Clinical outcomes of corrective fusion surgery from the thoracic spine to the pelvis for adult spinal deformity at 1, 2, and 5 years post-operatively

メタデータ	言語: English 出版者: Wolters Kluwer Health 公開日: 2023-12-11 キーワード (Ja): キーワード (En): 作成者: Arima, Hideyuki, Hasegawa, Tomohiko, Yamato, Yu, Yoshida, Go, Banno, Tomohiro, Oe, Shin, Mihara, Yuki, Ide, Koichiro, Watanabe, Yuh, Nakai, Keiichi, Kurosu, Kenta, Matsuyama, Yukihiro メールアドレス: 所属:
URL	http://hdl.handle.net/10271/0002000056

Clinical outcomes of corrective fusion surgery from the thoracic spine to the pelvis for adult spinal deformity at 1, 2, and 5 years post-operatively

Hideyuki Arima, M.D., Ph.D.[1]; Tomohiko Hasegawa, M.D., Ph.D. [1]; Yu Yamato, M.D., Ph.D. [1,2]; Go Yoshida, M.D., Ph.D. [1]; Tomohiro Banno, M.D., Ph.D. [1]; Shin Oe, M.D. Ph.D. [1,2]; Yuki Mihara, M.D. Ph.D. [1],Koichiro Ide, M.D. [1] Yuh Watanabe, M.D. [1] Keiichi Nakai, M.D. [1], Kenta Kurosu, M.D. [1],Yukihiro Matsuyama, M.D., Ph.D. [1]

1) Department of Orthopaedic Surgery, Hamamatsu University School of Medicine, 1-20-1 Handayama, Higashi-ku, Hamamatsu-city, Shizuoka, 431-3192 Japan

2) Division of Geriatric Musculoskeletal Health, Hamamatsu University School of Medicine, 1-20-1, Hamamatsu-city, Shizuoka, 431-3192 Japan

Corresponding author:

Hideyuki Arima M.D., Ph.D. (ORCID 0000-0003-0586-6818)

Department of Orthopedic Surgery,

Hamamatsu University School of Medicine Japan,

1-20-1, Handayama, Higashi-ku, Hamamatsu-city,

Shizuoka, JAPAN 431-3192

Tel: (+81)-53-435-2299

Fax: (+81)-53-435-2296

E-mail: arihidee@gmail.com

Conflicts of Interest and Source of Funding:

Arima, Hasegawa, Yoshida, Banno, Mihara, Ide, Watanabe, Nakai, Kurosu, and Matsuyama have nothing to disclose.

Yamato and Oe received donated laboratory funding from Medtronic Sofamor Danek Inc. (Memphis, TN, USA), Japan Medical Dynamic Marketing Inc. (Tokyo, Japan), and Meitoku Medical Institute Jyuzen Memorial Hospital (Hamamatsu, Japan).

No fund was received in support of this work

Ethics Approval

IRB approval: This study was reviewed and approved by the Hamamatsu University School of Medicine Institutional Review Board. (IRB No.20-264)

Author Contributions

Conception and design: Arima, Matsuyama.

Acquisition of data: all authors

Analysis and interpretation of data: all authors

Statistical analysis: Arima

Study supervision: Hasegawa, Matsuyama,

Drafting the article: Arima.

Critically revising the article: Hasegawa, Yamato, Yoshida, Banno, Oe, Mihara, Ide, Watanabe, Nakai, Kurosu, Matsuyama

Reviewed submitted version of manuscript: all authors

Approved the final version of the manuscript: all authors

Agree to be accountable for all aspects of the work: all authors

Acknowledgments

The authors would like to thank Ms. Nao Kuwahara, Ms. Tomoe Mabuchi, Mr. Taku Nagao and Mr. Tomokazu Suzuki, Secretaries of the Department of Orthopedic Surgery, for their excellence in technical assistance during data collection. We would like to thank Editage for English language editing.

Abstract

Study Design: Retrospective cohort study.

Objective: To investigate whether patient-reported outcomes (PROs) were consistent at 2 and 5 years after corrective fusion surgery from the thoracic spine to the pelvis in patients with adult spinal deformity (ASD) and to analyze whether revision surgery affected long-term outcomes.

Summary of Background Data: PROs up to 2 years after corrective surgeries for ASD have been well-studied, but there are few reports of mid- to long-term results.

Methods**:** We retrospectively analyzed patients with ASD who underwent corrective fusion surgery from the thoracic spine to the pelvis between 2010 and 2015. We investigated radiographic parameters and PROs (Scoliosis Research Society 22r [SRS-22r], Oswestry Disability Index [ODI]) pre-operatively and at 1, 2, and 5 years post-operatively, and the correlations between PROs at these time points. We also compared changes in PROs at 5 years in patients who underwent revision surgery and those who did not.

Results: A total of 131 patients who underwent corrective fusion surgery from the thoracic spine to the pelvis were analyzed. The PROs at 1 and 5 years after surgery showed significant correlations in all SRS-22r domains [function (r=0.620), pain (r=0.577), self-image (r=0.563), mental health (r=0.589), subtotal (r=0.663), and ODI (r=0.654)]. The PROs at 2 and 5 years after surgery showed significantly strong correlations in all domains [function (r=0.715), pain (r=0.678), self-image (r=0.653), mental health (r=0.675), subtotal (r=0.741), and ODI (r=0.746)]. There were no significant differences in the change in PROs at 5 years in any domain in patients who underwent revision surgery (all P>0.05).

Conclusions: One-year post-operative PROs improved significantly. Two-year PROs correlated strongly with 5-year post-operative PROs, indicating that 2-year PROs can predict longer term outcomes. The need for revision surgery did not influence the mid- to long-term clinical outcomes of corrective fusion surgery for ASD.

INTRODUCTION

Adult spinal deformities (ASD) are associated with poor spinal and pelvic alignment, resulting in a variety of problems such as back pain, lower extremity pain, gait disturbance, visceral disturbance, and psychological disturbance.[5,16,18] Patients with mild to moderate ASD can be treated with conservative therapies such as medication and exercise therapy, but surgical treatment is an option for patients whose daily activities and health-related quality of life deteriorate despite adequate conservative treatment.[12,22] Pre- and post-operative evaluation in patients with ASD generally involves assessment of radiological parameters in the sagittal and coronal planes on full-length freestanding spine radiographs. In addition, the Patient-Related Outcome (PRO) is used to evaluate the patient's subjective clinical outcomes. The Scoliosis Society Research (SRS)-22r questionnaire, developed in the United States, has been used widely for ASD patients because of its reliability, validity, and response to treatment.[9-11] The Oswestry Disability Index (ODI) questionnaire, which is widely used in spinal diseases, is also frequently used in the field of ASD.[15,31] Radiological and PRO evaluations for degenerative spine disease are generally performed at 2 years post-operatively. However, corrective fusion surgery from the thoracic spine to the pelvis for ASD can cause various problems, such as rod fractures associated with pseudoarthrosis, after that 2-year post-surgery timepoint. Therefore, 2-year post-operative evaluation may be inadequate. The purpose of this study was to investigate whether patient clinical outcomes are maintained from 2 to 5 years post-operatively in corrective fusion surgery for ASD from the thoracic spine to the pelvis. We also aimed to determine whether unanticipated revision surgeries affect long-term outcomes.

