Original Article

The impact of osteotomy grade and location on regional and global alignment following cervical deformity surgery

ABSTRACT

Introduction: Correction of cervical deformity (CD) often involves different types of osteotomies to address sagittal malalignment. This study assessed the relationship between osteotomy grade and vertebral level on alignment and clinical outcomes.

Methods: Retrospective review of a multi-center prospectively collected CD database. CD was defined as at least one of the following: C2–C7 Cobb >10°, cervical lordosis (CL) >10°, C2–C7 sagittal vertical axis (cSVA) >4 cm, and chin-brow vertical angle > 25°. Patients were evaluated for level and type of cervical osteotomy.

Results: 86 CD patients were included (61.4 ± 10.6 years, 66.3% female, body mass index 29.1 kg/m^2). 141 osteotomies were in the cervical spine and 79 were in the thoracic spine. There were 19 major osteotomies performed, with 47% at T1. Patients with an osteotomy in the cervical spine improved in T1 slope minus CL (TS CL), CL, and C2 slope (all $P < 0.05$). Patients with upper thoracic osteotomies improved in TS CL, cSVA, C2–T3, C2–T3 sagittal vertical axis (SVA), and C2 slope (all $P < 0.05$). Minor osteotomies in the upper thoracic spine showed improvement in cSVA (63 mm to 49 mm, $P = 0.022$), C2–T3 ($P = 0.007$), and SVA (16 mm to 27 mm, $P < 0.001$). The greatest amount of C2–T3 angular change occurred for patients with a major osteotomy at T2 (39.1° change), then T3 (15.7°), C7 (16.9 °), and T1 (13.5°). Patients with a major osteotomy in the upper thoracic spine showed similar radiographic changes from pre- to post-operative as patients with three or more minor osteotomies, although C2–T3 SVA trended toward greater improvement with a major osteotomy (22.5 mm vs. +5.9 mm, $P = 0.058$) due to lever arm effect.

Conclusions: CD patients undergoing osteotomies in the cervical and upper thoracic spine experienced improvement in TS– CL and C2 slope. In the upper thoracic spine, multiple minor osteotomies achieved similar alignment changes to major osteotomies at a single level, while a major osteotomy focused at T2 had the greatest overall impact in cervicothoracic and global alignment in CD patients.

Keywords: Cervical deformity surgery, global alignment, osteotomy, osteotomy location, regional alignment

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INTRODUCTION

Cervical spinal deformity is a broad category that encompasses a diverse group of spinal malalignment patterns.[1,2] The cervical spine allows the widest and most complex range of motion of all the spinal segments and supports the mass of the head, which can render it susceptible to a wide range of disorders and alignment pathology that warrant surgical consideration.[3,4] Malalignment can range from a simple biplanar deformity to a complex three-dimensional deformity with loss of coronal and sagittal alignment. This can manifest as pain and functional disability, as well as precipitate worsening neurologic sequelae through neuronal loss and demyelination. Primary drivers of cervical deformity (CD) include spondylotic arthropathies, idiopathic cervical paraspinal myopathies, and iatrogenic cervical kyphosis.[5-7]

Treatment of cervical deformities can present substantial challenge to the spinal deformity surgeon. The main objectives of CD surgery include the maintenance/restoration of horizontal gaze, decompression of neural elements, and an overall effort to reestablish the normative alignment of the cervical spine.[8,9] While a flexible, or passively correctable, deformity can be treated with a wide variety of strategies, such as anterior or posterior releases with instrumentation and fusion, a fixed or ankylosed deformity requires one or more osteotomies for realignment and neural decompression.[10] Choosing the level of the osteotomy is critical for both surgical planning and for minimizing the risks of neurologic injury. C7 is often chosen as the cervical osteotomy level due to the wider spinal canal at this level, and more mobile cervical nerve roots. Further, there is maximum preservation of neurological status at this level, in the event of spinal cord injury. However, T1 can also be chosen for osteotomy level if there is associated proximal thoracic kyphosis with a higher than normal T1 slope.[10]

Importantly, recent work has contributed to increased knowledge of changes in adjacent unfused segments and spinopelvic alignment and an increased appreciation of the interplay between the different spinal regions.[11,12] No study to date has clearly examined reciprocal changes in the cervical spine and global alignment parameters after cervical osteotomy for CD. Understanding the compensatory behavior of the mobile cervical spine and markers of regional and global alignment is important to planning the osteotomy level. Determining the degree of correction required for a given deformity requires anticipation of the reciprocal changes induced in subaxial, thoracic, and thoracolumbar alignment. In this regard, our aims in this study were to assess changes in cervical and global alignment parameters following surgical correction of CD with cervical osteotomy, based on osteotomy level chosen and type of osteotomy performed.

