BMC Musculoskeletal Disorders

RESEARCH

Open Access

Longitudinal cumulative outcome after adult spinal deformity surgery

Susanna Hiltunen[1*], Jussi P. Repo[3], Liisa Pekkanen[2], Hannu Kautiainen[4,5] and Kati Kyrölä[2]

Abstract

Backgrounds The primary aim of this study was to investigate how the level of disability, pain, and health-related quality of life (HRQL) change during comprehensive longitudinal follow-up period after adult spinal deformity (ASD) surgery. A secondary aim was to evaluate the prevalence and time of revision surgeries due to mechanical complications.

Methods Altogether 138 ASD patients were operated at Central Finland Central Hospital between 2007 and 2019. Patients' HRQL was followed up with the following patient-reported outcome questionnaires; the Oswestry Disability Index (ODI), the Pain Visual Analogue Scale (Pain-VAS) and the Scoliosis Research Society questionnaire version 30 (SRS-30). The operation criterion was severe symptomatic sagittal and/ or coronal spinal deformity.

Results Altogether, 128 patients were included. The ODI ($p < 0.001$), the leg Pain-VAS ($p < 0.001$), and the back Pain-VAS ($p < 0.001$) continued to improve up to five to seven years after ASD surgery. The achieved level remained significant at follow-up ($p < 0.001$). The improvement that was achieved in the first year in the SRS-30 domains did not deteriorate notably at longitudinal follow-up. Ten years cumulative prevalence of mechanical failure after surgery was 24% (95% CI: 12–44%).

Conclusions Patient-reported outcomes improve up to five to seven years after ASD surgery and seemed to remain significantly better than preoperative scores at longitudinal follow-up. The majority of the mechanical complications cumulated over the first two years of follow-up.

Keywords Adult degenerative spinal deformity, Follow-up, Patient-reported outcome measures, Quality of life, Spine

Backgrounds

Adult spinal deformities (ASD) develop from multiple etiologies and increase with age [1]. Moreover, the disease burden of ASD is comparable to other self-reported severe chronic conditions in the general population [2].

The drivers of surgical treatment among adults are more often intolerable pain and dysfunction than the radiographic degree of deformity [3]. However, the aim of the surgical treatment of ASD is to relieve the symptoms by decompressing neural elements and correcting the complex three-dimensional coronal and sagittal deformities [1]. ASD surgery has a positive impact on the health-related quality of life (HRQL) of patients. As a result, the

*Correspondence:
Susanna Hiltunen
susanna.hiltunen@pshyvinvointialue.fi
[1]Department of Orthopaedics, Traumatology and Hand Surgery, Kuopio University Hospital, Kuopio, Finland
[2]Wellbeing services county of Central Finland Hospital Nova, Jyväskylä, Finland
[3]Department of Orthopaedics and Traumatology, Unit of Musculoskeletal Disease, Tampere University Hospital and University of Tampere, Tampere, Finland
[4]Primary Health Care Unit, Kuopio University Hospital, Kuopio, Finland
[5]Folkhälsan Research Center, Helsinki, Finland

number of ASD surgeries has been increasing in the past decades [1, 2, 4].

After surgical correction, radiographic results may deteriorate over time [5, 6]. The capability to maintain the sagittal balance of the body weakens as patients lose muscular strength and bone mineral density or the neuromuscular condition progresses [7]. In addition, the normative values of patient-reported outcome measures (PROM) may also deteriorate with increased age [8]. To our best knowledge, there are very few large, comprehensive studies with long-term outcomes of ASD surgery using PROMs [9–11].

Studies of patient-reported outcomes (PROs) that take into account the potential need for revision surgery provide us with the information needed to improve the treatment of patients with ASD [1, 4, 5, 9–12]. Lifelong follow-up with assessment of disability and HRQL after ASD surgery is essential as patients have a long lifespan, and they have to live with the consequences of complex spine surgery [1, 2, 4, 13].

Methods

The primary aim of this study was to investigate how the level of disability, pain, and HRQL change during a comprehensive longitudinal follow-up period after adult spinal deformity (ASD) surgery. A secondary aim was to evaluate the prevalence and time of revision surgeries due to mechanical complications, as they may affect the outcome. Proximal junctional failure (PJF) was defined as a fracture of the upper instrumented vertebra or one vertebra above, pullout of instrumentation at the upper instrumented vertebra, and/or sagittal subluxation [14].

The study was an analysis of prospectively collected data. The hypothesis of this study was that surgical correction of ASD would result in long-term improvement in disability, pain, and HRQL. Between December 2007 and January 2019, 138 adult patients aged 18 years and older underwent surgery for ASD at Central Finland Central Hospital. Patients were included as ASD if their primary symptom was the loss of sagittal or coronal balancing of the spine, they had marked thoracolumbar sagittal malalignment (pelvic incidence minus lumbar lordosis (PI-LL) > 10°, sagittal vertical axis (SVA) > 5 cm, or pelvic tilt (PT) > 25°) and/or symptomatic, progressive coronal curves [15]. The aim of surgery was to restore a balanced spine according to the neutral values of spinopelvic parameters (Fig. 1). Surgically, this means first correcting the PI-LL mismatch, sagittal and coronal malalignments. The aim in the lumbar spine was to restore elliptical, harmonic lordosis proportion.

Fig. 1 Example of pre- and postoperative radiographs of a patient who underwent spinal deformity surgery

Preoperatively, all patients completed the Finnish ODI (the Oswestry Disability Index) version 2.0 [16] and separately the leg and back Pain-VAS (the Pain Visual Analogue Scale) questionnaires, and the Finnish SRS-30 (the Scoliosis Research Society) instrument was added to the postoperative set of questionnaires after completion of the adaptation and validation process [17]. The cross-sectional sets of questionnaires were sent three weeks prior to the answering deadlines on May 1, 2017 and May 1, 2020 (Fig. 2).

Spinopelvic parameters at different points of time were measured independently by two authors (SH and KK) and the final measurements were calculated as the mean of the measurements of the two observers. Values that clearly differed from each other were remeasured together and the consensus value was used in the analysis.

