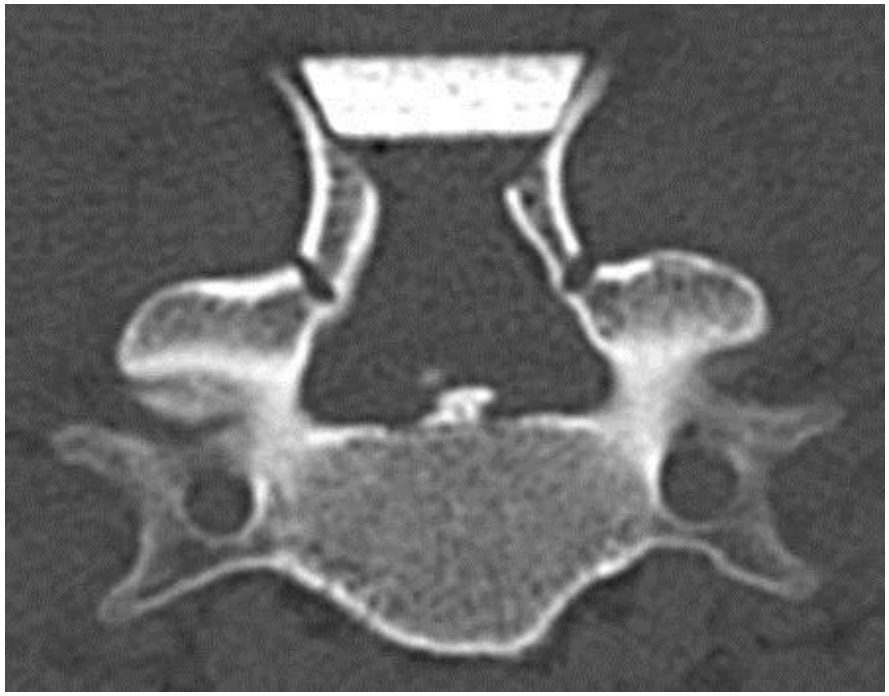


Hirabayashi S. *Spine & Spinal cord* 27:577-581, 2014

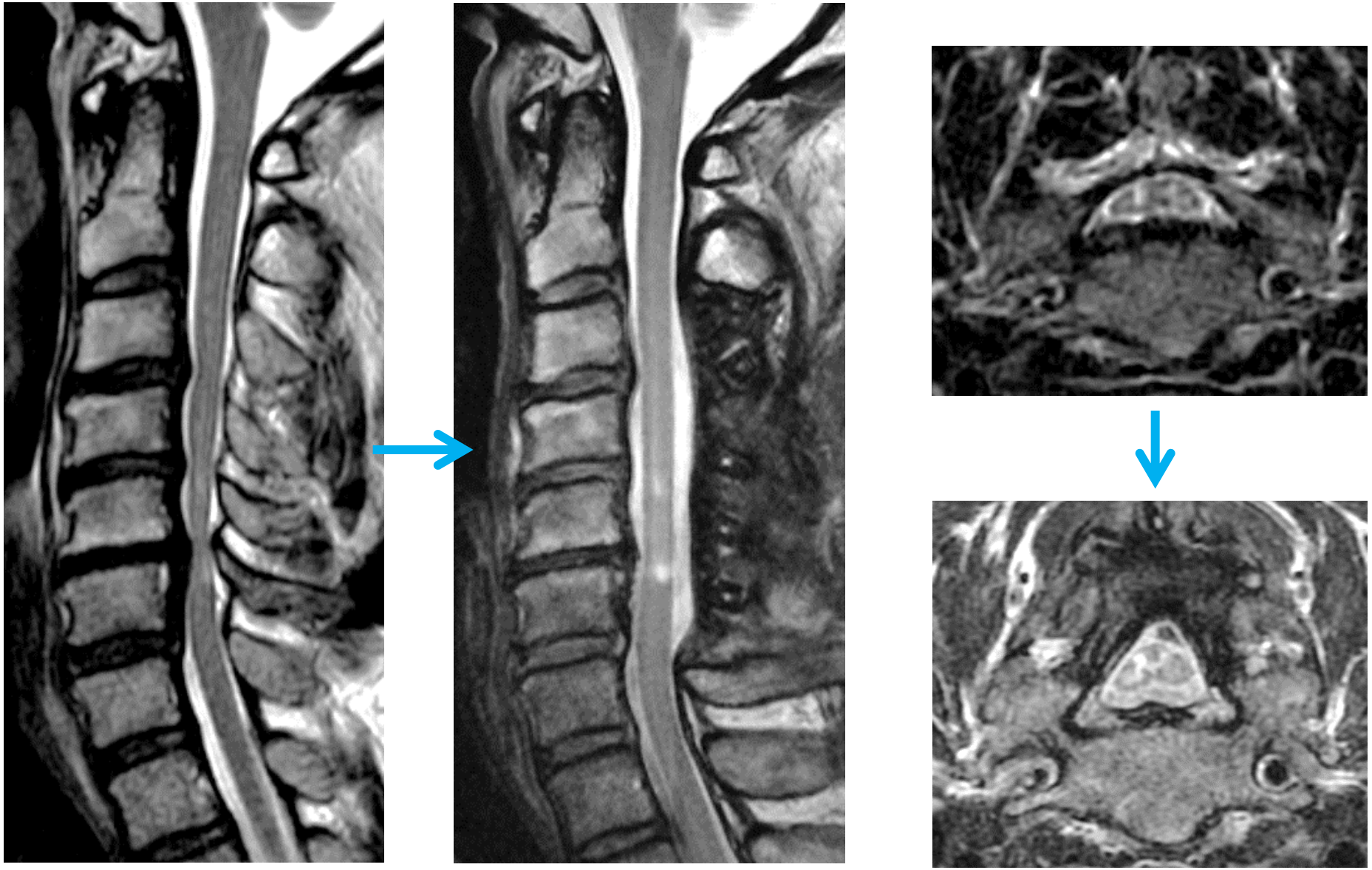
DDL for cervical spondylotic myelopathy 46 y.o. M

DDL for cervical spondylotic myelopathy

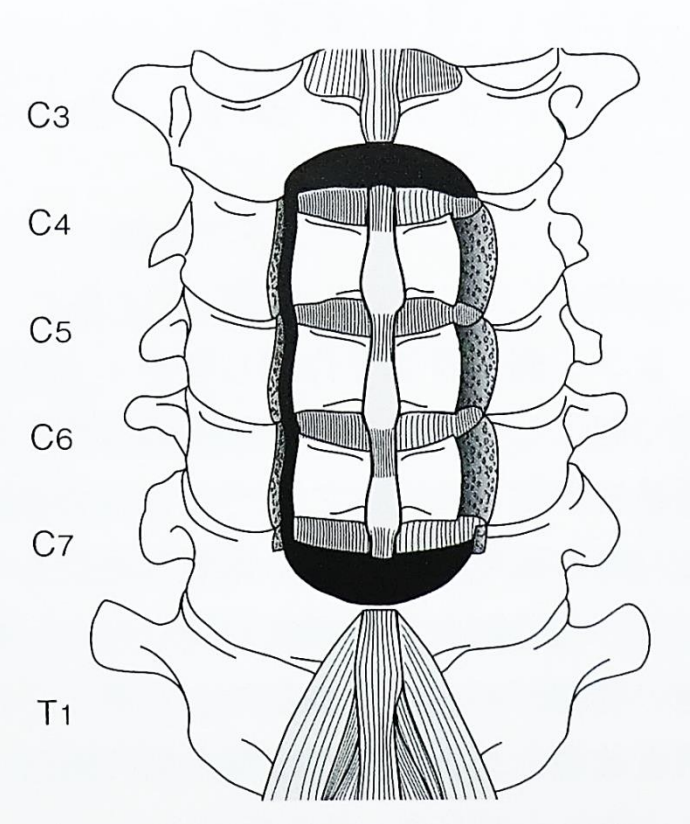


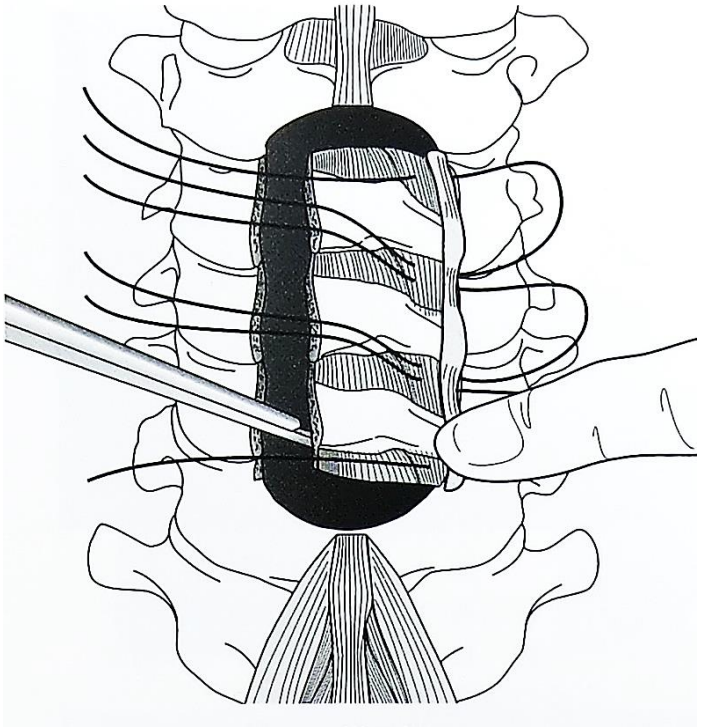


DDL for cervical spondylotic myelopathy



Open-door Laminoplasty



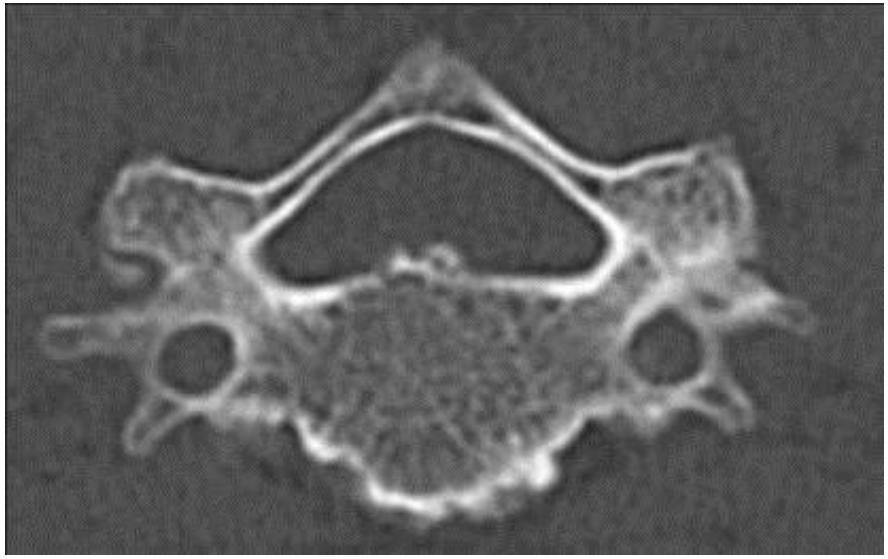


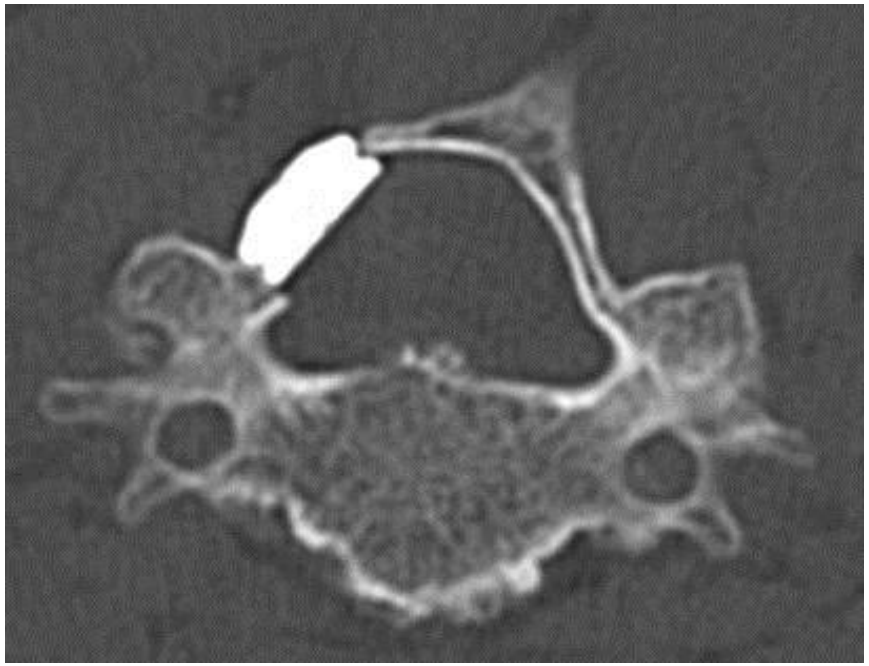
After making longitudinal grooves along the lamina-facet junction line bilaterally, the inner cortex is severed at the open side. Next, the spinous processes are pushed toward the hinge side and the hypertrophied ligamentum flavum is resected.

Matsumoto M. et al *Spine and Spinal Cord* 26(11):1033-1039, 2013

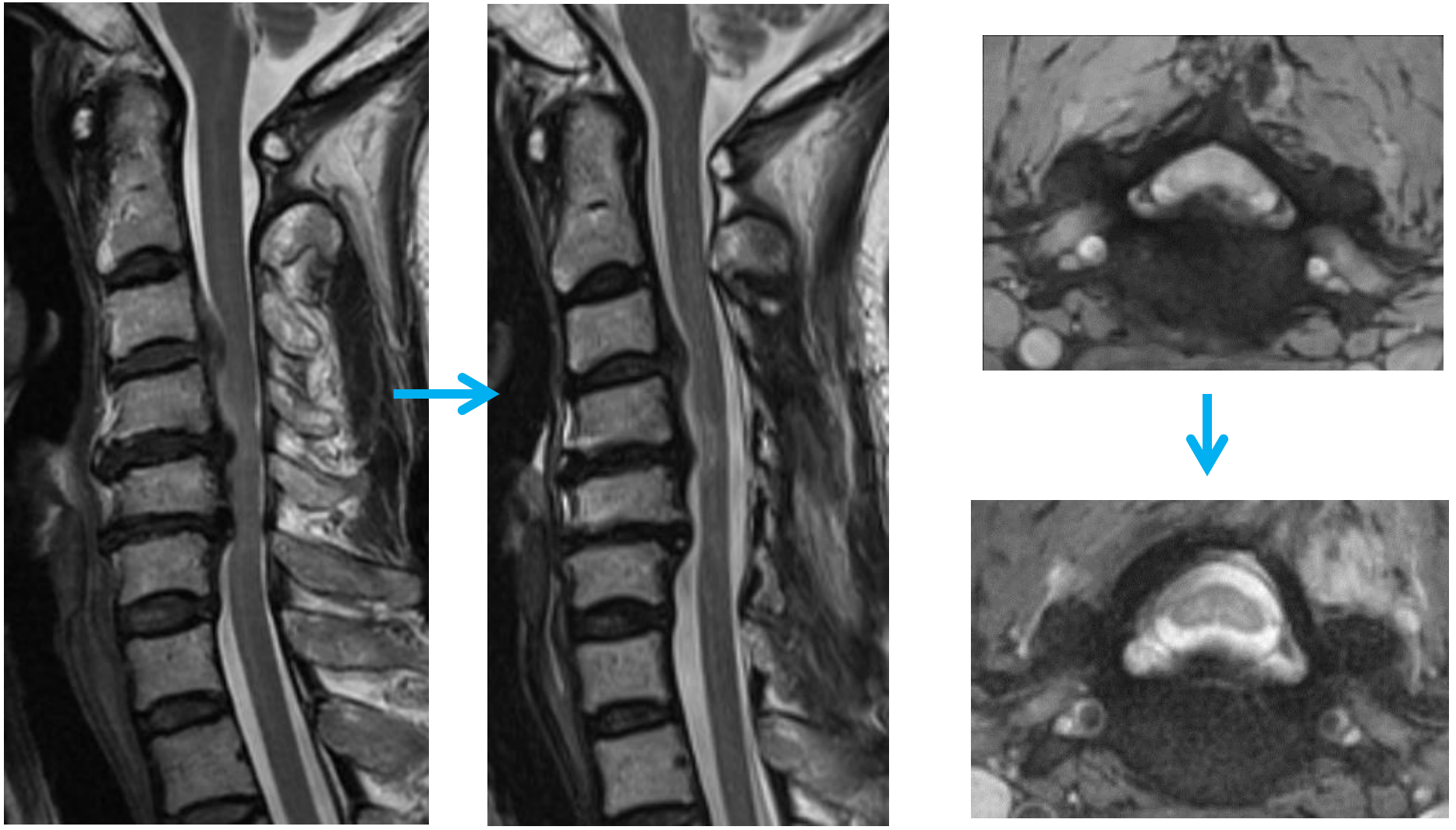
ODL for cervical spondylotic myelopathy 54 y.o. F

ODL for cervical spondylotic myelopathy





Open-door laminoplasty



Postoperative rehabilitation

Immediately after surgery, muscle exercises begin during bed rest.

