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Journal of Turkish Spinal Surgery (www.jtss.org), is the official publication of the Turkish Spinal Surgery Society. The first journal was printed on January, in 1990. It is a double-blind peer-reviewed multidisciplinary journal for the physicians who deal with spinal diseases and publishes original studies which offer significant contributions to developing of spinal knowledge. The journal publishes original scientific research articles, invited reviews and case reports accepted by the Editorial Board, in English.

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The manuscript submitted to the journal should not be previously published (except as an abstract or a preliminary report) or should not be under consideration for publication elsewhere. Every person listed as an author is expected to have been participating in the study to a significant extent. All authors should confirm that they have read the study and agreed to the submission to the Journal of Turkish Spinal Surgery for publication. This should be notified with a separate document as shown in the "Cover Letter" in the appendix. Although the editors and referees make every effort to ensure the validity of published manuscripts, the final responsibility rests with the authors, not with the journal, its editors, or the publisher. The source of any financial support for the study should be clearly indicated in the Cover Letter.

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Authors should mask patients' eyes and remove patients' names from figures unless they obtain written consent to do so from the patients, and this consent should be submitted along with the manuscript.

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Authors must state all possible conflicts of interest in the manuscript, including financial, institutional and other relationships that might lead to bias or a conflict of interest. If there is no conflict of interest, this should also be explicitly stated as none declared. All sources of funding should be

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acknowledged in the manuscript. All relevant conflicts of interest and sources of funding should be included on the title page of the manuscript with the heading "Conflicts of Interest and Source of Funding".

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ARTICLE WRITING

Clinically relevant scientific advances during recent years include the use of contemporary outcome measures, more sophisticated statistical approaches, and increasing use and reporting of well-formulated research plans (particularly in clinical research).

Scientific writing, no less than any other form of writing, reflects a demanding creative process, not merely an act: the process of writing changes thought. The quality of a report depends on the quality of thought in the design and the rigour of the conduct of the research. Well-posed questions or hypotheses interrelate with the design. Well-posed hypotheses imply design, and design implies the hypotheses. The effectiveness of a report relates to brevity and focus. Drawing attention to a few points will allow authors to focus on critical issues. Brevity is achieved in part by avoiding repetition (with a few exceptions to be noted), clear style, and proper grammar. Few original scientific articles need to be longer than 3000 words. Longer articles may be accepted if substantially novel methods are reported or if the article reflects a comprehensive review of the literature.

Although authors should avoid redundancy, effectively communicating critical information often requires repetition of the questions (or hypotheses/key issues) and answers. The questions should appear in the Abstract, Introduction, and Discussion, and the answers should appear in the Abstract, Results, and Discussion sections.

Although most journals publish guidelines for formatting a manuscript and many have more or less established writing styles (e.g., the American Medical Association Manual of Style), styles of writing are as numerous as authors. Journal of Turkish Spinal Surgery traditionally has used the AMA style as a general guideline. However, few scientific and medical authors have the time to learn these styles. Therefore, within the limits of proper grammar and clear, effective communication, we will allow individual styles.

Permissions: As shown in the example in the appendix (Letter of Copyright Transfer) the authors should declare in a separate statement that the study has not been previously published and is not under consideration for publication elsewhere. Also, the authors should state in the same statement that they transfer copyrights of their manuscript to our journal. Quoted material and borrowed illustrations: if the authors have used any material that had appeared in a copyrighted publication, they are expected to obtain a written permission letter, and it should be submitted along with the manuscript.

Review articles: The format for reviews substantially differ from those reporting original data. However, many of the principles noted above apply. A review still requires an Abstract, an Introduction, and a Discussion. The Introduction still requires focused issues and a rationale for the study. Authors should convey to readers the unique aspects of their reviews which distinguish them from other available material (e.g., monographs, book chapters). The main subject should be emphasized in the final paragraph of the Introduction. As for an original research article, the Introduction section of a review typically need not to be longer than four paragraphs. Longer Introductions tend to lose focus, so that the reader may not be sure what novel information will be presented. The sections after the Introduction are almost always unique to the particular review, but need to be organized in a coherent fashion. Headings (and subheadings when appropriate) should follow parallel construction and reflect analogous topics (e.g., diagnostic categories, alternative methods, alternative surgical interventions). If the reader considers only the headings, the

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logic of the review (as reflected in the Introduction) should be clear. Discussion synthesizes the reviewed literature as a whole coherently and within the context of the novel issues stated in the Introduction.

The limitations should reflect those of the literature, however, rather than a given study. Those limitations will relate to gaps in the literature that preclude more or less definitive assessment of diagnosis or selection of treatment, for example. Controversies in the literature should be briefly explored. Only by exploring limitations will the reader appropriately place the literature in perspective. Authors should end the Discussion with abstract statements similar to those which will appear at the end of the Abstract in abbreviated form.

In general, a review requires a more extensive literature review than an original research article, although this will depend on the topic. Some topics (e.g., osteoporosis) could not be comprehensively referenced, even in an entire monograph. However, authors need to ensure that a review is representative of the entire body of literature, and when that body is large, many references are required.

Original Articles: - Original articles should contain the following sections: "Title Page", "Abstract", "Keywords", "Introduction", "Materials and Methods", "Results", "Discussion", "Conclusions", and "References". "Keywords" sections should also be added if the original article is in English.

- Title (80 characters, including spaces): Just as the Abstract is important in capturing a reader's attention, so is the title. Titles rising or answering questions in a few brief words will far more likely do this than titles merely pointing to the topic. Furthermore, such titles as "Bisphosponates reduce bone loss" effectively convey the main message and readers will more likely remember them. Manuscripts that do not follow the protocol described here will be returned to the corresponding author for technical revision before undergoing peer review. All manuscripts in English, should be typed double-spaced on one side of a standard typewriter paper, leaving at least 2.5 cm. margin on all sides. All pages should be numbered beginning from the title page.

- Title page should include: a) informative title of the paper, b) complete names of each author with their institutional affiliations, c) name, address, fax and telephone number, e-mail of the corresponding author, d) address for the reprints if different from that of the corresponding author, e) ORCID numbers of the authors. It should also be stated in the title page that informed consent was obtained from patients and that the study was approved by the ethics committee.

The "Level of Evidence" should certainly be indicated in the title page (see Table-1 in the appendix). Also, the field of study should be pointed out as outlined in Table-2 (maximum three fields).

- Abstract: A150 to 250 word abstract should be included at the second page. The abstract should be written in English and for all articles. The main topics to be included in Abstract section are as follows: Background Data, Purpose, Materials- Methods, Results and Conclusion. The Abstract should be identical in meaning. Generally, an Abstract should be written after the entire manuscript is completed. The reason relates to how the process of writing changes thought and perhaps even purpose. Only after careful consideration of the data and a synthesis of the literature can author(s) write an effective abstract. Many readers now access medical and scientific information via Web-based databases rather than browsing hard copy material. Since the reader's introduction occurs through titles and abstracts, substantive titles and abstracts more effectively capture a reader's attention regardless of the method of access. Whether reader will examine an entire article often will depend on an abstract with compelling information. A compelling Abstract contains the questions or purposes, the methods, the results (most often quantitative data), and the conclusions. Each of these may be conveyed in one or two statements. Comments such as "this report describes…" convey little useful information.

-Keywords : Standard wording used in scientific indexes and search engines should be preferred. The minimum number for keywords is three and the maximum is five.

- Introduction (250 – 750 words): It should contain information on historical literature data on the relevant issue; the problem should be defined; and the objective of the study along with the problem-solving methods should be mentioned.

Most studies, however, are published to: (1) report entirely novel findings (frequently case reports, but sometimes substantive basic or clinical studies); (2) confirm previously reported work (eg, case reports, small preliminary series) when such confirmation remains questionable; and (3) introduce or address controversies in the literature when data and/or conclusions conflict. Apart from reviews and other special articles, one of these three purposes generally should be apparent (and often explicit) in the Introduction.

INSTRUCTIONS to AUTHORS

The first paragraph should introduce the general topic or problem and emphasize its importance, a second and perhaps a third paragraph should provide the rationale of the study, and a final paragraph should state the questions, hypotheses, or purposes.

One may think of formulating rationale and hypotheses as Aristotelian logic (a modal syllogism) taking the form: If A, B, and C, then D, E, or F. The premises A, B, and C, reflect accepted facts, whereas D, E, or F reflect logical outcomes or predictions. The premises best come from published data, but when data are not available, published observations (typically qualitative), logical arguments or consensus of opinion can be used. The strength of these premises is roughly in descending order from data to observations or argument to opinion. D, E, or F reflects logical consequences. For any set of observations, any number of explanations (D, E, or F) logically follows. Therefore, when formulating hypotheses (explanations), researchers designing experiments and reporting results should not rely on a single explanation.

With the rare exception of truly novel material, when establishing rationale authors should generously reference representative (although not necessarily exhaustive) literature. This rationale establishes the novelty and validity of the questions and places it within the body of literature. Writers should merely state the premises with relevant citations (superscripted) and avoid describing cited works and authors` names. The exceptions to this approach include a description of past methods when essential to developing rationale for a new method, or a mention of authors` names when important to establish historical precedent. Amplification of the citations may follow in the Discussion when appropriate. In establishing a rationale, new interventions of any sort are intended to solve certain problems. For example, new implants (unless conceptually novel) typically will be designed according to certain criteria to eliminate problems with previous implants. If the purpose is to report a new treatment, the premises of the study should include those explicitly stated problems (with quantitative frequencies when possible), and they should be referenced generously.

The final paragraph logically flows from the earlier ones, and should explicitly state the questions or hypotheses to be addressed in terms of the study (independent, dependent) variables. Any issue not posed in terms of study variables cannot be addressed meaningfully. Focus of the report relates to focus of these questions, and the report should avoid questions for which answers are well described in the literature (e.g., dislocation rates for an implant designed to minimize stress shielding). Only if there are new and unexpected information should data be reported apart from that essential to answer the stated questions.

- Materials - Methods (1000-1500 words): Epidemiological/ demographic data regarding the study subjects; clinical and radiological investigations; surgical technique applied; evaluation methods; and statistical analyses should be described in detail.

In principle, the Materials and Methods should contain adequate detail for another investigator to replicate the study. In practice, such detail is neither practical nor desirable because many methods will have been published previously (and in greater detail), and because long descriptions make reading difficult. Nonetheless, the Materials and Methods section typically will be the longest section. When reporting clinical studies, authors must state approval of the institutional review board or ethics committees according to the laws and regulations of their countries. Informed consent must be stated where appropriate. Such approval should be stated in the first paragraph of Materials and Methods. At the outset, the reader should grasp the basic study design. Authors should only briefly describe and reference previously reported methods. When authors modify those methods, the modifications require additional description.

In clinical studies, the patient population and demographics should be outlined at the outset. Clinical reports must state inclusion and exclusion criteria and whether the series is consecutive or selected; if selected, criteria for selection should be stated. The reader should understand from this description all potential sources of bias such as referral, diagnosis, exclusion, recall, or treatment bias. Given the expense and effort for substantial prospective studies, it is not surprising that most published clinical studies are retrospective.

Such studies often are criticized unfairly for being retrospective, but that does not negate the validity or value of a study. Carefully designed retrospective studies provide most of the information available to clinicians. However, authors should describe potential problems such as loss to follow-up, difficulty in matching, missing data, and the various forms of bias more common with retrospective studies.

If authors use statistical analysis, a paragraph should appear at the end of Materials and Methods stating all statistical tests used. When multiple tests are used, authors should state which

tests are used for which sets of data. All statistical tests are associated with assumptions, and when it is not obvious the data would meet those assumptions, the authors either should provide the supporting data (e.g., data are normally distributed, variances in gro-ups are similar) or use alternative tests. Choice of level of significance should be justified. Although it is common to choose a level of alpha of 0.05 and a beta of 0.80, these levels are somewhat arbitrary and not always appropriate. In the case where the implications of an error are very serious (e.g., missing the diagnosis of cancer), different alpha and beta levels might be chosen in the study design to assess clinical or biological significance.

- Results (250-750 words): "Results" section should be written in an explicit manner, and the details should be described in the tables. The results section can be divided into sub-sections for a more clear understanding.

If the questions or issues are adequately focused in the Introduction section, the Results section needs not to belong. Generally, one may need a paragraph or two to persuade the reader of the validity of the methods, one paragraph addressing each explicitly raised question or hypothesis, and finally, any paragraphs to report new and unexpected findings. The first (topic) sentence of each paragraph should state the point or answer the question. When the reader considers only the first sentence in each paragraph in Results, the logic of the authors` interpretations should be clear. Parenthetic reference to all figures and tables forces the author to textually state the interpretation of the data; the important material is the authors` interpretation of the data, not the data.

Statistical reporting of data deserves special consideration. Stating some outcome is increased or decreased(or greater or lesser) and parenthetically stating the p (or other statistical) value immediately after the comparative terms more effectively conveys information than stating something is or is not statistically significantly different from something else (different in what way? the reader may ask). Additionally, avoiding the terms 'statistically different' or 'significantly different' lets the reader determine whether they will consider the statistical value biologically or clinically significant, regardless of statistical significance.

Although a matter of philosophy and style, actual p values convey more information than stating a value less than some preset level. Furthermore, as Motulsky notes, "When you read that a result is not significant, don't stop thinking... First, look at the confidence interval... Second, ask about the power of the study to find a significant difference if it were there." This approach will give the reader a much greater sense of biological or clinical significance.

- Discussion (750 - 1250 words): The Discussion section should contain specific elements: a restatement of the problem or question, an exploration of limitations and as-sumptions, a comparison and/or contrast with information (data, opinion) in the literature, and a synthesis of the comparison and the author's new data to arrive at conclusions. The restatement of the problem or questions should only be a brief emphasis. Exploration of assumptions and limitations are preferred to be next rather than at the end of the manuscript because the interpretation of what will follow depends on these limitations. Failure to explore limitations suggests the author(s) either do not know or choose to ignore them, potentially misleading the reader. Exploration of these limitations should be brief, but all critical issues must be discussed, and the reader should be persuaded they do not jeopardize the conclusions.

Next, the authors should compare and/or contrast their data with data reported in the literature. Generally, many of these reports will include those cited as a rationale in the Introduction. Because of the peculiarities of a given study the data or observations might not be strictly comparable to that in the literature, it is unusual that the literature (including that cited in the Introduction as rationale) would not contain at least trends. Quantitative comparisons most effectively persuade the reader that the data in the study are "in the ballpark," and tables or figures efficiently convey that information. Discrepancies should be stated and explained when possible; when an explanation of a discrepancy is not clear that also should be stated. Conclusions based solely on data in the paper seldom are warranted because the literature almost always contains previous information.

Finally, the author(s) should interpret their data in light of the literature. No critical data should be overlooked because contrary data might effectively refute an argument. That is, the final conclusions must be consistent not only with the new data presented, but also that in the literature.

- Conclusion: The conclusions and recommendations by the authors should be described briefly. Sentences containing personal opinions or hypotheses that are not based on the scientific data obtained from the study should be avoided.

- References: References are numbered (Arabic numerals) consecutively in the order in which they appear in the text (note

INSTRUCTIONS to AUTHORS

that references should not appear in the abstract) and listed double-spaced at the end of the manuscript. The preferred method for identifying citations in the text is using within parentheses. Use the form of the "Uniform Requirements for Manuscripts" (http://www.icmje.org/about-icmje/faqs/icmje-recommendations/). If the number of authors exceeds seven, list first 6 authors followed by et al.

Use references found published in peer-reviewed publications that are generally accessible. Unpublished data, personal communications, statistical programs, papers presented at meetings and symposia, abstracts, letters, and manuscripts submitted for publication cannot be listed in the references. Papers accepted by peer-reviewed publications but not yet published ("in press") are not acceptable as references.

Journal titles should conform to the abbreviations used in "Cumulated Index Medicus".

Please note the following examples of journal, book and other reference styles:

Journal article:

Berk H, Akçalı Ö, Kıter E, Alıcı E. Does anterior spinal instrument rotation cause rethrolisthesis of the lower instrumented vertebra? J Turk Spinal Surg. 1997;8:5-9.

Book chapter:

Wedge IH, Kirkaldy-Willis WH, Kinnard P. Lumbar spinal stenosis. Chapter 5. In: Helfet A, Grubel DM (Eds.). Disorders of the Lumbar Spine. JB Lippincott, Philadelphia 1978;pp:61-8.

Entire book:

Paul LW, Juhl IH (Eds). The Essentials of Roentgen Interpretation. Second Edition, Harper and Row, New York 1965;pp:294-311.

Book with volume number:

Stauffer ES, Kaufer H, Kling THF. Fractures and dislocations of the spine. In: Rock-wood CA, Green DP (Eds.). Fractures in Adults. Vol. 2, JB Lippincott, Philadelphia 1984;pp:987-1092.

Journal article in press:

Arslantaş A, Durmaz R, Coşan E, Tel E. Aneurysmal bone cysts of the cervical spine. J Turk Spinal Surg. (In press).

Book in press :

Condon RH. Modalities in the treatment of acute and chronic low back pain. In: Finnison BE (Ed.). Low Back Pain. JB Lippincott (In press).

Symposium:

Raycroft IF, Curtis BH. Spinal curvature in myelomeningocele: natural history and etiology. Proceedings of the American Academy of Orthopaedic Surgeons Symposium on Myelomeningocele, Hartford, Connecticut, November 1970, CV Mosby, St. Louis 1972;pp:186-201.

Papers presented at the meeting:

Rhoton AL. Microsurgery of the Arnold-Chiari malformation with and without hydromyelia in adults. Presented at the Annual Meeting of the American Association of Neuro-logical Surgeons, Miami, Florida, April 7, 1975.

-Tables: They should be numbered consecutively in the text with Arabic numbers. Each table with its number and title should be typed on a separate sheet of paper. Each table must be able to stand alone; all necessary information must be contained in the caption and the table itself so that it can be understood independent from the text. Information should be presented explicitly in "Tables" so that the reader can obtain a clear idea about its content. Information presented in "Tables" should not be repeated within the text. If possible, information in "Tables" should contain statistical means, standard deviations, and t and p values for possibility. Abbreviations used in the table should be explained as a footnote.

