Effect of Different Types of Modic Changes on Segmental Motion and Disc Degeneration in Cervical Spine

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Abstract

Background: Few studies have reported the segmental motion characteristics of different types of Modic changes (MCs) in the cervical spine in contrast to the lumbar spine. Considering the close relationship between MCs and disc degeneration (DD), this study is designed to elucidate the relationship of MCs with DD and DD-based angular motion in the cervical spine.

Methods: MRI of C2/3~C6/7 from 594 patients were reviewed and those with MCs were selected and evaluated. MCs were defined as type 0, I, II, and III, and the grade of DD was classified from A to E (recorded from 1 to 5 points) as previously reported. DD score of each segment (sDD), total sDD of the entire cervical spine (tDD), and VAS score (neck pain) of each patient with MC were also recorded. Cervical lordosis (CL), C7 slope (C7S), segmental angular motion (sROM) and total angular motion of the entire cervical spine (tROM) were calculated from X-ray images.

Results: Totally 135 MC segments were evaluated. In the two groups of DD D and DD E, the sROM of MC I and III segments are smaller than that of MC 0 segments, and the sROM of MC II segments are similar to that of MC 0. In addition, MC I segments present smaller sROM than that of MC II in the group of DD E, and their sROM are larger than that of MC III in the group of DD D. No difference is found in tROM between the patients with MC I, II and III. Our results also show that MC I and III segments are associated with high sDD and tDD scores. Finally, the patients with MC I have larger CL and C7S than those with MC III, and there is no statistical difference in VAS scores of neck pain between the patients with MC I, II and III.

Conclusions: In the cervical spine, both MC I and III indicate decreased segmental angular motion and high disc degeneration grade. Cervical MCs may not be a sign of unstable neck pain or an indication for interbody fusion.

Background

Modic changes (MCs), which were firstly reported by Modic et al. in 1988 [1], were defined as signal intensity changes of vertebral endplates and subchondral bone observed from magnetic resonance imaging (MRI) of patients with spinal degenerative diseases [2]. Generally, MCs are classified into 3 types with different typically changed MRI signals: MC I, II, and III. Sometimes, authors also consider a normal endplate as MC type 0 or grade 0 [3, 4]. In the recent few decades, several authors believe that MC I will cause segmental instability, which requires lumbar interbody fusion [5-7], and our previous study also has shown that MC II can increase translational segmental motion while MC III can reduce segmental mobility in the lumbar spine [3]. However, the effects of different types of MCs on the cervical segmental motion remain unclear. The results of the previous studies only indicate that the presence of MC affect segmental mobility, but the specific role of MC I, II and III are still inconclusive [8, 9]. Moreover, since segmental mobility is determined by both the endplate and intervertebral disc [2], it is necessary to exclude the influence of the disc degeneration (DD) on the segmental mobility when discussing the

kinematic characteristics of MCs [3]. Therefore, in this study, we hypothesize that MC I, II and III have different effects on segmental mobility on the basis of the same grade of DD, and they may have some relationship with DD grades.

Methods

Patient Population

Informed consent was obtained from all individual participants in the study, and the study was approved by the Ethical Committee of Huashan Hospital of Fudan University (No. 2017-056). 594 cervical degenerative patients (317 men and 277 women, 58.7y ± 10.99) were reviewed from September 2018 to August 2019. The inclusion criteria were defined as patients who had neck pain with or without neurologic symptoms (i.e., radiculopathy or myelopathy). The exclusion criteria were trauma, infection, rheumatoid arthritis, spinal tumors, and history of cervical spine surgery. A total of 2975 segments from C2/3 to C6/C7 were retrospectively evaluated for all the patients in this study, and the patients with MC I, II and III were selected and evaluated for comparisons. Neck pain was record by using VAS (visual analogue scale) scores.

Image Assessment

All images were recorded by computer-based measurements, and all calculations were performed with Centricity Web 2.1 (GE Healthcare, Boston, Massachusetts, USA).

MRI was used for MC classification and DD grading. All MR images for MCs were reviewed twice by 2 blinded radiologists, and the intra- and inter-observer reliability of the ratings for MCs were assessed using the κ value and was assessed using 50 cases (250 intervertebral levels). MCs were classified into types 0, I, II, and III. Type 0, normal endplate; Type 1, hypointense signal on T1-weighted sequences and hyperintense signal on T2-weighted sequences; Type 2, hyperintense signal on T1 sequences and hyper- or iso-intense signal on T2 sequences; Type 3, hypointense signal on T1 and T2 sequences [3] (Fig. 1). Grading System for Cervical Intervertebral Disc Degeneration proposed by Hayashi et al [9] was used for DD (C2/3 to C6/7) grading (Table 1), and DD grade A to E was scored from 1 to 5 points. DD score of each segment (sDD) and total DD scores of the entire cervical spine from C2/3 to C6/7 (tDD) were both recorded.

