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ORIGINAL ARTICLE

Prediction of satisfaction after correction surgery for adult spinal deformity: differences between younger and older patients

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Abstract

Purpose Achieving an adequate level of patient's satisfaction with results is one of the goals of adult spinal deformity (ASD) surgery. However, it is unclear whether the same factors affect satisfaction in all patient populations. Patients' age influences the postoperative course and prevalence of complications after ASD surgery. The purpose of this study was to determine the factors predicting satisfaction 2 years after ASD surgery in younger and older patients.

Methods A total of 119 patients under 40 years old, 155 patients 40 to 65 years old, and 148 patients over 65 years old at surgery who were followed for a minimum of 2 years after surgery were included. Multivariate analysis was used to determine independent related factors with maximum AUC for satisfaction 2 years after surgery in each group. A propensity-matched cohort under equivalent demographic and clinical characteristics was used to confirm the results.

Results Logistic regression analyses revealed satisfaction among the under-40 group corresponded to prior spine surgery, complications, and self-image. That among the 40-to-65 group corresponded to neurologic complication, revision surgery, pain, and sagittal vertical axis restoration. Among the over-65 group satisfaction correlated with revision surgery, standing ability, and lumbar lordosis index restoration. Propensity score matching confirmed that sagittal alignment correction led to substantial satisfaction.

Conclusions In younger patients, avoiding complications and improving patients' self-image were essential for substantial satisfaction levels. In older patients, revision, standing ability, as well as sagittal spinopelvic alignment restoration, were the key factors. Surgeons should consider the differences in goals of each patient.

Keywords Adult spinal deformity · Patient satisfaction · Appearance · Propensity score · Sagittal alignment

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Introduction

Adult spinal deformity (ASD) can severely burden patients' health-related quality of life (HRQoL) [1]. Surgical managing for severe cases leads to improvements in HRQoL and is cost-effective [2, 3]. ASD's clinical symptoms include back pain, functional disability, and a disturbance of self-image and mental status. "Satisfaction with management" is considered a comprehensive factor in patient-centered measures following intervention. Therefore, one of the goals is achieving an adequate level of patient satisfaction with results, by addressing elements strongly correlated with satisfaction such as the improvement of self-image [4, 5].

ASD includes various pathologies and several potential diagnoses of deformity. However, diagnosing specific deformities can be difficult in certain cases due to its multifactorial origins and lack of diagnosis consensus. Alternatively, age is clearly identified for each patient and has been reported to influence components of the postoperative improvement of HRQoL [6, 7]. Furthermore, there were differences between the under-40-year-old group and others in preoperative HRQoL, except with regard to mental health [8]. Recently, the driving factors for surgical intervention were evaluated and divided into younger and older groups [9]. The aim of this study was to clarify the differences between younger, middle, and older patients and identify the crucial factors associated with postoperative satisfaction for each. This information is essential for surgeons so they can help their patients achieve a substantial level of satisfaction after surgery.

Methods

Patient inclusion

This study involved a retrospective analysis of prospectively collected data. The database included the data of all consecutive patients who received ASD treatments at six institutions. The inclusion criteria were age ≥ 18 years old and at least one of the following: coronal Cobb angle of the major curve ≥ 20 degrees, sagittal vertical axis (SVA) ≥ 5 cm, pelvic tilt (PT) ≥ 25 degrees, or thoracic kyphosis (TK) ≥ 60 degrees. In this study, the patients who received surgical treatment for ASD (spinal fusion of more than four levels) from 2009 to 2016 and completed a 2-years follow-up were included. We excluded from analysis cases with "neuromuscular" and "syndromic" deformity diagnoses, and candidates who did not answer questions 21 and 22 (related to satisfaction with management subdomain) in the Scoliosis Research Society-22 questionnaire (SRS-22R), taken at 2 years after surgery (Fig. 1).

Demographics and health-related quality of life measures

Preoperative demographic data (age, gender, body mass index, American Society of Anesthesiologists physical status, prior thoracolumbar spine surgeries, and potential diagnosis of deformity), surgical factors (surgical time, blood loss, transfusion, fusion levels, lower instrumented vertebra, three-column osteotomy), complications, and any revision surgery following ASD surgery were collected. We classified complications into four subgroups: perioperative (wound problem, dura tear, medicative, and infectious problem up to 30 days postsurgery); radicular (leg pain potentially related to radiculopathy); implant-related (pseudarthrosis, rod breakage, proximal junctional kyphosis, screw malposition); and other (such as late infection and prolonged back pain). SRS-22R, Oswestry Disability Index (ODI), Short Form-36 (SF-36), and a numerical rating scale (NRS) for back and leg pain were used for the measurement of HRQoL at baseline and 2 years after surgery. The improvement for HRQoL domains and subdomains were calculated as follows: score at 2 years after surgery—score at baseline for SRS-22R and SF-36; score at baseline—score at 2 years after surgery for ODI and NRS.

Outcomes

The "satisfaction with management" subdomain score of the SRS-22R at 2 years (Sat-2y score) was used to evaluate satisfaction after ASD surgery and was considered the primary outcome. The Sat-2y score was calculated as follows: (score of question 21 + score of question 22) / 2 [4, 10]. The score ranged from 1.0 (not satisfied) to 5.0 (very satisfied). An adequate level of Sat-2y score was defined as ≥ 4.5 in the subgroup analysis according to the median value.

