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ORIGINAL ARTICLE

Factors influencing spinal sagittal balance, bone mineral density, and Oswestry Disability Index outcome measures in patients with rheumatoid arthritis

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Abstract

Purpose To identify the factors influencing spinal sagittal alignment, bone mineral density (BMD), and Oswestry Disability Index (ODI) outcome measures in patients with rheumatoid arthritis (RA).

Methods We enrolled 272 RA patients to identify the factors influencing sagittal vertical axis (SVA). Out of this, 220 had evaluation of bone mineral density (BMD) and vertebral deformity (VD) on the sagittal plane; 183 completed the ODI questionnaire. We collected data regarding RA-associated clinical parameters and standing lateral X-ray images via an ODI questionnaire from April to December 2012 at a single center. Patients with a history of spinal surgery or any missing clinical data were excluded. Clinical parameters included age, sex, body mass index, RA disease duration, disease activity score 28 erythrocyte sedimentation rate (DAS28-ESR), serum anti-cyclic citrullinated peptide antibody, serum rheumatoid factor, serum matrix metalloproteinase-3, BMD and treatment type at survey, such as methotrexate (MTX), biological disease-modifying anti-rheumatic drugs, and glucocorticoids. We measured radiological parameters including pelvic incidence (PI), lumbar lordosis (LL), and SVA. We statistically identified the factors influencing SVA, BMD, VD, and ODI using multivariate regression analysis.

Results Multivariate regression analysis showed that larger SVA correlated with older age, higher DAS28-ESR, MTX nonuse, and glucocorticoid use. Lower BMD was associated with female, older age, higher DAS28-ESR, and MTX nonuse. VD was associated with older age, longer disease duration, lower BMD, and glucocorticoid use. Worse ODI correlated with older age, larger PI-LL mismatch or larger SVA, higher DAS28-ESR, and glucocorticoid use.

Conclusions In managing low back pain and spinal sagittal alignment in RA patients, RA-related clinical factors and the treatment type should be taken into consideration.

Keywords Spinal sagittal alignment · Oswestry Disability Index · Rheumatoid arthritis · Disease activity score · Glucocorticoid · Methotrexate

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Introduction

Spinal sagittal alignment has become important in assessing the pathology and health-related quality of life (HRQOL) associated with low back pain (LBP) in patients with adult spinal deformity (ASD) [1–3]. In particular, PI-LL mismatch, high PT, and large SVA have been shown to indicate worse Oswestry Disability Index (ODI) scores in ASD patients [4–6].

On the other hand, little attention has been given to spinal sagittal alignment and its influence on HRQOL in rheumatoid arthritis (RA) patients because lumbar spinal lesions associated with RA have been rare [7]. However, previous studies revealed that approximately 50–75% of patients with RA have a history of low back pain [8–10] and that patients with RA and low back pain showed significantly higher degrees of disability and depression than those without low back pain [11]. Therefore, management of low back pain in patients with RA is as important as that of joint destructions and cervical lesions for spine surgeons.

Previous studies showed that aging, loss of LL, and decreases in the quality and quantity of paravertebral muscle caused spinal sagittal imbalance [12–17]. In RA patients, clinical conditions are more complicated because they are administered various kinds of drugs which may influence bone metabolism and muscle, such as methotrexate (MTX), biological disease-modifying anti-rheumatic drugs (bioDMARDs), and glucocorticoids [18]; Previous studies revealed that MTX and bioDMARDs improve bone metabolism [19–21] and that RA itself and glucocorticoids cause bone fragility [22–30] and muscular atrophy [31–34].

We hypothesized that spinal sagittal alignment and ODI in RA patients are influenced by the disease activity and RA treatment type. We performed a cross-sectional cohort study at a single center to identify the factors influencing SVA, vertebral deformity (VD) on the sagittal plane, bone mineral density (BMD), and ODI in RA patients using statistical analysis.