Tables should complement not duplicate material in the text. They compactly present information, which would be difficult to describe in text form. (Material which may be succinctly described in text should rarely be placed in tables or figures.) Clinical studies for example, often contain complementary tables of demographic data, which although important for interpreting the results, are not critical for the questions raised in the paper. Well focused papers contain only one or two tables or figures for every question or hypothesis explicitly posed in the Introduction section. Additional material may be used for unexpected results. Well-constructed tables are self-explanatory and require only a title. Every column contains a header with units when appropriate.

- Figures: All figures should be numbered consecutively throughout the text. Each figure should have a label pasted on its back indicating the number of the figure, an arrow to show the top edge of the figure and the name of the first author. Black-and-white illustrations should be in the form of glossy prints (9x13 cm). The letter size on the figure should be large enough to be readable after the figure is reduced to its actual printing size. Unprofessional typewritten characters are not

accepted. Legends to figures should be written on a separate sheet of paper after the references.

The journal accepts color figures for publication if they enhance the article. Authors who submit color figures will receive an estimate of the cost for color reproduction. If they decide not to pay for color reproduction, they can request that the figures be converted to black and white at no charge. For studies submitted by electronic means, the figures should be in jpeg and tiff formats with a resolution greater than 300 dpi. Figures should be numbered and must be cited in the text.

- Style: For manuscript style, American Medical Association Manual of Style (9th edition). Stedman's Medical Dictionary (27th edition) and Merriam Webster's Collegiate Dictionary (10th edition) should be used as standard references. The drugs and therapeutic agents must be referred by their accepted generic or chemical names, without abbreviations. Code numbers must be used only when a generic name is not yet available. In that case, the chemical name and a figure giving the chemical structure of the drug should be given. The trade names of drugs should be capitalized and placed in parentheses after the generic names. To comply with trademark law, the name and location (city and state/country) of the manufacturer of any drug, supply, or equipment mentioned in the manuscript should be included. The metric system must be used to express the units of measure and degrees Celsius to express temperatures, and SI units rather than conventional units should be preferred.

The abbreviations should be defined when they first appear in the text and in each table and figure. If a brand name is cited, the manufacturer's name and address (city and state/country) must be supplied.

The address, "Council of Biology Editors Style Guide" (Council of Science Editors, 9650 Rockville Pike, Bethesda, MD 20814) can be consulted for the standard list of abbreviations.

-Acknowledgments: Note any non-financial acknowledgments. Begin with, "The Authors wish to thank..." All forms of support, including pharmaceutical industry support should also be stated in the Acknowledgments section.

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- **Practical Tips:**

1. Read only the first sentence in each paragraph throughout the text to ascertain whether those statements contain all critical material and the logical flow is clear.

2. Avoid in the Abstract comments such as, "... this report describes..." Such statements convey no substantive information for the reader.

3. Avoid references and statistical values in the Abstract.

4. Avoid using the names of cited authors except to establish a historical precedent. Instead, indicate the point in the manuscript by providing citation by superscribing.

5. Avoid in the final paragraph of the Introduction purposes such as, "... we report our data..." Such statements fail to focus the reader's (and author's!) attention on the critical issues (and do not mention study variables).

6. Parenthetically refer to tables and figures and avoid statements in which a table of the figure is either subject or object of a sentence. Parenthetic reference places interpretation of the information in the table or figure and not the table or figure.

7. Regularly count words from the Introduction through Discussion.

TABLE-1. LEVELS OF EVIDENCE

LEVEL- I .

1) Randomized, double-blind, controlled trials for which tests of statistical significance have been performed

2) Prospective clinical trials comparing criteria for diagnosis, treatment and prognosis with tests of statistical significance where compliance rate to study exceeds 80%

3) Prospective clinical trials where tests of statistical significance for consecutive subjects are based on predefined criteria and a comparison with universal (gold standard) reference is performed

4) Systematic meta-analyses which compare two or more studies with Level I evidence using pre-defined methods and statistical comparisons.

5) Multi-center, randomized, prospective studies

INSTRUCTIONS to AUTHORS

LEVEL –II.

1) Randomized, prospective studies where compliance rate is less than 80%

2) All Level-I studies with no randomization

3) Randomized retrospective clinical studies

4) Meta-analysis of Level-II studies

LEVEL– III.

1) Level-II studies with no randomization (prospective clinical studies etc.)

2) Clinical studies comparing non-consecutive cases (without a consistent reference range)

3) Meta-analysis of Level III studies

LEVEL- IV.

1) Case presentations

2) Case series with weak reference range and with no statistical tests of significance

LEVEL – V.

1) Expert opinion and review articles

2) Anecdotal reports of personal experience regarding a study, with no scientific basis

TABLE-2. CLINICAL AREAS

Anatomy

1. Morphometric analysis

Anesthesiology

Animal study

Basic Science

1. Biology
2. Biochemistry
3. Biomaterials
4. Bone mechanics
5. Bone regeneration
6. Bone graft
7. Bone graft substitutes
8. Drugs

Disc

1. Disc Degeneration
2. Herniated Disc
3. Disc Pathology
4. Disc Replacement
5. IDET

Disease/Disorder

1. Congenital
2. Genetics
3. Degenerative disease
4. Destructive (Spinal Tumors)
5. Metabolic bone disease
6. Rheumatologic

Biomechanics Cervical Spine

1. Cervical myelopathy
2. Cervical reconstruction
3. Cervical disc disease
4. Cervical Trauma
5. Degenerative disease

Complications

1. Early
2. Late
3. Postoperative

Deformity

1. Adolescent idiopathic scoliosis
2. Kyphosis
3. Congenital spine
4. Degenerative spine conditions

Diagnostics

1. Radiology
2. MRI
3. CT scan
4. Others

INSTRUCTIONS to AUTHORS

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Etiology

Examination

Experimental study

Fusion

1. Anterior
2. Posterior
3. Combined
4. With instrumentation

Infection of the spine

1. Postoperative
2. Rare infections
3. Spondylitis
4. Spondylodiscitis
5. Tuberculosis

Instrumentation

Meta-Analysis

Osteoporosis

1. Bone density
2. Fractures
3. Kyphoplasty
4. Medical Treatment
5. Surgical Treatment

Outcomes

1. Conservative care
2. Patient Care
3. Primary care
4. Quality of life research
5. Surgical

Pain

1. Chronic pain
2. Discogenic pain
3. Injections
4. Low back pain
5. Management of pain
6. Postoperative pain
7. Pain measurement

Physical Therapy

1. Motion Analysis
2. Manipulation
3. Non-Operative Treatment

Surgery

1. Minimal invasive
2. Others
3. Reconstructive surgery

Thoracic Spine

Thoracolumbar Spine

Lumbar Spine

Lumbosacral Spine

Psychology

Trauma

1. Fractures
2. Dislocations

Spinal cord

1. Spinal Cord Injury

Spinal stenosis

1. Cervical
2. Lumbar
3. Lumbosacral

Tumors

1. Metastatic tumors
2. Primary benign tumors
3. Primary malign tumors

INSTRUCTIONS to AUTHORS

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JOURNAL OF TURKISH SPINAL SURGERY

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JOURNAL OF TURKISH SPINAL SURGERY

EDITORIAL

Dear Colleagues,

Once again, it is my privilege to be publishing this, the 4th issue, of our professional journal this year. It is my sincere hope that it will continue to be a valuable reference that you will read and make use of in your professional lives. As you have come to expect, it includes several clinical research studies. I also want to thank those of you who have given so generously of your time and talents and have provided articles for the journal.

We are very happy to announce that JTSS is currently indexed in ten indices; Scopus, Ulakbim, Türkiye Atıf Dizini, J-Gate, Europub, Proquest, Gale Cengage learning, Ebsco Host and recently China Knowledge Resource Integrated.

In this issue, there are nine clinical research studies. The first study is a study concerning the "Long-Term Failure of Dynamic Rods Used in Full Dynamic Stabilization". The second is a research study entitled "Factors Causing Complications and Disability in Patients Operated for Spinal Stenosis with Posterior Decompression, Instrumentation and Fusion". In the third, one can read a clinical study entitled, "The Effect of Standing and Sitting Posture on the Angle of Trunk Rotation in Patients with Adolescent Idiopathic Scoliosis". The fourth article is a retrospective study, "Area Measurements Within The Foramen Magnum: Comparison Of 171 Patients With Symptomatic And Asymptomatic Chiari Malformation Type 1" The authors of the fifth study examined the "Evaluation Of Clinical And Radiological Outcomes In Degenerative Lumbar Spine Disorders Treated With Peek Rod". The sixth study is a retrospective study, "Management Of Subaxial Cervical Spine Fractures with Anterior Cervical Corpectomy and Anterior Plating - Single Center Experience" while, in the seventh, the authors wrote about "Comparison of Two Anesthesia Methods in Percutaneous Vertebroplasty for The Treatment of Single-Level Osteoporotic Vertebral Fractures" The eighth article is about "Long-Term Clinical and Radiological Results of Vertebral Augmentation Techniques in Osteoporotic Lumbar Compression Fractures: Vertebroplasty or Kyphoplasty?". The ninth article is a retrospective study, "Surgical Outcome of Full-Endoscopic Interlaminar Bilateral Decompression with Unilateral Approach for Lumbar Spinal Stenosis: A Clinical Study of 24 Patients"

I hope you found this issue thought provoking and edifying. As always, my goal is to try to provide you with the most current information about the latest developments in our field. My mission is, and has always been, to keep all of us on top of the most cutting-edge research in our field.

With kindest regards,

Editor in Chief

Metin Özalay, M.D., Prof.

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DOI: 10.4274/jtss.galenos.2023.68077

LONG-TERM FAILURE OF DYNAMIC RODS USED IN FULL DYNAMIC STABILIZATION

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ABSTRACT

Objective: Dynamic stabilization systems, which prevent degeneration and deformation of the lumbar spine by limiting segmental movement, have been used with increasing frequency over the years and have become an alternative to spinal fusion surgery. For a standard dynamic stabilization and for the system to work fully, the mechanical structure and material selection must be developed together. Our aim in this study was to compare clinically and radiologically the cases in which dynamic screws and different types of dynamic rods were used.

Materials and Methods: We retrospectively analyzed 57 patients who underwent surgery between 2012 and 2015 using dynamic transpedicular screw (Safinaz, Medikon) and dynamic rod [dream/agile/polyetheretherketone (PEEK)] systems. The patients were diagnosed following detailed neurological and radiological imaging examinations to determine the location of pain. Demographic data and visual analogue scale-oswestry disability index scores were obtained.

Results: The patients consisted of 23 (40.4%) males and 34 (59.6%) females with a mean age of 63.3±12.0 years (range 51-83 years) at initial symptom onset. The mean duration of clinical symptoms of the patients was 9.6 months. The mean follow-up period was 49.12 months. A dynamic transpedicular screw system was used in all patients. After the 3rd year postoperatively, rod breakage was detected in 3 patients in the agile rod group (20%) and in 4 patients in the dream rod group (22.2%). In the PEEK rod group, there were no patients with rod breakage.

Conclusion: The combination of dynamic pedicle screw and dynamic rod implants, obtained from the right material and properly designed, will be an important alternative among non-fusion dynamic implants, especially in patients with multi-segment degenerative disease.

Keywords: Dynamic screw, stabilization, dynamic rod, degenerative, disc disease

INTRODUCTION

Although there are many options for fracture, deformity, and degenerative spine surgery, decompression, and complementary posterior spinal instrumentation are seen as the gold standard treatment technique[1]. However, complications such as infection, instrumentation failure, failed back syndrome, adjacent segment disease, and pseudoarthrosis may be encountered after fusion surgery. The most important reason is the limitation of the physiologic movement after fixation and the increase in the load on the adjacent spine segment[2].

Rod failure, which frequently causes revision surgeries, is among the important instrument complications. While the risk of fracture increases especially in long segment fusions involving transitional regions, the other causes are advanced age, increase in body mass index, and presence of connectors[3]. Another important factor is the material of construction of the rod. It has been reported in the literature that rods made of titanium alloy or stainless steel are more durable than cobalt chrome or other materials[4].

Dynamic stabilization systems, which prevent degeneration and deformation of the lumbar spine by limiting segmental movement, have been used with increasing frequency over the years and have become an alternative option to spinal fusion surgery. With the preservation of segmental motion, stress at adjacent levels will decrease and the development of autism spectrum disorder can be prevented automatically. However, adequate spinal stability is necessary for successful results[5].

Dynesys system, which is one of the most widely used dynamic systems, has been used for more than ten years and is based on artificial ligament system technology[6]. As a result of tightening the rod (thread) by the surgeon, very hard or vice versa loose rods may occur. For this reason, the failure to provide a standard procedure has led to the emergence of disadvantages over time. For a standard dynamic stabilization and for the system to work fully, the mechanical structure and material selection must be developed together. For this reason, dynamic rods [dream/agile/polyetheretherketone (PEEK)] have been introduced and the use of full dynamic systems has gradually increased. There are publications in the literature that the rods break and lose

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their function because of the use of dynamic rods with a rigid screw system. However, to the best of our knowledge, there is no clinical study on the long-term results and functions of rods in cases where dynamic screws and dynamic rods are used. In this study, we aimed to report the long-term clinical results of 3 different dynamic rod systems.

MATERIALS AND METHODS

In this study, all procedures performed were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study was approved by the Atatürk University Clinical Research Ethics Committee (decision no: 12, date: 27.01.2022). Informed consent was obtained from all participants included in the study.

We retrospectively analyzed 57 patients who were operated on between 2012 and 2015, using dynamic transpedicular screw (Safinaz, Medikon) and dynamic rod (dream/agile/PEEK) systems (Figure 1). Patients with complete clinical and radiological follow-ups were included in the study. The cases that had been operated with at least 2 segments due to various lumbar pathologies were divided into 3 groups according to the type of dynamic rods used.

The patients were diagnosed following detailed neurological and radiological imaging examinations to determine the location of the pain. Demographic data and visual analogue scale-oswestry disability index (VAS-ODI) scores were obtained. Pre-procedural VAS-ODI scores were documented before the procedure and after the operation at the following time points: 3 months, 1 year, and year after that. The stability of the system was checked with the imagings taken at periodic intervals. Computed tomography (CT), magnetic resonance imaging, and direct X-ray were performed on all patients both preoperatively and postoperatively. In case of failure in any part of the dynamic system, time and patient complaints were noted.

During routine controls, fusion was evaluated by CT and dynamic radiographs in all patients at the 6th month follow-up. In addition, stability was subjectively confirmed by the absence of axial pain. The patients were followed up routinely in the outpatient clinic conditions. Detailed neurological examinations were performed and their complaints were compared. If there was improvement in the physical examination and symptoms of the patients, these patients were included in the group of those who benefited from the surgery. The groups were compared within themselves before and after dynamic stabilization.

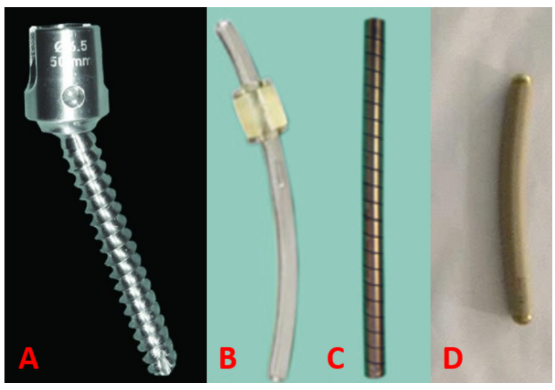

Figure 1. A) Safinaz screw, **B)** Agile rod, **C)** Dream rod, **D)** PEEK rod
PEEK: Polyetheretherketone

Surgical Procedure

All procedures were supervised and/or performed by the senior author (AFO). Participants were positioned prone on a radiolucent fluoroscopy table with general anaesthesia. The transpedicular screw system was performed with the aid of fluoroscopy, accompanied by anteroposterior and lateral images, after paravertebral muscle dissection with the Wiltse method. Additional microdiscectomy with the median approach was performed in patients who had disc extrusion or protrusion. Dynamic transpedicular screws and dynamic rods were used in all patients. The rigid segment of the agile rod was used in the microdiscectomy region, and the spacer segment of the agile rod was used in the degenerative disc disease region.

Statistical Analysis

All statistical analyses were performed using IBM SPSS 20.0 software (IBM Corp., Armonk, NY, USA). For the significant values, which groups were different from each other and what the source of this difference was between the groups were examined by postoperative comparison tests, including Tukey's honestly significant difference test. Since the variables in the data were obtained with a proportional or intermittent scale and were normally distributed, Pearson correlation analysis was performed. A two-tailed $p<0.05$ was considered to indicate statistically significant differences.

RESULTS

The patients consisted of 23 (40.4%) males and 34 (59.6%) females with a mean age of 63.3±12.0 years (range 51-83 years) at initial symptom onset. When the family histories of the patients were examined, no spinal trauma or oncological surgery was found. The patients also had no previous history of spinal surgery. Among the symptoms, low back pain was dominant, while sciatica was the most common accompanying symptom. The mean duration of clinical symptoms of the patients was 9.6 months. The mean follow-up period was 49.12 months.

A dynamic transpedicular screw system was used in all patients. Agile rod system was used in 15 (26.3%) patients, dream rod in 18 (31.6%) patients, and PEEK rod system in 24 (42.1%) patients. Stabilization operation including at least 2 segments was applied to all patients. While degenerative disc disease was the predominant pathology, stenosis was the pathology that followed it. Baseline demographic and procedural characteristics by localization are summarized in Table 1.

When the VAS-ODI scores were examined, a significant improvement was observed at the 3rd month control (p<0.05) (Table 2). No statistically significant change was observed in their scores in routine follow-ups. There was no significant difference between gender, including segment and pathology in terms of both VAS-ODI score changes, and also there was no significant correlation between age and VAS-ODI score changes (p>0.05).

The difference about the clinical relief between at the end of third month and at the end of the twelfth, and twenty-fourth months were not statistically significant (p>0.05). No additional complaints were detected in the last clinical evaluation of the patients. In the instrumentation system, no signs of insufficiency were detected in all patients until the 3rd year. The absence of additional pain complaints in the patients was used for subjective evaluation of fusion. It was also confirmed with routine imaging modalities.

