

Does Smoking Affect Short-Term Patient-Reported Outcomes After Lumbar Decompression?

Global Spine Journal
2021, Vol. 11(5) 727-732
© The Author(s) 2020
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/2192568220925791
journals.sagepub.com/home/gsj



Dhruv K. C. Goyal, MD¹ , Srikanth N. Divi, MD¹, Daniel R. Bowles, MD¹, Victor E. Mujica, MD¹, I. David Kaye, MD¹ , Mark F. Kurd, MD¹, Barrett I. Woods, MD¹, Kris E. Radcliff, MD¹, Jeffrey A. Rihn, MD¹, D. Greg Anderson, MD¹, Alan S. Hilibrand, MD¹ , Christopher K. Kepler, MD¹, Alexander R. Vaccaro, MD, PhD, MBA¹ , and Gregory D. Schroeder, MD¹

Abstract

Study Design: Retrospective cohort study.

Objective: The goal of this study was to determine how smoking status influences patient-reported outcome measurements (PROMs) in patients undergoing lumbar decompression surgery.

Methods: Patients undergoing lumbar decompression between 1 to 3 levels at a single-center, academic hospital were retrospectively identified. Patients <18 years old, and those undergoing surgery for infection, trauma, tumor, or revision, with less than 12 months of follow-up were excluded. Patients were divided into 3 groups: (1) never smokers (NSs); (2) current smokers (CSs); and (3) former smokers (FSs). PROMs analyzed included the Physical Component Score and Mental Component Score of the Short Form-12 Health Survey, the Oswestry Disability Index, and Visual Analogue Scale Back and Leg pain scores. One-way ANOVA was used to compare preoperative and postoperative scores between smoking groups, and multiple linear regression analysis was performed to determine whether smoking status predicted change in each outcome score, controlling for factors such as age, sex, body mass index, and other clinical variables. A *P* value <.05 was considered to be significant.

Results: A total of 195 patients were included in the final cohort, with 121 (62.1%) patients in the NS group, 22 (11.3%) in the CS group, and 52 (26.6%) in the FS group. There were no significant differences between groups at baseline or postoperatively. Smoking status was also not a significant predictor of change in any outcome scores over time on multivariate analysis.

Conclusion: These results suggest that smoking status does not significantly affect short-term complications or outcomes in patients undergoing lumbar decompression surgery.

Keywords

patient reported outcome measurements (PROMs), SF-12 Physical Component Score (PCS-12), SF-12 Mental Component Score (MCS-12), Oswestry Disability Index (ODI), Visual Analogue Scale Back pain (VAS Back), Visual Analogue Scale Leg pain (VAS Leg), lumbar decompression, smoking, revisions, readmissions, surgical site infections (SSI)

Introduction

Lumbar decompression is a commonly performed and successful procedure to address radicular symptoms secondary to spinal stenosis or disc herniations.¹ By removing compression on nerve roots in the lumbar spine, patients experience immediate symptom resolution and long-term relief.² However, success of surgical interventions can still depend on patient-specific risk factors. One factor in particular—smoking and

¹ Thomas Jefferson University, Philadelphia, PA, USA

Corresponding Author:

Dhruv K. C. Goyal, Department of Orthopaedic Surgery, Rothman Orthopaedic Institute, Thomas Jefferson University, 925 Chestnut Street, 5th Floor, Philadelphia, PA 19107, USA.
Email: dhruvkgoyal@gmail.com



Creative Commons Non Commercial No Derivs CC BY-NC-ND: This article is distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 License (<https://creativecommons.org/licenses/by-nc-nd/4.0/>) which permits non-commercial use, reproduction and distribution of the work as published without adaptation or alteration, without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (<https://us.sagepub.com/en-us/nam/open-access-at-sage>).

nicotine products—has consistently been implicated as a risk factor for increased reoperation rates and surgical site infections (SSIs) following lumbar surgery.^{3,4} Nicotine leads to local arterial vasoconstriction, limiting microvascular circulation and inhibiting perfusion—both of which are essential processes in normal physiological healing after surgery.^{5,6}

Smoking is associated with negative self-reported patient outcomes in a variety of common lumbar spine procedures, including lumbar fusion surgeries.⁷⁻⁹ Furthermore, smoking cessation prior to fusion procedures leads to improved postoperative functional status, satisfaction, and return to work rates.¹⁰ Despite these relatively well-known risks associated with smoking, there is currently a paucity of literature evaluating smoking status and its influence on patient-reported outcome measurements (PROMs) in patients undergoing lumbar decompression surgery.¹¹ Therefore, the goal of this study was to determine how smoking status influences PROMs in patients undergoing lumbar decompression surgery.