Patients and methods

Eligibility criteria

We enrolled consecutive RA patients at our hospital from April to December 2012. The inclusion criteria allowed patients from whom written informed consent was obtained, who were ≥ 18 years of age, and who met the American College of Rheumatology/European League Against Rheumatism classification criteria for RA in 1987 [35] or 2010 [36]. When informed consent could not be obtained or was withdrawn later, any clinical data were missing, or the patients had a history of spinal surgery, the patients were excluded. In our hospital, many studies associated with RA are simultaneously performed, and patients are allowed to participate in individual studies as they wish. To identify the factors influencing SVA and ODI, we performed physical examination of joints, serum tests, and standing lateral X-ray, dual-energy X-ray absorptiometry (Discovery DXA system, Hologic, Inc) at hip as well as administered the Patient's Global Assessment of RA disease activity questionnaire and ODI as a patient-based outcome of HRQOL related to low back pain. The study protocol followed the guidelines of the Declaration of Helsinki and was approved by the local ethics committee in our institution.

RA-related clinical parameters

Clinical parameters at enrollment were recorded by the attending rheumatologists and included age, sex, body mass index, disease duration of RA, serum anti-cyclic citrullinated peptide antibody, serum rheumatoid factor, serum matrix metalloproteinase-3, BMD and type of treatment, such as MTX, bioDMARDs, and glucocorticoids. Disease activity score 28-erythrocyte sedimentation rate (DAS28-ESR) was calculated as the disease activity of RA.

Spinal sagittal alignment

Spinal sagittal alignment and VD were measured and diagnosed on digitized lateral standing X-ray images with the subject in the fists-on-clavicle positions by two observers who used picture archiving and communication systems software (GE Medical Systems, Milwaukee, WI). PI, LL (L1-S), SS, PT, TK (T5-12), and SVA were measured according to a previously reported method [5]. The presence of at least one VD between T5-L5 levels was diagnosed according as grade ≥ 1 by the semiquantitative method originally described by Genant et al. [37]. One observer was a medical student, and the other was a clinical fellow, both of whom were blinded to each other's measurement values and VD diagnosis. For the statistical analyses, we used data from a clinical fellow. The data from the medical student were used to ensure the reliability of these measurements between the two observers. The clinical fellow measured these parameters again at ≥ 3 months after the first measurement and analyzed intra-observer reliability.

Statistical analysis

Statistical analysis was performed using JMP Pro, version 12.0.0 (SAS, Institute Inc., Cary, NC, USA). Intra- and inter-observer reliabilities of the radiological measurement and the kappa coefficients of the diagnosis of VD between the two observers were calculated. Spearman's rank correlation coefficient was used in the univariate association analysis between continuous objective and explanatory variables that were not normally distributed. Continuous objective variables were compared using the Student's *t* test if normally distributed and using the Wilcoxon rank sum test, if nonnormal. On univariate analysis of binary objective variables, simple logistic regression was used for continuous explanatory variables and Fisher's exact probability test for binary explanatory variables. A p value of < 0.05 was considered statistically significant. Multivariate regression models of factors influencing SVA, BMD, and ODI were made using the least-squares method, and a model of factors influencing VD was made with multiple logistic regression analysis wherein explanatory parameters were selected using the forward stepwise method, which indicated the least AIC value, as previously reported [38, 39]. The candidate explanatory parameters of SVA and BMD were age, sex, disease duration of RA, DAS28-ESR, MTX use, bioDMARDs use, and glucocorticoid use on the basis of our hypothesis that disease activity of RA and type of RA treatment influence sagittal spinal alignment. In the VD analysis, we added BMD to these candidate explanatory parameters. In the ODI analysis, we added SVA and PI-LL to these candidate explanatory factors and selected them as dependent variables.

Results

A total of 370 RA patients were enrolled. After exclusion of 98 patients, 272 patients were finally included for analyzing the factors influencing SVA (Group SVA). In Group SVA, BMD values were available in 220 patients, and they were included for analyzing BMD and VD (subgroup VD). Moreover, 183 patients in Group SVA completed the ODI questionnaire and were included for analyzing ODI (subgroup ODI) (Fig. 1).