After a few days, move around using a walker or wheelchair is allowed wearing a soft neck collar.

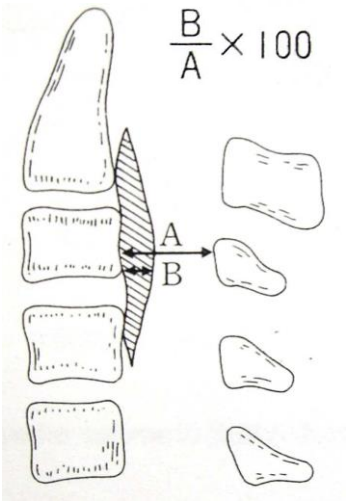
At the end of 1 month, the collar is discarded.

Inappropriate candidates for Laminoplasty

Large OPLL (B/A ×100 ≧ 50-60%, or B ≧7mm)

Local kyphosis at the most affected level

Hypermobility at the most affected level



Iwasaki M. *Spine and Spinal Cord* 26(11), 1047-54,2013

Issue 2

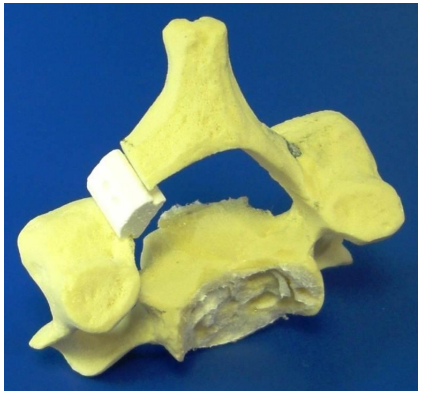
Eur Spine J (2010) 19:1690–1694
DOI 10.1007/s00586-010-1369-y

ORIGINAL ARTICLE

Comparison of enlargement of the spinal canal after cervical laminoplasty: open-door type and double-door type

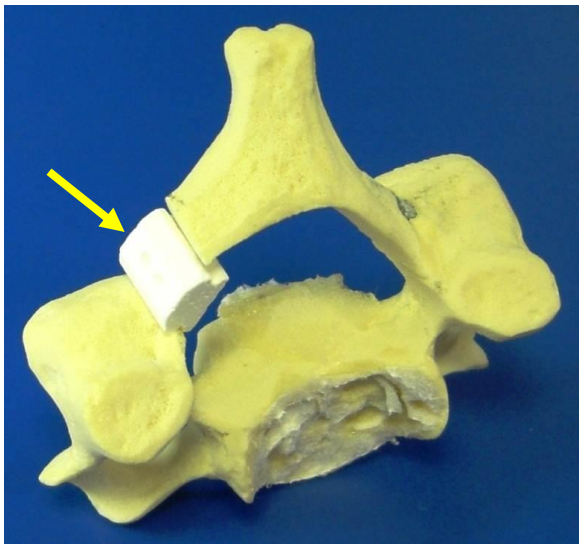
Shigeru Hirabayashi · Hironobu Yamada ·
Takao Motosuneya · Yoshinobu Watanabe ·
Makoto Miura · Hiroya Sakai · Takashi Matsushita

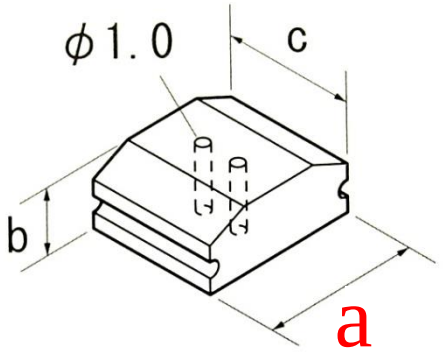
Open-door type



Double-door type

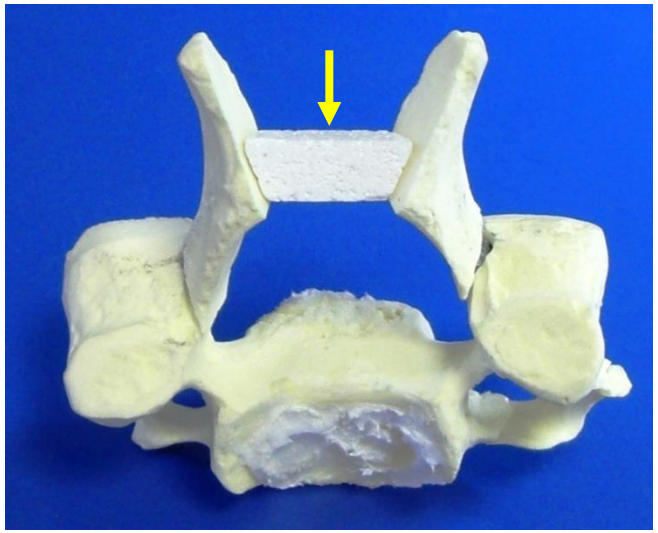
Spacer used in standard ODL

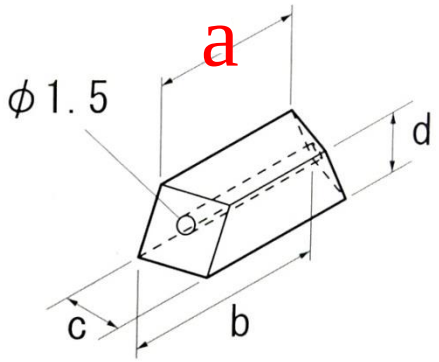




a = 12 mm at C5 and C6 levels

Spacer used in standard DDL



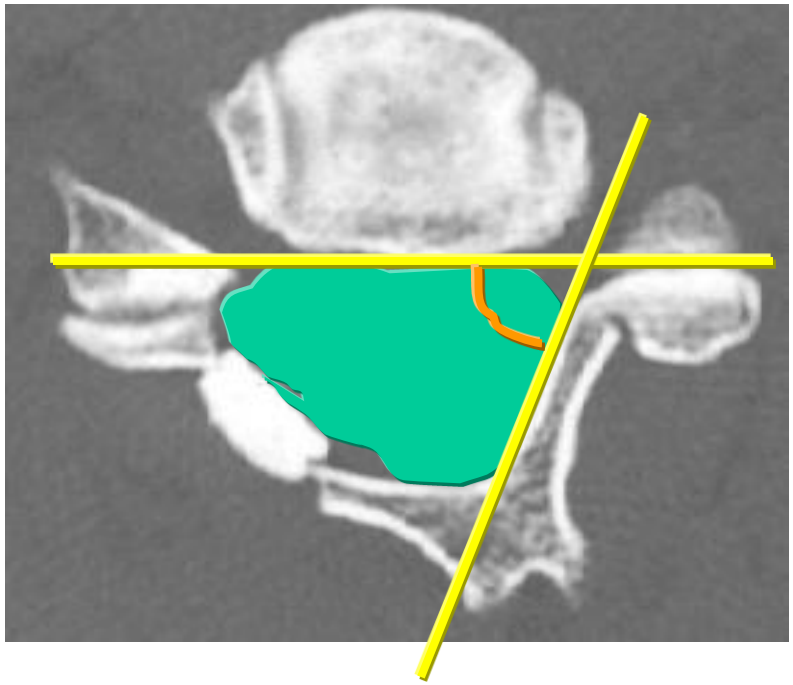


a = 19 mm at C5 and C6 levels

The fixation depth is about 8 mm superficial from the inner cotex of the lamina.

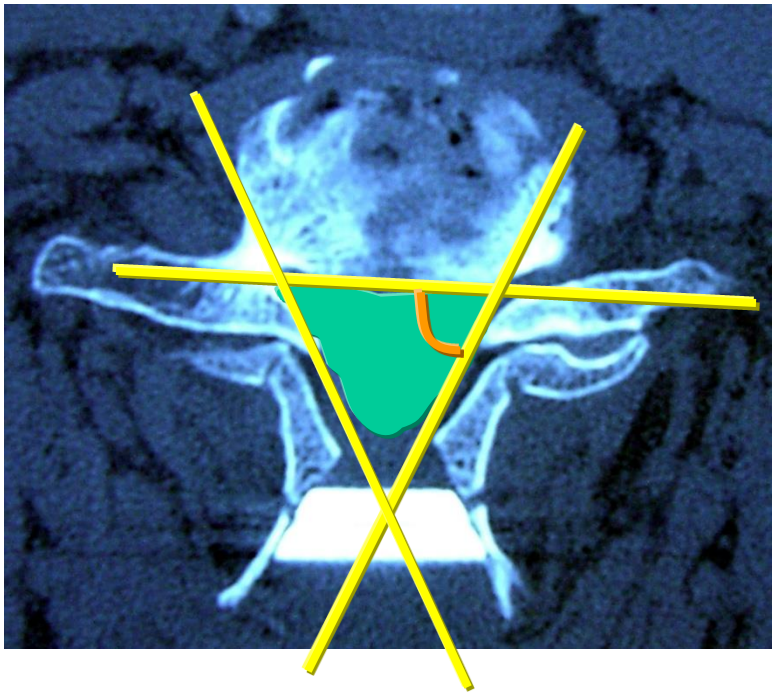
Spinal canal space and inclination angle investigated

(using soft program of computer: Image J)



Tension-band laminoplasty (TBL)

(One method of ODL)



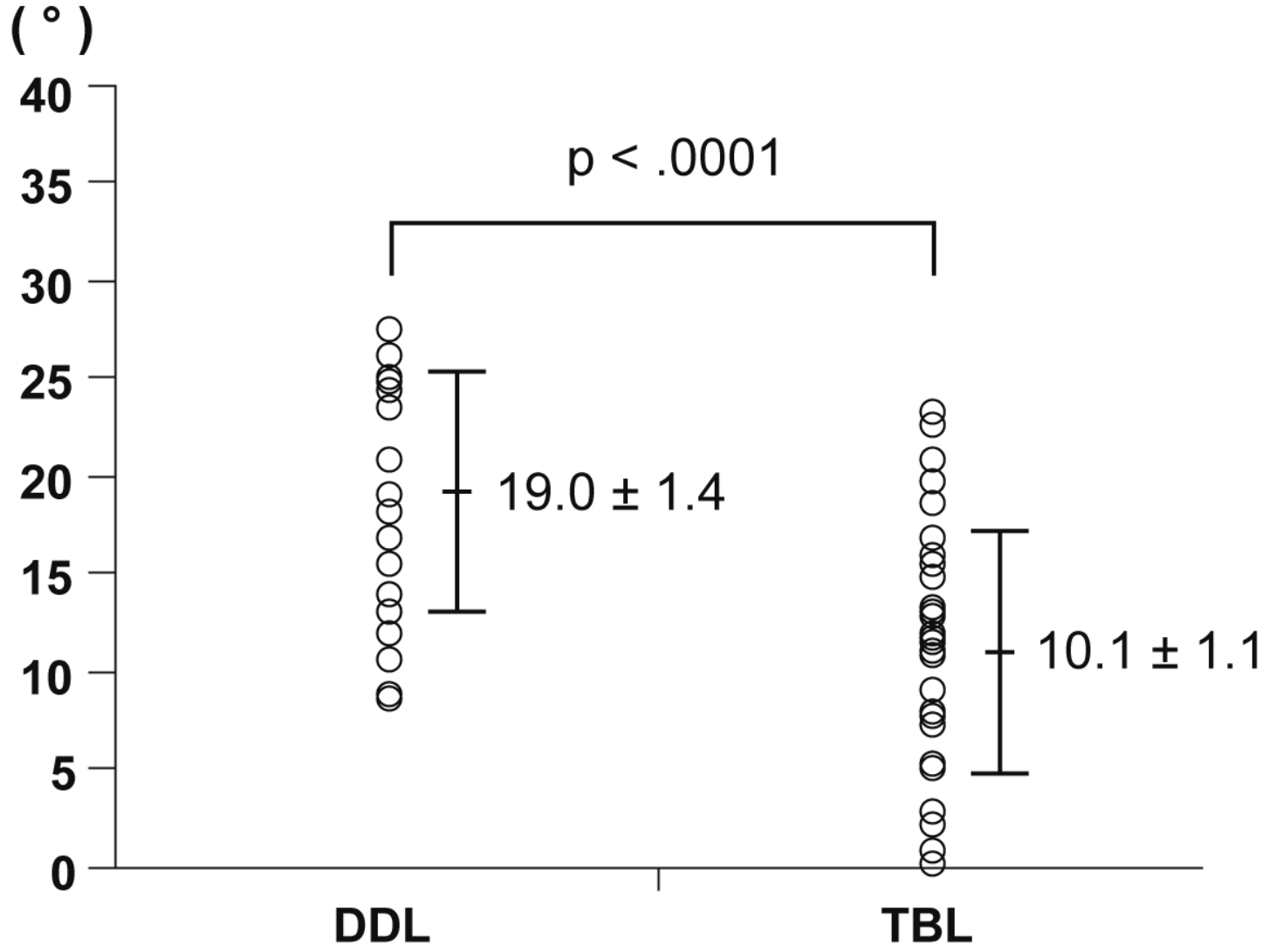
Double-door laminoplasty (DDL)

