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Accuracy of Screw Placement in Lumbar Transpedicular Fixation: A Comparative Study between Open and Percutaneous Techniques Using a Novel Classification Model

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Abstract

Background Data: In the late fifties of the last century, Boucher described posterior pedicle screw placement for the first time for treatment of a diversity of spinal pathologies. Currently, there are three methods for pedicle screw placement: the free hand, the fluoroscopy guided open and the percutaneous techniques. Despite being reported safe and accurate, percutaneous pedicle screw insertion is still being investigated in comparison to the traditional open technique.

Purpose: In this study, the authors are trying to find out if there was any superiority of one technique regarding accuracy of screw placement.

Study Design: This is a retrospective comparative study designed to assess the accuracy of screw placement in the sagittal plane in patients who underwent lumbar transpedicular fixation by open versus percutaneous techniques.

Patients and Methods: Patients were categorized into two groups: group A including patients who underwent open surgery and group B patients who underwent percutaneous fixation. Each screw was categorized according to the sagittal plane into one of the following classes: Class 0: with no cortical penetration at all, Class 1: with a single cortical penetration denoting accepted entry point and trajectory, Class 2: with 2 cortices penetration violating the lateral cortex of the pedicle and/or the vertebral body and Class 3: with 3 cortices penetration and a medially maldirected trajectory violating the roof and floor of the lateral recess.

Results: The current study included 51 patients distributed as 28 patients (55 %) in group A and 23 patients (45 %) in group B. A total of 262 screws were investigated with 134 (51.15 %) screws in group A and 128 (48.85 %) screws in group B. Cross tabulation of raw data of different screw type distribution among the two patients' groups preliminarily revealed a quite favorable screws position among group A patients with 94.77% of screws in class 1, 4.48% in class 2 and 0.75% of screws in class 3 compared to 81.25%, 12.5% and 6.25% respectively in group B of patients. However, statistical analysis using Chi Square test for individual screws' groups related to specific pedicles failed to show any significant difference with each one of the pertinent P-values>0.05. On the other hand, comparison of maldirected screws (classes 2 and 3 collectively) between the two groups confirmed a statistically high significant difference in the

number of maldirected screws per patient with a mean of 0.25 screw/patient in group A compared to 1.043 screw/patient in group B (P-value < 0.001).

Conclusion: Percutaneous pedicle screw insertion technique is an accepted technique regarding screw accuracy when properly indicated having the advantages of being less traumatic and more cosmetic with its inherent complications and drawbacks including financial issues, more radiation exposure and longer operative time. (2017ESJ144)

Keywords: Percutaneous pedicle screw, open pedicle screw fixation, pedicle screw accuracy, lumbar spine

Introduction

In the late fifties of the last century, Boucher[1] described posterior pedicle screw placement for the first time. Ever since, this technique was used for treatment of a diversity of spinal pathologies including degenerative, traumatic and neoplastic diseases in addition to deformities.[2,7,9,12] With improvements in understanding biomechanics and metallurgical properties, this technique of pedicle screw assisted spinal fusion has become the most commonly used tool for spinal internal fixation. This technique uses each of the three columns of the spine to minimize motion at the involved segment to promote fusion and aid in early ambulation.[3,4,10,16]

An accurate screw placement has been always the main surgical challenge. Screw misplacement carries the risk of having an inadequate construct, unintended durotomy and, moreover, an incidence of inadvertent neurological injury of 1%-11%.[5,12,15]

Currently, there are three methods for pedicle screw placement: the free hand, the fluoroscopy guided open and the percutaneous techniques with the fluoroscopy guided open technique being the most frequently used one.[3,7,16] The traditional open technique has been always believed to have the disadvantage of extensive paraspinal muscles dissection and retraction for exposure of the necessary bony landmarks that may be a direct cause of more blood loss and a prolonged postoperative hospital stay and recovery time especially from pain.[3,4,5]

Having the advantage of avoiding the forementioned drawbacks of the open techniques, the percutaneous pedicle screw insertion using fluoroscopic guidance has been introduced in 1977 by Magerl[8] as a minimally invasive alternative that is frequently sought out by patients and their families.[4] Today, the percutaneous technique is gaining more popularity for treatment of an expanding variety of spinal pathologies.[6,13,15] However, the lack of direct visualization of bony landmarks and tactile feedback may be considered a challenge for accurate screw placement that can be, in part, overcome by the inevitable increased use of image guidance with its inherent risk of higher radiation exposure.[5]

Despite being reported safe and accurate, percutaneous pedicle screw insertion is still being investigated in comparison to the traditional open technique.[6] In this study, the authors are trying to find out if there is any superiority of one technique regarding accuracy of screw placement.

