INTERNATIONAL JOURNAL of SPINE SURGERY

Long-Term Results of Charité Lumbar Disc Replacement: A 17-Year Follow-Up in a Workers' Compensation Cohort

Jack Carlson and Matthew Giblin

Int J Spine Surg 2022, 16 (5) 831-836
doi: https://doi.org/10.14444/8345
https://www.ijssurgery.com/content/16/5/831

This information is current as of October 11, 2024.

Email Alerts Receive free email-alerts when new articles cite this article. Sign up at: http://ijssurgery.com/alerts

The International Journal of Spine Surgery
2397 Waterbury Circle, Suite 1,
Aurora, IL 60504, Phone: +1-630-375-1432
© 2022 ISASS. All Rights Reserved.
Downloaded from https://www.ijssurgery.com/ by guest on October 11, 2024

International Journal of Spine Surgery, Vol. 16, No. 5, 2022, pp. 831–836
https://doi.org/10.14444/8345
© International Society for the Advancement of Spine Surgery

Long-Term Results of Charité Lumbar Disc Replacement: A 17-Year Follow-Up in a Workers' Compensation Cohort

JACK CARLSON, MBBS (Hons I)[1] AND MATTHEW GIBLIN, MBBS, FRACS, FAOrthoA
[1]*Western Sydney University School of Medicine, Campelltown, Australia*

ABSTRACT

Background: Lumbar total disc replacement (TDR) is an alternative to lumbar fusion for the management of degenerative disc disease. This study aims to provide insight into the long-term clinical outcomes of lumbar TDR with a mean follow-up of 17.2 years in a group of workers' compensation patients.

Methods: A total of 26 workers' compensation patients with radiographically confirmed discogenic low back pain were treated with the Charité total lumbar disc replacement. Visual analog scale (VAS) scores were assessed before and after the surgery. At follow-up, patients were assessed on quality of life, employment, further lumbar spine surgeries, and associated complications. Simple nonparametric statistical analysis was performed by the first author using Microsoft Excel.

Results: Sixteen patients (62%) were able to be contacted with a mean follow-up time of 17.2 years. VAS scores at 17 years were significantly lower than their preoperation level. Of those 16 patients, 81% returned to work and worked for an average of 9.1 years after surgery. Additionally, 6 (38%) patients underwent further lumbar spinal surgery, of whom 4 underwent fusions of the adjacent segment. Nearly all patients (94%) were satisfied with the surgery.

Conclusion: This study suggests lumbar TDR may be a useful treatment for degenerative disc disease in select workers' compensation patients.

Clinical Relevance: Clinically relevant improvements in pain and employment can be achieved with the charite lumbar TDR in the treatment of degenerative disc disease in workers' compensation patients. These results are sustained over the long term.

Level of Evidence: 4.

TDR

Keywords: spine surgery, total disc replacement, low back pain, workers' compensation

INTRODUCTION

Chronic low back pain is the persistence of pain beyond 3 months and is often related to mechanical dysfunction.[1] Low back pain affects approximately 16% of the Australian population and is the most common musculoskeletal condition for which patients consult their general practitioners.[2] Low back pain is a significant cause of morbidity and loss of productivity and is one of the most common reasons for workers' compensation claims.[3,4] Low back pain costs the Australian Health system approximately $2.8 billion every year, representing 2.4% of total health expenditure.[3]

Traditionally, spinal fusion has been used for the treatment of low back pain unresponsive to conservative measures; however, for more than two decades now,[5] total disc replacement (TDR) has been offered as an alternative for select patients, but implementation rates of TDR have been relatively low.[6] Patients suitable for TDR typically have painful disc degeneration unresponsive to at least 6 months of nonoperative care with no obvious pathology on radiography or magnetic resonance imaging and a positive provocative discogram.[7,8] Given the risk of vertebral body fracture during implementation, TDR is generally reserved for younger patients with no evidence of osteopenia.[7]

Despite initial success with spinal arthrodesis improving quality of life and disability, recurrent chronic low back pain and the development of adjacent segment disease (ASD) have led to the development of the lumbar TDR in an attempt to maintain mobility and reduce the risk of ASD.[9] Harrop et al's systematic review reported a rate of ASD of 1% in patients who underwent TDR compared with a rate of 14% in the group of patients who underwent spinal arthrodesis; however, this effect was dampened by patient's age and increased follow-up time.[10] Despite promising early results, debate still exists as to whether lumbar TDR can reduce the rate of ASD in the long term.[10–12]