MATERIALS AND METHODS

Patient population

This study was reviewed and approved by our Institutional Review Board and adhered to the principles of the Declaration of Helsinki. We obtained written informed consent from all participants to publish our findings. In this study, patients were diagnosed with ASD if they were 18 years or older with confirmed presence of at least one of the following: coronal scoliosis with a Cobb angle ≥20°, a sagittal vertical axis ≥5 cm, pelvic tilt ≥25°, or thoracic kyphosis ≥60°. The cohort included patients with ASD who underwent corrective fixation surgeries from the thoracic spine to the pelvis between 2010 and 2015 at a single institution and were available for follow-up for at least 5 years. Patients with spinal deformities associated with infection, malignancy, and neuromuscular disease were excluded. Patients with incomplete clinical outcome data were excluded. Data on the following characteristics were extracted: age, sex, body mass index (BMI) (kg/m^2), Charlson Comorbidity Index (CCI),[14] and American Society of Anesthesiologists classification (Table 1). The pathology of scoliosis was investigated. Regarding surgical data, the number of fused vertebrae, the upper instrumented vertebrae (UIV) level, presence or absence of an iliac screw, whether surgery was performed in two stages, total operation time, total intra-operative blood loss, peri-operative complications (surgical, neurological, medical), and revision surgery within 5 years after surgery were investigated (Table 2). Surgical complications included surgical site infection and hematoma, neurological complications including two or more levels of weakness on a manual muscle strength test that were either transient or permanent, and medical complications including deep venous thrombosis, cardiac disease, cerebral disease, pneumonia, gastrointestinal disease, urinary tract infection, and delirium. In this study, we defined surgical site infections as those that required surgical debridement for deep infection.

Radiographic measurements

Full-length freestanding posteroanterior and lateral spine radiographs obtained at baseline and at 2 and 5 years after surgery were analyzed. Board-certified spine surgeons used standard techniques to measure spinopelvic parameters, including thoracic kyphosis (Cobb angle between the superior endplate of T-5 and the inferior endplate of T-12), lumbar lordosis (LL; Cobb angle between the superior endplate of L-1 and superior endplate of S-1), pelvic tilt (angle subtended by a vertical reference line originating from the center of the femoral head and the midpoint of the sacral endplate), pelvic incidence (PI; angle between the line perpendicular to the sacral plate at its midpoint and the line connecting this point to the femoral head axis), and sagittal vertical axis (the distance of the C-7 plumb line from the posterior-superior aspect of the sacrum).[1,26] The inter-observer correlation coefficients for thoracic kyphosis, LL, pelvic tilt, PI, sacral slope, and sagittal vertical axis were 0.751, 0.736, 0.882, 0.744, 0.730, and 0.837, respectively.[4]

PRO measurements

PRO measurement data obtained at baseline and at 1, 2, and 5 years post-operatively were analyzed. The SRS-

22r is a scoliosis-specific health-related quality of life (HRQOL) questionnaire with 22 items and six domains: Function, Pain, Self-image, Mental health, Satisfaction, and Subtotal.[7,19] Each domain score ranges from 1 to 5 points, with higher scores indicating better outcomes.[6-8] The scale has been reported as reliable and valid in populations with ASD.[9-11] The ODI is also the recommended PRO measurement for patients with spine and spinal cord disorders.[15] The ODI has 10 subdomains that measure pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sex life, social life, and travelling. The score for each domain ranges from 0 (best health) to 5 (worst health). The ODI is another widely used method of assessing ASD (Tables 4 and 5).[31]

Statistical analyses

All values are expressed as mean ± standard deviation (SD). The Shapiro-Wilk test was used to verify the assumption regarding the normal distribution of the data. A paired sample t-test and Wilcoxon signed-rank test were used for within-group comparisons of continuous variables. Differences between groups were evaluated using the unpaired two-sample t-test or Mann-Whitney test. The chi-square or Fisher exact test was used to test for significant differences in categorical study parameters between both groups. Differences between three groups were assessed using a one-way ANOVA. Post hoc comparisons were made using the Tukey test or Games-Howell multiple comparisons test. The Spearman's correlation coefficient was used to assess the relationship between SRS-22r domain scores at 2 years and 5 years post-operatively. The Spearman correlation coefficient was interpreted as follows: <0.20 = very weak, 0.20–0.39 = weak, 0.40–0.59 = moderate, 0.60–0.79 = strong, and 0.80–1.0 = very strong. A *P*-value <0.05 was considered statistically significant. Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) software (version 26.0; SPSS, Chicago, IL, USA).

RESULTS

Participant characteristics

Of 304 patients who underwent corrective fusion surgery for ASD during the study period, 174 met the inclusion criteria, and 131 (75.3% of eligible patients) of these patients could be followed up using HRQOL questionnaires for 5 years post-operatively (Figure 1). The average age was 67.1±9.5 years (112 females). The average BMI was 23.2±4.0 kg/m^2. The mean CCI was 0.5±0.8. The pathologies of patients undergoing corrective fusion surgery for ASD are shown in Table 1.

Surgical details and outcomes

The UIV was T4 in six patients, T5 in three patients, T6 in three patients, T7 in four patients, T8 in 14 patients, T9 in 25 patients, T10 in 69 patients, T11 in five patients, and T12 in two patients (Table 2). Pelvic fixation was performed using S1 screws for 11 (8%) patients and iliac screws for 120 (92%) patients. The mean number of fused vertebrae was 9.9±1.7. The types of procedure performed included 37 (28%) pedicle subtraction osteotomies, 16 (12%) vertebral column resections, and 26 (20%) lateral lumbar interbody fusions. Unanticipated revision surgeries were performed 60 times in 48 patients (37%) with ASD. Thirty-four patients had one unanticipated revision surgery, 10 had two, and two had three.