Clinical study

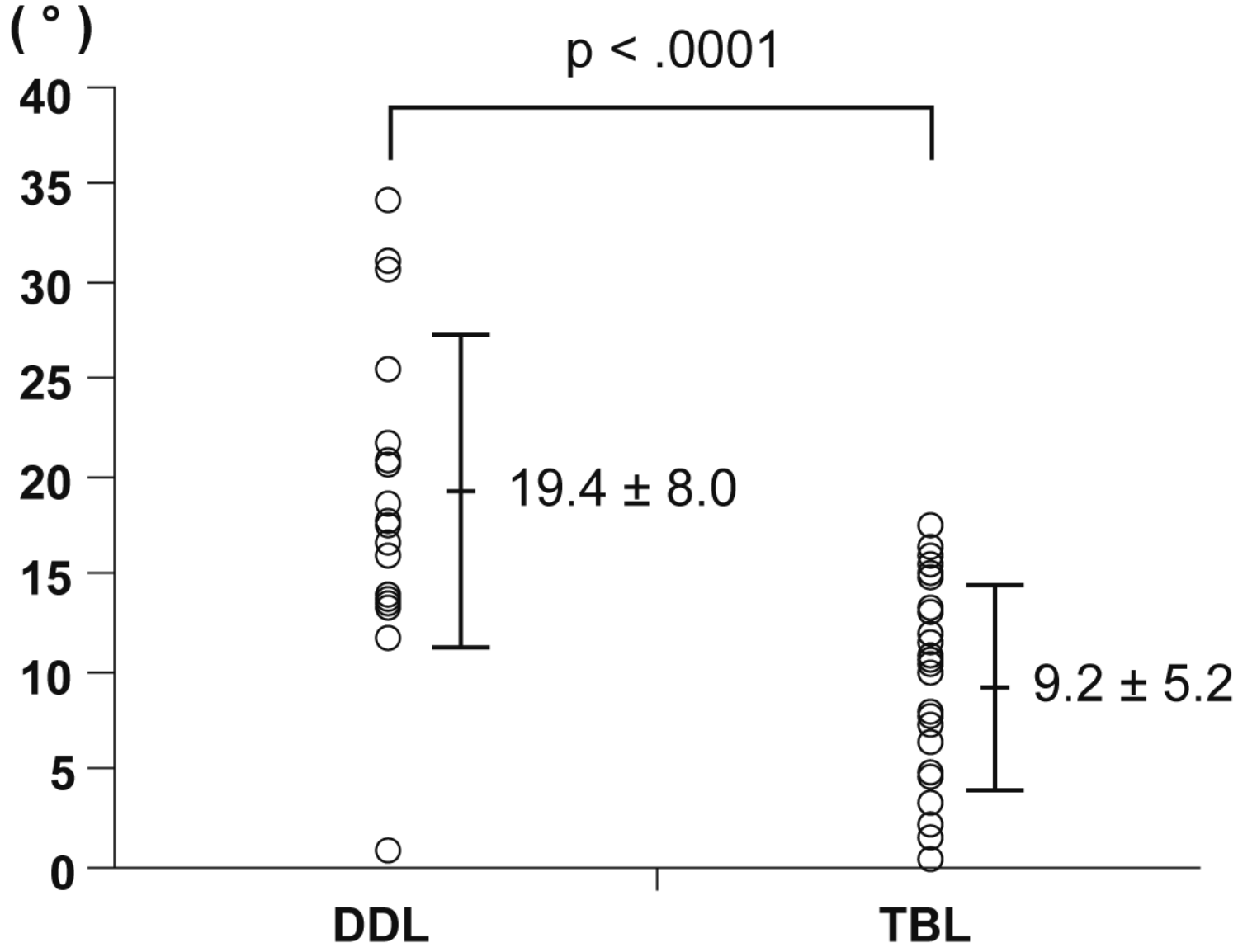
	Patients	M / F	Age	Average
TBL for OPLL	13	10 / 3	51 - 83	60.1
TBL for CSM	20	12 / 8	31- 83	63.7
DDL for CSM	20	17 / 3	29 - 89	62.8

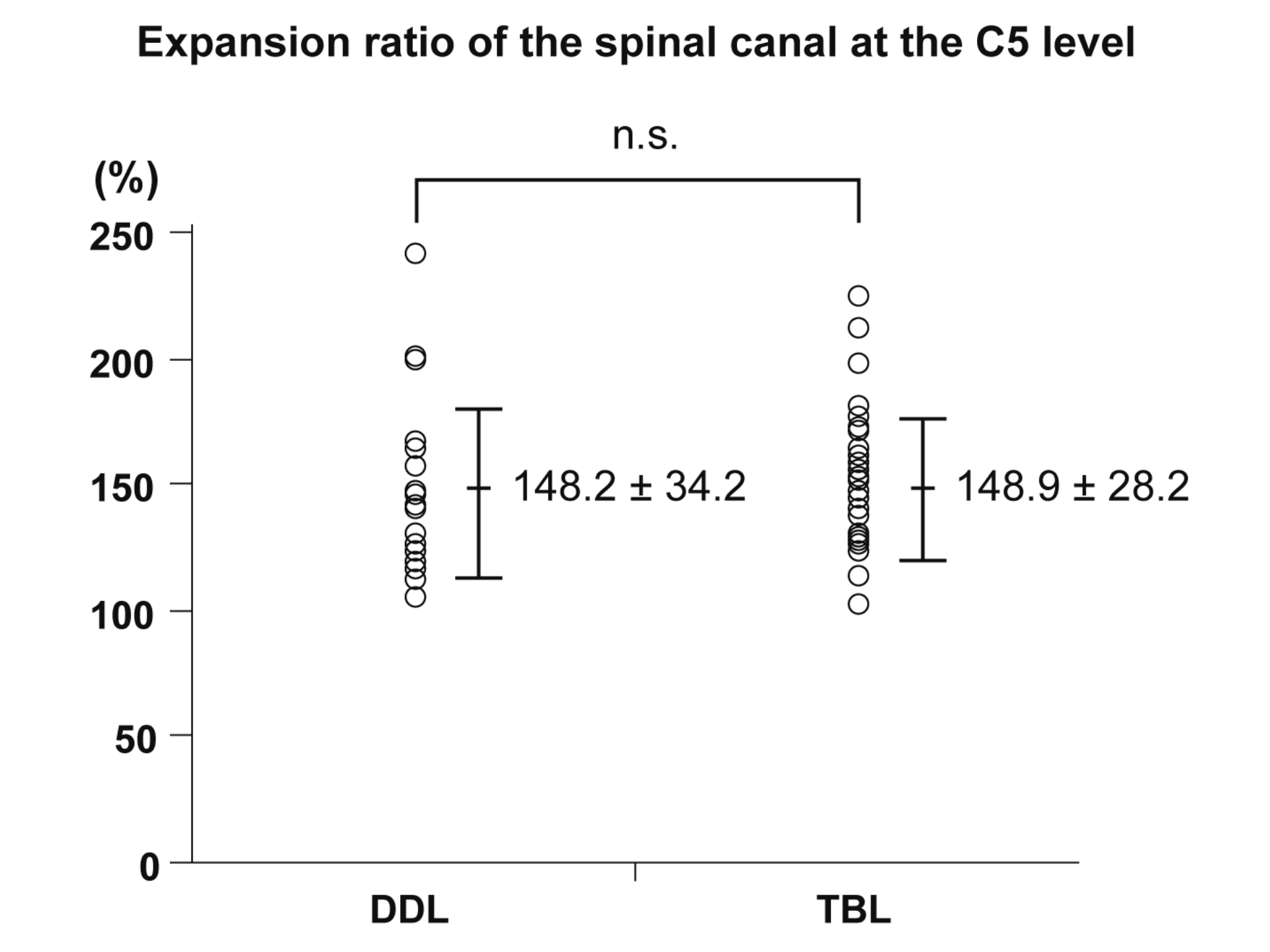
TBL: Tension-band laminoplasty （one method of open-door type)
OPLL : Ossificationn of the posterior longitudinal ligament
CSM : Cervical spondylotic myelopathy

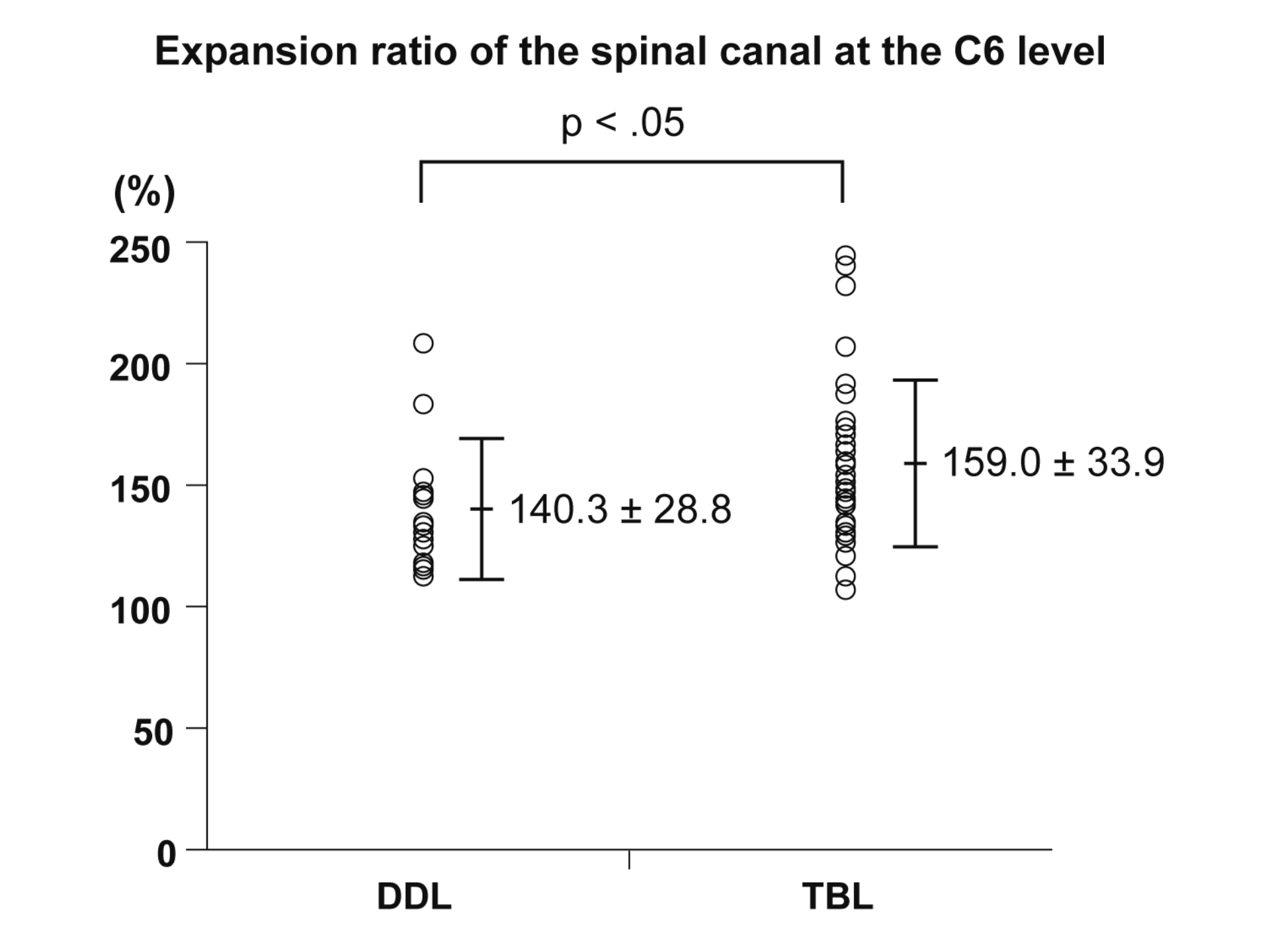
Increased inclination angle of the C5 lamina



Increased inclination angle of the C6 lamina




Expansion ratio of the spinal canal at the C5 level
n.s.
(%)
250
200
150
100
50
0
148.2 ± 34.2
148.9 ± 28.2
DDL
TBL


Expansion ratio of the spinal canal at the C6 level
p < .05
(%)
250
200
150
100
50
0
140.3 ± 28.8
159.0 ± 33.9
DDL
TBL

Results

1. The mean inclination angle at C5 and C6 level was about 20 degree in DDL, and about 10 degree in TBL (hinge side).
   It was significantly larger in DDL than TBL ($p < 0.0001$).

2. At C5 level, the expansion ratio was about 150% in both DDL and TBL. There was no significant difference between them.

3. At C6 level, the expansion ratio was about 140% in DDL and about 160% in TBL. It was significantly larger in TBL than DDL ($p < 0.05$).

Issue 3

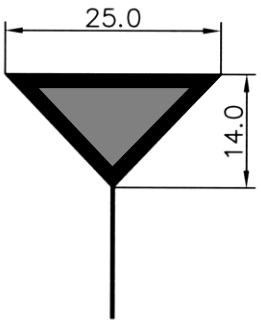
Significance of the Maintenance of the Spinous Process and the Stability of an Artificial Spacer in Double-door Laminoplasty --- Figure Analyses

Shigeru Hirabayashi, Keitaro Murata, Iwao Yamamoto,

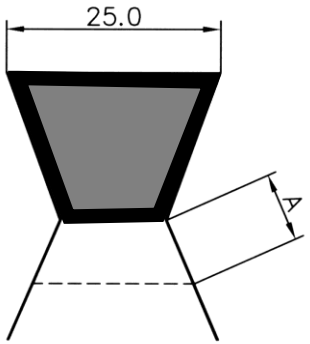
Makoto Miura, Takashi Matsushita

J. Spine Res. 2 : 66-72, 2011

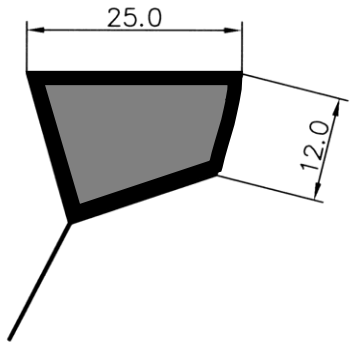
Shape of the spinal canal at C5 and C6 level



