Correlation Analysis for the Selection of Microtitanium Plates with Different Specifications for use in a Cervical Vertebral Dome Expansion Laminoplasty

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Research article

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Title page

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Correlation analysis for the selection of microtitanium plates with different specifications for use in a cervical vertebral dome expansion laminoplasty

Abstract:

Backgrounds: Cervical vertebral dome expansion laminoplasty is a new surgical method for the treatment of cervical spondylosis. We analyzed correlations between the selection of microtitanium plates with different specifications for use in a cervical vertebral dome expansion laminoplasty to establish guidance for the selection of suitable microtitanium plates.

Methods: Sixteen patients that underwent the new, full lamina posterior spinal canal enlargement with a cervical spinal stenosis angioplasty procedure for treatment of their cervical spinal cords were recruited at our hospital. From February 2017-September 2018, medical records confirmed that all patients underwent cervical CT and MRI tests pre- and postsurgery. The anteroposterior diameter of the spinal canal, changes in the cross-sectional area of the spinal canal, and the pre- and postsurgery distance of the cervical spinal cord after applying microtitanium plates with different lengths were measured by Mimics version 17.0 software. A statistical regression and correlation analysis of relevant specification parameters of the microtitanium plate was then studied.

Results: As the size of the microtitanium plate increased, we found that the cross-sectional area of cervical spinal canal and distance between the descendants of the lamina and the distance of cervical spinal cord concordantly increased. The regression equation associated with sagittal diameter, cross-sectional area, and posterior movement distance of the cervical spinal cord was obtained.

Conclusions: The use of the corresponding regression equations enabled the prediction of the cervical spinal canal parameters and posterior movement distance of the cervical spinal cord when adopting different specifications of the microtitanium plate for different segments of the cervical vertebrae. This analysis guided the selection of microtitanium plates with appropriate specifications for different cervical vertebrae in a cervical vertebral dome expansion laminoplasty.

Keywords: Spinal canal enlargement; Miniature titanium plate; Laminar back distance; Cervical spinal stenosis; Medical imaging measurement

Backgrounds

With the progression of modern society, cervical spondylosis has appeared to be one of the most common orthopedic diseases. It is caused by a reduction in the anteroposterior diameter and effective volume of the spinal canal [1]. Generally, patients with severe symptoms and signs need surgical treatment [2]. In 1977, Hirabayashi [3] first proposed an internal fixation of a single open-door miniature titanium plate. After years of development, the internal fixation of a single open-door miniature titanium plate has achieved good clinical results and is now recognized by the majority of orthopedic specialists as one of the most commonly used methods for treating cervical spondylosis-related diseases. With the improvement of posterior cervical surgery, many scholars have improved and optimized the associated surgical methods.

Our team has also improved in this context. According to the principle and purpose of cervical spinal canal osteoplasty in the treatment of cervical spondylopathy, we have finally developed a cervical vertebral dome expansion laminoplasty. This type of surgery involves lavage of the lamina at the junction of the C3-C7 bilateral lamina and the facet joint and requires the lamina to be completely moved backward. In this process, we attempted to protect and retain the relevant tissue structures attached to the spinous process, such as the supraspinous ligament and interspinous ligament, while keeping the spinous process in the original center position and enlarging the spinal canal. This procedure permits the spinal cord to drift backward, thus reducing the pressure on the cervical spinal cord. Then, we used our own microtitanium plate to fix the two sides of the lamina to form a strong structure. These operations preserve the posterior muscle ligament complex of the cervical spine, which keeps the cervical spine in a stable state and reduces the occurrence of any complications that might include axial symptomology [4].

Figure 1. Cervical vertebral dome expansion laminoplasty procedure diagram

According to research by Zhao Bin [5] et al., 16 patients treated with the controllable dome-type laminectomy and posterior extension of the spinal canal improved significantly after surgery. The average JOA score at the last follow-up increased to 14.6 ± 1.4 points, the postoperative nerve function improvement rate was 87.23% ± 3.81%, and Frankel's grade also changed from D to E before the operation, indicating that the operation method is reliable and that the clinical effect is significant. According to the imaging data of the follow-up patients, it can be seen that the internal fixation of the titanium plate shows no looseness or breakage and there is no increase in the imaging manifestation of the spinal cord bulges than before.

During the cervical vertebral dome expansion laminoplasty, the posterior distance of the lamina determines the change in the anteroposterior diameter of the spinal canal, enlargement of the cross-sectional area of the spinal canal, and the distance of the spinal cord to drift backward. If the lamina is not adequately moved backward, then the spinal cord cannot be fully decompressed, and the clinical symptoms do not significantly improve. Additionally, if the distance of the posterior lamina movement is too large, the spinal cord will excessively drift backward, and the nerve roots will be significantly pulled as a result, which might then cause the occurrence of C5 nerve root palsy symptoms. According to studies by Lubelski et al., the cervical spinal canal diameter is enlarged by 1 mm, and the probability of C5 nerve root paralysis is increased by approximately 69% ［6］.Therefore, an appropriate lamina posterior distance is crucial if clinical efficacy and recovery from the surgical procedure is to be realized. In addition, the distance of the posterior lamina movement depends on the structure of the vertebral body and the specifications of the custom microtitanium plate. The choice of differently sized microtitanium plates for different cervical segments will influence the achievement of different posterior lamina distances. Thus, a selection of suitable microtitanium plates for different internal cervical segments to enable strong internal fixation represents an important part and focus of study.

In the current study, we measured and analyzed CT and MRI data of 16 patients with the cervical vertebral dome expansion laminoplasty at our medical center. We measured the distance of the posterior lamina, the enlarged area of the spinal canal, and the drift distance of the spinal cord. The intent of the study was therefore to explore the correlation between the different types of microtitanium plates in different cervical segments in terms of the above three parameters. We also sought to establish guidance for the selection of suitable microtitanium plates in the setting of a posterior tracheal angioplasty with the aim of achieving improved surgical results and clinical efficacy.

Methods

Data selection

Our current clinical research program is concordant with the Helsinki Declaration and was approved by the local Ethics Review Committee of the Second Hospital of Shanxi Medical University (2018LL039). All obtained images were used for scientific research, and the signed and informed consent of patients and their families was obtained.

In February 2017 through September 2018, 16 patients that underwent the cervical vertebral dome expansion laminoplasty for the treatment of their cervical spinal cord were selected and recruited to the study on the basis of their medical records. The patients included 14 males and 2 females, which were aged 49 - 76 years, with a mean age of 57.3 ± 1.7 years. All 16 patients underwent cervical CT and MRI before and after surgery. The CT data were obtained in the DICOM format by a 0.5-row thin-layer scan of a 64-row CT machine.

Material selection

Different types of custom cervical posterior microtitanium plates were developed and selected for intraoperative application, and their dimensions are listed as follows: 27 x 4.5 x 1; 4 holes, 29 x 4.5 x 1; 4 holes, and 31 x 4.5 x 1; 4 holes.

