COMPARATIVE ANALYSIS OF THE EFFECTIVENESS OF THE COMBINED METHOD OF INSERTING PEDICLE SCREWS WITH THE FREE-HAND TECHNIQUE IN PATIENTS WITH IDIOPATHIC SCOLIOSIS

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Objective. To analyze intraoperative data and results of treatment of patients with idiopathic scoliosis with two options of the open insertion of pedicle screws using the free-hand technique.

Material and Methods. The data of 457 patients aged 16–35 years who underwent surgical treatment for idiopathic scoliosis by one surgeon were analyzed. In 236 patients (Group I), the screws were placed manually, and in 221 (Group II) – using power tool. The preparation of the canal for pedicle screws in both groups was performed using the free-hand technique. The correct position of the screws was assessed intraoperatively using an image intensifier and neurophysiological monitoring. The duration of surgery and X-ray monitoring, blood loss, and the presence of intra- and postoperative complications were assessed.

Results. In Group I, 4243 screws were inserted, and in Group II – 3978. The correct position of pedicle screws was recorded in 89.1 % of cases in Group I, and in 89.6 % of cases in Goup II. In Group I, the incorrect position of anchor elements was detected in 10.9 % of cases, and in Group II – in 10.4 % of cases. The number of screws re-positioned intraoperatively corresponded to the number of incorrectly positioned screws. There was a statistically significant difference in the volume of intraoperative blood loss and duration of surgery between patients of both groups ($p < 0.05$).

Conclusion. The development and active introduction of high-tech methods of surgical treatment of spinal deformities increase the number of interventions performed annually. The proposed combined method of surgical treatment seems to be optimal because manual formation of the canal reduces the risk of intraoperative complications, and the use of power tool during screw placement shortens duration of surgery and reduces blood loss.

Key Words: pedicle screws, idiopathic scoliosis, insertion technique.

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Scoliosis is a three-dimensional spine deformity, the causes of which may be different. One of the most common types is idiopathic scoliosis [1, 2]. In the United States, this pathology occurs in 1–3 % of the country's population and forms the largest group of spinal curvatures [3, 4]. In Russia, there is no exact information on the incidence, however, according to various sources [5, 6], it varies from 2 to 10 %, accounting for 50–80 % of all spinal deformities.

Spontaneous deformity onset and rapid progression often lead to a cosmetic defect (gibbous costalis), which, coupled with orthopedic problems, causes social alienation of such patients [7]. Early detection and conservative treatment are crucial for preventing disease progression. At the same time, 1–5 % of all patients suffering from idiopathic scoliosis require surgical treatment [8].

The introduction of the 3rd generation instrumentation by Cotrel et al. [9] enabled a significant breakthrough in treating idiopathic scoliosis. Many studies compared hook systems with screw ones [10–14], assessed the safety and risks of complications for patients [15–17]; notably, most researchers came to the conclusion that the method of choice is a screw-only arrangement [18–20].

Thus, at the moment, the gold standard of surgical treatment of idiopathic scoliosis is posterior correction with pedicle screws inserted by the free-hand technique [21], which allows screws to be inserted both in the thoracic and lumbar spine without constant X-ray monitoring. The technique has been actively developed and widely used around the world, while a number of studies [22–24] have shown that orthopedists are the leaders in its using for injuries of the musculoskeletal system, particularly, hand and the entire upper limb.

To facilitate and speed up the using of methodology developed by Lenke [21], Seehausen et al. [25] suggested in 2015 the use of power tools to form a transpedicular canal and install a screw, and also compared this technology with using hand tool technique. The

researchers concluded that the use of power tools reduces the surgery time, decreases the risk of screw revision, and also poses an equally low risk of patient injury. Further studies of the Seehausen technique were reflected in the papers that considered the advantages and disadvantages of this technique [26, 27].

The multicentric study presented by Skaggs et al. [28] in 2021 showed that formation of a transpedicular canal using hand and power tools gives similar results in terms of the number of intraoperative injuries and screw revisions. Despite this, many surgeons still doubt using power tools to form a canal in the vertebral pedicle and insert the screw due to the expected high risks of damaging neural structures and great vessels. To make this technique popular, we propose a combined method of forming a canal and inserting a pedicle screw.

The objective is to analyze intraoperative data and the results of treating patients with idiopathic scoliosis under two options for open insertion of pedicle screws using the free-hand technique.

Material and Methods

Design: retrospective single-center study.

Patients

A retrospective analysis of the data on 457 patients aged 16–30 years who underwent surgical treatment of idiopathic scoliosis from the posterior approach was carried out. All surgeries were performed by one surgeon. The inclusion criteria:

– idiopathic scoliosis of the thoracic, thoracolumbar and lumbar localization;

– no previous surgical interventions on the spine;

– no cancer diseases.