However, after the 3rd year postoperatively, some patients from agile and dream rod groups showed worsening in the VAS-ODI score values, and in the control images, insufficiency and fracture of the rod systems were observed in each group. Rod breakage was detected in 3 patients in the agile rod group (20%) and in 4 patients in the dream rod group (22.2%). In the PEEK rod group, there was no patient with rod breakage (Table 1).

In total patient cohort, except for subcutaneous hematoma and superficial tissue infection, no serious complications were encountered. Screw loosening was found on plain radiographs in one patient in the PEEK rod group (Table 3). Except for rod breaks and secondary revision cases, none of the cases required revision surgery secondary to screw malposition, adjacent segment disease, or screw loosening. At the last follow-up visit, no implant-related complications requiring revision were observed. Some of the illustrative case in this series are shown in Figures 2-4.

DISCUSSION

Disc tissue is one of the most important structures that play a role in the mobility and stability of the spine. As a result of degeneration, the disc structure deteriorates, so pain inevitably arises in the deteriorated joint. Although there are many factors that predispose to degeneration, instability is among the most common causes in pathophysiological mechanisms. Degenerative instability develops as a result of numerous causes, including disc degeneration, expansion in hypertrophic

Table 1. Summarized data of patients

		Mean ± SD	Median (IQR)
Age (years)		63.3±12.0	67.0 (51.0-83.0)
Clinical and radiological follow-up (month)		49.12±4.3	-
Duration of clinical symptoms (month)		9.3±3.7	-
		n	%
Gender	Female	34	59.6
	Male	23	40.3
Stabilization	Short segment (2)	20	35.1
	Long segment (2-4)	37	64.9
Localization	Lumbosacral	27	47.3
	Lumbar	30	52.7
Type of rods/break	Agile	15/3	26.3/20
	Dream	18/4	31.6/22.2
	PEEK	24/-	42.1/-

SD: Standard deviation, PEEK: Polyetheretherketone, IQR: Interquartile range

Table 2. Comparison of VAS-ODI scores of patients before and after treatment (3rd year control)

		Preoperative		Postoperative		Change		
		Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)	p
Dream rod	**VAS score**	8.5±0.6	8.0 (8.0-9.0)	3.3±0.8	3.0 (3.0-3.0)	5.2±1.2	5.0 (5.0-6.0)	0.006
	ODI score	65.2±15.4	66.0 (56.0-72.0)	23.9±11.4	20.0 (16.0-24.0)	41.3±15.0	44.0 (34.0-48.0)	0.007
Agile rod	**VAS score**	8.2±0.4	8.1 (8.0-9.0)	3.6±0.9	3.1(3.0-3.3)	4.6±1.2	5.2 (5.0-6.3)	0.008
	ODI score	64.1±16.6	67.0 (55.0-73.0)	24.3±12.1	21.0 (17.0-23.0)	39.8±15.9	43.0 (33.0-47.0)	0.009
PEEK rod	**VAS score**	8.3±0.2	8.0 (8.0-9.0)	3.1±0.5	3.0 (3.0-3.3)	5.2±1.0	5.0 (5.0-6.3)	0.007
	ODI score	62.7±18	66.0 (54.0-72.0)	22.8±11.7	21.0 (18.0-24.0)	39.9±15.9	43.8 (34.0-48.0)	0.008

SD: Standard deviation, IQR: Interquartile range, VAS-ODI: Visual analogue scale-oswestry disability index

posterior facet joints, looseness in ligaments and increased movement[7].

Today, fusion surgeries are still accepted as the "gold standard" in the treatment of painful low back syndrome all over the world. Good results have been obtained from fusion surgeries performed to treat the disc and relieve this pain. However, one of the biggest problems of these surgeries is adjacent segment disease, causing early degeneration of the discs adjacent to the fusion distance due to overload and fusion surgeries. Fusion surgeries also cause the destruction of a motion segment and thus adversely affect the lumbar biomechanics. Despite the positive results of fusion surgeries, these complications have made the current method controversial[8].

Diagnosis and treatment methods for disc origin pain have made great progress especially in the last two decades. Conservative methods have become more popular due to the problems caused by fusion surgeries, and fusion surgeries have been avoided unless necessary[9]. However, with the concept of dynamic system becoming a reality in the treatment of degenerative spine, dynamic stabilization has become an increasingly popular approach in the surgical treatment of chronic low back pain due to disc degeneration. Graf[10] thought that if hypermobility in facet joints due to degeneration is removed, its rotation will be controlled. Therefore, he compressed the facet joints with an artificial ligament named after him, using pedicular screws, and he laid the foundations of dynamic stabilization by compressing the facet joints with using artificial ligament and transpedicular screw system[10].

Then, with the emergence of the system's deficiencies, the Dynesis system was developed. However, the surgeon's adjustment of the tension of the spacers used in the Dynesis system has led to the questioning of the dynamism of the system, especially in long-segment stabilization cases[11]. Later, von Strempel et al.[12] introduced a new concept in dynamic stabilization by adding a joint to the screw head. In addition, rods capable of flexion and extension despite various loads have also been produced. PEEK and carbon fiber rods are movable and are offered to compress the bone graft for fusion purposes. However, it is not yet known what features the ideal moving rod should have. Posterior dynamic stabilization may provide an advantage over rigid fixation when used as a complement to the posterior tension band in lumbar fusion surgery[13].

Along with the proliferation of rods produced from different styles and materials, studies have been revealed in the literature, especially on rigid screws and the use of these dynamic rods. Traditional fixation systems made of titanium alloy or stainless

Table 3. Complications by groups

	Screw loose	Rod breakage/ time (mn)	Subcutaneous hematoma/infection
Agile	-	3/39	1/1
Dream	-	4/38.75	-/1
PEEK	1	-/-	1/-

PEEK: Polyetheretherketone

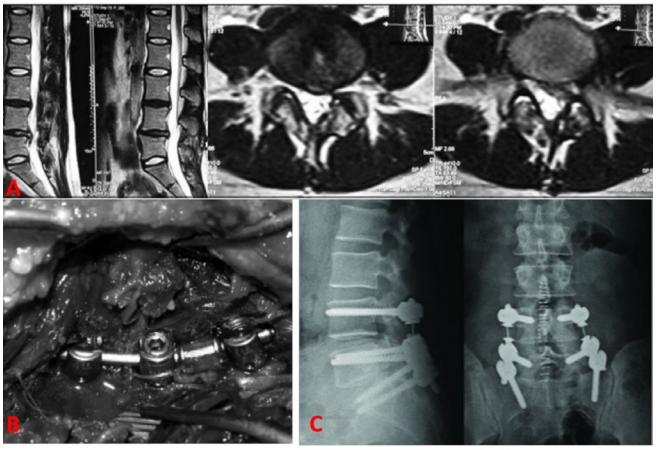

Figure 2. Thirty-year-old male patient with severe left leg pain and recurrent disc hernia. Sagittal and axial section MRIs **(A)** and intraoperative view **(B)** are seen. An agile rod was used with dynamic screws. Antero-posterior and lateral radiographic views after the operation **(C)**
MRI: Magnetic resonance imaging

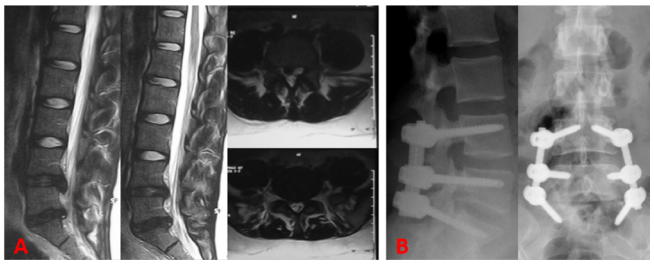

Figure 3. Forty-year-old male patient with back and right leg pain. Sagittal and axial section MRIs **(A)** are seen. A dream rod was used with dynamic screws. Antero-posterior and lateral radiographic views after the operation **(B)**
MRI: Magnetic resonance imaging

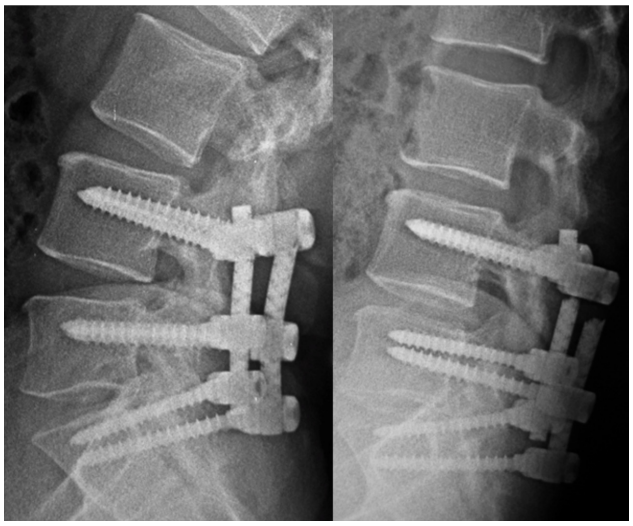

Figure 4. A 53-year-old male patient who was operated for lumbar stenosis. On the 38th month follow-up radiographs, it is observed that the dream rod is broken

steel, which have rigidity levels that are not compatible with bone, would cause abnormal kinematic behavior and load sharing locally. In their study, Wu et al.[14] reported that faster bone fusion and better fusion quality were obtained in the PEEK rod group when the Titanium rod group was compared with the PEEK rod group. Kang et al.[15] also conclude that the PEEK and carbon fiber reinforced-PEEK rod systems reduce the possibility of breakage of the pedicle screw and provide more flexibility to the lumbar spine, compared to titanium rod. Chang et al.[16] compared the PEEK rod system to titanium rod at (L3-L4) level under 10 Nm pure moment and also conclude the same. In the study of Li et al.[17], it was stated that both PEEK rods and titanium rods can provide reliable fixation in lumbar fusion surgery. It was also emphasized that PEEK rods may be better than titanium rods in improving postoperative dysfunction, reducing lower extremity pain, and improving bone graft fusion rate[17].

There is not much data in the literature regarding the use of dynamic screw dynamic rod systems in clinical practice. Our aim was to demonstrate the biomechanical adequacy of the dynamic screw and rod system through finite element and cadaver studies. We used a rod that we developed ourselves and named it the talin rod as the dynamic rod. In this study, the biomechanical effects of dynamic, semi-rigid, and rigid posterior stabilization systems on the lumbar spine were reported. The resulting range of motion (ROM), facet joint loads, intradiscal pressures, and stresses in pedicle screws were observed and compared for all cases. As a result, in hybrid moment flexion, extension, right and left lateral bending, the dynamic screw-dynamic rod combination yielded results closest to those of the intact spine. Similarly, when examining ROM values at the L4-5 segment, it was observed that the dynamic combination provided results close to those of the intact spine[18,19].

In our study, in cases where dynamic stabilization was applied with the dynamic screw dynamic rod system, despite the various dynamic rod structures used, if there was no problem in the system, very satisfactory clinical results were obtained. Significant clinical relief has been achieved in patients both in the early postoperative controls and in the long-term results. However, screw fractures were observed in the dream and agile rod groups after 3 years, and it was revealed that the complaints of the patients recurred. It has been observed that the complaints resolved after the broken rods were replaced with PEEK rods in revision surgeries. Although the use of dynamic screw-dynamic rod is an important alternative to fusion surgery in degenerative disc patients, it has been observed that the type of materials used is directly related to long-term clinical results.

Study Limitations

Clearer and more accurate results can be obtained with prospective randomized controlled studies with a higher number of patients. As it is not a standard operation, this study had to be performed with a small number of patients.

CONCLUSION

The combination of dynamic pedicle screw and dynamic rod implants, obtained from the right material and properly designed, will be an important alternative option among non-fusion dynamic implants, especially in patients with multi-segment degenerative disease.

Ethics

Ethics Committee Approval: This study was approved by the Atatürk University Clinical Research Ethics Committee (decision no: 12, date: 27.01.2022).

Informed Consent: Informed consent was obtained from all participants included in the study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: Ö.A., A.F.Ö., Concept: Ö.A., A.F.Ö., M.K.K., Design: Ö.A., A.F.Ö., Data Collection or Processing: M.Y.A., C.G., Analysis or Interpretation: M.Y.A., C.G., M.K.K., Literature Search: M.Y.A., C.G., Writing: M.Y.A., A.F.Ö.

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FACTORS CAUSING COMPLICATIONS AND DISABILITY IN PATIENTS OPERATED FOR SPINAL STENOSIS WITH POSTERIOR DECOMPRESSION, INSTRUMENTATION AND FUSION

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ABSTRACT

Objective: Spinal stenosis, characterized by spinal canal narrowing and neural structure compression, leads to debilitating symptoms and impacts quality of life. Surgical interventions for spinal stenosis are on the rise because of an aging population and advancing surgical techniques. However, complications can undermine outcomes. Understanding the factors contributing to complications is crucial for optimizing outcomes. This study aimed to identify complications and disability factors in patients undergoing posterior spinal instrumentation for spinal stenosis.

Materials and Methods: Data from patients who underwent surgery for degenerative spinal stenosis were retrospectively analyzed. Factors including age, gender, cage usage, instability, and preoperative mobility were evaluated. Complications, including infection and adjacent segment degeneration, were documented. Statistical analysis was performed to identify correlations and significant differences.

Results: Sixty four patients were included in the study. 79.7% of the patients were women. The mean follow-up time was 46.56 months. The study revealed correlations between preoperative mobility status and infection rates, with immobile patients at higher risk (p=0.034). Gender disparities were noted, with female patients exhibiting more functional disability (Oswestry score female 12.41, male 7.00, p=0.044). Cage usage correlated with worse outcomes (p=0.007), and spinal instability was associated with poorer functional scores (p=0.015). Complications were observed in 13 (20.3%) patients. Infection was detected in 5 patients, postoperative neurodeficiency in 2 patients, re-operation in 13 patients (20.3%), and adjacent segment degeneration in 9 patients (14.1%).

Conclusion: Despite limitations, this study provides valuable insights into factors influencing complications and disability in spinal stenosis surgery. Tailoring interventions based on these findings could enhance patient outcomes.

Keywords: Spinal stenosis, posterior spinal instrumentation, cage usage, spinal instability

INTRODUCTION

Spinal stenosis is a degenerative condition characterized by the narrowing of the spinal canal, resulting in compression of neural structures and subsequent symptoms such as pain, numbness, and functional limitations[1,2]. It is a common spinal disorder, particularly prevalent in the aging population, and can significantly impact an individual's quality of life[3,4].

With the increasing aging population and advances in surgical techniques, the number of patients undergoing surgical interventions for spinal stenosis has been steadily rising[5-7]. However, despite the effectiveness of surgical treatments, complications can arise, leading to prolonged hospital stays, increased healthcare costs, and potentially worse patient outcomes[8-10].

Understanding the factors contributing to complications and disability in patients operated for spinal stenosis is of paramount importance for optimizing surgical outcomes and improving patient care. By identifying these factors, healthcare providers can implement strategies to minimize complications and enhance patient recovery[4,9].

The aim of this study is to determine the factors causing complications and disability in patients who underwent surgical intervention, specifically posterior spinal instrumentation, for spinal stenosis. This investigation will shed light on the potential risk factors associated with unfavorable postoperative outcomes, allowing for tailored management approaches and improved patient outcomes.

The findings of this study have the potential to guide clinical decision-making and optimize patient outcomes in spinal stenosis surgery. By identifying the factors associated

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with complications and disability, healthcare providers can implement targeted interventions, such as infection prevention strategies, personalized rehabilitation programs, and meticulous evaluation of spinal stability, to minimize adverse events and enhance patient recovery.

MATERIALS AND METHODS

After obtaining ethical approval, patients who underwent posterior spinal instrumentation and fusion due to degenerative spinal stenosis were retrospectively selected from the archive. This study was approved by the İzmir Bakırçay University Ethics Committee (decision no: 1139, date: 26.07.2023).

Patients with unresponsive conservative treatment, severe pain, decreased walking distance, and neurological deficits underwent surgery. Detailed medical history, physical examination, neurological evaluation, plain radiographs, and magnetic resonance imaging (MRI) were performed before surgical intervention. Patients with congenital stenosis, pediatric cases, spinal stenosis due to tumor-related causes, those treated with anterior instrumentation, and those who underwent only release without fusion were excluded from the study. Patients with spinal stenosis caused by factors such as recurrent or initial disc herniation, facet arthrosis, thickened ligamentum flavum, degenerative spondylolisthesis, and foraminal narrowing were included in the study. Reasons for preferring posterior instrumentation and fusion as a surgical technique; history of failed disc surgery, instability, advanced facet joint degeneration, multiple segment stenosis, and need for bilateral laminectomy. All patients included in the study had degenerative instability. We did not have any traumatic, isthmic, congenital or iatrogenic instability patients. There was no iatrogenic instability in patients who had previously had failed disc surgery and who we applied posterior spinal instrumentation. Some of these patients already had instability before disc surgery.

Patient-specific data including age, gender, follow-up duration, levels of operation, use of cages, presence of instability (spondylolisthesis), file information, preoperative MRI, plain radiographs, and postoperative plain radiographs along with computed tomography (CT) scan for screw placement verification were collected. Neurological status and mobility grades were recorded based on file information before surgery. Preoperative neurological statuses were categorized as weakness and severe pain (able to walk), mobilization with wheelchair assistance (less pain), inability to walk with severe pain, and presentation with severe pain and cauda equina syndrome. Postoperative clinical scoring was conducted using the oswestry disability index and visual analog scale (VAS) for pain assessment. Complications such as deep infection, iatrogenic neurological deficits, re-operation, adjacent segment degeneration, and non-fusion were defined, documented, and registered.