Experimental methods

The obtained DICOM data from the pre- and postoperative CT (DICOM formatted data was obtained from a 0.5-row CT 0.5-mm thin-layer scan) were imported into Mimics version 17.0 software for measuring the desired data, including the measurement of the anteroposterior diameter of the spinal canal and the cross-sectional area of the spinal canal when using a small titanium plate in different cervical segments. The distance of the spinal cord drifting back in different cervical segments was measured using Photoshop CS5 software.

Figure 2. Different types of cervical posterior microtitanium plates

Data of the cervical posterior lamina retraction distance

Mimics version 17.0 software was used to 1) measure the sagittal diameter of the midpoint of the vertebral pedicle in the midpoint of the C3-7 segment and 2) measure the midpoint of the posterior margin of the vertebral body or the pathological mass to the midpoint of the posterior border of the spinal canal, which were recorded as "a". The same method was used to measure the sagittal diameter of the spinal canal after completing a cervical vertebral dome expansion laminoplasty, which was recorded as “A”. Thus, the lamina back movement distance was determined as “A-a.”

Figure 3. Preoperative spinal anteroposterior diameter a.

Figure 4. Postoperative spinal anteroposterior diameter A.

Data of the change in cervical spinal canal cross-sectional area

Using Mimics version 17.0 software to measure the cross-sectional area (CSA) of the midpoint plane of the cervical vertebral pedicle in each segment of C3-7, we found that when taking measurements, the anterior border of the spinal canal was the posterior edge of the vertebral body or the trailing edge of the pathological mass. In addition, the posterior border was the leading edge of the segmental lamina, and the inner edge of the pedicle on both sides served as the boundary between those sides. The cross-sectional area was recorded as S1, and the same method was used to measure the CSA of the enlarged spinal canal after the new, full backward shift of the lamina in the spinal canal, which was recorded as S2. The increased CSA of the spinal canal was recorded as S2-S1.

Figure 5. Preoperative spinal canal cross-sectional area S1

Figure 6. Postoperative spinal canal cross-sectional area S2

Data of the spinal cord posterior distance in the cervical spinal canal

Measuring the distance of the spinal cord by Photoshop CS5 software, we used the midpoint of the posterior wall of the vertebral body as the starting point. Alternatively, if there was an occupying pathological tissue, the midpoint of the occupying tissue in the spinal canal was used as the starting point of measurement. Using the sagittal midpoint of the cervical spinal cord as the measurement endpoint, we recorded the distance between both of these points. The distance from the midpoint of the spinal cord to the posterior wall of the vertebral body was recorded and defined as “c”; the same method was used to measure the distance between the two points by MRI after completing the cervical vertebral dome expansion laminoplasty, wherein the distance between the front end of the spinal cord and the posterior wall of the vertebral body was recorded as “C”. Thus, the distance of the cervical spinal cord was defined as C-c.

Statistical analysis

All data were statistically analyzed by SPSS version 17.0 software. Data are expressed as the mean plus/minus the standard deviation about the mean ($\overline{X}$ ± SD). Pearson's correlation analysis was performed to observe the relationship between the different segmental lamina posterior distances, spinal canal enlargement, and backward drift distance of the cervical spinal cord with different specifications of microtitanium plates. Pearson's correlation analysis was also used to perform a linear regression to establish a regression equation of the measured data.

Results

All 16 patients were safely and successfully treated by surgery. The clinical outcome was good following the surgical procedure. One of the patients had symptoms of C5 nerve root palsy, and the painful symptoms were significantly relieved by conservative treatments, such as nutritional nerves. The symptoms disappeared completely after two months postsurgery. The following are the number of titanium plates used in the cervical vertebrae and the relationship between the different cervical vertebra segment-related spinal canal parameters and microtitanium plate specifications. The posterior laminar distance of each segment, the enlarged area of the spinal canal, and the posterior movement distance of the cervical spinal cord increased with increasing size of the microtitanium plate, as shown in Table 2.

Table 1. Number of different titanium plates used in different segments of the cervical vertebra

Table 2. Relationship between the different cervical vertebra segments as they related to the spinal canal parameters and microtitanium plate specifications.

Pearson's correlation analysis was used to compare the relationship between the lamina posterior distance, spinal canal enlargement, cervical spinal cord backward drift distance and titanium plates with different specifications (Table 2). It was found that the different specifications of microtitanium plates had the following significant effects on the posterior movement distance of the lamina: C3 was 0.771 ($P<0.05$), C4 was 0.863 ($P<0.05$), C5 was 0.823 ($P<0.05$), C6 was 0.842 ($P<0.05$), and C7 was 0.869 ($P<0.05$). The enlarged area of the C3 spinal canal was 0.789 ($P<0.05$), C4 was 0.862 ($P<0.05$), C5 was 0.845 ($P<0.05$), C6 was 0.880 ($P<0.05$), and C7 was 0.784 ($P<0.05$). The backward drift distance of the cervical spinal cord at C3 was 0.829 ($P<0.05$), C4 was 0.908 ($P<0.05$), C5 was 0.896 ($P<0.05$), C6 was 0.935 ($P<0.05$) and C7 was 0.852 ($P<0.05$).

Establishing correlation equations. The regression equations for the different posterior distances of the cervical vertebrae and the microtitanium plate specifications are as follows:

C3: $\hat{Y}$ =0.067+2.326X (R2=0.594), C4: $\hat{Y}$ =0.086+4.335X (R2=0.746), C5: $\hat{Y}$ =0.337+1.698X (R2=0.678), C6: $\hat{Y}$ =0.219+3.592X (R2=0.710), C7: $\hat{Y}$ =0.146+5.628X (R2=0.755).

The regression equations for the different cervical segmental canal enlargement areas and microtitanium plate specifications are as follows:

C3: $\hat{Y}$ =2.065+35.455X (R^2=0.622), C4: $\hat{Y}$ =3.420+62.750X (R^2=0.743), C5: $\hat{Y}$ =6.912+30.373X (R^2=0.713), C6: $\hat{Y}$ =3.955+77.175X (R^2=0.774), C7: $\hat{Y}$ =5.405+0.952X (R^2=0.614).

The regression equations for the backward drift distance of the cervical spine segments and the specifications of the microtitanium plates are shown below:

C3: $\hat{Y}$ =0.039+2.230X (R^2=0.686), C4: $\hat{Y}$ =0.084+1.265X (R^2=0.824), C5: $\hat{Y}$ =0.098+1.685X (R^2=0.802), C6: $\hat{Y}$ =0.068+2.189X (R^2=0.874), C7: $\hat{Y}$ =0.086+1.545X (R^2=0.727).