Clinical and radiological parameters

Clinical and radiological parameters in both groups are summarized in Table 1. In these groups, the mean age was more than 62 years; females accounted for more than 85%; MTX use accounted for more than 72%, bioDMARDs for approximately 30%, and glucocorticoid use for approximately 35% (Fig. 2). The intra- and inter-observer reliabilities and kappa coefficients of radiographic measurements were all excellent (Table 2).

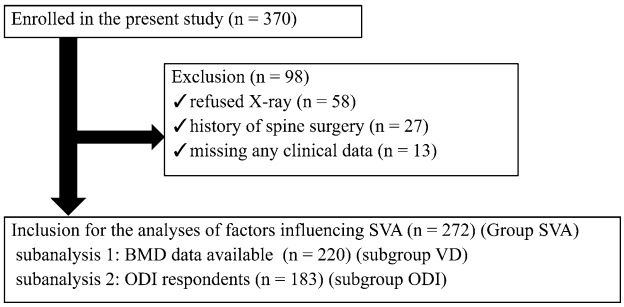

Fig. 1 Flow chart of patients finally included. *SVA* sagittal vertical alignment, *BMD* bone mineral density, *VD* vertebral deformity on the sagittal plane, *ODI* Oswestry Disability Index

SVA

On univariate analyses, larger SVA was significantly associated with older age, longer disease duration, higher DAS28-ESR, MTX nonuse, bioDMARDs nonuse, and glucocorticoid use. On multivariate regression models, the explanatory factors of larger SVA were older age, higher DAS28-ESR, MTX nonuse, and glucocorticoid use (Table 3).

BMD

On univariate analyses, lower BMD was associated with older age, longer disease duration, higher DAS28-ESR, female and MTX nonuse. On multivariate regression models, the explanatory factors of lower BMD were older age, female, higher DAS28-ESR, and MTX nonuse (Table 4).

VD

On univariate analyses, the presence of VD was significantly associated with older age, longer disease duration, higher DAS28-ESR, lower BMD, bioDMARDs nonuse, and glucocorticoid use. On multivariate regression models, the explanatory factors of VD were older age, longer disease duration, lower BMD, and glucocorticoid use (Table 5).

ODI

On univariate analyses, worse ODI was significantly associated with older age, longer disease duration, larger SVA, larger PI-LL, higher DAS28-ESR, and glucocorticoid use. On multivariate regression models, the explanatory factors of worse ODI were older age, larger SVA, higher

Table 1 Clinical and radiographic data of patients in Group SVA, subgroup VD, and subgroup ODI. The mean ± standard deviation of each variable is shown