To date, the number of long-term studies on TDR remain small. Several studies have demonstrated similar results between spinal fusion and TDR surgery,[13–15] and more recent cohort studies have suggested high rates of

Downloaded from https://www.ijssurgery.com/ by guest on October 11, 2024

return to work (RTW) with good short-term to midterm clinical and radiological results in TDR patients.[16–19]

Workers' compensation status has always been thought to have a poor prognosis following surgery, especially surgery for low back pain alone.[20,21] In the early days of this study, patients were often advised that conservative treatment was the only form of management for low back pain. This study aimed to provide insight into the long-term clinical outcomes of lumbar TDR for low back pain in a workers' compensation cohort with a mean follow-up of 17.2 years. For this study, we measured the effect of surgery on pain, return to employment, and quality of life.

MATERIALS AND METHODS

Study Protocol and Patient Selection

A total of 26 workers' compensation patients with radiographically confirmed discogenic low back pain were treated with the Charité artificial disc replacement by the senior author between 2001 and 2007. All patients underwent a medical history and physical examination, lumbar radiography, and provocative discography to determine the diagnosis of discogenic back pain. Patients with radicular symptoms, abnormal endplate anatomy, spondylolisthesis, active facet disease, prior spinal surgery, osteoporosis, age 55 years or older, or infectious, or oncological etiologies were excluded from this study. Private patients were not included in this study. Inclusion criteria for this study were patients younger than 55 years who exhausted conservative management of lower back pain and had a positive provocative discogram.

Visual analog scale (VAS) scores were assessed preoperatively for every patient as a standard of care. Unfortunately, 7 patients' preoperative VAS scores were lost to our data set due to a system error. These patients were contacted by phone as part of the follow-up and asked to recall their VAS scores from before the operation with the knowledge that the operating surgeon declined to operate on patients whose VAS scores were below a score of 7 out of 10.

Patient Follow-Up

Patients were contacted by mail and phone for consent to have their medical records assessed and for further participation in this survey. Prior to surgery, patients were asked to complete a VAS for pain. At follow-up, patients were asked to complete a further VAS score for pain, a EuroQol 5-Dimension 5-level (EQ-5D-5L) quality-of-life index, and further questions related to subsequent lumbar spine surgeries, complications from those surgeries, and employment outcomes, including the return to employment, the duration of return, and level of activities they returned to work under. Patients were also asked if they would repeat the surgery given the same circumstances.

Surgical Technique

The patient was positioned in the French position, and the procedure was performed as described in the literature. Particular attention, however, was taken to elements of the procedure.

All levels above L5-S1 were approached via a longitudinal incision and a left retroperitoneal approach. The L5-S1 level was approached through a Pfannenstiel incision, and the disc space was explored from a right retroperitoneal approach, keeping the left side free for further surgery.

In preparation of the disc, the entire endplate cartilage was removed, and attention was taken to not penetrate the endplate or rupture the lateral annulus. To prevent adherence to the disc space, a gortex graft was applied at the end of the procedure. Postoperatively, core stability exercises were instituted by the hospital physiotherapist once pain settled. Patients were advised to avoid heavy lifting or repetitive bending for 2 months.

Statistical Analysis

Statistical analysis was performed by the first author using Microsoft Excel 365 Version 2201 (14931.20120). The Mann-Whitney *U* test was used to determine differences in age, preoperative VAS scores, and quality-of-life scores between patients who were lost to follow-up and those who were followed up as well as those with further surgery compared with no further surgery. Fisher exact test was used to determine differences in gender distribution between groups that were lost to follow-up as well as opioid use between those requiring further surgery and those who did not. The Wilcoxon signed rank test was used to assess the difference between preoperative and postoperative VAS scores. Significance was accepted to be at the $P < 0.05$ level.

RESULTS

Patient Demographics

A total of 16 patients responded to the follow-up phone interview in late 2020. The mean follow-up duration was 17.2 years (range 12.5–19.5). All patients included in this study were workers' compensation

Downloaded from https://www.ijssurgery.com/ by guest on October 11, 2024

Table 1. Mann-Whitney *U* test (lost vs found preoperative VAS and age at surgery) and Fisher exact test (lost vs found gender).