Surgically, patients were operated on in a prone position under general anesthesia. Prophylactic antibiotic therapy (1 g cefazolin sodium) was administered to the patients. A posterior longitudinal incision was made to access the subcutaneous tissues. Paravertebral muscles around the spinous processes were dissected after passing through the fascia. Facet joints were exposed for visualization. Hemostasis was achieved using cautery or bipolar methods. Segment identification was aided by fluoroscopy. Pedicle screws were placed using fluoroscopic guidance at appropriate levels. Laminectomy was performed as necessary for affected regions. Procedures such as hypertrophic ligamentum flavum removal, excision of extruded disc material (if present), release of dural adhesions (if present), excision of facet joints, and removal of bone compressions (if present) were carried out. Wide decompression was preferred in revision cases with dural adhesions and in cases of stenosis in which more than one segment is affected. Cages were placed for posterior lumbar interbody fusion in segments with instability. Polyaxial pedicle screws were fixed using pre-bent rods. Intermediate connectors were placed. Allografts and autografts were mixed and placed in posterolateral corners after obtaining bone grafts from the patient. After hemostasis, the wound was closed with a single Hemovac drain (Figure 1).

Postoperative plain radiographs and CT scans for screw placement verification were obtained. In patients, the presence of fusion was monitored through anteroposterior and lateral direct radiographs. Patients were assisted to sit on the bedside on the first postoperative day. In-bed exercises were initiated immediately. Patients in stable condition were mobilized with a brace at 24-36 hours postoperatively. Patients with improved general conditions were discharged with palliative pain management. Wound care continued for two weeks. During

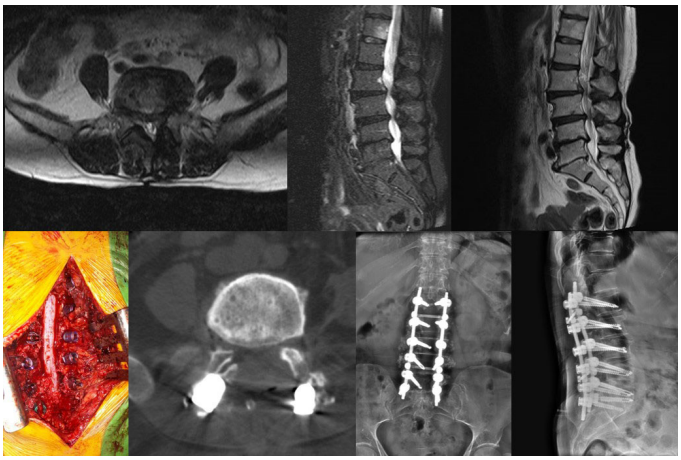

Figure 1. Widening of the stenosis in the spinal canal with laminectomy and application of posterior spinal instrumentation due to recurrence and severe spinal stenosis in a patient who had previously undergone disc surgery (the AP diameter of the canal is 4 mm preoperavely, 13 mm postoperatively)
AP: Anteroposterior

this time, patients continued home exercises. Monthly follow-up with plain radiographs was initiated after the first month. Active physical therapy was started after the first month.

Statistical Analysis

Statistical analysis was done with SPSS program. Conformity of numerical data to normal distribution was done with Shapiro-Wilk test. T-test was used when there was normal distribution between two independent groups, Mann-Whitney U test was used in cases where there was normal distribution between two independent groups. Pearson or Spearman test was used as correlation test $p<0.05$ was accepted as statistical significance level.

RESULTS

Sixty-four patients with clinical follow-up were included in the study. The mean age of the patients was 62 (34-81). There were 51 (79.7%) female and 13 (20.3%) male patients. mean follow-up times were 48.56 (12-134) months. Mean VAS scores were 3.22 (1-9). The mean oswestry scores were 11.31 (2-45) (Table 1).

Thirteen (20.3%) patients were operated on because of shortened walking distance, 35 (54.7%) patients with neurological findings, 6 (9.4%) patients with acute-subacute cauda equina, and 10 (15.6%) patients who were in a wheelchair for long periods of time (Table 1).

Fifteen of the patients had previously undergone discectomy for disc herniation. Cage was applied to 25 patients (39.1). There was instability in 24 patients (37.5%). The average number of levels was 4.42 (2-7) (Table 1).

Complications were seen in a total of 13 (20.3%) patients. Infection was detected in 5 patients, postoperative neurodeficiency in 2 patients, re-operation in 13 patients (20.3%), and adjacent segment degeneration in 9 patients (14.1%) (Table 1).

In the comparison of categorical data with each other (sex, disc surgery, cage use, instability and preoperative mobilization-neurological status and complication, infection, adjacent segment degeneration, reoperation rate and neurological complication); there was a significant difference between preoperative mobilization status and infection ($p=0.034$, Pearson chi-square test). There was no statistically significant difference between gender, disc surgery, cage use, instability rates and complication rates ($p>0.050$, chi-square test) (Table 2).

According to the Spearman correlation test, a significant correlation was found between age and of oswestry score and the number and stabilization levels ($p=0.023$ and <0.001). Naturally, VAS scores and oswestry scores were also correlated with each other ($p<0.001$).

When the patients were divided into two groups according to gender, disc surgery status, cage use, instability and presence of complications, and the VAS and oswestry scores were compared, the oswestry score was found to be lower in female patients ($p=0.044$, Mann-Whitney U test). Oswestry scores of the patients using cage were lower ($p=0.07$). Oswestry and

Table 1. General information of demographics, clinical results and complications of the patients

Demographic, radiologic and clinical results		Number/mean	SD/%
Age (years)		62.00	11,445 SD
Gender	Male	13	20.3%
	Female	51	79.7%
Follow-up time (months)		46.56	31,488 SD
Preop lumbar disc operation		15	23.4%
Spinal enstrumantation levels (mean)		4.42	2-7 (range)
Cage use		25	39.1%
Instability		24	37.5%
Preoperative neurological status	Weakness and severe pain	35	54.7%
	In a wheelchair	10	15.6 %
	Inability to walk and severe pain	13	20.3%
	Cauda equina syndrome	6	9.4%
Oswestry score		11.31	10,711 SD
VAS score		3.22	2,119
Complication		13	20.3%
Infection		5	7.8%
Re-operation		13	20.3%
Non-union		1	1.6%
Adjent segment degeneration		9	14.1%

SD: Standard deviation, VAS: Visual analog scale

VAS scores were significantly worse in patients with instability (p=0.05 and 0.015). Again, the clinical scores of the patients who developed complications (oswestry and VAS) were worse than those who did not (p<0.001 and 0.002) (Table 3).

DISCUSSION

The present study aimed to identify the factors contributing to complications and disability in patients who underwent posterior spinal instrumentation for spinal stenosis. The findings provide valuable insights into the causes of complications, functional outcomes, and potential risk factors associated with this surgical intervention.

One notable finding is the association between preoperative mobilization status and infection rates. The study demonstrates that patients who were immobile for extended periods before the operation, such as those reliant on wheelchairs, had a higher incidence of postoperative infections. This aligns with previous research emphasizing the importance of optimizing patient mobility and minimizing preoperative immobilization to reduce the risk of surgical site infections[11,12].

Gender differences were also observed in terms of pain and disability. Female patients exhibited higher oswestry scores, indicating greater functional disability, compared to male patients. This finding is consistent with other studies that have reported higher pain levels and poorer functional outcomes in female patients undergoing spinal surgeries[13,14]. Further investigation is warranted to explore the underlying mechanisms contributing to these gender disparities and to develop tailored management strategies.

Additionally, the utilization of interbody fusion with a cage was associated with increased pain and disability, as reflected in the oswestry scores. This finding suggests that cage usage may be linked to poorer functional outcomes in patients undergoing spinal stenosis surgery. While the present study did not delve into the specific reasons for this association, it is possible that patient-related factors, such as instability, revision cases or increased surgical time, may influence postoperative pain and disability[15]. Future studies should delve deeper into this relationship to guide the selection and optimization of surgical approaches[16].

Another significant factor impacting outcomes was spinal instability, which was associated with worse functional scores. This finding aligns with the existing literature, which highlights the negative impact of instability on clinical outcomes following spinal surgery[17,18]. Spinal instability may lead to altered biomechanics, increased stress on adjacent segments, and compromised surgical outcomes[19]. Thus, meticulous

Table 2. Presentation of significance (p-values) obtained from cross-tables of demographic data and complication rates in table format

	Complication	Infection	Neurological complication	Re-operation	Adjacent segment degeneration
Gender	0.439*	0.574*	1,000*	0.439*	0.185*
Preop LDH operation	0.482*	0.329*	1,000*	0.482*	0.427*
Cage use	0.492**	1,000*	0.516*	0.492**	0.463*
instability	0.751*	0.355*	1,000*	1,000*	0.464*
Preoperative neurological status	0.170**	**0.034****	0.535**	0.514**	0.347**

*Fisher's exact test, **Pearson chi-square test, LDH: Lumbar disc hernia

Table 3. Investigation of the relationship between oswestry and VAS scores using the Mann-Whitney U test in the presence of variables such as age, instability, use of cage, prior disc herniation surgery, and overall complications

		Oswestry	SD	p value*	VAS score	SD	p value*
Gender	Female	12.41	11.204	**0.044**	3.39	2.201	0.181
	Male	7.00	7.348		2.54	1.664	
Instability	Yes	9.04	11.161	0.050	2.58	2.125	**0.015**
	No	12.68	10.334		3.60	2.048	
Cage usage	Yes	7.88	8.555	**0.007**	2.60	1.756	0.053
	No	13.51	11.457		3.62	2.255	
Previous lumbar disc surgery	Yes	11.53	9.680	0.534	3.47	1.995	0.409
	No	11.24	11.101		3.14	2.170	
Complication	Yes	23.77	14.538	**<0.001**	5.54	2.989	**0.002**
	No	8.14	6.573		2.63	1.326	

*Mann-Whitney U test, SD: Standard deviation, VAS: Visual analog scale

evaluation and appropriate management of spinal instability are crucial for optimizing patient outcomes in spinal stenosis surgery.

Regarding complications, the study reported an overall complication rate of 20.3%. Infection was the most frequent complication, followed by re-operation and adjacent segment degeneration. These findings are consistent with the known complications associated with spinal stenosis surgery[8,11]. The identification of these complications emphasizes the importance of comprehensive perioperative care, including stringent infection control measures and close postoperative monitoring, to minimize the incidence and impact of these adverse events.

Study Limitations

It is important to acknowledge the limitations of this study. The retrospective design and relatively small sample size may limit the generalizability of the findings. Future prospective studies with larger cohorts are warranted to validate and expand upon these results. Additionally, factors such as patient comorbidities, surgical techniques, and implant characteristics were not extensively explored in this study and may influence outcomes in spinal stenosis surgery. Further investigations considering these factors are necessary to provide a more comprehensive understanding of the relationship between patient characteristics, surgical variables, and clinical outcomes.

CONCLUSION

This study highlights several important factors associated with complications and disability in patients undergoing posterior spinal instrumentation for spinal stenosis. Preoperative mobilization status, gender, cage usage, and spinal instability were identified as significant factors impacting postoperative pain and functional outcomes. These findings contribute to our understanding of the complexities of spinal stenosis surgery and emphasize the need for personalized patient management strategies. By optimizing patient mobility, considering gender-specific factors, and carefully evaluating and addressing spinal instability, healthcare professionals can strive to improve surgical outcomes and enhance the overall quality of care for patients with spinal stenosis.

Ethics

Ethics Committee Approval: This study was approved by the İzmir Bakırçay University Ethics Committee (decision no: 1139, date: 26.07.2023).

Informed Consent: Retrospective study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: M.A., A.C.T., A.İ.K., C.K., S.Ç., Concept: M.A., A.C.T., A.İ.K., C.K., S.Ç., Design: M.A., A.C.T., A.İ.K., C.K., S.Ç., Data Collection or Processing: M.A., A.C.T., A.İ.K., C.K., S.Ç., Analysis or Interpretation: M.A., A.C.T., A.İ.K., C.K., S.Ç., Literature Search: M.A., A.C.T., A.İ.K., C.K., S.Ç., Writing: M.A., A.C.T., A.İ.K., C.K., S.Ç.

Conflict of Interest: The authors have no conflicts of interest to declare.

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EFFECT OF STANDING AND SITTING POSTURES ON THE ANGLE OF TRUNK ROTATION IN PATIENTS WITH ADOLESCENT IDIOPATHIC SCOLIOSIS

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ABSTRACT

Objective: The objective of this study was to evaluate the immediate effect of relaxed and corrected posture applied while sitting and standing on the angle of trunk rotation (ATR) in adolescent idiopathic scoliosis (AIS) patients.

Materials and Methods: The study included 38 patients with AIS. Corrected sitting and standing postures were taught according to the Schroth Best Practice® method, and patients were asked to sit/stand for 5 min. ATR was measured using a scoliometer before and after four postural positions: relaxed sitting and standingand corrected sitting and standing.

Results: The mean age of the participants was 14 years, the Cobb angle was 28.63°, and the ATR was 8.14°. Baseline ATR values increased after relaxed sitting and standing postures and decreased after corrected sitting and standing ($p<0.001$). Improvements in corrected sitting were superior to corrected standing ($p<0.001$). ATR values increased more in relaxed sitting than in relaxed standing ($p=0.008$).

Conclusion: The results showed that corrected posture might have a corrective effect on scoliosis curvature during activities of daily living (ADL). Integrating ADL adaptations into a rehabilitation program may help decrease asymmetric loading on the spine in growing adolescents with AIS.

Keywords: Adolescent idiopathic scoliosis, angle of trunk rotation, posture, activities of daily living

INTRODUCTION

Scoliosis, a three-dimensional deformity of the spine, can be differentiated from different etiologies, but the adolescent idiopathic form is the most frequently seen[1]. Adolescent idiopathic scoliosis (AIS) is a deformity of the trunk in otherwise healthy adolescents[2].

Conservative scoliosis treatment approaches mainly focus on stopping the progression of the curvature and improving the deformity by reversing the biomechanical factors, which are assumed to be the etiopathogenetic factors of scoliosis[3,4]. Although biomechanical theories vary, they address the ongoing effects of gravitational forces on the spine[5]. Gravitational forces act on the spine all day long, so conservative management of scoliosis should include correction techniques during the activities of daily living (ADL)[6-8]. The Schroth Best Practice® (SBP) program, one of the scoliosis-specific conservative methods, includes load modification protocols that allow patients to influence postural control through self-correction during various daily activities[6,9]. Self-correction is the transformation of the new/corrected posture into a natural one. This approach helps prevent the progression of scoliosis by not allowing increases in curvature or asymmetric loading during daily activities[3,4,7].

Studies investigating the effect of daily living activities in treating patients with AIS are limited. In a study by Weiss et al.[10], comparisons were made of the results of a 2-week activity of daily living (ADL)-based rehabilitation program and a 4-week exercise-based rehabilitation program in the treatment of patients with AIS. Similar results were reported to be obtained in both programs, but the ADL-based rehabilitation seemed to provide better time efficiency[10].

Relaxed postural habits in ADL in patients with AIS have been discussed in literature generally in terms of sitting and standing postures. In patients with AIS, hyperextension of the upper thoracic region due to standing in a relaxed posture may increase, and the degree of curvature may increase accordingly[11]. It has been stated that the relaxed sitting

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posture increases the curvature similar to that of the standing posture[11,12].

There are no studies examining the changes in the spine during standing and sitting in the corrected posture in patients with AIS. With the current increased use of technology, increased sedentary behaviors and sitting times, especially in children, have also become a problem[13]. Therefore, this study aims to assess the immediate effect of the relaxed and corrected posture applied in sitting and standing daily living activities to prevent the progression of scoliosis.

MATERIALS AND METHODS

Study Design

This cross-sectional study included individuals with AIS who presented at the Physiotherapy and Rehabilitation Department of Bandırma Onyedi Eylül University between December 2021 and March 2022.

This study was approved by the Bandırma Onyedi Eylül University Ethics Committee (study number: 2021-61, date: 12.11.2021, no: 2021-29).

Participants

The study inclusion criteria were defined as age >10 years and a diagnosis of AIS with a Cobb angle of >10°. Patients were excluded from the study if they had non-idiopathic scoliosis, any contraindications for exercise, a history of spinal surgery, apex ≥T6, any chronic disease that required neurological or psychiatric medication, or any mental problems.

Variables

The demographic characteristics of the participants were recorded, including age, gender, weight, height, age at first diagnosis, exercise habits, current treatments, and brace use.

The degree of curvature in the coronal plane was assessed radiographically using the Cobb method[14]. The Risser sign was used to determine the age of bone development[15]. The Cobb angle and Risser sign were obtained from X-ray measurements, routinely required for the diagnosis of AIS, so no new X-rays were requested. The Cobb method is the gold standard for measuring curvature[16]. However, the angle of trunk rotation (ATR) measurement can be used in clinical devices as a safe and reliable alternative to serial radiographs[17]. The degree of trunk rotation correlates with the Cobb angle[18,19]. Therefore curvature status can be assessed by Scoliometer measurements of the trunk rotation angle, which are reliable and repeatable up to 3°[17]. In this study, the ATR measurement was made with a Scoliometer®[20]. Each patient was evaluated by the same experienced therapist. The therapist stood behind the patient for the standardization of the measurements. He/she was asked to bend forward until the scapulae aligned with the pelvis. Care was taken not to flexion the knee. The children's feet were open until the therapist's feet intervened and parallelled each other. The maximum value was recorded as the definition of the ATR measurement, and no marking was defined for it. Therefore, the maximum value was taken before and after each posture on the same day following the same procedure[21]. The ATR measurement was performed on the same day, before and after each intervention by the same researcher. The value measured before relaxed and corrected postures was recorded as baseline ATR.

Augmented Lehnert-Schroth (ALS) classification was used to describe the curve type. According to the ALS classification, the 3CH (functional three curves, hip protrusion), 3CTL (functional three curves, thoracolumbar with hip protrusion), 3CN (functional three curves, neutral with the balanced pelvis), 3CL (functional three curves with the long lumbar counter curve), 4C (functional four curves, double major), 4CL (functional four curves with single lumbar) and 4CTL (functional four curves with single thoracolumbar)[4,22]. Functional 3-curve patterns primarily define thoracic curves, and functional 4-curves represent double major or single lumbar and thoracolumbar curves and additional lumbosacral curves[4,22,23].