Variables	Group SVA $n = 272$	Subgroup VD $n = 220$	Subgroup ODI $n = 183$
Age at survey (years)	62.7 ± 12.8	62.7 ± 12.8	62.0 ± 12.2
Disease duration (years)	13.6 ± 11.4	13.2 ± 11.6	13.7 ± 11.7
Sex			
Male	37 (13.6%)	28 (12.7%)	22 (12.0%)
Female	235(86.4%)	192 (87.3%)	161 (87.9%)
BMI (kg/m^2)	21.4 ± 3.2	21.5 ± 3.3	21.4 ± 3.0
DAS-28ESR	3.20 ± 1.18	3.18 ± 1.16	3.23 ± 1.19
Serum RF positive	239 (87.8%)	197 (89.5%)	151 (82.5%)
Serum ACPA positive	240 (88.2%)	195 (88.6%)	151 (82.5%)
MMP-3 (ng/ml)	131.1 ± 127.6	128.1 ± 128.2	126.0 ± 118.8
MTX use	196 (72.0%)	168 (76.4%)	139 (76.0%)
MTX dosage in user (mg/week)	7.28 ± 3.19	7.33 ± 3.22	7.15 ± 2.90
bioDMARDs use	80 (29.4%)	69 (31.4%)	63 (34.4%)
Abatacept	15 (18.8%)	13 (18.8%)	9 (14.3%)
Adalimumab	5 (6.3%)	5 (7.2%)	4 (6.3%)
Etanercept	19 (23.8%)	15 (21.7%)	14 (22.2%)
Infliximab	26 (32.5%)	26 (37.7)	23 (36.5%)
Tocilizumab	15 (18.8%)	10 (14.5%)	13 (20.6%)
Glucocorticoid use	102 (37.5%)	78 (35.5%)	66 (36.1%)
Glucocorticoid dosage in user (mg/day)	4.84 ± 3.02	4.44 ± 2.34	4.46 ± 2.10
BMD (g/cm^2)	n/a	0.712 ± 0.139	n/a
The presence of VD	46 (16.9%)	40 (18.2%)	31 (16.9%)
ODI (%)	n/a	n/a	19.4 ± 18.3
PI (°)	48.9 ± 12.0	48.2 ± 11.9	48.6 ± 12.1
LL (°)	41.4 ± 15.2	41.7 ± 15.6	40.9 ± 15.8
PT (°)	16.1 ± 9.8	15.2 ± 9.5	15.8 ± 9.0
SS (°)	32.8 ± 10.0	33.0 ± 10.2	32.8 ± 10.1
TK (°)	26.2 ± 13.3	26.8 ± 13.7	25.6 ± 13.5
SVA (mm)	33.6 ± 42.7	34.1 ± 44.6	32.5 ± 41.1

BMI body mass index, *DAS-28 ESR* disease activity score-28 erythrocyte sedimentation rate, *RF* rheumatoid factor, *ACPA* anti-cyclic citrullinated peptide antibody, *MMP-3* matrix metalloproteinase-3, *MTX* methotrexate, *bioDMARDs* biological disease-modifying anti-rheumatic drugs, *ODI* Oswestry Disability Index, *PI* pelvic incidence, *LL* lumbar lordosis, *PT* pelvic tilt, *SS* sacral slope, *TK* thoracic kyphosis, *SVA* sagittal vertical axis, *BMD* bone mineral density, *VD* vertebral deformity on the sagittal plane

DAS28-ESR, and glucocorticoid use ($p < 0.001$). PI-LL could be substituted for SVA (Table 6).

Discussion

Understanding the pathology of spinal sagittal alignment and LBP in patients with RA is an important issue that spine surgeons can contribute to on our own initiative. In this study, we found that RA-related clinical factors and the treatment type of RA were associated with SVA, BMD, VD, and ODI.

The present study clarified that larger SVA and PI-LL mismatch were associated with worse ODI and that older age was associated with larger SVA and worse ODI in RA patients; both of these suggest a similar tendency in ASD [4–6, 12, 13]. Lee et al. recently revealed that a worse C7PL/sacrofemoral distance was associated with a worse visual analog scale score for back pain and that a worse spinosacral angle was associated with a worse ODI and SRS-22 in RA patients. Because the concepts of these parameters are correction value of SVA by height and pelvic shape, our results indicated similar trends [40].

Higher disease activity was found to be associated with lower BMD, larger SVA, and worse ODI in RA patients. Yamada et al. revealed that disease activity is one of the risk factors for severe LBP in RA patients [8]. Our results