Radiographic parameters

Radiographic measurements were collected from all patients pre-operatively, from 125 patients at 2 years post-operatively, and from 106 patients at 5 years post-operatively. The mean 2-year post-operative LL, pelvic tilt, PI minus LL, sagittal vertical axis, and coronal Cobb angle improved significantly from 11.6° to 42.6°, 35.5° to 25.6°, 41.4° to 10.8°, 114.1 mm to 58.0 mm, and 28.2° to 9.0°, respectively (all P<0.001) (Table 3). The mean LL, pelvic tilt, PI minus LL, sagittal vertical axis, and coronal Cobb angle were maintained from 2 years post-operatively to 5 years post-operatively (all P>0.05).

PRO measurement parameters

The mean 2-year post-operative SRS-22r Function, Pain, Self-image, Mental health, Subtotal, and ODI improved significantly from 2.57 to 3.12, 2.91 to 3.74, 2.07 to 3.42, 2.50 to 3.32, 2.50 to 3.40, and 45.4 to 30.8, respectively (all P<0.001) (Figure 2). The mean SRS-22r Function, Pain, Self-image, Mental health, Subtotal, and ODI were maintained from 1 year post-operatively to 5 years post-operatively (all P>0.05). The 1-year post-operative PROs correlated significantly with the 5-year post-operative PROs [SRS-22r function (r=0.620), pain (r=0.577), self-image (r=0.563), mental health (r=0.589), subtotal (r=0.663), and ODI (r=0.654)] (Table 4). The 2-year post-operative PROs correlated significantly with the 5-year post-operative

PROs [SRS-22r function (r=0.715), pain (r=0.678), self-image (r=0.653), mental health (r=0.675), subtotal (r=0.741), and ODI (r=0.746)] (Table 4). The correlation coefficients between 1-year and 5-year post-operative PROs ranged from 0.5 to 0.7, indicating a moderate to strong correlation, and the correlation coefficients between 2-year and 5-year post-operative PROs were over 0.6, which was a strong correlation.

Comparison of PRO changes over 5 years between patients who underwent unanticipated revision surgery after the index surgery and those who did not

Unanticipated revision surgeries (60 surgeries in 48 patients) were performed due to rod fracture (N=37), proximal junctional failure (PJF) (N=8), hematomas (N=5), implant-related disorders (N=3), distal junctional failure (N=3), malalignment (N=2), and infection (N=2). There were no significant differences in age, sex, or comorbidities between patients who underwent unanticipated revision surgery after index surgery (N=48) and those who did not (N=83). There was no significant difference in the amount of change in PROs at 5 years after surgery (Δ 5 years vs. baseline) (Table 5).

DISCUSSION

In this single-center study, we investigated the changes in PROs at baseline and at 1, 2, and 5 years after corrective fusion surgery from the thoracic spine to the pelvis for ASD. The results showed that 1-year and 2-year post-operative PROs correlated with 5-year post-operative PROs. The correlation between the 2-year and 5-year post-operative PROs was stronger than the correlation between the 1-year and 5-year post-operative PROs, indicating that clinical outcomes stabilize at 2 years post-operatively and that long-term clinical outcomes can be predicted. In addition, although not statistically significant, the value of the SRS-22r function item and ODI tended to improve from 2 to 5 years after surgery. Considering that there is no significant difference in the spino-pelvic alignment between 2 and 5 years post-operatively, even if there is no change in the alignment, functional disability due to long range immobilization in the mid- to long-term may be reduced as a result of adjustment or compensation by movement of other joints, such as the hip.

Corrective fusion surgery for ASD often involves long range fusion from the thoracic spine to the pelvis, which leads to mechanical complications such as rod fractures in areas of inadequate bony fusion and stress concentration at the superior end of the fixation, resulting in proximal junctional adjacent disorders.[17,28] In the past, these mechanical complications have been reported to result in reduced activities of daily living and the need for revision surgery. These unanticipated revision surgeries have also been reported to inhibit the improvement of PROs.[25] In this study, 37% of patients underwent one or more unanticipated reoperations. From the standpoint of healthcare economics, it is important to minimize the number of unanticipated revision surgeries.[2] However, the results of this study showed that these unanticipated reoperations did not have a negative impact on patients' PRO improvement. The reason why reoperations did not affect the long-term results may be that by the 5-year post-operative evaluation, back pain due to poor alignment associated with rod fracture and neurological symptoms and pain associated with PJF had been addressed with revision surgery, and the symptoms had already improved. In other words, this implies that appropriate reoperation revision surgeries for post-operative mechanical and other complications can improve and maintain patients' clinical outcomes in the mid- and long-term.

In corrective fusion surgery for ASD, an important aspect of improving clinical outcomes is the improvement of global sagittal alignment. In this series, we showed that the reduction in LL at baseline was improved and maintained for 5 years post-operatively. In addition, there was no progression of thoracic kyphosis, which suggests that global sagittal alignment was maintained. The degree of correction and patient selection are important in improving clinical outcomes.[3] ASD can be caused by a variety of factors, including disc degeneration, vertebral fractures, and remnants of idiopathic scoliosis. It is important to develop a surgical strategy according to the algorithm so that appropriate correction can be achieved.[24] In addition, spinal deformities in elderly patients are more invasive and have more peri-operative complications.

The importance of the sliding scale of surgery in minimizing complications has also been reported.[30] The improvement of clinical outcomes after corrective surgery for ASD is also related to improved patient satisfaction.[20] Because of the large number of implants used in corrective fusion surgery for ASD, medical costs are not low.[2,13] However, as shown in the results of this study, corrective fusion can improve and maintain the PROs in patients with ASD over the mid- to long-term. Efforts to reduce the number of revision surgeries as much as possible will be necessary in the future.

For rod fractures, the efficacy of four rods with long additional rods has been reported.[29] In addition, the importance of appropriate screw length setting,[27] the method of UIV selection,[32] rod contour at the proximal end,[21] and avoidance of overcorrection[21,23] have also been reported to prevent neurological complications associated with proximal junctional kyphosis. These measures may reduce the number of revision surgeries and provide stable long-term results.

The strengths of this study are its large number of cases with complete PROs (131 cases) and the follow-up rate of more than 75%, which represents a very low dropout rate for a relatively long follow-up period of 5 years. However, there were several limitations to this study. First, due to the limited number of patients, we were not able to examine each ASD pathology separately. In addition, the finding of the present study that PROs are maintained in the mid- to long-term even after unanticipated revision surgery might be an overestimation, since an analysis of a larger dataset showed that unexpected revision surgery has a negative impact on PROs after ASD surgery[25]. Therefore, it is necessary to re-evaluate the results in a larger sample in the future. Second, there were cases of incomplete standing total spine radiological evaluation at 5 years post-operatively. Third, we were not able to evaluate bone density and therapeutic agents for osteoporosis. In the evaluation for ASD, long-term results at 10 and 20 years are also important and need further investigation.