Radiographic evaluation

Full-length standing radiographs were taken in the standardized upright position at baseline and 2 years. The coronal Cobb angle, coronal distance from C7 to center sacral vertical line (C7-CSVL), SVA, T5-T12 TK, T12-L1 lumbar lordosis (LL), pelvic incidence (PI), lumbar lordosis index (LLI), PT, and global tilt (GT) were measured at each institution.

Statistical Analyses

Patients were divided into younger, middle, and older age groups (18–39 years old, 40 to 65 years old, and 65–84 years old) according to their age during surgery

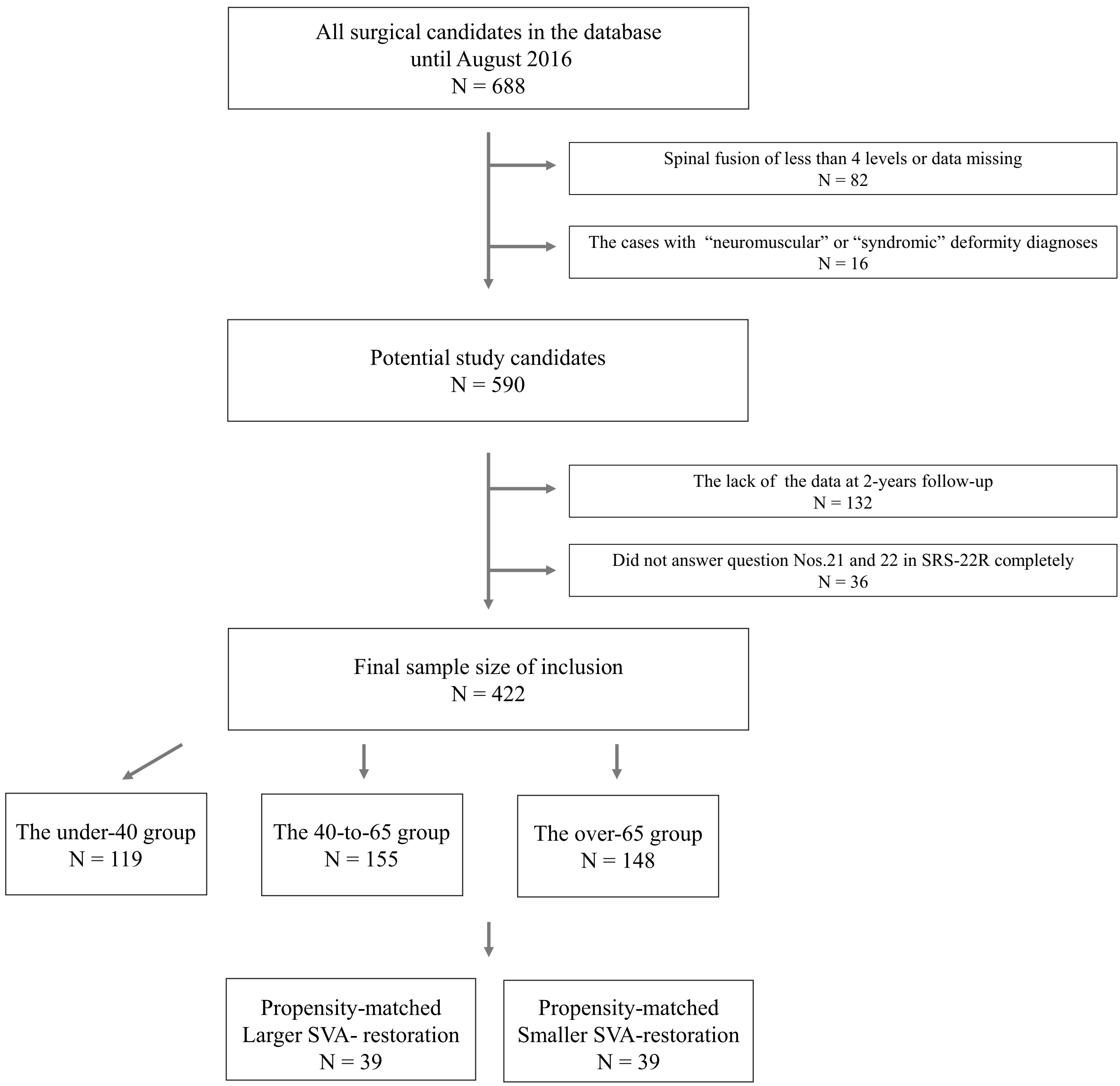


Fig. 1 Flowchart outlining inclusion criteria of participants

[11]. For both age groups, *t* tests with Welch modification for continuous variables and chi-square tests for categorical variables were conducted to evaluate the differences between the patient groups reaching high satisfaction (Sat-2y score over 4.5) and low satisfaction (Sat-2y score under 4.0). Spearman's rank correlation was used to assess the relationship between Sat-2y scores and each HRQoL component. Each correlation strength was considered by assessing the absolute value of the correlation coefficient as follows: 0.8–1 (very strong); 0.6–0.8 (strong); 0.4–0.6 (moderate); 0.2–0.4 (weak) [4].