METHODS

Data source

This study is a retrospective review of a prospectively collected database of CD patients enrolled from 13 sites within the United States. Internal review board approval was obtained at each participating site before study initiation, and informed consent was given by each included patient. Inclusion criteria for the database were patients aged ≥18 years and radiographic evidence of CD at baseline assessment, defined as the presence of at least 1 of the following: cervical kyphosis (C2–C7 Cobb angle >10°), cervical scoliosis (C2–C7 coronal Cobb angle >10°), C2–C7 sagittal vertical axis (cSVA) >4 cm, or chin-brow vertical angle (CBVA) >25°. CD patients meeting radiographic inclusion with available baseline and 1-year follow-up data were included in this study. Patients with active tumors or infections were excluded from the study.

Data collection

Demographic and clinical data collected included patient age, sex, body mass index (BMI), prior cervical surgery, and Charlson Comorbidity Index. Surgical data collected included operative time, estimated blood loss (EBL), surgical approach, off-label use of bone morphogenetic protein 2, osteotomy use and number of osteotomies, levels fused, and instrumentation used.

Patients were evaluated using full-length free-standing lateral spine radiographs (36" long-cassette) at baseline and 1-year postoperative follow-up visit. Radiographs were analyzed using dedicated and validated software (SpineView®; ENSAM, Laboratory of Biomechanics, Paris, France) at a single center with standard techniques.[13-16] Measured cervical spine parameters included cSVA (offset from the C2 plumbline and the posterosuperior corner of C7), C2–C7 lordosis (CL: Cobb angle between C2 inferior endplate and C7 inferior endplate), T1 slope minus CL (TS − CL: mismatch between T1 slope and cervical lordosis), and CBVA (angle subtended between the vertical line and the line from the brow to the chin). Measured spinopelvic parameters included sagittal vertical axis (SVA: C7 plumb line relative to the posterosuperior corner of S1), pelvic incidence minus lumbar lordosis (PI − LL: mismatch between pelvic incidence and lumbar lordosis), and pelvic tilt (PT: angle between the vertical and the line through the sacral midpoint to the center of the two femoral heads).

Patient stratification

Patients were evaluated for level and type of cervical osteotomy. Osteotomy grading used the Ames-International Spine Study

Group (ISSG) Osteotomy Classification [Table 1]: partial facet resection (Grade 1), complete facet resection/Ponte (Grade 2), partial or complete corpectomy (Grade 3), uncovertebral joint resection (Grade 4), opening wedge (Grade 5), closing wedge (Grade 6), and vertebral column resection (Grade 7).[17] Patients were categorized based on undergoing a major osteotomy defined as either a Grade 6 or 7 osteotomy or a minor osteotomy (Grades 1–5). Patients were also stratified by the vertebral level of the osteotomy: cervical (C7 and above), upper thoracic (T1–T6), and lower thoracic (T7–T12).

Statistical analysis

The distribution of osteotomy vertebral levels and grade at each level were assessed with descriptive analyses. Radiographic changes in cervical and global sagittal alignment parameters were analyzed and broken down by the region of the osteotomy (cervical, upper thoracic, or lower thoracic). Alignment changes were also assessed by the grade of the osteotomy within each region of the spine. Independent *t*-tests for continuous variables and Chi-squared tests for categorical variables were used to assess differences between radiographic and clinical outcomes. Two-sided $P < 0.05$ were considered statistically significant. All analyses were performed using SPSS version 23 (version 21.0, Armonk, NY, USA).