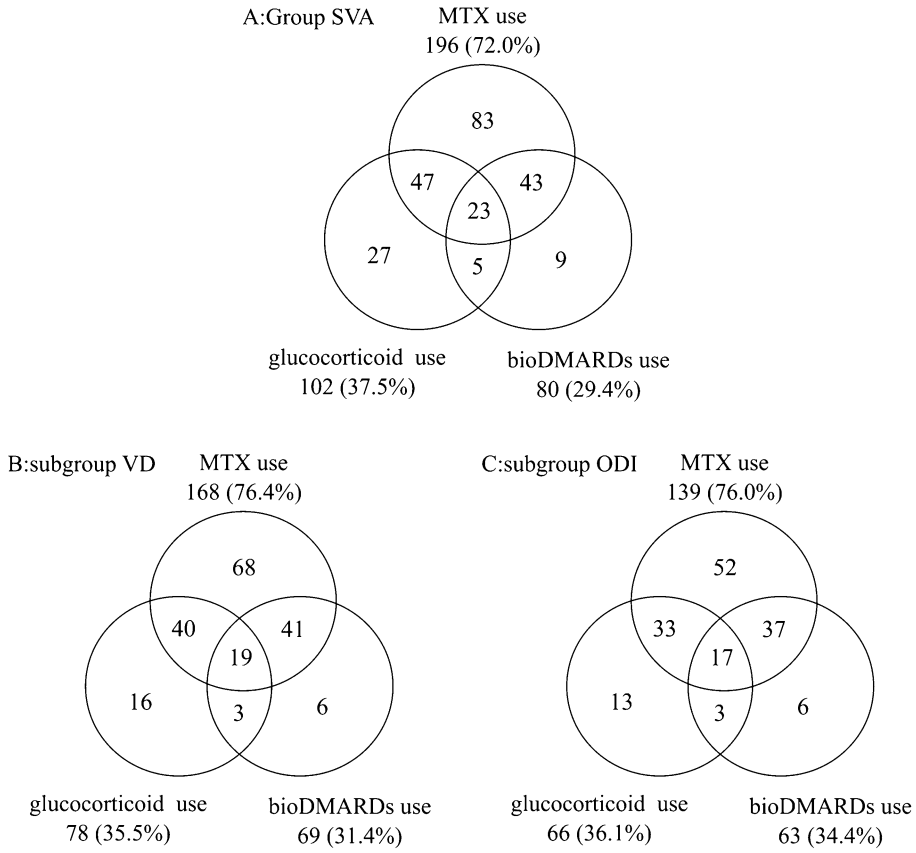

Fig. 2 Number of the patients treated with each treatment type in Group SVA, subgroup VD, and subgroup ODI. *MTX* methotrexate, *bioDMARDs* biological disease-modifying antirheumatic drugs, *SVA* sagittal vertical alignment, *BMD* bone mineral density, *VD* vertebral deformity on sagittal plane, *ODI* Oswestry Disability Index

Table 2 Inter-observer and intra-observer reliabilities of sagittal spinal alignment and the kappa coefficient of the diagnosis of VD between the observers

Parameters	Intra-observer reliability	Inter-observer reliability
PI	0.963	0.980
LL	0.995	0.994
PT	0.994	0.986
SS	0.988	0.962
TK	0.987	0.975
SVA	0.995	0.998
	Kappa coefficient	
Diagnosis of VD	1.000	

PI pelvic incidence, *LL* lumbar lordosis, *PT* pelvic tilt, *SS* sacral slope, *TK* thoracic kyphosis, *SVA* sagittal vertical axis, *VD* vertebral deformity on the sagittal plane

are same in LBP and indicate that pain and dysfunction of extremities associated with RA put some burden on the standing posture. In addition, our results indicate an indirect association between disease activity and VD by decreasing BMD. With respect to BMD, through a retrospective study, Takahashi et al. revealed that the risk factors for BMD of < 70% in RA patients who were treated with biologics were older age, being a female, longer disease duration, history of past vertebral fracture, higher Steinbrocker classification, and lower body mass index [41], which supports our study results. Regarding VD, Sakai et al. revealed that the Lansbury Index and Ochi's classification, which are both scales of disease activity, reflected the severity of lumbar changes on X-ray and MRI changes [42]. In addition, Kim et al. reported a case of 56-year-old RA patient who presented with a rapidly progressive double-level isthmic spondylolisthesis at L4/5 and L5/S; this pathology is similar to that of spinal neuropathy [43]. Therefore, it is possible that RA itself may cause vertebral deformity or instability and lead to larger SVA. From another point of view, there are several suggestive reports on the association between RA and lean body mass [44, 45], which may be the important pathology decreasing paravertebral muscle mass. We could not directly demonstrate the association between RA and lumbar muscle atrophy in our study; this should be investigated in the future.