Logistic regression models were constructed to adjust for potential confounding factors. The explanatory variables included using the forward stepwise method were selected with reference to the results in univariate and correlation analyses. Receiver operator characteristic curves were measured, and the corresponding area under the curve (AUC) was used to evaluate the predictive performance of each regression model. A total of nine models in the under-40 group, 12 models in the 40-to-65 group, and 15 models in the over-40 group were tested to identify the model with the largest AUC. Finally, propensity score matching was conducted using 1:1 nearest-neighbor matching without replacement. Achieving an adequate level of Sat-2y scores was considered the primary outcome, and SVA-restoration from baseline was the primary predictive variable. The calculation of the propensity score included variables that showed differences between higher and lower SVA-restoration subgroups.

Table 1 The distribution of potential diagnosis of deformity between the three age groups

	Potential diagnosis of deformity (cases)			
	Idiopathic scoliosis	Scheuermann's disease	Degenerative kyphoscoliosis	Others
The under-40 group	83	15	3	18
The 40-to-65 group	69	3	44	39
The over-65 group	24	1	101	22

Results

The analysis included 422 patients (340 female and 82 male) who met the criteria out of 690 surgical candidates registered in the database (Fig. 1). Follow-up rate at 2 years was 78%. The under-40 group (mean age: 26.5), the 40-to-65 group (mean age: 55.3), and the over-65 group (mean age: 72.2) included 119, 155, and 148 patients, respectively. A difference was noted in potential diagnosis of deformity, surgical factors, and radiographic parameters between each group (Tables 1 and 2).

Univariate analysis between high satisfaction and low satisfaction patients

In the under-40 group, patients attaining high satisfaction were more likely to have a lower number of prior surgeries, and fewer complications and revision surgeries than low satisfaction patients (Fig. 2). No significant difference in other demographic data or surgical data was found. At 2 years, high satisfaction patients accomplished better scores in all HRQoL subdomains tested than low satisfaction patients. High satisfaction patients had lower SVA, higher LLI, and

Table 2 The detailed numerical results of surgical data and radiographic parameters

	The under-40 group	The 40-to-65 group	The over-65 group
Surgical data			
Number of fusion levels	10.8	10.9	9.2
LIV (upper L3/L4-5/S1-iliac) (%)	69.7/22.7/7.6	9.0/32.9/58.1	2.0/17.6/80.4
Three column osteotomy (%)	13.4	22.6	22.3
Surgical time (min)	317	317	305
Blood loss (ml)	1118	1829	1563
Radiographic at baseline			
The coronal Cobb angle (°)	48.9	42.6	25.3
C7-CSVL (mm)	−6.5	−2.4	5.2
Sagittal vertical axis (mm)	−4.9	49.6	78.2
Thoracic kyphosis (°)	34.6	30.9	30.9
Lumbar lordosis (°)	−55.5	-37.1	−33.5
Lumbar lordosis index	1.10	0.68	0.57
Pelvic tilt (°)	13.7	23.4	27.6
Global tilt (°)	11.4	28.9	37.5
Radiographic at 2y			
The coronal Cobb angle (°)	24.1	23.5	15.8
C7-CSVL (mm)	−5.7	0.7	2.1
Sagittal vertical axis (mm)	−8.6	33.6	47.7
Thoracic kyphosis (°)	28.5	37.7	41.3
Lumbar lordosis (°)	−57.7	−47.5	−46.4
Lumbar lordosis index	1.12	0.89	0.82
Pelvic tilt (°)	13.1	22.4	25.3
Global tilt (°)	10.9	24.5	31.2

LIV Lower instrumented vertebra, *C7-CSVL* Coronal distance from C7 to the center sacral vertical line