original shape



after DDL



after ODL

A: distance from the inner cortex of lamina to the center of a spacer

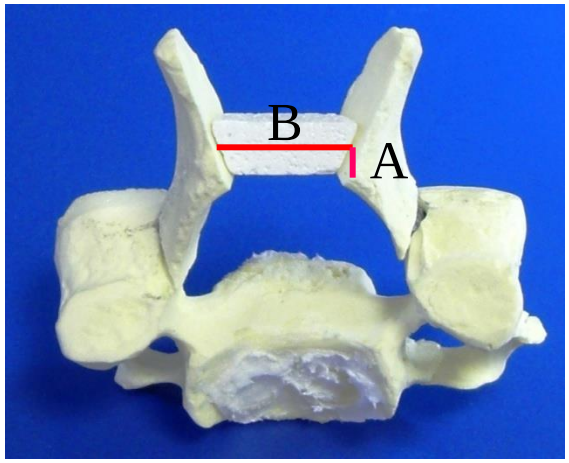
by Delmas & Pineau

DDL: double-door laminoplasty
ODL: open-door laminoplasty

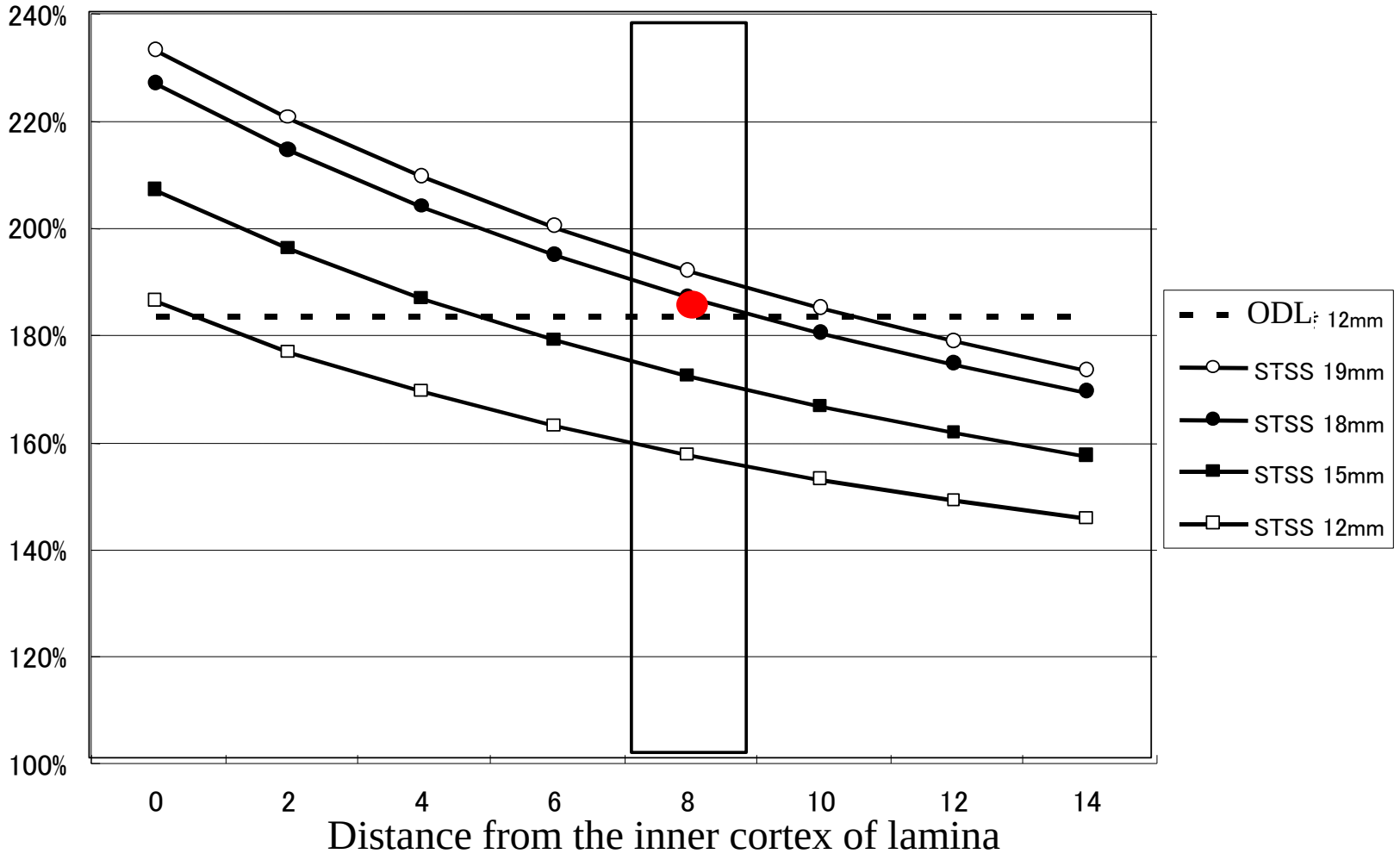
The expansion ratio of the spinal canal in DDL depends on both the depth of a spacer (A) and the width of a spacer (B)

B \ A	0	2	4	6	8	10	12	14
19 mm	233	220	209	200	192	185	178	173
18 mm	227	214	204	195	187	180	174	169
15 mm	207	196	187	179	172	166	161	157
12 mm	186	176	169	163	157	153	149	145

（%）



Expansion ratio of the spinal canal



The expansion ratio of DDL using a spacer with 18 mm in width and 8 mm in depth is almost the same as that of ODL using a spacer with 12mm in width.

In ODL (TBL), the expansion of the spinal canal depends on the width of a spacer.

In DDL, the expansion depends on both the width and depth of a spacer

The comparison of the expansion ratio in both ODL and DDL performed by figure analysis well corresponded to the clinical results.

Technical advantages

Open-door laminoplasty (ODL)

Easier decompression procedure

Double-door laminoplasty (DDL)

Easier fixation of spacers

Direct visual confirmation of bilateral decompression

Appropriate indications

Open-door laminoplasty (ODL)

CSM combined with radiculopathy

Severe prominence of OPLL

Patients with tiny spinous processes

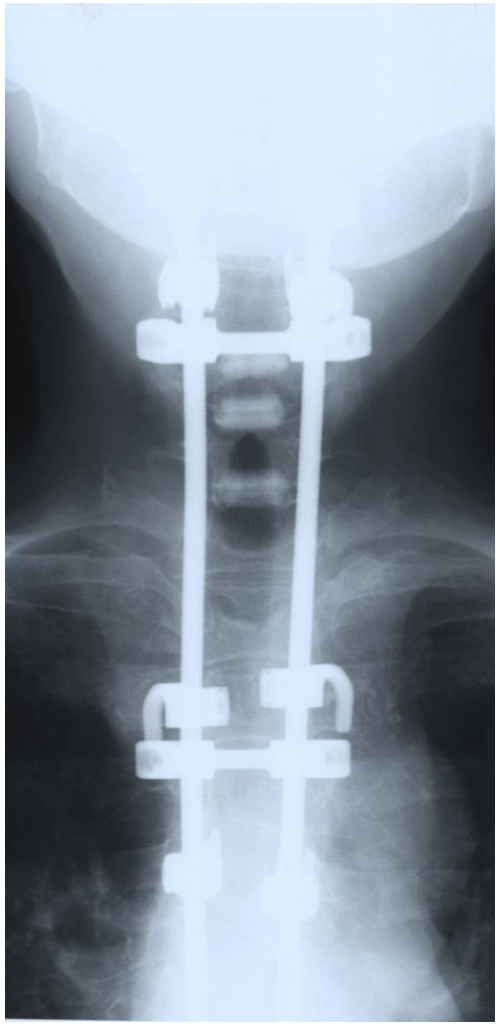
Double-door laminoplasty (DDL)

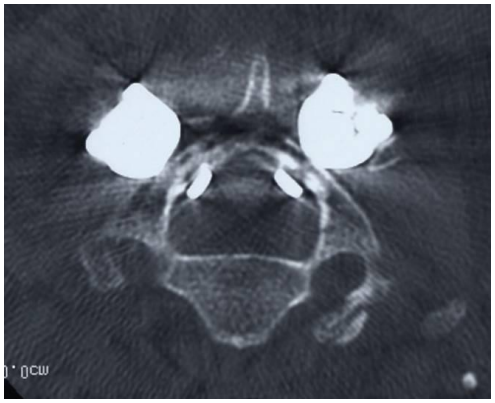
Usual CSM

Small and slight prominence of OPLL

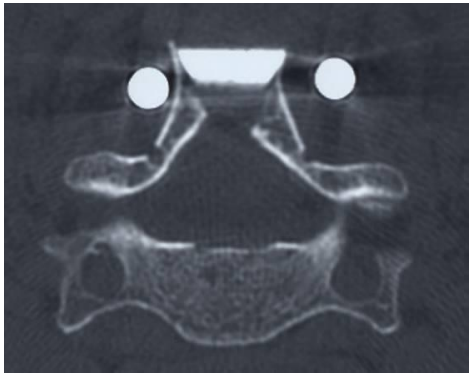
Combined fixation using instrument

RA with C1-C2 instability and spinal canal stenosis of the cervical spine adequate indication of DDL





C2 level



C5 level

Conclusions

Even now, it is unclear what is the least expantion ratio of the spinal canal to obtain adequate decompression of the spinal cord.

It is the best for a surgeon to perform surgery by his or her most familiar method.

However, it is necessary to recognize the features and limits of each surgical method.

Issue 4

Change of sagittal alignment of the cervical spine

Cervical spondylotic myelopathy followed more than 1 year

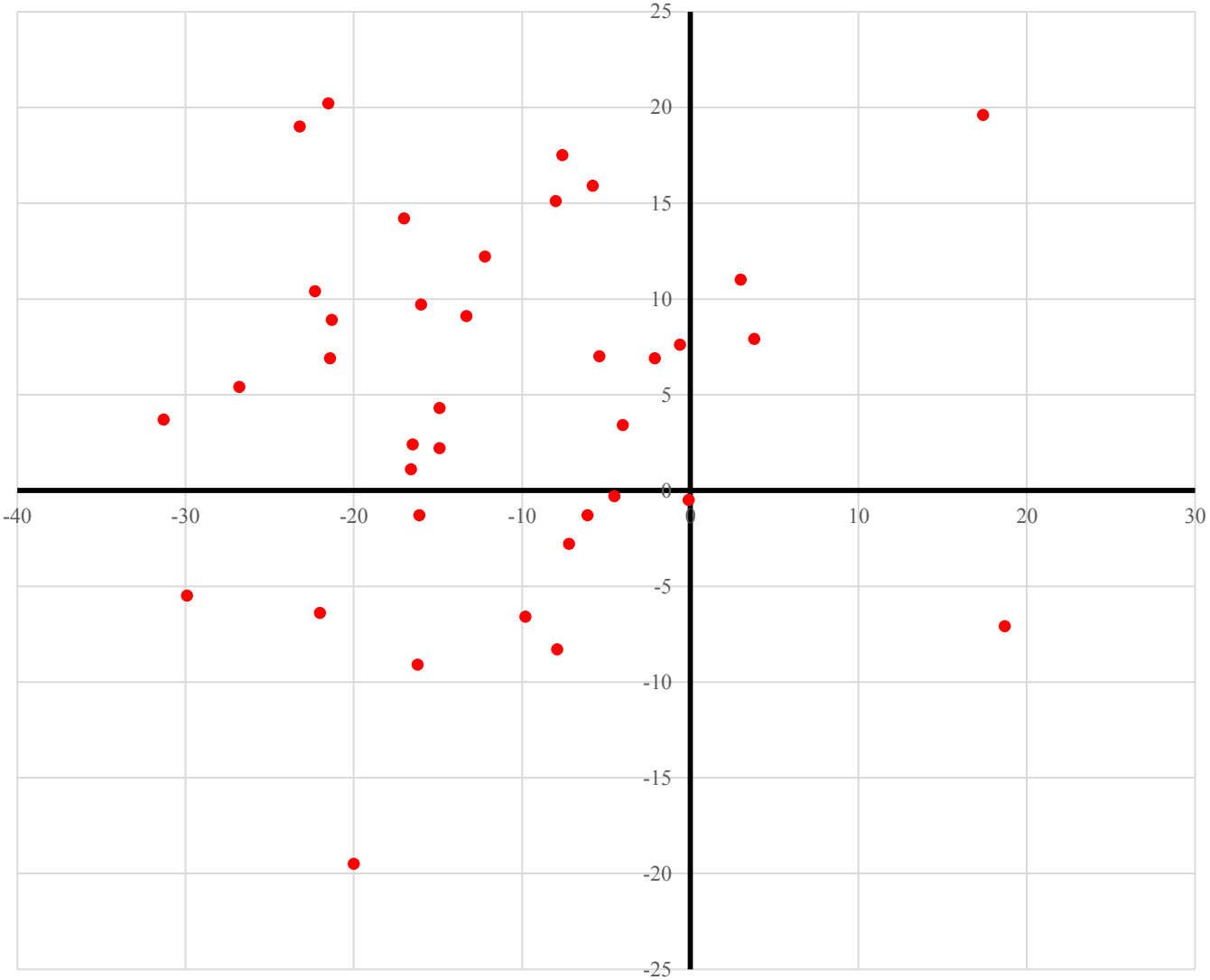
operated level: C3 - C6 or C7

measure: C2-C7 angle

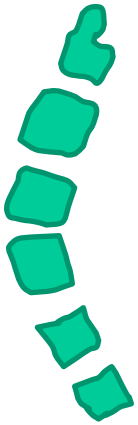
	DDL	ODL
Patients	37	20
M / F	33 / 4	8 / 12
Age (average)	34 - 87 (64.1)	44 - 85 (68.9)
Operated laminae	5 laminae: 12	5 laminae: 15
	4 laminae: 25	4 laminae: 5

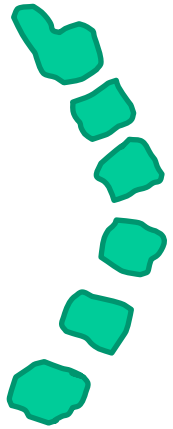
DDL (37 patients)