Methods

After institutional review board approval was obtained, patients who underwent a primary lumbar decompression surgery (including discectomy or laminectomy) between 2013 and 2017 at a single academic center were retrospectively identified. Patients older than 18 years with at least 1 year of clinical follow-up were included in the cohort. Patients who underwent surgery for infection, trauma, or tumor were excluded from the final cohort. Patient demographics, including age, sex, body mass index (BMI), months followed up, and duration of preoperative symptoms (<3 months, 3-6 months, >6 months) were recorded. Surgical variables, including the number of levels decompressed and whether a minimally invasive surgery (MIS) technique was used were identified. PROMs were collected on a prospective basis at baseline and postoperatively through the institution's patient outcome collection database (OBERD, Columbia, MO): the Physical Component Score (PCS-12) and Mental Component Score (MCS-12) of the Short Form-12 Health Survey, the Oswestry Disability Index (ODI), and Visual Analogue Scale Back (VAS Back) and Leg (VAS Leg) pain scores. Secondary outcomes, including rates of revision surgery, 30- and 90-day readmission rates, and SSI, as defined by the Centers for Disease Control's National Healthcare Safety Network were recorded.¹²

Patients were divided into 3 groups based on their preoperative smoking status: (1) never smoker (NS), (2) current smokers (CS), or (3) former smoker (FS). Demographic characteristics and surgical factors were then compared between groups using either Kruskal-Wallis H testing with Dunn multiple pairwise comparison post hoc analysis for continuous data or Pearson χ^2 analysis and Fisher exact test for categorical data. A paired-samples *t*-test was used to determine improvement in PROMs within groups. Differences between groups were compared at baseline and postoperative time points. In addition, delta scores (Postoperative score – Baseline score) were also compared. Two additional measures of patient outcome improvement

were included: recovery ratios (RRs) and the percentage of patients who achieved the minimum clinically important difference (%MCID) at final follow-up.¹³⁻¹⁶ RRs were defined as [Delta score/(Optimal score – Baseline score)], with 100 and 0 used as optimal scores for PCS-12/MCS-12 and ODI/VAS Back/VAS Leg, respectively.¹³ The %MCID was calculated based on the following PROM threshold values: PCS-12, 8.8 points; MCS-12, 9.3 points; ODI, 5.3 points; VAS Back, 2.1 points; and VAS Leg, 2.4 points.^{15,16} Multiple linear regression was used to determine whether smoking status was a predictor of PROMs, controlling for the aforementioned demographic and surgical variables. All statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS) version 24 (IBM Corporation, Armonk, NY).

Results

A total of 195 patients were included, with 121 (62.1%) in the NS group, 22 (11.3%) in the CS group, and 52 (26.6%) in the FS group. Mean age was 60 [58, 62] years, mean BMI was 30.0 [29.1, 30.8] kg/m², and total number of male patients was 145 (74.4%). There were 124 (63.6%) patients with symptoms for <3 months, 58 (29.7%) patients with symptoms for between 3 and 6 months, and 13 (6.7%) patients with symptoms for >6 months. A total of 94 (48.2%) patients underwent single-level decompression, 67 (34.4%) patients underwent 2-level surgery, and the remaining 34 (17.4%) patients underwent surgery at 3 levels. A total of 68 (34.9%) patients underwent surgery using the MIS technique. There was a significant difference between groups with regard to age: FSs were significantly older than NSs and CSs (NS, 58.0 years; CS, 59.0 years; FS, 67.0 years; $P < .001$). Otherwise, there were no differences between groups with regard to sex, BMI, months followed up, symptom duration, number of levels decompressed, or the MIS technique (Table 1).

Patients in all groups improved after surgery with regard to PROMs, except for CSs who did not demonstrate a significant improvement in terms of MCS-12 ($P = .600$) and VAS Back ($P = .084$) pain scores and FSs who did not exhibit improvement in MCS-12 ($P = .535$) scores after surgery. When analyzing differences in PROMs between groups, there were no significant differences found at baseline, postoperatively, or with regard to delta scores. When considering RRs and %MCID between groups, the FS group demonstrated a greater RR (67.4%) than both NS (46.0%) and CS (47.4%) groups ($P = .046$). Finally, with multivariate analysis, smoking status was not a significant predictor of any PROMs (Table 2).

