Original Article

Optimal anatomical angle and distance for drilling in cervical oblique corpectomy: A surgical anatomical study

ABSTRACT

Background: One of the difficulties of oblique corpectomy, less discussed in the literature, is the problem of how to achieve an optimum corpectomy. Therefore, this anatomico-radiological study was conducted to shed light on the use of the microscope at an appropriate angle and optimum drill distances in clinical cases undergoing cervical oblique corpectomy surgery.

Materials and Methods: We examined the average distance of the diagonal line extending from the medial aspect of the ipsilateral vertebral foramen to the contralateral pedicle in cervical computed tomography -angiography axial scans in four cervical vertebrae, C3, C4, C5, and C6. We also measured the average angle between this diagonal trajectory and the horizontal line, making a total of 712 measurements in 89 patients.

Results: We found that horizontal drilling with an average length of 23–26 mm at an acute angle of about 22° –23° is optimal for adequate decompression of the spinal cord in the oblique corpectomy approach. Depending on the patient and the level of the vertebra, the distance and the angle of the horizontal drilling may range from 18 mm to 31 mm and from 15° to 33°, respectively.

Conclusions: For an optimum cervical oblique corpectomy that provides adequate spinal cord decompression and maintains spinal stability, it is necessary to operate under a surgical microscope positioned at an acute angle and to know the horizontal drilling distance.

Keywords: Anatomy, cervical oblique corpectomy, cervical vertebrae, multilevel corpectomy, neck anatomy, surgical anatomy, vertebral anatomy

INTRODUCTION

With the rapid developments in technology, simulation and virtual reality systems in both cranial and spinal surgery are increasingly used not only in the training of neurosurgical residents but also in surgical planning.[1] This requires a more precise definition of alternative surgical approaches and an augmentation of surgical anatomical knowledge. The most commonly performed methods in the treatment of cervical spondylotic myelopathy are laminectomy with or without implants, laminoplasty, anterior median corpectomy with fusion, and multilevel discectomy.[2,3] The cervical oblique corpectomy is an alternative to these more common approaches.[4] The first steps of the cervical oblique corpectomy technique were taken by Henry,[5] Verbiest and Paz y Geuse[6] and Hakuba,[7] and its present form was developed by George *et al*.[8] Although the cervical oblique corpectomy approach has been known for almost 60 years as a surgical treatment for cervical spondylotic myelopathy and its effectiveness is similar to other anterior and posterior interventions, it is seldom preferred by surgeons. Apart from the belief that anterior cervical approaches generally have more complications than posterior approaches, the main reasons reported in the literature for the avoidance of

Access this article online	
	Quick Response Code
Website: www.jcvjs.com	
DOI: 10.4103/jcvjs.jcvjs_26_23	

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Submitted: 04-Mar-23 **Accepted:** 12-Apr-23
Published: 13-Jun-23

How to cite this article: Baran O, Saygi T, Balak N. Optimal anatomical angle and distance for drilling in cervical oblique corpectomy: A surgical anatomical study. J Craniovert Jun Spine 2023;14:137-43.

the cervical oblique corpectomy are the additional surgical challenges, due to the probability of injury to the cervical sympathetic chain and vertebral artery (VA) being higher compared to other anterior procedures.[9-12]

Another main difficulty of oblique corpectomy, less discussed in the literature, is the problem of how to achieve an optimum corpectomy. It is difficult to achieve optimally shaped corpectomy in an area where the carotid artery, sympathetic trunk, vagal nerve, and VA are in a close proximity[13] [Figure 1]. It has been suggested that the ideal oblique corpectomy consists of two steps in the form of vertical and horizontal drilling of vertebral bodies to obtain an oblique, convex shape, which preserves the vertebral body bone to the greatest possible extent [Figure 2]. Furthermore, different angles of the surgical microscope and different positions of the cervical spine are likely to cause large differences in the final corpectomy as well [Figure 3]. Excessive vertebral bone resection may cause instability, and too little bone resection cannot provide adequate decompression of the anterior spinal cord.[10] There is no good intraoperative landmark for knowing when to stop the horizontal drilling. The drilling limit beyond the midline is usually estimated by calculating the distance posteriorly from the contralateral pedicle to the ipsilateral anterior edge of the vertebral body on preoperative computed tomography (CT) axial scans. This limit can be termed the *contralateral point*.