Glucocorticoid use was associated with VD, larger SVA, and worse ODI in the current study. de Nijs et al. revealed that glucocorticoid use in RA patients results in abnormally shaped vertebra with change of height on the sagittal plane more frequently than that in glucocorticoid nonusers [26]. Our results indicate the same tendency and that vertebral

Table 3 Univariate and multivariate regression analyses of factors influencing SVA (Group SVA)

Univariate analysis using Spearman's rank correlation coefficient		
Candidate variables	ρ	p
Age at survey (years)	0.549	< 0.001*
Disease duration (years)	0.167	0.006*
DAS-28 ESR	0.248	< 0.001*

Univariate analysis using Wilcoxon rank sum test		
Candidate variables	Mean SVA value and SE (mm)	p
Sex		0.072
Female	32.04 ± 2.78	
Male	43.84 ± 7.01	
MTX use		0.004*
User	28.92 ± 3.01	
Nonuser	45.81 ± 4.83	
bioDMARDs use		0.004*
User	22.07 ± 4.71	
Nonuser	38.46 ± 3.04	
Glucocorticoid use		0.003*
User	43.16 ± 4.18	
Nonuser	27.93 ± 3.23	

Multivariate regression model of SVA (mm) indicating the least AIC

AIC = 2723.84

Adjusted R-squared = 0.303

$p < 0.001$

Variables finally selected	Unstandardized regression coefficients	SE	Standardized regression coefficients	p
Age at survey (years)	1.627	0.178	0.486	<0.001
DAS-28 ESR	3.627	1.904	0.100	0.058
MTX (user = 1, nonuser = 0)	−7.960	4.901	−0.084	0.106
Glucocorticoid (user = 1, nonuser = 0)	8.247	4.539	0.094	0.070

DAS-28 ESR disease activity score-28 erythrocyte sedimentation rate, *MTX* methotrexate, *bioDMARDs* biological disease-modifying anti-rheumatic drugs, *SVA* sagittal vertical alignment, *SE* standard error

* < 0.05

Table 4 Univariate and multivariate regression analyses of factors influencing BMD (subgroup VD)

Univariate analysis using Spearman's rank correlation coefficient		
Candidate variables	ρ	p
Age at survey (years)	− 0.377	< 0.001*
Disease duration(years)	− 0.242	< 0.001*
DAS-28 ESR	− 0.330	< 0.001*

Univariate analysis using Student's t test		
Candidate variables	Mean BMD value ± SE (g/cm^2)	p
Sex		< 0.001*
Female	0.700 ± 0.010	
Male	0.799 ± 0.026	
MTX use		0.029*
User	0.724 ± 0.011	
Nonuser	0.676 ± 0.019	
bioDMARDs use		0.087
User	0.736 ± 0.017	
Nonuser	0.702 ± 0.011	
Glucocorticoid use		0.126
User	0.693 ± 0.016	
Nonuser	0.723 ± 0.012	

Multivariate regression model of BMD (g/cm^2) indicating the least AIC

AIC = − 276.33

Adjusted R-squared = 0.224

$p < 0.001$

Variables finally selected	Unstandardized regression coefficients	SE	Standardized regression coefficients	p
Age at survey (years)	− 0.0034	0.0007	− 0.314	<0.001
Sex (female = 1, male = 0)	− 0.1059	0.0257	− 0.254	<0.001
DAS-28 ESR	− 0.0211	0.0076	− 0.176	0.006
MTX (user = 1, nonuser = 0)	0.0320	0.0203	0.098	0.117

