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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.

GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.

ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ, რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

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Содержание:

EFFECTIVENESS IN INDIRECT DECOMPRESSION USING MINIMALLY INVASIVE SURGERY – TRANSFORAMINAL LUMBAR INTERBODY FUSION IN SINGLE-LEVEL LUMBOSACRAL SPONDYLOLISTHESIS

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Abstract.

Background: The lateral indirect decompression shows many advantages over the posterior approach for patients with low-grade spondylolisthesis or mild canal stenosis. While the minimally invasive surgery - transforaminal lumbar interbody fusion (MIS TLIF) was considered a favourable approach for most surgeons, it can also archive nerve release without exposure, especially with the use of intraoperative neuromonitoring which provides safer and fewer complications. **Materials and methods**: From 2022 to March 2024, 20 single-level lumbosacral spondylolisthesis was performed MIS TLIF technique, in which, the superior-articular process was removed only to enlarge the Kambin's triangle without exposure to nerve structure. Intraoperative neuromonitoring was followed in every single step during surgery. Patient information was recorded during pre-, intra-operation, and follow-up at 6- and 12-months post-operation; we also collected demographic data, operation time, blood loss, VAS, ODI, modified MacNab criteria, radiographic evaluation including x-ray and MRI pre-, post-operation, and complications. **Results**: 20 patients were followed up for more than 12 months. Mean age: 52,1 and mean follow-up 15,2 months. VAS back pain: 7,4 preoperatively and 0.8 at the final. VAS of leg pain was 7,1 preoperatively and 0,9 at the final. ODI was 52,4% preoperatively and 15,6% at the final. The mean operation time is 80,7 mins, blood loss is less than 100 ml. The average ambulation is 1,2 days, and the hospital stay is 4,7 days. MIS TLIF was associated with a very good reduction of spondylolisthesis, an increase in disc height (+6 mm), foraminal height (+3,1 mm), and segmental lordosis (+4,8°). The correction to normal of the listhesis was 85%. Pelvic parameters were not significantly changed. According to the modified MacNab criteria: 75% excellent, 20% good, and 5% fair. There was no complication was recorded.**Conclusions**: The indirect decompression using MIS TLIF seems to be a safe, effective, and favourable technique in management for patients with single-level lumbosacral spondylolisthesis.

Key words. MIS TLIF, indirect decompression, spondylolisthesis, intraoperative neuromonitoring, Visual Analogue Scale (VAS), Oswestry Disability Index (ODI).

Introduction.

Minimally invasive surgery (MIS) has progressed significantly in the past 2 decades [1]. Advances in image guidance and instrumentation technology have evolved to maximize patient-reported outcomes (PROs) and radiographic evaluation [2,3]. In the management of spondylolisthesis, MIS TLIF was considered a promising treatment with decreased blood loss, shorter lengths of stay, more rapid mobilization, lower opioid use, and earlier return to work, while maintaining comparable long-term clinical outcomes.

The indirect decompression used in MIS TLIF is a proposed modification to the standard MIS TLIF [4]. This approach points to the Kambin's triangle after partial removing the superior articular process, without exposure to the neural structures, the intervertebral cage was prepared followed by intraoperative neuromonitoring with less risk to both exiting and traversing nerve roots [5]. The achievement from indirect decompression via facetectomy, discectomy, and restoration of disc height and segmental realignment.

The objective of this study is to evaluate the clinical outcomes and radiographic results of indirect decompression in MIS-TLIF. We report (1) PRO (patient-reported outcomes) measures; (2) radiographic outcomes of sagittal segmental, regional lumbar, and pelvic parameters; the safety and complications.

Patients and Methods.

Patients' selection:

PRO measures: A prospectively maintained surgical database was retrospectively reviewed and followed to treat lumbosacral spondylolisthesis (grade I and II) with MIS TLIF from Jan 2022 to March 2024. We collected information on demographics, clinical characteristics, and operative details. PRO measures were assessed preoperatively and during routine postoperative clinic visits at postoperation, 6 months, and 12 months follow-up. We used the VAS (VAS/10) for back pain and leg pain; and ODI [1] (ODI/50) for physical disability.