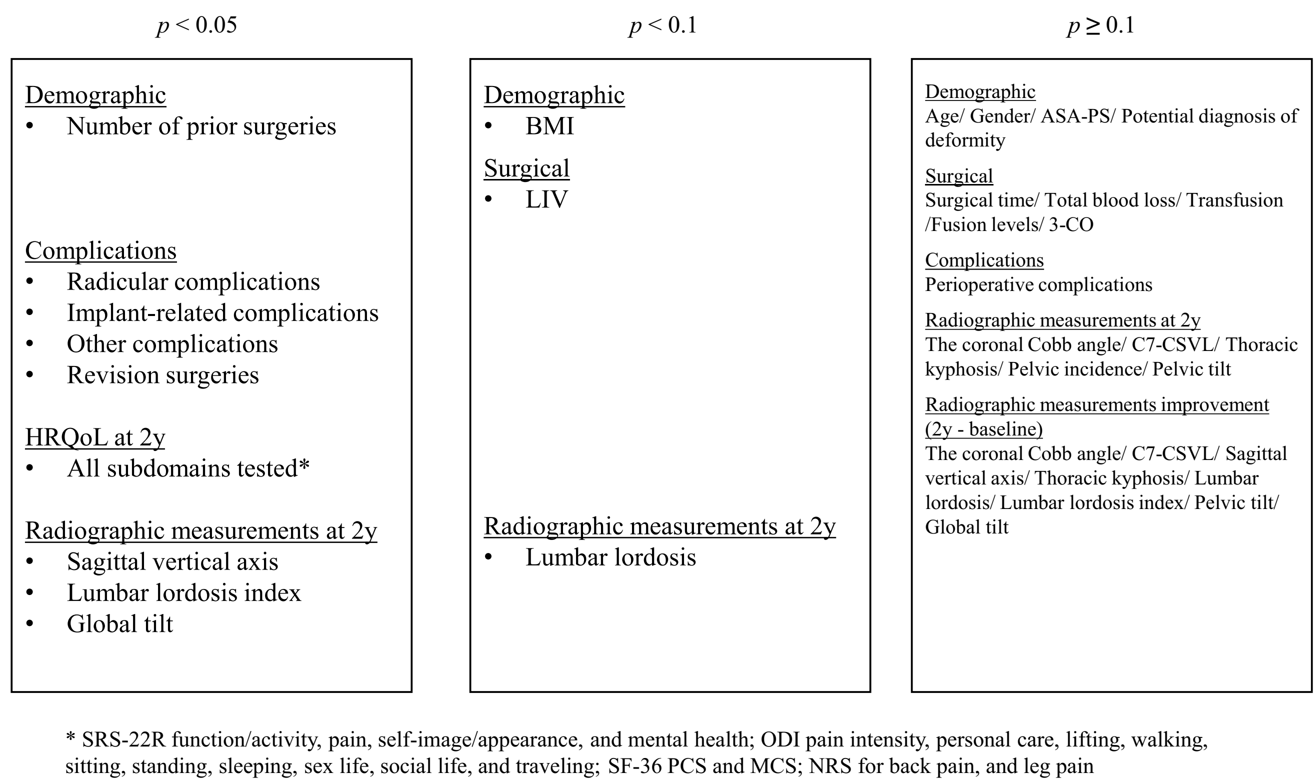


Fig. 2 Univariate analysis between high satisfaction and low satisfaction patients in the under-40 group

lower GT at 2 years. In the 40–65 group, patients reaching high satisfaction were more likely to have an idiopathic scoliosis diagnosis, and fewer radicular complications and revision surgeries (Fig. 3). At 2 years, high satisfaction patients accomplished better scores in all HRQoL subdomains tested than low satisfaction patients, and larger improvements from baseline were accomplished in LL, GT, and LLI. In the over 65 group, patients reaching high satisfaction were more likely to have fewer implant-related complications and revision surgeries than low satisfaction patients (Fig. 4). At 2 years, high satisfaction patients accomplished better scores in all HRQoL subdomains tested, except NRS leg pain, than low satisfaction patients. Larger improvements from baseline were accomplished in SVA, LL, LLI, and GT in high satisfaction patients than the others.

Correlation of HRQoL with Sat-2y score

Strong correlations with Sat-2y scores were found for SRS-22R self-image/appearance and ODI social life at 2 years, and moderate correlations were found for ODI sex life, personal care, and traveling subdomains in the under 40 group (Table 3). There was a moderate correlation of Sat-2y scores with SRS-22R pain, self-image/appearance, mental health, ODI pain intensity, social life, sex life, and standing subdomains in the 40–65 group. In the over-65 group, ODI standing and social life, SRS-22R self-image/appearance, and pain subdomains at 2 years were found to have moderate correlations.

Logistic regression analyses

The model with the largest AUC (0.775) consisted of a prior surgery history (odds ratio [OR]: 0.27, 95% confidential interval [CI]: 0.09–0.83), complication history (OR: 0.34, 95% CI: 0.14–0.87), and SRS-22R self-image/appearance subdomain scores at 2 years (OR: 16.97, 95% CI: 3.36–85.64) as factors associated with adequate levels of Sat-2y scores in the under-40 group (Table 4). Revision surgery history and radiographic parameters were not selected as explanatory components in any tested model. In the 40–65 group, the largest AUC (0.828) model consisted of radicular complication history (OR: 0.18, 95% CI: 0.07–0.79), revision surgery history (OR: 0.23, 95% CI: 0.04–0.79), SVA-restoration until 2 years (OR: 6.65, 95% CI: 2.02–21.79), and SRS-22R pain subdomain score (OR: 8.53, 95% CI: 2.97–24.52) (Table 5).

In the over-65 group, the largest AUC (0.833) model consisted of implant-related complication history (OR: 0.39, 95% CI: 0.15–0.98), LLI restoration until 2 years (OR: 3.30, 95% CI: 1.29–8.48), and ODI standing subdomain score at 2 years (OR: 0.08, 95% CI: 0.03–0.26) as the factors