In total, 7 (3.6%) patients required revision surgery for one of the following reasons: deep SSI, disease at an adjacent level, or recurrent stenosis or disc herniation, with no difference in revision rates ($P = .814$). There were 2 (1.7%) patients who were readmitted prior to the 30-day postoperative mark and 7 (3.6%) who were readmitted up to 90 days postoperatively, with no statistical differences noted between groups ($P > .05$; Table 3).

Table 1. Demographic Characteristics and Surgical Factors of Cohort, by Smoking Groups.

| | Never smoker (n = 121) | Current smoker (n = 22) | Former smoker (n = 52) | P value ^a |
|----------------------------------|------------------------|-------------------------|------------------------|----------------------|
| Age | 58.0 [55.0, 60.0] | 59.0 [54.0, 63.0] | 67.0 [64.0, 69.0] | <.001 ^b |
| Sex | | | | .198 |
| M | 93 (76.9%) | 18 (81.8%) | 34 (65.4%) | |
| F | 28 (23.1%) | 4 (18.2%) | 18 (34.6%) | |
| BMI | 30.3 [29.0, 31.5] | 29.8 [28.2, 31.5] | 29.2 [27.8, 30.7] | .733 |
| Follow-up (months) | 13.0 [12.5, 13.5] | 12.7 [12.1, 13.4] | 13.0 [12.2, 13.8] | .335 |
| Symptom duration | | | | .187 |
| <3 Month | 74 (59.5%) | 15 (68.4%) | 37 (71.3%) | |
| 3-6 Months | 42 (34.7%) | 6 (27.3%) | 10 (19.3%) | |
| >6 Months | 7 (5.8%) | 1 (4.3%) | 5 (9.4%) | |
| Levels decompressed | | | | .240 |
| 1 | 63 (52.1%) | 6 (27.3%) | 25 (48.1%) | |
| 2 | 38 (31.4%) | 12 (54.6%) | 17 (32.7%) | |
| 3 | 20 (16.5%) | 4 (18.1%) | 10 (19.2%) | |
| Minimally invasive spine surgery | | | | .724 |
| No | 78 (64.5%) | 16 (72.7%) | 33 (63.5%) | |
| Yes | 43 (35.5%) | 6 (27.3%) | 19 (36.5%) | |

Abbreviations: M, male; F, female; BMI, body mass index.

^aKruskal-Wallis *H* test (Dunn multiple pairwise comparison post hoc analysis), Pearson χ^2 analysis, or Fisher exact test for group comparison.

^bIndicates statistical significance.

Discussion

The adverse effects of smoking have been well documented in patients undergoing lumbar fusion.¹⁷ In addition to decreasing vascularity at the postoperative site, smoking is associated with increased rates of osteoporosis with reduced trabecular bone thickness and overall poor bone health.¹⁸ These factors all contribute to result in increased rates of pseudarthrosis following lumbar fusion surgery.^{8,19} In addition, smoking has been shown to be associated with worse PROMs in lumbar fusion patients.²⁰⁻²² Despite these known risks in fusion surgery, postoperative outcomes in patients undergoing lumbar decompression surgery are less well established.

In this study, there were no significant differences in baseline, postoperative, or delta outcome scores between groups. Similarly, there were no differences in complication or readmission rates, and results of multiple linear regression analysis indicated that smoking status was not a significant predictor of worse outcomes for any PROMs. All groups also demonstrated significant improvement from baseline to final follow-up for most PROMs except for the following: CS did not significantly improve in MCS-12 scores ($P = .600$) or VAS Back scores ($P = .084$) after surgery, and FS did not improve MCS-12 scores only ($P = .534$). Furthermore, the FS group had a higher proportion of patients that achieved MCID in VAS Back scores compared with the NS and CS groups (67.4% vs 46.0% and 47.4%, respectively; $P = .046$).