Thus, we decided to conduct an anatomico-radiological study to shed light on the use of the microscope at an appropriate angle and optimum drill distances in clinical cases undergoing cervical oblique corpectomy surgery. We were unable to find any published studies regarding the angle and average distance necessary to reach the contralateral point during a horizontal drilling. Therefore, we sought to identify the angle and mean distance needed to achieve an optimum corpectomy.

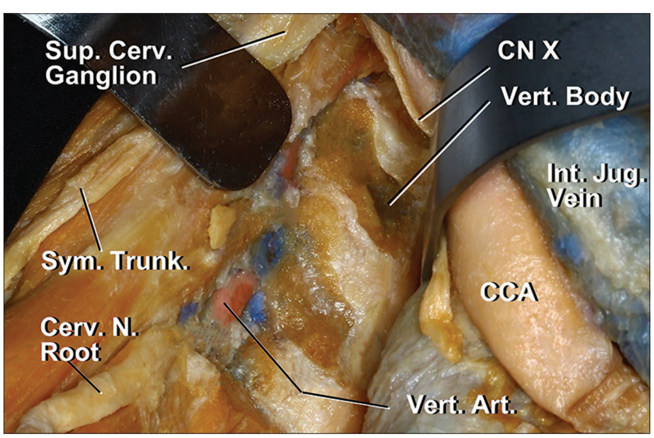

Figure 1: Surgical anatomical route of oblique corpectomy is shown on a cadaver specimen. The carotid artery, sympathetic trunk, vagal nerve, and VA are in a close proximity.[13] Written permission for reproduction was obtained from Elsevier. Sup. Cerv. Gang - superior cervical ganglion, CCA - common carotid artery, Int. Jug: internal jugular, CN - Cranial nerve, VA - vertebral artery

MATERIALS AND METHODS

Study design

In this retrospective observational study of a cohort of consecutive cases, we retrospectively examined cervical CT-angiographic examinations of 89 patients who had undergone cervical CT-angiography for any diagnostic purpose in the 6-month period between January and June 2020. The design and method of this research were similar to published the radiological studies.[14] The study was conducted according to General Data Protection Regulation (2016/679) of the European Parliament and of the Council and all procedures performed comply with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its subsequent amendments.

CT angiography scanning was performed on a GE Optima CT660 unit (GE Healthcare Japan Corporation, Tokyo, Japan). Patients were generally referred to radiology from different clinics with a prediagnosis of cerebrovascular disease. In the