Postoperative change toward kyphosis



Preope. lordosis

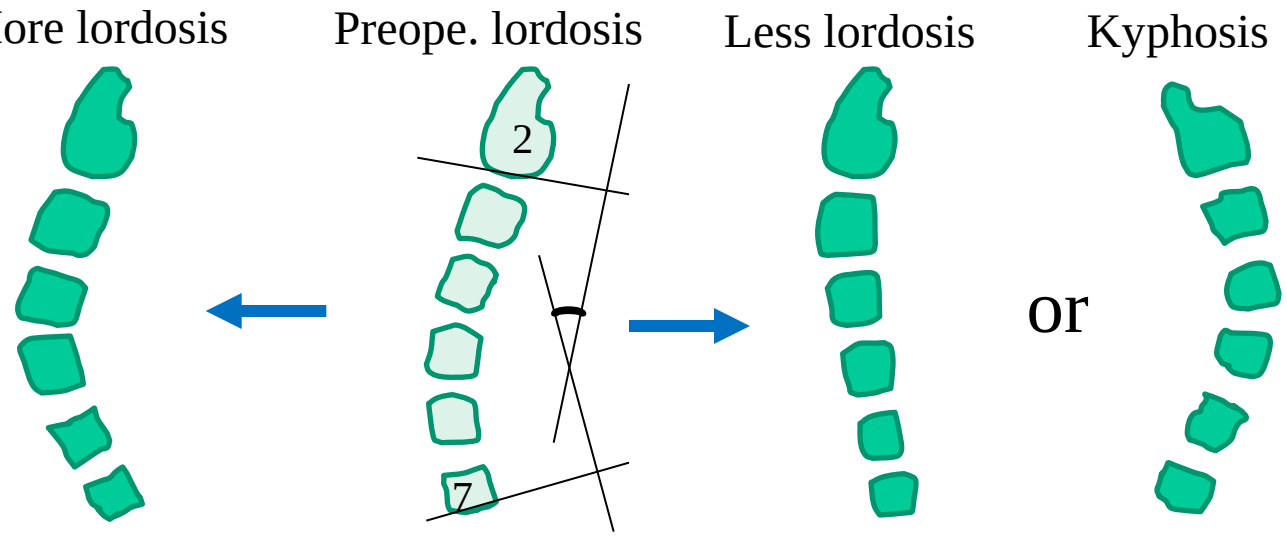




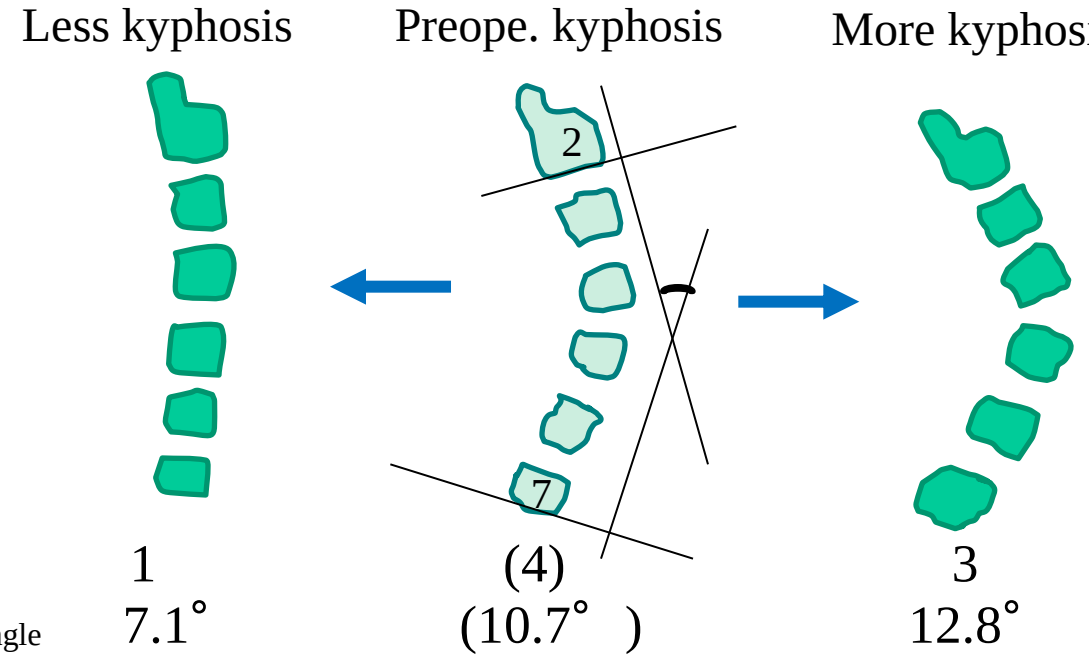
Preope. kyphosis

Postoperative change toward lordosis

DDL



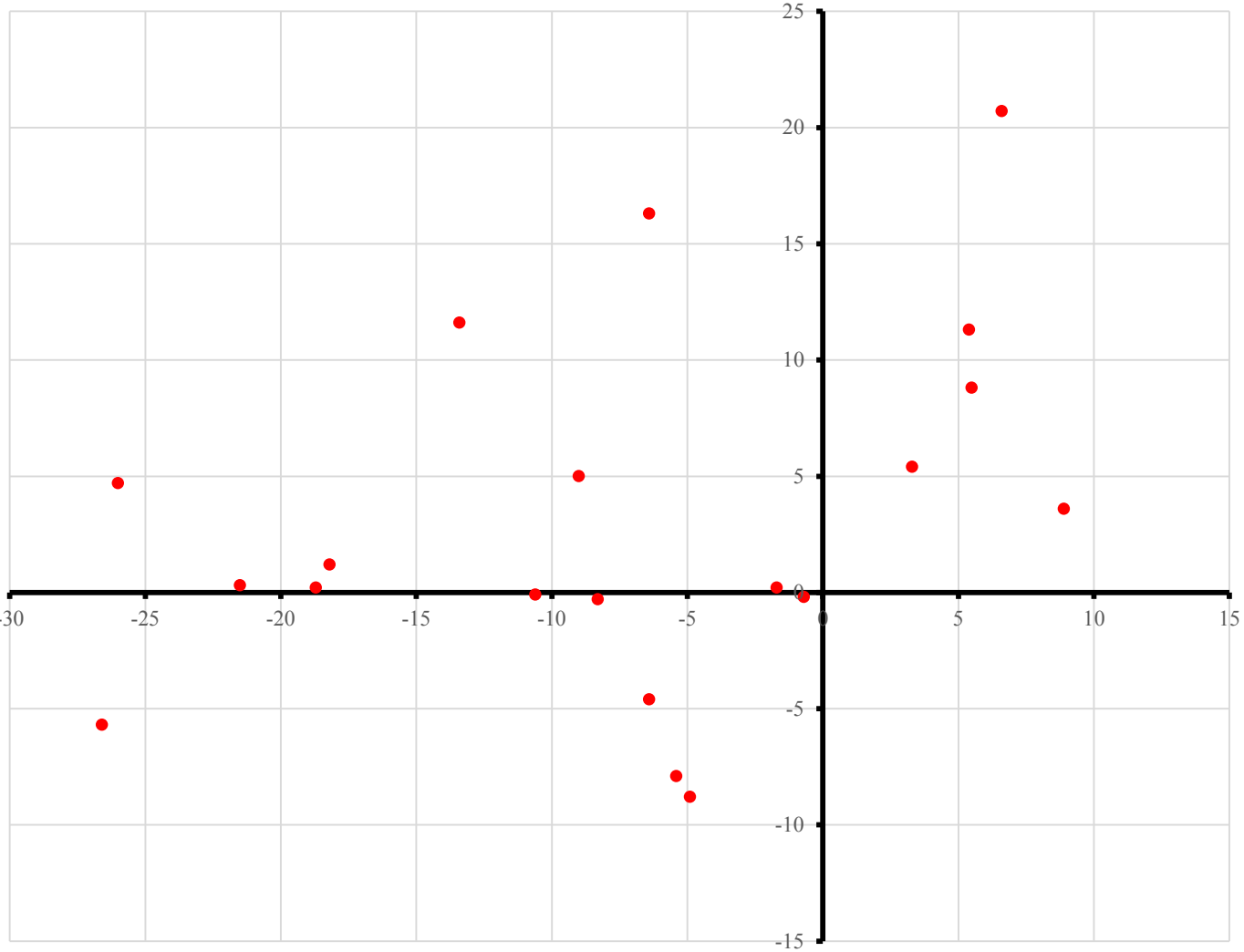
	More lordosis	Preope. lordosis	Less lordosis	Kyphosis
patients	11	(33)	16	6
Average change angle	5.6°	(14.0°)	8.3°	11.7°



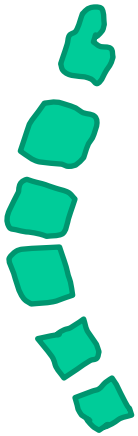
	Less kyphosis	Preope. kyphosis	More kyphosis
patients	1	(4)	3
Average change angle	7.1°	(10.7°)	12.8°

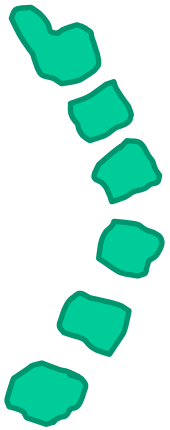
ODL (20 patients)

Postoperative change toward kyphosis



Preope. lordosis

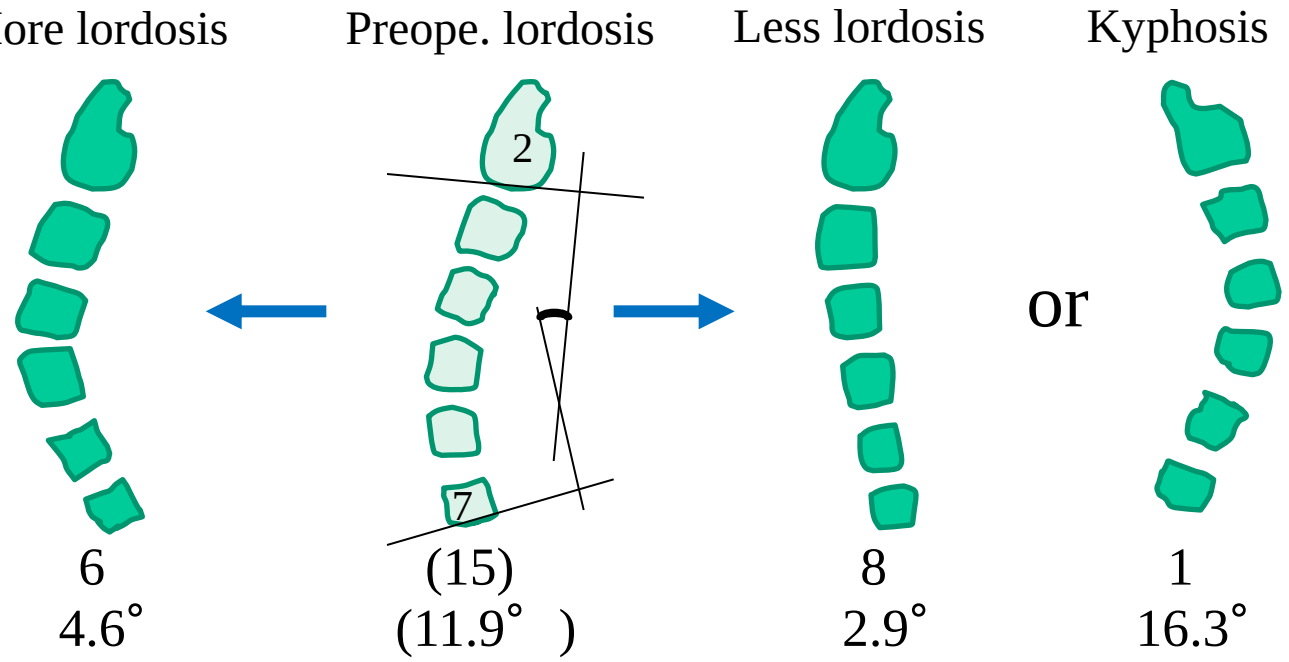


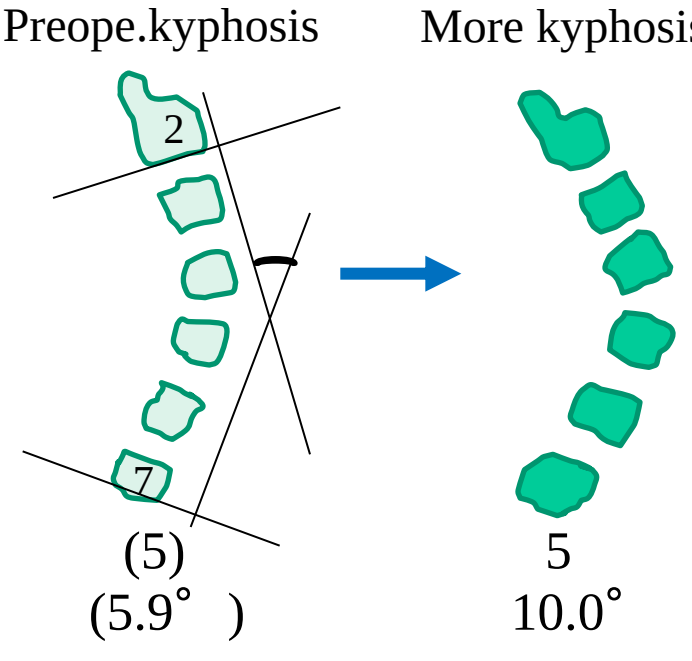


Preope. kyphosis

Postoperative change toward lordosis

ODL


More lordosis
Preope. lordosis
Less lordosis
Kyphosis
or
2
7
patients
6
(15)
8
1
Average change angle
4.6°
(11.9°)
2.9°
16.3°


Preope.kyphosis
More kyphosis
2
7
patients
(5)
5
Average change angle
(5.9°)
10.0°

Results

1. Almost all patients in both DDL and ODL had lordotic alignment of the cervical spine preoperatively.

2. In both types, the preoperative lordorsis changed toward less lordosis or kyphosis postoperatively in about 10 degrees in about 60 % of patients.

3. The change toward more kyphosis in patients with preoperative kyphosis was also about 10 degrees.

Issue 5

Anatomical Analyses and Thoughts on the Cause of Postoperastive C5 Palsy

Shigeru Hirabayashi, Hiromu Yamamoto, Ryutaro Shiboi

Makoto Miura, Takashi Matsushita, Nobuyuki Tsuzuki

The Journal of the Japanese Society for Spine Surgery and Related Research 20: 868-873, 2009

Definition of postoperative C5 palsy

De novo or increasing muscle weakness at mainly the C5 lesion with slight or without sensory disturbance after cervical surgery

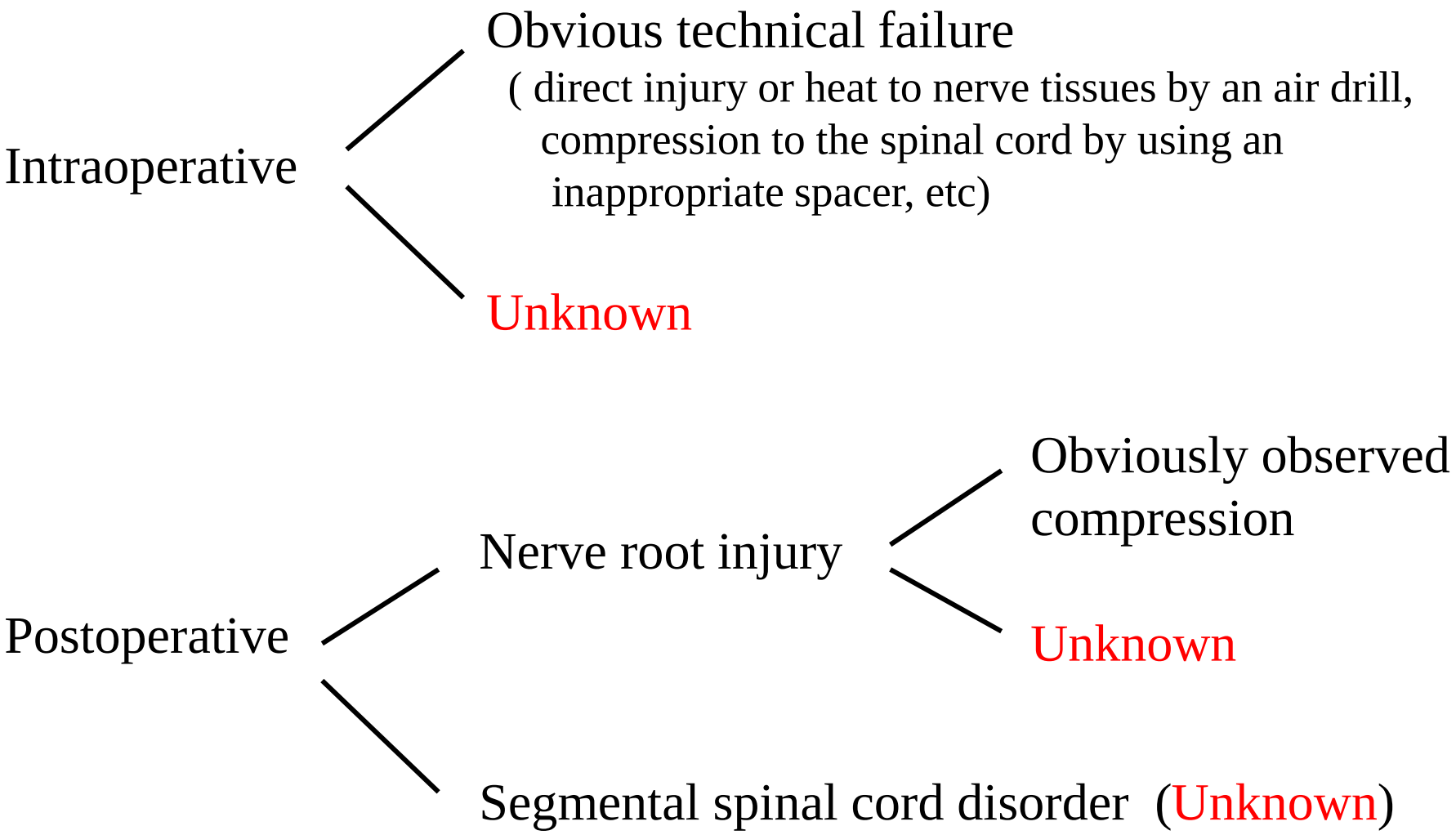
Two theories concerning of the cause

nerve root injury
(distraction, compression)

segmental spinal cord disorder
(ischemia, recirculation)

→ It is unclear yet which of these is correct.