Patient Characteristics	Patients Followed Up (n = 16)	Patients Lost to Follow Up (n = 10)	*P* Value
Preoperative VAS scores, mean	9.5	7.5	**0.001**
Age at surgery, mean	42.0	37.4	0.16
Gender, male:female	8:8	7:3	0.28
Workers' compensation, *n*	16	10	

Abbreviation: VAS, visual analog scale.
Note: Boldface indicates statistically significant findings.

patients. A summary of patient demographics is provided in Table 1.

Patients who were lost to follow-up had less pain preoperatively compared with those who responded to follow-up (P = 0.001). There was no significant gap in age or gender between the 2 groups. All 7 patients who lost their preoperative VAS scores (due to system error) belonged to the group that was followed up and were subsequently asked to recall their VAS score as they remembered it before the surgery. These 7 patients reported a mean preoperative VAS score of 9.7 compared with the preoperative VAS scores of 9.4 in the other 9 patients who were followed up.

Pain Relief and Quality of Life

The mean preoperative VAS score for the 16 patients analyzed in this study was 9.5 (SD 0.6). At follow-up 17.2 years later, VAS scores were significantly lower at 3.1 (SD 2.4) ($P < 0.001$). The 10 patients lost to follow-up had a mean preoperative VAS score of 7.5.

VAS scores for those who required further surgery averaged 5.3 at follow-up (Table 2), compared with VAS scores of 1.8 in patients who did not require further surgery (P = 0.004). Of the 16 patients who were followed up, 5 (31%) had undergone further lumbar spine surgery and were on prescription opioid pain medication to manage their lower back pain. Patients who did not require further surgery did not require opioids for pain management. The mean EQ-5D-5L score for quality of life for the entire cohort was 0.68 (SD 0.2). Patients who underwent further surgery had a lower quality of life at follow-up of 0.45 (SD 0.2) compared with patients who did not require further surgery 0.81 (SD 0.1) (P = 0.002). Out of the 16 patients, 15 (94%) reported they would repeat the surgery given similar circumstances.

Table 2. Mann-Whitney *U* test (further surgery vs no further surgery age, VAS preoperative, VAS postoperative, EQ-5D-5L) and Fisher exact test (further surgery vs no further surgery gender and opioid use).

Patient Characteristics	No Further Surgery (n = 10)	Further Surgery (n = 6)	*P* Value
Gender, male:female	4:6	4:2	0.94
Age at surgery, y, mean	41	44	0.91
VAS preoperative, mean	9.6	9.5	1.0
VAS postoperative, mean	1.8	5.3	**0.004**
Postoperative opioid use, %	0%	83%	**0.042**
Quality of life, mean	0.81	0.45	**0.002**

Abbreviations: EQ-5D-5L, EuroQol 5-Dimension 5-level instument; VAS, visual analog scale.
Note: Boldface indicates statistically significant findings.

Employment Outcomes

Out of the 16 patients, 13 (81%) who followed up at 17 years returned to work after the Charité disc replacement for some period. Of those 13, 7 (54%) returned to preinjury duties (PID), and 6 (46%) returned to light duties. Patients who returned to work worked on average for 9.1 years (SD 7.04). Six patients were still working at the time of follow-up with the longest duration of employment being over 18 years. Of the remaining 8 patients, 6 cited back pain as the main contributor to their retirement while the other 2 retired for other reasons. Of the 6 patients who required further surgery, 5 returned to work after the initial TDR. After reoperation (Table 3), 2 of these 5 patients returned to work and worked an additional 10 and 7 years, respectively.

Complications and Further Surgery

Out of the 16 patients, 3 (19%) reported complications from the index procedure, including 2 medical complications (hypotension and anaphylaxis) and 1 surgical complication (ilioinguinal nerve damage).

Out of the 16 patients, 6 (38%) underwent further lumbar spinal surgery, of whom 4 underwent fusions of the adjacent segment. The average time to reoperation was 6.5 years after the index surgery, with 2 patients requiring second surgery more than 13 years after their index surgery. Two patients required further surgery at the level of the original TDR. A summary of the further surgeries required after TDR is shown in Table 4.