Patients and Methods

This is a retrospective comparative study designed to assess the accuracy of screw placement in the sagittal plane in patients who underwent lumbar transpedicular fixation by open versus percutaneous techniques. Patients from both genders were enrolled in the study and there was no age restriction. The studied cases were operated upon and followed at the Ain Shams university hospitals, Cairo, Egypt, in the period between July 2012 and January 2017. Patients with traumatic and degenerative pathologies were included in the study. On the other hand, patient with a radiologically evident hardware failure and patients complicated with deep post-operative infection were excluded from the studied population. Images of post-operative CT scans with thin cuts for the lumbar spine were collected for all patients.

Patients were categorized into two groups: *group A* including patients who underwent open surgery and *group B* patients who underwent percutaneous fixation group. To assess the accuracy of screw placement, all CT images were reviewed by an independent observer blindly without being informed about the technique used for the examined image. Furthermore, each screw is categorized according to the sagittal plane into one of the following classes (Figure 1): Class 0: with no cortical penetration at all and a completely laterally

malpositioned extra osseous screw trajectory. Class 1: with a single cortical penetration denoting accepted entry point and trajectory. However, a bicortical properly directed screw with no more than 5 mm anterior penetration was still considered class 1. Class 2: with 2 cortices penetration denoting an accepted entry point with a laterally maldirected trajectory violating the lateral cortex of the pedicle and/or the vertebral body. Class 3: with 3 cortices penetration denoting an accepted or medially located entry point with a medially maldirected trajectory violating the roof and floor of the lateral recess. Additionally, a craniocaudal maldirection with violation of the intervertebral foramen above or below was considered in this category. Class N: where the precise screw position could not be identified.

The authors adopted such novel categorization system as it simply but accurately classifies different screw entry points and trajectories according to the sagittal (mediolateral) plane. Characteristics of investigated screws regarding side, vertebral level and screw class were documented. Additionally, statistical comparative results using Chi Square test between similar pedicles regarding screws classes were also incorporated as pertinent P-values. For statistical purposes, screws in classes 2 and 3 were grouped together as maldirected screws and compared (using independent t-test) with class 1 screws which were considered acceptable screws. Moreover, a comparison between preoperative and postoperative values of visual Analogue Score for radicular pain in each patient group was performed using paired t-test.

Results

The current study included 51 patients distributed as 28 patients (55%) in group A and 23 patients (45%) in group B. Patient´s demographics are demonstrated in table 1.

An intervertebral cage was used in 4 (14.4%) of patients in group A and in 2 (8.7%) of patients in group B. The main indication for surgery was degenerative pathologies accounting for 38 (74.5%) cases with details outlined in figure 2.

A total of 262 screws were investigated with 134 (51.15%) screws in group A and 128 (48.85%) screws in group B. Distribution of different screw classes among each group with their relative weights are illustrated in table 2.

Characteristics of investigated screws regarding side, vertebral level and screw class are detailed in table 3. The largest number of screws was applied to L 4 and L 5 levels (84 and 82 screws respectively) followed by S 1 and L 3 levels (36 and 34 screws respectively). Cross tabulation of raw data of different screw type distribution among the two patients' groups preliminarily revealed a quite favorable screws position among group A patients with 94.77% of screws in class 1, 4.48% in class 2 and 0.75% of screws in class 3 compared to 81.25%, 12.5% and 6.25% respectively in group B of patients. However, statistical analysis using Chi Square test for individual screws' groups related to specific pedicles failed to show any significant difference (Table 3) with each one of the pertinent $P>0.05$.

