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ORIGINAL ARTICLE

The most appropriate cervical vertebra for the measurement of occipitocervical inclination parameter: a validation study of C3, C4, and C5 levels using multi-positional magnetic resonance imaging

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Abstract

Purpose To evaluate which cervical level is the most appropriate level to measure occipitocervical inclination (OCI).

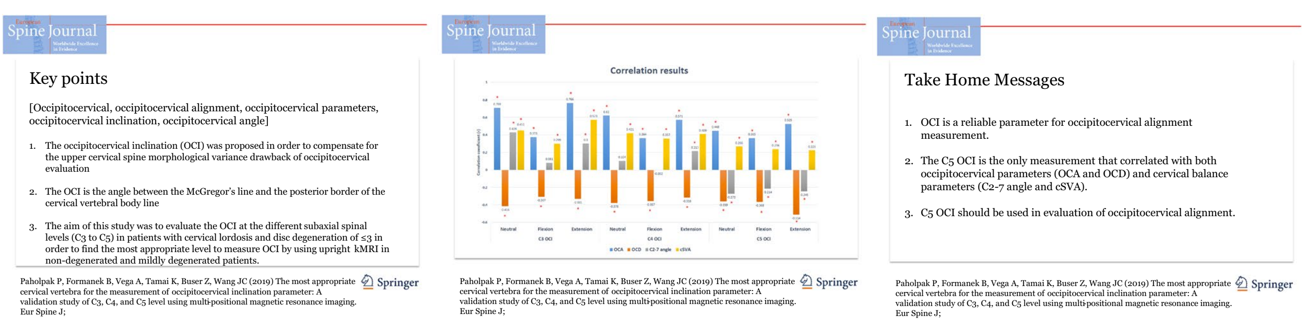
Methods Sixty-two patients with multi-positional MRI: 24 males and 38 females, who had cervical lordosis and had a disk degeneration grade of 3 or less were included. We measured patient's OCI at C3, C4, and C5, occipitocervical angle (OCA), occipitocervical distance (OCD), C2–7 angle, and cervical sagittal vertical axis (cSVA) in neutral, flexion, and extension position. The correlation between OCI and OCA, OCD, C2–7 angle, and cSVA on each cervical level in all three positions was tested using Pearson's correlation coefficient test. The difference between OCIs at each cervical level was tested by Wilcoxon signed-rank test. *p* value of less than 0.05 was set as a statistically significant level.

Results C5 OCI showed statistically significant correlation with OCA, OCD, C2–7 angle, and cSVA in all three positions ($p<0.05$, $r=0.214$–0.525). C3 OCI in flexion ($p=0.393$, $r=0.081$) and C4 OCI in neutral and flexion (neutral $p=0.275$, r 0.104; flexion $p=0.987$, $r=0.002$) did not show significant correlation with C2–7 angle. There was a statistically significant difference between C3, C4, and C5 OCIs in neutral and extension position ($p<0.05$). At the same time, OCI showed statistically strong correlation between adjacent cervical levels ($p<0.001$, $r=0.627$–0.822).

Conclusion C5 cervical level is the most appropriate level for OCI measurement. OCI should be measured at the same cervical level at all time. C4 OCI can reliably substitute C5 OCI in case C5 which is invisible on radiographic image.

Graphical abstract

These slides can be retrieved under Electronic Supplementary Material.



Keywords Occipitocervical · Occipitocervical alignment · Occipitocervical parameters · Occipitocervical inclination · Occipitocervical angle

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Extended author information available on the last page of the article

Introduction

The position of the occiput in relation to the cervical spine is an important parameter when considering occipitocervical fusion procedure. Subaxial spine malalignment, global malalignment, and complications such as dysphagia and respiratory disorders might develop when the occiput is fused to the cervical spine in inappropriate position or non-functional position [1–3]. In order to avoid postoperative complications, the occiput should be fused in appropriate functional position.