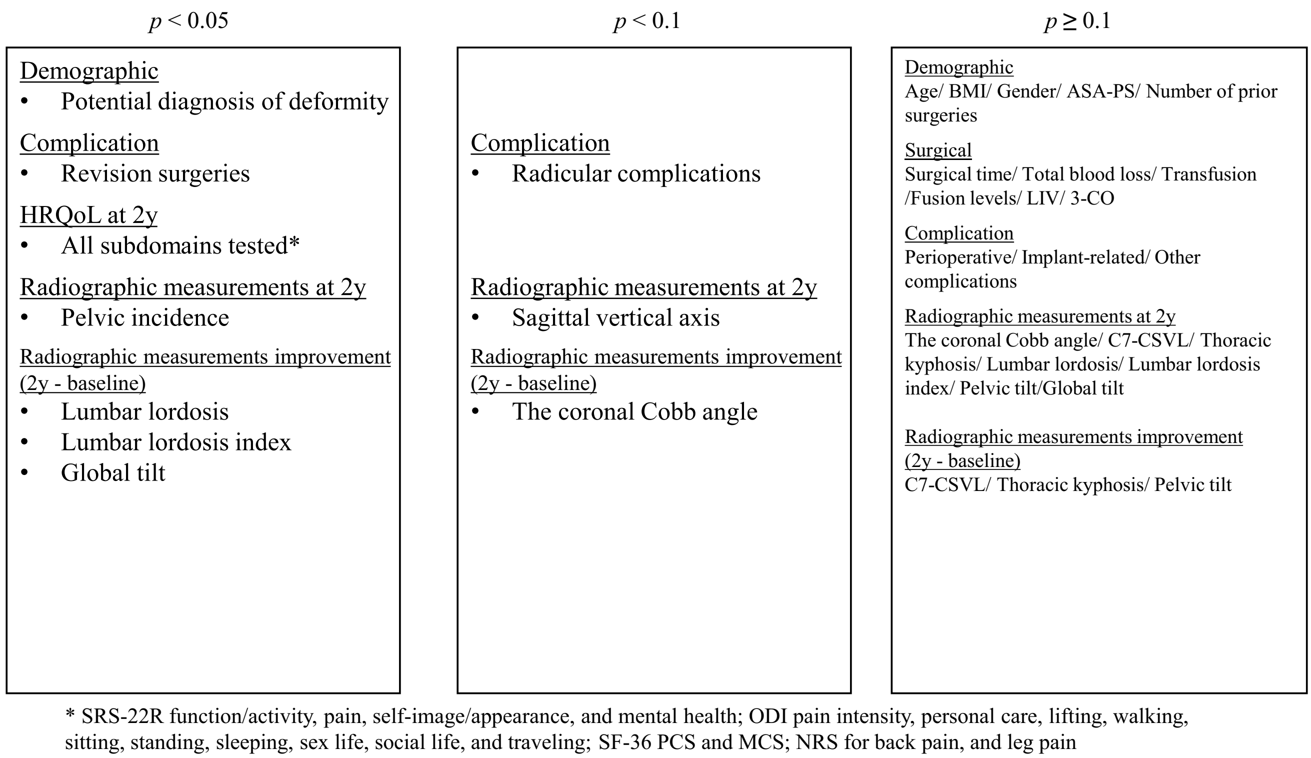


Fig. 3 Univariate analysis between high satisfaction and low satisfaction patients in the 40–65 group

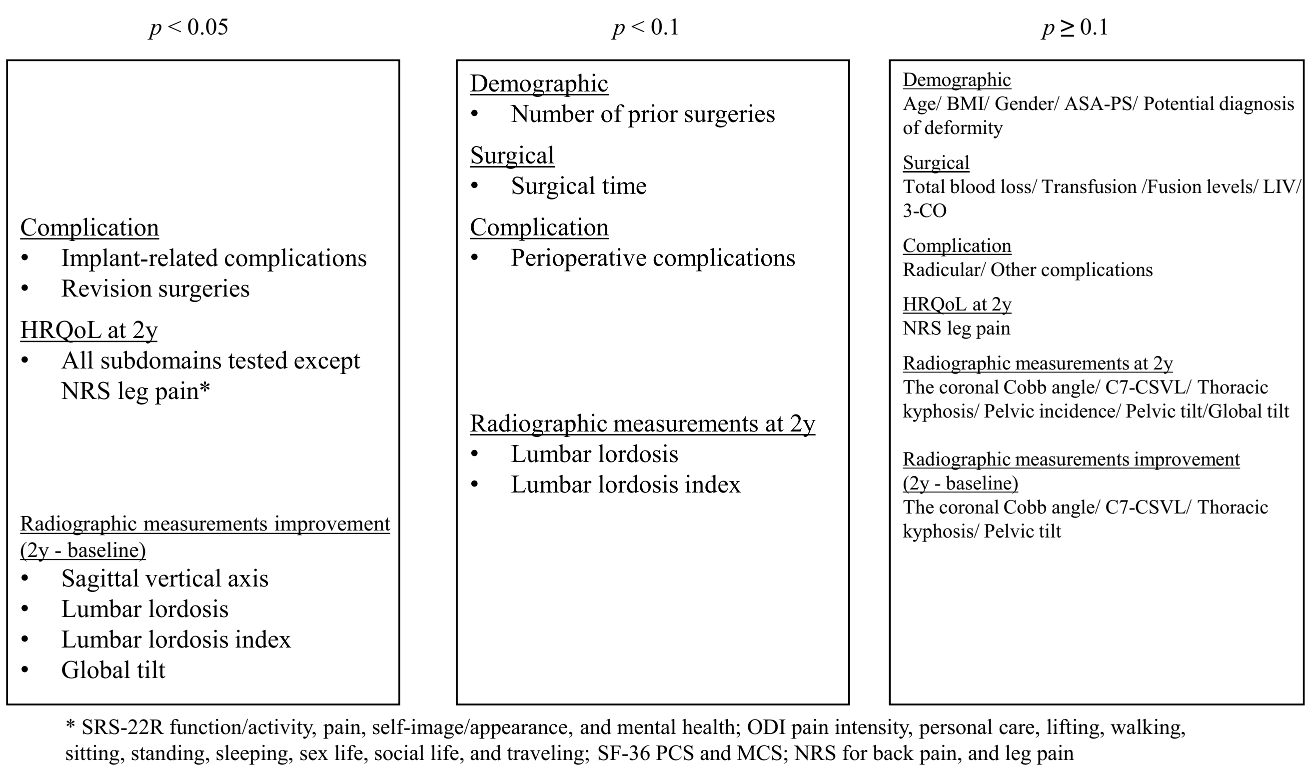


Fig. 4 Univariate analysis between high satisfaction and low satisfaction patients in the over-65 group