Discussion

The cervical vertebral dome expansion laminoplasty was performed by moving the lamina as a whole and using a custom microtitanium plates with different specifications for internal fixation. At the same time, the volume of the spinal canal was enlarged and the spinal cord drifted backward, thereby alleviating clinical symptoms; thus, the clinical curative effect was highly acceptable. According to Zhao Bin's research [5], the clinical efficacy of this surgical method could be clarified. However, different sizes of microtitanium plates can provide different distances of posterior lamina movement, consequently affecting the enlarged areas of the spinal canal and the backward drift of the cervical spinal cord. Therefore, the selection of a microtitanium plate with a suitable size in different cervical segments is essential for the surgical treatment of cervical spondylosis.

Sodeyama et al. [7] found that after posterior cervical surgery, the distance of the spinal cord to the dorsal side ranged from 0 to 6.6 mm, and the clinical effect was only evident when the spinal cord was moved more than 3 mm. At the same time, relevant research has also shown [8-10] that the sagittal diameter of the spinal canal can achieve better clinical efficacy when expanded by 4-5 mm. According to research by Imagama [11] et al., when the posterior distance of the C5 segment in the spinal cord exceeded 5 mm, the probability of seeing C5 nerve root paralysis symptoms was significantly greater than that of a cervical spinal cord posterior movement distance of less than 5 mm. Therefore, the range of the posterior movement of the lamina is 4-5 mm, and when the spinal cord drifts more than 3 mm, a good clinical effect is possible.

With the use of a regression equation analysis in this study, we found that the C3 segment uses a microtitanium plate with a specification of 27 x 4.5 x 1 with 4 holes, which can achieve a posterior laminar movement distance of 4.634.131±0.051 mm and a spinal retraction distance of 3.276±0.039 mm. The C4 segment uses a microtitanium plate with a specification of 29 x 4.5 x 1; 4 holes, which can achieve a posterior laminar movement distance of 6.838±0.015 mm and a backward spinal cord movement of 3.670±0.104 mm. The C5 segment uses a microtitanium plate with a specification of 31 x 4.5 x 1; 4 holes, which can achieve a posterior laminar movement distance of 12.155±0.210 mm and a backward spinal cord movement distance of 4.737±0.044 mm. The C6 segment uses a microtitanium plate specification of 31 x 4.5 x 1; 4 holes, which can achieve a posterior lamina movement of 9.830±0.251 mm and a backward spinal cord movement distance of

4.160±0.071 mm. The C7 segment uses a microtitanium plate specification of 31 x 4.5 x 1; 4 holes, which can achieve a posterior lamina movement of 9.582±0.100 mm and a backward spinal movement distance of 4.160±0.071 mm.

It is indicated that the use of microtitanium plates with a specification of 27 x 4.5 x 1; 4 holes in the C3 segment can achieve good clinical results. The same clinical effect can be achieved by using the 29 x 4.5 x 1; 4 holes microtitanium plate in the C4 segment, the 31 x 4.5 x 1; 4 holes microtitanium plate in the C5 segment, the 29 x 4.5 x 1; 4 holes microtitanium plate in the C6 segment, or 27 x 4.5 x 1; 4 holes the microtitanium plate in the C7 segment.

Similarly, according to the regression equations obtained in this study, the operator can calculate and predict the parameters of the posterior movement distance of the cervical vertebrae obtained when using different sizes of microtitanium plates for different segments of the cervical vertebra; thus, it is possible to select the most suitable microtitanium plate for surgical treatment.

In this study, one patient developed C5 nerve root palsy after surgery. We consider that it was related to the excessive distance of the posterior lamina movement caused by the selection of a microtitanium plate that was too large during the operation, thus causing an excessive drift of the cervical spinal cord. Imagama [11] found that 43 patients had obvious symptoms of C5 nerve root palsy through an imaging study of 1858 patients undergoing posterior cervical surgery. The average distance of the cervical spinal cord was 3.9 mm. In this patient, a miniature titanium plate with a specification of 31 x 4.5 x 1; 4 holes was selected in the C5 segment. The posterior vertebral plate distance was 12.79 mm, the enlarged area of the spinal canal was 184.56 mm^2, and the cervical spinal cord was moved backward by 5.13 mm. Through the regression equation, we found that for this patient in this cervical segment, the selection of a microtitanium plate with a specification of 29 x 4.5 x 1; 4 holes could achieve the ideal clinical effect, which indicates the necessity of this study.

In summary, the cervical vertebral dome expansion laminoplasty can effectively increase the posterior lamina distance, enlarged area of the spinal canal, and backward drift distance of the spinal cord. In addition, the custom dome-type microtitanium plates plays a vital role in the strong internal fixation of the cervical vertebra.

Conclusions

This study further clarified the most suitable titanium plate size for use in different cervical segments. Based on the results of the study, we recommend the use of the cervical vertebral dome expansion laminoplasty procedure for the treatment of cervical spondylosis with the use of the following microtitanium plates: 27 x 4.5 x 1; 4 holes in the C3 segment, 29 x 4.5 x 1; 4 holes in the C4 segment, 31 x 4.5 x 1; 4 holes in the C5 segment, 29 x 4.5 x 1; 4 holes in the C6 segment, and 27 x 4.5 x 1; 4 holes in the C7 segment. Of course, when the impact of the surgical operation is excluded [12], the specifications of the microtitanium plate should be flexibly selected according to the individual anatomy of the patient and the pathological condition.

List of Abbreviation： Not applicable

Declaration

Ethics approval and consent to participate: Our current clinical research program is concordant with the Helsinki Declaration and was approved by the local Ethics Review Committee of the Second Hospital of Shanxi Medical University (2018LL039). All obtained images were used for scientific research, and the signed and informed consent of patients and their families was obtained.

Consent for publication: Before the start of this study, we have informed patients and their families that we are going to analyze their statistics on medical imaging data and write articles.All patients and their families expressed their informed consent and had no objections.All patients agreed that the articles written could be published.

Availability of data and material: All data generated or analyzed 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:R-tZ and BZ were in charge of and contributed to all stages of the present study. X-dL were responsible for the original data collection. Y-bZ and X-fZ contributed to interpreting the data and writing the final manuscript. Y-zJ, X-nW and D-tQ contributed to reviewing the accuracy of the data. All authors read and approved the final manuscript.