Few studies have evaluated smoking status and outcomes following lumbar decompression surgery, with mixed results. Mehta and Sharma²³ reviewed 143 patients undergoing either lumbar microdiscectomy or decompression surgery and found no significant differences in ODI, VAS Back, or VAS Leg scores between groups. In a separate prospective study conducted by Stienen et al,²⁴ a total of 102 nonsmokers, CSs, and

FSs were followed up to 1 year postoperatively with no differences between groups at the 4 week and 1-year postoperative time points in terms of PCS-12 and VAS pain scores.²⁴ Furthermore, the authors found that smokers were as likely to achieve favorable outcome scores for PCS-12 and MCS-12 compared with their nonsmoking counterparts. In a separate follow-up analysis, the same authors noted a similar trend between smokers and nonsmokers up to 4.5 years after surgery.²⁵ The results of these studies are similar to the findings in the present study, with little postoperative differences in short-term PROMs.

However, other studies analyzing smoking and lumbar decompression surgery have found contrary findings. A previous study performed by Jazini et al²² found that whereas preoperative PROMs did not vary between groups, CSs undergoing decompression surgery had significantly worse 12-month ODI scores ($P = .013$). This study, however, did not incorporate a multivariate analysis in the assessment of smoking and outcomes; hence, baseline differences between groups were not controlled for in the analysis.²² Gulati et al²⁶ compared nonsmokers and CSs in a retrospective review of 825 patients after microdecompression surgery and found that CSs not only had worse preoperative ODI, but also significantly worse changes in ODI improvement at 1 year ($P = .01$). Additionally, the authors reported that 69.6% of nonsmokers achieved MCID compared with only 60.8% of CSs ($P = .008$).²⁶ However, Gulati et al included only microdecompression surgeries, whereas the present study also included multi-level laminectomies. That being said, it is difficult to make even comparisons between the aforementioned studies and the present analysis, based on inherent differences between the 2 cohorts. The present analysis demonstrated no significant differences in patient-reported outcomes between smoking groups on univariate and multivariate analysis. Although smoking

Table 2. Patient-Reported Outcome Measurement (PROM) Comparisons Between Smoking Groups.^a

| | | Never smoker (NS; n = 121) | Current smoker (CS; n = 22) | Former smoker (FS; n = 52) | P value ^b | β-Coefficient [95% CI], P value ^c |
|----------|----------------------|-------------------------------|--------------------------------|-------------------------------|----------------------|---|
| PCS-12 | Pre | 31.7 [30.2, 33.3] | 32.3 [28.6, 36.1] | 30.9 [28.1, 33.6] | .577 | NS: — |
| | Post | 42.0 [40.2, 43.9] | 42.1 [37.8, 46.4] | 41.9 [38.9, 44.8] | .992 | CS: 0.312 [−4.488, 5.111], .898 |
| | Delta | 10.1 [8.0, 12.1] | 10.0 [4.9, 15.1] | 10.4 [7.0, 13.8] | .886 | FS: 0.132 [−3.343, 3.608], .940 |
| | RR | 14.0% | 14.2% | 13.9% | .940 | |
| | %MCID | 54.9% | 42.1% | 48.9% | .524 | |
| | P Value ^d | <.001 ^e | .001 ^e | <.001 ^e | — | |
| MCS-12 | Pre | 49.8 [47.7, 52.0] | 51.0 [44.8, 57.2] | 50.9 [47.9, 54.0] | .810 | NS: — |
| | Post | 52.7 [50.9, 54.5] | 52.5 [47.0, 58.0] | 52.6 [49.7, 55.4] | .851 | CS: −1.271 [−5.911, 3.369], .589 |
| | Delta | 2.9 [0.8, 5.0] | 1.3 [−3.8, 6.4] | 1.1 [−2.7, 4.9] | .690 | FS: −2.759 [−6.116, 0.598], .107 |
| | RR | 3.1% | 0.6% | 0.2% | .721 | |
| | %MCID | 25.7% | 31.6% | 21.3% | .668 | |
| | P Value ^d | .007 ^e | .600 | .534 | — | |
| ODI | Pre | 42.9 [39.5, 46.3] | 38.1 [28.5, 47.7] | 42.2 [36.6, 47.7] | .499 | NS: — |
| | Post | 20.6 [17.2, 24.1] | 19.2 [9.6, 28.9] | 19.7 [14.9, 24.5] | .840 | CS: −2.635 [−12.509, 7.239], .599 |
| | Delta | −21.8 [−26.5, −17.1] | −20.5 [−31.1, −9.9] | −23.2 [−30.2, −16.2] | .931 | FS: −0.428 [−7.426, 6.571], .904 |
| | RR | 40.1% | 55.8% | 25.4% | .610 | |
| | %MCID | 73.1% | 82.4% | 76.7% | .765 | |
| | P Value ^d | <.001 ^e | .001 ^e | <.001 ^e | — | |
| VAS Back | Pre | 6.2 [5.3, 7.1] | 5.5 [3.8, 7.3] | 6.1 [5.2, 7.0] | .847 | NS: — |
| | Post | 2.9 [2.4, 3.4] | 3.6 [2.2, 4.9] | 2.7 [2.0, 3.3] | .583 | CS: 0.650 [−0.931, 2.232], .418 |
| | Delta | −3.0 [−4.0, −2.0] | −1.9 [−4.0, 0.3] | −3.1 [−4.3, −2.0] | .501 | FS: −0.424 [−1.569, 0.721], .465 |
| | RR | 33.4% | 26.4% | 44.3% | .615 | |
| | %MCID | 51.3% | 47.4% | 69.6% | .046 ^e | |
| | P Value ^d | <.001 ^e | .084 | <.001 ^e | — | |
| VAS Leg | Pre | 6.4 [5.9, 6.9] | 6.7 [5.3, 8.2] | 6.7 [5.8, 7.6] | .552 | NS: — |
| | Post | 2.8 [2.3, 3.3] | 2.5 [1.2, 3.9] | 2.7 [1.9, 3.5] | .849 | CS: −0.267 [−1.740, 1.207], .722 |
| | Delta | −3.6 [−4.3, −2.8] | −4.1 [−6.0, −2.1] | −4.0 [−5.0, −2.9] | .780 | FS: −0.317 [−1.381, 0.748], .558 |
| | RR | 45.0% | 56.8% | 44.3% | .947 | |
| | %MCID | 62.2% | 63.2% | 67.4% | .730 | |
| | P Value ^d | <.001 ^e | <.001 ^e | <.001 ^e | — | |