Statistical methods

The descriptive statistics were presented as means with standard deviation (SD), as medians with range or as counts with percentages. Longitudinal measures of the changes in outcomes were estimated with mixed-effect REML (restricted maximum likelihood) regression models and an unstructured covariance structure (i.e., the Kenward-Roger method for calculating the degrees of freedom). The effect of time was used in the models as square terms. Mixed models allowed the analyses of unbalanced datasets without imputation, and therefore we analyzed all available data with the full analysis set. The Kaplan-Meier method was used to estimate the probability of cumulative incidence of failure. Normal distributions were evaluated graphically and with the Shapiro–Wilk test. All analyzes were performed with Stata 17.0 (Stata-Corp LP; College Station, TX, USA).

Results

A total of 128 (93%) patients were eligible for analysis (Fig. 2). Altogether, 87 (68%) patients were female, aged mean (SD) 65 (9.1), range 22 to 81 years at index surgery. Of the 128 patients, 42 (33%) had two or more chronic diseases. During follow-up, six patients died

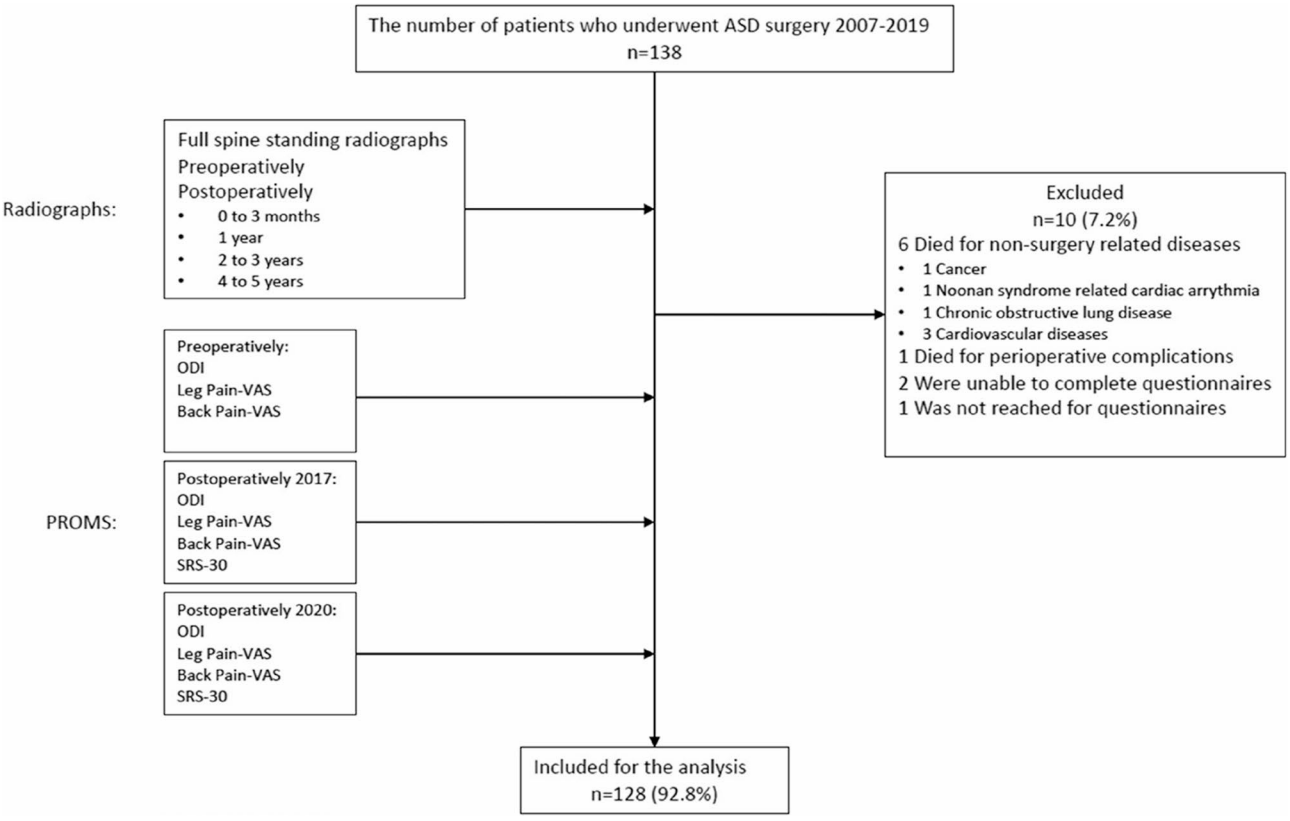

Fig. 2 Patient flow chart. Flow chart depicting patient selection. ODI; the Oswestry Disability Index, SRS-30; the Scoliosis Research Society questionnaire version 30, VAS; the Visual Analogue Scale

of non-surgery related causes and one of perioperative complications. Two patients were unable to complete the questionnaires due to a neurological condition, and one was not reached.

Mean follow-up time for the first set of questionnaires in 2017 was median (min - max) 4.3 (1.0–9.4) years and 4.6 (1.3–12.4) years for the second set of questionnaires in 2020. A total of 90 patients answered the first and 121 patients answered the second set of questionnaires.

In our cumulative patient data, the follow-up period was five years or longer in 63 (49%) patients. A ten-year follow-up period was accumulated for 17 (13%) patients of 128 [see Additional file 1].

