Comparison of Cranial Facet Joint Violation Rate Between Percutaneous and Open Pedicle Screw Placement

A Systematic Review and Meta-Analysis

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Abstract: Percutaneous and open pedicle screw placements have been widely used in lumbar fusion surgery. However, there are conflicting reports of cranial facet joint violation rate for the 2 techniques.

To better determine the rate of cranial facet joint violation, a systematic review and meta-analysis was performed in the present study.

We searched the established electronic literature databases including MEDLINE, EMBASE, World of Science, and the Cochrane Central Register of Controlled Trials databases for trials involving the 2 pedicle screw placement techniques. Odds ratio (OR) and 95% confidence interval (CI) were calculated.

Four comparative trials with a cumulative sample size of 881 patients and 1755 cranial pedicle screws were identified and analyzed. The results showed that cranial facet joint violation rate was 18.18% (154/847) in percutaneous group and 18.72% (170/908) in open group. The pooled data revealed that there was no significant difference in the violation rate (OR 0.75, 95% CI 0.24–2.30, P = 0.62). In addition, there was also no significant difference for the rate of severe violation between the 2 techniques (OR 1.20, 95% CI 0.55–2.62, P = 0.64, random effect model).

Based on the current data, the meta-analysis shows that similar cranial facet joint violation rate occurs during the percutaneous and open pedicle screw placement techniques. In addition, taking the limitations of this study into consideration, it was still not appropriate to draw such a strong conclusion. More well-designed prospective randomized controlled trials are needed to assess violation rate for the 2 techniques in the future.

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Abbreviations: CI = confidence interval, OPS = open pedicle screw, OR = odds ratio.

INTRODUCTION

Since first introduced by Boucher,1 the pedicle screw system has been widely used in the instrumentation of the lumbar spine.2,3 The open pedicle screw (OPS) insertion has proved to be a safe and standard means for lumbar fusion surgery. With the emergence of minimally invasive techniques, the use of percutaneous pedicle screws has become increasingly popular.4–6 Compared with the conventional open technique, the percutaneous pedicle screw placement could avoid extensive detachment of muscle, leading to reduced blood loss, less postoperative pain, faster recovery, and rehabilitation.7,8 Cranial facet joint violation of lumbar surgery has been an underappreciated consequence of pedicle screw placement. Injury to the cranial facet joint has been regarded as a cause of adjacent segment degeneration.9,10 Violation of facet joint could cause postoperative pain due to the impingement and instability. A better understanding of cranial facet joint violation could elucidate the prevalence of junction syndrome and facet joint arthropathy following the lumbar fusion surgery.

Previous studies reported that the rates of cranial facet joint violation ranged from 7% to 58% with percutaneous pedicle screw placement technique11–13 and from 15% to 100% using open technique.14–16 However, it is still not clear whether percutaneous technique is accompanied with higher cranial facet joint violation rate in lumbar surgery. Thus, we compared the rate of facet joint violation for the 2 techniques in this review and meta-analysis.

MATERIALS AND METHODS

The reporting of the present review adhered to the preferred reporting items for systematic reviews and meta-analyses statements.17 Ethical approval was not necessary for this meta-analysis as the results for publication only involved identified pooled data from individual studies that have received ethics approval.

Literature Search

A literature research was identified by searching MEDLINE, EMBASE, World of Science, and the Cochrane Central Register of Controlled Trials databases. Retrieval time was from the time when databases were built through June 2014. The key words and text words used in the search included percutaneous, open, pedicle screw, minimally invasive, cranial facet joint, superior facet joint, facet joint violation, and facet impingement. To identify other relevant studies, we manually scanned reference lists from identified trials and reviewed articles. Two investigators independently reviewed all subjects, abstracts, and full texts of articles that were potentially eligible based on abstract review. The eligible trials were then selected according to the study eligibility criteria.