RESULTS

Patient sample

Eight-six CD patients were included (61.4 ± 10.6 years, 66.3% female, BMI 29.1 ± 8.3 kg/m^2). Mean operative time was 377.6 ± 214.3 min, mean EBL was 853.9 ± 865.4 ccs, and mean length of hospital stay was 6.4 days. The mean upper instrumented vertebrae was C3 and the mean lower instrumented vertebrae was T3. The mean number of levels fused was 7.7 ± 3.7. Twenty-nine patients underwent a major osteotomy. There were a total of 141 osteotomies performed in the cervical spine, with the most common levels being C6 (26.2%), C5 (24.1%), and C7 (23.4%), followed by C4 (20.6%) and C3 [5.7%, Table 2]. A total of 79 osteotomies were performed in the thoracic spine, with 75% occurring above T5 (most commonly T1 and T2). There were 19 major osteotomies performed (Grades 6–7), with 9 (47%) at T1. There was one major osteotomy performed at C7, four at T2, three at T3, and two at T4.

Baseline deformity and type of surgery

The most common baseline diagnoses for these CD patients were kyphosis of the cervicothoracic region (47%), cervical stenosis (20%), and iatrogenic kyphosis (14%). Using the Ames CD classification system, the baseline deformity descriptors for the cohort were 47 C, 27 CT, 4 S, and 8 T. 16% of patients underwent an anterior corpectomy, 48% underwent an anterior discectomy, and 55% underwent a posterior decompression.

Table 1: Ames-International Spine Study Group osteotomy classification and distribution of osteotomy vertebral levels

Ames-ISSG osteotomy classification	
Osteotomy grade	**Resection**
Grade 1	Partial facet resection
Grade 2	Complete facet resection/Ponte osteotomy
Grade 3	Partial or complete corpectomy
Grade 4	Uncovertebral joint resection
Grade 5	Opening wedge osteotomy
Grade 6*	Closing wedge osteotomy
Grade 7*	Vertebral column resection

*A major osteotomy. ISSG - International Spine Study Group

Table 2: Distribution of osteotomies by vertebral level

	n (%)
Cervical osteotomy vertebral levels (*n*=141)	
C3	8 (5.7)
C4	29 (20.6)
C5	34 (24.1)
C6	37 (26.2)
C7	33 (23.4)
Thoracic osteotomy vertebral levels (*n*=79)	
T1	27 (31.4)
T2	14 (16.3)
T3	10 (11.6)
T4	8 (9.3)
T5	3 (3.5)
T6	6 (3.5)
T7	3 (2.3)
T8	1 (1.2)
T9	3 (3.5)
T10	2 (2.3)
T11	1 (1.2)
T12	1 (1.2)

Radiographic outcomes by deformity type

Patients with C-type deformity had significant improvement from baseline to 1 year in T1 Slope, TS–CL, C2–C7 lordosis, C2–T3 angle, and C2 slope ($P < 0.001$). Patients with CT-type deformity had significant 1-year improvement in TS–CL, C2–C7 lordosis, cSVA, C2–T3 angle, C2–T3 SVA, C2 slope, and SVA ($P < 0.05$). Patients with S-type deformity had 1-year improvement in TS–CL. Patients with T-type deformity had significant 1-year improvement in C2–T3 SVA [Table 3].

Osteotomies in the cervical spine

Patients with an osteotomy in the cervical spine improved in TS–CL, CL, C2–T3 angle, and C2 slope [Table 4]. These patients with an osteotomy in the cervical spine worsened

Table 3: Radiographic alignment changes assessed pre- and 1-year post-operatively for Ames Cervical Deformity Descriptors

Radiographic parameters	Preoperative	Postoperative	Δ	*P*
C descriptor				
T1 slope (°)	20.71 (12.08)	28.18 (11.78)	−7.47 (8.07)	<0.001
TS−CL (°)	33.97 (18.77)	22.37 (10.72)	11.60 (16.59)	<0.001
C2–C7 lordosis (°)	−14.01 (16.09)	5.80 (12.12)	−19.81 (14.88)	<0.001
C2–T3 angle (°)	−14.29 (19.55)	0.40 (14.26)	−14.69 (19.89)	<0.001
C2 slope (°)	32.81 (19.62)	21.06 (11.17)	11.75 (17.28)	<0.001
CT descriptor				
SVA (mm)	20.20 (77.40)	39.65 (73.54)	−19.44 (44.33)	0.031
TS−CL (°)	43.25 (17.51)	33.97 (13.58)	9.28 (16.97)	0.010
C2-C7 lordosis (°)	−3.47 (17.91)	9.72 (15.91)	−13.19 (17.59)	0.001
cSVA (mm)	63.15 (14.10)	48.08 (11.07)	15.07 (15.97)	<0.001
C2–T3 angle (°)	−24.00 (16.99)	−2.69 (16.11)	−21.31 (19.79)	<0.001
C2–T3 SVA (mm)	106.09 (23.78)	90.26 (19.08)	15.83 (24.73)	0.005
C2 slope (°)	46.84 (19.17)	33.63 (13.94)	13.21 (18.76)	0.002
S descriptor				
TS−CL (°)	11.96 (9.59)	26.82 (14.66)	−14.86 (25.01)	0.019
T descriptor				
C2–T3 SVA (mm)	124.83 (12.25)	98.29 (24.89)	26.54 (26.79)	0.026