Intervention/Experimental Design

After the demographic and clinical evaluation, adolescents were requested to sit in a chair in a relaxed and comfortable position that they would normally adopt during the day and to hold this position for 5 minutes (Figure 1a). To evaluate standing, the adolescent was asked to stand in the position that she/he was used to during the day and to hold that position for 5 minutes (Figure 2a).

Then, the participants were asked to sit for 5 minutes in the corrected posture, which had been taught specifically for their curve pattern. The patients were requested to stand in a corrected posture for 5 minutes for the standing task. The corrected sitting and standing postures were applied according to the curve patterns defined in the daily living activities education, which is one of the components of the SBP program. The Schroth-based SBP program has been under development since 2004[4]. For all 3-curve patterns, the corrected movement for sitting and standing postures is described as "lowering the shifted pelvis (thoracic concave side) and translating the thoracic spine to the side of concavity" (Figures 1b, 2b)[6]. In addition to the 3-curve pattern, in the 3CH pattern, the convex side leg crosses the concave leg to strengthen the pelvic tilt in a corrected sitting position and the convex side knee semi-flexion in a corrected standing position. In the 3CN pattern, the concave leg crosses the convex leg, or both feet rest on the floor to strengthen pelvic glide and prevent pelvic tilt in a corrected sitting position[4]. For 4-curve patterns, the corrected movement for sitting and standing posture is described as lowering the shifted pelvis (thoracic convex side) and translating the thoracic spine to the side of concavity[6]. In addition to the 4-curve pattern, in the 4CL pattern, the concave-side pelvis is shifted by the ipsilateral knee semi-flexion during corrected standing, while the lumbar concave side is shifted by the concave-side pelvis tilt while in a corrected sitting position. Since the curvature

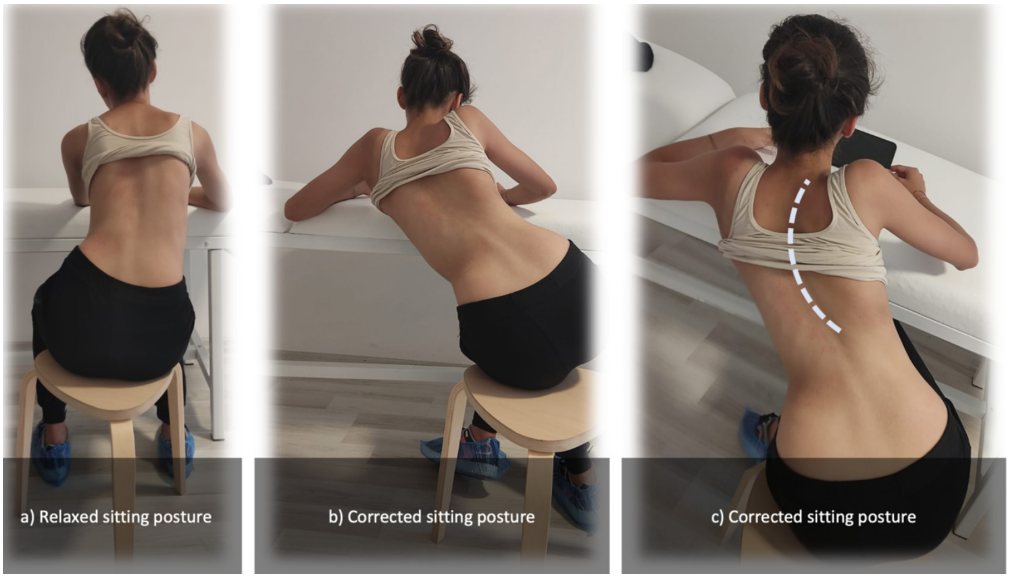

Figure 1. Sitting posture **a)** relaxed sitting posture, **b, c)** corrected sitting posture

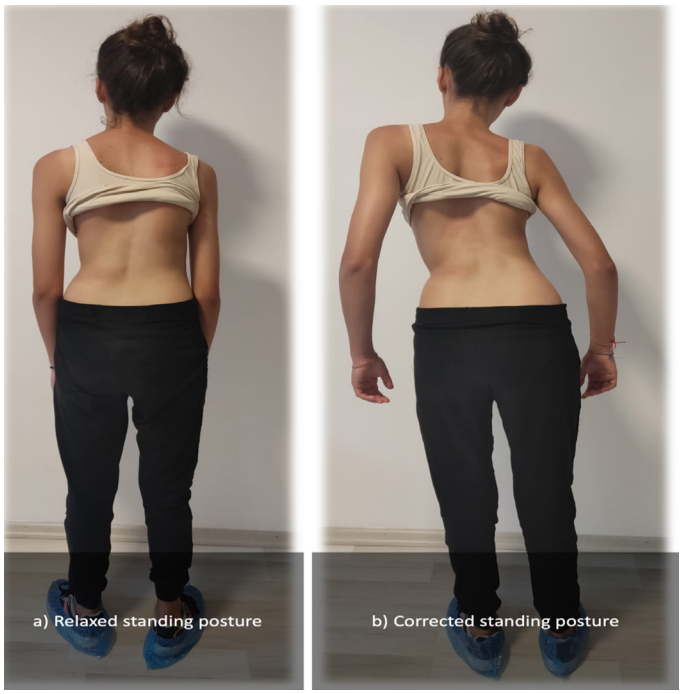

Figure 2. Standing posture **a)** relaxed standing posture, **b)** corrected standing posture

pattern is the only major curvature pattern in the 3CTL and 4CTL patterns, the same corrections in the 3C pattern were applied[4].

Between all conditions, a rest period of 10-15 minutes was given. In all postural conditions, the patients were asked to watch a video on a mobile phone or read a book to simulate an environment close to daily habits. After 5 minutes of sitting or standing respectively, trunk rotation was measured three times, and the average value was re-recorded.

Statistical Analysis

IBM SPSS Statistics version 23 software was used to analyze the data obtained in the study statistically (IBM Corp., Armonk, NY, USA). The normality of the data was checked with the Shapiro-Wilks test; the data was found to show heterogeneous distribution. Descriptive statistics were reported as mean, standard deviation, range, minimum, and maximum values. The Wilcoxon signed-rank test was used to evaluate the changes from baseline in each postural condition, and the Mann-Whitney U test was applied in the comparisons of the differences between the different postural conditions. The relationships between Cobb angle, ATR, and age were evaluated with the Spearman correlation test. A value of $p<0.05$ was deemed statistically significant for all tests.

RESULTS

Participants and Sample Characteristics

From a total of 41 patients evaluated, 38 patients with a mean age of 14 years were included in this study. The mean Cobb angle was 28.63°, the mean ATR was 8.14°, and the mean Risser grade was 2.80 (Table 1). The curvature pattern in 16 subjects (57.9%) was functional 3-curve (major thoracic), and in 12 (42.1%) was functional 4-curve (major lumbar/double major).

Comparison of Baseline and After the Postural Conditions

A significant increase was determined from the baseline ATR values after relaxed habitual sitting and habitual standing postures ($p<0.001$). There was a statistically significant decrease in ATR values after corrected sitting and standing postures ($p<0.001$), which indicated improvement in the deformity (Table 2).

Table 1. Demographic characteristics of the participants

Variables	Frequency n (%)
Gender	Female - 26 (68.4%) Male - 12 (31.6%)
Risser grade	Risser 0- 5 (13.20%) Risser 1- 4 (10.50%) Risser 2- 6 (15.80%) Risser 3- 8 (21.10%) Risser 4- 7 (18.40%) Risser 5- 8 (21.10%)
	Mean ± SD (min-max)
Age (years)	14.07±2.57 (10-20)
Heigh (cm)	164.10±9.04 (146-184)
Weight (kg)	51.05±14.63 (31-104)
Cobb angle (°)	28.63±9.69 (12-60)
ATR (°)	8.14±4.20 (2-23)

SD: Standard deviation, Min: Minimum, Max: Maximum °: Degree, cm: Centimeter, kg: Kilogram, %: Percentage

Table 2. Changes in ATR values in sitting and standing postures

ATR values	Sitting position Mean ± SD Min-max	Standing position Mean ± SD Min-max
After relaxed posture	9.86±4.38 3.50-25.00	9.30±4.32 3.50-25.00
After corrected posture	5.25±3.95 1.00-20.00	6.28±4.22 1.00-23.00
Mean difference Relaxed-corrected posture	-4.61±1.73 (-2 - -10.00)	-3.01±0.94 (-4.50 - -1.00)
P value Relaxed-corrected posture	**<0.001****[b]	**<0.001****[b]
Mean difference Baseline-relaxed posture	1.70±1.05 1.50 (0 - 5.00)	1.15±0.98 1.00 (0-3.50)
P value Baseline-relaxed posture	**<0.001****[a]	**<0.001****[a]
Mean difference Baseline-corrected posture	-2.89±1.55 -3.00 (-7.00 - 0)	-1.85±1.08 -2.00 (-4.50 - 0)
P value Baseline-corrected posture	**<0.001****[a]	**<0.001****[a]

[a]Wilcoxon signed-rank test,[b]Mann-Whitney U test, **p<0.001
SD: Standard deviation, Min: Minimum, Max: Maximum, ATR: Angle of trunk rotation

Comparison of Relaxed and Corrected Postural Conditions

There was a statistically significant difference in ATR values obtained in relaxed and corrected sitting and standing postures (p<0.001) (Table 2).

Comparison of Sitting and Standing Postural Conditions

Significantly greater improvements were determined in the corrected sitting postures compared to the corrected standing postures (p<0.001). The ATR values increased more in relaxed sitting posture than in relaxed standing (p=0.008).

Comparison of ATR Values According to Gender and Age Groups

When the participants were separated into two groups according to the curve patterns (functional three and functional four curve patterns) and compared, the differences obtained in ATR values after corrected sitting and standing postures were similar (p>0.05). The ATR values were similar when the subjects were compared according to gender and age groups of younger and older than 14 years (p>0.05).

DISCUSSION

The aim of this study was to evaluate the acute effect of corrected ADL on the ATR in patients with scoliosis. The results showed that sitting and standing in the habitual relaxed posture in the short-term negatively affected ATR. Short-term sitting and standing in the corrected posture significantly improved the ATR, indicating an immediate improvement of the deformity.

In individuals with scoliosis, postural changes are seen in the head, shoulder, scapula, waist, and pelvis according to the curvature pattern[23]. When scoliosis patients are standing, the pelvis shifts to the thoracic concave side in a 3-curve curvature pattern, while in a 4-curve, the pelvis shifts to the thoracic convex side[6]. Patients with AIS also tend to carry more weight on one leg than the other[23]. These postural changes continue during ADL, leading to asymmetrical loading on the growing spine.

In general, conservative scoliosis treatment approaches are supposed to reduce or eliminate the asymmetrical loading on the spine[4,23]. Asymmetrical loading is based on the Hueter-Volkmann Law and the "vicious cycle" concept. The Hueter-Volkmann Law states that increased mechanical compression acting on growth plates impairs skeletal growth, and reduced loading increases skeletal growth[3].

Asymmetric loading increases asymmetric development/growth, which increases spinal curvature by increasing asymmetric bone and disc development. This cycle continues naturally or until it is stopped externally[3,24]. Therefore, the asymmetrical load that occurs during ADL (sitting/standing) can increase the curvature according to this principle, and regulating daily activities in a corrected posture can reduce the curvature.

There is a current increase in sedentary lifestyles, including screen time, leisure time, and school and homework, in children and adolescents[13]. Sitting and standing are important because asymmetric sitting postures may foster the progression of spinal curvatures[25]. Previous studies have reported increased curvature in relaxed sitting and standing postures[11,12]. This study observed an increase in trunk rotation angle after short-term relaxed sitting and standing postures, similar to the literature[11,12].

In this study, the degree of trunk rotation was investigated with Scoliometer. Smidt et al.[12] compared the sitting position of individuals with scoliosis and healthy individuals with a non-invasive computer model. They reported that while sagittal plane changes were similar, lateral curvature increased while sitting in individuals with scoliosis[12]. Gram and Hasan[11] evaluated the apex angle in sitting comfortably and standing upright and placed markers at the upper end, apex, and lower end of the curve, as well as on the vertebrae at C7 and S1. With this method, the front plane apex angle and lateral slope were measured. However, the current study did not measure the change in frontal correction. Since lateral flexion and rotation occur together due to the double movement of the spine[26], only the amount of trunk rotation was measured in this study. The Cobb method is the gold standard for measuring lateral spinal curvature magnitude[16], and the degree of trunk rotation correlates with the Cobb angle[18,19]. Therefore measurement of the ATR can be used in clinical devices as an alternative to serial radiographs[17]. Although there are differences in the evaluation parameters used in previous studies, the application times of relaxed sitting and standing postures were similar[11,12]. In the current study, it was determined that the maximum ATR value measured after sitting in the relaxed posture was higher than in the relaxed standing posture. The ATR value measured at the baseline decreased more with the corrected sitting than with the standing posture. This result may be due to the activation of different muscles in sitting and standing[27,28] and changes in the pelvis and sagittal plane of the spine. This issue can be addressed in future studies.

Gram and Hasan[11] stated that patients with single, either thoracic or lumbar curvature tend to move laterally to the convex side. Subjects with double curvature tend to move to the convexity of the lumbar curvature in all postures except relaxed sitting, thus reducing the angle of the lumbar apex and exacerbating the thoracic angle. The improvements obtained in the corrected sitting and standing postures in the current study were similar for both the three and four-functional curve patterns. Since the number of cases with different curvature patterns according to the ALS classification was small, no further analysis was performed according to the curve patterns. According to the SBP® method, corrected ADLs are applied according to the individual's curve pattern. Hence, patients learn to oto-correct and decrease asymmetric loading on the spine, particularly in the frontal plane in both static and dynamic postures[4]. In the current study, there was observed to be a significant decrease in ATR values after sitting and standing in corrected postures, which were taught as described in the SBP approach. To the best of our knowledge, no study in the literature has investigated the immediate or long-term effects of sitting and standing in the corrected posture according to the curve pattern. Weiss et al.[10] compared the results of a 2-week ADL-based rehabilitation program and a 4-week exercise-based SBP rehabilitation program. It was reported that the improvements were similar in the two groups, but ADL-based rehabilitation seemed to provide better time efficiency[10].

Study Limitations

The measurement of changes in the spine only with the degree of rotation can be considered a limitation of this study. Another limitation is that only a short-term improvement of the ATR is demonstrated with ADL postures. There is a need for further studies to evaluate the effect of prolonged corrected ADL postural rehabilitation to reach a well-balanced stance with different objective outcome measures. The clinical implication might be that sitting and standing postures during ADL affect

the curvature in patients with AIS. This finding might have important clinical implications for more emphasis on ADL education in rehabilitation programs and regular follow-up of ADL habits in patients with AIS. However, corrected ADL exercises need to be integrated into 3-dimensional with a well-balanced corrected posture. Postural compensations that may occur during ADL, can be corrected by therapists more frequently checking how individuals with scoliosis perform their ADL activities during each therapy session. Also, it can be recommended that the different behavior of curvature patterns is examined in daily living activities in future studies with larger sample sizes.

CONCLUSION

The results of currents study showed that short-term sitting and standing in the corrected posture significantly improved the trunk rotation in patients with AIS, indicating an immediate improvement. Integrating ADL adaptations in a rehabilitation program may help decrease asymmetric loading on the spine in growing adolescents with scoliosis. Future studies are still needed to evaluate the long-term effects of these corrected exercises on posture and scoliotic curves.

Ethics

Ethics Committee Approval: This study was approved by the Bandırma Onyedi Eylül University Ethics Committee (study number: 2021-61, date: 12.11.2021, no: 2021-29).
Informed Consent: Informed consent was obtained from all parents and patients.
Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: B.A., T.K.Ç., Concept: B.A., T.K.Ç., Design: B.A., T.K.Ç., A.A., Data Collection or Processing: B.A., Analysis or Interpretation: B.A., T.K.Ç., A.A., Literature Search: B.A., T.K.Ç., A.A., Writing: B.A., T.K.Ç., A.A.
Conflict of Interest: The authors have no conflicts of interest to declare.
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AREA MEASUREMENTS WITHIN THE FORAMEN MAGNUM: COMPARISON OF 171 PATIENTS WITH SYMPTOMATIC AND ASYMPTOMATIC CHIARI MALFORMATION TYPE 1

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ABSTRACT

Objective: In previous studies, different radiological measurement techniques could not reliably distinguish patients with symptomatic Chiari type 1 malformation (CMI) from those with asymptomatic CMI. We aimed to develop a new perspective to select patients with CMI for surgery by calculating the brainstem area (BA), cerebellar tonsillar area (CTA), foramen magnum area (FMA), and CTA/BA ratio in T2 MR axial imaging at the foramen magnum level.

Materials and Methods: Eighty six symptomatic and 85 asymptomatic patients evaluated by neurosurgeons were included in the study. The patients' BA, CTA, FMA, and CTA/BA ratios were calculated by two neuroradiologists. In addition, the measurements of the operated patients in the postoperative period were re-made, and the pre-operative and postoperative measurements were compared.

Results: The mean BA was 1.57 cm^2 and 1.76 cm^2 in symptomatic and asymptomatic patients, respectively ($p<0.05$). The cut-off value between symptomatic patients with BA and asymptomatic patients was 1.74 cm^2. The results of our study were found to be statistically significant in such a way that BA measurements can show the amount of compression on the brainstem. The mean postoperative BA (1.73±0.32) was higher than the mean pre-operative BA (1.58±0.35; $p<0.001$). There was no difference between the mean postoperative BA of symptomatic patients (1.73±0.33) and the mean BA of asymptomatic patients. Symptomatic patients' CTAs were wider than asymptomatic patients. In addition, FMA was different between symptomatic and asymptomatic patients ($p<0.001$).

Conclusion: BA and FMA may provide a new perspective on the distinction between symptomatic and asymptomatic CMI.

Keywords: Chiari type 1 malformation, brainstem, symptomatic, asymptomatic

INTRODUCTION

According to imaging-based prevalence studies, Chiari type 1 malformation (CMI) affects between 0.24% and 3.6% of the population[1]. This heterogeneous abnormality is characterized by impaired cerebrospinal fluid (CSF) circulation through the foramen magnum[2]. While cerebellar tonsillar herniation is part of CMI's definition, numerous studies indicate a weak correlation between the degree of cerebellar tonsil herniation and the manifestation of clinical symptoms such as syringomyelia[3]. Prior research has further demonstrated that patients with a lesser degree of tonsillar herniation could exhibit severe clinical symptoms, whereas those with a higher degree may remain asymptomatic[4,5].