There was no deterioration in motor function in any of the included patients from both groups, pain improvement was evident and statistically significant in both groups when comparing preoperative and postoperative values of Visual Analogue Score with $P<0.001$ in both groups. On comparing preoperative and postoperative values of Visual Analogue Score for radicular pain in each patient group using paired t-test, the mean post-operative VAS for group A was 0.643 versus 2.957 for group B; however, a statistically significant difference could not be found (Table 4).

As outlined in table 5, comparison of the total number of class 1 screws (acceptable screws) in each patient between both patients' groups using the independent t-test failed to show a statistically significant difference (means; 4.536 for group A and 4.522 for group B with $P=0.964$) while comparison of maldirected screws (classes 2 and 3 collectively) between the two groups confirmed a statistically high significant difference in the number of maldirected screws per patient with a mean of 0.25 screw/patient in group A compared to 1.043 screw/patient in group B ($P<0.001$).

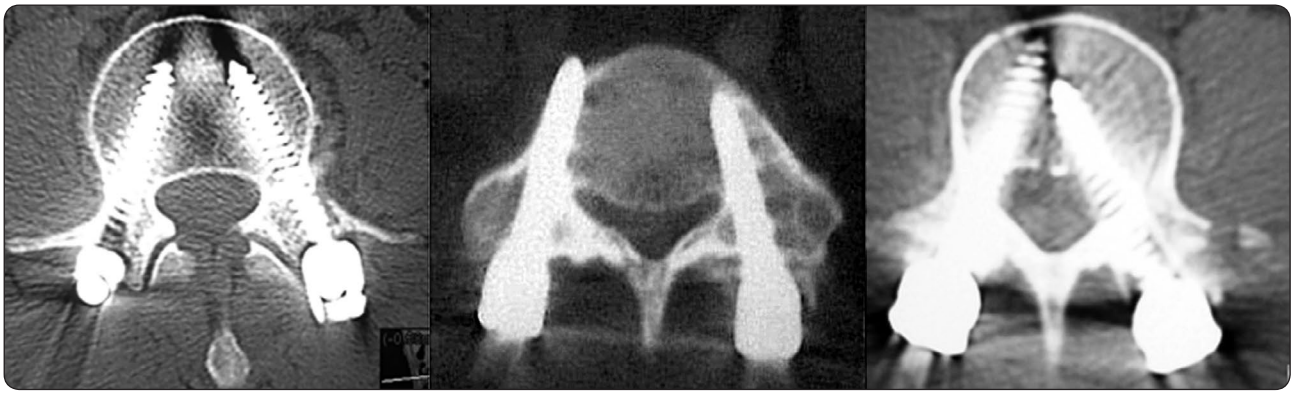

Figure 1. Axial cuts of bone window CT scan for different classes of screws showing: class 1 third lumbar pedicles screws bilaterally (left), a class 2 right fifth lumbar pedicle screw (middle) and a class 3 left third lumbar pedicle screw (right).

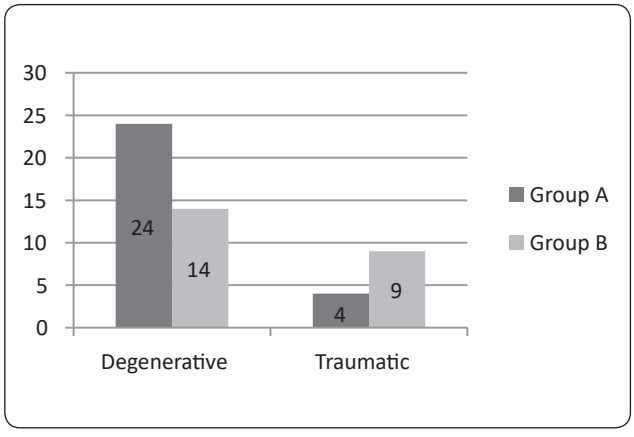

Figure 2. A chart showing the main indication for surgery in the included cases.