There are several radiographic parameters including occipitocervical angle (OCA) [4], occipitocervical distance (OCD) [4], occiput-C2 angle (O-C2 angle) [2, 5] posterior occipitocervical angle [6], and mandible cervical distance [7], used for the measurement of occipitocervical relationship. These parameters were frequently used to evaluate the functional position of the occiput in relation to the cervical spine and for prediction of postoperative dyspnea and dysphagia. However, OCA, OCD, and O-C2 angle are highly dependent upon the anatomy of the upper cervical spine. The OCA is the angle between a line drawn parallel to C3 upper endplate and the McRae's line. The McRae's line is a radiographic line drawn on a lateral skull radiograph or midsagittal section of CT or MRI, joining the basion and opisthion. If there are changes in the upper C3 endplate, the OCA will be difficult to measure, and it will also be difficult to draw the McRae's line [1, 4]. The OCD is the shortest distance between occipital protuberance and the uppermost part of the spinous process of the axis. The axis spinous process has frequent morphological variation with known morphological difference between genders [1, 4, 7]. The O-C2 is represented by a line drawn parallel to the inferior endplate of the axis and the McGregor's line. The McGregor line is the line connecting posterior edge of the hard palate to the most caudal point of the occipital curve and is a modification of the Chamberlain line, which is the line joining the back of hard palate with the opisthion on a lateral view of the craniocervical junction. It is very difficult to measure O-C2 if there are variations of C2 anatomy by any causes [1, 2, 5, 8].

In order to compensate for the upper cervical spine morphological variance drawback of occipitocervical evaluation, the occipitocervical inclination (OCI) parameter was proposed by Yoon et al. [1]. The OCI is the angle between the McGregor's line and the posterior border of the C4 vertebral body line. The OCI has been shown to be superior to other parameters in the presence of upper cervical spine morphological alteration, due to the ease in obtaining measurement during surgery using C-arm. The reason for using the C4 for OCI measurement is because the C4 is the apex of cervical lordosis and the least affected by cervical lordosis. Nevertheless, the apex of the cervical lordosis is usually known to be at the C4–5 spinal segment [9]. The aim of this study was to evaluate the OCI at the different subaxial spinal levels (C3–C5) in patients with cervical lordosis and disk degeneration of ≤ 3 in order to find the most appropriate level to measure OCI by using upright multi-positional MRI in non-degenerated and mildly degenerated patients. We excluded C6 and C7 from evaluation because even if C6 and C7 are clearly visualized on MRI, they are often not reliably visualized on plain radiograph and on C-arm, which leads to limitation in clinical practice [1, 10, 11].