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Figure 1. cervical vertebral dome expansion laminoplasty procedure diagram

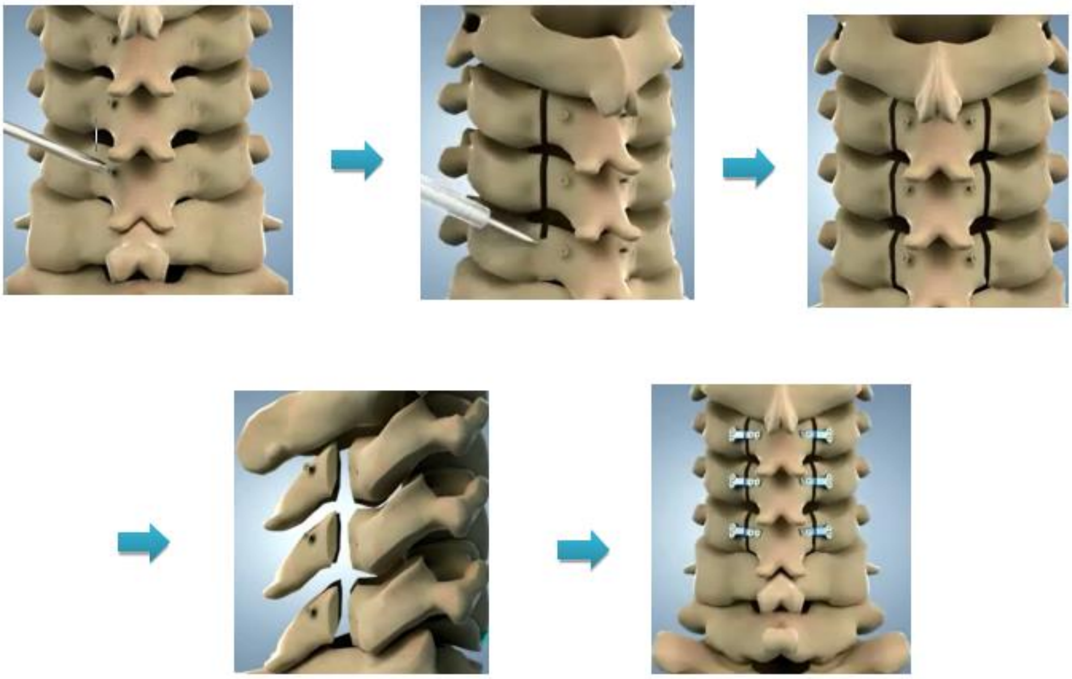

Figure 2. Different types of cervical posterior microtitanium plates

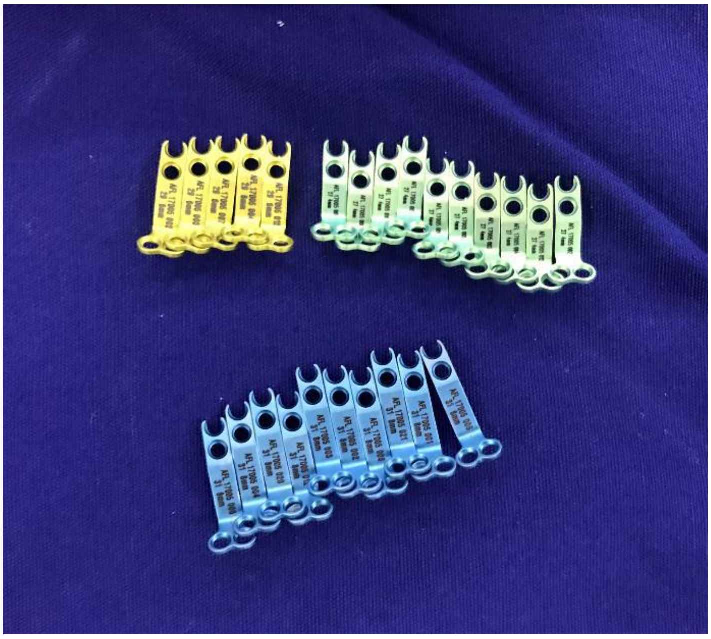

Figure 3. Preoperative spinal anteroposterior diameter a.

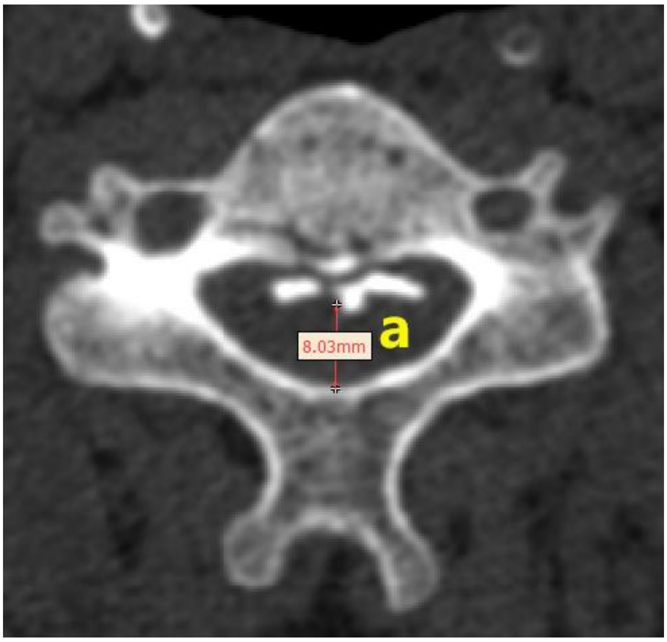

Figure 4. Postoperative spinal anteroposterior diameter A.