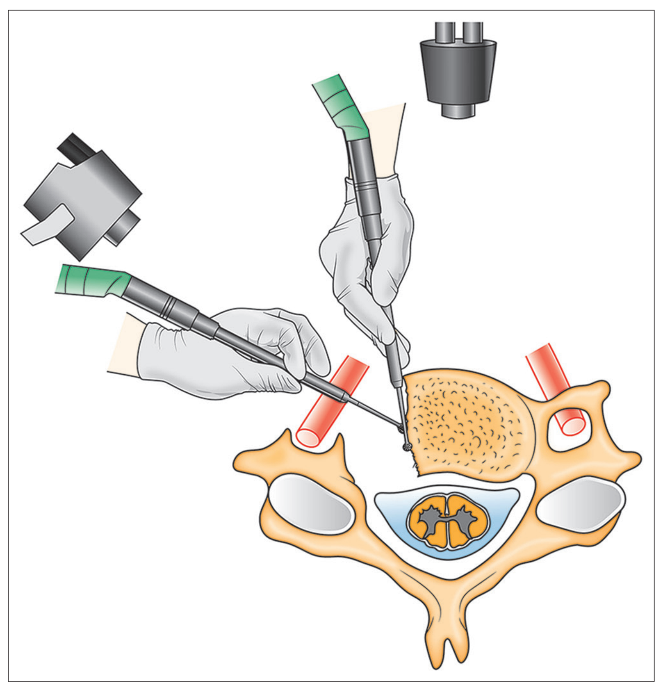

Figure 2: Oblique corpectomy consists of two steps in the form of vertical and horizontal drilling of vertebral bodies to obtain an oblique, convex shape, which preserves the vertebral body bone to the greatest possible extent. Vertebral drilling is first performed vertically until the cancellous bone is completely drilled. Then, drilling is continued diagonally until the contralateral pedicle is reached. (Sketch by the corresponding author)

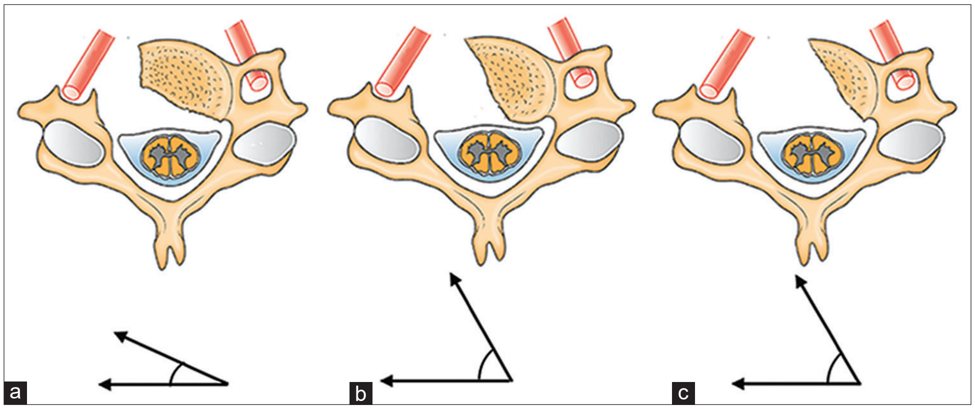

Figure 3: Ideally, oblique corpectomy should provide adequate spinal cord decompression while requiring minimal bone resection that will not impair spinal stability. The geometry of vertical and horizontal (oblique) bone drilling is important at this point. An optimum drilling example is shown in (a). Two examples of undesirable oblique corpectomy are shown in (b) (insufficient decompression) and (c) (excessive bone resection). Modifications in vertical drilling width and horizontal (oblique) drilling angle could theoretically be the cause of obviously different final appearances in the examples given. (Sketch by the corresponding author)

scan, the gantry was not angled. The data collection began 10 s after the initiation of the administration of the contrast medium through a 4 cc/s power injector to adjust the run time to arterial blood flow. The contrast agent dose, which was 80 cc iohexol 350 mgI/mL for each vial, was attuned according to the body mass index of each patient. The scanning frame started caudally, right up below the level of the clavicles, and extended as far as possible to the cephalad. Table movement was equal to the collection collimation thickness (range = 1.25). Spiral data were reconstructed at a slice thickness of 0.625 mm with a spiral rotation time of 0.8 s. On average, a total of 185 axial sections were obtained on the scanner.

Exclusion criteria

The following cases were excluded: patients under the age of 18 years, patients without adequate contrast enhancement in the VA on CT-angiography, patients with a history of neck or head trauma and patients who had previously undergone neck surgery.