Table 3 Correlation of HRQoL subdomains at 2 years with the Sat-2y score

The under-40 group		The 40-to-65 group		The over-65 group	
Subdomains	|ρ|	Subdomains	|ρ|	Subdomains	|ρ|
ODI social life	0.63	SRS-22R pain	0.54	ODI standing	0.58
SRS-22R self-image	0.62	SRS-22R self-image	0.54	ODI social life	0.46
ODI sex life	0.43	ODI pain intensity	0.50	SRS-22R self-image	0.45
ODI personal care	0.43	ODI social life	0.47	SRS-22R pain	0.41
ODI traveling	0.42	ODI sex life	0.47		
		ODI standing	0.46		
		SF-36 PCS	0.45		
		SRS-22R mental health	0.41		

ODI Oswestry disability index; *SRS-22R* The scoliosis research society-22R; *SF-36* Short form-36; *PCS* Physical component score

Table 4 Significant variables selected by forward stepwise analysis and AUC of each model in the under-40 group

	Radiographic parameters at 2 years tested		
	SVA	LLI	GT
HRQoL domains tested			
none	prior spine surgery complication	prior spine surgery complication	prior spine surgery complication
AUC	0.694	0.694	0.694
SRS-22R self-image at 2y	prior spine surgery complication SRS-22R self-image	prior spine surgery complication SRS-22R self-image	prior spine surgery complication SRS-22R self-image
AUC	0.775*	0.775*	0.775*
ODI social life at 2y	prior spine surgery complication ODI social life	prior spine surgery complication ODI social life	prior spine surgery complication ODI social life
AUC	0.768	0.768	0.768

HRQoL Health related quality of life, *AUC* Area under the curve, *SRS-22R* The Scoliosis research society-22R, *ODI* Oswestry disability index, *SVA* Sagittal vertical axis, *LLI* Lumbar lordosis index, *GT* Global tilt

associated with adequate levels of Sat-2y scores (Table 6). Revision surgery history was not selected as an explanatory component in any model.

Propensity-matched cohort in the patients over 40 years old

We divided the patients of over 40 years old (the 40–65 and over 65 groups) into two subgroups: larger SVA-restoration (≥ 20 mm) and smaller SVA-restoration (< 20 mm). Univariate analysis demonstrated the larger SVA-restoration subgroup had an older age, higher number of prior surgeries, and less diagnoses of idiopathic scoliosis. They had lower scores on preoperative SRS-22R self-image/appearance and higher imbalance in the sagittal plane than did the smaller SVA-restoration group (Table 7). The calculation of propensity score included age, prior surgery, potential diagnosis of deformity, preoperative SRS-22R self-image/appearance score, coronal Cobb angle, C7-SCVL, SVA, and GT.

After propensity score matching, 39 patients were included in each cohort: larger SVA-restoration and smaller SVA-restoration (Fig. 1). Post-matching assessment of cohort balance showed no differences in any variables between the two cohorts (Table 8). The larger SVA-restoration cohort showed a significantly higher percentage of patients who achieved adequate levels of Sat-2y scores than the other group (OR: 13.6, 95% CI: 4.30–42.99).

Discussion

This study demonstrated the differences in clinical and radiographic factors associated with patient satisfaction after ASD surgery in younger and older age groups. The best prediction model for patient satisfaction in the under-40 group was prior thoracolumbar spine surgery, complications, and a score on the SRS-22R self-image/appearance subdomain at 2 years. In contrast, the best model in the 40–65 group

Table 5 Significant variables selected by forward stepwise analysis and AUC of each model in the 40-to-65 group

	Radiographic parameters improvement tested		
	SVA	LLI	GT
HRQoL domains tested none	Radicular complication Revision surgery SVA	Revision surgery LLI	Revision surgery
AUC	0.725	0.653	0.584
SRS-22R self-image at 2y	Radicular complication Revision surgery SVA SRS-22R self-image	Revision surgery LLI SRS-22R self-image	Revision surgery SRS-22R self-image
AUC	0.817	0.783	0.725
SRS-22R pain at 2y	Radicular complication Revision surgery SVA SRS-22R pain	SRS-22R pain	SRS-22R pain
AUC	0.828*	0.709	0.709
ODI standing at 2y	Radicular complication Revision surgery SVA ODI standing	ODI standing	ODI standing
AUC	0.775	0.701	0.701

HRQoL Health related quality of life, *AUC* Area under the curve, *SRS-22R* The Scoliosis research society-22R, *ODI* Oswestry disability index, *SVA* Sagittal vertical axis, *LLI* Lumbar lordosis index, *GT* Global tilt

Table 6 Significant variables selected by forward stepwise analysis and AUC of each model in the over-65 group

	Radiographic parameters improvement tested		
	SVA	LLI	GT
HRQoL domains tested none	Implant-related complication SVA	Implant-related complication LLI	Implant-related complication GT
AUC	0.754	0.702	0.714
SRS-22R self-image at 2y	SVA SRS-22R self-image	Implant-related complication LLI	Implant-related complication GT
AUC	0.781	0.757	0.771
SRS-22R pain at 2y	SVA SRS-22R pain	Implant-related complication LLI SRS-22R pain	Implant-related complication GT SRS-22R pain
AUC	0.776	0.739	0.763
ODI standing at 2y	SVA ODI standing	Implant-related complication LLI ODI standing	GT ODI standing
AUC	0.813	0.833*	0.819
ODI social life at 2y	SVA ODI social life	Implant-related complication LLI ODI social life	Implant-related complication GT ODI social life
AUC	0.773	0.793	0.778