Significance was set at $P<0.05$. TS−CL - T1 slope minus cervical lordosis; SVA - Sagittal vertical axis; cSVA - C2–C7 SVA; CT - Cervicothoracic

Table 4: Radiographic alignment changes assessed pre- and 1-year post-operatively for patients with an osteotomy in the cervical spine

Radiographic parameters	Preoperative	Postoperative	Δ	*P*
Pelvic tilt (°)	19.35 (9.6)	17.8 (9.52)	−1.55 (5.04)	0.031
PI−LL (°)	2.97 (15.97)	2.12 (15.41)	−0.84 (9.02)	0.503
T4–T12 thoracic kyphosis (°)	−37.89 (13.4)	−42 (14.96)	−3.92 (9.01)	0.003
SVA (mm)	8.22 (70.02)	26.15 (60.47)	18.96 (56.51)	0.026
T1 slope (°)	24.56 (13.34)	32.78 (14.76)	7.62 (8.89)	<0.001
TS−CL (°)	36.49 (19.14)	24.48 (13)	−11.11 (17.89)	<0.001
C2–C7 lordosis (°)	−12.59 (16.17)	8.38 (13.53)	19.04 (17.2)	<0.001
cSVA (mm)	39.93 (26.09)	36.21 (18.8)	−4.75 (18.27)	0.100
C2–T3 angle (°)	−15.79 (19.24)	2.27 (14.57)	17 (20.42)	<0.001
C2–T3 SVA (mm)	66.02 (38.35)	70.76 (29.66)	3.23 (23.77)	0.384
C2 slope (°)	36.4 (20.23)	23.05 (13.44)	−12.68 (18.18)	<0.001

Significance was set at $P<0.05$. TS−CL - T1 slope minus cervical lordosis; SVA - Sagittal vertical axis; cSVA - C2–C7 SVA; PI−LL - Pelvic incidence minus lumbar lordosis

in T1 slope (25°–33°, $P < 0.001$) and increased in SVA (9 mm to 28 mm, $P = 0.026$).

Osteotomies in the upper thoracic spine

Patients with upper thoracic osteotomies improved in TS–CL, cSVA, C2–T3, C2–T3 SVA, and C2 slope [all $P < 0.05$, Table 5]. Minor osteotomies in the upper thoracic spine showed improvement in cSVA (63 mm to 49 mm, $P = 0.022$), C2–T3 ($P = 0.007$), and SVA (−16 mm to 27 mm, $P < 0.001$). The greatest amount of C2–T3 angular change occurred for patients with a major osteotomy at T2 (39.1° change), then T3 (15.7°), C7 (16.9°), and T1 (13.5°). Patients with a major osteotomy in the upper thoracic spine showed similar radiographic changes from pre- to post-operative as patients with three or more minor osteotomies, although C2–T3 SVA trended toward greater improvement with a major osteotomy (−22.5 mm vs. +5.9 mm, $P = 0.058$) due to lever arm effect.

Osteotomies in the lower thoracic spine

There were three Grade 1 osteotomies and two Grade 2 osteotomies performed in the lower thoracic spine. Patients undergoing an osteotomy in the lower thoracic spine did not significantly improve in any cervical or global alignment parameters from pre- to post-operative but did trend toward improvement in TS–CL, cSVA, and global SVA [Table 6].