The preoperative characteristics of the patient population are presented in Table 1. Pre- and postoperative spinopelvic parameters are presented in Table 2. The mean (median; range) number of the fused levels was eight (nine; one to 16), and 70 (54%) of the patients had eight or more levels of fusion. Decompression was performed in a total of 91 (71%) patients simultaneously with deformity surgery. Four (3.1%) patients underwent surgery as planned in two stages. The lowest fixation was performed at the pelvis in 94 (73%), at the S1 vertebra in 27 (21%), and above the S1 vertebra in seven (5.4%) patients. Of the 128 patients, 127 (99%) had posterior rod construction. Of them, 86 (68%) patients had two, 10 (8.0%) had three and 31 (24%) had four longitudinal rods. In all posterior instrumentations, titanium alloy pedicle screws were used. The posterior rod material used was titanium alloy in 102 (80%) patients, cobalt-chrome in 25 (19%) and titanium-cobalt-chrome hybrid in one (1.0%). The surgical technique was in situ Smith-Petersen or posterior resection Ponte osteotomy in 23 patients (18%), pedicle subtraction osteotomy (a three-column osteotomy) in 53 patients (41%) and anterior interbody fusion in 52 patients (41%). Interbody cages were used in the ALIF technique in the anteriorly operated spaces. In addition, in the osteotomies, we used a TLIF implant in the anterior part of the wide osteotomy as a wedge to avoid lateral or anteroposterior dislocation of the spine. If the entire surgery was performed only posteriorly, a 360-degree fusion was performed in the presacral space to improve ossification of the junction, using a TLIF cage and bone graft with an ossification indication.

Preoperative mean (SD) ODI was 52% (13%) which indicates severe disability. The ODI changed −10% (95% CI: −12% to −8.0%; $p<0.001$) within two years after surgery. The outcome that was achieved within 2 years postoperatively remained at ten-year follow-up (95% CI: −7.0–5.0%; $p=0.65$). Postoperatively, the ODI scores

Table 1 Preoperative characteristics in the study population ($n=128$)

Parameter	Measures
Age (years), mean (SD)	65 (9.1)
Female, n (%)	87 (68)
BMI, mean (SD)	27 (4.3)
Previous low back fusion, n (%)	48 (38)
Spinal stenosis, n (%)	91 (71)
Main surgical diagnosis, n (%)	
Spondylarthrosis and sagittal malalignment	48 (38)
Degenerative de novo-scoliosis	49 (38)
Adolescent idiopathic scoliosis	9 (7.0)
Parkinson's disease	15 (12)
Post-traumatic deformity	6 (4.7)
High grade spondylolisthesis or -ptosis	1 (0.8)
Chronic co-morbidities, n (%)	
Diabetes	21 (16)
Severe lung condition	23 (18)
Rheumatoid disease	16 (13)
Osteoporosis	20 (16)
Neuromuscular disease*	22 (17)
Depression	30 (23)
Neuropathic pain syndrome	27 (21)
Two or more chronic diseases	42 (33)
SRS-Schwab deformity classification, n (%)	
Mild	28 (22)
Moderate	33 (26)
Severe	67 (52)

BMI Body mass index kg/m^2,*PROM* Patient-reported outcome measure

*Parkinson's disease (n=15), axial myopathy (n=6), spastic diplegia (n=1)

Table 2 Spinopelvic parameters at different points of time

Parameter Mean (SD)	Pre	Post 0–3 mo	Post 1 y	Post 2–3 y	Post 4–5 y
PI (°)	62 (14)	62 (15)	62 (14)	62 (14)	61 (14)
LL (°)	38 (20)	56 (13)	55 (14)	54 (14)	53 (12)
PI-LL (°)	24 (19)	6.3 (14)	7.0 (14)	7.8 (15)	7.9 (15)
PT (°)	25 (11)	20 (11)	20 (12)	21 (11)	21 (12)
TPA (°)	27 (13)	18 (10)	19 (11)	21 (12)	22 (13)
SVA (mm)	88 (62)	45 (43)	51 (50)	66 (50)	68 (50)

LL Lumbar lordosis, *mo* Months, *PI-LL* PI minus LL, *PI* Pelvic incidence, *post* postoperatively, *pre* preoperatively, *PT* Pelvic tilt, *SD* Standard deviation, *SVA* C7 sagittal vertical axis, *TPA* T1 pelvic angle, *y* Years

continued to improve for five years (Fig. 3). There was no difference in the ODI scores between sexes ($p=0.41$).

Preoperatively, the mean (SD) VAS-Back was 69 (23) mm and VAS-Leg was 66 (26) mm, and both decreased significantly within two years after surgery: the VAS-Back by 19 mm (95% CI: −23 mm to −15 mm; $p<0.001$) and the VAS-Leg by 15 mm (95% CI: −19 mm to −10 mm; $p<0.001$) (Fig. 4). However, both VAS scores continued to improve through seven years postoperatively and were significantly better ten years postoperatively than after the first year of convalescence ($p<0.001$).

The SRS-30 (the Scoliosis Research Society questionnaire version 30) scores were measured from the first to the tenth postoperative year. The best scores were in the domains of satisfaction with management, pain, and mental health in rank order (Fig. 5). The level that was achieved one year postoperatively for the total score and the five domains of the SRS-30 remained at ten years, and the changes during the follow-up were insignificant ($p=0.63$–0.81).

Mean values of patient-reported outcome measures at different points of time are presented in Table 3.

A total of 20 (15%) patients had 23 mechanical complications that required reoperation due to risk of instability or if the patient's symptoms were associated to the mechanical complication visible on radiograph. Of these, 11 were proximal junctional failures (PJFs) and 12 rod breakages (RBs). Mechanical complications that did not require reoperation included 4 PJF and 6 RB. Ten years cumulative prevalence of mechanical failure after surgery was 24% (95% CI: 12–44%) (Fig. 6). Median time for PJF was 4.5 months (range 0.5–48 months) and for RB 21 months (range 6–120 months) after index surgery.

Discussion

In the present cumulative, longitudinal clinical study, the authors followed the changes in patients' disability and HRQL up to 10 years after ASD surgery. The study population achieved a significant long-term improvement in disability and HRQL after ASD surgery. The improvement of disability continued for five and pain for seven years postoperatively. The good outcome was not lost at ten-year follow-up. It is important to note that in our patient group, whose average age was 65 years, there is a significant number of other chronic diseases that affect the quality of life appear during a long follow-up period.

There are few studies that report PROs after more than two to five years postoperatively [5, 9, 10, 18, 19]. These studies support the findings of the present study that the postoperative result of ASD surgery should not be evaluated earlier than 2 years after the surgery.