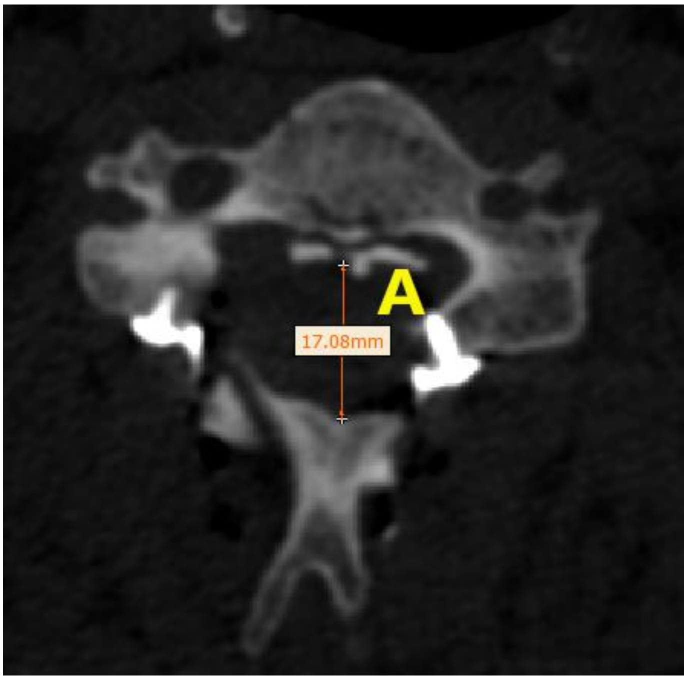

Figure 5. Preoperative spinal canal cross-sectional area S1

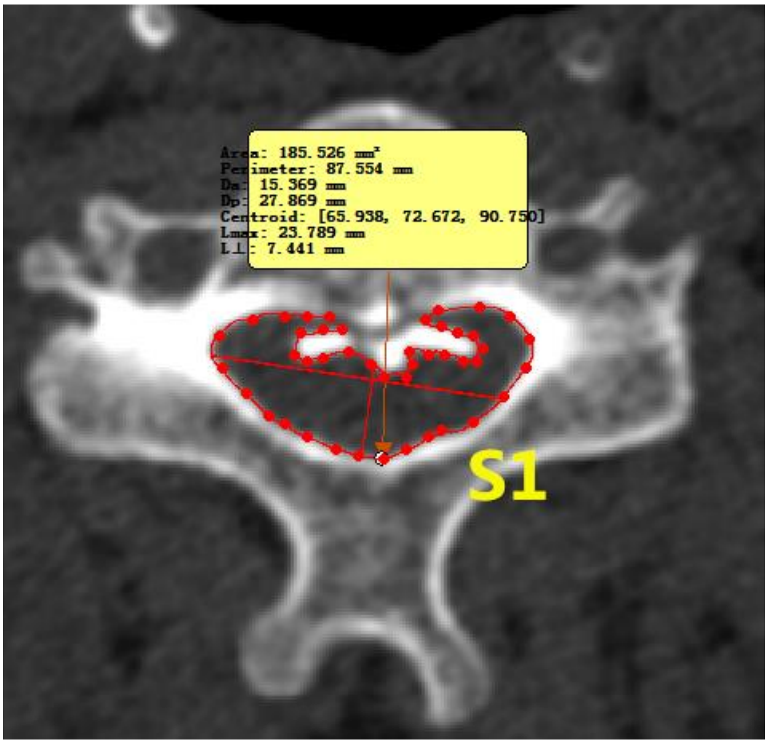

Figure 6. Postoperative spinal canal cross-sectional area S2

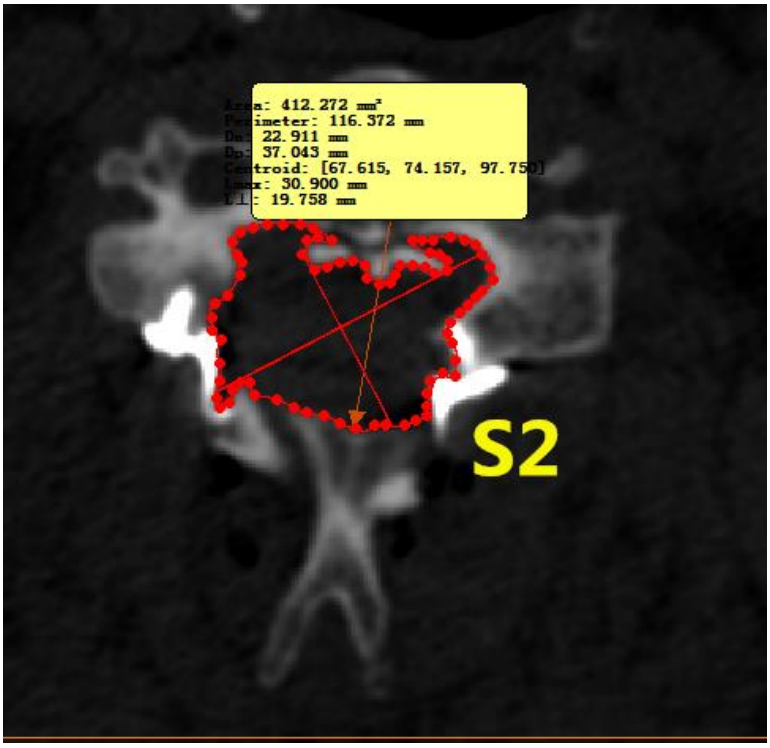

Table 1. Number of different titanium plates used in different segments of the cervical vertebra

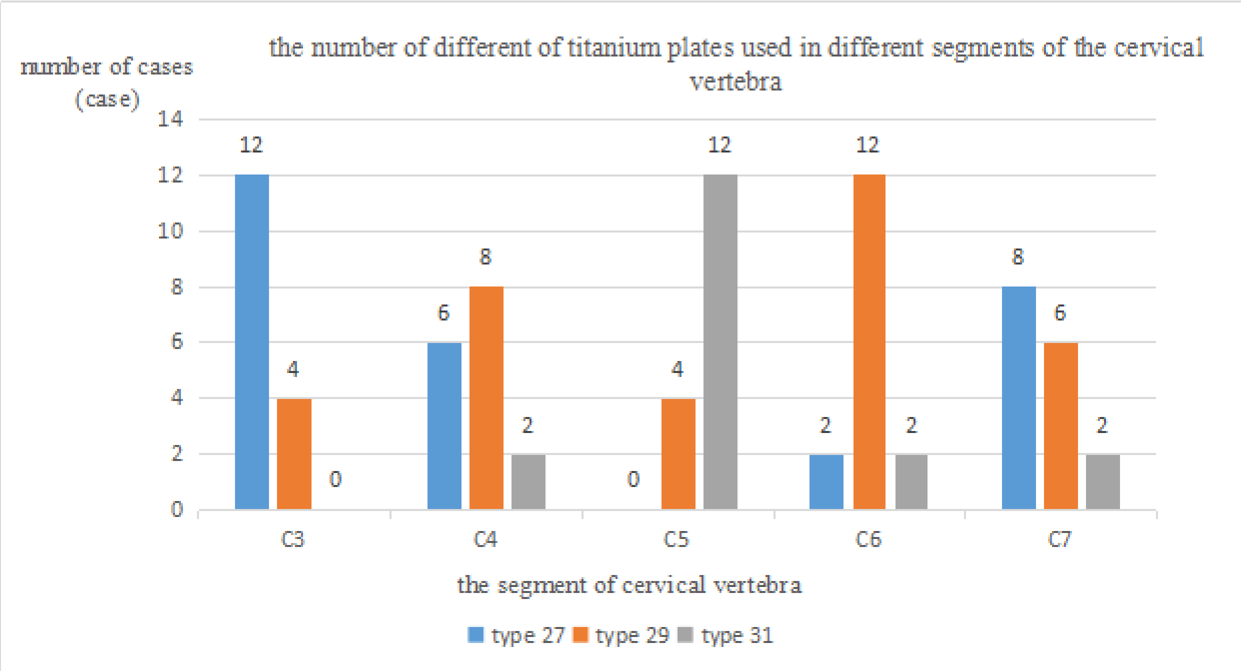

Table 2. Relationship between the different cervical vertebra segments as they related to the spinal canal parameters and microtitanium plate specifications.