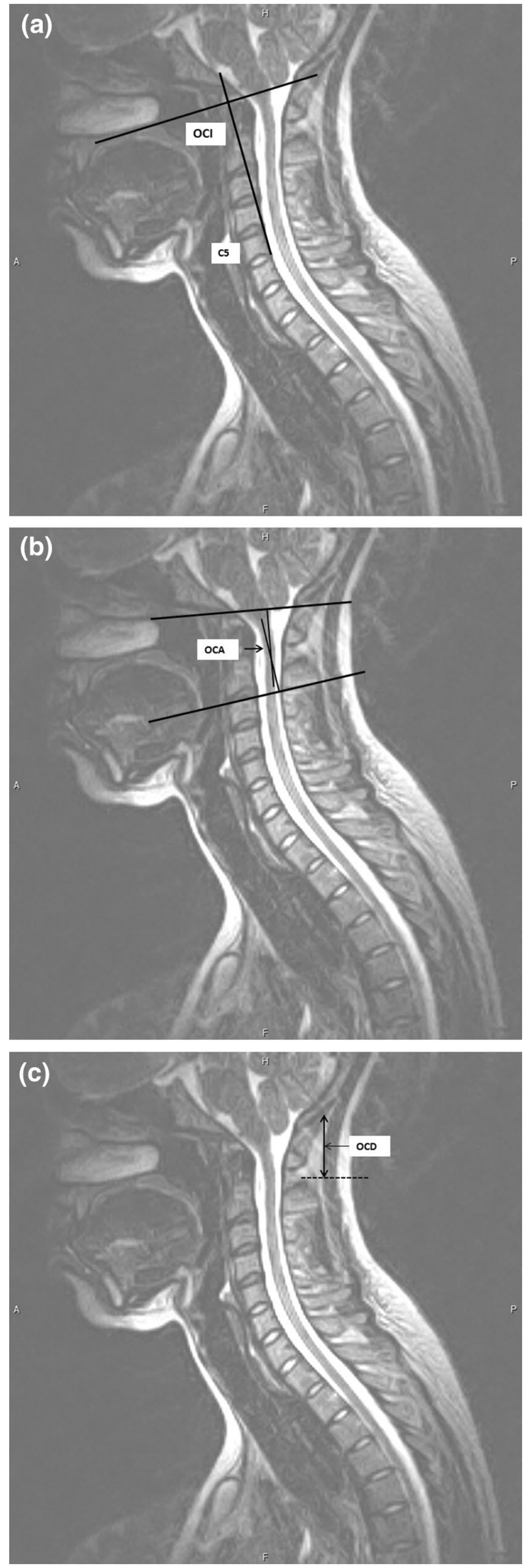
Materials and methods

We evaluated all patients who were referred by a physician to a private radiology center to obtain multi-positional MRI of the cervical spine between November 2010 and August 2017. The inclusion criteria were: (a) cervical lordosis curvature in neutral position, (b) disk degeneration of less than grade 3 [12] (Table 1), and (c) MRI images were clear and had no artifact in all three positions imaged. Patients with cervical spine straight alignment and kyphosis alignment, cervical disk herniation, cervical degenerative spondylolisthesis, cervical spinal segment kyphosis, inflammatory diseases of the spine, congenital anomaly, cervical spine infection, cervical spine tumor, and previous cervical spine surgery were excluded from the study. We also excluded patients whose MRI images exhibited artifact,

Table 1 Grading of cervical disk degeneration

Grade	Nucleus signal intensity	Nucleus structure	Distinction of nucleus and annulus	Disk height
I	Hyperintense	Homogeneous, white	Clear	Normal
II	Hyperintense	Inhomogeneous with horizontal band, white	Clear	Normal
III	Intermediate	Inhomogeneous, gray to black	Unclear	Normal to decreased
IV	Hypointense	Inhomogeneous, gray to black	Lost	Normal to decreased
V	Hypointense	Inhomogeneous, gray to black	Lost	Collapsed

Fig. 1 Measurement of occipitocervical parameters on MRI images. ▶ **a** The occipitocervical inclination (OCI) at C5 cervical spine level. The angle formed by the McGregor's line (line that drawn from postero-superior aspect of the hard palate and the most caudal point of midline occipital curve) and the line drawn from posterior border of the C5 vertebral body, **b** the occipitocervical angle (OCA) is the angle formed by the McRae's line (line drawn between the foramen magnum anterior and posterior edges) and the superior endplate of C3 vertebra, **c** the occipitocervical distance (OCD) is the shortest distance of the vertical line between occipital protuberance and the uppermost part of spinous process of the axis



which obscured the exact measurement on multi-positional MRI. After all inclusion and exclusion criteria were met, 62 patients were included in this study.

Multi-positional MRI

Multi-positional MRI of the cervical spine was performed using a 0.6 Tesla MRI scanner (Upright Multi-Position, Fornar Corp., New York, NY, USA). The MRI is an iron-frame electromagnetic type and 46 cm pole-to-pole, horizontal gap to the patient. The MRI unit uses a horizontal, transverse to the patient orientation, front-open and top-open design, allowing patients to be scanned in the weight-bearing position. The image protocol included T1- and T2-weighted sagittal fast spin-echo images that were obtained using a flexible surface coil with the patient seated in upright weight-bearing neutral, flexion, and extension positions.

Multi-positional upright MRI is a noninvasive technology which allows for patient's scans in weight-bearing positions, including neutral, flexion, and extension [13, 14]. The multi-positional MRI can be reliably used to measure the angular parameters in the cervical spine comparable to dynamic plain radiograph [15].

Occipitocervical inclination (OCI)

OCI is the angle formed by the line connecting the posterior border of the cervical vertebral body and the McGregor's line (Fig. 1a). The McGregor's line is defined as a line from the postero-superior aspect of the hard palate and the most caudal point of the midline occipital curve. We measured OCI at C3, C4, and C5 levels in neutral, flexion, and extension positions.

Occipitocervical angle (OCA) and occipitocervical distance (OCD)

OCA is the angle formed by the McRae's line and the superior endplate of C3 line (Fig. 1b). The McRae's line is drawn between the foramen magnum anterior and posterior edges.