DISCUSSION

Despite enthusiasm for alternative surgical treatment for lower back pain, implementation rates of TDR have been relatively low. Thus, there is a paucity of evidence as to the long-term efficacy of lumbar TDR for the treatment of degenerative disc disease beyond 10 years, let alone in a group of workers' compensation patients.[16,18,22] Previous systematic reviews suggest that

Downloaded from https://www.ijssurgery.com/ by guest on October 11, 2024

Table 3. Further surgeries required after TDR.

Index TDR Site	Reoperation	Duration Between Surgeries
L5-S1 TDR (2003)	L4-L5 fusion (2016) L3-L4 TDR (2016)	13 y
L5-S1 TDR (2004)	L3-L4 fusion (2009)	5 y
L3-L4-L5 TDR (2003)	L5-S1 fusion (2016)	13 y
L5-S1 TDR (2002)	Foraminotomy (2003)	1 y
L4-L5-S1 TDR (2003)	L3-L4 fusion (2010) L4-L5 fusion (2018)[a] L5-S1 fusion (2019)[a]	7 y
L4-L5 TDR (2003)	Discectomy (2004) L4-L5-S1 fusion (2005)[a]	1 y

Abbreviation: TDR, total disc replacement.
[a]Denotes further surgery at the index (operated) level.

lumbar TDR provides improvements to quality-of-life measures in the medium to long term and substantial pain relief in the short to medium term with pain relief documented as long as 12 years.[16,18,22–24] Our study reports improved pain and quality-of-life measures after 17 years in a group of workers' compensation patients. In this study, 15 of 16 patients (94%) would repeat the surgery given similar circumstances, which reinforces international data that TDR is a popular surgery among patients.[16,18,23,25] Bai et al's meta-analysis reported TDR as superior to spinal fusion in single-level patients using similar metrics of VAS, patient satisfaction, reoperation rates, and quality of life.[26]

The literature reports a medium- to long-term reoperation rate of TDRs ranging between 0 and 39% with a mean reoperation rate of 12% in studies that follow patients for longer than 3 years.[22] In that systematic review, the mean reoperation time was 0.8–6.9 years after TDR surgery, which is similar to our reported reoperation time of 6.5 years.[22] Our reoperation rate of 38% and reoperation time of 6.5 years may reflect 2 late reoperations approximately 13 years after the original TDR. These late reoperations of the adjacent segment may not have been captured in studies of shorter follow-up time. Our study found reoperation to be associated with poorer outcomes in VAS scores, opioid use, and quality of life. Similarly, poorer long-term results with further spinal surgery after TDR have been demonstrated in other studies.[27] However, despite this comparatively high reoperation rate and associated poorer outcomes in those who required further surgery, it is worth noting that these poorer outcomes were still an improvement compared with the reported preoperative VAS scores. While patients were selected according to the Charité implementation guidelines, further identification and selection of patients with isolated single-level disc disease with minimal psychosocial risk factors may further improve patient outcomes.[7,17,28,29]

The rate of opioid prescription for patients with TDR has been reported as high as 71.2% at 24 months postoperation.[30] This study reports that 5 of 16 (31%) patients required opioids for the management of their low back pain 17 years after TDR. All patients in this study had previously exhausted conservative management before surgery was offered, with many patients requiring opioid-based analgesia for pain management before surgery. It is interesting to note that the only patients who required opioids at follow-up were those who had further lumbar spinal surgery; 4 had undergone further spinal fusion surgery, while the fifth patient underwent a foraminotomy a year after surgery. This patient reported a good initial response to the TDR but unfortunately developed diffuse idiopathic skeletal hyperostosis syndrome more than a decade later.

All patients in our study were workers' compensation patients. The RTW rate of 81% and the return to PID of 54% in workers' compensation cohorts are considerably higher than the RTW and PID rates of 40 and 11%, respectively, previously described in the Australian literature.[30] Their study indicated poor RTW and high rates of ongoing opioid management (71%) at 24 months, leading the authors to conclude "along with the poor evidence base for these procedures … [this result] forces us to question the role of fusion and TDR surgeries in a workers' compensation population."[30] We believe that the patient's RTW is based on several factors. First, the recovery and rehabilitation for TDR are faster than they are for spinal fusion.[14,31] Second, we believe patients' and employers' expectations for recovery are greater, as they tend to compare TDR with other orthopedic joint replacements with good clinical outcomes.