Table 1. Patient´s Demographic Data

	Male	Female	Age distribution
Group A	20 (71.4 %)	8 (28.6 %)	43.14 (16 – 61) years
Group B	10 (43.5%)	13 (56.5%)	50.17 (21 – 71) years

Table 2. Distribution of Different Screw Classes among each Group

	Class 1	Class 2	Class 3	Total
Group A	127 (94.77%)	6 (4.48%)	1 (0.75%)	134
Group B	104 (81.25%)	16 (12.5%)	8 (6.25%)	128

Table 3. Comparative Results Using Chi Square Test between Similar Pedicles Regarding Screws Classes and Pertinent P Values

			Class 1	Class 2	Class 3	P value	Total
Lumbar 1	Right	Group A	2	0	0	Na	10
		Group B	3	0	0		
	Left	Group A	2	0	0	Na	
		Group B	3	0	0		
Lumbar 2	Right	Group A	3	0	0	0.408	16
		Group B	4	0	1		
	Left	Group A	2	0	1	0.168	
		Group B	5	0	0		
Lumbar 3	Right	Group A	6	0	0	0.370	34
		Group B	8	1	2		
	Left	Group A	6	0	0	0.539	
		Group B	9	1	1		
Lumbar 4	Right	Group A	25	1	0	0.110	84
		Group B	13	3	0		
	Left	Group A	26	0	0	0.197	
		Group B	15	0	1		
Lumbar 5	Right	Group A	20	4	0	0.478	82
		Group B	13	3	1		
	Left	Group A	23	1	0	0.357	
		Group B	15	2	0		
Sacral 1	Right	Group A	6	0	0	0.063	36
		Group B	7	5	0		
	Left	Group A	6	0	0	0.407	
		Group B	9	1	2		

Table 4. Comparison between Pre and Postoperative Root Pain VAS in both Groups Using Paired t-test

		Min	Max	Mean±SD	CI 95%	P value
Group A	PreOp root pain VAS	0.0	10.0	7.143±3.076	6.004 - 8.282	< 0.001
	PostO root pain VAS	0.0	2.0	0.643±0.731	0.372 - 0.914	
Group B	PreOp root pain VAS	0.0	9.0	6.13±2.897	4.947 - 7.314	< 0.001
	PostO root pain VAS	0.0	6.0	2.957±1.846	2.202 - 3.711	

Table 5. Comparison between Acceptable and Maldirected Screws in both Groups Using Independent t-test.

		N	Screw per patient (Mean±SD)	CI 95%	P value
Acceptable	Group A	28.0	4.536±1.138	4.114 - 4.957	0.964
	Group B	23.0	4.522±1.039	4.097 - 4.946	
Maldirected	Group A	28.0	0.25±0.441	0.087 - 0.413	< 0.001
	Group B	23.0	1.043±0.976	0.645 - 1.442	

Discussion

As long as there is no solid definition for the so-called safe zone, accuracy in pedicle screw placement should refer to screws that are totally contained within the vertebral pedicle and body with no cortical violation other than the screw entry point.[12] In the current study, the authors tried hardly to find a statistically significant difference between open and percutaneous techniques for pedicle screw placement in the lumbar spine regarding the radiological accuracy of the screws and its impact on the nearby nerve roots that may be affected by a maldirected screw. Screws in the first sacral level were added to the studied ones as this level is commonly incorporated into a lumbar construct.

Regarding the statistically insignificant difference in raw data of different screw classes distribution among the two patients' groups, results of the current study were supported by those reported by Ikeuchi et al,[6] who found no statistically significant difference regarding pedicle wall penetration rate between open and percutaneous groups. This phenomenon can be explained by the fact that the vast majority of screws in both groups were class 1 with minor portions distributed between classes 2 and 3. This hypothesis can be supported by the results of the comparison of the total number of class 1 screws (acceptable screws) in each patient between both patients' groups that also failed to show a statistically significant difference presumably due to the forementioned reason. On the other hand, comparison of maldirected screws (classes 2 and 3 collectively) between the two groups confirmed a statistically high significant difference in the number of maldirected screws per patient (P<0.001). Idler et al,[10] Mark et al,[15] and Tsuang et al,[14] reported better results regarding the number of cortical breaches complicating percutaneous lumbar screws placements with an overall accuracy of 98.47%, 97.7% and 94.1% respectively while Spitz et al,[13] reported an overall accuracy of 96.7%. On the other hand, Mohi Eldin et al,[11] reported an accuracy rate that was comparable to that reported in the current study (79.4% versus 81.25 % respectively) regarding the percutaneous group. Regarding open technique, Mohanty et al,[10] reported a pedicle breach rate of 8.76 % while Tianming et al,[16] reported a 25.3% breach rate.