Abbreviations: PCS-12, Short-Form-12 Physical Component Score; MCS-12, Short-Form-12 Mental Component Score; ODI, Oswestry Disability Index; VAS Back, Visual Analogue Score Back pain; VAS Leg, VAS Leg pain.

^aRecovery ratios (RRs) were calculated for PROM improvement scores using the following formula: [PROM Delta/(Ideal Score − Preoperative PROM)]. Ideal scores: PCS-12 = 100; ODI, VAS Back and Leg = 0. The percentage of patients reaching MCID at 1-year follow-up was recorded as %MCID. MCID cutoff values: PCS-12: 8.8; MCS-12: 9.3; ODI: 5.3; VAS Back: 2.1; and VAS Leg: 2.4.

^bKruskal-Wallis H test (Dunn multiple pairwise comparison post hoc analysis) or Pearson χ^2 analysis for between-group comparison.

^cMultiple linear regression analysis.

^dPaired-samples t-test for within-group comparison.

^eIndicates statistical significance ($P < .05$).

Table 3. Revisions, Readmissions, and Infections Between Smoking Groups.^a

| | Never smoker (n = 121) | Current smoker (n = 22) | Former smoker (n = 52) | P value ^b |
|-------------|------------------------|-------------------------|------------------------|----------------------|
| Revision | | | | .814 |
| No | 116 (95.9%) | 21 (95.5%) | 51 (98.1%) | |
| Yes | 5 (4.1%) | 1 (4.5%) | 1 (1.9%) | |
| Infection | 2 (1.7%) | 0 (0.0%) | 0 (0.0%) | .539 |
| Other | 3 (2.4%) | 1 (4.5%) | 1 (1.9%) | .455 |
| Readmission | | | | |
| 30-Day | 119 (98.3%) | 22 (100.0%) | 52 (100.0%) | .539 |
| No | 2 (1.7%) | 0 (0.0%) | 0 (0.0%) | |
| Yes | | | | |
| 90-Day | | | | |
| No | 116 (95.9%) | 22 (100.0%) | 50 (96.2%) | .628 |
| Yes | 5 (4.1%) | 0 (0.0%) | 2 (3.8%) | |

^aOther reasons for revision: recurrent pain with adjacent segment disease, recurrent stenosis secondary to spondylolisthesis, or recurrent disc herniation.