Although the ODI score that was achieved postoperatively remained during the follow-up period, the postoperative ODI score in our patient population was clearly worse than the normative ODI score, which has been reported to be around 10 [20]. Tonosu et al. reported that the ODI score deteriorates with age [8]. In a multicenter retrospective review, Wang et al. reported that ODI and VAS improve significantly at two-year follow-up [5]. However, during the four-year follow-up, patients on average had lost 24% of the improvement achieved at two years, a finding that differs from our outcomes [5]. In the present study, the slight decline in Pain-VAS and the ODI scores may result from the normative changes with aging, especially when the patients in our data also

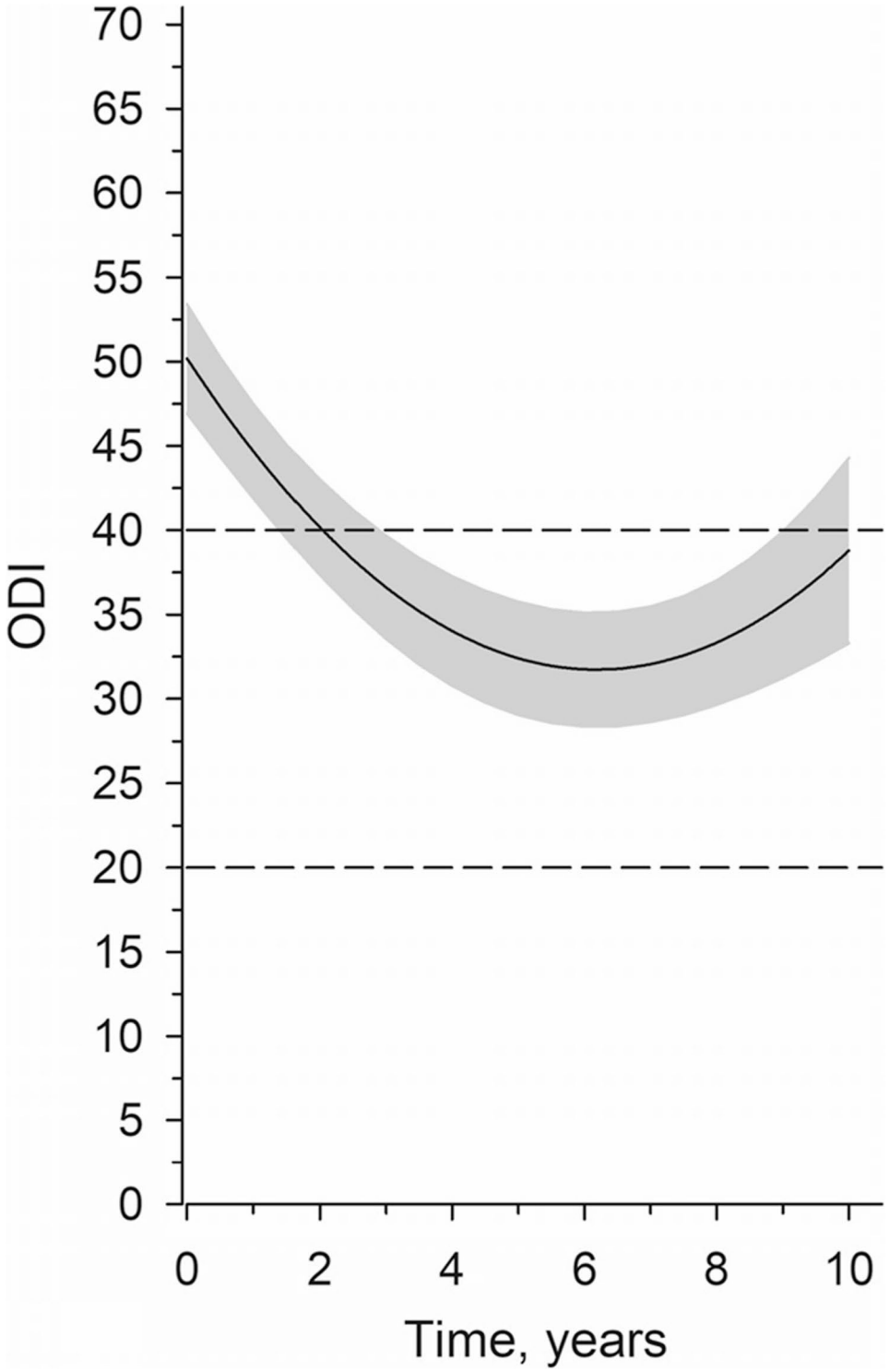

Fig. 3 The Oswestry Disability index (ODI%) after ASD surgery. The Oswestry Disability index (ODI%) after ASD surgery in ten-year follow-up. The effect of time was used in the models as square terms. The shaded area represents a 95% confidence interval