OCD is the shortest distance of the vertical line between occipital protuberance and the uppermost part of spinous process of the axis (Fig. 1c).

C2–7 angle

The C2–7 angle (cervical lordotic measurement) was measured as the angle between the tangent lines of the lower endplates of the axis and C7 (Fig. 2). The positive value was the kyphotic alignment, and the negative value was the lordotic alignment.

Cervical sagittal vertical axis (cSVA)

Sagittal vertical axis C2–C7 is the horizontal distance between the center of C2 and the posterior edge of the C7 upper endplate (Fig. 2). The center of C2 was determined as the point of intersection of crossing diagonals within the C2 vertebral body on the central sagittal MRI picture [16, 17]. Positive value mean center of C2 is anterior to the posterior edge of the C7 upper endplate, and negative value mean center of C2 is posterior to the posterior edge of the C7 upper endplate.

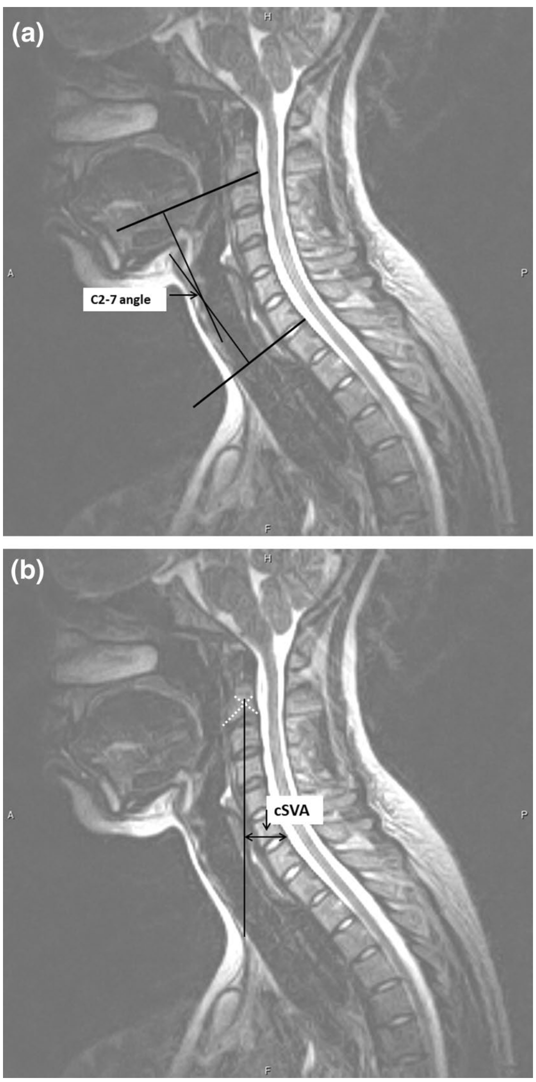


Fig. 2 Cervical parameters. **a** C2–7 angle is the angle formed by the inferior endplate of the C2 vertebra line and the inferior endplate line of C7 vertebra, **b** cervical sagittal vertical axis (cSVA) is the horizontal distance between the center of C2 and the posterior edge of the C7 upper endplate

Statistical analysis

All multi-positional MRI images were evaluated independently by three evaluators. The intraclass correlation coefficients (ICCs) were used to analyze intra- and inter-observer reliability. The ICCs value was assessed as follows: 0–0.2 indicated slight agreement, 0.21–0.4 fair agreement, 0.41–0.6 moderate agreement, 0.61–0.8 substantial agreement, and 0.81–1 excellent agreement [18].

Pearson's correlation coefficient was used to test correlation between C3–5 OCI and C2–7 angle, cSVA, OCA, and OCD. The changes in C3–5 OCI, OCA, and OCD were tested for correlation with the change in C2–7 angle between positions (neutral–flexion and neutral–extension) by using Pearson's correlation coefficient. For OCI itself, the correlation between C3 OCI, C4 OCI, and C5 OCI was analyzed. A Pearson correlation coefficient (r) of 0.00–0.19 was considered a very weak correlation, r of 0.20–0.39 was considered weak correlation, r of 0.40–0.59 was considered moderate correlation, r of 0.60–0.79 was considered strong correlation, and r of 0.80–1.0 was considered very strong correlation [19]. The significant correlation between parameters was further analyzed by simple linear regression analysis. The statistically significant difference level was set at the p value of less than 0.05.