Surgical technique: The operation was performed under general anesthesia, with the patient in the prone position. A neurological monitoring system was used to monitor somatosensory evoked potentials and free-running electromyography during the whole procedure. The tubular retractor position on the entry point on the skin was ~ 4 – 5 cm from the midline, heading to the lateral border of the superior articular process. Kambin's triangle was exposed by removing the superior articular process and the partial inferior articular process. A series of intervertebral space dilators was inserted into the disc space to create sufficient space for the implant. Curettes, reamers, and pituitary rongeurs were used to prepare the space for the endplate through the tubular retractor. Local bone and synthetic bone grafts were used with a cage for interbody fusion, then percutaneous pedicle screws through the same skin incision were placed followed by intraoperative neuromonitoring under fluoroscopic guidance. Rods placement, compression, and finally skin closure.

Radiographic measures.

Sagittal segmental parameters were taken on upright lateral radiographs of the lumbosacral spine. Serial radiographs were

obtained preoperatively, postoperatively, and during routine postoperative follow-up at 6 and 12 months. Sagittal segmental parameters were disc height (DH), foraminal height (FH), segmental lordosis (SL), and spondylolisthesis grade (Figure 1).

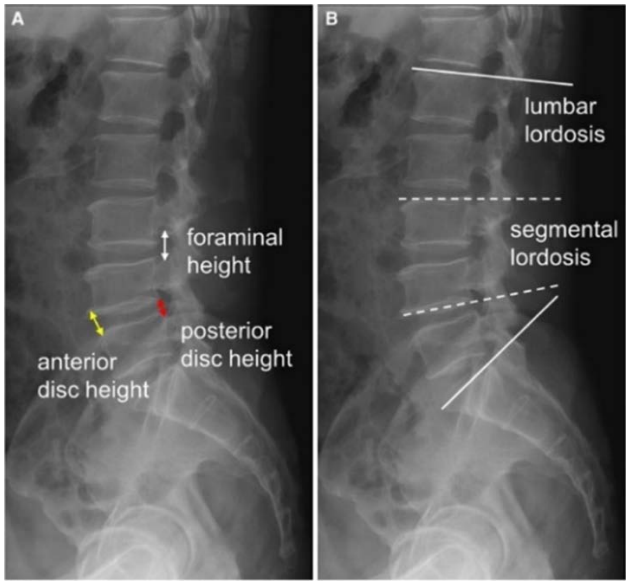

Figure 1. *Lumbo-sacral parameters on lateral x-ray.*

- DH was measured anteriorly, from the inferior endplate of the upper vertebra to the superior endplate of the lower vertebra.
- FH was measured as the interpedicular space.
- SL was measured as the lateral Cobb angle at the superior and inferior endplates of the spinal unit.
- The grade of listhesis was measured as the percentage offset (slip) of the vertebral body posterior wall relative to the adjacent lower body (Figure 2).

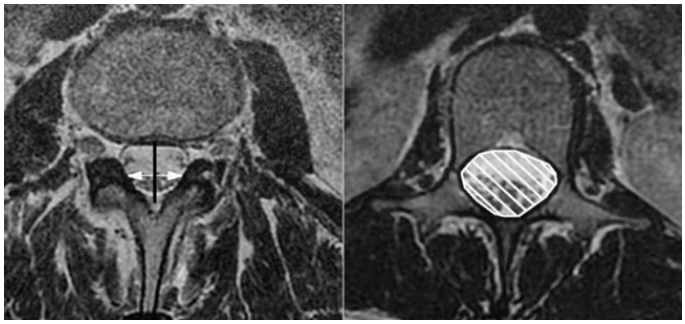

Figure 2. *Lumbar central spinal canal dimensions on MRI scans.*

Lumbar central spinal canal dimensions were made on preoperative and postoperative T2-weighted MRI scans. The anteroposterior and transverse dimensions of the dural sac were measured manually at a single axial slice through the center of the disc at the affected level(s). The anteroposterior length of the spinal canal was measured from the posterior edge of the intervertebral disk space to the most posterior point of the bony canal in the axial plane. The transverse length was measured as the distance between the inner surfaces of flaval ligaments on a line connecting the joint space of facet joints.

The cross-sectional area of the spinal canal was measured on preoperative and postoperative T2-weighted MRI scans at a single axial slice through the center of the disc at the affected levels.

Statistical analysis.

All statistical analyses were performed using SPSS 20.0 software (SPSS Inc., Chicago, IL, USA). Qualitative and continuous variables were described as percentages and medians (with interquartile ranges [IQRs]). Quantitative variables were compared using the T-test. P-values < 0.05 were considered significant.

- All participants provided written informed consent for their participation in the study.
- Patient consent was obtained for the study with due care to maintain his/her privacy.
- Our Institutional Review Board approved this study (Ref: 844 /GCN-HDDDNCYSH-DHYHN, dated April 20, 2023).