Table 1
Grading System for cervical intervertebral disc degeneration

DD Grade	Score	Nucleus signal intensity	Nucleus structure	Distinction of nucleus and annulus	Disc height
A	1	Hyperintense	Homogeneous, white	Clear	Normal
B	2	Hyperintense	Inhomogeneous with horizontal band, white	Clear	Normal
C	3	Intermediate	Inhomogeneous, gray to black	Unclear	Normal to decreased
D	4	Hypointense	Inhomogeneous, gray to black	Lost	Normal to decreased
E	5	Hypointense	Inhomogeneous, gray to black	Lost	Collapsed

Angular motion range, which was measured from X-ray images in flexion and extension positions, was selected for kinematical evaluation in this study (Fig. 2a and b). It is not only because most of the authors consider angular motion change as the most important value affected by cervical MCs [8, 10, 11], but also due to the trivial translational change caused by cervical MCs when is compared to the angular motion change [8]. Briefly, vertebral bodies were marked at 4 points (anterior-inferior, anterior-superior, posterior-superior, and posterior-inferior) from C2 inferior endplate to C7 superior endplate, and segmental angular motion range (sROM) was calculated as the absolute value of the difference between the angle between adjacent vertebral bodies in flexion and in extension in degrees. Similarly, total angular motion range (tROM) was recorded as the difference in C2–C7 angle (defined as the angle formed by the inferior end plates of C2 and C7) during flexion and extension (Fig. 2a and b). In addition, cervical lordosis (CL) and C7 slope (C7S) were also measured for all the patients from X-ray images in neutral positions (Fig. 2c). CL was judged based on the C2–C7 Cobb angle, and C7S was defined as the angle formed by the horizontal plane and the upper end plate of C7. C7S was used instead of T1 slope because of difficulty in measuring T1 slope in many patients. The calculations of all patients were conducted and recorded by an experienced spine specialist twice and the final values of angular motion, CL and C7S were the means of the two measurements. Pain killers were routinely used before patients underwent imaging studies to ensure clear and accurate images.

Statistical analysis

Statistical analyses were performed using SPSS (version 20; SPSS, Chicago, IL) computer software and values were expressed as mean ± standard deviation (SD). A P value of 0.05 was considered statistically significant. One-way ANOVA followed by LSD was applied to compare VAS, DD scores, cervical motions and sagittal parameters between different MC types; independent-sample t test was used to compare sROM between DD grade D and E. The reliability of diagnosis of MCs was assessed as follows: κ: 0–0.2 showed 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.

Results

Prevalence of MCs

MC I to III were observed in 119 (20%) of 594 patients, including 20 cases of MC I, 87 cases of MC II and 12 cases of MC III.

MC I to III were observed on 135 segments, including MC I on 20 segments, MC II on 103 segments, and MC III on 12 segments. Most of the MCs were found on C5/C6 (48 segments), followed by C6/7 (40 segments), C4/5 (24 segments), C3/4 (15 segments), and C2/3 (8 segments)Table 2.

No MC was observed on the segment with normal disc (DD grade A); MC I and III were not found on the segments with DD grade B either. Several groups had relatively small numbers: DD B-MC II (2 segments), DD C-MC I (1 segment), DD C-MC III (1 segment), DD D-MC III (5 segments), DD E-MC I (9 segments) and DD E- MC III (6 segments) Table 2.