The difference between each of the cervical levels in occipitocervical inclination was analyzed by using Wilcoxon signed-rank test. The Mann–Whitney U test was used to analyze the difference between genders in OCI, OCA, and OCD. The significant level was set at the p value of less than 0.05.

The SPSS version 23.0 (Chicago, IL) was used to perform all statistical analyses.

Results

Sixty-two patients: 24 males and 38 females with a mean age 43.26 years (range 20–64), were enrolled in this study.

The ICCs for C3–5 OCI, OCD, C2–7 angle, and cSVA were excellent agreement in all positions (0.821–0.946), and the OCA showed substantial agreement in all positions (0.681–0.759).

The C3–5 OCI, OCA, OCD, C2–7 angle, and cSVA value in three positions are shown in Table 2.

For OCI, there were statistically significant differences between OCIs at the different cervical vertebral levels in all

Table 2 Occipitocervical inclination of C3–C5, occipitocervical angle, occipitocervical distance, and C2–7 angle in neutral, flexion, and extension position

Parameters ($N=62$ patients)	Position	Mean	SD
Occipitocervical inclination			
Occiput-C3 inclination (°)	Neutral	96.82	7.75
	Flexion	87.77	7.38
	Extension	110.23	10.96
Occiput-C4 inclination (°)	Neutral	100.39	8.94
	Flexion	88.68	9.82
	Extension	118.95	11.12
Occiput-C5 inclination (°)	Neutral	104.04	10.94
	Flexion	87.77	11.14
	Extension	127.79	11.31
Occipitocervical angle (°)	Neutral	22.87	8.78
	Flexion	14.22	9.03
	Extension	34.71	10.13
Occipitocervical distance (mm)	Neutral	18.79	5.18
	Flexion	24.12	6.48
	Extension	10.15	3.46
C2–7 angle (°)	Neutral	− 17.11	11.12
	Flexion	8.63	12.65
	Extension	− 32.77	16.96
Cervical SVA (mm)	Neutral	24.69	12.68
	Flexion	43.24	13.48
	Extension	5.94	10.95

For C2–7 angle: negative value is cervical lordosis, and positive value is cervical kyphosis

SVA sagittal vertical axis

Table 3 Statistical analysis between occipitocervical inclinations at C3, C4, and C5

	Neutral	Flexion	Extension
O-C3: O-C4	0.003*	0.241	< 0.001*
O-C3: O-C5	< 0.001*	0.025*	< 0.001*
O-C4: O-C5	0.0078*	0.004*	< 0.001*

*Statistically significant at the p value of less than 0.05 by Wilcoxon signed-rank test

three positions—except between C3 and C4 OCIs in flexion position (Table 3).

The correlation between OCIs at different cervical level data is shown in Table 4. OCI between contiguous vertebral levels (C3–4, C4–5) showed significantly strong to very strong correlation (r of 0.627–0.822) in all three positions. Between C3 and C5 OCIs, the results showed moderate to strong correlation in all three positions (r of 0.438–0.601).

Figure 3 demonstrates correlation between C3–5 OCI and OCA, OCD, C2–7 angle, and cSVA. C3 OCI showed significantly moderate to strong correlation with OCA, weak to moderate correlation OCD, and weak to moderate correlation with cSVA in all three positions. Only the neutral and extension positions of C3 OCI had significantly moderate and weak correlation with C2–7 angle. C4 OCI showed significant weak to strong correlation with OCA, OCD, and cSVA in all positions, but only significant weak correlation with C2–7 angle in extension position. C5 OCI showed significantly weak to moderate correlation in all three positions with OCA, OCD, C2–7 angle, and cSVA.