BMD bone mineral density, *VD* vertebral deformity on the sagittal plane, *DAS-28 ESR* disease activity score-28 erythrocyte sedimentation rate, *MTX* methotrexate, *bioDMARDs* biological disease-modifying anti-rheumatic drugs, *SE* standard error

* < 0.05

deformity associated with glucocorticoid use leads to larger SVA and worse ODI. Another possible explanation is that glucocorticoids may cause atrophy of paravertebral muscles. Glucocorticoids are known to cause myopathy characterized by proximal muscle weakness, particularly of the pelvic girdle muscle, only after weeks or months of glucocorticoid use [31]. Assuming that the bulk and strength of lumbar spine muscles influence spinal sagittal alignment [16, 17], we speculate that glucocorticoid use is associated with a larger SVA by causing muscular atrophy. However, we could not demonstrate this in our study.

MTX use was associated with higher BMD and smaller SVA in the present study; bioDMARDs did not show such

Table 5 Univariate and multivariate regression analyses of factors influencing VD (subgroup VD)

Univariate logistic regression analysis		
Candidate variables	Unit OR (95% CI)	*p*
Age at survey (years)	1.11 (1.07–1.16)	< 0.001*
Disease duration (years)	1.05 (1.03–1.09)	< 0.001*
DAS-28 ESR	1.50 (1.12–2.05)	0.008*
BMD (g/cm^2)	0.0016 (0.000072–0.0261)	< 0.001*
Univariate analysis using Fisher's exact probability test		
Candidate variables	OR (95% CI)	*p*
Sex (female/male)	1.02 (0.365–2.88)	0.962
MTX (user/nonuser)	0.778 (0.358–1.69)	0.540
bioDMARDs (use/nonuser)	0.404 (0.169–0.965)	0.039*
Glucocorticoid (use/nonuser)	2.71 (1.35–5.44)	0.006*
Multivariate regression analysis of the presence of VD indicating the least AIC		
AIC = 159.34		
R-squared = 0.286		
$p < 0.001$		
Variables finally selected	Unit OR and OR (95% CI)	*p*
Age at survey (years)[#]	1.11 (1.06–1.17)	<0.001
Disease duration (years)[#]	1.04 (1.01–1.08)	0.009
BMD (g/cm^2)[#]	0.00775 (0.000297–0.165)	0.002
Glucocorticoid (user/nonuser)[‡]	2.67 (1.19–6.23)	0.018

VD vertebral deformity on the sagittal plane, *CI* confidence interval, *BMD* bone mineral density, *DAS-28 ESR* disease activity score-28 erythrocyte sedimentation rate, *MTX* methotrexate, *bioDMARDs* biological disease-modifying anti-rheumatic drugs, *SE* standard error, *OR* odds ratio

* < 0.05

[#]Unit OR

[‡]OR

association. Previous reports have shown that MTX with bioDMARDs improved bone metabolism or bone mineral density in patients with RA [19, 21]. Assuming a similar trend in this study, there is a possibility that MTX and bioDMARDs influence SVA by improving bone metabolism, although MTX was associated only with BMD and not directly with VD in our study.

Multivariate regression model of ODI revealed that the impact of a 20 mm change in SVA on ODI is equivalent to as much as 0.6 change in DAS-28 ESR, corresponding to a basic unit when evaluating the efficacy of RA treatment [46]. This suggests that an improvement in ODI cannot be accomplished when RA is not well controlled.