Table 2
sROM and sample size of the measured segments with or without MCs

DD Grades	MCs	C2/3	C3/4	C4/5	C5/6	C6/7	Total (Seg.)
A	0	5.2□1 seg.□	/	/	/	/	1
	I	/	/	/	/	/	0
	II	/	/	/	/	/	0
	III	/	/	/	/	/	0
B	0	2.05±0.23 □55 seg.□	5.2±3.13 □15 seg.□	13.2±5.74 □14 seg.□	5.6□1 seg.□	7.9□1 seg.□	86
	I	/	/	/	/	/	0
	II	5.0□1 seg.□	7.7□1 seg.□	/	/	/	2
	III	/	/	/	/	/	0
C	0	5.52±3.27 □39 seg.□	7.98±5.51 □49 seg.□	8.21±4.7 □37 seg.□	8.30±5.19 □21 seg.□	7.11±4.13 □26 seg.□	172
	I	/	/	/	/	7.0□1 seg.□	1
	II	5.07±3.58 □4 seg.□	10.23±5.86 □4 seg.□	8.57±5.13 □9 seg.□	5.72±4.48 □9 seg.□	5.40±3.35 □5 seg.□	31
	III	/	/	0.78□1 seg.□	/	/	1
D	0	4.89±2.58 □16 seg.□	8.47±4.45 □35 seg.□	6.79±3.72 □31 seg.□	8.23±4.29 □30 seg.□	6.95±4.00 □35 seg.□	147
	I	/	4.05□1 seg.□	3.43±1.48 □3 seg.□	5.15±2.25 □5 seg.□	2.9□1 seg.□	10
	II	12.63±7.67 □3 seg.□	7.14±4.88 □7 seg.□	5.72±3.67 □6 seg.□	6.15±3.39 □18 seg.□	5.34±3.91 □13 seg.□	47
	III	/	/	/	0.7±0.57□2 seg.□	0.77±0.51 □3 seg.□	5
E	0	/	5.9±1.37□5 seg.□	7.43±4.65 □13 seg.□	4.23±3.93 □19 seg.□	4.05±1.06 □17 seg.□	54
	I	/	/	2.3□1 seg.□	2.93±1.24 □4 seg.□	2.39±0.29 □4 seg.□	9
	II	/	7.3±2.69□2 seg.□	3.80±3.99 □3 seg.□	6.56±2.71 □7 seg.□	2.85±3.32 □11 seg.□	23
	III	/	/	1.0□1 seg.□	2.36±1.62 □3 seg.□	0.3±0.04□2 seg.□	6
Total(n)		119 (MC in	119 (MC in	119 (MC in	119 (MC in	119 (MC in	595

	8 seg.)	15 seg.)	24 seg.)	48 seg.)	40 seg.)

The inter-observer agreement of MC was substantial with a κ value of 0.744. The intra-observer agreement of MC of the two radiologists was excellent with a κ value of 0.878 and 0.855.

sROM and tROM of different types of MCs

Because only 1 MC I and 1 MC III segment was observed in the group of DD C (Table 2), statistical analysis was conducted for the MC segments in the group of DD D and DD E (Fig. 3).

In the group of DD D, MC 0 segments (7.11°±4.04) have significantly larger sROM than those with MC I (4.38°±1.82, P=0.024) and III (0.69°±0.34, P□0.01); Segments with MC I and II (6.35°±4.27) present larger sROM than those with MC III (P=0.038; P□0.01) ; No difference is found in sROM between segments with MC 0 and II (P=0.205), and between segments with MC I and II (P=0.132).

In the group of DD E, similar trend is observed. MC 0 segments (5.32°±3.8) have larger sROM than those with MC I (2.33°±1.04, P□0.01) and III(1.30°±1.27, P□0.01); Segments with MC II (5.04°±2.79) have larger sROM than those with MC III (P□0.01). However, we also find MC II segments present larger sROM than MC I segments (P=0.012). No difference is found in sROM between the segments with MC 0 and II(P=0.574), and between the segments with MC I and III(P=0.408).

Results of the comparison in sROM between the groups of DD D and DD E show that, the segments with MC 0 and I in the group DD D have significantly larger sROM than those in the group of DD E (P=0.035 and □0.01).

No statistical difference is found in tROM between the patients with MC I, II and III (P=0.527).

DD and VAS scores of the segments and the patients with different types of MCs

As is shown in Fig. 4a, the segments with MCs are associated with significantly higher sDD scores than those without MCs (MC 0) (all P□0.05); the segments with MC I present higher sDD scores than those with MC II (P=0.015); the segments with MC III present higher sDD scores than MC II though statistical difference is not observed (P=0.052). According to Fig. 4b, the patients with MC I and III have higher tDD scores than those with MC II (all P□0.05), but no significant difference is found between MC I and MC III (P=0.114).

As is shown in Fig. 4c, no statistical difference is observed in the VAS scores of neck pain between the patients with MC I, II and III (P=0.356).

Sagittal parameters of the patients with different types of MCs

According to Fig. 5, the patients with MC I have larger CL and C7S than those with MC III (P=0.016 and 0.046 respectively).