Table 4 Pearson's correlation coefficient between occipitocervical inclinations at C3–C5 in three positions

Pearson's correlation	Position	Correlation coefficient (r)	p value
O-C3: O-C4	Neutral	0.750	< 0.001*
	Flexion	0.627	< 0.001*
	Extension	0.677	< 0.001*
O-C3: O-C5	Neutral	0.438	< 0.001*
	Flexion	0.477	< 0.001*
	Extension	0.601	< 0.001*
O-C4: O-C5	Neutral	0.781	< 0.001*
	Flexion	0.822	< 0.001*
	Extension	0.672	< 0.001*

O-C3 occipitocervical inclination at C3 level, *O-C4* occipitocervical inclination at C4 level, *O-C5* occipitocervical inclination at C5 level

*Statistically significant at the p value of less than 0.05

OCA showed significantly weak correlation with C2–7 angle in neutral and extension. For the OCD, there was no significant correlation with C2–7 in all positions. For cSVA, the OCA showed significantly moderate correlation with cSVA in all three positions, whereas no statistical correlation existed between OCD and cSVA (Table 5).

For the value representing a difference between C2–7 and OCI, only the C5 OCI had significantly very weak to weak correlation between neutral–flexion position and neutral–extension position. In addition, there was a trend for a very weak correlation between flexion and extension (Table 6).

Table 7 shows difference between genders for all parameters. Only OCD showed statistically significant difference between genders in all positions.

Discussion

In the current study, the C5 OCI showed statistically significant correlation with all occipitocervical parameters (OCA and OCD), cervical alignment, and balance parameters (C2–7 angle and cSVA). The OCI, OCA, C2–7 angle, and cSVA did not differ between genders. Only OCD had gender differences in all three positions.

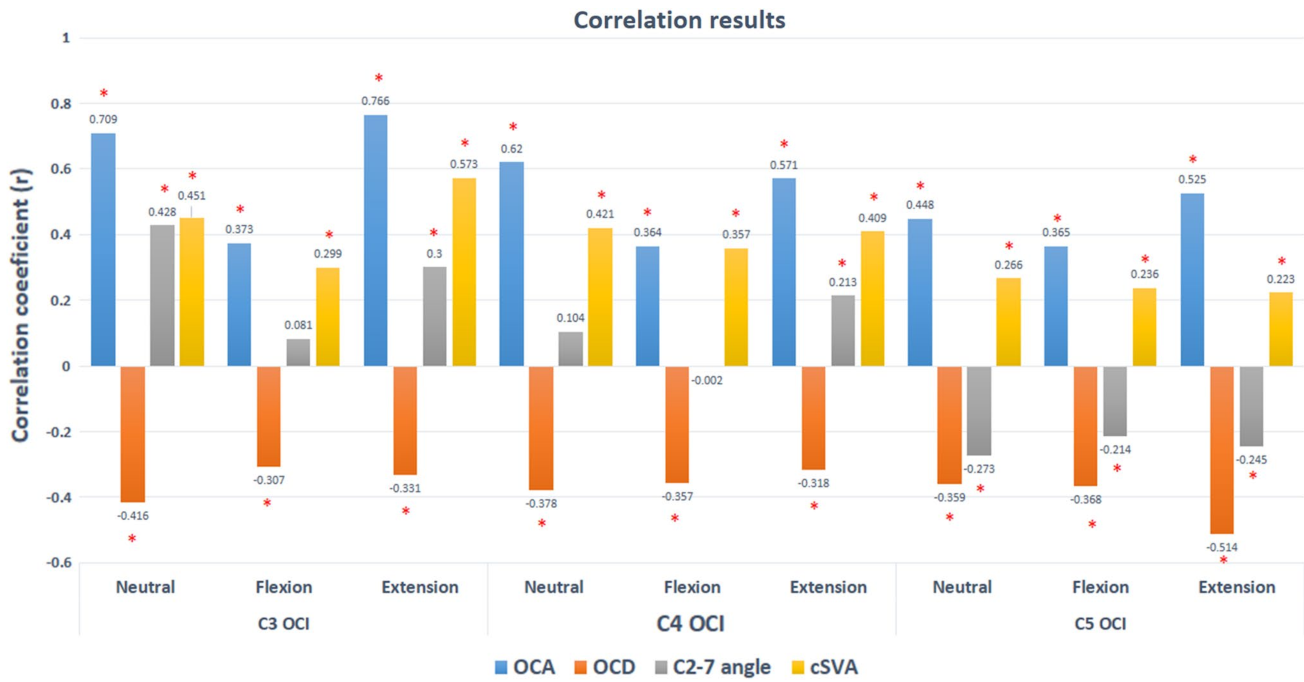


Fig. 3 Correlation results of C3–5 OCI with OCA, OCD, C2–7 angle, and cSVA parameters in neutral, flexion, and extension positions. O-C3 is occipitocervical inclination at C3 level, O-C4 is occipitocervical inclination at C4 level, O-C5 is occipitocervical inclination at C5 level, OCA is occipitocervical angle, OCD is occipitocervical distance, and cSVA is cervical sagittal vertical axis. *Statistically significant at the p value of less than 0.05