^bPearson χ^2 analysis or Fisher exact test for group comparison.

seems to have a physiological effect on microcirculation and, hence, overall perfusion in previously mentioned studies, the present study did not observe any clinical differences between groups based on smoking status. Hence, practitioners may consider not precluding patients from receiving simple, decompression surgery for degenerative lumbar pathology based solely on smoking status until further evidence is available.

Few studies have examined differences in complication rates or readmission rates in decompression surgery.^{27,28} Similar to the present study, Stienen et al²⁵ noted no significant differences in deep wound infections or reoperations between nonsmoking and smoking groups. However, Bydon et al³ demonstrated smoking to be a significant predictor of reoperation after lumbar laminectomy.

There are several limitations to this study. It is a retrospective review of prospectively collected data and is, thus, subject to reporting bias. Smoking status was self-reported by patients, which could result in incorrect categorization of FS patients who identified as nonsmokers. In addition, the total number of pack-years and perioperative smoking cessation status was not available for CSs or FSs, further decreasing the study's ability to categorize patients. There were a relatively low number of patients in the CS group, creating relatively uneven patient groups, which limited the extent of our statistical analysis.

Conclusion

The results of this study suggest that short-term patient outcomes after lumbar decompression may be similar regardless of smoking status. Further research with larger cohorts is needed to validate these findings.

Authors' Note

This study was approved by the institutional review board at the Thomas Jefferson University Hospital. Each author certifies that his or her institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.





Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Dhruv K. C. Goyal, MD  <https://orcid.org/0000-0002-5789-5410>
 I. David Kaye, MD  <https://orcid.org/0000-0002-0797-8760>
 Alan S. Hilibrand, MD  <https://orcid.org/0000-0001-8811-9687>
 Alexander R. Vaccaro, MD, PhD, MBA  <https://orcid.org/0000-0002-8073-0796>

References

1. Anjarwalla NK, Brown LC, McGregor AH. The outcome of spinal decompression surgery 5 years on. *Eur Spine J*. 2007;16:1842-1847. doi:10.1007/s00586-007-0393-z
2. Deyo RA. Treatment of lumbar spinal stenosis: a balancing act. *Spine J*. 2010;10:625-627. doi:10.1016/j.spinee.2010.05.006
3. Bydon M, Macki M, De la Garza-Ramos R, et al. Smoking as an independent predictor of reoperation after lumbar laminectomy: a study of 500 cases. *J Neurosurg Spine*. 2015;22:288-293. doi:10.3171/2014.10.SPINE14186
4. Kong L, Liu Z, Meng F, Shen Y. Smoking and risk of surgical site infection after spinal surgery: a systematic review and meta-analysis. *Surg Infect*. 2017;18:206-214. doi:10.1089/sur.2016.209
5. Silverstein P. Smoking and wound healing. *Am J Med*. 1992;93(1A):22S-24S.
6. Elmasry S, Asfour S, de R Vaccari JP, Travascio F. Effects of tobacco smoking on the degeneration of the intervertebral disc: a finite element study. *PLoS One*. 2015;10:e0136137. doi:10.1371/journal.pone.0136137
7. Martin CT, Gao Y, Duchman KR, Pugely AJ. The impact of current smoking and smoking cessation on short-term morbidity risk after lumbar spine surgery. *Spine (Phila Pa 1976)*. 2016;41:577-584. doi:10.1097/BRS.0000000000001281
8. Brown CW, Orme TJ, Richardson HD. The rate of pseudarthrosis (surgical nonunion) in patients who are smokers and patients who are nonsmokers: a comparison study. *Spine (Phila Pa 1976)*. 1986;11:942-943.
9. Andersen T, Christensen FB, Laursen M, Høy K, Hansen ES, Bünger C. Smoking as a predictor of negative outcome in lumbar spinal fusion. *Spine (Phila Pa 1976)*. 2001;26:2623-2628.
10. Carpenter CT, Dietz JW, Leung KY, Hanscom DA, Wagner TA. Repair of a pseudarthrosis of the lumbar spine: a functional outcome study. *J Bone Joint Surg Am*. 1996;78:712-720. doi:10.2106/00004623-199605000-00011
11. Deshpande PR, Rajan S, Sudeepthi BL, Nazir CPA. Patient-reported outcomes: a new era in clinical research. *Perspect Clin Res*. 2011;2:137-144. doi:10.4103/2229-3485.86879
12. Centers for Disease Control and Prevention. Surgical site infection (SSI) event. 2019. <https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscscscurrent.pdf>. Accessed May 9, 2019.
13. Radcliff K, Davis RJ, Hisey MS, et al. Long-term evaluation of cervical disc arthroplasty with the Mobi-C[®] cervical disc: a randomized, prospective, multicenter clinical trial with seven-year follow-up. *Int J Spine Surg*. 2017;11:31. doi:10.14444/4031
14. Asher AL, Kerezoudis P, Mummaneni PV, et al. Defining the minimum clinically important difference for grade I degenerative lumbar spondylolisthesis: insights from the Quality Outcomes Database. *Neurosurg Focus*. 2018;44:E2. doi:10.3171/2017.10.FOCUS17554
15. Parker SL, Mendenhall SK, Shau D, et al. Determination of minimum clinically important difference in pain, disability, and quality of life after extension of fusion for adjacent-segment disease. *J Neurosurg Spine*. 2012;16:61-67. doi:10.3171/2011.8.SPINE1194