Discussion

In the lumbar spine, each type of MC has a different effect on the segmental mobility, and a specific type of MC may be the cause of low back pain and an indication of fusion [3, 5-7, 12]. As more and more scholars begin to pay attention to cervical spine MC [8, 9], it is also of important clinical significance to explore the influence of different types of cervical spine MCs on segmental mobility. Considering that there is a close relationship between MC and DD, and the segmental mobility is determined by both endplate and intervertebral disc degeneration [3, 12], this study aims to explore the kinematic characteristics of cervical spine MC based on the grading of DD, and to analyze the relationship between MC type and intervertebral disc degeneration grade.

1. Prevalence and distribution of the cervical MCs

The prevalence of cervical MCs is lower than those of the lumbar spine, resulting in fewer related studies. According to our results, 20% patients have cervical MCs and most of them are MC II, which is similar to previous reports (16.9%~19.2%) [8, 9, 13].

Most of the MCs are found on C4/5, C5/6 and C6/7, especially on C5/6, which is also consistent with the literatures [8, 9, 13-17]. The reason to explain why C5/6 is the most common level to exhibit MCs is not difficult because C5/6 is believed to have larger segmental motion range than any other levels [18, 19]. Similarly, it can also explain why MC is often observed on C4/5, because C4/5 also has great segmental mobility [20].

The reason for why more MCs are found on C6/7 than C4/5 in our study is interesting. Several authors have reported the effects of MCs on cervical sagittal balance and many of them suggested that patients with MCs have larger cervical curvature, larger T1 slope or C7S [21-23]. Higher T1 slope or C7S needs more CL to keep horizontal balance, which may cause more stress and hypermobility at the bottom of the cervical spine (C5/6 and C6/7), resulting in unusual mechanical stress and more endplate degeneration [21].

2. MC I indicate small sROM and advanced DD grade.

MC I are considered as the early phase of endplate degeneration, although only a few authors clearly reported the effects of MC I on segmental motion, they are still believed to cause segmental instability in

the lumbar spine [5, 24-27]. However, in this study, we find that the segments with MC I present lower sROM than those with MC 0 in the group of DD D and DD E, which is actually consistent with the conclusions of Hayashi et al [9]. Moreover, the VAS scores of neck pain in the patients with MC I are similar to that of patients with MC II and III (Fig. 4c), indicating that MC I may not be the cause of unstable neck pain.

According to previous reports, the reason why cervical MC I can cause segmental motion reduction is because MC I are always accompanied by advanced DD grades that can significantly decrease segmental motion [9, 19]. Our results also show that the sDD scores of MC I are significantly higher than those of MC II and similar to those of MC III (Fig.4a), more importantly, we even find that between the segments with the same DD grade, the segments with MC I present much smaller sROM than those with MC 0 and MC II, indicating that MC I itself has the effect of reducing sROM (Fig.3a).

As the CL, C7S and tDD of the patients with MC I are relatively large (Fig. 4b and 5), the reason why MC I is always accompanied by high-grade DD can be explained by cervical spine aging, because the increase in CL and C7S is considered to be a compensatory change in the aging process of the cervical spine [28].

3. MC II indicate unchanged sROM and it is the transition phase of endplate degradation between MC I and III

Though MC II are accompanied by lower sDD, tDD scores than those of MC I and MC III (Fig. 4a and 4b), we still consider MC II as the middle transition phase between MC I and III for the following reasons:

(1) During the degeneration process from DD A to DD D, though sROM keeps decreasing, the difference is not actual significant, but when disc degenerate from DD D to DD E, sROM reduction becomes statistically significant [19]. This theory is also supported by our result which is that, when disc degenerate from grade D to E, sROM of MC 0 and I decrease significantly (Fig. 3a). As a result, in the segments with advanced DD (especially grade E), sROM are primarily determined by the status of endplate degeneration instead of the disc, which has been proven by us in the lumbar spine [3]. In this study, when MC I turn into MC II in DD E, sROM increase significantly (Fig. 3a), which is the same as that of MC II in the lumbar spine, that is, MC II is a transitional phase between MC I and III that can increase segmental mobility [3];

(2) Both MC I and II are unstable and they can convert to each other [2], as a result, though MC I have higher DD scores than those of MC II in our study, several of them may be actually converted from MC II, indicating that they may have longer degeneration process than expected. In addition, many segments with MC I-II mixed type are found in our study, which can also support this theory.