Herniation of cerebellar tonsils within the foramen magnum impedes CSF flow, leading to Valsalva-induced headaches and syrinx formation[6,7]. Additionally, herniated cerebellar tonsils can compress the cervicomedullary junction and lower cranial nerves, potentially causing dysphagia, sleep apnea, and a loss of gag reflex[8]. Surgical indications for CMI are primarily driven by the patient's clinical symptoms[9]. Undoubtedly, a case of syringomyelia and CMI presenting with pyramidal signs necessitates surgical intervention[3]. However, the role of surgery in cases featuring only headaches or asymptomatic syringomyelia remains less clear. Extensive studies have explored the significance of radiological measurements of the foramen magnum in making surgical decisions for CMI patients[4,9-12]. Nevertheless, the symptoms of CMI are primarily caused by the compression of cerebellar tonsils on the brainstem and increased CSF pressure at the foramen magnum[9]. Headaches are more likely to occur due to dural stretch when the tonsils constrict the foramen magnum during Valsalva maneuvers[13]. Consequently, symptoms such as headaches from dural pressure and swallowing, respiratory distress, or sensory disorders due to brainstem pressure are often accompanied by an increase in pressure at the level of the foramen magnum in symptomatic cases.

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We hypothesize that measuring brainstem compression could serve as a reliable criterion for determining surgical indications in these patients. The objective of this study is to offer a new perspective for selecting CMI patients for surgical intervention. We aim to calculate the brainstem area (BA), cerebellar tonsillar area (CTA), foramen magnum area (FMA), and the ratio of cerebellar tonsil area to BA, using T2 axial imaging that passes through the McRae line at the foramen magnum (Figure 1).

MATERIALS AND METHODS

Method and Data Collection

We conducted a retrospective analysis of all patients diagnosed with CMI at our clinic between January 2011 and January 2021. Within this period, a total of 171 patients (86 symptomatic and 85 asymptomatic) who underwent evaluations by neurosurgeons at our facility were included in the study. Those who underwent surgical intervention for CMI were classified as symptomatic. A comprehensive search was conducted for all MR images of the brain and cervical spine in our institution's imaging report database, using the keywords "Chiari", "syringomyelia", and "syrinx". This search was intentionally broad to minimize the risk of overlooking relevant records. The initial search results were manually reviewed, and patients were excluded if their records showed a tonsillar herniation of less than 5 mm or the presence of other pathologies.

Patients were classified as clinically asymptomatic if they met the following criteria:

- No observable signs or symptoms of tonsillar herniation. Symptoms associated with CMI include Valsalva-induced occipital headaches, neck pain, central sleep apnea, extremity numbness or paresthesias, dysphagia, impaired fine motor skills, and gait disturbances.
- Lack of symptoms related to CMI as confirmed by two neurologists at our hospital.

For all qualifying patients, a supplementary review of all hospital documents, including admission notes, surgical notes, and radiological and imaging studies, was conducted to ensure no exclusion criteria were missed. Patients who met all criteria were deemed clinically asymptomatic.

After exclusions, two groups were formed: A symptomatic group of 86 patients and an asymptomatic group of 85 patients. Radiographic CMI was defined as cerebellar tonsillar herniation extending at least 5 mm below the foramen magnum in all subjects. Patients with intracranial mass lesions or a history of cranial or spinal surgery were excluded from the study.

Magnetic resonance imaging (MRI) scans were performed using 1.5-T (Magnetom Aera, Siemens, Erlangen, Germany) and 3-T (Magnetom Skyra, Siemens, Erlangen, Germany) scanners. Intravenous gadolinium was not routinely administered. Both T2-weighted sagittal and axial images and T1-weighted sagittal images were obtained.

All images were stored in a separate offline workstation (Syngo via Version VB30A, Siemens). Measurements were independently conducted by two neuroradiologists who were blinded to the patients' treatment status. The cerebellum, brainstem, and FMA at the level of the foramen magnum were measured using T2 axial imaging that passed through the McRae line at the foramen magnum (Figure 1). The CTA/BA ratio was also calculated. The extent of tonsillar herniation was determined based on T2-weighted MRI in the sagittal plane, marked by drawing a vertical line from the McRae line to the tip of the lower cerebellar tonsil.

This study was conducted with the approval of the Ethics Committee of Selçuk University Faculty of Medicine (decision no: 2021/189, date: 07.04.2021).

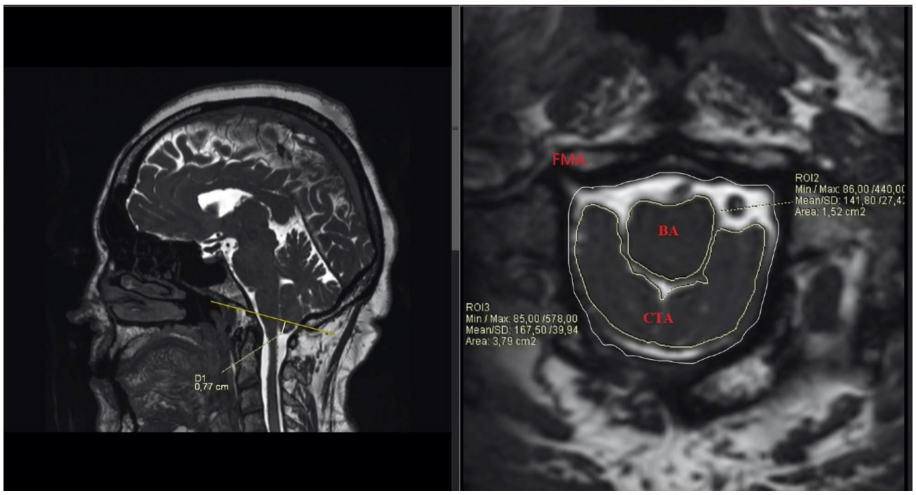

Figure 1. Measurements at the level of the foramen magnum
The brainstem area (BA), cerebellar tonsillar area (CTA), and foramen magnum area (FMA) are delineated. BA represents the area of the brainstem, and CTA represents the area of the cerebellar tonsils, both measured at the level of the foramen magnum. FMA indicates the overall area of the foramen magnum

Statistical Analysis

All data were evaluated using the Statistical Package for the Social Sciences (SPSS) 22.0 statistical package and presented as numbers, percentages, means, and standard deviations. Kurtosis and skewness values were assumed to be normal variances between -1.5 and +1.5[14]. Using multivariate statistics (Boston, Pearson), an intergroup chi-squared test was performed on categorical data frequency distribution. Student's t-test was used to compare the measurements of two distinct groups for a particular variable. A paired sample t-test was used to compare the mean values of a group or sample for a variable at two different times. Receiver operating curve analysis was performed to determine the cutoff value for all parameters. The highest sum of sensitivity and specificity values was used as the optimum cutoff value. A p value of <0.05 was considered statistically significant.

RESULTS

A total of 171 patients were included in the study, with a mean age of 39.85±13.49 years, ranging from 18 to 71 years. The patient population comprised two groups: 50.3% (n=86) were symptomatic, and 49.7% (n=85) were asymptomatic. Gender distribution was 29.8% male (n=51) and 70.2% female (n=120), with no statistically significant differences between the symptomatic and asymptomatic groups (p=0.376).

The mean BA were 1.57 cm^2, 1.76 cm^2 in symptomatic patients, in asymptomatic patients, respectively (p<0.05). The cut-off value for BA between the two groups was determined to be 1.74 cm^2 (p<0.05). CTA showed mean values of 4.23 cm^2 in symptomatic patients and 4.62 cm^2 in asymptomatic patients (p<0.05). No statistically significant difference was observed in the ratio of CTA to BA between the two groups (Table 1 and Figure 2). FMA showed mean values of 7.45 cm^2 and 11.03 cm^2 in symptomatic and asymptomatic patients, respectively (p<0.001).

The mean postoperative BA (1.73±0.32) was higher than the mean pre-operative BA (1.58±0.35; p<0.001). There was no difference between the mean postoperative BA of symptomatic patients (1.73±0.33) and the mean BA of asymptomatic patients (1.76±0.466; p=0.602; Table 2).

Among males, the mean BA were 1.67 cm^2, 1.89 cm^2 in symptomatic patients, in asymptomatic patients, respectively (p<0.05). The mean CTA were 4.28 cm^2, 4.89 cm^2 in symptomatic patients, in asymptomatic patients, respectively (p>0.05; Table 3). Among females, the mean BA were 1.54 cm^2, 1.69 cm^2 in

Table 1. Comparison of BA, CTA, CTA/BA, FMA between symptomatic and asymptomatic patients

Area (cm^2)	Patient	n	Mean	SD	p
BA	Symptomatic	86	1.57	0.35	**0.004**
	Asymptomatic	85	1.76	0.46	
CTA	Symptomatic	86	4.24	1.1	**0.028**
	Asymptomatic	85	4.62	0.18	
CTA/BA	Symptomatic	86	2.79	0.92	0.85
	Asymptomatic	85	2.76	0.9	
FMA	Symptomatic	86	7.45	1.28	**<0.001**
	Asymptomatic	85	11.03	1.59	

BA: Brainstem area, CTA: Cerebellar tonsillar area, FMA: Foramen magnum area, SD: Standard deviation

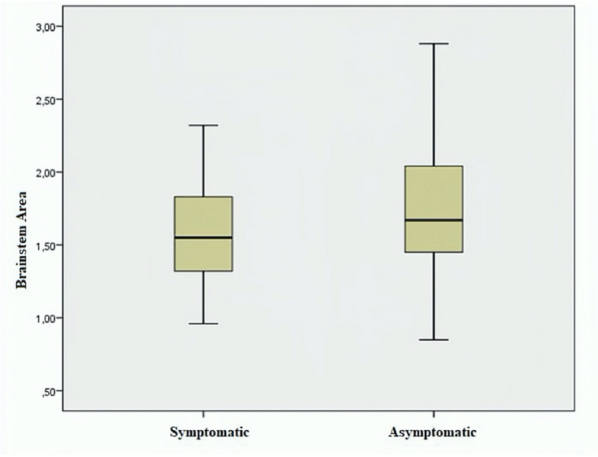

Figure 2. Comparison of BA between symptomatic and asymptomatic patients
BA: Brainstem area

Table 2. Comparison of BA of pre-operative and post-operative patients and post-operative and asymptomatic patients

Area (cm^2)	Mean	n	SD	p
Pre-op BA	1.58	86	0.35	**<0.001**
Post-op BA	1.73	86	0.32	
Area (cm^2)	Mean	n	SD	p
Post-op BA	1.73	86	0.32	0.6
Asymptomatic BA	1.76	85	0.46	

BA: Brainstem area, SD: Standard deviation

symptomatic patients, in asymptomatic patients, respectively ($p<0.05$). The mean CTA were 4.22 cm^2, 4.48 cm^2 in symptomatic patients, in asymptomatic patients, respectively ($p>0.05$). In this study, the ratio of the CTA to the BA was not statistically significant between the two groups (Table 3).

The mean BA were 1.79 cm^2, 1.61 cm^2 in male, in female, respectively. The BA was statistically significantly higher in male patients than in female patients ($p=0.01$; Table 4). When asymptomatic patients were considered as a separate group, the BAs of males were larger than those of females ($p<0.05$) (Table 4).

DISCUSSION

Clinical Symptoms and Signs

CMI is known to induce an array of symptoms and radiological findings due to the herniation of cerebellar tonsils through the foramen magnum[15]. While the headaches experienced by patients are generally a result of dural stretching, other symptoms like respiratory distress and sensory issues often arise from brainstem compression[16,17]. However, existing literature has indicated a weak relationship between tonsillar herniation and these symptoms[3-5].

Our study introduces a new perspective concerning the tolerability of the brainstem to mechanical forces. The extent to which the brainstem can tolerate compression may be a pivotal factor in the onset of clinical symptoms. When this tolerance is exceeded, complications such as a decrease in interstitial fluid and thinning of the brainstem could manifest.

The Role of Radiological Findings in Clinical Decision-Making

Here, the relevance of radiological findings in the clinical decision-making process deserves exploration. Soft tissue density can be calculated by adding the areas of the brainstem and cerebellar tonsils and proportioning this sum to the FMA, as done by Fuell et al.[9]. However, this method does

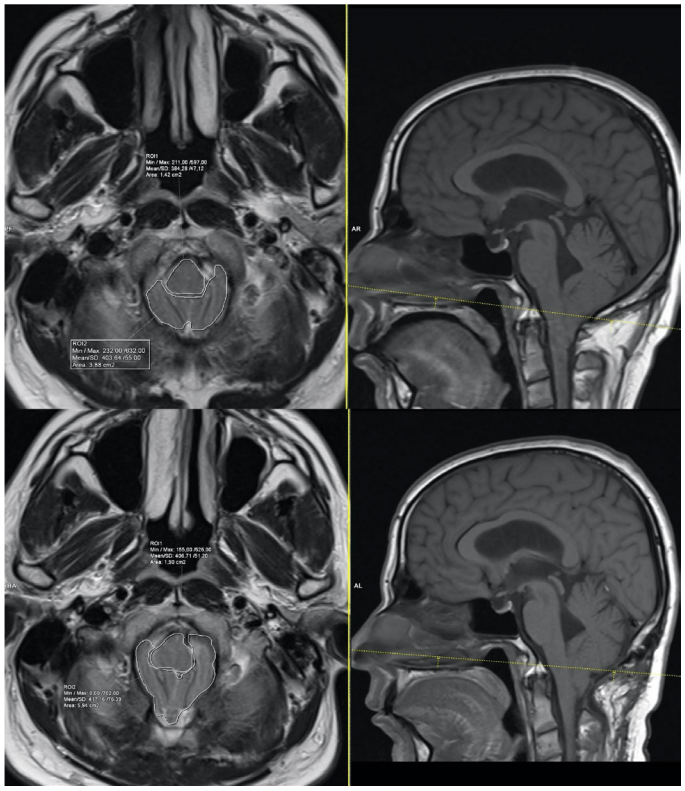

Figure 3. Preoperative and postoperative measurements changes
In a patient diagnosed with Chiari malformation type I (CMI), BA and CTA measurements were observed in pre-operative and post-operative MRI scans. In the pre-operative MRI, the BA was measured to be 1.42 cm^2, while the post-operative BA increased to 1.90 cm^2. Similarly, the pre-operative CTA was 3.88 cm^2 and expanded to 5.94 cm^2 in the post-operative MRI. Importantly, these measurements were taken at a consistent axial section level and angle in both pre-operative and post-operative scans
BA: Brainstem area, MRI: Magnetic resonance imaging, CTA: Cerebellar tonsillar area

Table 3. Comparison of symptomatic and asymptomatic patients according to gender groups BA, CTA, CTA/BA

	Area (cm^2)	Patient	n	Mean	SD	p
Male	BA	Symptomatic	23	1.67	0.35	**0.046**
		Asymptomatic	28	1.9	0.43	
	CTA	Symptomatic	23	4.28	1.17	0.11
		Asymptomatic	28	4.9	1.49	
	CTA/BA	Symptomatic	23	2.6	0.67	0.76
		Asymptomatic	28	2.69	1	
Female	BA	Symptomatic	63	1.55	0.34	**0.045**
		Asymptomatic	57	1.7	0.46	
	CTA	Symptomatic	63	4.22	1.07	0.16
		Asymptomatic	57	4.49	0.98	
	CTA/BA	Symptomatic	63	2.85	1	0.74
		Asymptomatic	57	2.8	0.84	

BA: Brainstem area, CTA: Cerebellar tonsillar area, SD: Standard deviation

Table 4a. Comparison of BA, CTA, CTA/BA between gender in all patients

Area (cm^2)	Gender	n	Mean	SD	p
BA	Male	51	1.8	0.41	**0.01**
	Female	120	1.61	0.41	
CTA	Male	51	4.62	1.39	0.161
	Female	120	4.35	1.03	
CTA/BA	Male	51	2.65	0.86	0.28
	Female	120	2.82	0.92	

BA: Brainstem area, CTA: Cerebellar tonsillar area, SD: Standard deviation

Table 4b. Comparison of BA, CTA, CTA/BA between gender in asymptomatic patients

Area (cm^2)	Gender	n	Mean	SD	p
BA	Male	28	1.9	0.43	**0.049**
	Female	57	1.7	0.46	
CTA	Male	28	2.69	1	0.63
	Female	57	2.79	0.84	
CTA/BA	Male	28	4.9	1.49	0.13
	Female	57	4.5	0.98	

BA: Brainstem area, CTA: Cerebellar tonsillar area, SD: Standard deviation

not account for the subarachnoid space. The significance of the subarachnoid space for potential complications like syringomyelia has been shown by Taylor et al.[10]. Nonetheless, this approach is not appropriate for patients who have not yet developed syrinx.

Comprehensive Methodological Approaches and Findings

In our study, we focused on three primary scenarios regarding the pressure exerted on the brainstem:

- Radiological differences in the brainstem between symptomatic and asymptomatic patients with CMI,
- Changes in the brainstem following foramen magnum decompression in symptomatic patients with CMI,
- Measurable radiological differences in the FMA between symptomatic and asymptomatic patients with CMI.

Under these scenarios, measurements of BA could indicate the amount of compression exerted on the brainstem. Specifically, we found that the BA was significantly smaller in symptomatic patients (p=0.004) and observed a significant increase in BA postoperatively (p<0.001). This result has been reported for the first time in the literature. After reviewing the pathophysiology, the cerebellar tonsil, which should not be normally present at the foramen magnum level in patients with CMI, begins to cover a specific area in patients with CMI. When cerebellar tonsil herniation worsens, the pressure increases and the volume of interstitial fluid in the brainstem reduces to tolerate the increased pressure[18,19]. Because there are connections between CSF and interstitial fluid and they work together on management of intracranial pressure[10,19,20]. The interstitial fluid is withdrawn by moving to the cranial and caudal sides. For all abovementioned reasons, we believe that interstitial fluid loss in the brainstem at the foramen magnum level may be one of the causes of BA thinning. The scarcity of studies on this topic in the literature is also notable. These data suggest that the tolerability of the brainstem to compression is a crucial factor in symptom development and surgical decision-making.