Measurement procedure

A DICOM imaging application (OsiriX MD version 9.0.1 DICOM viewer, OsiriX imaging software, Pixmeo, Geneva, Switzerland) was used to make the measurements. The cervical CT-angiography files of each patient were opened in the screen, simultaneously showing axial, coronal, and sagittal images of the patient. Then, the axial section passing through the middle of the C3 vertebral foramen was selected by observing the coronal and sagittal sections. In the selected axial scan, the junctional point where the anterior arm of the transverse process connects with the body of vertebra was marked (such as the minimum or vertex point of an imaginary U-shaped parabola) [Figure 4a]. We arbitrarily called this point the anterior ipsilateral foraminal point or simply, the foraminal (F) point. After defining this, the edge of the contralateral pedicle of the inner side of the spinal canal was marked, again at its vertex point. We arbitrarily called this second point the posterior contralateral pedicular point or simply, the pedicular (P) point. Then we measured the diagonal distance between the F and P points using the measurement tool of the DICOM viewer and recorded it as the F-P distance at C3. Then the angle between the diagonal F-P line and the horizontal line running through the P point was measured and recorded as the angle at C3. We arbitrarily called this angle the pedicle angle (the angle p or the angle FPH) [Figure 4b]. Decimals were rounded. The same procedure and measurements were repeated for the C4, C5, and C6 vertebrae and recorded using Microsoft® Excel for Mac Version 16.41 software (Microsoft®, Redmond, WA, USA).

Statistical analyses

The SPSS version 20 program (IBM SPSS Statistics, Armonk, NY, USA) was used to conduct the statistical analyses. The mean ± standard deviation (SD), minimum, and maximum were calculated as the descriptive values of the obtained data. Values were compared using the independent sample *t*-tests. Using a Pearson correlation analysis, the associations between age and sex and the distance and angle values were determined. Tests of normality were done using the Shapiro–Wilk and Kolmogorov–Smirnov tests. Estimates for the parameters were generated with a 95% confidence interval. Significance was considered as $P < 0.05$.

RESULTS

In the 6-month period between January and June 2020, the cervical CT angiograms of 112 patients were analyzed. After the application of the exclusion criteria, 89 patients in total met the inclusion criteria. At the four cervical vertebrae, C3, C4, C5, and C6, a total of 712 measurements were made (356 F-P distances and 356 angles). Of the 89 patients, 46 were female (51.7%), and 43 were male (48.3%). The mean age of the patients was 51.7 ± 19.3 years (mean ± SD) (ranging from 18 to 91). The mean female age was 50.4 ± 18 years (ranging from 18 to 87) and the mean male age was 53 ± 20.8 years (ranged between 23 and 91).

The mean F-P distance at the C3, C4, C5, and C6 levels were 23.0 ± 1.7 mm (range = 18–27 mm), 24.0 ± 1.7 mm (range = 20–28 mm), 25.2 ± 2 mm (range = 20–31 mm), and 25.8 ± 1.9 mm (range = 22–31 mm), respectively. The distribution of the distance values is shown in Figure 5. The F-P distance values were higher for males than females at all levels studied (independent samples *t*-test for equality of means in 95% confidence interval: $P = 0.001$, $P = 0.001$, $P = 0.000$ and $P = 0.000$ at C3, C4, C5, and C6 levels, respectively). Table 1 shows the average values of distance measurements for males and females separately. While there was no statistically significant correlation between age and distance measurements at C3 and C4 levels (Pearson correlation test, $P > 0.05$), significant correlations were found at C5 and C6 levels (Pearson's correlation test, $P = 0.028$ and $P = 0.028$, respectively). The distance increased with age at these two levels.

The mean angle *P* at the C3, C4, C5, and C6 levels were 21.9° ± 3.1° (range = 15°–30°), 22.0° ± 3.1° (range = 15°–32°), 23.3° ± 3.3° (range = 15°–33°), and 23.2° ± 3.1° (range = 18°–33°), respectively. The distribution of the angle values is shown in Figure 6. There was a statistically significant correlation between age and angle measurements at all levels studied (Pearson correlation test: $P = 0.005$, $P = 0.004$, $P = 0.002$ and $P = 0.000$ at C3, C4, C5, and C6 levels, respectively). The angle increased with age. The angle measurements of males and females did not show a significant difference at any level studied. Table 2 shows the average values of angle *P* measurements for males and females separately.