4. MC III indicate the final phase of endplate degeneration process, which can significantly reduce sROM

MC III is the final and stable phase of endplate degeneration process and is wildly agreed to significantly decrease segmental angular and translational motion in the lumbar spine [2, 3]. According to our results, similar results are found in the cervical spine, that is, MC III indicate small sROM and high-level DD grade. However, the patients with MC III have significantly smaller CL and C7S than those with MC I, indicating that high-grade DD may be due to the straight cervical spine rather than cervical spine aging [28].

5. Effect of MCs on tROM

The tROM of patients with MCs are affected by many factors. In our study, neck pain degree and disc degeneration level of the entire cervical spine are considered the most important.

Our results show that no statistical difference in tROM is found between the patients with MC I, II and III, and they are all smaller than the normal range [29]. Though pain killers were routinely used before patients underwent imaging studies, the effects of pain on decreasing cervical motion cannot be completely ruled out which may finally cause the similarity of tROM between the patients with MC I, II and III [Fig. 4c]. In addition, we find that the sDD scores of the segments with MCs are higher than that of the segments without MCs, and MC I and III have similar high sDD and tDD scores [Fig. 4a and b], which indicate that the overall high degree of degeneration of the cervical spine limits the tROM of the patients with MCs.

Conclusions

In the cervical spine, the segments with MC I and III present smaller angular motion range than those with MC II and MC 0, though no difference in total cervical motion range are found between the patients with MC I, II and III. Both MC I and III indicate high disc degeneration degree but they are probably due to cervical aging and small cervical lordosis respectively. Finally, cervical MCs may not be a sign of unstable neck pain or an indication for interbody fusion.

Abbreviations

MC: Modic change

DD: Disc degeneration

VAS: Visual analogue scale

sDD: DD score of each segment

tDD: Total DD scores from C2/3 to C6/7

sROM: Segmental angular motion range

tROM: Total angular motion range

CL: Cervical lordosis

C7S: C7 slope

Declarations

Ethics approval and consent to participate

Informed consent was obtained from all individual participants in the study, and the study was approved by the Ethical Committee of Huashan Hospital of Fudan University (No. 2017-056), Shanghai, China

Consent to publish

Not applicable

Availability of data and materials

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

None

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Authors' contributions

FZ, JWand HCX performed the study. FZL was responsible for coordination, data collection/interpretation and proofreading of the final manuscript. FZ, JWand HCX conceived of the study and participated in its design. All authors read and approved the final manuscript.

Acknowledgements

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Figures

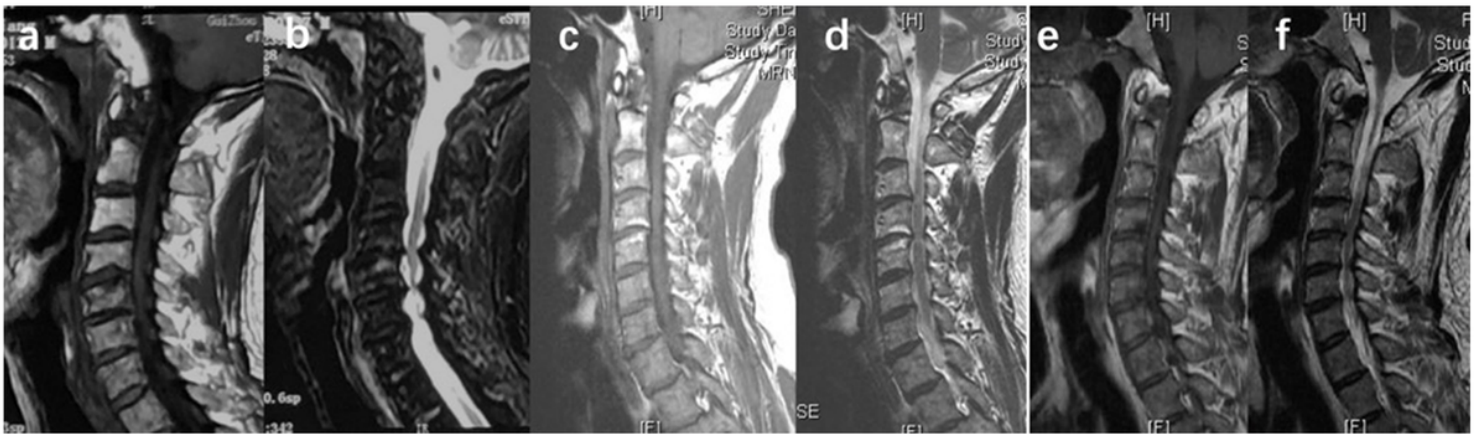

Figure 1

MRI images of MC I, II and III a, b: MC I in C4–5 seen as low signal in T1-weighted (a) and a high signal in T2-weighted sequences (b). c, d: MC II in C4–5 seen as high signal in T1-weighted (c) and a high signal in T2-weighted sequences (d). e, f: MC III in C4–5 seen as low signal in T1-weighted (e) and a low signal in T2-weighted sequences (f).