CONCLUSIONS

PROs improved at 1 year after corrective thoracic spine-pelvic fusion surgery for ASD, and these improvements were maintained at 5 years post-operatively. Although both the 1-year and 2-year post-operative PROs were correlated with the 5-year post-operative PROs, the 2-year post-operative PROs correlated more strongly with the 5-year post-operative PROs. This indicates that long-term clinical outcomes can be predicted from the 2-year post-operative PROs. Moreover, revision surgery did not negatively influence the mid- to long-term clinical outcomes of corrective fusion surgery for ASD.

REFERENCES

1. Ames CP, Smith JS, Scheer JK, et al. Impact of spinopelvic alignment on decision making in deformity surgery in adults: A review. *J Neurosurg Spine* 2012;16:547-64.
2. Arima H, Hasegawa T, Yamato Y, et al. Cost-Effectiveness of Corrective Fusion Surgeries for Adult Spinal Deformities: A Comparison by Operative Method. *Spine (Phila Pa 1976)* 2021;Publish Ahead of Print.
3. Arima H, Hasegawa T, Yamato Y, et al. Factors Associated with Improved Quality of Life Outcomes in Patients Undergoing Surgery for Adult Spinal Deformity. *Spine (Phila Pa 1976)* 2021;46:E384-E91.
4. Arima H, Yamato Y, Hasegawa T, et al. Extensive Corrective Fixation Surgeries for Adult Spinal Deformity Improve Posture and Lower Extremity Kinematics During Gait. *Spine (Phila Pa 1976)* 2017;42:1456-63.
5. Arima H, Yamato Y, Hasegawa T, et al. Discrepancy between Standing Posture and Sagittal Balance during Walking in Adult Spinal Deformity Patients. *Spine (Phila Pa 1976)* 2016.
6. Asher M, Min Lai S, Burton D, et al. Discrimination validity of the scoliosis research society-22 patient questionnaire: relationship to idiopathic scoliosis curve pattern and curve size. *Spine (Phila Pa 1976)* 2003;28:74-8.
7. Asher M, Min Lai S, Burton D, et al. The reliability and concurrent validity of the scoliosis research society-22 patient questionnaire for idiopathic scoliosis. *Spine (Phila Pa 1976)* 2003;28:63-9.
8. Asher M, Min Lai S, Burton D, et al. Scoliosis research society-22 patient questionnaire: responsiveness to change associated with surgical treatment. *Spine (Phila Pa 1976)* 2003;28:70-3.
9. Baldus C, Bridwell KH, Harrast J, et al. Age-gender matched comparison of SRS instrument scores between adult deformity and normal adults: are all SRS domains disease specific? *Spine (Phila Pa 1976)* 2008;33:2214-8.
10. Berven S, Deviren V, Demir-Deviren S, et al. Studies in the modified Scoliosis Research Society Outcomes Instrument in adults: validation, reliability, and discriminatory capacity. *Spine (Phila Pa 1976)* 2003;28:2164-9; discussion 9.
11. Bridwell KH, Berven S, Glassman S, et al. Is the SRS-22 instrument responsive to change in adult scoliosis patients having primary spinal deformity surgery? *Spine (Phila Pa 1976)* 2007;32:2220-5.
12. Bridwell KH, Glassman S, Horton W, et al. Does treatment (nonoperative and operative) improve the two-year quality of life in patients with adult symptomatic lumbar scoliosis: a prospective multicenter evidence-based medicine study. *Spine (Phila Pa 1976)* 2009;34:2171-8.

13. Carreon LY, Glassman SD, Lurie J, et al. Cost-effectiveness of Operative versus Nonoperative Treatment of Adult Symptomatic Lumbar Scoliosis an Intent-to-treat Analysis at 5-year Follow-up. *Spine (Phila Pa 1976)* 2019;44:1499-506.

14. Charlson ME, Pompei P, Ales KL, et al. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;40:373-83.

15. Fairbank JC, Couper J, Davies JB, et al. The Oswestry low back pain disability questionnaire. *Physiotherapy* 1980;66:271-3.

16. Glassman SD, Berven S, Bridwell K, et al. Correlation of radiographic parameters and clinical symptoms in adult scoliosis. *Spine (Phila Pa 1976)* 2005;30:682-8.

17. Hart RA, McCarthy I, Ames CP, et al. Proximal junctional kyphosis and proximal junctional failure. *Neurosurg Clin N Am* 2013;24:213-8.

18. Hasegawa T, Ushirozako H, Yamato Y, et al. Impact of adult spinal deformity corrective surgery in patients with the symptoms of gastroesophageal reflux disease: a 5-year follow-up report. *Eur Spine J* 2020;29:860-9.

19. Hashimoto H, Sase T, Arai Y, et al. Validation of a Japanese version of the Scoliosis Research Society-22 Patient Questionnaire among idiopathic scoliosis patients in Japan. *Spine (Phila Pa 1976)* 2007;32:E141-6.

20. Hayashi K, Boissière L, Guevara-Villazón F, et al. Factors influencing patient satisfaction after adult scoliosis and spinal deformity surgery. *J Neurosurg Spine* 2019;31:408-17.

21. Ishihara M, Taniguchi S, Adachi T, et al. Rod contour and overcorrection are risk factors of proximal junctional kyphosis after adult spinal deformity correction surgery. *Eur Spine J* 2021;30:1208-14.

22. Kelly MP, Lurie JD, Yanik EL, et al. Operative Versus Nonoperative Treatment for Adult Symptomatic Lumbar Scoliosis. *J Bone Joint Surg Am* 2019;101:338-52.

23. Maruo K, Ha Y, Inoue S, et al. Predictive factors for proximal junctional kyphosis in long fusions to the sacrum in adult spinal deformity. *Spine (Phila Pa 1976)* 2013;38:E1469-76.

24. Matsuyama Y. Surgical treatment for adult spinal deformity: Conceptual approach and surgical strategy. *Spine Surg Relat Res* 2017;1:56-60.

25. Núñez-Pereira S, Vila-Casademunt A, Domingo-Sàbat M, et al. Impact of early unanticipated revision surgery on health-related quality of life after adult spinal deformity surgery. *Spine J* 2018;18:926-34.

26. O'Brien M, Kuklo T, Blanke K, et al. Spinal Deformity Study Group Radiographic Measurement Manual. *Medtronic Sofamor Danek USA, Inc (Memphis)* 2005.

27. Oe S, Yamato Y, Hasegawa T, et al. Low occupancy rate of the pedicle screw in the vertebral body leads to upper instrumented vertebral fracture. *Sci Rep* 2020;10:10270.

28. Smith JS, Shaffrey CI, Ames CP, et al. Assessment of symptomatic rod fracture after posterior instrumented fusion for adult spinal deformity. *Neurosurgery* 2012;71:862-7.