As illustrated previously, a more profound improvement could be detected in group A (mean post-operative VAS for group A= 0.643 versus 2.957 for group B). This can be explained by the fact that group A contained less maldirected screws and that patients in group A were offered a more generous root decompression than patients in group B. In their series of 29 patients who underwent 1 or 2 level posterolateral instrumented fusion for symptomatic

spondylolistheses via the percutaneous technique, Eric et al,[4] reported a 3 months postoperative VAS of 2.9 which was nearly identical to the reported value in group B in the current study.

Conclusions

It can be concluded that the percutaneous pedicle screw insertion technique is an accepted technique regarding screw accuracy when properly indicated having the advantages of being less traumatic and more cosmetic with its inherent complications and drawbacks including financial issues, more radiation exposure and longer operative time. However, complications and drawbacks can be minimized by more practice and by taking the decision of the choice of the technique according to the operating surgeon's preference.

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الملخص العربي

دقة وضع البرغي في التثبيت القفنجية القطنية: دراسة مقارنة بين التقنيات المفتوحة والطبيعية باستخدام نموذج تصنيف جديد

البيانات الخلفية: في أواخر الخمسينات من القرن الماضي، وصف باوتشر موضع المسمار العنقي الخلفي لأول مرة لمعالجة مجموعة متنوعة من أمراض العمود الفقري. حاليا، هناك ثلاثة أساليب لوضع المسمار العنقي: اما باستخدام اليد الحرة او عن طريق الفتح و الاسترشاد الاشعة السينية او باستخدام التقنيات محدودة التدخل عن طريق الجلد. وعلى الرغم من اثبات ان كل الطرق تعتبر آمنة ودقيقة فانه لا يزال البحث مستمرا لمقارنة دقة المسمار العنقي عن طريق الجلد مع التقنية المفتوحة التقليدية.

الغرض: في هذه الدراسة، هي محاولة الباحثين لمعرفة ما إذا كان هناك أي تفوق لاحدى التقنيتين فيما يتعلق بدقة موضع المسمار.

تصميم الدراسة: دراسة مقارنة بأثر رجعي مصممة لتقييم مدى دقة وضع المسمار في المرضى الذين خضعوا لتثبيت الفقرات القطنية باستخدام المسمار العنقي القطني طريق الفتح و الاسترشاد بالاشعة السينية او باستخدام التقنيات محدودة التدخل عن طريق الجلد.

المرضي و الطرق: تم تصنيف المرضى إلى مجموعتين: مجموعة A للمرضى الذين خضعوا للجراحة طريق الفتح و الاسترشاد الاشعة السينية المفتوح والمجموعة B للمرضى من مجموعة التثبيت عن طريق الجلد باستخدام التقنيات محدودة التدخل. تم تصنيف كل المسمار وفقا لاتجاهه الى واحد من الفئات التالية: الفئة 0: لا اختراق للقشرة العظمية على الإطلاق، الفئة 1: اختراق للقشرة العظمية فى نقطة واحدة تدل على نقطة دخول ومسار مقبولتين ، الفئة 2: اختراق للقشرة العظمية فى نقطتين تدل على اختراق للقشرة العظمية لعنق أو جسم الفقرة، الفئة 3: اختراق للقشرة العظمية فى ثلاثة نقاط تدل على انحراف مسار المسمار للداخل مع المرور فى القناه الشوكيه.

النتائج: شملت الدراسة الحالية 51 مريضا وزعت كالاتى 28 (55%) مريض في المجموعة A و 23 (45 %) مريض في المجموعة B. بمقارنة المسامير غير المثالية بين الفريقين تأكد وجود فرقا كبيرا ذو قيمة إحصائيا مرتفعة بمتوسط 0.25 مسمار لكل مريض في المجموعة A بالمقارنة بمتوسط 1.043 مسمار لكل مريض في المجموعة B.

الاستناج: ان اسلوب وضع المسمار العنقي عن طريق الجلد باستخدام التقنيات محدودة التدخل للفقرات القطنية أسلوب مقبول فيما يتعلق بدقة المسمار.