Study Eligibility Criteria

We systematically reviewed published studies according to the following criteria: original clinical comparative studies, the
studies compared the rate of cranial facet joint violation between percutaneous and OPS placement techniques in lumbar surgery, the studies reported the detailed amount of cases suffering from the cranial facet violation, and computed tomography (CT) was used to assess facet joint violation. All selected studies were independently reviewed by 2 investigators for inclusion into the final analysis. Any inconsistencies were resolved through discussion until a consensus was reached.

Data Extraction
Data were extracted by 2 independent reviewers. The outcome of interest was rate of cranial facet joint violation for 2 different pedicle screw insertion techniques. The following data were also extracted: year of publication, study type, number of patients, and patient characteristics. Any disagreement between the reviewers was resolved by discussion.

Assessment of Methodological Quality
The Newcastle–Ottawa Quality Assessment Scale was used to assess nonrandomized observational studies. This scoring system evaluated studies on the basis of the selection of patients in the case and control groups, the comparability of the 2 groups, and the outcomes of the single studies. On the basis of these criteria, studies are scored between 0 and 9 stars. Six stars or greater was considered to be sufficiently high quality.

Statistical Analysis
The rate of cranial facet joint violation, as the dichotomous data, was analyzed using odds ratio (OR) measure and 95% confidence interval (CI). Moreover, heterogeneity across trials were evaluated with $I^2$ statistic, and was defined if $I^2$ was >50%. If heterogeneity existed, a random-effect model was used to assess the overall estimate. Otherwise, a fixed-effect model was chosen. All tests were 2-tailed and $P < 0.05$ was considered significantly different. Then, the meta-analyses were performed on the extracted data with the Review Manager (Version 5.1. Copenhagen: The Nordic Cochrane Centre, Cochrane Collaboration, 2011).

RESULTS

Selected Studies and Characteristics
The details of literature search and selection are displayed in Figure 1. After detailed evaluation, 4 independent retrospective trials with a cumulative sample size of 881 patients and 1755 cranial pedicle screws were included in the overall meta-analysis. For the quality assessment of the 4 studies, the Newcastle–Ottawa Quality Assessment Scale grades were 6 to 8 stars, which were regarded as high quality of the studies. The detailed characteristics of these studies are shown in Table 1.
Meta-Analysis Results

All the 4 articles21–24 presented the number of pedicle screws suffering from facet joint violation. There are 847 pedicle screws in percutaneous insertion group and 908 in open technique group. The rate of cranial facet joint violation was 18.18% (154/847) in percutaneous group and 18.72% (170/908) in open group. The pooled data revealed that there was no significant difference in the complication rate (OR 0.75, 95% CI 0.24–2.30, \(P = 0.62\), random effect model) with the heterogeneity of \(I^2 = 89\%\), \(P < 0.01\) (Figure 2).

Because of the obvious heterogeneity among the 4 trials, the sensitivity analysis was added. Statistical heterogeneity is reduced if the trial by Yson et al22 is removed. The pedicle screws were inserted using intraoperative Three-Dimensional (3-D) CT computer navigation in the study by Yson et al22 comparing with fluoroscopic guidance in other 3 studies. Removal of this trial reduced the heterogeneity and still results in no significant difference for facet joint violation rate between the 2 techniques (Figure 3).

Among the 4 trials, 221,22 presented different grading criteria to evaluate the degree of facet joint violation. All the 4 trials adopted the CT scans to analyze the violations. Because the severe facet joint violation may cause severe adverse effects after surgery, we made additional analysis of severe degree of facet joint violation. In this study, the severe violation was defined as intra-articular facet joint violation, which refers to the screw crossing or traveling within the articular surface of the facet. Yson et al22 reported 0 pedicle screw with severe violation in percutaneous group and 10 in open group. Babu et al21 reported 41 in percutaneous group and 23 in open group. The cases included in another 2 study21,22 are intra-articular only. The pooled data indicated that the rate of severe violation was 7.91% (67/847) in percutaneous group and 5.73% (52/908) in open group. However, there was no significant difference between the 2 techniques (OR 1.20, 95% CI 0.55–2.62, \(P = 0.64\), random effect model) (Figure 4).