Classification of the conjectured causes of C5 palsy



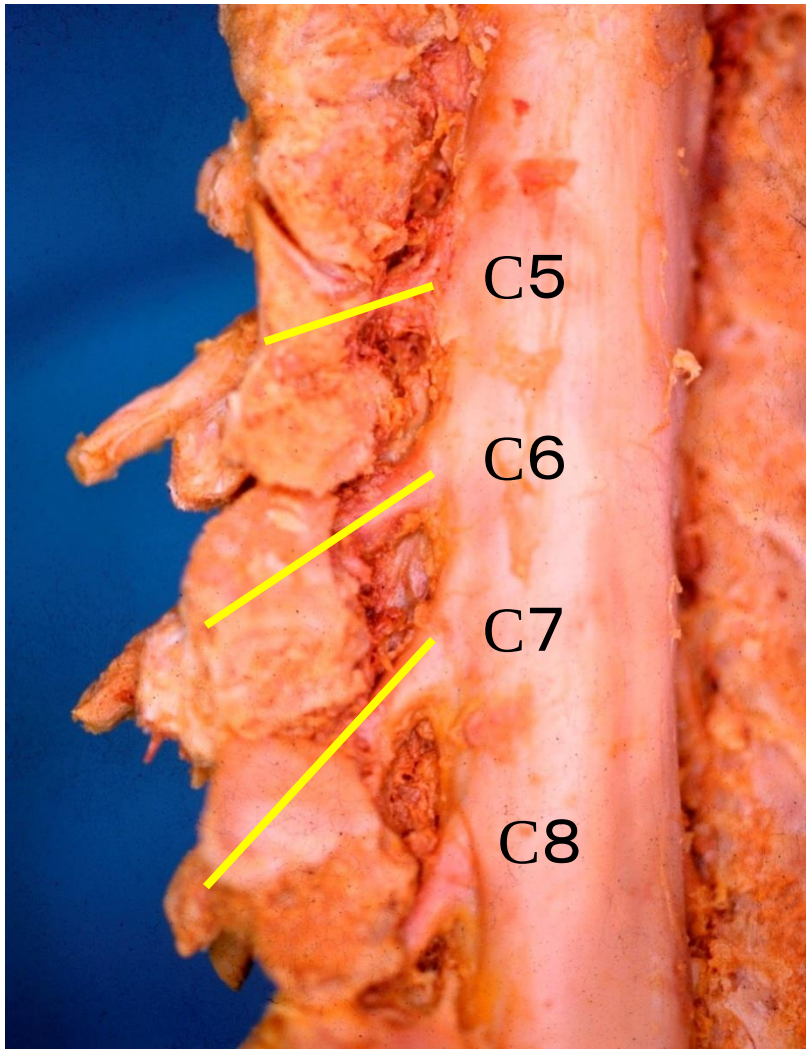
Purpose and method

Anatomical study using 25 cadavers to prove our estimation that the C5 palsy may occur by distraction and compression of the spinal neve at near the foramen

To consider a countermeasure to prevent C5 palsy after cervical laminoplasty

Results

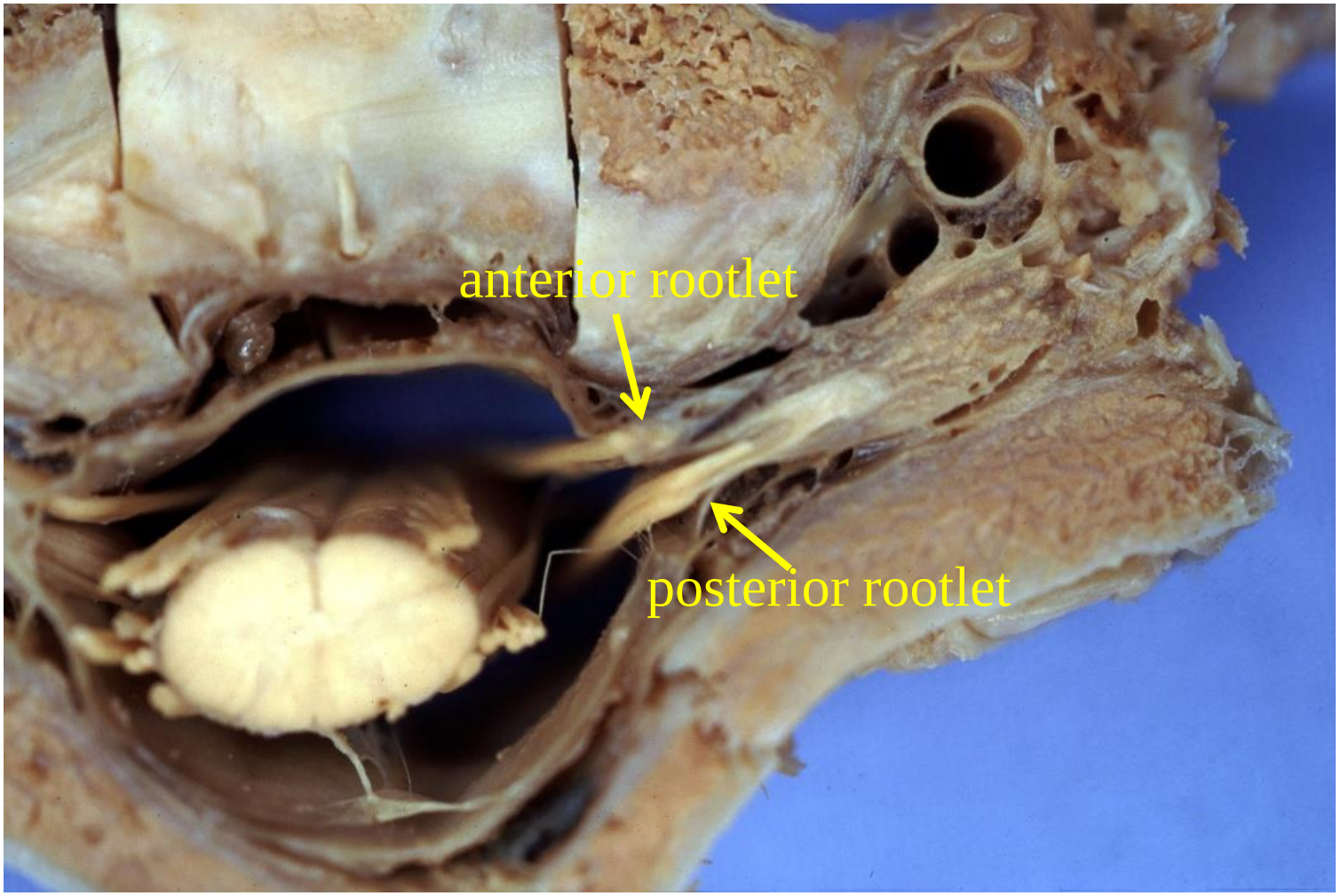
Distance of each nerve root composed of the brachial plexus



Among the cervical nerve roots composed of the brachial plexus, the distance between the division from the dura mater and the exit of the foramen is shortest at the C5 nerve root.

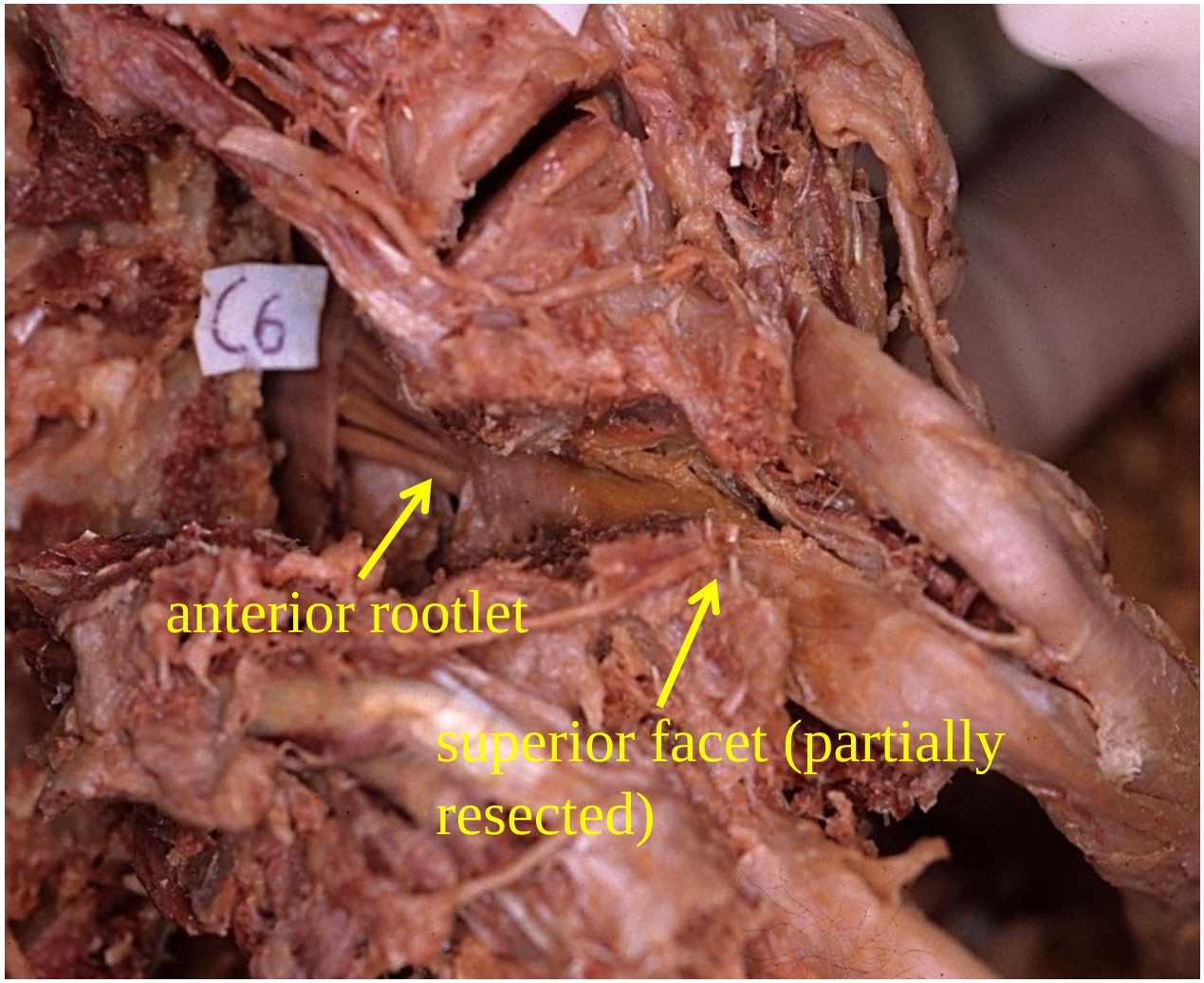
→ The capacity of moving freely is estimated to be smallest at the C5 nerve root.

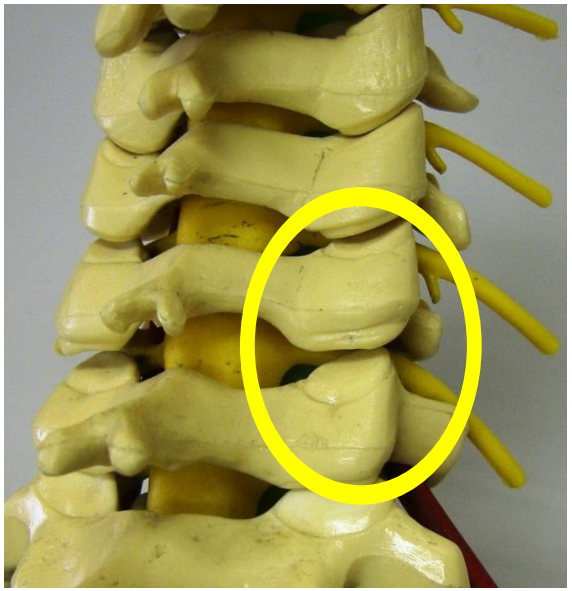
Anterior and posterior rootlets at the foramen



The anterior rootlet of the cervical nerve enters into the foramen anterocaudal side of the posterior rootlet.

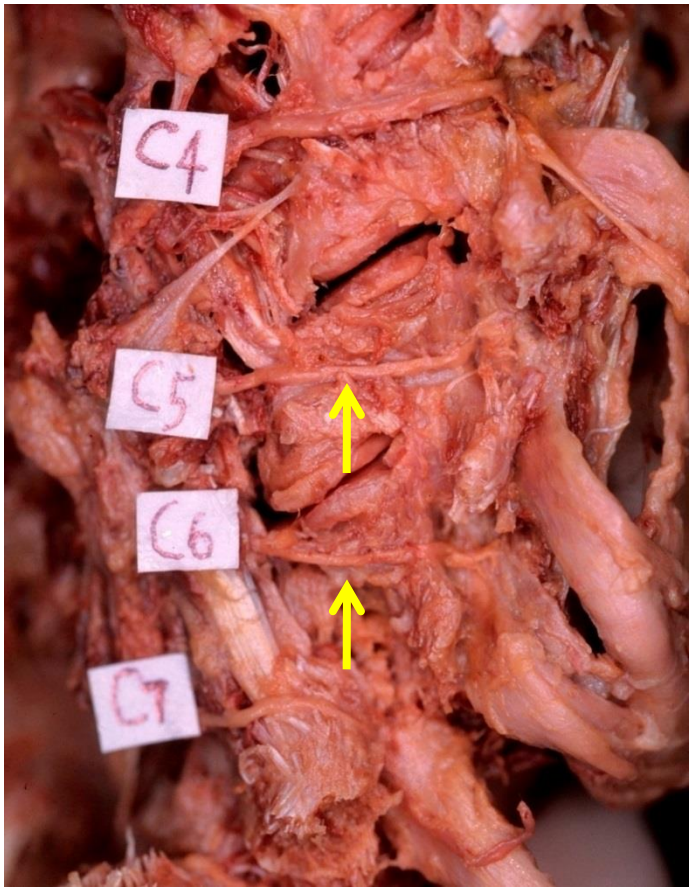
Anterior rootlet adjacent to the tip of the superior facet

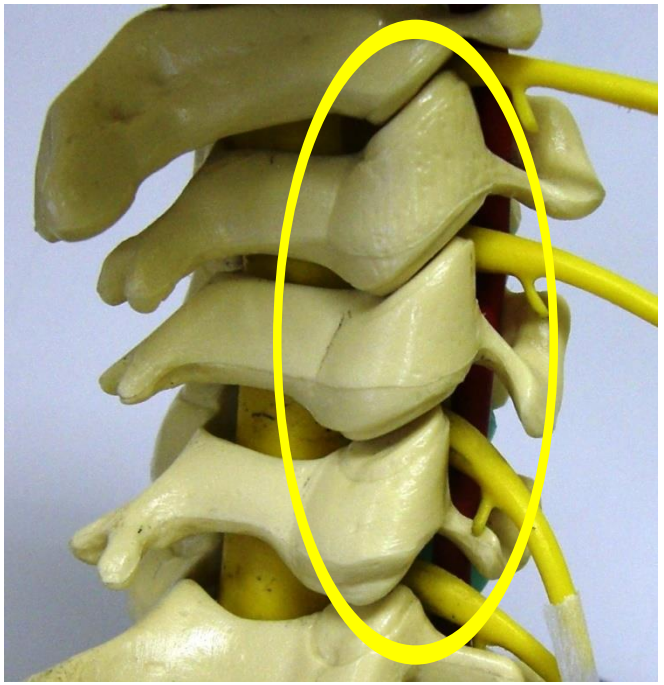




The anterior rootlet runs adjacent to the tip of the superior facet where the foramen is narrowest.