DISCUSSION

Successful CD correction focuses not only on restoring the appropriate cervical alignment but also on understanding and optimizing regional and global alignment parameters. This can be critical for prevention of secondary disorders in the adjacent segments. The location and type of osteotomy for CD should be selected to achieve the goals of deformity correction, while minimizing risks for neurologic injury,

Table 5: Radiographic alignment changes assessed pre- and 1-year post-operatively for patients with an osteotomy in the upper thoracic spine

Radiographic parameters	Preoperative	Postoperative	Δ	*P*
Pelvic tilt (°)	18.29 (12.93)	17.61 (11.84)	−0.68 (7.64)	0.590
PI−LL (°)	−0.68 (22.39)	−0.29 (20.1)	0.39 (11.67)	0.842
T4–T12 thoracic kyphosis (°)	−39.74 (19.35)	−44.82 (16.48)	−4.77 (10.43)	0.010
SVA (mm)	3.67 (77.67)	22.47 (77.82)	18.59 (65.33)	0.107
T1 slope (°)	37.32 (16.96)	39.72 (14.97)	0.77 (11.86)	0.709
TS−CL (°)	40.34 (20.85)	31.36 (14.7)	−7.84 (19.13)	0.033
C2–C7 lordosis (°)	−1.43 (23.71)	8.62 (18.4)	7.63 (20.33)	0.049
cSVA (mm)	56.04 (18.94)	47.8 (11.86)	−10.57 (16.55)	0.002
C2–T3 angle (°)	−19.99 (23.02)	−3.47 (18.82)	16.1 (24.77)	0.001
C2–T3 SVA (mm)	96.58 (32.54)	86.32 (20.38)	−14.01 (27.39)	0.009
C2 slope (°)	42.01 (22.6)	30.94 (15.35)	−10.51 (20.72)	0.010

Significance was set at $P<0.05$. PI−LL - Pelvic incidence minus lumbar lordosis; TS−CL - T1 slope minus cervical lordosis; SVA - Sagittal vertical axis; cSVA - C2–C7 SVA

Table 6: Radiographic alignment changes assessed pre- and 1-year post-operatively for patients with an osteotomy in the lower thoracic spine

Radiographic parameters	Preoperative	Postoperative	Δ	*P*
Pelvic tilt (°)	11.71 (19.78)	18.7 (14.82)	6.98 (11.16)	0.299
PI−LL (°)	−15.86 (25.62)	−2.86 (24.24)	13.01 (14.55)	0.172
T4–T12 thoracic kyphosis (°)	−54.2 (9.92)	−47.05 (3.91)	7.15 (10.13)	0.253
SVA (mm)	−6.72 (79.91)	15.71 (77.33)	22.43 (60.25)	0.511
T1 slope (°)	36.86 (6.4)	37.69 (7.47)	0.82 (5.56)	0.787
TS−CL (°)	44.36 (31.46)	34.76 (12.03)	−9.6 (29.14)	0.557
C2–C7 lordosis (°)	−7.5 (27.74)	2.93 (9.08)	10.43 (30.47)	0.543
cSVA (mm)	57.08 (16.44)	49.64 (8.21)	−7.44 (21.75)	0.543
C2–T3 angle (°)	−19.65 (21.67)	−9.58 (13.67)	10.08 (29.98)	0.550
C2–T3 SVA (mm)	93.05 (20.67)	89.71 (13.02)	−3.33 (25.11)	0.808
C2 slope (°)	44.73 (31.54)	36.57 (11.4)	−8.15 (31.88)	0.644

Significance was set at $P<0.05$. PI−LL - Pelvic incidence minus lumbar lordosis; TS-CL - T1 slope minus cervical lordosis; SVA - Sagittal vertical axis; cSVA - C2–C7 SVA

and adverse reciprocal changes. To that end, we sought to quantify changes in cervical and global alignment parameters following cervical osteotomy, based on osteotomy level chosen and type of osteotomy performed. We found that cervical and upper thoracic spine osteotomies affected improvement in TS−CL and C2 slope. In the upper thoracic spine, multiple minor osteotomies (Ames-ISSG Osteotomy Classification Grades 1–5) achieved similar alignment changes to major osteotomies (Ames-ISSG Osteotomy Classification Grades 6–7) at a single level. A major osteotomy at T2 had the largest overall effect on cervicothoracic and global alignment. These data may be helpful in aiding with surgical planning for CD correction and providing quantitative understanding for postoperative changes in regional and global alignment.