Results.

Baseline Characteristics: Demographics and Operative Details:

A total of 20 patients (65% male) underwent indirect decompression using MIS-TLIF at 20 levels. The mean age at surgery was 52,1 ± 9,2 years old (range 35-65). 12/20 (60%) procedures were performed at L5S1. The mean postoperative follow-up duration was 15.2 months. The average operation time was 80,7 mins, blood loss was 67,3ml and no transfusion was needed. Patients can be able to sit on the same day and can walk on the next day (Table 1).

Table 1. *Demographic and Operative Characteristics of MIS-TLIF Patients.*

Patient characteristics		**N = 20**
Level		20 levels
Age		52,1 ± 9,2
Sex (Male/Female)		13/7
Grade of spondylolisthesis	**I**	6 (30 %)
	II	14 (70 %)
Level	**L45**	8
	L5S1	12
Mean follow-up		15,2months
Operation time		80,7 ± 15 mins
Blood loss		67,3 ± 22,5 ml
Ambulation day		1,2 ± 0,5 days
Discharged		4,7 ± 0,7 days

Patient-Reported Outcomes:

Patients experienced significant improvements in self-reported measures of low back pain, leg pain, and disability. Mean VAS back pain decreased from 7,4/10 ± 0,8 to 3,3 ± 1 postoperatively and 0,8 ± 0,6 at 12 months. Mean VAS leg pain decreased from 7,1/10 ± 0,9 to 1,1 ± 0,7 postoperatively, and 0,9 ± 0,7 at 12 months.

Similarly, the mean cumulative ODI score improved from 52,4 ± 4,3 % at baseline to 29 ± 1,8 % postoperatively and 15,6 ± 1,4 at 12 months (Figure 3).