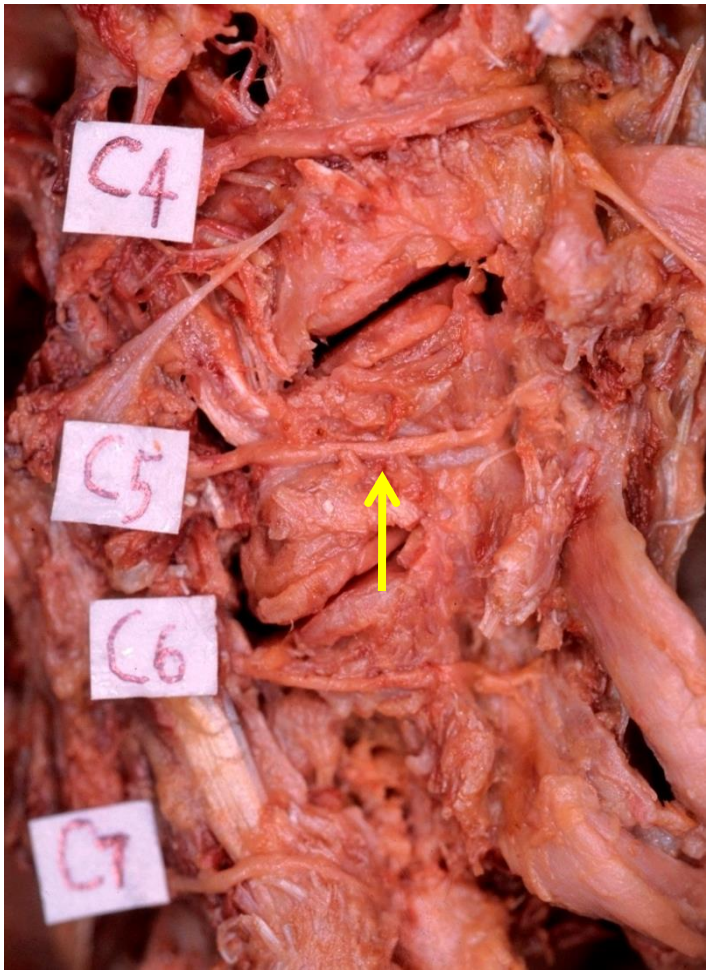
Medial branch of the posterior ramus

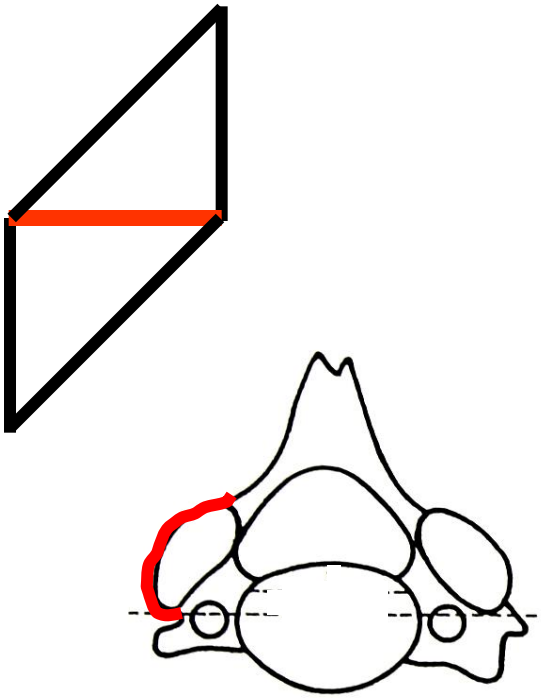




After dividing from the posterior ramus proper near the exit of the foramen, the medial branch runs posteriorly in contact with the lateral side of the facet joint column.

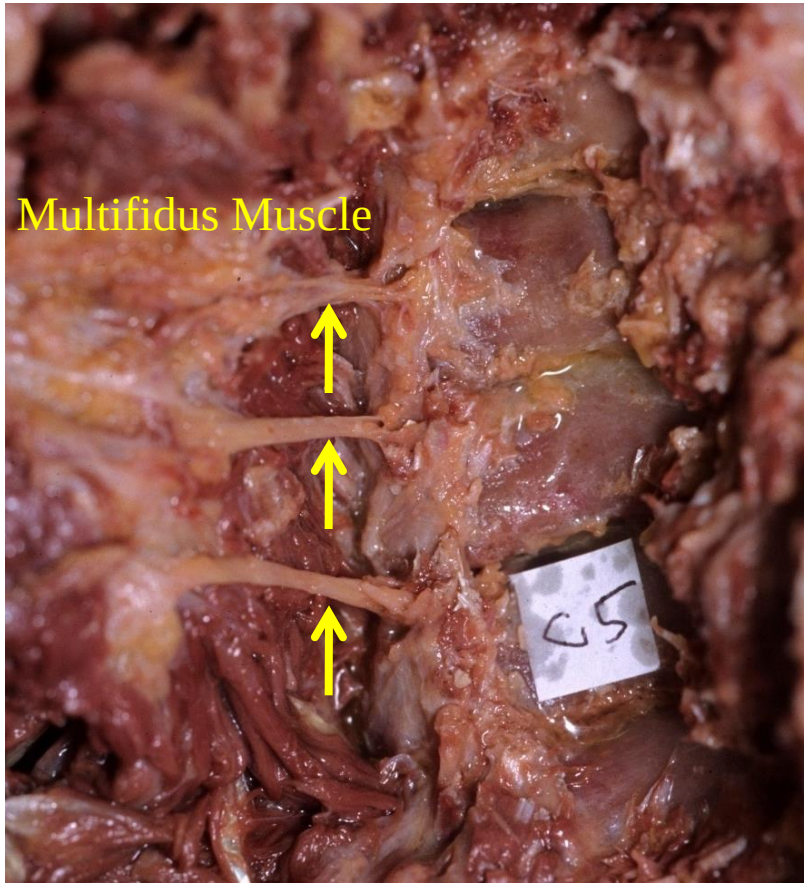
Medial branch of the posterior ramus running in the shortest distance

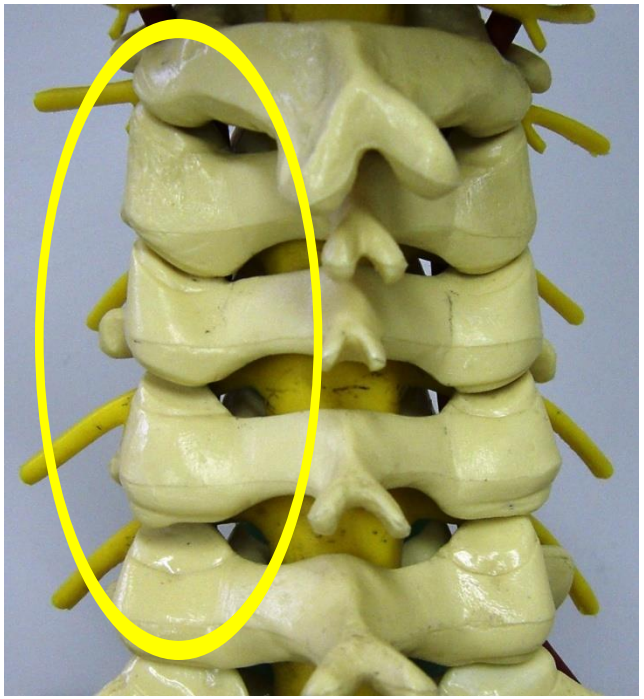




The running line of the medial branch corresponds to a diagonal line of a parallelogram that is formed at the lateral side of the facet joint column.

Muscle branch of the medial branch of the posterior ramus





The medial branch finally divides into the capsule branch of the facet joint and the muscle branch of the multifidus muscles.

Summary of our results

- Among the roots composed of the brachial plexus, C5 nerve root runs in the shortest distance.
- Anterior rootlet runs adjacent to the narrowest part of the foramen.
- Medial branch of the posterior ramus runs in the shortest distance in contact with the lateral side of the facet joint column.

Discussion

Features of C5 palsy (343 cases)

One-half of the patients were accompanied by sensory disturbance or intolerable pain at the C5 lesion.

92 % of patients had hemilateral palsy and only 8 % had bilateral palsy.

Almost all palsy occurred within a week after surgery, and in rare patients, it occurred 2 or 4 weeks later.

In rare patients, palsy occurred at the C6, C7, and C8 lesion alone or combined.

Sakaura H et al. *Spine* 28:2447-2451, 2003

Incidence of C5 palsy in C-spine surgery

Over all 4.6% (in 48 reports)

Approach anterior 4.3%
posterior 4.7%
open-door 5.3%
double-door 4.3%

Disorders (in 17 reports)
OPLL 8.3%
CSM 5.6%

⟶ There were no significant differences between two types.

Sakaura H et al. *Spine* 28:2447-2451, 2003

Prognosis

Finally, in severe cases (MMT 0-2), 71 % recovered up to MMT 4.

In slight cases (MMT 3 or 4), 96% recovered up to MMT 5.

Sakaura H et al. *Spine*28:2447-2451, 2003

Duration to recovery

	severe case (MMT 0-2)	slight case (MMT 3 or 4)
Within 3m.	4 %	48 %
3－6m.	52 %	30 %
Over 6m.	44 %	22 %

About 60% of severe cases and about 80 % of slight cases recovered within 6 months.

Sakaura H et al. *Spine*28:2447-2451, 2003

Incompatible with theory of segmental spinal cord disorder

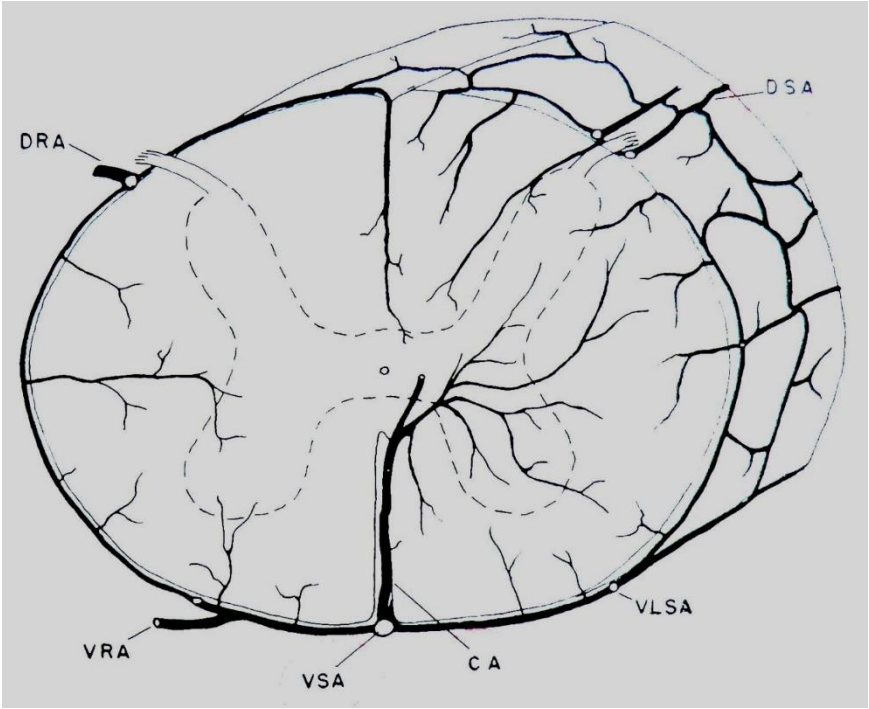
The affected lesion is very limited (C5 segment, hemilateral).

In cases with sensory disturbance combined, that segment is the same of motor segment.

The palsy occurs not immediately but within a week after surgery.

Anastomoses of the artery and vein within the spinal cord are very rich. Affection of very limited area is thought to seldom occur by ischemia or recirculation that the theory of segmental spinal cord disorder is based on.

Artery of the spinal cord (by Austin GA)



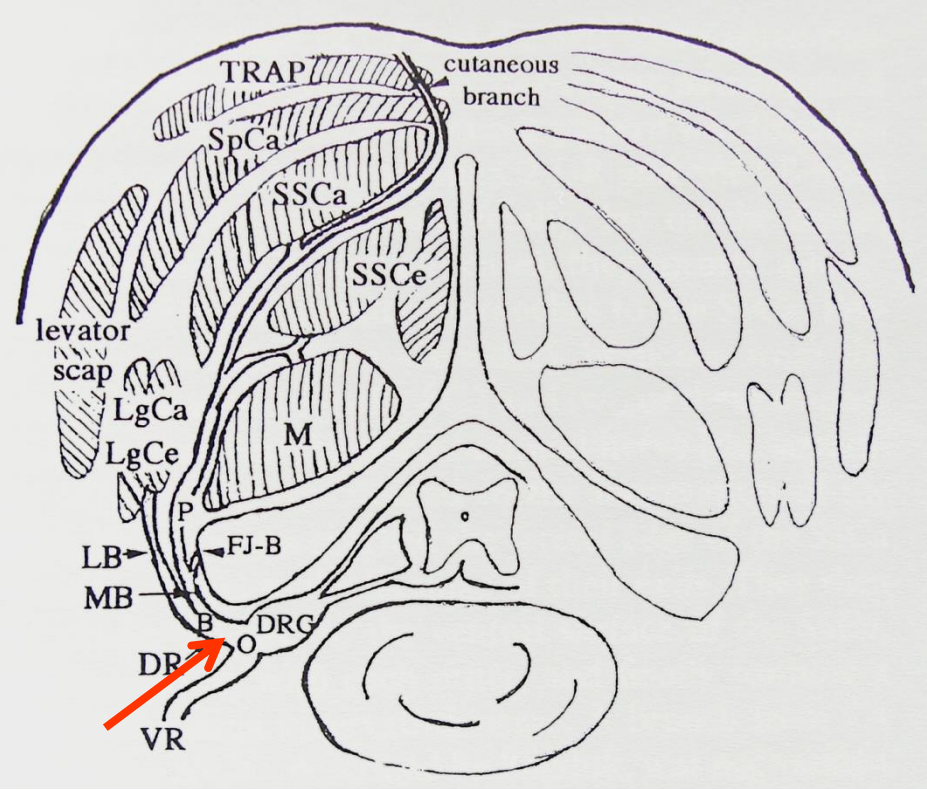
CA: central artery, VSA: ventral spinal artery, DSA: dorsal spinal artery

Thoughts on the mechanism in the theory of nerve root injury

The anterior rootlets of the cervical nerve seem to tend to mechanically be stretched and compressed in the foramen.