29. Yamato Y, Hasegawa T, Togawa D, et al. Long additional rod constructs can reduce the incidence of rod fractures following 3-column osteotomy with pelvic fixation in short term. *Spine Deform* 2020;8:481-90.

30. Yoshida G, Hasegawa T, Yamato Y, et al. Predicting Perioperative Complications in Adult Spinal Deformity Surgery Using a Simple Sliding Scale. *Spine (Phila Pa 1976)* 2018;43:562-70.

31. Yoshida G, Hasegawa T, Yamato Y, et al. Minimum Clinically Important Differences in Oswestry Disability Index Domains and Their Impact on Adult Spinal Deformity Surgery. *Asian Spine J* 2019;13:35-44.

32. Yoshida G, Ushirozako H, Hasegawa T, et al. Preoperative and Postoperative Sitting Radiographs for Adult Spinal Deformity Surgery: Upper Instrumented Vertebra Selection Using Sitting C2 Plumb Line Distance to Prevent Proximal Junctional Kyphosis. *Spine (Phila Pa 1976)* 2020;45:E950-e8.

FIGURE LEGENDS

Figure 1. Participant eligibility flowchart

Figure 2. SRS-22r and ODI scores from baseline to 1, 2, and 5 years post-operatively after corrective fusion surgery from the thoracic spine to the pelvis for ASD.

*** indicates *P*-value <0.001

SRS-22r, Scoliosis Research Society 22r; ODI, Oswestry Disability Index; ASD, adult spinal deformity

Table 1. Patients background

Number	131
Age	67.1 ± 9.5
Female N (%)	112 (86)
Body Mass Index	23.2 ± 4.0
Charlson Comorbidity Index	0.5 ± 0.8
ASA classification N (%)	
ASA 1	22 (17)
ASA 2	104 (79)
ASA 3	5 (4)
Pathology N(%)	
Degenerative kyphoscoliosis	59 (45)
Degenerative kyphosis	34 (26)
Kyphosis after vertebral fracture	16 (12)
Adult scoliosis	11 (8)
Iatrogenic kyphosis	11 (8)

* Mean values are presented as mean ± SD. ASA, American Society of Anaesthesiologists.

Table 2. Surgical details

Variables	Total
No. of fused vertebrae	9.9 ± 1.7
T4	6 (5)
T5	3 (2)
T6	3 (2)
T7	4 (3)
T8	14 (11)
T9	25 (19)
T10	69 (53)
T11	5 (4)
T12	2 (2)
Iliac screw N (%)	120 (92)
Staged surgery N (%)	37 (28)
Pedicle subtraction osteotomy	37 (28)
Vertebral column resection	16 (12)
Lateral lumbar interbody fusion	26 (20)
Total operation time (min)	424.2 ± 80.4
Total intraoperative blood loss(ml)	1731.2 ± 1093.4
Overall complication N (%)	43 (33)
Surgical complication	8 (6)
Neurological complication	15 (12)
Medical complication	30 (23)
Revision surgery N (%)	48 (37)

Mean values are presented as mean ± SD. UIV, upper instrumented level.

Table 3. Radiographic findings and clinical outcome findings

Parameters	**Baseline**	**2-year Postoperative**	**5-year Postoperative**	***P value*†**	Baseline vs. 2-yr *P value*‡	Baseline vs. 5-yr *P value*§	2-yr vs. 5-yr *P value*¶
Radiographic parameters							
TK(°)	22.8 ± 19.3	42.4 ± 14.4	42.4 ± 16.1	**<0.001**	**<0.001**	**<0.001**	1.000
LL (°)	11.6 ± 20.0	42.6 ± 12.3	40.9 ± 11.2	**<0.001**	**<0.001**	**<0.001**	0.501
PT (°)	35.5 ± 10.8	25.6 ± 9.5	26.7 ± 9.5	**<0.001**	**<0.001**	**<0.001**	0.616
PI minus LL (°)	41.4 ± 21.3	10.8 ± 16.1	12.7 ± 13.9	**<0.001**	**<0.001**	**<0.001**	0.600
PJA angle (°)	4.5 ± 7.2	17.3 ± 10.2	17.7 ± 10.7	**<0.001**	**<0.001**	**<0.001**	0.966
SVA (mm)	114.1 ± 78.1	58.0 ± 58.9	67.3 ± 56.9	**<0.001**	**<0.001**	**<0.001**	0.440
Cobb (°)	28.2 ± 23.8	9.0 ± 8.6	10.4 ± 8.6	**<0.001**	**<0.001**	**<0.001**	0.485
Clinical outcome parameters							
SRS-22r Function	2.57 ± 0.70	3.20 ± 0.81	3.28 ± 0.92	**<0.001**	**<0.001**	**<0.001**	0.727
SRS-22r Pain	2.91 ± 0.87	3.74 ± 0.85	3.71 ± 0.90	**<0.001**	**<0.001**	**<0.001**	0.936
SRS-22r Self-image	2.07 ± 0.75	3.39 ± 0.80	3.22 ± 0.87	**<0.001**	**<0.001**	**<0.001**	0.237
SRS-22r Mental health	2.50 ± 0.94	3.30 ± 0.92	3.32 ± 0.93	**<0.001**	**<0.001**	**<0.001**	0.983
SRS-22r Satisfaction	NA	3.53 ± 0.86	3.54 ± 0.89	NA			
SRS-22r Subtotal	2.50 ± 0.61	3.41 ± 0.69	3.38 ± 0.78	**<0.001**	**<0.001**	**<0.001**	0.939
Oswestry Disability Index	45.4 ± 16.5	30.6 ± 17.8	28.0 ± 19.6	**<0.001**	**<0.001**	**<0.001**	0.500

Mean values are presented as mean ± SD. SVA, sagittal vertical Axis; PI, pelvic incidence; LL lumbar lordosis; PT, pelvic tilt ; PJA, proximal junctional angle, TK, thoracic kyphosis. Bold type indicates statistical significance. †Comparison between groups. NA, not applicable; SRS, scoliosis research society

Table 4. Spearman correlations of patients' reported outcome between 1-year and 5-year postoperatively, and between 2-year and 5-year postoperatively				
Parameter	**1-year and 5-year postop correlation coefficient**	***P Value* ***	**2-year and 5-year postop correlation coefficient**	***P Value* †**
SRS-22r Function	0.620	**<0.001**	0.715	**<0.001**β
SRS-22r Pain	0.577	**<0.001**	0.678	**<0.001**
SRS-22r Self-image	0.563	**<0.001**	0.653	**<0.001**
SRS-22r Mental health	0.589	**<0.001**	0.675	**<0.001**
SRS-22r Subtotal	0.663	**<0.001**	0.741	**<0.001**
Oswestry Disability Index	0.654	**<0.001**	0.746	**<0.001**
*† Bold type indicates statistical significance.				