The patients were divided into 2 groups. The study group (Group I) consisted of 236 patients who underwent surgery in the period from January 1 to December 31, 2019 with only manual installation of pedicle screws. The control group (Group II) included 221 patients who underwent surgery in the period from January 1 to December 31, 2021; pedicle screws were inserted using power tool (a medical drill).

The average period of postoperative follow-up in Group I was 27.5 ± 7.1 months, in Group II – 8.2 ± 4.8 months.

Technique

The canal was prepared for insertion of pedicle screws in both groups using the free-hand technique. After the standard stages of surgical access to the posterior elements of the vertebrae, facetectomy throughout the area of preplanned instrumentation, and determination of the screw insertion point, the cortical plate was perforated with an awl in the area of the pedicle projection, and a foramen primum was formed with a filler, palpating the walls and the bottom (it is important that they are osteal over the whole circumference of the foramen), the length of the screw stroke was determined, the screw thread was cut with a tap, after which the screw was inserted either manually (with a screwdriver) or using power tool [29].

The correct position of the pedicle screws was assessed and confirmed intraoperatively using image intensifier and neurophysiological monitoring. In case of an unsatisfactory position of a screw, the procedure was redone.

The following factors indicated an incorrect screw position during an intraoperative X-ray study:

– a screw passing medially or laterally from the pedicle on an anterioposterior X-ray image;

– a screw does not cross the medial part of the pedicle on an anterioposterior X-ray image;

– a crew passes above or below the pedicle on a lateral X-ray image [29].

Neurophysiological monitoring was performed to prevent conduction and radicular neurological complications. The modalities of motor and somatosensory evoked potentials, spontaneous EMG, and pedicle screw test were used. Muscle responses were recorded using needle electrodes in a segmental arrangement, based on a surgery level. In the pedicle screw test, stimulation was performed by manual testing, with single stimuli for the lumbar level, and trains of 5 stimuli for the thoracic level. The stimulation intensity was 2–20 mA, the stimulus duration was 200 μs, a stimulation level of 8 mA was used as a safety criterion, no muscle response occurred. EMG-responses were assessed in the absence of muscle relaxation, under the control of neuromuscular block assessment. In our study 38 screws were reinserted following intraoperative monitoring.

Preoperative studies included MRI and CT of the entire spine, postural X-rays in two projections, and bending test. Case records were analyzed to determine the patient's age at the time of surgery, gender, body mass index, diagnosis, chronic diseases, as well as any postoperative complications. Procedure reports were analyzed to assess surgery duration and image intensifier control, the volume of blood loss, and any intraoperative complications associated with preparing a pedicle canal or screw placement.

Correct postoperative screw positioning was checked by X-ray control. Routine CT-study was not performed.

Postoperative complications were assessed using the Clavien-Dindo classification modified in 2022 for patients with idiopathic scoliosis [30].

Statistical analysis

Data for descriptive statistics are presented as M ± SD, where M is the mean trait value, SD is the standard deviation. The frequency characteristics of numerical criteria were compared by Fisher's exact test. The differences between the compared groups were considered statistically significant at $p < 0.05$. Statistical analysis was carried out using the Mann-Whitney U-test, the Pearson's chi-squared test using Microsoft Office Excel and Statistica 12.0.

Results

Case records and surgical protocols of 457 patients were analyzed. The compared groups are matched in terms of the main characteristics of patients, including comorbidities (Table 1).

The total number of pedicle screws in both groups was 8681. The groups did not have significant differences in characteristics related to the level of fixation (in both groups, most of the anchoring

elements were installed in the thoracic spine), the correct position of screws, and the frequency of their repositioning. There were no injuries of the dura mater due to canal formation or during screw insertion in both groups (Table 2).

At the same time, when assessing the volume of intraoperative blood loss and the surgery duration, a statistically significant difference was revealed between patients of both groups ($p < 0.05$); the time needed for image intensifier control in the groups turned out to be comparable (Table 3).

In Group I, postoperative grade I complications according to Clavien-Dindo were diagnosed in 92 (38.9 %) patients, and grade II – in 23 (9.7 %), which practically did not differ from Group II, where grade I complications were noted in 87 (39.4 %) patients, grade II – in 22 (9.6 %). None of the patients in both groups had complications of III, IV (a, b) and V grades. Grade I complications corresponded to $p = 0.684$; grade II – to $p = 0.573$.

Discussion

Idiopathic scoliosis is one of the most common diseases of the musculoskeletal system all over the world [1, 2], manifesting, as a rule, during a period of intensive growth in adolescence, more often in females, as noted in our study. Conservative methods of treatment that make it possible to timely diagnose and correct a deformity or postpone the surgery until the end of bone growth [31–33] are not always effective, and surgical treatment is often necessary.