In the present study, FMA was higher in asymptomatic patients than in symptomatic patients (p<0.001). We believe that this explains why cerebellar tonsillar herniation length is not important in terms of symptoms or surgical decision making. Because of the larger FMA, the cerebellar tonsils do not put pressure on the brainstem and do not obstruct CSF circulation. As a result, they do not cause any symptoms[21].

A previous study identified no clinically useful 2D or 3D measurements that could reliably distinguish patients with symptoms attributable to CMI from patients with asymptomatic CMI[22]. However, area measurements were not performed in this study. Our study showed that BA and FMA measurements are very important in CMI. As in other recent studies, we state the necessity of area measurement studies at the level of the foramen magnum in CMI[9,10].

Age and Gender Factors

Previous studies have shown that the tolerability of brain tissue to mechanical forces can vary with age[21]. This could lead to the establishment of percentiles by measuring BAs in different age and gender groups. For example, we observed significant gender-based differences in BA (p<0.05) (Table 4).

Study Limitations

The main limitation of our study is the small sample size and retrospective design.

CONCLUSION

In summary, our study indicates that measurements of BA and FMA are critical in the diagnosis and treatment of CMI. However, future studies should validate these findings using more comprehensive methodologies. Specifically, more exhaustive methods that take into account the subarachnoid space and interstitial fluid dynamics should be developed.

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Ethics

Ethics Committee Approval: This study was conducted with the approval of the Ethics Committee of Selçuk University Faculty of Medicine (decision no: 2021/189, date: 07.04.2021).

Informed Consent: Retrospective study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: B.G., H.K., Concept: D.K.G., Design: D.K.G., Data Collection or Processing: B.G., H.C., Ö.F.T., Analysis or Interpretation: Ö.F.T., H.K., Literature Search: B.G., D.K.G., H.K., Writing: B.G., H.K.

Conflict of Interest: The authors have no conflicts of interest to declare.

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EVALUATION OF CLINICAL AND RADIOLOGICAL OUTCOMES IN DEGENERATIVE LUMBAR SPINE DISORDERS TREATED WITH PEEK ROD

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ABSTRACT

Objective: This study aimed to evaluate the clinical and radiological outcomes of patients undergoing transpedicular screw and polyetheretherketone (PEEK) rod stabilization for the surgical treatment of degenerative diseases of the lumbar spine.

Materials and Methods: A retrospective analysis was conducted on 51 patients diagnosed with degenerative spine disease, such as recurrent disc herniation, spinal stenosis, spondylolisthesis, and adjacent segment disease, who underwent bilateral transpedicular screw-PEEK rod stabilization between May 2017 and November 2020. Preoperative and postoperative assessments included lumbar lordosis angles, sacral slope, pelvic incidence, pelvic tilt, visual analog scale (VAS) scores, PROLO economic and social scores, and the presence of adjacent segments and fusion.

Results: The study included 51 patients with a mean age of 62.5 years (range: 18-85 years), with 56.8% (29 patients) being female and 43.2% (22 patients) being male. Surgical procedures involved single-level stabilization in 16 patients, two-level stabilization in 21 patients, three-level stabilization in 9 patients, and four-level stabilization in 5 patients. The mean follow-up period was 52.4 months. Postoperatively, there was a significant reduction in VAS scores from a mean of 8.2±1.3 to 3.4±1.7 ($p \leq 0.01$). No significant changes were observed in the lumbar lordosis angle, sacral slope, pelvic tilt angle, and pelvic incidence angle. The mean PROLO score improved from 3.5±1.2 preoperatively to 7.6±1.5 postoperatively. Fusion was observed in 43 patients during the follow-up period.

Conclusion: The use of PEEK rods in the surgical treatment of degenerative lumbar spine diseases may lead to improved postoperative quality of life and reduced implant-related complications. Furthermore, our findings suggest that patients without sagittal balance impairment may benefit from PEEK rod stabilization without significant changes in spinal alignment. However, further comparative and long-term studies are required to better understand the efficacy and outcomes of PEEK rod systems in this treatment approach.

Keywords: Degenerative lumbar spine, PEEK, dynamic stabilization, VAS, PROLO

INTRODUCTION

Degenerative lumbar spine diseases, such as spinal stenosis, disc degeneration, and spondylolisthesis, affect millions of people worldwide and can significantly impact their quality of life[1]. With the advancement of medical technology, various surgical interventions have been developed to alleviate symptoms and restore spinal stability. One such innovation is the use of polyetheretherketone (PEEK) rods in the treatment of these conditions[2].

PEEK, a high-performance polymer, has gained popularity in spinal surgery due to its biocompatibility, radiolucency, and mechanical properties resembling human bone[3]. The use of PEEK rods as an alternative to traditional metallic rods has shown promising results in the management of degenerative lumbar spine diseases. This article aims to provide an overview of the outcomes and clinical experiences associated with the utilization of PEEK rods in the treatment of these conditions.

The utilization of PEEK rod systems in spinal surgery gained Food and Drug Administration approval for transpedicular screw instrumentation as early as 2007. PEEK material exhibits minimal *in vivo* toxicity and possesses remarkable resistance to chemical and radiation damage[4]. In comparison to titanium rods, which have a high rigidity of 114 GPa, the less rigid PEEK rods with a stiffness of 3.2 GPa have demonstrated the ability to effectively distribute load-bearing forces. Additionally, PEEK rods have been suggested to enhance the rate of intervertebral bone fusion according to established principles[5]. Several studies in the literature have reported satisfactory fusion

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outcomes with the use of PEEK rod systems[6-8]. Nevertheless, the findings of these studies remain contentious due to limitations such as short follow-up durations, small sample sizes, and conflicting clinical results.

Rigid stabilization techniques in spinal surgery have been associated with a decrease in the range of motion of the spinal column, which can subsequently lead to increased stress on adjacent segments following the operation. This heightened stress on the bone-screw interface has been known to contribute to instrumentation issues and the development of pseudoarthrosis[9].

MATERIALS AND METHODS

In this retrospective analysis, conducted between May 2017 and November 2020, a total of 51 patients who sought treatment for degenerative spine disease and underwent bilateral transpedicular screw-PEEK rod stabilization were included. The patients were selected from Ankara Numune Training and Research Hospital, Ankara Bilkent City Hospital, and Marmara University Medical Faculty Neurosurgery Clinics. Ethical approval for this study was obtained from the Ankara City Hospital No. 2 Clinical Research Ethics Committee (decision no: E2-21-05, date: 10.03.2021).

Radiological and clinical data of the patients were collected retrospectively. The study specifically focused on patients diagnosed with degenerative spine diseases in the lumbar region, such as recurrent disc herniation, lumbar spinal stenosis, spondylolisthesis, adjacent segment disease, scoliosis, among others. Patients with active infection or pathological vertebral fractures, those with a body mass index exceeding 40 kg/m^2, and individuals diagnosed with ankylosing spondylitis were excluded from the study. Additional exclusion criteria included patients with a follow-up period of less than 12 months postoperatively or those lacking preoperative and postoperative visual analog scale (VAS) and PROLO scores.

In this article, various spinal and pelvic parameters, including lumbar lordosis, sacral slope, pelvic tilt, and pelvic incidence, were assessed and compared before and after surgery. These measurements play a crucial role in understanding spinal alignment and pelvic orientation. By comparing these measurements in the preoperative and postoperative periods, the authors can evaluate the effectiveness of surgical interventions and their impact on spinal alignment and pelvic orientation. This information is vital for tailoring treatment plans and ensuring optimal patient outcomes.

All surgical procedures were performed by experienced surgical teams at two different centers, with patients under general anesthesia and positioned prone, using a median midline skin incision. Nerve decompression and discectomy were performed as needed. Transpedicular titanium screws were inserted and verified with fluoroscopy during surgery. Subsequently, the levels with screw fixation were stabilized using a PEEK rod. The deliberate decision was made to steer clear of fusion procedures in order to maintain the innate mobility of the vertebrae. Instead, a dynamic stabilization approach was adopted. However, a one-level PEEK cage was employed to stabilize spinal movement in 14 patients with spondylolisthesis and to reinstate disc space in 9 patients with recurrent disc issues, a strategy recognized for enhancing the likelihood of achieving interbody fusion. Concurrently, autologous bone grafts were strategically placed at the bases of the screws to mitigate the risk of screw pull-out. The selection of autologous bone grafts included the utilization of bone graft material from the surgical site's vicinity in some instances, known as local bone grafting. This approach encompassed the use of bone that was extracted during spinal decompression or harvested from nearby anatomical structures. Additionally, in cases where a segment of a vertebra had been excised, this excised bone was repurposed as graft material through a technique referred to as vertebral body grafting. This multifaceted approach underscored the emphasis on both maintaining vertebral motion physiology and ensuring the structural integrity of the procedure.

In the context of lumbar spondylosis management, a precise surgical approach was undertaken involving medial facetectomy. It is important to note that a complete facetectomy procedure was not executed in any of the patients. This distinction in surgical methodology reflects the deliberate and tailored nature of the interventions employed, highlighting the clinical expertise and patient-centered care that guided the treatment decisions in this cohort.

An aspiration drain was placed at the surgical site, and following hemostasis, closure was performed in accordance with the anatomical plan. Postoperatively, patients received intravenous antibiotics for 24-48 hours. Mobilization of patients with a lumbosacral corset containing four steel underwires began at the 6th postoperative hour. Patients continued to use these corsets for approximately 3 weeks during mobilization.

Clinical evaluations of the patients were conducted using the VAS and PROLO economic and functional scoring systems. Retrospectively, preoperative and postoperative scores were collected from patient files. Radiological assessments included measurements of lumbar lordosis, sacral slope, pelvic tilt, and pelvic incidence angles, performed by two different individuals before and after the surgery. Additionally, postoperative computed tomography (CT) images were reviewed to evaluate screw loosening and fusion in patients.

A comprehensive radiologic imaging protocol was established for the postoperative monitoring of patients in this study. Specifically, radiologic imaging was performed on postoperative day 1, followed by a subsequent assessment at the first follow-up visit on postoperative day 45. Subsequently, additional assessments took place at the 6-month and 1-year milestones post-surgery. Beyond the first year, patients were scheduled for annual radiologic evaluations, unless they presented with any specific complaints or concerns warranting more frequent assessments.

Statistical Analysis

Statistical analysis was performed using two software packages: IBM SPSS 25.0 (Armonk, NY: IBM Corp.) and MedCalc 15.8 (MedCalc Software bvba, Ostend, Belgium). Descriptive statistics, such as frequency, percentage, mean, standard deviation, median, and minimum-maximum values, were calculated to summarize the data. To compare qualitative data, chi-square tests, including Pearson's chi-square test, Yates' Corrected chi-square test, and Fisher's Exact test, were utilized. The normality of data distribution was assessed using the Smirnov test, skewness-kurtosis analysis, and graphical methods such as histograms, Q-Q Plots, Stem-and-Leaf plots, and Boxplots. Independent Samples t-tests were employed for comparing normally distributed quantitative data between groups, while the Mann-Whitney U test was used for non-normally distributed data. The relationship between variables was examined using Spearman's rho Correlation test. A statistical significance level of p=0.05 was considered for all analyzes.

RESULTS

The study included a total of 51 patients with a mean age of 62.5 years (ranging from 18 to 85 years). Among the participants, 56.8% (29 patients) were female, and 43.2% (22 patients) were male. The diagnoses of the patient of 11 cases of adjacent segment disease, 14 cases of spondylolisthesis, 14 cases of lumbar spinal stenosis, 9 cases of recurrent disc herniations, and 1 case of instrument revision. In terms of surgical procedures, single-level stabilization was performed in 16 patients (one disc-2 vertebral segments), two-level stabilization in 21 patients, three-level stabilization in 9 patients, and four-level stabilization in 5 patients. In addition to the PEEK rod stabilization, intervertebral PEEK cage placement was performed in 23 cases. The patients were followed for a minimum of 32 months, with a mean postoperative observation period of 52.4 months. None of the cases required revision surgery. Two patients experienced dural injuries during the operation, which were not amenable to primary suturing. These injuries were managed by closure using fibrin tissue glue and muscle graft. No complications were observed during the postoperative wound follow-up, including wound infection or abscess formation in any of the patients (Table 1).

The preoperative mean VAS score, which measures pain intensity, was found to be 8.2±1.3. Moreover, postoperatively, there was a substantial reduction in pain, with the mean VAS score decreasing to 3.4±1.7. This change was statistically significant (p≤0.01), indicating that the surgical intervention effectively alleviated pain in the patients. Furthermore, the PROLO Economic and Functional Scoring system, which assesses the economic and functional aspects of treatment, demonstrated a significant improvement in patients' scores. The preoperative mean PROLO score was 3.5±1.2, whereas the postoperative mean score increased to 7.6±1.5 and it's statistically significant (p≤0.01), indicating positive outcomes in both economic and functional domains (Table 2).

Regarding the radiological parameters analyzed, there were no statistically significant changes in the mean lumbar lordosis angle, sacral slope, pelvic tilt angle, or pelvic incidence angle. The mean preoperative lumbar lordosis angle was 45.4, which increased slightly to 48.2 postoperatively (p>0.05). Similarly, there were minimal changes in the sacral slope (32.4 to 35.9), pelvic tilt angle (24.9 to 24.2), and pelvic incidence angle (58.2 to 56.4), all of which were not statistically significant (p>0.05) (Table 2). Also, no statistically significant difference were observed between the groups concerning etiologic parameters.

In 23 patients, a noteworthy approach was employed involving the application of single-level PEEK cages. These PEEK cages were exclusively utilized in patients requiring multilevel stabilization procedures, with a distinct focus on employing them solely for single-level applications. This distinctive approach underscores the commitment to preserving dynamic spinal function, even in cases where a single-level fusion was necessary. Consequently, this method prioritized dynamic stabilization across the entire spectrum of spinal stabilization needs, offering a comprehensive and patient-centered solution.

Upon conducting a thorough comparison between two distinct

Table 1. Patient characteristics

Parameter	Value
Total patients	51
Mean age	62.5 years (range: 18 to 85 years)
Gender distribution	Female: 56.8% (29 patients) Male: 43.2% (22 patients)
Diagnoses	- Adjacent segment disease: 11 cases - Spondylolisthesis: 14 cases - Lumbar spinal stenosis: 14 cases - Recurrent disc herniations: 9 cases - Instrument revision: 1 case
Follow-up period	Minimum: 32 months Mean: 52.4 months
Dural injuries	4 cases (managed with fibrin tissue glue and muscle graft)
Postoperative complications	2 cases (CSF fistula)

CSF: Cerebrospinal fluid

Table 2. Clinical and radiological findings

Measurements	Preoperative (mean ± SD)	Postoperative (mean ± SD)	P value
Lumbar lordosis	45.4±11.2	48.2±11.5	>0.05
Sacral slope	32.4±8	35±9.5	>0.05
Pelvic tilt angle	24.9±8.6	24.2±8.9	>0.05
Pelvic incidence	58.2±10.7	56.4±8.3	>0.05
VAS	8.2±1.3	3.4±1.7	≤0.01
PROLO	3.5±1.2	7.6±1.5	≤0.01

VAS: Visual analogue scale, SD: Standard deviation

groups, namely the single-level PEEK cage combined with multilevel PEEK rod group and the PEEK rod alone group, a noteworthy observation emerged. In all assessed parameters, no statistically significant differences were detected between these groups. This finding led to the considered conclusion that maintaining these groups as an undivided entity would not compromise the homogeneity of the study sample. Such a decision underscores the robustness of the study's design and ensures that the results are derived from a comprehensive and coherent dataset.

During the follow-up period, screw loosening was observed in four cases. Out of these, only one patient experienced symptomatic screw loosening, while the remaining cases were asymptomatic with only radiological evidence. Fortunately, no instances of rod breakage were reported throughout the follow-up period.

Additionally, fusion was observed in 43 cases during the follow-up period, indicating successful fusion at the treated segment. However, fusion was not yet observed in the facet joints in 8 cases, suggesting a need for further evaluation or longer follow-up to assess the fusion status in these areas.

Overall, the study demonstrated favorable surgical outcomes in terms of pain relief and functional improvement, as evidenced by significant reductions in VAS scores and improvements in PROLO scores. Although there were no significant changes in the analyzed radiological parameters. The occurrence of screw loosening was relatively low, with only one symptomatic case. These findings contribute to our understanding of surgical interventions for spinal disorders and highlight the importance of long-term follow-up to assess fusion and detect potential complications.

Early complications were detected in 7 instances. Among these, screw malposition was observed in four cases (7.8%) during the early period. Cerebrospinal fluid fistula occurred in 2 cases (3.8%), and 1 case (1.9%) necessitated reoperation. Late complications of adjacent segment disease in 7 cases (13.7%) and pseudoarthrosis in 9 cases (17.6%).

DISCUSSION

Lumbar degenerative disease commonly arises due to intricate degenerative conditions that exert pressure on the neural components. The alignment and inclination of facet joints are closely associated with disc degeneration in the lumbar spine[10]. In cases of mild lumbar stenosis, conservative treatment is typically initiated as the initial step, but its efficacy is limited due to symptom exacerbation during movement. However, in advanced cases, the degenerative process worsens neural stenosis, often necessitating surgical intervention. Microsurgery and lumbar stabilization using rigid and dynamic systems form the foundation of surgical treatment. Within our study, we conducted a comparison between preoperative and postoperative dynamic systems, evaluating clinical, radiological, and surgical complications. While there were no discernible differences between the two groups in terms of Lumbar Lordosis, Sacral Slope, Pelvic Tilt Angle, and Pelvic Incidence, statistically significant differences were observed in VAS and PROLO scores.

In the treatment of degenerative lumbar diseases, there has been a growing trend in utilizing semi-rigid materials like PEEK rods to assist fusion procedures. PEEK polymer possesses an elasticity similar to that of bone (17 GPa) and offers adequate rigidity for promoting bone fusion without exerting excessive stress on the spinal columns, unlike titanium rods. This characteristic makes PEEK rods a favorable choice for supporting fusion in recent years[11,12].