### DISCUSSION

Facet joint violation during pedicle screw placement has long been a concern, which is regarded as a risk factor for adjacent segment degeneration following the lumbar fusion. Percutaneous pedicle screw placement may accompany more frequent cranial facet joint violations because of the potential limitation of screw entry site selection. There are conflicting data for the facet joint violation related to both percutaneous and OPS insertion.

To our knowledge, this study is the first quantitative comparative meta-analysis comparing the rate of cranial facet violation in percutaneous and OPS placement in lumbar surgery. Four comparative trials in the literatures were included in our systematic review. In order to assess the facet joint violation rate in 2 different pedicle screw insertion techniques, we extracted relative data as much as possible and pooled the outcome whenever possible. The reported facet violation rates caused by pedicle screw insertion have been highly variable in the literatures with either percutaneous or open techniques. Yson et al22 reviewed the literatures and concluded that the weighted mean rated was 27% for percutaneous technique and 23% for open group. Knox et al11 reviewed the postoperative CT scans of 61 patients who

| Studies          | Date of Operations | Groups                  | Number of Patients | Age, y | Sex (M/F) | Number of Facet Violation/Cranial Pedicle Screws | NOS Score |
|------------------|--------------------|-------------------------|-------------------|--------|-----------|-----------------------------------------------|----------|
| Babu et al21     | Jan 2007 to Nov 2011 | Percutaneous            | 153               | 61.1 ± 1.1 | 70/83 | 123/306                                      | ******   |
|                  |                    | Open                    | 126               | 60.1 ± 1.1 | 63/63 | 86/252                                       | ******   |
| Yson et al22     | Nov 2006 to Dec 2011 | Percutaneous            | 64                | 57.5 (12–87) | 76/112 | 5/125                                        | ******   |
|                  |                    | Open                    | 124               | 64                | 65/245 | 5/125                                        | ******   |
| Lau et al23      | 2006–2011          | Percutaneous            | 142               | 53.0 ± 14.8      | 55/87 | 9/284                                        | ******   |
|                  |                    | Open                    | 140               | 53.3 ± 13.3      | 62/78 | 12/280                                       | ******   |
| Jones-Quaidoo et al24 | Not mentioned   | Percutaneous            | 66                | 42.5 ± 11.6      | 29/37 | 17/132                                       | ******   |
|                  |                    | Open                    | 66                | 57.8 ± 11.6      | 24/42 | 7/131                                        |          |

NOS = Newcastle–Ottawa Scale.

![FIGURE 2](image) Forest plot: OR in cranial facet joint violation rate and 95% CI for percutaneous versus OPS placement. No significant difference was found for the violation rate between the 2 methods. "Favors OPS" means the violation rate is lower in OPS fixation group. "Favors PPS" means the violation rate is lower in PPS fixation group. CI = confidence interval, OPS = open pedicle screw, OR = odds ratio, PPS = percutaneous pedicle screw.
underwent minimally invasive transforminal lumbar interbody fusion and found that the cranial facet joint violation was 6.6% (8/122). Park et al13 and Patel et al12 reported that the rates of the cranial facet joint violation were 31.5% (58/184) and 58% (28/48), respectively, by percutaneously placed pedicle screws in lumbar spine surgery. As for the open insertion technique, different violation rates were reported. Shah et al14 reported that the facet joint violation occurred in 20% of the screws in OPS insertion. Moshirfar et al15 retrospectively reviewed 204 patients with OPS insertion and revealed that the facet violation rate was 15%. Chen et al16 revealed a 100% incidence of facet violation using the Roy–Camille method whereas 36% with the Weinstein method.