For us, the key factor in choosing a treatment method is a patient and a surgeon safety. In scoliosis correction, we, like most researchers, use neurophysiological monitoring [34–36] in addition to image intensifier control to prevent conduction and radicular neurological complications. This technique allows minimizing the risks of incorrect insertion of screws. A high level of reliability of intraoperative monitoring in the surgical treatment of idiopathic scoliosis has been repeatedly demonstrated earlier [37, 38].

It should be noted that the pedicle screws insertion using hand tools is associated with certain oscillatory motions. It may change a screw trajectory and disrupt the bone walls of an earlier formed canal. Cadaveric studies have shown that power tools reduce screw sway during insertion [39]. Our study also confirms the effectiveness of power tool for implanting anchoring elements.

Seehausen et al. [25] paid special attention to selecting the instrument power during canal formation. The authors pointed out that this is a key factor, which can lead to damaging vascular structures as well as other complications. In our study, this indicator could not be monitored due to the lack of auto-regulation of speed and power, and therefore the parameters of power tool were controlled by the surgeon.

The Clavien-Dindo classification of the grades of postoperative complications, first proposed in 1992, included four grades [40]. In 2004 it was expanded to seven grades by adding life-threatening conditions and long-term disability [41]. In 2022 a modification of this classification for patients with idiopathic scoliosis was proposed [30], which we employed in our work. The first experience of its use allows us to confirm a more objective assessment of all complications, particularly, identifying a number of minor complications, which are often not reflected in most studies. Implementing this classification into the work of the department will facilitate development of an adapted Russian-language version of the classification for subsequent implementation in wide clinical practice.

The study showed that using power tool to install pedicle screws does not increase the risk of complications: none of the patients required revision intervention during the entire follow-up period. At the same time, the volume of blood loss and the duration of the surgery with the use of power tool turned out to be less. Although other authors do not point at any statistically significant difference in these indicators [25, 28], believing that special care is required when preparing a transpedicular canal with power tool during its formation in the vertebral pedicle, increasing the surgery time and blood loss.

Conclusion

Continuous improvement of surgical techniques, development of the quality of the surgeons' knowledge and skills, introduction of new methods of treatment and diagnostics contribute to better surgical care. The proposed combined method of pedicle screw insertion with comparable risks of intraoperative complications can reduce surgery duration and blood loss.

To assess long-term results, further studies are needed including multicentric ones which will allow a more detailed analysis of the effectiveness and safety of power tool in the surgical treatment of patients with idiopathic scoliosis.

Table 1
Characteristics of patients of the studied groups

Indicator	Group I (n = 236)	Group II (n = 221)	p
Average age, years	19.5 ± 1.8	20.3 ± 1.4	0.961
Gender, n %			
Male	93 (39.4)	90 (40.7)	0.287
Female	143 (60.6)	131 (59.3)	
Body mass index, kg/m^2	20.9 ± 2.7	21.5 ± 2.3	0.385
Chronic diseases, n (%)			
Diabetes mellitus	3 (1.3)	2 (0.9)	0.752
Gastritis	8 (3.4)	7 (3.2)	0.845
First grade obesity	4 (1.7)	3 (1.4)	0.687
Hypotheriosis	3 (1.3)	4 (1.8)	0.697

Table 2
Comparative characteristics of installed screws in the studied groups

Indicator	Group I (n = 236)	Group II (n = 221)	p
Total number of screws, n	4243	3978	0.275
Screws in the thoracic spine, n (%)	2593 (61.6)	2649 (66.6)	0.301
Screws in the lumbar spine, n (%)	1650 (38.9)	1329 (33.4)	0.123
Correct screw position, n (%)	3778 (89.1)	3562 (89.6)	0.189
Incorrect screw position, n (%)	465 (10.9)	416 (10.4)	0.354
Screws re-positioned intraoperatively, n	465	416	0.265
Dura mater damage due to the formation of a canal or during screw insertion, n	0	0	–

Table 3
Comparison of the studied groups according to the surgery duration, image intensifier control and the level of blood loss

Indicator	Group I (n = 236)	Group II (n = 221)	p
Surgery duration, min	260.8 ± 77.5	242.1 ± 55.3	0.034
Duration of image intensifier control, min	5.3 ± 1.8	5.5 ± 1.6	0.512
Blood loss, ml	950.4 ± 173.2	876.4 ± 167.5	0.041

Particular interest may represent the effect of the pedicle screw insertion technique on damage to the hand and the entire upper limb of the surgeon beyond the scope of this study. It is not yet possible to evaluate this indicator, although the use of combined canal formation and the insertion of a pedicle screw may have a positive effect on these indicators.

Limitations on the study validity. The study is a single-center retrospective, with all surgical interventions performed by one surgeon with extensive (more than 10 years) experience in instrumental fixation of the spine, which eliminates the influence of the learning curve for installing pedicle screws.

The study had no sponsors. The authors declare that they have no conflict of interest.

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