Microtitanium plate specifications	Laminar back distance (mm)			Expanded area of spinal canal (mm2)			Spinal backward drift distance (mm)		
	Type 27	Type 29	Type 31	Type 27	Type 29	Type 31	Type 27	Type 29	Type 31
C3	4.131±0.051	4.265±0.066	-	91.210±2.435	95.340±2.133	-	3.276±0.039	3.354±0.009	-
C4	6.665±0.096	6.838±0.015	7.010±0.170	156.630±4.082	160.720±4.235	171.840±4.338	3.580±0.097	3.670±0.104	3.960±0.153
C5	-	11.480±0.172	12.155±0.210	-	230.830±5.573	244.655±3.948	-	4.540±0.079	4.737±0.044
C6	9.780±0.234	9.830±0.251	10.560±0.2278	183.740±7.071	191.940±4.538	199.630±4.458	4.080±0.071	4.160±0.071	4.340±0.083
C7	9.582±0.100	9.790±0.169	10.240±0.100	146.636±5.289	160.870±6.241	165.30±6.123	3.865±0.066	4.070±0.093	4.180±0.099

Figures

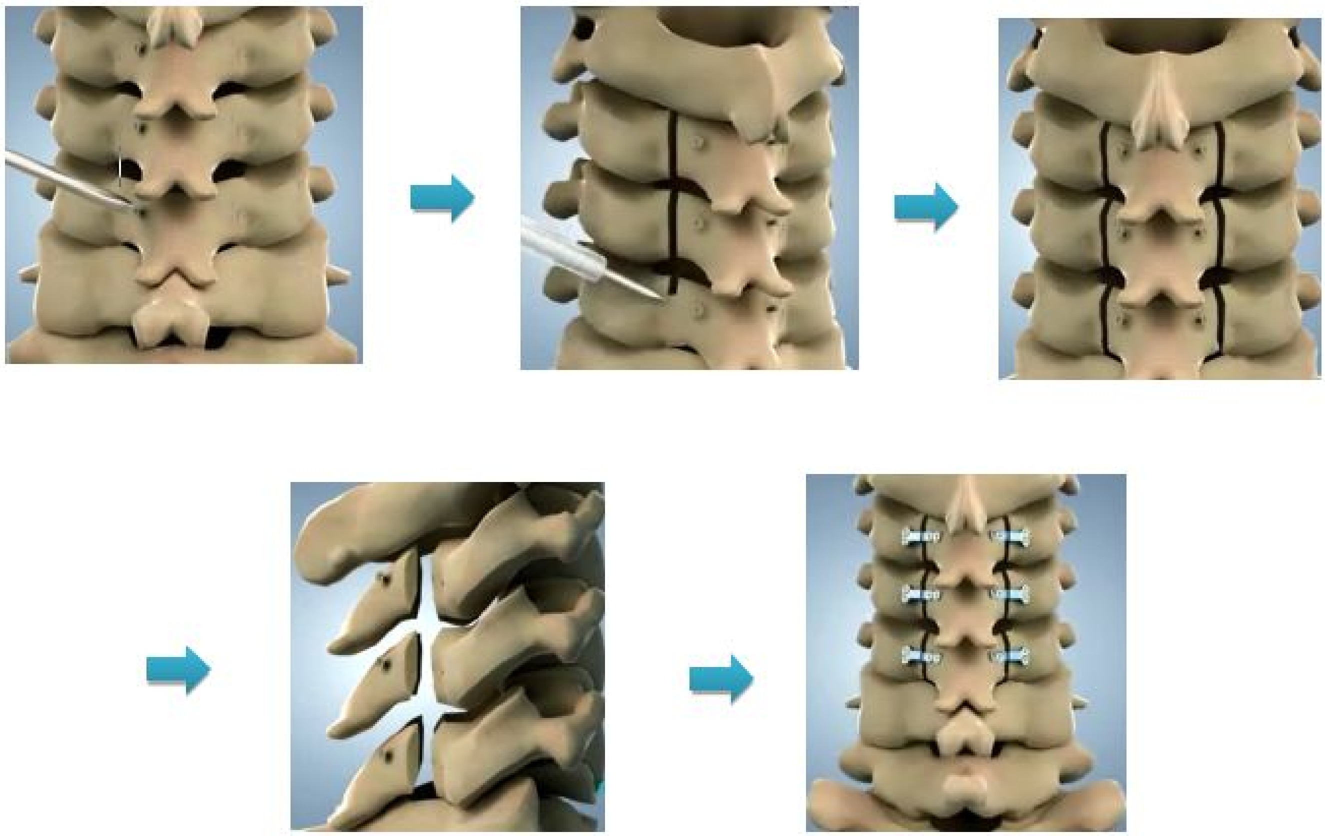

Figure 1

Cervical vertebral dome expansion laminoplasty procedure diagram

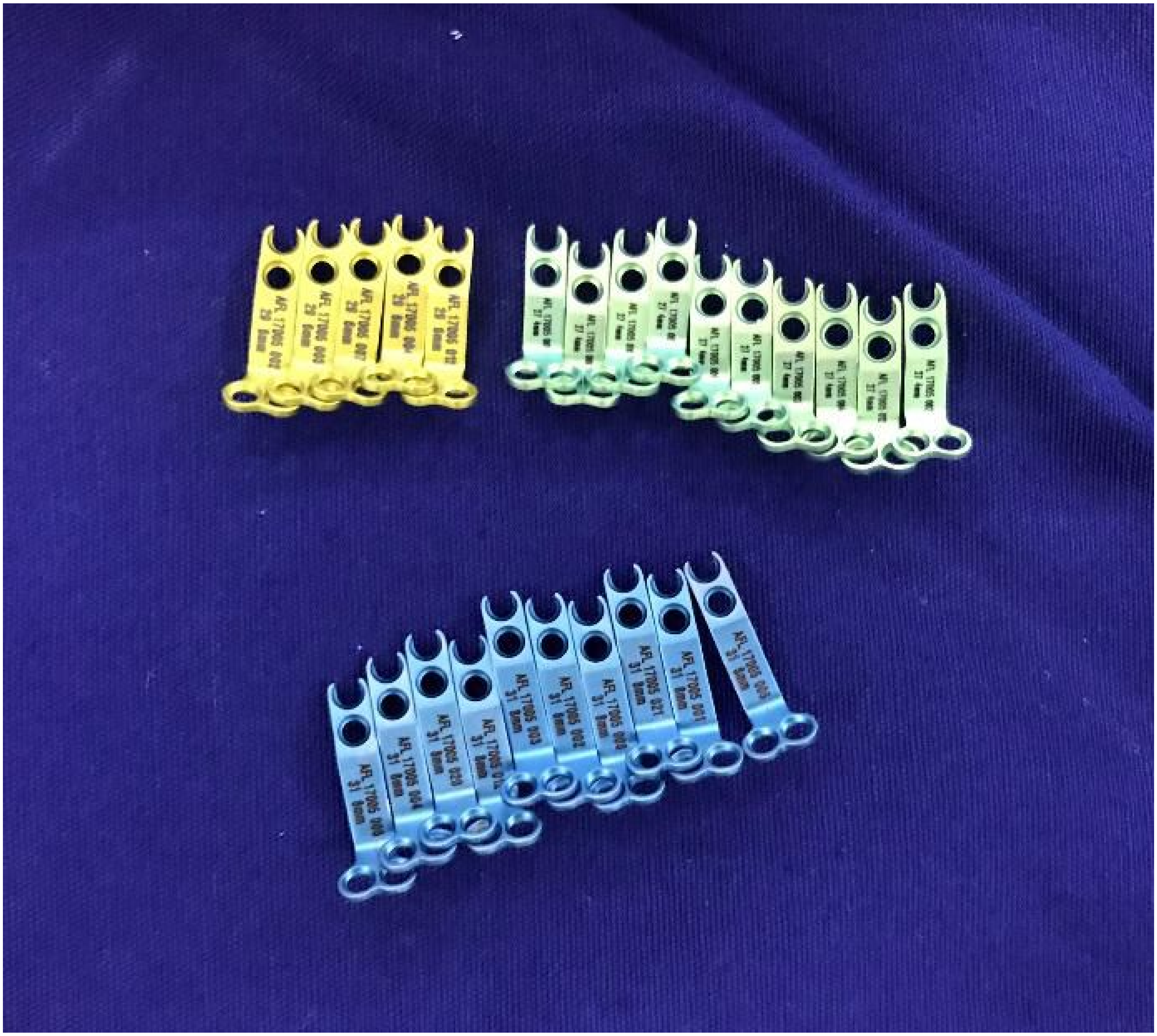

Figure 2

Different types of cervical posterior microtitanium plates

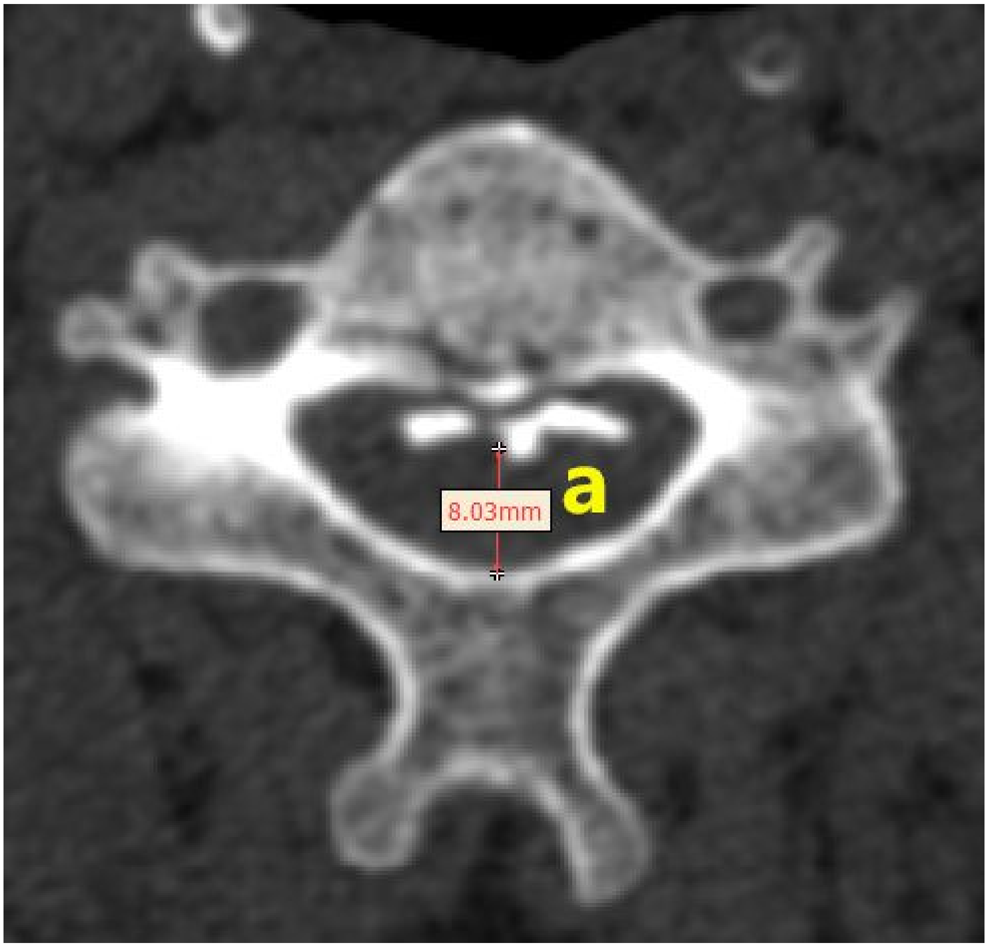

Figure 3

Preoperative spinal anteroposterior diameter a.

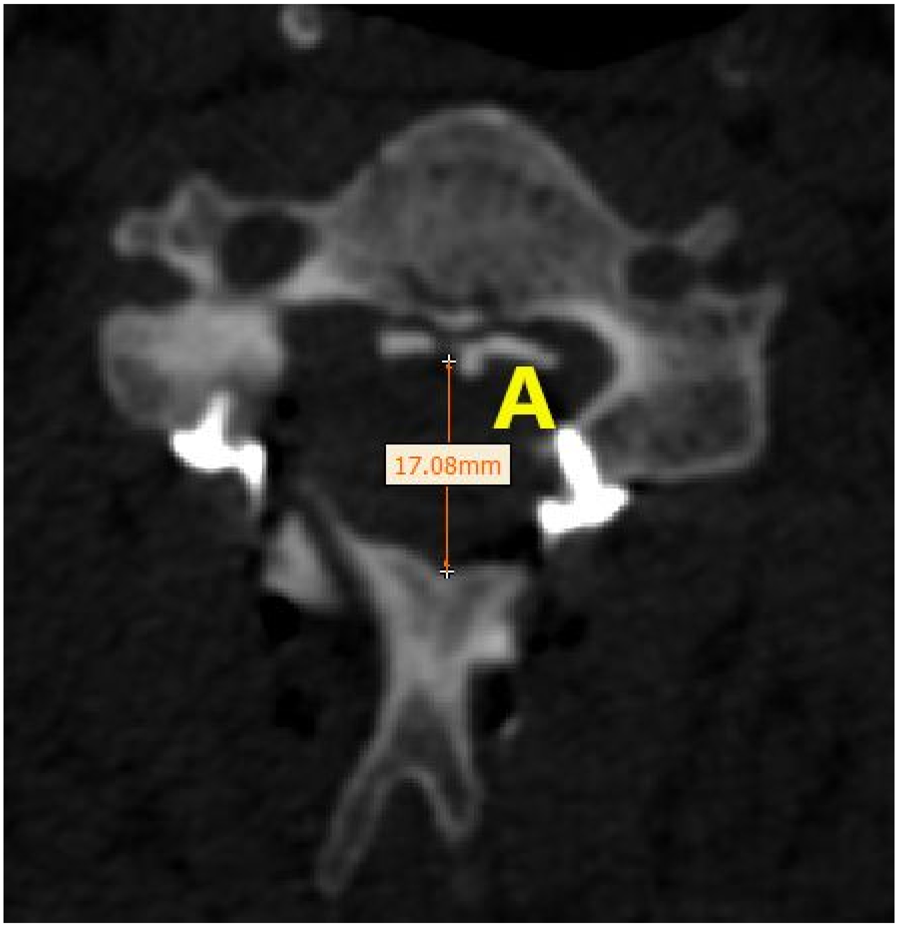

Figure 4

Postoperative spinal anteroposterior diameter A.