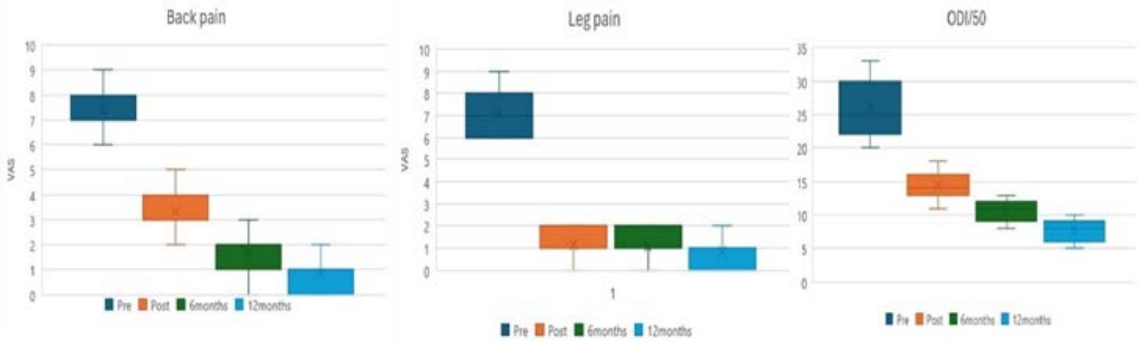

Figure 3. *Patient-Reported Outcomes (p<0,05).*

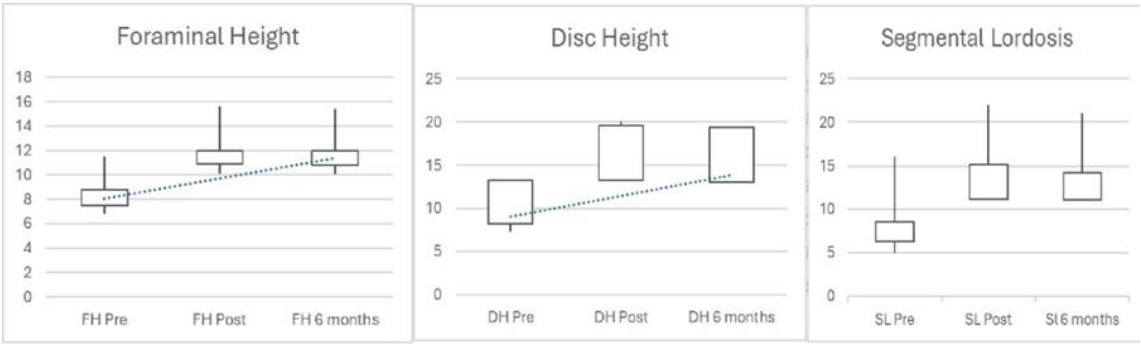

Figure 4. *Sagittal Radiographic Measures (p<0,05).*

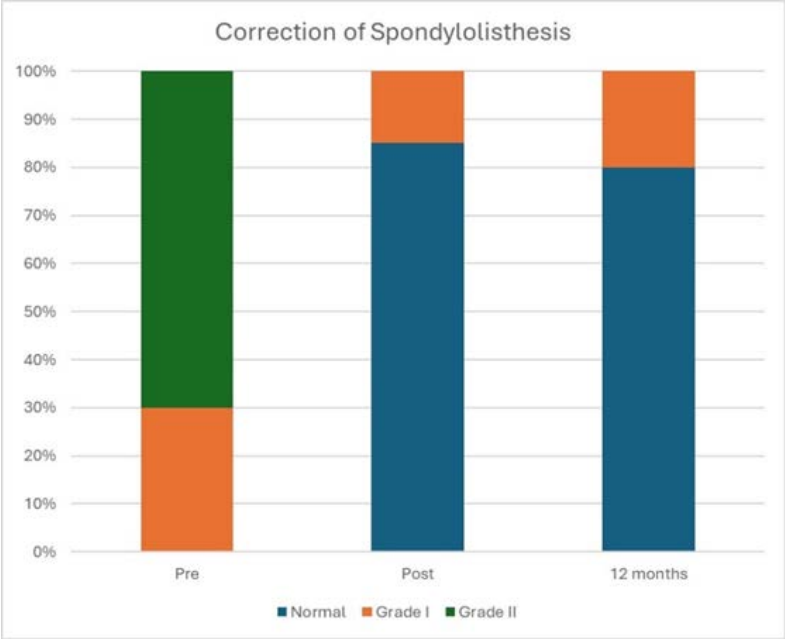

Figure 5. *Sagittal correction postoperation.*

The Macnab Criteria [1].

According to the criteria: 75% excellent, 20% good, and 5% fair.

No complications were reported.

Radiographic Outcomes:

Indirect decompression in MIS-TLIF followed by intraoperative neuromonitoring was associated with immediate and sustained increases in index-level FH, DH, and SL. Mean FH increased significantly from 9 ± 1,6 mm preoperatively to 12,3 ± 1,5 mm immediately postoperatively and was 12,1 ± 1,5mm on the last follow-up, total FH increased by 3,1 ± 1,1mm. Similarly, DH increased from 10,5 ± 2,2 mm to 17,1 ± 2,2 mm immediately following surgery and was sustained at 16,6 ± 2,1mm late postoperatively, total DH increased by 6,1 ± 1,1mm (Figure 4).

There was an immediate and large increase in SL from 8,9 ± $3,9^0$ preoperatively to 14,9 ± $3,3^0$ postoperatively (mean paired change $4,9^0$, p = 0,05). SL increases were maintained during late follow-up (Figure 5).

There was a sustained postoperative reduction in spondylolisthesis. Prior to surgery, 6/20 (30%) operative levels had grade I spondylolisthesis, and the remaining 14/20 (70%) were grade II (>25% slip). Postoperation, the total correction to normal balance was 85% but after 12 months, it slightly decreased to 80%.

Discussion.

Summary of the Findings:

In summary, patients with lumbosacral spondylolisthesis who underwent MIS-TLIF with indirect decompression followed by intraoperative neuromonitoring experienced immediate and sustained improvements in clinical outcomes and radiographic sagittal segmental parameters. PRO measures for VAS and ODI were improved during short- and long-term follow-up. We observed immediate increases in the surgical unit: anterior DH (□6,1 mm), FH (□3,1 mm), and SL (□ $4,8^0$). To be sure of the correction, we need to release the apophyseal ring on the ipsilateral and contralateral sides between vertebrates (Figure 6).

However, our stratified analysis showed significant differences between strata by preoperative overall lumbar lordosis, suggesting that the variance in segmental and regional lordotic changes is explained by baseline radiographic factors. Specifically, preoperative hypolordosis was associated with large positive corrections in SL and overall lumbar lordosis.

In our study, the average time of surgery was only 80,7 mins, blood loss less than 100ml and the patient could walk on the day postoperation. To archive that, we used intraoperative neuromonitoring followed by fluoroscope during disc preparation and interbody fusion, if the signal changed, we had to check again and put the cage directly on live fluoroscopy to be sure that the cage is on the right position.