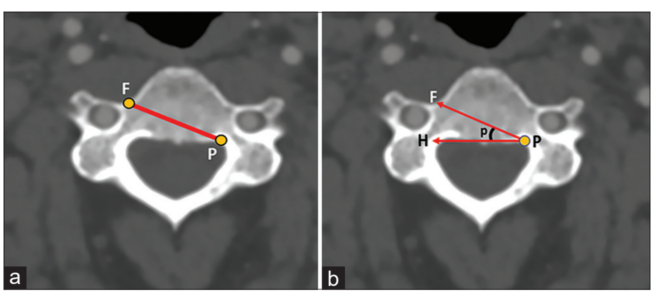

Figure 4: Measurement methods of F-P distance and p angle. (a) Axial CT-angiography scan shows F point, P point and measured line of the distance between them, (b) Axial CT-angiography scan shows the measurement of P angle between F-P line arm and a horizontal arm running through P point. CT - Computed tomography, F - Foraminal, P - Pedicular

DISCUSSION

In this study, we found that a horizontal drilling with an average length of 23–26 mm at an acute angle of about 22°–23° is optimal for adequate decompression of the spinal cord in the oblique corpectomy approach. Depending on the patient and the level of the vertebra, the distance and the angle of the horizontal drilling may range from 18 mm

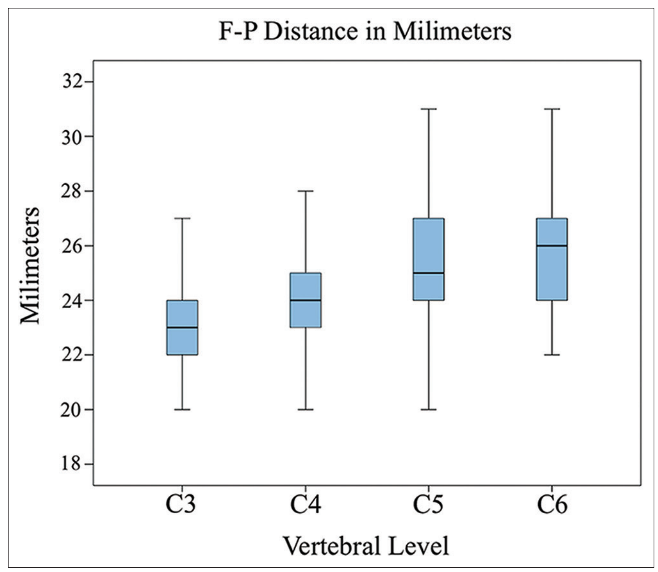

Figure 5: The boxplot diagram displays the distribution of the distance values for four vertebral levels in a standardized way. The mean F-P distance at the C3, C4, C5, and C6 levels were 23.0 ± 1.7 mm (range = 18–27 mm), 24.0 ± 1.7 mm (range = 20–28 mm), 25.2 ± 2 mm (range = 20–31 mm), and 25.8 ± 1.9 mm (range = 22–31 mm), respectively. F - Foraminal; P - Pedicular

Table 1: The average values of distance measurements are shown for males and females separately

	Summary of F–P distance measurements									
	Female					Male				
	Mean (mm)	Maximum (mm)	Minimum (mm)	SD	Total (*n*)	Mean (mm)	Maximum (mm)	Minimum (mm)	SD	Total (*n*)
Distance at C3	23	26	18	2	46	24	27	21	2	43
Distance at C4	23	27	20	2	46	25	28	22	2	43
Distance at C5	25	28	20	2	46	26	31	22	2	43
Distance at C6	25	28	22	1	46	27	31	23	2	43

The decimals of the figures are not shown in the table. SD - Standard deviation, F - Foraminal; P - Pedicular

Table 2: The average values of angle P measurements are shown for males and females separately