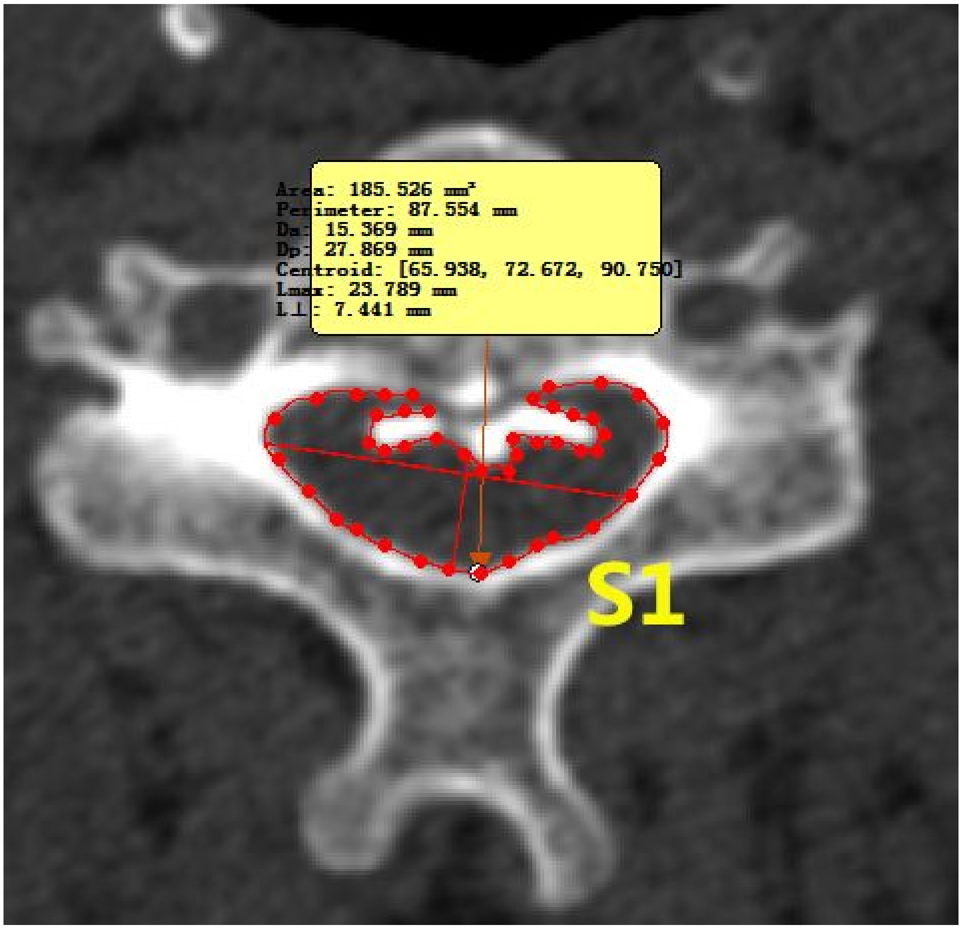

Figure 5

Preoperative spinal canal cross-sectional area S1

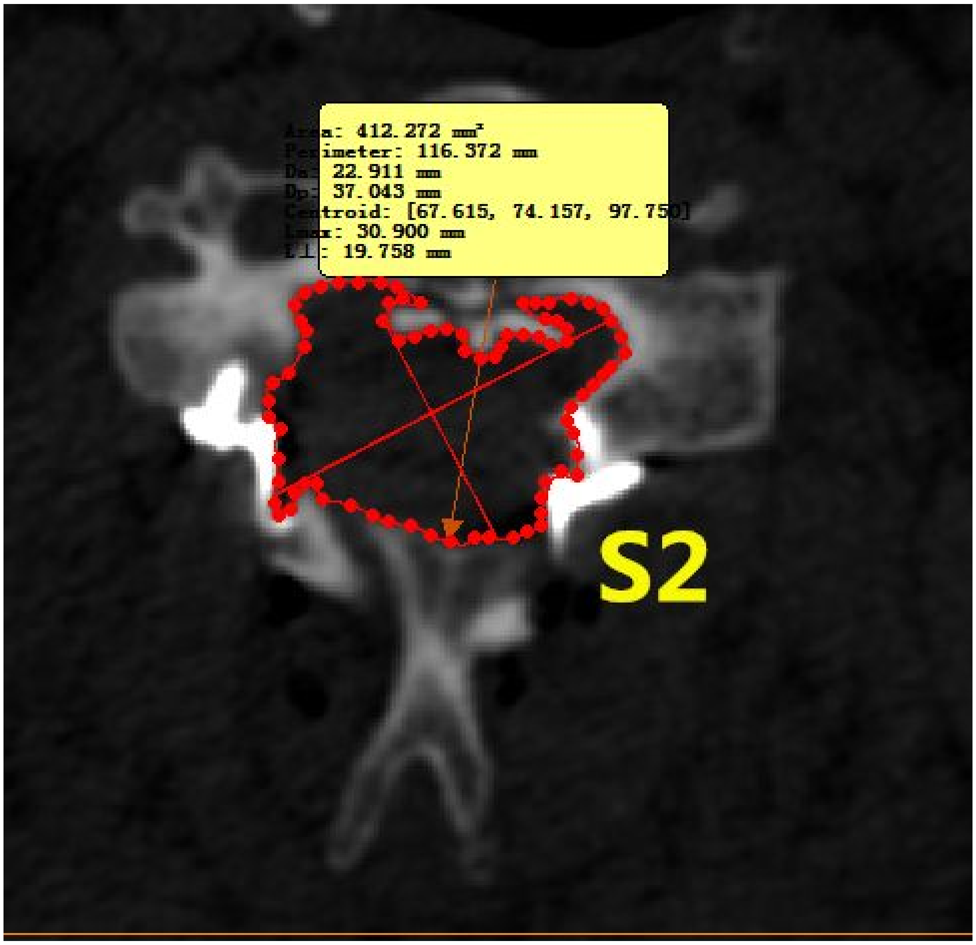

Figure 6

Postoperative spinal canal cross-sectional area S2