16. Ma C, Wu S, Xiao L, Xue Y. Responsiveness of the Chinese version of the Oswestry Disability Index in patients with chronic low back pain. *Eur Spine J*. 2011;20:475-481. doi:10.1007/s00586-010-1624-2
17. Schroeder GD, Kepler CK, Hilibrand AS. The effect of smoking on patients having spinal surgery. *Curr Orthop Pract*. 2016;27:140-145. doi:10.1097/BCO.0000000000000331
18. Berman D, Oren JH, Bendo J, Spivak J. The effect of smoking on spinal fusion. *Int J Spine Surg*. 2017;11:29. doi:10.14444/4029
19. Hermann PC, Webler M, Bornemann R, et al. Influence of smoking on spinal fusion after spondylodesis surgery: a comparative clinical study. *Technol Health Care*. 2016;24:737-744. doi:10.3233/THC-161164
20. Sandén B, Försth P, Michaëlsson K. Smokers show less improvement than nonsmokers two years after surgery for lumbar spinal stenosis: a study of 4555 patients from the Swedish spine register. *Spine (Phila Pa 1976)*. 2011;36:1059-1064. doi:10.1097/BRS.0b013e3181e92b36
21. Slover J, Abdu WA, Hanscom B, Weinstein JN. The impact of comorbidities on the change in short-form 36 and Oswestry scores following lumbar spine surgery. *Spine (Phila Pa 1976)*. 2006;31:1974-1980. doi:10.1097/01.brs.0000229252.30903.b9
22. Jazini E, Glassman SD, Bisson EF, Potts EA, Carreon LY. Do former smokers exhibit a distinct profile before and after lumbar spine surgery? *Spine (Phila Pa 1976)*. 2018;43:201-206. doi:10.1097/BRS.0000000000002293
23. Mehta R, Sharma H. Does smoking affect the outcomes of lumbar decompression surgery? *SICOT J*. 2017;3:65. doi:10.1051/sicotj/2017050
24. Stienen MN, Smoll NR, Hildebrandt G, Schaller K, Gautschi OP. Influence of smoking status at time of surgery for herniated lumbar disk on postoperative pain and health-related quality of life. *Clin Neurol Neurosurg*. 2014;122:12-19. doi:10.1016/j.clineuro.2014.04.015
25. Stienen MN, Joswig H, Smoll NR, et al. Short- and long-term effects of smoking on pain and health-related quality of life after non-instrumented lumbar spine surgery. *Clin Neurol Neurosurg*. 2016;142:87-92. doi:10.1016/j.clineuro.2016.01.024
26. Gulati S, Nordseth T, Nerland US, et al. Does daily tobacco smoking affect outcomes after microdecompression for degenerative central lumbar spinal stenosis? A multicenter observational registry-based study. *Acta Neurochir (Wien)*. 2015;157:1157-1164. doi:10.1007/s00701-015-2437-1
27. Fang A, Hu SS, Endres N, Bradford DS. Risk factors for infection after spinal surgery. *Spine (Phila Pa 1976)*. 2005;30:1460-1465.
28. Veeravagu A, Patil CG, Lad SP, Boakye M. Risk factors for postoperative spinal wound infections after spinal decompression and fusion surgeries. *Spine (Phila Pa 1976)*. 2009;34:1869-1872. doi:10.1097/BRS.0b013e3181adc989