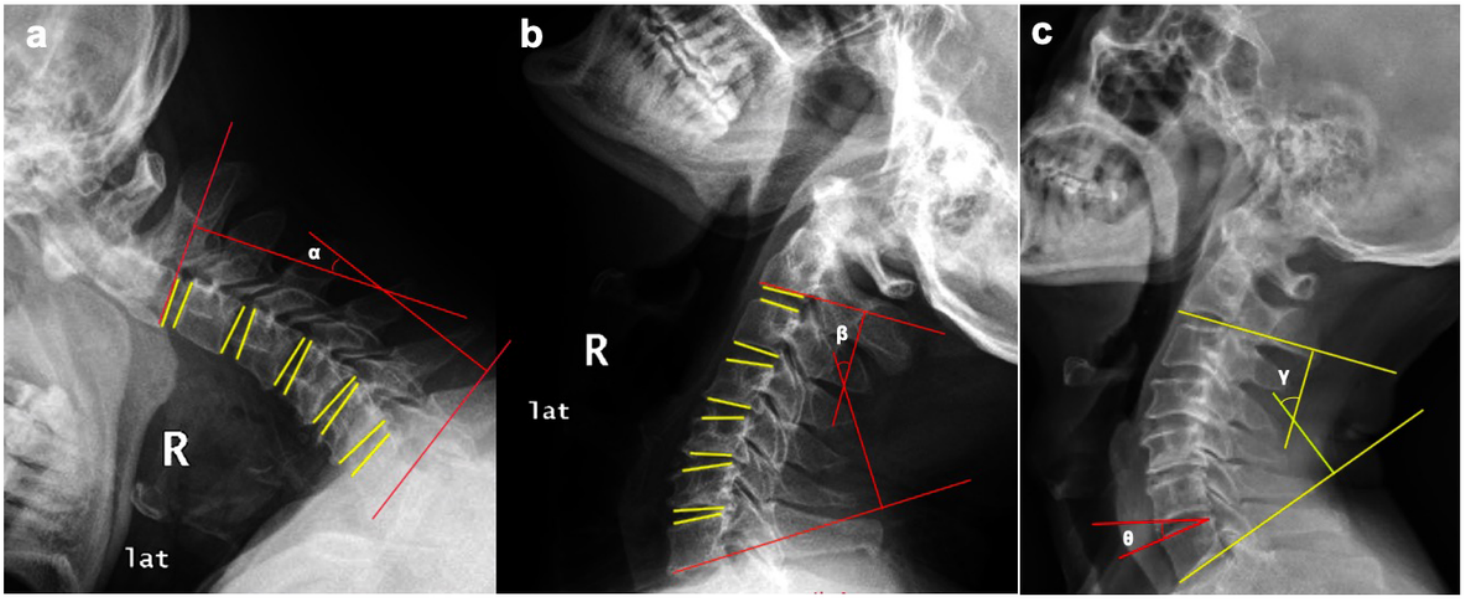

Figure 2

sROM was defined as the angle difference formed between yellow lines of each segment from extension(a) and flexion(b), and tROM was defined as the angle difference between C2-7 angle (α and β) difference from flexion (a) and extension (b). CL and C7S were indicated as γ and θ in the neutral X-ray image (c).