Table 5 Correlation between C2–7 angle and occipitocervical angle and occipitocervical distance

	C2–7 angle			cSVA		
	Neutral	Flexion	Extension	Neutral	Flexion	Extension
Occipitocervical angle	0.334* ($p<0.001$)	0.111 ($p=0.24$)	0.320* ($p=0.001$)	0.508* ($p<0.001$)	0.330 ($p<0.001$)	0.552* ($p<0.001$)
Occipitocervical distance	−0.051 ($p=0.588$)	−0.158 ($p=0.96$)	0.017 ($p=0.855$)	0.009 ($p=0.928$)	−0.032 ($p=0.736$)	−0.030 ($p=0.751$)

cSVA cervical sagittal vertical axis

*Statistically significant at the p value of less than 0.05

Table 6 Correlation between the difference among three positions (neutral–flexion, neutral–extension, and flexion–extension) of C2–7 angle and occipitocervical inclination at C3–5, occipitocervical angle, and occipitocervical distance

	C2–7 angle		
	Neutral–flexion	Neutral–extension	Flexion–extension
Occiput-C3 inclination	0.064 ($p=0.499$)	0.025 ($p=0.794$)	0.062 ($p=0.514$)
Occiput-C4 inclination	0.006 ($p=0.954$)	−0.007 ($p=0.944$)	0.031 ($p=0.743$)
Occiput-C5 inclination	−0.195* ($p=0.039$)	−0.273* ($p=0.003$)	−0.175 ($p=0.064$)
Occipitocervical angle	0.136 ($p=0.151$)	0.09 ($p=0.343$)	0.135 ($p=0.154$)
Occipitocervical distance	−0.153 ($p=0.107$)	0.07 ($p=0.46$)	−0.52 ($p=0.581$)

*Statistically significant at the p value of less than 0.05

Although the OCA and OCD are considered as a standard parameter for occipitocervical alignment in neutral position, they depend on the anatomy of the upper cervical spine [1, 4]. Changes in the upper cervical spine morphology can affect OCA and OCD measurements, while also causing difficulty in correctly measuring the McRae's line [1]. The OCI

Table 7 Statistical analysis between genders in OCI, OCA, OCD, C2–7 angle, and cSVA

	Male (mean ± SD)	Female (mean ± SD)	*p* value
OCI C3 (°)			
Neutral	100.2 ± 8.36	99.69 ± 8.99	0.592
Flexion	89.75 ± 8.65	89.48 ± 9.05	0.651
Extension	115.02 ± 10.77	112.43 ± 11.47	0.784
OCI C4 (°)			
Neutral	101.83 ± 8.5	101.95 ± 9.19	0.175
Flexion	88.11 ± 8.82	91.6 ± 9.88	0.833
Extension	121.25 ± 10.98	119.3 ± 14.3	0.102
OCI C5 (°)			
Neutral	101.77 ± 10.12	104.74 ± 10.46	0.618
Flexion	86.25 ± 9.5	90.25 ± 10.72	0.145
Extension	126.5 ± 11.99	128.57 ± 10.35	0.34
OCA (°)			
Neutral	25.48 ± 9.12	25.98 ± 8.99	0.304
Flexion	15.51 ± 8.16	17.05 ± 8.98	0.538
Extension	38.48 ± 10.33	37.2 ± 9.67	0.191
OCD (mm)			
Neutral	19.18 ± 4.69	17.57 ± 4.96	0.042*
Flexion	25.41 ± 5.75	22.67 ± 5.86	0.008*
Extension	10.95 ± 3.52	9.27 ± 2.94	0.014*
C2–7 angle (°)			
Neutral	− 15.79 ± 10.89	− 17.9 ± 11.34	0.069
Flexion	9.84 ± 13.68	7.84 ± 12.08	0.148
Extension	− 33.02 ± 12.05	− 32.61 ± 19.59	0.116
cSVA (mm)			
Neutral	24.56 ± 17.22	24.77 ± 8.98	0.14
Flexion	45.92 ± 15.88	41.54 ± 11.64	0.056
Extension	5.66 ± 13.1	6.12 ± 9.53	0.148