HRQoL Health related quality of life, *AUC* Area under the curve, *SRS-22R* The Scoliosis research society-22R, *ODI* Oswestry disability index, *SVA* Sagittal vertical axis, *LLI* Lumbar lordosis index, *GT* Global tilt

Table 7 The characteristics of patients attaining larger and smaller sagittal vertical axis restoration

	Mean Larger SVA-restoration	*p* Smaller SVA-restoration	
Demographics			
Age (y)	66.2	62.2	0.002
Number of prior surgeries	0.91	0.45	0.010
Potential diagnosis of deformity (Idiopathic/Degenerative/Others) (%)	22.0/52.0/26.0	40.0/44.8/15.2	0.012
Preoperative HRQoL			
SRS-22R self-image/appearance	2.05	2.25	0.033
Preoperative radiographic			
The coronal Cobb angle (°)	31.4	36.0	0.119
C7-CSVL (mm)	12.1	−2.7	0.003
SVA (mm)	104.5	34.6	< 0.001
Lumbar lordosis (°)	−24.0	−40.7	< 0.001
Pelvic tilt (°)	29.3	24.1	< 0.001
Global tilt (mm)	42.8	27.7	< 0.001

HRQoL Health related quality of life, *SRS-22R* The Scoliosis research society-22R, *C7-CSVL* Coronal distance from C7 to the center sacral vertical line, *SVA* Sagittal vertical axis

Table 8 The characteristics of patients attaining larger and smaller sagittal vertical axis restoration cohorts after propensity score matching

	Mean Larger SVA-restoration	*p* Smaller SVA-restoration	
Demographics			
Age (y)	64.6	62.8	0.378
Number of prior surgeries	1.00	0.72	0.382
Potential diagnosis of deformity (Idiopathic/Degenerative/Others) (%)	12.8/51.3/35.9	30.8/43.6/25.6	0.150
Preoperative HRQoL			
SRS-22R self-image/appearance	2.10	2.12	0.912
Preoperative radiographic			
The coronal Cobb angle (°)	32.6	32.5	0.987
C7-CSVL (mm)	5.5	1.5	0.597
SVA (mm)	77.7	71.7	0.560
Lumbar lordosis (°)	−29.9	−33.7	0.370
Pelvic tilt (°)	25.7	27.1	0.499
Global tilt (mm)	35.4	35.0	0.899

HRQoL Health related quality of life, *SRS-22R* The Scoliosis research society-22R, *C7-CSVL* Coronal distance from C7 to the center sacral vertical line, *SVA* Sagittal vertical axis

was radicular complications, revision surgery, a score on the SRS-22R pain subdomain, and improvement in SVA from baseline. That in the over-65 group was implant-related complications, ODI standing subdomain score at 2 years, and improvement in LLI. Propensity score matching suggested larger SVA-restoration in patients over 40 years old was associated with higher satisfaction.

Several studies suggest the improvement of coronal radiographic parameters such as a coronal Cobb angle or trunk shift may lead to adequate self-image and satisfaction after corrective surgery in adolescent idiopathic scoliosis candidates [12, 13]. In ASD populations, SRS-22R self-image/appearance subdomain and ODI score improvement from baseline, back pain relief, revision surgery, as well as SF-36 MCS score at baseline have been reported as factors influencing satisfaction [4, 10, 14–17]. However, limited literature addresses the differences in the crucial components of satisfaction following intervention between the age groups.

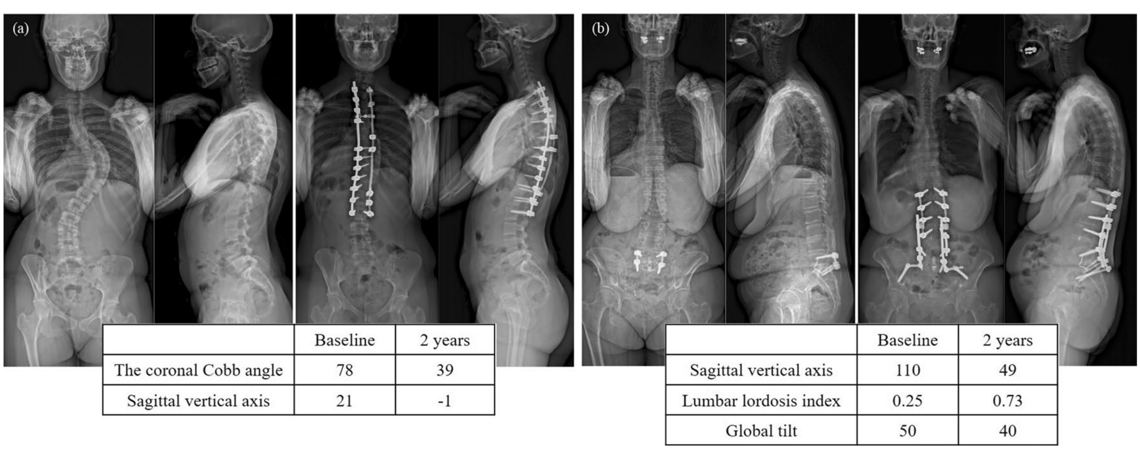
In the under-40 group, contrary to past reports on adolescent patients, radiographic measurements of coronal alignment did not differ between low and high satisfaction patients [13]. The coronal alignment should not be overlooked in ASD patients [18]. However, the amount of coronal correction itself seemed less influential in patient satisfaction. Alternatively, the scores on SRS-22R self-image/appearance and ODI social life subdomains at 2 years were the most strongly associated with Sat-2y score in the correlation analysis. A possible reason is that impairments in HRQoL such as self-image are the main driving factors for surgical intervention in young adult patients [9]. The score on the ODI personal care subdomain had a subsequent relevance. This result was not in agreement with the other groups, suggesting younger patients might expect to care for themselves without assistance. In multivariate analysis, prior surgery history and complications were independent influencing factors of Sat-2y, while the correlation between complications and patient satisfaction is controversial, our study found complications influenced all patient populations [10, 15]. No regression model for Sat-2y contained radiographic parameters. Some reports have published about sagittal alignment restoration's importance for young scoliosis candidates [19]. However, according to our findings, it is uncertain if patients with radiographic malalignment but without HRQoL impairments will achieve adequate satisfaction following ASD surgery (Fig. 5a).