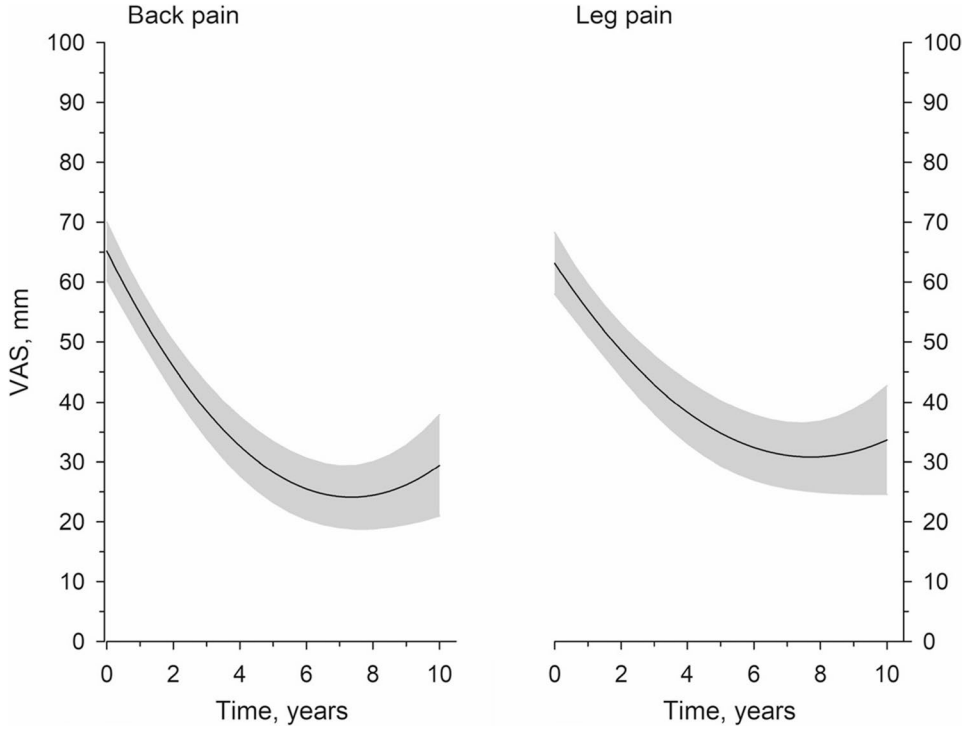

Fig. 4 The Back and leg pain Visual Analogue Scale scores after ASD surgery. The Back and leg pain Visual Analogue Scale scores after ASD surgery in ten-year follow-up. The effect of time was used in the models as square terms. The shaded area represents a 95% confidence interval

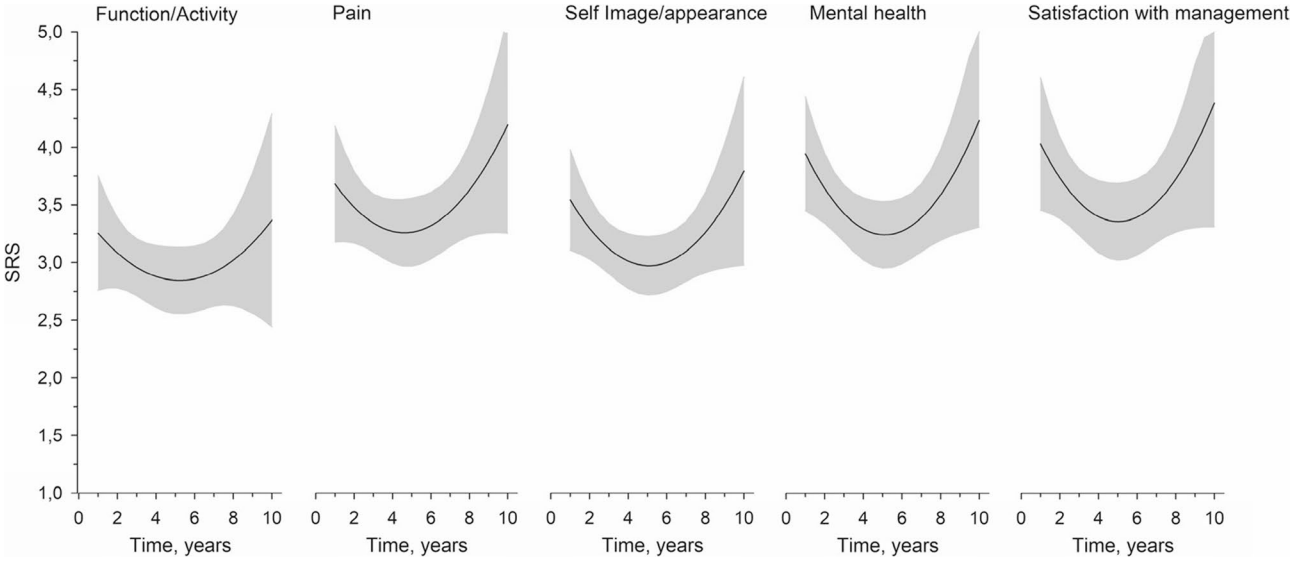

Fig. 5 The SRS-30 domains after ASD surgery. The SRS-30 domains after ASD surgery in ten-year follow-up. The effect of time was used in the models as square terms. The shaded area represents a 95% confidence interval

had other chronic diseases that can affect the results [2, 8]. Similar outcomes to those of traditional open surgery were achieved with a combination of minimally invasive techniques by Anand et al. [9]. In their study, the PROs of adult patients with mild spinal deformities improved and remained significantly better at intervals of 2 to 5 years after surgery [9].

After complex ASD surgery, both Adogwa et al. [10] and Zuckerman et al. [11] reported that PROs improved for up to two years and that the results were maintained at five-year follow-up. Adogwa et al. also found that PROs collected at 2-year follow-up may accurately predict long-term PROs [10]. Major surgery-related complications did not affect the outcomes in the study by

Table 3 Patient-reported outcome measures at different points of time

PROM Mean (SD, median, min– max)	Pre	2017	2020
ODI (%)	52 (13, 52, 20–80)	36 (20, 33, 3.0–82)	35 (19, 36, 2.0–84)
Back Pain-VAS (mm)	69 (23, 73, 5.0–98)	31 (23, 23, 1.0–90)	34 (29, 25, 0.0–92)
Leg Pain-VAS (mm)	66 (26, 73, 0.0–98)	36 (30, 34, 0.0–100)	38 (31, 40, 0.0–97)
SRS-30 Total		3.3 (0.76, 3.3, 1.4–4.9)	3.3 (0.78, 3.4, 1.4–5.0)
SRS Function/activity		3.0 (0.91)	3.0 (1.0)
SRS Pain		3.4 (0.88)	3.5 (0.90)
SRS Self image/appearance		3.2 (0.81)	3.2 (0.79)
SRS Mental health		3.5 (0.93)	3.5 (0.90)
SRS Satisfaction with management		3.6 (1.1)	3.6 (1.0)

ODI The Oswestry Disability Index, *Pre* Preoperatively, *PROM* Patient-Reported Outcome Measure, *SRS* The Scoliosis Research Society, *VAS* The Visual Analogue Scale

Zuckerman et al. [11]. These findings support the results from the present clinical study.