Table 4. Wilcoxon signed rank test (preoperative vs postoperative VAS).

Patient population	VAS Preoperative	VAS 17.2 y	*P* Value
Total patients	8.8 (n = 26)	3.1 (n = 16)	**<0.001**
Followed up	9.5 (n = 16)	3.1 (n = 16)	
Lost to follow-up	7.5 (n = 10)	N/A	

Abbreviations: N/A, not applicable; VAS, visual analog scale.
Note: Boldface indicates statistically significant findings.

Limitations

There were several limitations to this study. The first limitation is the small sample size of 26 patients with a follow-up rate of 62%. This follow-up rate is perhaps a reflection of the extended follow-up time, with many patients uncontactable via phone or mail and some patients who died in that time. This follow-up rate is consistent with

Downloaded from https://www.ijssurgery.com/ by guest on October 11, 2024

other long-term studies of TDR and represents difficulties in studying patients over long periods.[32] The second notable limitation is the retrospectivity of 7 patients who lost their preoperative VAS scores due to a computer system malfunction. These patients were asked to recall their preoperative VAS scores at follow-up. This introduces a potential element of recall bias, as they may have recalled their pain being more severe than it in fact was at the time. However, when compared with the preoperative VAS scores of the patients who did follow-up with the study, we note that the scores are similarly high around 9.4/10 and 9.7/10, respectively. Furthermore, the primary surgeon did not operate on any patient with a VAS score less than 7/10 at the time of surgery. A further limitation of this study is that we did not gather radiologic data and compare outcomes in those with low VAS scores compared with high VAS scores, nor did we assess ASD. Body mass index has been shown to be a potential outcome predictor in other studies; however, body mass index was not assessed in this study.[33]

The literature currently suggests that due to the mobility characteristics of TDR, ASD is not as common in patients undergoing TDR, compared with arthrodesis in the short to medium term. A systematic review by Wang and Arnold reported that patients who underwent arthrodesis for lumbar degenerative disc disease were 6 times more likely to require surgical treatment for ASD than those who underwent TDR.[34] ASD, however, was not assessed in this study.

CONCLUSION

This study presents the outcomes of 16 patients treated with the Charité TDR with a mean follow-up of 17 years, in a workers' compensation cohort. An RTW was achieved in 81% of cases, and they were employed for an average of more than 9 years, with many still employed at the time of follow-up. Pain was significantly reduced at 17 years, and many patients did not require opioid analgesia for pain relief. These results demonstrate that satisfactory long-term clinical results can be achieved for workers' compensation patients using the Charité TDR.

ACKNOWLEDGMENTS

We thank Dr William Sears for his help in the preparation of this manuscript.

REFERENCES

1. Rozenberg S. Chronic low back pain: definition and treatment. *Rev Prat*. 2008;58(3):265–272.

2. Australian Commission on Safety and Quality in Health Care. *Low Back Pain Clinical Care Standard*. https://www.safetyandquality.gov.au/standards/clinical-care-standards/low-back-pain-clinical-care-standard. Accessed September 26, 2021.

3. Australian Institute of Health and Welfare. *Back Problems, What Are Back Problems?*. https://www.aihw.gov.au/reports/chronic-musculoskeletal-conditions/back-problems/contents/what-are-back-problems. Accessed September 26, 2021.

4. Franklin GM, Wickizer TM, Coe NB, Fulton-Kehoe D. Workers' compensation: poor quality health care and the growing disability problem in the United States. *Am J Ind Med*. 2015;58(3):245–251. doi:10.1002/ajim.22399

5. Griffith SL, Shelokov AP, Büttner-Janz K, LeMaire JP, Zeegers WS. A multicenter retrospective study of the clinical results of the LINK SB charité intervertebral prosthesis. the initial european experience. *Spine (Phila Pa 1976)*. 1994;19(16):1842–1849. doi:10.1097/00007632-199408150-00009

6. Kwon BK, Vaccaro AR, Grauer JN, Beiner J. Indications, techniques, and outcomes of posterior surgery for chronic low back pain. *Orthop Clin North Am*. 2003;34(2):297–308. doi:10.1016/s0030-5898(03)00014-2

7. Büttner-Janz K, Guyer RD, Ohnmeiss DD. Indications for lumbar total disc replacement: selecting the right patient with the right indication for the right total disc. *Int J Spine Surg*. 2014;8:12. doi:10.14444/1012