In the present study, we pooled the data from 4 comparative trials consisting of 881 patients and 1755 cranial pedicle screws. The meta-analysis indicated that although the rate of cranial facet joint violation in open technique group is higher than percutaneous group (18.72% vs 18.18%), there is no significant difference. Because of high heterogeneity among the 4 studies, a sensitivity analysis was performed by removing a study, which did not affect the pooled results.

Among the facet joint violations, severe violation refers to the screw’s travels within the facet joint articular surface, which damages the facet complex. It could lead to the severe adverse effect of biomechanical forces and accelerate adjacent segment disease. So, additional analysis of severe violation was also performed. The analysis indicated that although the rate of severe violation was higher in percutaneous techniques than open group (7.91% vs 5.73%), there was no significant statistical difference.

In a biomechanical cadaveric study, Cardoso et al25 reported that the range of motion in supra-adjacent segment increased after bilateral facet breach. In a finite element analysis, Kim et al26 showed that facet joint violation model caused by pedicle screws yield great increases in facet contact force and intradiscal pressure. These biomechanical analyses showed that facet joint violation might be a significant risk factor for the development of adjacent segment degeneration after spinal fusion with pedicle screw fixation.

The violation rates for different lumbar level were also analyzed in some studies. In the research by Park et al,13 the facet joint violation related to percutaneous pedicle screw placement occurred approximately 3.3 times more frequently at L5-S1 level than at the other-level fusions. Moshirfar et al15 found that 48% of the cranial facet joint violation occurred at the level of L5 during the OPS fixation. Yson et al22 revealed that there is a trend of an increasing likelihood of facet joint violation form L1 to L5. This may be due to the facet orientation and presence of iliac crests at the more caudal levels of lumbar spine. The facet joint rotates progressively into a more coronal orientation from L1 to L5.27 These anatomical characteristics interrupt the selection of ideal entry point and sufficient insertion trajectory of pedicle screws for both percutaneous and open techniques.

There are several literatures referring the risk factors for facet joint violation. Both the studies by Babu et al21 and Lau et al23 reminded that obesity is an independent risk factor for increased facet joint violation. For obese patients, it is often difficult to obtain the correct entry point and trajectory for pedicle screw insertion. In addition, Babu et al21 also indicated that age <65 and depth of the spine were identified as independent risk factors for severe facet violation. The study by Shah et al14 showed that the incidence of the cranial facet joint violation was independent of the side, sex, diagnosis, level of screw insertion, and whether it was a primary or revision case. Some limitations exist in this meta-analysis. First, I prominent drawback is that only 4 retrospective comparative studies were included in this meta-analysis. The results of pooled analysis might therefore be accompanied by bias. Second, the included studies had obvious heterogeneity, which lowered the quality of evidence for the outcome. Further studies on facet joint violation related to pedicle screw placement are

FIGURE 3. Forest plot: OR in cranial facet joint violation rate and 95% CI for percutaneous versus OPS placement in sensitivity analysis. No significant difference was found for the violation rate between the 2 methods. "Favors OPS" means the violation rate is lower in OPS fixation group. "Favors PPS" means the violation rate is lower in PPS fixation group. CI = confidence interval, OPS = open pedicle screw, OR = odds ratio, PPS = percutaneous pedicle screw.

FIGURE 4. Forest plot: OR in severe violation rate and 95% CI for percutaneous versus OPS placement. No significant difference was found for the violation rate between the 2 methods. "Favors OPS" means the violation rate is lower in OPS fixation group. "Favors PPS" means the violation rate is lower in PPS fixation group. CI = confidence interval, OPS = open pedicle screw, OR = odds ratio, PPS = percutaneous pedicle screw.
needed in order to better understand and reduce the adjacent segment disease after lumbar fusion.

CONCLUSIONS

In conclusion, our meta-analysis indicates that percutaneous and OPS placements accompany similar cranial facet joint violation rates. In addition, taking the limitations in this study into consideration, it is still not appropriate to make a strong conclusion related to the 2 techniques. More well-designed prospective randomized controlled trials are needed to assess the violation rate for the 2 techniques in the future.

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