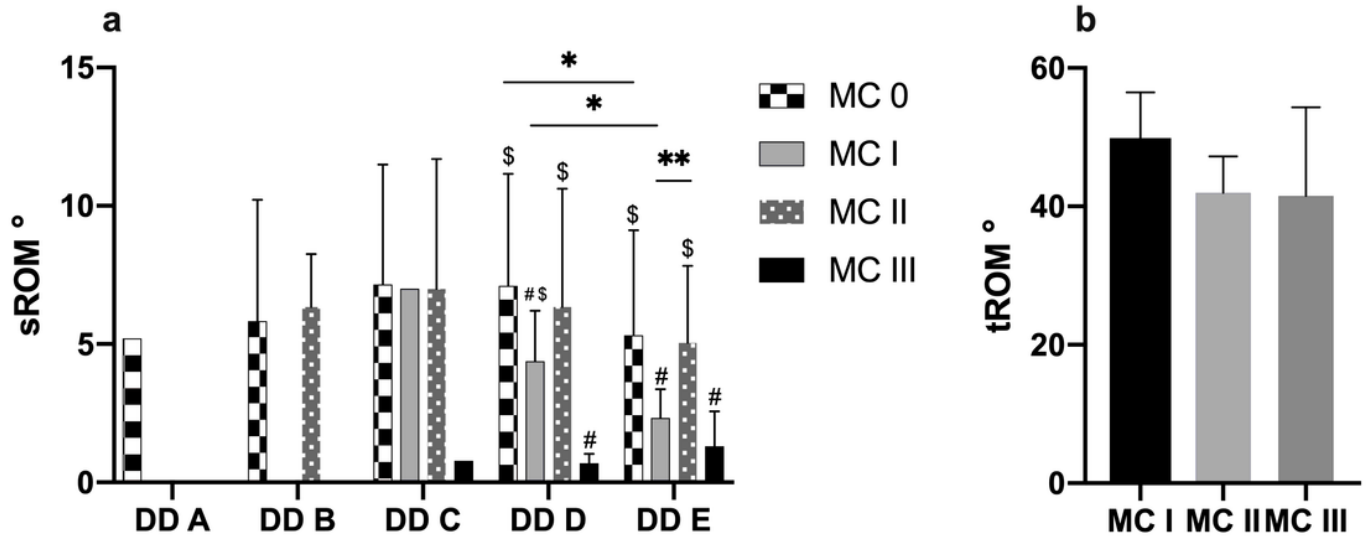

Figure 3

sROM and tROM of different MC types. * indicates segments in the group of DD D present significantly larger sROM than those in the group of DD E (P=0.035 in MC 0 and P=0.03 in MC I); ** indicates the statistical difference in sROM between MC I and II in the group pf DD E; # indicates MC I and III have statistically smaller sROM than MC 0; $ indicates the sROM of MC 0, I and II are significantly larger than that of MC III;