MIS-TLIF With a lordotic Interbody Device:

The use of expandable interbody devices provides additional sagittal segmental correction when compared with historical data on MIS lumbar fusions using static devices. Several studies examine the effects of device type on sagittal segmental parameters after traditional or MIS-TLIF. Yee et al. [6] showed that patients undergoing TLIF experienced marginal increases in SL, regardless of whether expandable ($1–2^0$) or static devices were used. However, in a radiographic analysis by Hawasli et al. [5], patients who underwent MIS-TLIF with expandable versus static devices showed larger increases in DH (8,2mm vs 2,6mm cm), FH (1,3mm vs 5 mm), and SL (5.2^0 vs 2.3^0). We did not perform a direct comparison by device type. However, we speculate that expandable devices may add greater DH and SL to widen the interpedicular distance, as compared to static devices, with no meaningful difference in endplate subsidence or fusion.

Our results compare favorably with published radiographic and clinical outcomes after MIS-TLIF, but to create more lordosis, we try to put the interbody device more anterior but not too far in case of anterior longitudinal ligament rupture. In a retrospective cohort of 44 patients who underwent MIS-TLIF at 49 levels and 1.5 yr median follow-up, Massie et al. [2] observed significant changes in sagittal segmental parameters, specifically increases of 4.94^0 in SL and 3,1mm in posterior DH, and a reduction of 4,3mm in spondylolisthesis. They did not observe significant increases in spinopelvic parameters of the sagittal vertical axis or PT (Figure 7).

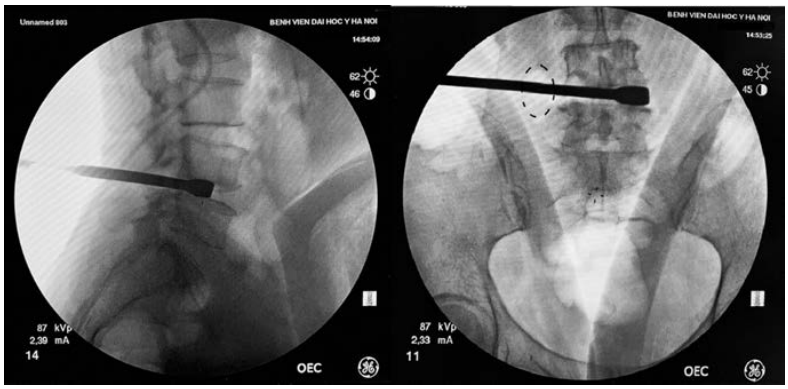

Figure 6. *Intraoperative fluoroscope shows approach from ipsilateral to contralateral apophyseal ring for maximum release.*

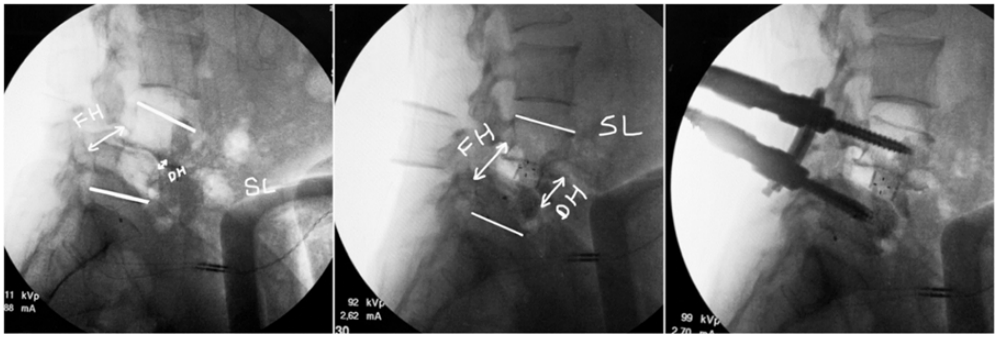

Figure 7. *Radiographic improvements: Preop: DH 3,1mm, FH 5,2mm, SL +13,2⁰, after interbody fusion: DH 11mm, FH 6,1, SL -7,2⁰ and final correction with percutaneous screws.*

Local and Regional Sagittal Balance After MIS:

The restoration of local and regional sagittal balance is an important consideration after MIS. In a literature review comprising 1182 patients from 24 anterior, lateral, and posterior/transforaminal MISS lumbar interbody fusion study cohorts (6 studies examining MIS-TLIF), Uribe et al. [3] reported a $3,9^0$ increase in SL, from an average of $8,1^0$ preoperatively to $12,0^0$ postoperatively. In a subsequent systematic review, Carlson et al. [7] identified 9 studies that reported SL and regional lordotic changes after MIS-TLIF. The mean preoperative SL was $12,7^0$ and postoperative SL was 15^0, an increase of $2,1^0$. Change in SL ranged between $0,1^0$ and $8,4^0$, with most reports between 0^0 and 3^0. This is slightly lower than observed in our series. Notably, the majority (111/171, 65%) of included cases in the systematic review used static interbody devices, which may provide less lordotic restoration than lordotic interbody devices [2,5]. The authors were cautious in their publication because of marked variability within the literature in the measurement and reporting of radiographic parameters.