This effect is thought to be largest in the C5 nerve root because the running distance there is shortest and therefore the degree of free movement is most limited.

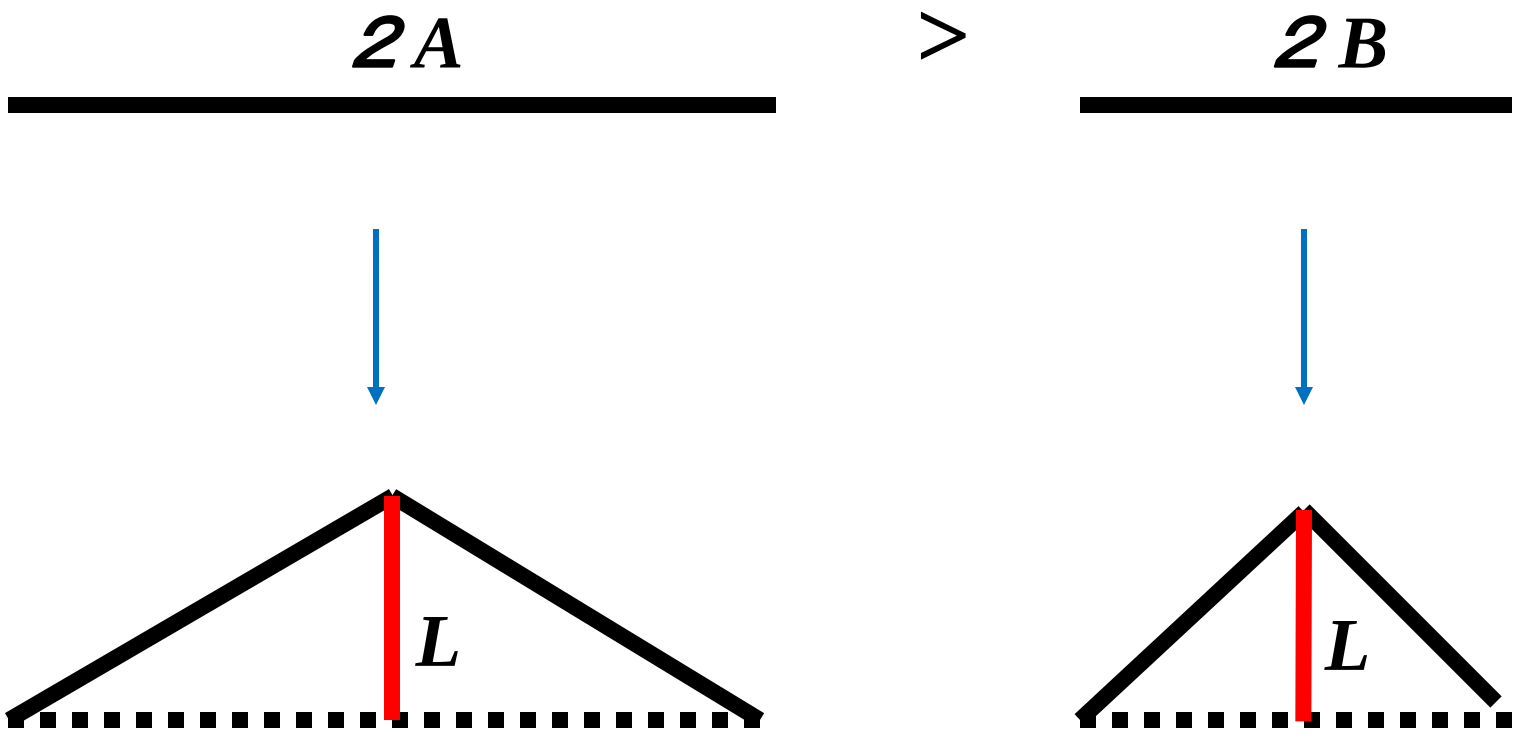
Length of the posterior ramus proper



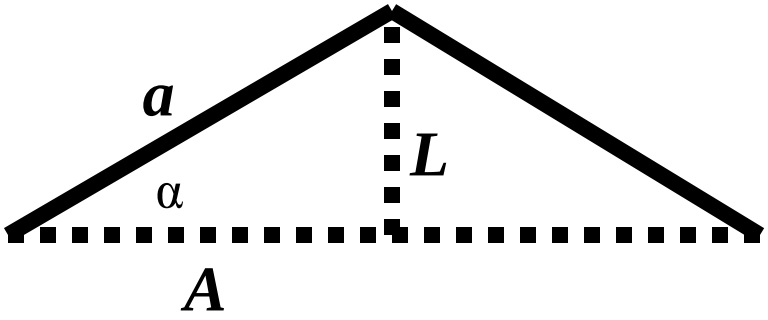
C3	5
C4	3
C5	3
C6	5
C7	7
C8	10 (mm)

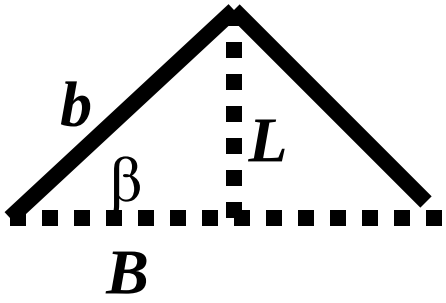
Zhang J et al. *Spine* 28: 1379-1384, 2003

If elastic fibers with two different lengths are elevated at the center up to the same height, the distraction ratio is larger in the shorter fiber than the longer one.



Proof using a trigonometric function





$L = A \tan \alpha = B \tan \beta \qquad A > B,$ **therefore**

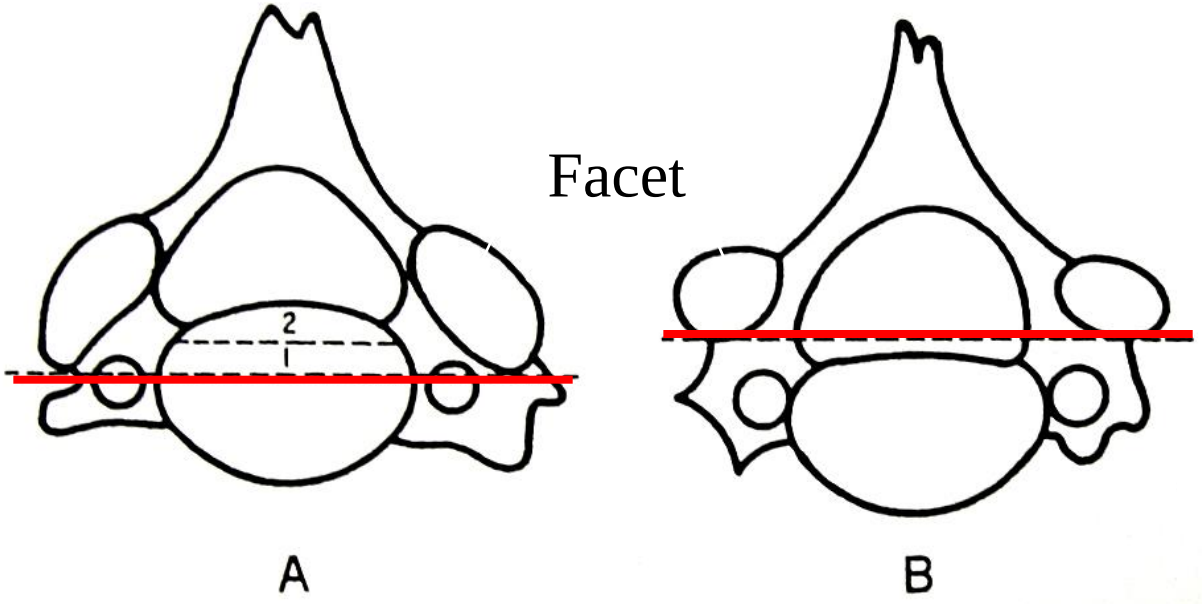
$\tan \alpha < \tan \beta$, **that is,** $\alpha < \beta$

$a / A = \sec \alpha, \qquad b / B = \sec \beta$

$\sec \alpha < \sec \beta,$ **therefore finally**

$a / A < b / B$

Anterior prominence of facet joint

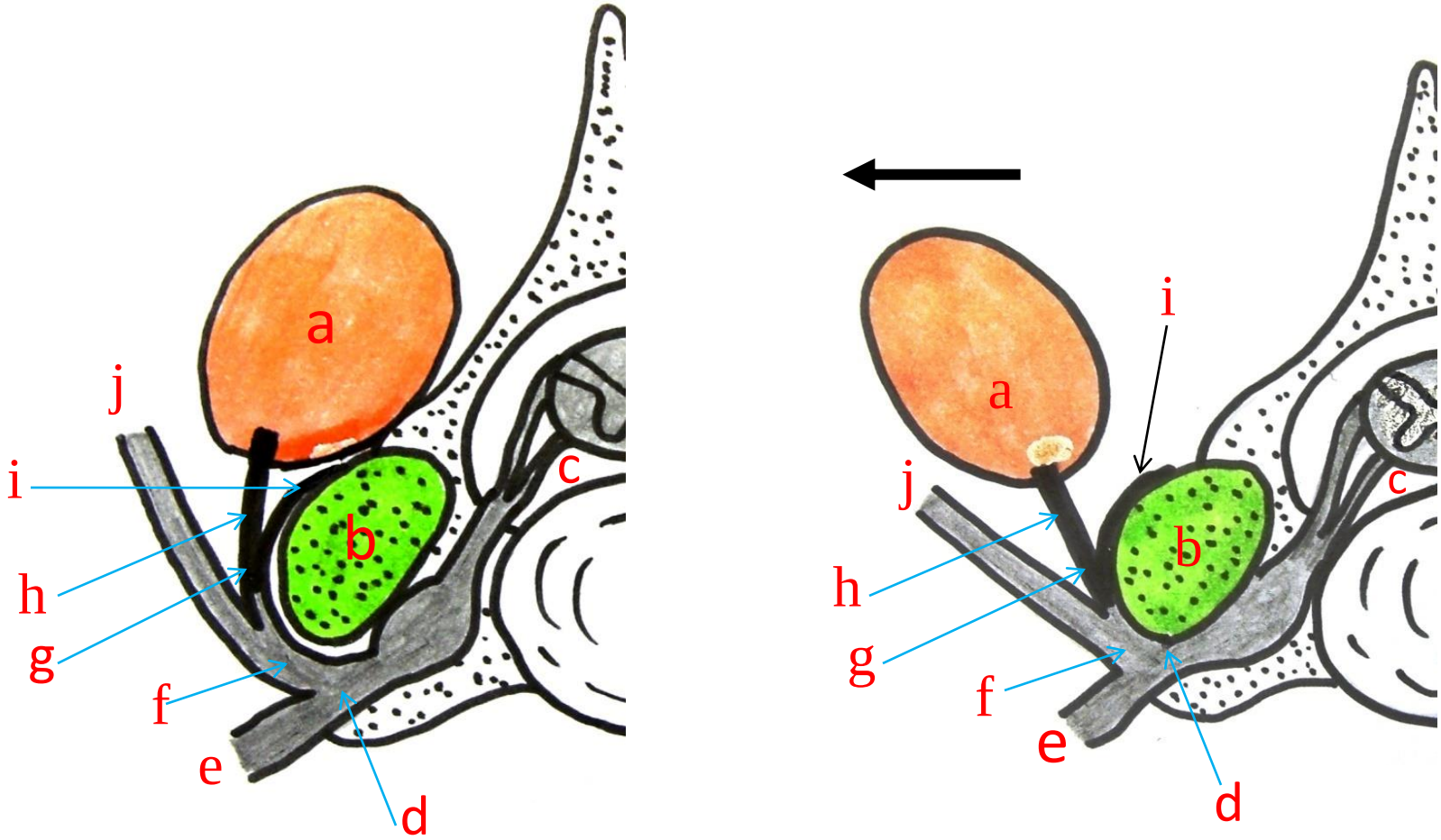


	C3	C4	C5	C6	C7
A	58%	87%	83%	58%	26%
B	42%	13%	17%	42%	74%

Tsuzuki N, et al. *Eur Spine J* 2: 191-196, 1993

In patients with hypertrophied facet joint due to degenerative changes, the influence of these stretches and compressions becomes larger, because the medial branch of the posterior ramus runs posteriorly in contact with the lateral side of the facet joint column.

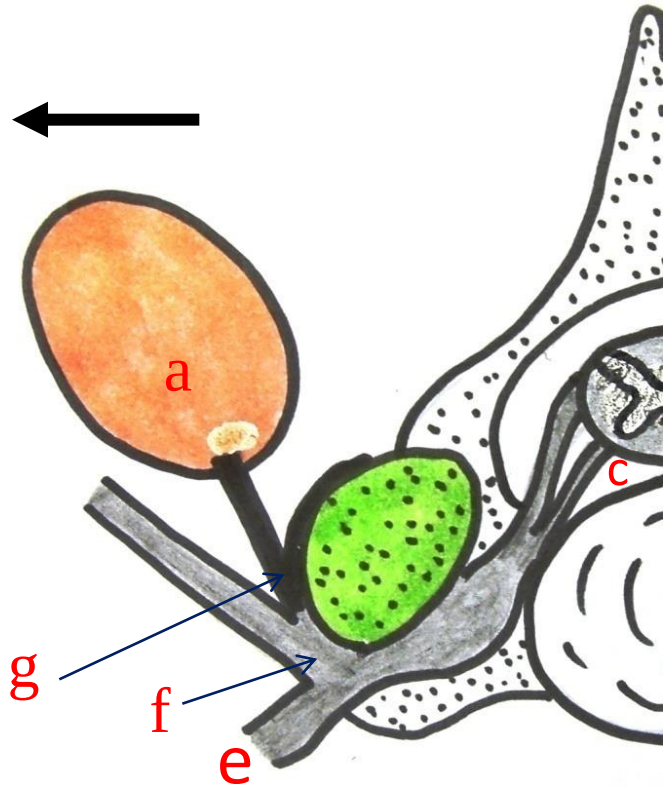
Lateral retraction of multifidus muscle



a: multifidus muscle, b: facet joint, c: anterior rootlet, d: spinal nerve,
e: anterior ramus f: posterior ramus proper, g: medial branch, h: muscle branch,
i: capsular branch j: lateral branch

Hirabayashi S, *ISRN Orthopedics* Volume 2011, Article ID 637185, 7 pages, 2011

If the multifidus muscles (a) is severely retracted laterally during posterior surgery, not only the medial branch of the posterior ramus (g) but also the anterior (e) and posterior rami (f) and the anterior rootlet (c) are simultaneously stretched and compressed against adjacent structures.



Hirabayashi S, *ISRN Orthopedics* Volume 2011, Article ID 637185, 7 pages, 2011

Conclusions

Based on our anatomical analysis using 25 cadavers, we have concluded that this palsy is most likely caused by the C5 nerve root compression and stretch near the exit of the foramen.

To prevent and decrease the postoperative C5 palsy, it is recommended that too severe lateral stretch of the multifidus muscles for a long time must be avoided.

During laminoplasty, intermittent relaxation of tension of the hooks to the muscles may be one method of solution.

Welcome to Japan !

Thank you for your attention