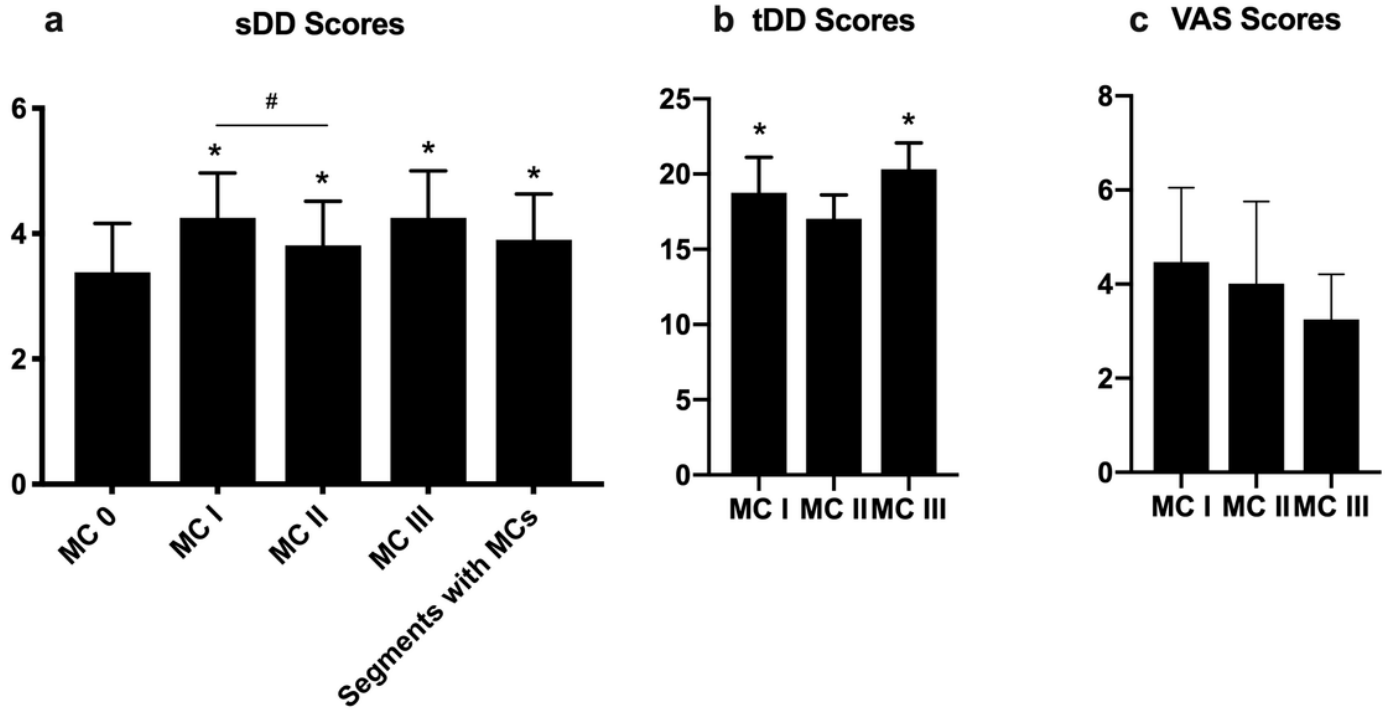

Figure 4

sDD scores(a), tDD scores(b) and VAS scores (Neck pain, c) for the patients with MC I, II and III. a: * indicates that the sDD score of MC 0 is significantly lower than that of any other MC type (P□0.01); # indicates that the sDD score of MC I is significantly higher than that of MC II (P=0.015); b: * indicates the tDD score of MC II is significantly lower than those of MC I and III (all P□0.05); c: No statistical difference is observed in the VAS scores of neck pain between the patients with MC I, II and III (P=0.356).

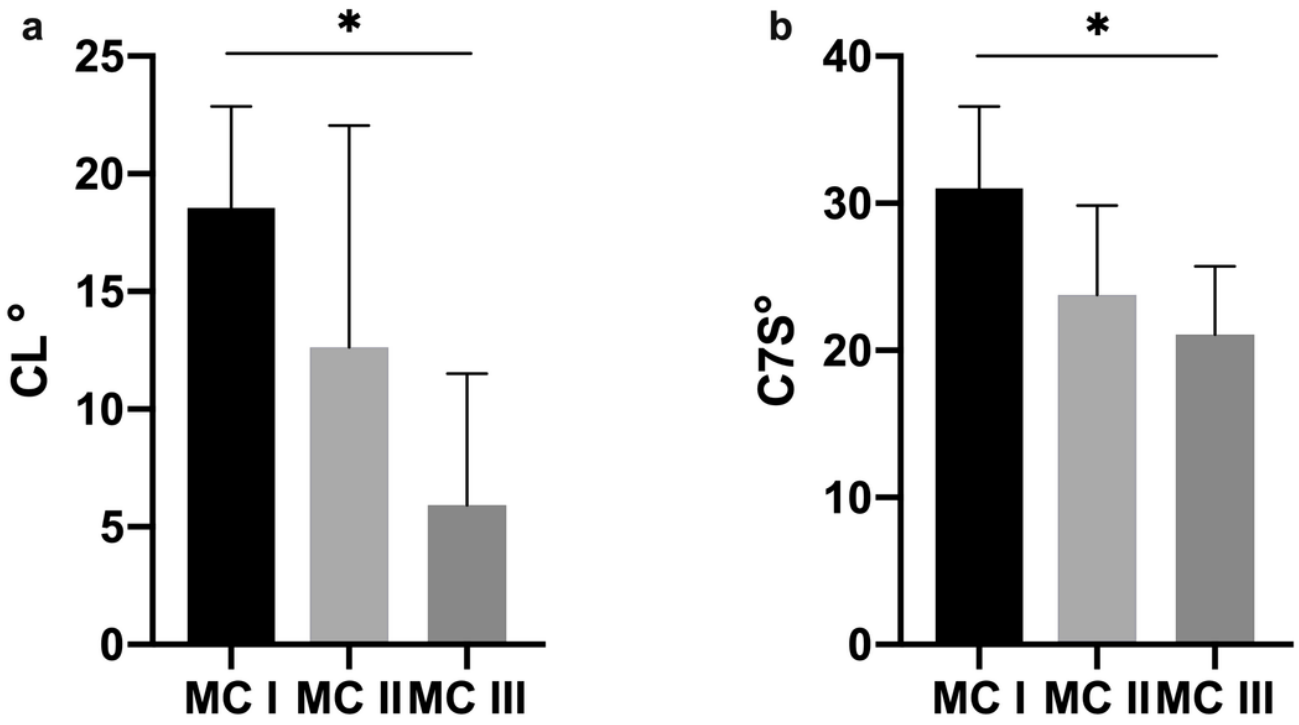

Figure 5

CL(a) and C7s(b) of the patients with different MC types. a: * indicates patients with MC III have much lower CL than those with MC I (P=0.016); b: * indicates patients with MC I much larger C7S than those with MC III (P=0.046).