	Summary of P-angle measurements									
	Female					Male				
	Mean (degrees)	Maximum (degrees)	Minimum (degrees)	SD	Total (*n*)	Mean (degrees)	Maximum (degrees)	Minimum (degrees)	SD	Total (*n*)
Angle at C3	21	30	15	3	46	22	30	15	3	43
Angle at C4	22	32	15	3	46	22	28	15	3	43
Angle at C5	23	32	19	3	46	23	33	15	3	43
Angle at C6	23	33	18	3	46	23	31	18	3	43

The decimals of the figures are not shown in the table. SD - Standard deviation, P - Pedicular

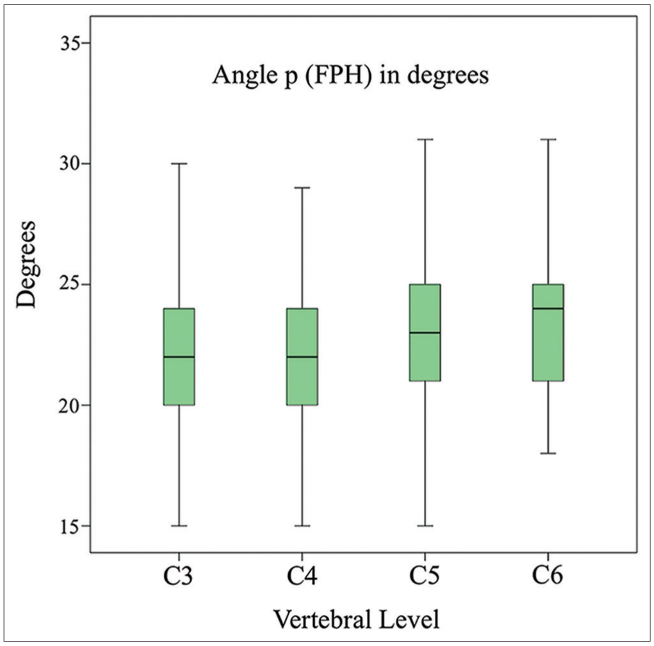

Figure 6: The boxplot diagram displays the distribution of the p angle values for four vertebral levels. The mean angle p at the C3, C4, C5, and C6 levels were 21.9° ± 3.1° (range = 15°–30°), 22.0° ± 3.1° (range = 15°–32°), 23.3° ± 3.3° (range = 15°–33°), and 23.2° ± 3.1° (range = 18°–33°), respectively

to 31 mm and from 15° to 33°, respectively. This distance indicates the point at which the contralateral drill extension will stop during horizontal drilling. A team with extensive experience in the oblique corpectomy method reported that this distance usually ranges between 22 and 28 mm.[10] This observation is consistent with our findings.

Although various clinical studies on cervical oblique corpectomy have been reported in the literature, no criterion has been specified for how much bone resection can be performed without disturbing spinal stability.[15] In the oblique corpectomy, there is a natural tendency to either under-resect the bone with inadequate decompression or to unnecessarily drill in the horizontal plane in a way that jeopardizes spinal stability. In the oblique corpectomy, vertebrectomy is initially performed by resecting the cancellous bone from the medial ipsilateral VA vertically to the bony cortex on the dura, approximately 8 mm wide, and then drilling horizontally.[10] It is very important that the surgical microscope be brought to an inclined position at this moment. Insufficient slope causes drilling to fall short of the contralateral end of the compressing parts.[16] However, there is no exact degree of this angle in horizontal drilling that has been agreed upon by all. One study suggested to proceed obliquely between 40° and 45° from the vertical axis (between 45° and 50° from the horizontal axis), but our findings suggest that this angle should be much narrower for optimum corpectomy that best preserves spinal stability.[17] In this study, we revealed that this angle of inclination is a very narrow acute angle.