Unfortunately, we did not have preoperative SRS-30 scores, so we could not evaluate the effect of surgery on SRS-30, but we can conclude that the result achieved with surgery was maintained during the follow-up period. In our study the greatest improvements were seen in the Satisfaction with Management and Pain domains. With complex ASD treated patients, Riley et al. [19] found that the SRS-22r improved significantly across all domains after surgery at a minimum follow-up of two years. The greatest improvements were seen in the Pain and Self-Image domains. The SRS-22r questionnaire differs from the SRS-30 questionnaire in that the latter also contains items intended only for patients who have undergone spinal surgery. The study population in Riley et al.'s study was on average fourteen years younger than our cohort, which may explain differences in evaluating one's own appearance and attractiveness. On the other hand, the changes in the SRS-30 domains in our study were small and, based on the statistical analyses, the changes were not significant. The changes in our study were smaller than minimal important differences of the domains of the SRS-22r in the study presented by Bago et al. [21].

In the present population, pain was relieved by both Pain-VAS and the SRS-30 Pain domain, and the improvements achieved remained during the follow-up period. Pain relief has been shown to be the patients' primary expectation after ASD surgery [22].

Loss of function may be more readily accepted when patients have a good relationship with their surgeon and trust in their own health care team, even though persistent pain is not easily tolerated [23]. In the present study, good and long-lasting pain relief was associated with high satisfaction with management measured with the SRS-instrument. The causality of this finding, however, cannot be proved, as patient-reported experience measures were not included in the study. Black et al. [24] found that the experienced level of communication and the patient's trust in their doctor after elective musculoskeletal surgery associated with good PROs. In the present study setting, the patients were treated with a dedicated team of ASD surgeons, and the families were incorporated in the process.

In the present study, most of the revision surgeries for mechanical failure were performed within two years of the index surgery. However, the total number of revisions was small and cumulated over the first two years of follow-up. This did not, however, allow a proper analysis of the effect of the revisions on long-term outcomes and patients' satisfaction with management. In our previously published study, which was partly based on the same population, we investigated the applicability of the Global Alignment and Proportion (GAP) Score [14] for predicting those mechanical complications that lead to revision surgery [25]. Our study revealed that a GAP score of five or higher increased the risk of revision surgery. Patient satisfaction is included in very few patient-reported outcome instruments, and the item is easily biased [23]. Correlation of patient satisfaction with PROMs, complications, or radiographic parameters may be weak [23, 26]. Even major complications with reoperations [27] or pelvic fusion have not been reported to negatively affect patient satisfaction [28].

A strength of the present study is the single institution with an experienced spine surgery team and an established, thorough preoperative patient selection protocol. There has been a considerable loss of patients in long-term follow-up in many previous studies, ranging from 23 to 72% [10, 11, 19]. In the present study, however, the loss of patients to follow-up was considerably smaller (7%). While national administrative registries may offer large comprehensive populations for long-term follow-up, they often lack the clinical and PRO data contained in physician-managed databases [29]. The patients reside mostly within the hospital catchment area, and patient loss to longitudinal follow-up is minimal. The present real-life study results are generally applicable to similar populations, aiding in the interpretation of the treatment effectiveness of adult ASD surgery.

A weakness of this study is the relatively small study population (128 patients included), although this number compares favorably with previously published studies (47–91 patients included) [5, 9–11, 19]. In addition, the heterogeneity of the population constrained high-quality sub-group analyses. The outcome was not measured at