Table 5. Comparison of PRO changes over 5 years between patients who underwent unanticipated revision surgery after the index surgery and those who did not

Parameter	**Revision (N=48)**	**No revision (N=83)**	***P Value ****
Age	65.2 ± 10.0	68.1 ± 9.1	0.088
Female N (%)	38 (79)	74 (89)	0.118
Body Mass Index	23.7 ± 3.5	22.9 ± 4.2	0.291
Charlson Comorbidity Index	0.5 ± 0.8	0.4 ± 0.8	0.618
Δ5yr SRS-22r Function	0.79 ± 0.92	0.68 ± 0.88	0.519
Δ5yr SRS-22r Pain	0.67 ± 0.90	0.86 ± 0.98	0.270
Δ5yr SRS-22r Self-image	1.20 ± 1.01	1.12 ± 1.11	0.671
Δ5yr SRS-22r Mental health	0.92 ± 0.95	0.76 ± 1.09	0.374
Δ5yr SRS-22r Subtotal	0.91 ± 0.73	0.86 ± 0.82	0.702
Δ5yr Oswestry disability index	-17.4 ± 17.0	-16.8 ± 19.5	0.987

Mean values are presented as mean ± SD. Bold type indicates statistical significance. ***Comparison of PRO changes over 5 years in patients who underwent unanticipated revision surgery after the index surgery and those who did not.

Figure 1

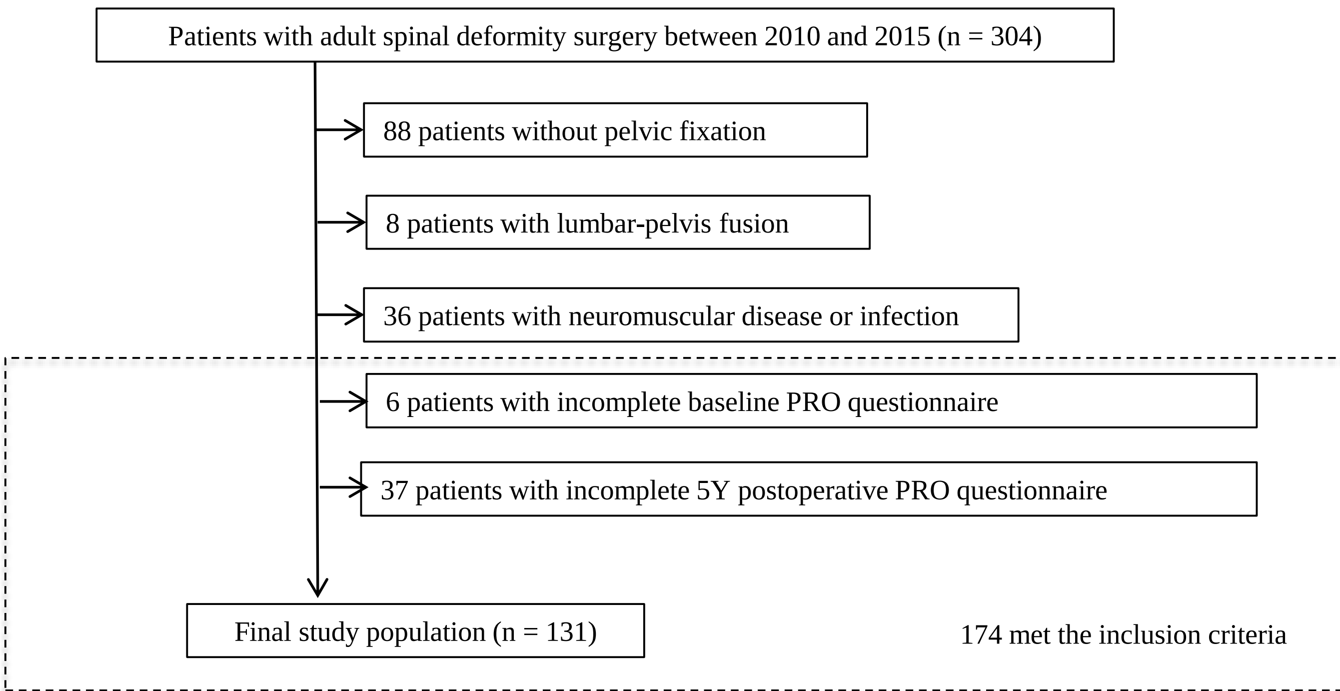

Patients with adult spinal deformity surgery between 2010 and 2015 (n = 304)
88 patients without pelvic fixation
8 patients with lumbar-pelvis fusion
36 patients with neuromuscular disease or infection
6 patients with incomplete baseline PRO questionnaire
37 patients with incomplete 5Y postoperative PRO questionnaire
Final study population (n = 131)
174 met the inclusion criteria

Figure 2A

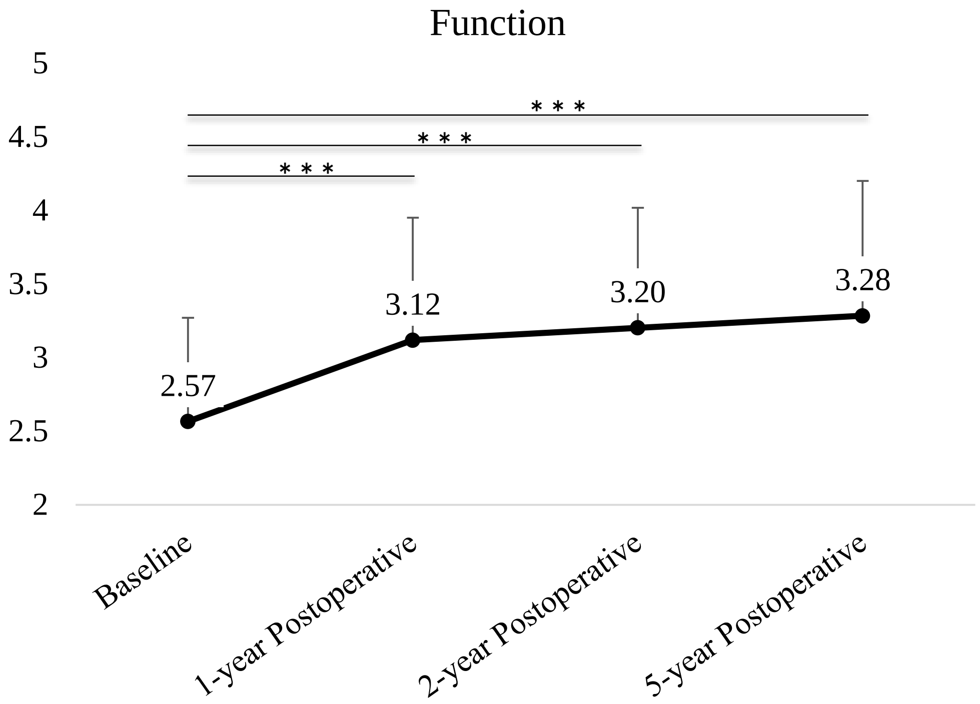

Function
5
4.5
4
3.5
3
2.5
2
* * *
* * *
* * *
2.57
3.12
3.20
3.28
Baseline
1-year Postoperative
2-year Postoperative
5-year Postoperative