8. Walker J, El Abd O, Isaac Z, Muzin S. Discography in practice: a clinical and historical review. *Curr Rev Musculoskelet Med*. 2008;1(2):69–83. doi:10.1007/s12178-007-9009-9

9. Berg S. On total disc replacement. *Acta Orthop Suppl*. 2011;82(343):1–29. doi:10.3109/17453674.2011.575327

10. Harrop JS, Youssef JA, Maltenfort M, et al. Lumbar adjacent segment degeneration and disease after arthrodesis and total disc arthroplasty. *Spine (Phila Pa 1976)*. 2008;33(15):1701–1707. doi:10.1097/BRS.0b013e31817bb956

11. McAfee PC, Cunningham BW, Devine J, Williams E, Yu-Yahiro J. Classification of heterotopic ossification (HO) in artificial disk replacement. *J Spinal Disord Tech*. 2003;16(4):384–389. doi:10.1097/00024720-200308000-00010

12. Rainey S, Blumenthal SL, Zigler JE, Guyer RD, Ohnmeiss DD. Analysis of adjacent segment reoperation after lumbar total disc replacement. *Int J Spine Surg*. 2012;6:140–144. doi:10.1016/j.ijsp.2012.02.007

13. Radcliff K, Spivak J, Darden B, Janssen M, Bernard T, Zigler J. Five-year reoperation rates of 2-level lumbar total disk replacement versus fusion: results of a prospective, randomized clinical trial. *Clin Spine Surg*. 2018;31(1):37–42. doi:10.1097/BSD.0000000000000476

14. Blumenthal S, McAfee PC, Guyer RD, et al. A prospective, randomized, multicenter food and drug administration investigational device exemptions study of lumbar total disc replacement with the CHARITE artificial disc versus lumbar fusion: part I: evaluation of clinical outcomes. *Spine (Phila Pa 1976)*. 2005;30(14):1565–1575. doi:10.1097/01.brs.0000170587.32676.0e

15. Guyer RD, McAfee PC, Banco RJ, et al. Prospective, randomized, multicenter food and drug administration investigational device exemption study of lumbar total disc replacement with the CHARITE artificial disc versus lumbar fusion: five-year follow-up. *Spine J*. 2009;9(5):374–386. doi:10.1016/j.spinee.2008.08.007

16. Siepe CJ, Heider F, Wiechert K, Hitzl W, Ishak B, Mayer MH. Mid- to long-term results of total lumbar disc replacement: a prospective analysis with 5- to 10-year follow-up. *Spine J*. 2014;14(8):1417–1431. doi:10.1016/j.spinee.2013.08.028

Downloaded from https://www.ijssurgery.com/ by guest on October 11, 2024

17. Park SJ, Lee CS, Chung SS, Lee KH, Kim WS, Lee JY. Long-term outcomes following lumbar total disc replacement using prodisc-II: average 10-year follow-up at a single institute. *Spine (Phila Pa 1976)*. 2016;41(11):971–977. doi:10.1097/BRS.0000000000001527

18. Scott-Young MN, Lee MJ, Nielsen DEA, Magno CL, Kimlin KR, Mitchell EO. Clinical and radiological mid-term outcomes of lumbar single-level total disc replacement. *Spine (Phila Pa 1976)*. 2018;43(2):105–113. doi:10.1097/BRS.0b013e3182345aa2

19. Scott-Young M, McEntee L, Zotti M, et al. Patient-reported outcome measures after multilevel lumbar total disc arthroplasty for the treatment of multilevel degenerative disc disease. *Spine (Phila Pa 1976)*. 2020;45(1):18–25. doi:10.1097/BRS.0000000000003201

20. Russo F, De Salvatore S, Ambrosio L, et al. Does workers' compensation status affect outcomes after lumbar spine surgery? A systematic review and meta-analysis. *Int J Environ Res Public Health*. 2021;18(11):6165. doi:10.3390/ijerph18116165

21. Gum JL, Glassman SD, Carreon LY. Is type of compensation a predictor of outcome after lumbar fusion? *Spine (Phila Pa 1976)*. 2013;38(5):443–448. doi:10.1097/BRS.0b013e318278ebe8