In recent years, much has been written about the chain of correlations from the sacropelvis to the occipital region, illustrating that deformities in the thoracic and lumbar spine can induce compensatory changes in cervical spine alignment.[18,19] While alignment changes in the thoracic spine and pelvic parameters have been more commonly studied, there is growing understanding of the effects of CD correction. Ames *et al*. initially described the following sequence of relationships: an increase in pelvic incidence corresponds to an increase in lumbar lordosis, which corresponds to an increase in thoracic kyphosis, which then correlates with an increase in cervical lordosis. Further, patients with increased SVA uniformly had increased cervical lordosis, as a compensatory measure.[20]

In the case of a primary CD, regional and global alignment change both preoperatively and postoperatively as compensatory mechanisms. T1 slope refers to the angle of the T1 endplate relative to a horizontal line; the normal range for T1 slope is 22°–32°. The T1 slope has been shown to be a predictor of cSVA and correlates significantly with cervical lordosis and cSVA.[20,21] The results of this study indicate that a cervical spine and upper thoracic spine osteotomy all contributed to significant improvement in TS–CL, as did a lower thoracic spine osteotomy, though not significantly so. This is critical since in all postoperative measurements, TS–CL was <36.4°, which is the cutoff that has been shown to be associated with an increased risk of distal junctional kyphosis (DJK).[22] Similarly, cervical spine and upper and lower thoracic spine osteotomies achieved a cSVA < 56.3°, the threshold associated with increased potential for DJK.

In the case of a significant thoracic kyphotic deformity, an abnormal T1 slope, and subaxial cervical hypolordosis, with overall cervical sagittal malalignment, a major osteotomy may be required at the cervicothoracic junction. Major osteotomies are often used in fixed inflexible deformities as lower grade osteotomies may not be suitable for these cases. A single-level Grade 6 or Grade 7 cervical osteotomy has been shown to yield 23°–54° of correction.[23] However, the results in this study support multiple minor or Grade 1–5 osteotomies to achieve similar alignment goals as a single-level major osteotomy in the upper thoracic spine. Major osteotomies in the cervical spine carry with them the risk of a highly unstable spinal column; sudden, uncontrolled osteoclasis; or overcorrection or subluxation of the spinal cord; all of which can cause spinal cord injury. In this regard, demonstrating equivalence in alignment outcomes with multiple minor osteotomies is helpful for surgical planning and minimizing risks of neurologic injury.

The T2 vertebral level is the natural inflection point between the kyphotic alignment of the thoracic spine and lordotic alignment of the cervical spine. The results of this study indicate that a major osteotomy at T2 affected the greatest amount of C2–T3 angular change. This is consistent with other studies demonstrating that an upper thoracic pedicle subtraction osteotomy contributes to significant improvement in cervical lordosis.[24] Fixation benefits of performing an osteotomy at T2 instead of C7 include the ability to obtain reliable pedicle screw fixation above and below the osteotomy, facilitating osteotomy closure, as well as the larger pedicle sizes of the T1 to T3 vertebrae, relative to cervical vertebrae. Importantly, there is less concern for injury to the T2 nerve root, compared with the C8 nerve root, which carries risk of injury with a C7 major osteotomy.

This study was not without limitations. First, the retrospective design introduces the possibility of selection bias. In addition, the patients in this series were treated by surgeons who treat a large volume of adults with spinal deformity, which may limit the generalizability of our results. However, the exclusivity also conferred uniformity, and one might expect these types of surgical procedures to be performed at tertiary care centers by surgeons with similar experience.

While there is no single correct answer in cervical spinal deformity planning, having a systematic algorithm for selecting a surgical approach and level and type of osteotomy required is critical to achieving alignment goals, while minimizing potential for neurologic injury. The results of this study provide insight into the degree of correction achieved with cervical versus upper and lower thoracic osteotomies, as well as knowledge of resultant regional alignment changes. While surgical decisions largely center around the patient's disability and pain, an understanding of expected radiographic changes is critical to ensure a successful surgical outcome and for a more accurate prognosis of the patient's postoperative alignment.

CONCLUSION

Cervical deformity patients undergoing osteotomies in the cervical and upper thoracic spine experienced improvement in TS-CL and C2 slope. In the upper thoracic spine, multiple minor osteotomies achieved similar alignment changes to major osteotomies at a single level, while a major osteotomy focused at T2 had the greatest overall impact in cervicothoracic and global alignment in CD patients. These findings may aid with surgical planning for cervical deformity correction and provide a better understanding of postoperative changes in regional and global alignment.

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Conflicts of interest

There are no conflicts of interest.

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