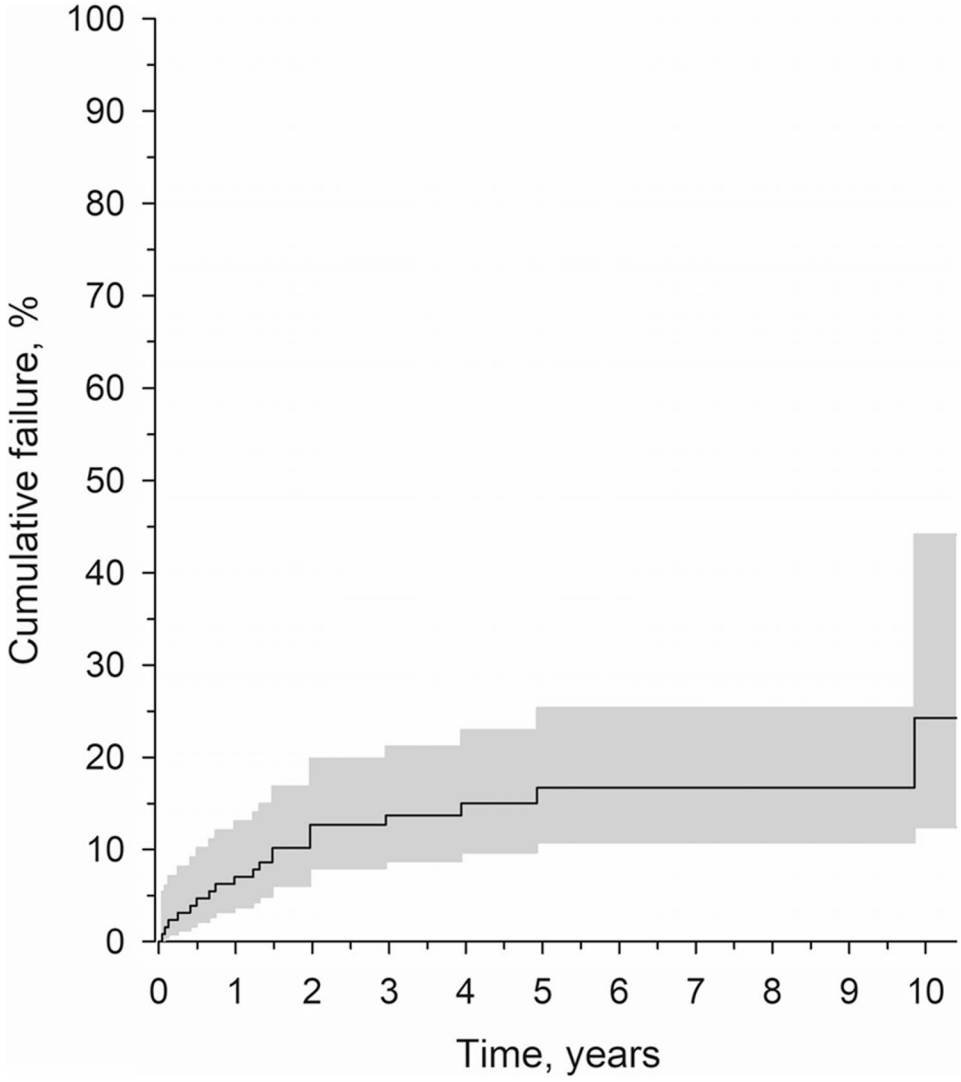

Fig. 6 Cumulative mechanical failure after ASD surgery. Cumulative mechanical failure after ASD surgery. Comprises proximal junctional failure or rod breakage that required surgical treatment. The shaded area represents a 95% confidence interval

fixed points of time, but a mathematical model was used after the repeated cross-sectional comprehensive sets of questionnaires. The SRS-30 questionnaire was not implemented in our clinic until it was translated into Finnish and culturally validated in 2017 [17], and the lack of preoperative SRS-30 scores is a limitation of the study. We used the older SRS-30 version instead of the more recent SRS-22r, as the SRS Society withdrew the SRS-30 during the course of our research. The SRS-30 was already in use in operated patients at the start of the study, so we did not see it as reasonable to change it during the study in order to maintain consistency of data between patients. Nevertheless, we chose to continue using the SRS-30 because it included questions targeted to patients who have undergone surgery. Unfortunately, due to the cumulative nature of the study, 51% of patients achieved a follow-up time of less than 5 years, and the 10-year outcome could only be achieved in 13% of patients.

In the future, the lifelong follow-up after ASD surgery and comparison with the general population could give information on long-term morbidity and disability after long spinal fusion and aging. As patient experience of the treatment may bias the outcomes, including patient-reported experience measures with PROMs for an ASD surgery cohort is also worthy of future study.

Conclusions

After adult spinal deformity correction surgery, disability and pain improved up to five to seven years and seemed to remain significantly better than preoperative scores at longitudinal follow-up. Pain relief and satisfaction with the management were the highest scoring SRS instrument domains after ASD surgery. The majority of

mechanical complications cumulated over the first two years of follow-up.

Abbreviations

ASD	Adult spinal deformity
BMI	Body mass index (kg/m^2)
CI	Confidence interval
GAP score	Global Alignment and Proportion Score
HRQL	Health-related quality of life
LL	Lumbar lordosis
max	Maximum (the highest value)
min	Minimum (the lowest value)
mo	Months
ODI	The Oswestry Disability Index
PI-LL	Pelvic incidence minus lumbar lordosis
PI	Pelvic incidence
PJF	Proximal junctional failure
Post	Postoperatively
pre	Preoperatively
PRO(s)	Patient-reported outcome(s)
PROM(s)	Patient-reported outcome measure(s)
PT	Pelvic tilt
RB	Rod breakage
REML	Restricted maximum likelihood
SD	Standard deviation
SRS-22r	The Scoliosis Research Society questionnaire-22 revised
SRS-30	Scoliosis Research Society questionnaire version 30
SRS	The Scoliosis Research Society
SVA	C7 sagittal vertical axis
TPA	T1 pelvic angle
VAS	The Pain Visual Analogue Scale
y	Years

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12891-025-08927-y.

Additional file 1.

Acknowledgements
Not applicable.

Authors' contributions
All authors (S.H., J.R., L.P, H.K and K.K) made a substantial contribution to the conception or design of the work; or the acquisition, analysis, or interpretation of data. H.K. did the static analyzes and based on them Figs. 3, 4, 5 and 6. K.K. made Table 1. S.H made Table 2, and 3; figure 1 and additional file figure in collaboration with other authors. All authors drafted the article or revised it critically for important intellectual content. All authors approved the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content.

Funding
This study was funded by the Finnish Government Research Fund and the University of Eastern Finland. The funders had no role in the design of the study and collection, analysis, and interpretation of data or in writing the manuscript.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the ethical committee of Central Finland Health Care District (diary number 17U/2012). The study was conducted in accordance with the current laws of the study country. Patient's permission to participate and to publish the clinical study were acquired at admission to treatment to the institution and approved by the chief medical physician. The informed consent we obtained from all patients participating in the study was written.

Consent for publication
Patient's permission to participate and to publish the clinical study were acquired at admission to treatment to the institution and approved by the Chief Medical Physician. The informed consent we obtained from all patients participating in the study was written.

Competing interests
The authors declare no competing interests.