22. Cui XD, Li HT, Zhang W, Zhang LL, Luo ZP, Yang HL. Mid- to long-term results of total disc replacement for lumbar degenerative disc disease: a systematic review. *J Orthop Surg Res*. 2018;13(1):326. doi:10.1186/s13018-018-1032-6

23. Lu S, Hai Y, Kong C, et al. An 11-year minimum follow-up of the charite III lumbar disc replacement for the treatment of symptomatic degenerative disc disease. *Eur Spine J*. 2015;24(9):2056–2064. doi:10.1007/s00586-015-3939-5

24. Pokorny G, Marchi L, Amaral R, Jensen R, Pimenta L. Lumbar total disc replacement by the lateral approach-up to 10 years follow-up. *World Neurosurg*. 2019;122:e325–e333. doi:10.1016/j.wneu.2018.10.033

25. Lemaire J-P, Carrier H, Sariali E, Sari Ali E-H, Skalli W, Lavaste F. Clinical and radiological outcomes with the charité artificial disc: a 10-year minimum follow-up. *J Spinal Disord Tech*. 2005;18(4):353–359. doi:10.1097/01.bsd.0000172361.07479.6b

26. Bai D-Y, Liang L, Zhang B-B, et al. Total disc replacement versus fusion for lumbar degenerative diseases - a meta-analysis of randomized controlled trials. *Medicine (Baltimore)*. 2019;98(29):e16460. doi:10.1097/MD.0000000000016460

27. Laugesen LA, Paulsen RT, Carreon L, Ernst C, Andersen MØ. Patient-reported outcomes and revision rates at a mean follow-up of 10 years after lumbar total disc replacement. *Spine (Phila Pa 1976)*. 2017;42(21):1657–1663. doi:10.1097/BRS.0000000000002174

28. DePuy Spine. *Clinical Investigation of the SB Charite III Intervertebral Disc Spacer* [clinicaltrials.gov]. 2014. https://clinicaltrials.gov/ct2/show/NCT00215306. Accessed May 10, 2022.

29. Halpin RJ, Sugrue PA, Gould RW, et al. Standardizing care for high-risk patients in spine surgery: the northwestern high-risk spine protocol. *Spine (Phila Pa 1976)*. 2010;35(25):2232–2238. doi:10.1097/BRS.0b013e3181e8abb0

30. Harris IA, Dantanarayana N, Naylor JM. Spine surgery outcomes in a workers' compensation cohort: spine surgery outcomes. *ANZ J Surg*. 2012;82(9):625–629. doi:10.1111/j.1445-2197.2012.06152.x

31. Berg S, Tullberg T, Branth B, Olerud C, Tropp H. Total disc replacement compared to lumbar fusion: a randomised controlled trial with 2-year follow-up. *Eur Spine J*. 2009;18(10):1512–1519. doi:10.1007/s00586-009-1047-0

32. Putzier M, Funk JF, Schneider SV, et al. Charité total disc replacement-clinical and radiographical results after an average follow-up of 17 years. *Eur Spine J*. 2006;15(2):183–195. doi:10.1007/s00586-005-1022-3

33. Goyal A, Elminawy M, Kerezoudis P, et al. Impact of obesity on outcomes following lumbar spine surgery: a systematic review and meta-analysis. *Clin Neurol Neurosurg*. 2019;177:27–36. doi:10.1016/j.clineuro.2018.12.012

34. Wang JC, Arnold PM, Hermsmeyer JT, Norvell DC. Do lumbar motion preserving devices reduce the risk of adjacent segment pathology compared with fusion surgery? A systematic review. *Spine (Phila Pa 1976)*. 2012;37(22 Suppl):S133–S143. doi:10.1097/BRS.0b013e31826cadf2

Funding: The authors received no financial support for the research, authorship, and/or publication of this article.

Declaration of Conflicting Interests: The authors report no conflicts of interest in this work.

Corresponding Author: Jack Carlson, Western Sydney University School of Medicine, 30, Narellan Rd & Gilchrist Dr, Campbelltown, NSW 2560, Australia; jack@dcarlson.com.au

Published 09 September 2022

This manuscript is generously published free of charge by ISASS, the International Society for the Advancement of Spine Surgery. Copyright © 2022 ISASS. To see more or order reprints or permissions, see http://ijssurgery.com.

Downloaded from https://www.ijssurgery.com/ by guest on October 11, 2024