Regional (OLL) lordotic changes after MISS lumbar interbody fusions are influenced by multiple factors, including operative levels, number of levels treated, interbody device position, device type, internal fixation, and use of compressive techniques. In a systematic review of 19 MISS lumbar interbody fusion cohorts and 720 patients, Uribe et al. [3] reported a significant increase of $3,7^0$ in regional lordosis, from an average of $43,5^0$ preoperatively to $47,2^0$ postoperatively.

Segmental and regional lordotic changes may be explained by variations in preoperative lordosis. In the previously mentioned report, Uribe et al. [3] found a significant inverse relationship between preoperative OLL and postoperative change in OLL ($r2 = 0.41$), whereas SL did not have a similar association ($r2 = 0.001$).

For these reasons, Uribe et al. [3] make the distinction between alignment "preservation" and "restoration/correction." Alignment changes, particularly lordosis increases, are possible after MIS lumbar interbody fusion, even MIS-TLIF. However, the extent of correction gained largely depends on preoperative spinal lordosis.

Interbody Fusion and Device Subsidence.

In a meta-analysis by Parajon et al. [8] of 40 reports and 1533 patients, fusion rates for MIS-TLIF were high, ranging from 91,8% to 99,1%, regardless of graft material. At a minimum follow-up of 12 months, fusion rates for patients with recombinant bone morphogenic protein were 98,8% and 93,1%, respectively. In the report by Massie et al. [2], in which titanium expandable interbody devices were used, the fusion rate was 96% at 12 months and the subsidence rate was 6,1%, and none of the cases were clinically significant nor required revision surgery. Although these results are reassuring, and well-powered, prospective studies with extended follow-up are needed to estimate the risks of long-term complications with expandable devices, including adjacent segment disease, subsidence, and pseudarthrosis.

Intraoperative NeuroMonitoring (IONM) During Surgery.

Intraoperative Neuromonitoring assessments during surgery were introduced and have developed into a useful tool, especially in deformities and spinal cord surgery. Sharan et al. [9] could not find any evidence in the literature that IONM can help in preventing nerve root injuries during pedicle screw fixation.

Little is known so far about the possible positive effect of surgical decompression procedures on the electrophysiological response and functional outcome. Piasecki et al. [10] found that immediate neurophysiological response in IONM after decompressive surgery for lumbar stenosis is correlated with positive effects on clinical outcomes after 8 months follow-up, but at late follow-up (more than 28 months), is not applicable to late follow-up. Piasecki et al. [10] suggest that the intraoperative neurophysiological improvement during decompressive surgery may predict clinical outcomes at 6 months after surgery.

In our study, all patients used IONM, during the procedure, we recorded every single step: facetectomy, disc preparation, interbody fusion, and percutaneous screws. The signal raised during surgery was strongly associated with the improvement of clinical symptoms postoperative. All procedures were facilities done and also recorded no complications.

Limitations of the Study.

Our study has several views to take into consideration. First, this is a single observational study with a relatively small sample size, short time follow-up, and some missing variables. Second, radiographic results are subject to measurement error because of variable radiograph quality and because of observer errors. Moreover, as it is not possible to blind reviewers to a patient's operative state, measurements made on postoperative radiographs may be systematically biased to favourable changes in sagittal parameters.

Conclusion.

Patients undergoing indirect decompression using MIS-TLIF with lordotic interbody devices experienced clinically meaningful improvements in PROs. Radiographic sagittal segmental parameters of SL, anterior DH, FH, and spondylolisthesis were improved early. This MIS-TLIF was associated with significant regional lordotic, feasible to perform with safety, mostly excellent, and good results without any complications.

Data availability statement.

All collected data are available for this study. Data will be provided upon request.

Authors' contributions.

TTK, KDH, and DHA: conceived the research idea, developed the research design, and conducted the research.

TTK, HMT, HTHV, NTHN, and BTM: performed the statistical analysis.

All authors contributed substantially to the write-up of the article.

All authors reviewed and approved the final draft of the manuscript, and all take responsibility of the content of the publication.

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