In horizontal drilling, an indicator is also needed to verify the adequacy of the decompression of the spinal cord. This is usually provided by measuring the distance between the medial border of the ipsilateral VA and the contralateral pedicle on preoperative CT scanning or by using an intraoperative image guided system.[18] Intraoperative ultrasonography may also be useful in determining the adequacy of the decompression.[16] In addition, it is possible to limit the vertebral body drilling by preserving three fourths of its width for an adequate decompression of the anterior spinal cord.[19]

It may be possible to work at a steeper angle by slightly turning the head and neck to the opposite side, but in this working position there is a risk of losing orientation under the microscope and inadvertently removing excess bone. Although we could work comfortably in the laboratory by turning the head and neck of the cadaver to the opposite side as much as we wanted, we still could not always achieve the optimum bone removal and decompression we wanted. In addition, the possibility of lateral deviation of the patient on the operating table is limited in actual surgery.

Therefore, we consider that the safest working position when performing an oblique corpectomy is the neutral position of the neck parallel to the ground. Thus, the angle of the microscope appears to be the most important factor for optimal drilling of the vertebral body in oblique corpectomy.

The biomechanics of oblique corpectomy have been reviewed or studied in animal and human spines.[20-22] In a study on human cadavers, kinematic change was significantly less than that seen in standard anterior corpectomy with and without a plate, even though oblique corpectomy increased the range of motion by 15% more than normal in all directions.[20] One-or two-level anterolateral oblique corpectomy did not result in spinal instability in a sheep model.[21]

The oblique corpectomy approach is a challenging procedure and has a difficult initial learning process. As with many neurosurgical methods, it is very important that this procedure is performed adequately in the cadaver laboratory and that preoperative imaging is carefully analyzed.[23] Advances in technology and medical science have resulted in more complex and costly surgical procedures.[24] The increasing world population, the increase in the elderly population, the burden of chronic diseases and the COVID pandemic necessitate cost-effective and fair use of resources; the gaining of technical abilities is essential both for the efficient use of resources and for ensuring patient safety and is thus indispensable in ethical medicine education and training.[25,26] We hope that the information provided in our study will be useful not only for spine surgeons during surgery, but also helpful for trainees who are receiving ethical surgical training for patient safety.

Limitations and strengths

The relatively high heterogeneity of anatomical structures makes it impossible to give a general recommendation on when to stop drilling. The metric parameters measured could be different in cases with severe osteochondrosis or ossification of posterior longitudinal ligaments. A significant difference has been found between healthy individuals and patients with cervical spondylotic myelopathy in terms of some parameters measured on magnetic resonance images.[27] Patients requiring this surgery are likely to have pathological changes such as bony spurs, facet joint hypertrophy, and the ossification of posterior longitudinal ligament that may affect measurement on CT scans. Thus, more practical results can be obtained if measurements are made in patients who undergone this surgery in the future. The problem of how much bone can be safely removed without compromising the stability of the relevant vertebral body is also not fully resolved. In other words, it has not been proven whether it is absolutely safe to remove a part of bone as we recommend based on our findings. In addition, it is not possible to precisely determine the optimum angle of the microscope intraoperatively. Despite the above-mentioned limitations, our study is the first surgical anatomical study to attempt to provide a quantitative description of the oblique corpectomy (OC) technique that has been performed to date based on the practical experience of surgeons.

CONCLUSIONS

For an optimum cervical oblique corpectomy that provides adequate spinal cord decompression and maintains spinal stability, it is necessary to operate under a surgical microscope positioned at an acute angle and to know the horizontal drilling distance. This study reveals to spinal surgeons that the angle of the surgical microscope and the position of the patient are extremely crucial in cervical oblique corpectomy. Our findings should be supported by cadaver dissection and biomechanical studies in future.

Ethical statement

The study was conducted according to the General Data Protection Regulation (2016/679) of the European Parliament and of the Council. All procedures performed comply with the 1964 Helsinki declaration and its subsequent amendments.

Acknowledgments

The authors are grateful to Mrs. Ann Hazinedar for her helping in editing.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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