Figure 2B

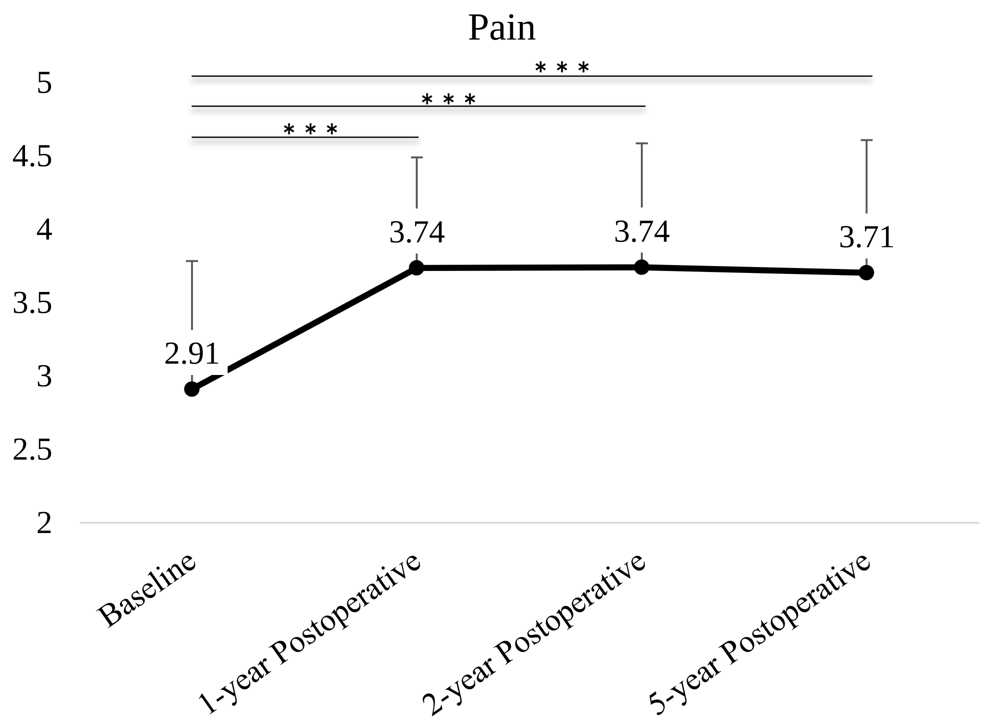

Pain
* * *
* * *
* * *
5
4.5
4
3.5
3
2.5
2
2.91
3.74
3.74
3.71
Baseline
1-year Postoperative
2-year Postoperative
5-year Postoperative

Figure 2C

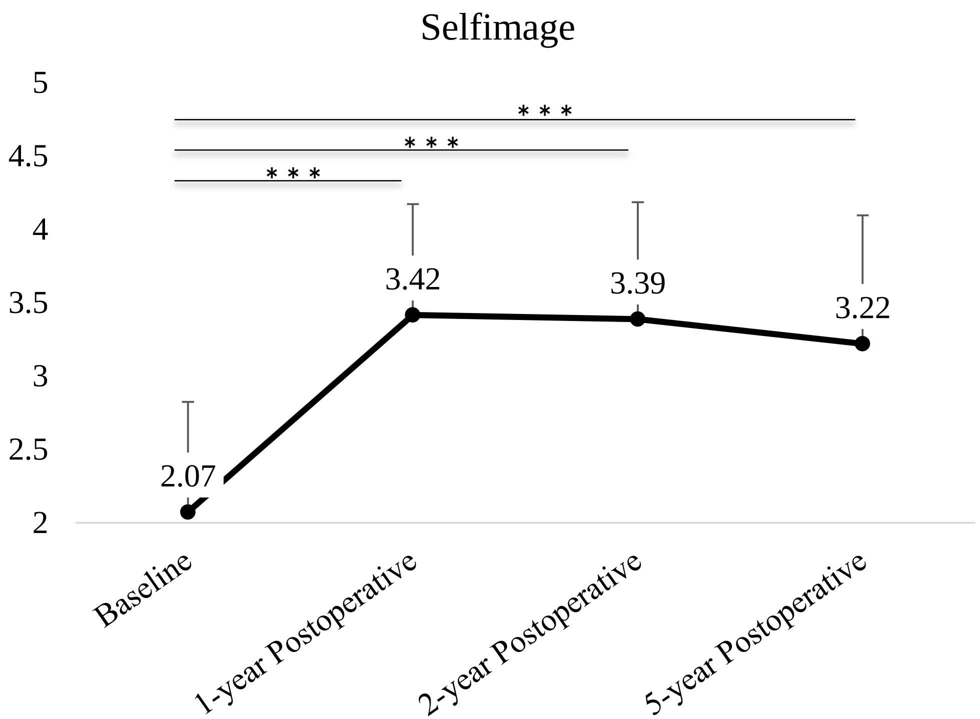

Selfimage
5
4.5
4
3.5
3
2.5
2
* * *
* * *
* * *
3.42
3.39
3.22
2.07
Baseline
1-year Postoperative
2-year Postoperative
5-year Postoperative