Received: 4 May 2024 / Accepted: 25 June 2025
Published online: 26 July 2025

References

1. Diebo BG, Shah NV, Boachie-Adjei O, Zhu F, Rothenfluh DA, Paulino CB, et al. Adult spinal deformity. Lancet. 2019;394:160–72.
2. Pellisé F, Vila-Casademunt A, Ferrer M, Domingo-Sàbat M, Bagó J, Pérez-Grueso FJS, et al. Impact on health related quality of life of adult spinal deformity (ASD) compared with other chronic conditions. Eur Spine J. 2015;24:3–11.
3. Pizones J, Martin-Buitrago MP, Perez-Grueso FJS, Vila-Casademunt A, Alanay A, Obeid I, et al. Function and clinical symptoms are the main factors that motivate thoracolumbar adult scoliosis patients to pursue surgery. Spine (Phila Pa 1976). 2017;42:E31–6.
4. Sciubba DM, Yurter A, Smith JS, Kelly MP, Scheer JK, Goodwin CR, et al. A comprehensive review of complication rates after surgery for adult deformity: A reference for informed consent. Spine Deform. 2015;3:575–94.
5. Wang MY, Park P, Tran S, Anand N, Nunley P, Kanter A, et al. Intermediate-term clinical and radiographic outcomes with less invasive adult spinal deformity surgery: patients with a minimum follow-up of 4 years. Acta Neurochir (Wien). 2020;162:1393–400.
6. Inoue S, Khashan M, Fujimori T, Berven SH. Analysis of mechanical failure associated with reoperation in spinal fusion to the sacrum in adult spinal deformity. J Orthop Sci. 2015;20:609–16.
7. Kawabata A, Yoshii T, Sakai K, Hirai T, Yuasa M, Inose H, et al. Identification of predictive factors for mechanical complications after adult spinal deformity surgery: A Multi-Institutional retrospective study. Spine (Phila Pa 1976). 2020;45:1185–92.
8. Tonosu J, Takeshita K, Hara N, Matsudaira K, Kato S, Masuda K, et al. The normative score and the cut-off value of the Oswestry disability index (ODI). Eur Spine J. 2012;21:1596–602.
9. Anand N, Baron EM, Khandehroo B, Kahwaty S. Long-term 2- to 5-year clinical and functional outcomes of minimally invasive surgery for adult scoliosis. Spine (Phila Pa 1976). 2013;38:1566–75.
10. Adogwa O, Karikari IO, Elsamadicy AA, Sergesketter AR, Galan D, Bridwell KH. Correlation of 2-year SRS-22r and ODI patient-reported outcomes with 5-year patient-reported outcomes after complex spinal fusion: A 5-year single-institution study of 118 patients. J Neurosurg Spine. 2018;29:422–8.
11. Zuckerman SL, Cerpa M, Lenke LG, Shaffrey CI, Carreon LY, Cheung KMC, et al. Patient-reported outcomes after complex adult spinal deformity surgery: 5-year results of the scoli-risk-1 study. Global Spine J. 2022;12:1736–44.
12. Safaee MM, Ames CP, Smith JS. Epidemiology and socioeconomic trends in adult spinal deformity care. Neurosurgery. 2020;87:25–32.
13. Klineberg EO, Passias PG, Poorman GW, Jalai CM, Atanda A, Worley N, et al. Classifying complications: assessing adult spinal deformity 2-Year surgical outcomes. Global Spine J. 2020;10:896–907.
14. Yilgor C, Sogunmez N, Boissiere L, Yavuz Y, Obeid I, Kleinstück F, et al. Global alignment and proportion (GAP) score. J Bone Joint Surg. 2017;99:1661–72.
15. Diebo BG, Henry J, Lafage V, Berjano P. Sagittal deformities of the spine: factors influencing the outcomes and complications. Eur Spine J. 2014;24:3–15.
16. Pekkanen L, Kautiainen H, Ylinen J, Salo P, Häkkinen A. Reliability and validity study of the Finnish version 2.0 of the Oswestry disability index. Spine (Phila Pa 1976). 2011;36:332–8.
17. Kyrölä K, Järvenpää S, Ylinen J, Mecklin J-P, Repo JP, Häkkinen A. Reliability and validity study of the Finnish adaptation of scoliosis research society questionnaire version SRS-30. Spine (Phila Pa 1976). 2017;42:943–9.

18. Zuckerman SL, Cerpa M, Lenke LG, Shaffrey CI, Carreon LY, Cheung KMC, et al. Patient-Reported Outcomes After Complex Adult Spinal Deformity Surgery: 5-Year Results of the Scoli-Risk-1 Study. Global Spine J. 2021;12:219256822098827.
19. Riley MS, Bridwell KH, Lenke LG, Dalton J, Kelly MP. Health-related quality of life outcomes in complex adult spinal deformity surgery. J Neurosurg Spine. 2018;28:194–200.
20. Fairbank JCT, Pynsent PB. The Oswestry disability index. Spine (Phila Pa 1976). 2000;25:2940–53.
21. Bagó J, Pérez-Grueso FJS, Les E, Hernández P, Pellisé F. Minimal important differences of the SRS-22 patient questionnaire following surgical treatment of idiopathic scoliosis. Eur Spine J. 2009;18:1898–904.
22. Ryu WHA, Platt A, O'Toole JE, Fontes R, Fessler RG. Patient expectations of adult spinal deformity correction surgery. World Neurosurgery. 2021;146:e931–e939. https://doi.org/10.1016/j.wneu.2020.11.035. Epub 2020 Nov 16
23. Hamilton DK, Kong C, Hiratzka J, Contag AG, Ailon T, Line B, et al. Patient satisfaction after adult spinal deformity surgery does not strongly correlate with Health-Related quality of life scores, radiographic parameters, or occurrence of complications. Spine (Phila Pa 1976). 2017;42:764–9.
24. Yagi M, Fujita N, Tsuji O, Nagoshi N, Asazuma T, Ishii K, et al. Low Bone-Mineral density is a significant risk for proximal junctional failure after surgical correction of adult spinal deformity. Spine (Phila Pa 1976). 2018;43:485–91.
25. Hiltunen S, Repo JP, Pekkanen L, Kautiainen H, Kyrölä K. Mechanical complications and reoperations after adult spinal deformity surgery: a clinical analysis with the GAP score. Eur Spine J. 2023;32:1421–8.
26. Ring D, Leopold SS. Editorial—Measuring satisfaction: can it be done?? Clinical orthopaedics and related research. Clin Orthop Relat Res. 2015;473:3071–3.
27. Passias PG, Soroceanu A, Yang S, Schwab F, Ames C, Boniello A, et al. Predictors of revision surgical procedure excluding wound complications in adult spinal deformity and impact on patient-reported outcomes and satisfaction. J Bone Joint Surg - Am Volume. 2016;98:536–43.
28. Hart RA, Hiratzka J, Kane MS, Lafage V, Klineberg E, Ames CP, et al. Stiffness after Pan-Lumbar arthrodesis for adult spinal deformity does not significantly impact patient functional status or satisfaction irrespective of proximal endpoint. Spine (Phila Pa 1976). 2017;42:1151–7.
29. Buckland AJ, Poorman G, Freitag R, Jalai C, Klineberg EO, Kelly M, et al. National administrative databases in adult spinal deformity surgery. Spine (Phila Pa 1976). 2017;42:1248–54.

Publisher's Note