O-C3 occipitocervical inclination at C3 level, *O-C4* occipitocervical inclination at C4 level, *O-C5* occipitocervical inclination at C5 level, *OCA* occipitocervical angle, *OCD* occipitocervical distance, *cSVA* cervical sagittal vertical axis

*Statistically significant at the *p* value of less than 0.05

parameter was introduced in order to compensate for the drawback of the upper cervical spine morphological alteration and the McRae's line.

In the study done by Yoon et al. [1], the C4 OCI value was 102.51° ± 8.87° in neutral, 87.04° ± 7.15° in flexion, and 129.43° ± 11.24° in extension on lateral radiograph. In our study, C4 OCI results were comparable to the previous study, 100.39° ± 8.94° in neutral, 88.68° ± 9.82° in flexion, and 118.95° ± 11.12° in extension. Furthermore, the OCI of C3–C5 in our study showed statistically significant correlation with OCA and OCD, which reflected our results confirming the OCI. Regardless of the level of the cervical vertebra, OCI C3–C5 is one of the reliable parameters for the measurement of occipitocervical alignment. The OCI also showed statistically significant correlation with cervical sagittal balance parameters in all positions comparable with the OCA parameter. The OCD was the least correlated with the other parameters and had statistically significant differences between genders. Our data confirmed previously published literature that the OCD varied among genders and was dependent on morphological variety of the spinous process of the axis [1, 7].

When comparing OCI between different cervical spinal levels, we found that the C5 OCI was the only vertebrae that showed statistically significant correlation with all parameters in all positions, especially with C2–7 angle. C5 OCI and C2–7 angle had a negative correlation in all positions, larger cervical lordosis (negative value), and larger OCI. The C3 OCI and C4 OCI did not show significant correlation with C2–7 angle in all positions, which is different than previously reported. One of the explanations for this inconsistency could be the sample size and the difference in patient groups.

The OCI value between C3, C4, and C5 was different in each position except C3 and C4 OCI in flexion position. From our results, we suggest that surgeons should use the same cervical vertebra to measure the OCI value from preoperative evaluation to postoperative follow-up. Although the OCI value showed statistically significant difference between different cervical vertebra, there was a strong to very strong correlation among them, especially at the adjacent level.

The limitation of this study was the small sample size due to strict inclusion criteria, which can be one explanation for the difference in correlation results of C4 OCI and C2–7 angle. However, the advantage of this study was that we analyzed non-degenerated to moderately degenerated cervical lordosis patients, providing a baseline value for each parameter, and we compared the OCI parameter among three cervical spinal levels.

In conclusion, OCI is a reliable parameter for occipitocervical alignment measurement. The C5 OCI is the only measurement that correlated with both occipitocervical parameters (OCA and OCD) and cervical balance parameters (C2–7 angle and cSVA). C5 OCI should be used in the evaluation of occipitocervical alignment, especially in patients with changes in the upper cervical spine morphology. In a case of C5 invisibility, C4 OCI can be used as a reliable substitute for C5 OCI because of their strong correlation.

Compliance with ethical standards

Conflict of interest No conflicts of interest for the current study.

Disclosure Disclosures outside of submitted work: ZB- consultancy: Xenco Medical, AO Spine (past); Research Support: SeaSpine (paid directly to institution); JCW - Royalties – Biomet, Seaspine, Amedica, DePuy Synthes; Investments/Options – Bone Biologics, Pearldiver,

Electrocore, Surgitech; Board of Directors - North American Spine Society, AO Foundation (20,000 honorariums for board position, plus travel for board meetings), Cervical Spine Research Society; Editorial Boards - Spine, The Spine Journal, Clinical Spine Surgery, Global Spine Journal; Fellowship Funding (paid directly to institution): AO Foundation.

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