There were several limitations in the present study. First, this was a cross-sectional study, and the types of treatment were only evaluated from the survey results. The effect of dosage and duration of each treatment could not be precisely evaluated because any change of MTX and glucocorticoid dosing was not completely recorded during the treatment period. Second, the number of MTX nonusers, bioDMARDs users, and glucocorticoid users was small. Hence, these patient groups tended to be heterogeneous. Third, selection biases could not be excluded in subgroups. Fourth, we did not assess regional lumbar lesions, paravertebral muscle strength, or alignment of the lower extremity. Fifth, there were some conflicts of

Table 6 Univariate and multivariate regression analyses of factors influencing ODI (subgroup ODI)

Univariate analysis using Spearman's rank correlation coefficient				
Candidate variables	ρ			p
Age at survey (years)	0.306			< 0.001*
Disease duration (years)	0.169			0.023*
SVA (mm)	0.247			< 0.001*
PI-LL (°)	0.187			0.011*
DAS-28 ESR	0.287			< 0.001*
Univariate analysis using Wilcoxon rank sum test				
Candidate variables	Mean ODI value ± SE (%)			p
Sex				0.523
Female	19.61 ± 1.44			
Male	18.09 ± 3.91			
MTX use				0.166
User	18.06 ± 1.54			
Nonuser	23.75 ± 2.74			
bioDMARDs use				0.347
User	16.75 ± 2.30			
Nonuser	20.84 ± 1.66			
Glucocorticoid use				0.003*
User	25.21 ± 2.19			
Nonuser	16.17 ± 1.65			
Multivariate regression model of ODI (%) using SVA as a dependent factor				
AIC = 1554.83 Adjusted R-squared = 0.177 $p < 0.001$				
Variables finally selected	Unstandardized regression coefficients	SE	Standardized regression coefficients	p
Age at survey (years)	0.274	0.120	0.182	0.023
SVA (mm)	0.074	0.035	0.166	0.037
DAS-28 ESR	2.456	1.084	0.160	0.025
Glucocorticoid (use = 1, nonuse = 0)	6.213	2.616	0.164	0.019
Multivariate regression model of ODI (%) using PI-LL as a dependent factor				
AIC = 1554.25 Adjusted R-squared = 0.180 $p < 0.001$				
Variables finally selected	Unstandardized regression coefficients	SE	Standardized regression coefficients	p
Age at survey (years)	0.337	0.108	0.224	0.002
PI-LL (°)	0.211	0.095	0.158	0.027
DAS-28 ESR	2.460	1.082	0.160	0.024
Glucocorticoid (use = 1, nonuse = 0)	6.015	2.622	0.158	0.023

SVA sagittal vertical axis, *PI* pelvic incidence, *LL* lumbar lordosis, *DAS-28 ESR* disease activity score-28 erythrocyte sedimentation rate, *MTX* methotrexate, *bioDMARDs* biological disease-modifying anti-rheumatic drugs, *ODI* Oswestry Disability Index, *SE* standard error

* < 0.05

interest outside the present study and we could not exclude the bias in the choice of treatment type.

In conclusion, disease activity and the treatment type should be taken into consideration in assessing spinal sagittal alignment and ODI in RA patients. Therefore, spine surgeons and rheumatologists should cooperate and manage LBP in RA patients.

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Compliance with ethical standards

Conflict of interest For the present study, we received no payment or support in any aspect of the submitted work. However, outside the submitted work, there are several conflicts of interest, which are as follows: During this study, M. F., M. H, and M. T. belonged to the Department of the Control for Rheumatic Disease, which is financially supported by four pharmaceutical companies (Mitsubishi Tanabe, Chugai, Bristol-Myers Squibb, and Eisai). Five pharmaceutical companies (Pfizer, Astellas, AbbVie GK, Ayumi, Taisyo Toyama, and Eisai) provided scholarship donations to this center. M. H. received a research grant from Astellas. H. I. received research grants from Bristol-Myers Squibb, and Astellas. T. M. received grants from 8 pharmaceutical companies (Acterion, Ayumi, Astellas, Bristol-Myers Squibb, Chugai, Daiichi-Sankyo, Eisai, and Mitsubishi Tanabe) and payment for lectures from two pharmaceutical companies (Chugai and Mitsubishi Tanabe). K. M., B. O., S. F., K. S., S. L., H. Y., S. T., and S. M. declare no conflicts of interest for the present study.

Ethical approval The approval of the institutional ethics committee of Kyoto University was obtained for this study.

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