Figure 2D

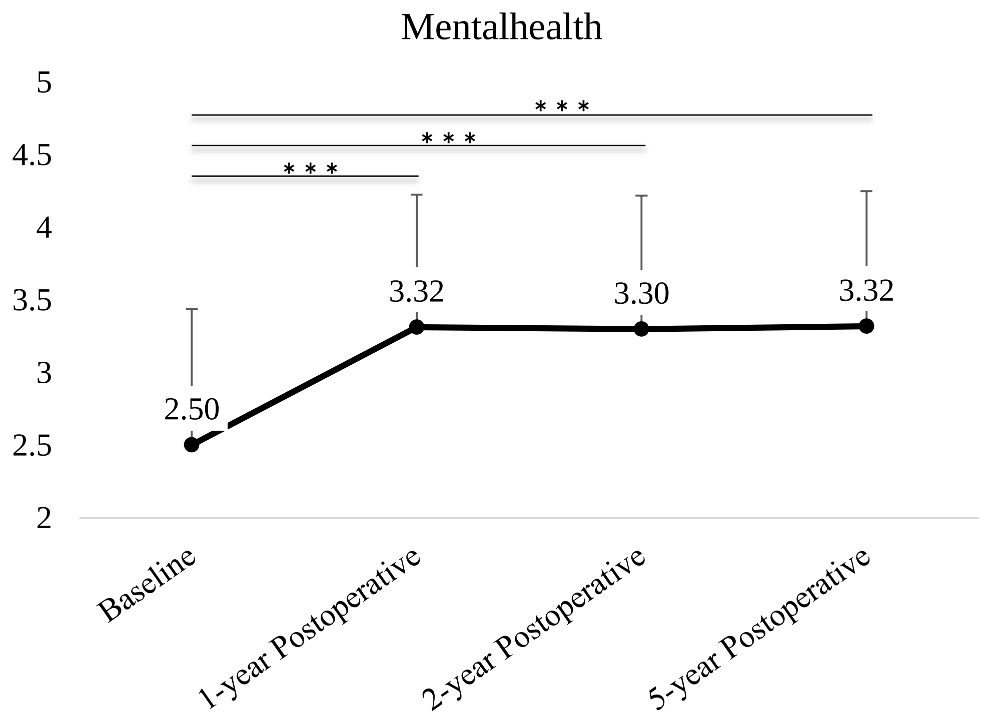

Mentalhealth
5
4.5
4
3.5
3
2.5
2
* * *
* * *
* * *
2.50
3.32
3.30
3.32
Baseline
1-year Postoperative
2-year Postoperative
5-year Postoperative

Figure 2E

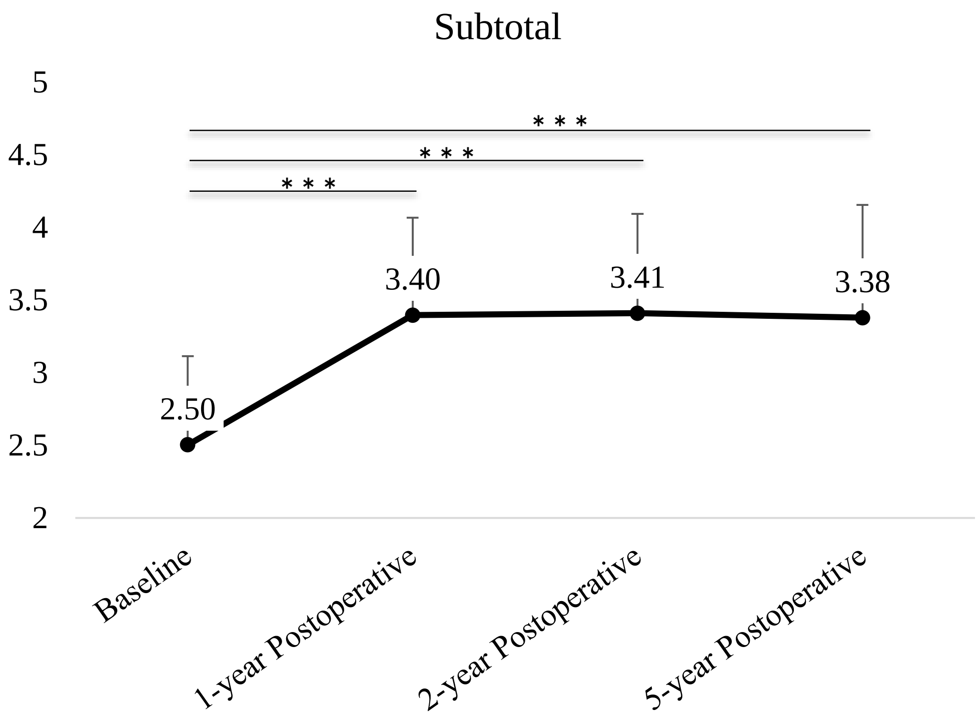
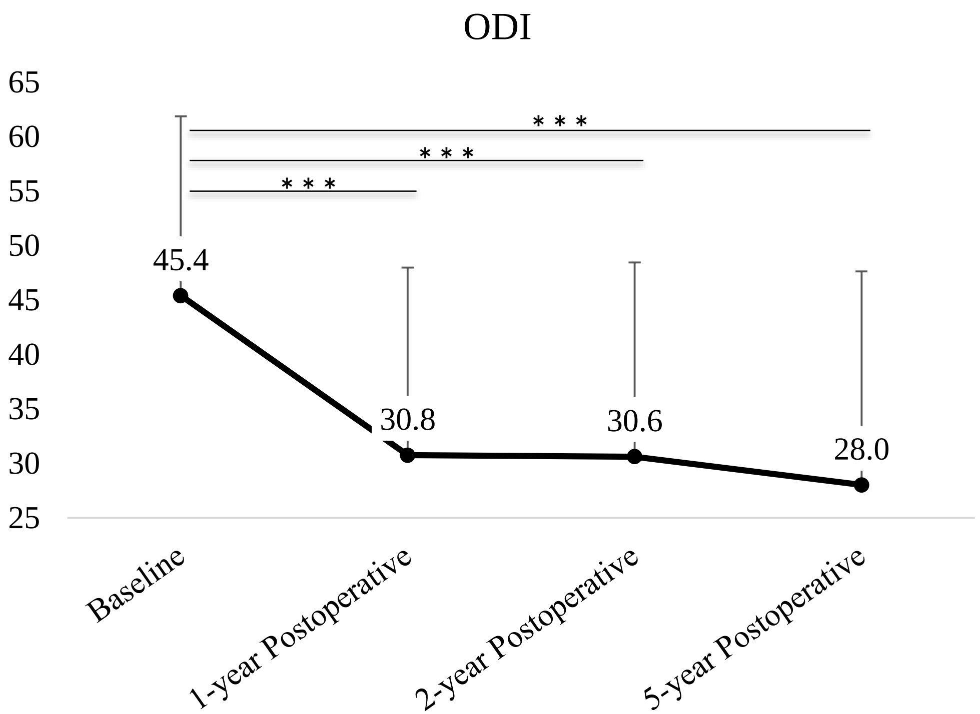

Subtotal
5
4.5
4
3.5
3
2.5
2
* * *
* * *
* * *
2.50
3.40
3.41
3.38
Baseline
1-year Postoperative
2-year Postoperative
5-year Postoperative

Figure 2F


ODI
65
60
55
50
45
40
35
30
25
* * *
* * *
* * *
45.4
30.8
30.6
28.0
Baseline
1-year Postoperative
2-year Postoperative
5-year Postoperative