For the 40–65 and the over-65 group, pain and standing subdomain scores showed subsequent relevance for satisfaction as well as self-image scores, suggesting pain relief and regaining standing ability were the main issues. These results were reasonable because pain and disability determine the treatment of ASD in older populations [9, 20]. In the regression model, sagittal alignment restoration from baseline was found to be the factor determining satisfaction in both groups. The impact on satisfaction of implant-related complication or revision surgery was consistent with the past reports [15]. The GAP score system helps surgeons to predict mechanical complications after surgery [21]. The "multi-rod construct" has been reported to reduce mechanical complications and revision rates [22, 23]. Sagittal alignment correction and maintenance using those devices for pain relief or regaining standing ability might be an ideal surgical model in terms of patients' satisfaction (Fig. 5b).

This was not a prospective study. Whether larger sagittal alignment restoration prospectively leads to patients achieving high satisfaction has not been proven. We added a propensity-matched cohort to the patients over 40 years old. To adjust for demographic and surgical factors that could affect sagittal alignment restoration, SVA-restoration over 20 mm indicated positive effects on postoperative satisfaction. Despite ASD patients representing various pathologies and symptoms, surgeons need to take into consideration attaining appropriate sagittal alignment in surgery with middle to older patient populations. This does not imply that maximal correction might be desirable, as overcorrection does not provide any benefits [24].

This study may be the first effort to clarify the differences between the age groups in terms of predictive factors of patients' satisfaction after ASD surgery. We included a large number of participants for each group that allowed us to construct several multivariate models to find the best one. The findings suggested that treatment goals of ASD and tips to reach adequate satisfaction are different from one another. Each patient has their own background; age is one of the factors, but the surgeons should consider them to find adequate surgical methods and goals. Moreover, propensity-matched cohort strengthened the evidence that sagittal alignment correction leads to substantial satisfaction in mid- to older-aged patients. The analysis overcomes the weakness of the retrospective study model.

This study has several limitations. First, participants completed only 2 years of follow-up. It is unknown how



	Baseline	2 years
The coronal Cobb angle	78	39
Sagittal vertical axis	21	-1

	Baseline	2 years
Sagittal vertical axis	110	49
Lumbar lordosis index	0.25	0.73
Global tilt	50	40

Fig.5 Case example (baseline and 2y) of two patients with adequate satisfaction with results; (**a**) The under-40 group, preoperative self-image was 2.6 and improve to 4.2 at 2y. (**b**) The over-65 group, sagittal alignment restoration was acceptable

the elucidated factors might change over a longer period. Mechanical complications and revision rates are expected to increase with follow-up time after primary surgery. Second, patients' satisfaction is subjective; there might be other relevant factors we did not include in the analysis such as the relationship between patients and medical providers. Previous research suggests satisfaction is not concurrent with objective clinical findings [25]. However, this study demonstrated several differences in the elements contributing to satisfaction between the age groups. We analyzed several factors, including demographic, surgical, clinical, and radiographical factors.

In conclusion, self-image and social life had strong correlations with satisfaction, followed by improvement of personal care ability in patients under 40 years old. Prior surgery history, complications, and SRS-22R self-image scores were independent explanatory factors of satisfaction. In contrast, pain and standing ability showed similar correlations to those of self-image and social life in patients over 40 years old. The best regression model included radicular complications, revision surgery, SRS-22R pain scores, and SVA improvement in patients under 65 years old and implant-related complications, ODI standing score, and LLI improvement in patients over 65 years old. Propensity matching cohort analysis revealed that the sagittal alignment correction led to substantial satisfaction. These results suggest that surgeons and medical professionals need to adapt their focus for each ASD group to achieve adequate postoperative satisfaction.

Compliance with ethical standards

Conflict of interest KH received research grants from Konishi Foundation for International Exchange. LB has received research support from Depuy Synthes and is a consultant of Medicrea, and Spineart. FP has received research support from Depuy Synthes, and Medtronic and is a consultant of Depuy Synthes. FJSP has received research support from Depuy Synthes and is a consultant of K2M, and Depuy Synthes. FK has received research support from Depuy Synthes and a speaker honorarium from Depuy Synthes. AA has received research support from Depuy Synthes, Medtronic and a speaker honorarium from Medtronic. IO has received research support from Depuy Synthes and is a consultant of Depuy Synthes, and Medtronic, and has royalties of Alphatec, Clariance, and Spineart. ESSG has received research support from Depuy Synthes, and Medtronic.

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