In a relevant clinical study by De Iure et al.[13], a retrospective analysis was performed on 30 cases who underwent stabilization utilizing a PEEK rod. The obtained clinical data during the 18-month follow-up period exhibited satisfactory outcomes. Similarly, Huang et al.[14] performed a prospective evaluation on 31 cases, similar to our study population, who underwent PEEK rod stabilization. The clinical data collected during the 24-month follow-up period showed favorable results, particularly in terms of Japanese Orthopaedic Association (JOA) and Oswestry Disability Index scores.

In a prospective study carried out by Qi et al.[6] in 2013, a comparison was made between posterior fusion surgery utilizing PEEK rods and surgery utilizing titanium rods. The study revealed positive changes in VAS and JOA scores in both groups. Moreover, no statistically significant difference was observed between the two groups regarding clinical outcomes. In the one-year follow-up, an absence of screw failure or pedicle fracture was observed in patients who underwent treatment with PEEK rods. Although PEEK rods possess a semirigid nature that carries a potential risk of pseudarthrosis, all patients treated with PEEK rods achieved interbody fusion. This successful fusion is likely attributed to the anterior column load sharing and intervertebral space self-compressing characteristics of PEEK rods. The primary objective of the surgery, achieving lumbar fusion, was accomplished with the utilization of PEEK rods, leading to significant improvement in clinical outcomes for these patients. This outcome demonstrates the feasibility and efficacy of employing PEEK rods in surgical interventions. However, it is important to note that a loss of disc space height was observed during the follow-up period in the PEEK group. Nevertheless, PEEK rods effectively maintained lumbar lordosis and disc space height, meeting the required criteria. Overall, these findings highlight the potential of PEEK rods as a valuable modality in achieving successful lumbar fusion and improving patient outcomes.

These findings support the growing body of evidence highlighting the effectiveness and comparable clinical outcomes of PEEK rod stabilization in spinal surgeries. The utilization of PEEK rods presents a promising option for achieving satisfactory clinical results in patients undergoing spinal stabilization procedures. Further research and larger-scale studies are warranted to validate these findings and explore additional long-term outcomes.

One argument against non-fusion procedures is the potential risk of implant failure. However, in our study, three-dimensional CT scan reconstructions revealed no instances of rod breakage. This suggests that PEEK rod systems offer superior implant safety compared to pedicle-based dynamic stabilization procedures, as previous studies have indicated that screw loosening is a common complication in such procedures[15]. The use of PEEK rod systems has been shown to reduce the likelihood of implant failure, including screw loosening. This has been supported by cadaveric testing[16] and finite element studies[17], which have demonstrated optimized load sharing and reduced stress at the bone-screw interface with PEEK rods. While this study demonstrated statistical improvement in VAS and PROLO scores, it remains uncertain whether these results were solely attributed to posterior segmental stabilization or nerve decompression. Nonetheless, the utilization of PEEK rods holds the potential to enhance postoperative quality of life and reduce complications associated with implantation. Furthermore, our findings, which indicated no significant changes in lordosis angle and spinopelvic angles, suggest that individuals without pre-existing lordosis and spinopelvic angle distortions derived benefits from this treatment approach.

Furthermore, the absence of significant changes in spinopelvic angles within our study implies that patients who are suitable candidates for PEEK rod utilization tend to exhibit normal spinopelvic angles. This observation suggests that individuals with pre-existing spinopelvic angle abnormalities may not experience substantial benefits from the use of PEEK rods. Considering spinopelvic angles in patient selection and treatment planning may contribute to optimizing outcomes in PEEK rod-based interventions. Further investigations are warranted to explore the relationship between spinopelvic angles and the effectiveness of PEEK rod stabilization, as well as to evaluate the potential impact on clinical outcomes in patients with abnormal spinopelvic parameters.

Study Limitations

There are several limitations to consider in this study. Firstly, the sample size was relatively small, which may limit the generalizability of the findings. A larger sample size would provide more robust results and improve the statistical power of the study. Secondly, the study only focused on comparing the outcomes of PEEK rod stabilization and did not include a comparison with stabilization systems utilizing rods made of other materials. A comparative analysis with different rod systems could provide valuable insights into the effectiveness of PEEK rods in comparison to other elements. Future studies should aim to address these limitations and incorporate a larger patient cohort with comparative analyzes to enhance the understanding of PEEK rod systems in the context of spinal stabilization procedures.

CONCLUSION

The utilization of PEEK rods holds promise in enhancing postoperative quality of life and minimizing implant-related complications. Furthermore, our study revealed that patients without pre-existing sagittal balance impairment derived benefits from PEEK rod stabilization, as there were no significant changes observed in lumbar lordosis and sagittal balance angles of the spine.

Ethics

Ethics Committee Approval: Ethical approval for this study was obtained from the Ankara City Hospital No. 2 Clinical Research Ethics Committee (decision no: E2-21-05, date: 10.03.2021).
Informed Consent: Retrospective study.
Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: G.G., Y.G., A.D., Concept: G.G., İ.G., A.D., Design: İ.G., Ay.K., R.K., Data Collection or Processing: R.K., Ay.K., A.K., Analysis or Interpretation: E.Ç., A.K., Y.G., A.D., Literature Search: G.G., E.Ç., A.D.,Writing: G.G., İ.G., E.Ç.
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MANAGEMENT OF SUBAXIAL CERVICAL SPINE FRACTURES WITH ANTERIOR CERVICAL CORPECTOMY AND ANTERIOR PLATING-SINGLE CENTER EXPERIENCE

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ABSTRACT

Objective: Anterior cervical corpectomy and fusion (ACCF) is a surgical treatment option for cervical trauma. It is usually preferred to better decompress the spinal cord and preserve cervical alignment. Meanwhile, there are some contradictions regarding the indications of this procedure. The aim of this study was to present our series on the use of ACCF in subaxial cervical traumas.

Materials and Methods: The data of 20 patients who underwent ACCF for subaxial cervical trauma between 2016 and 2021 were retrospectively reviewed. The demographic, clinical, and radiological characteristics of the patients were collected and presented in detail. American Spinal Injury Association (ASIA) scores and Cobb's angles were statistically compared for the pre- and postoperative periods.

Results: The mean age was 48.7 (23-78) years. The female/male ratio was 1/5. The most common type of trauma was motor vehicle accident (55%), followed by falls and diving traumas. The most frequently affected level was C6. All cases underwent single-level ACCF, and anterior plating was performed after the placement of an expandable titanium cage. Cobb's angles and ASIA scores were significantly improved in all patients.

Conclusion: ACCF is a good option for subaxial cervical fractures to obtain better clinical and radiological outcomes. It has less complication risk and provides excellent cervical alignment. Further clinical studies with larger series are needed to demonstrate the efficacy of this procedure.

Keywords: Corpectomy, cervical fracture, Cobb angle, outcome

INTRODUCTION

Cervical spine injury occurs in 2.4% of patients with blunt trauma[1]. It is generally seen in young males and the most common reasons are fall accidents (FA) and motor vehicle accidents (MVA)[2,3]. The most commonly affected area in the subaxial cervical spine is the C6 and C7[1-3]. Fractures after high-energy trauma often cause spinal instability and nerve compression[1]. In cases with major spinal damage, pathology is present in an additional segment of the spine in 20% of the cases, and this damage doesn't necessarily have to be in the adjacent segment[4,5].

Surgical treatment methods and frequency for spinal injury are increasing in both younger and older patients[1,6,7]. It is especially preferred in the treatment of the elderly with fractures secondary to osteoporosis or malignancy[1,2,7-9]. The main goal of surgery is the restoration of vertebral body height, ensuring the continuity of the normal spinal axis, and stabilization[2,9,10]. Another goal is the fusion of stabilized segments[3]. In surgical treatment, anterior, posterior, and combined approaches can be preferred[9]. The method to be preferred first is still a matter of debate. The generally accepted approach is the decompression of the segment causing compression on the spinal canal[4,6].

The anterior approaches are less traumatic and allow access to the target area without damaging the paraspinal muscles[11]. One of the most widely accepted anterior approaches is anterior cervical corpectomy and fusion (ACCF)[1,12]. Our aim is to evaluate the postoperative outcomes and complications of cases where we perform ACCF and anterior plating in subaxial cervical spine fractures. We reviewed the clinical and radiologic results of anterior cervical corpectomy in trauma patients, as well as the safety of the procedure.

MATERIALS AND METHODS

Study Design

The study was initiated after obtaining the University of Health Sciences, Gülhane Training and Research Hospital Ethical Committee approval (decision no: 2021-238, date: 20.05.2021). In this study, patients who underwent ACCF at our institution between 2016 and 2021 were retrospectively evaluated. Cases between the ages of 18 and 80 who underwent surgery due to

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trauma were included in the study. Patients who underwent an anterior cervical procedure at a different center, those outside the age range of 18-80 years, and patients who underwent ACCF for non-traumatic reasons were excluded.

Data Collection

Records of patients were collected from electronic databases. Patient data including age, gender, type of trauma, time elapsed until surgery, preoperative and postoperative American Spinal Injury Association (ASIA) scores, length of hospitalization, and perioperative complications were recorded. Preoperative radiological images, postoperative early-phase and final follow-up radiological images [computed tomography (CT), X-ray, magnetic resonance imaging], and intraoperative neuromonitoring data were examined.

Radiological Assessment

The images were grouped into preoperative, early postoperative, and final follow-up categories. The C2-T1 Cobb angle was measured for all cases preoperatively and postoperatively and evaluated by two independent surgeons. Additionally, postoperative fusion assessment was conducted in the cases. Furthermore, the height of the corpectomized segment was compared between early-phase and final follow-up controls. The height of adjacent vertebrae, implant position, and spinal canal diameter were measured. The spinal canal diameter was determined by measuring the distance between the posterior border of the vertebral corpus and the mid-anterior point of the corresponding lamina on mid-sagittal cervical tomography images.

Statistical Analysis

IBM SPSS Statistics software version 28.0.1.0 (IBM, SPSS, Chicago, Illinois, USA) was used for the statistical analysis of this study data. The collected data are expressed as mean ± standard deviation. The Shapiro-Wilk test was used to evaluate whether parameters were normally distributed. Paired sample t-test were used to compare normally distributed parameters in the same group, while the Wilcoxon rank sum test was used for comparing data without normal distribution.

Surgical Technique

Under general anesthesia, with intraoperative neuromonitoring, the patient was placed in a supine position with slight head retraction and 10 degrees of contralateral rotation. Using an oblique skin incision, the classic Smith-Robinson approach was employed for anterior cervical intervention. Sharp dissections were performed to reach the prevertebral fascia. Subsequently, vertebral body identification was achieved through blunt dissections. The level for corpectomy was confirmed using lateral X-ray. Upper and lower intervertebral disc spaces were visualized. Kaspar retractors were placed on the upper and lower vertebral bodies and a distraction was performed. The subsequent stages of the procedure were carried out under a microscope. Bilateral longus colli muscles were laterally retracted. Bilateral upper and lower uncovertebral joints (UVJ) were identified (Figure 1). Special attention was given to identifying UVJ to avoid iatrogenic vertebral artery (VA) injury. After discectomy of the upper and lower intervertebral disc spaces, the endplates of the adjacent vertebrae were decorticated (decortication is important in terms of functional fusion, but this procedure is performed so gently, not to damage the cortical bone). Corpectomy was performed with a high speed diamond drill and rounger. After placement of the expandable titanium cage, its position was checked with lateral and anterior-posterior (A-P) X-rays. The bones obtained from the corpectomy are then placed on the sides of the cage to contribute to the fusion. Anteriorly, the cervical plate was fixed to the upper and lower vertebral corpus with screws (Figure 2). Then, 1 gram of vancomycin powder was placed on the operation field, drainage was placed and the operation was completed.

Baseline motor evoked potential (MEP) is performed before starting skin incision. Continuous electromyelography and somatosensorial evoked potential montoring was performed throughout the operation. MEP is performed at intervals and the surgeon is informed by comparing with baseline. The cuff of the endotracheal intubation tube is lowered during surgical manipulations to prevent compression of the recurrent laryngeal nerve between the trachea and soft tissue.

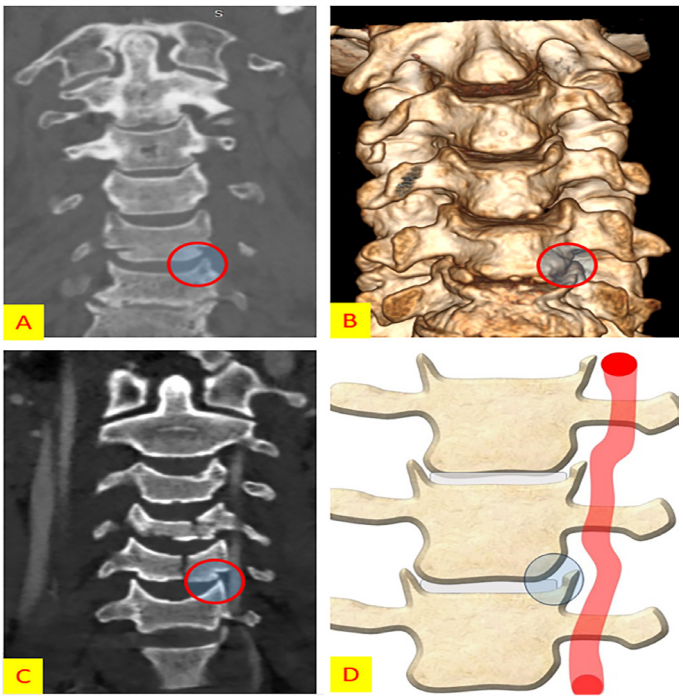

Figure 1. The coronal section of cervical CT reveals left UVJ at C5-C6 level with anterior aspect **(A)** and reconstructed posterior aspect **(B)**. Left C5-C6 UVJ of another patients at coronal plan of CT angiogram **(C)** and illustration shows the relationship between the joint and vertebral artery **(D)**
CT: Computed tomography, UVJ: Uncovertebral joints

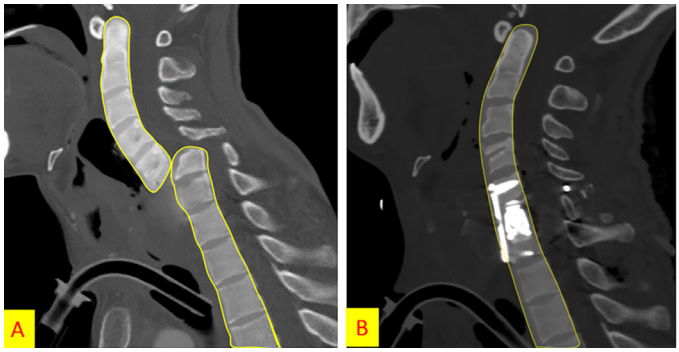

Figure 2. The preoperative **(A)** and postoperative **(B)** sagittal CT scan images show preoperative fracture and dislocation at C5-C6 level and postoperative instrumentation
CT: Computed tomography

RESULTS

Data from 20 cases that met the inclusion criteria for participation were evaluated. The average age of the patients was 48.7 (23-78) and the female/male ratio was determined as 1/5. The most common type of trauma was first MVA (n=11) with 55%, followed by FA (n=7) with 35%, and diving trauma (n=2) with 10%. The most frequently affected vertebra is C6. All cases underwent single level corpectomy. In all cases, anterior plating was performed after placement of an expandable titanium cage. Additionally, posterior instrumentation was added to the treatment of the 3 patients. In 1 case, we added posterior fusion because of facet locking or fracture. In 2 cases, decompression was performed due to posterior spinal canal compression. in these cases, ACCF was supported with posterior fusion to prevent the development of iatrogenic kyphotic deformity in the future. The average ACCF duration is 136 minutes but total operation time including PF is 153.8 minutes (80-290). The average length of hospitalization is 6.4 (3-30) days. Last follow-up 100% fusion rate was observed. One patient underwent urgent reoperation at the 8th postoperative hour due to a hematoma causing airway compression in the surgical site. Wound dehiscence was detected in 2 patient. One patient with frequent left C5 root irritation on neuromonitoring was found to have root injury on postoperative examination. Baseline neuromonitoring records worsened in 1 patient. Current data showed a 15% decline compared to the baseline data. No postoperative neurologic deficit was detected. The demographic, epidemiologic and clinical characteristics of the patients were summarized (Table 1). Preoperative VA occlusion was detected in 1 patient. The preoperative C2-T1 Cobb angle was 6.6 (± SD) degrees, which was measured as 13.8 (± SD) degrees in the postoperative final assessment. Comparison of preoperative and postoperative Cobb in patients showed a statistically significant difference, with the postoperative group having a significantly higher Cobb value (p<0.001) (Table 2). Five patients had preoperative kyphotic angulation 0.4-37 degrees (mean: 11.2). The mean preoperative length of between the adjacent vertebral bodies was 1.8 (± SD) cm, and postoperatively it was measured as 2.2 (± SD) cm. We found the statistically significant differences (p<0.001). The preoperative diameter of the cervical canal was 0.99 (± SD) cm, and postoperatively it was measured as 1.52 (± SD) cm. Differences of cervical canal diameter is significant higher in preoperative group (p<0.001). Transient dysphagia was observed in 4 patient during the early postoperative period, which improved within 7-10 days. In the early postoperative period, hoarseness was detected in 6 patient. Two patients were diagnosed with recurrent laryngeal nerve injury. Prednisolone treatment was initiated for these cases. Complete recovery was observed in 5 patient, partial hoarseness persisted in 1 patient, and at the 3-month follow-up, complete recovery was noted. At the first hospitalization, 10 patients were ASIA E, 4 patients were ASIA C, 5 patients were ASIA D and 1 patient was ASIA A. At the last postoperative control, 12 patients were evaluated as ASIA E, 3 patients as ASIA C, 4 patients as ASIA D, 1 patient as ASIA A. Neurological improvement was observed in 4 patient when compared to the preoperative physical examination. The patients were followed for a minimum of 6 months, maximum of 18 months, with an average follow-up of 10.2 months. All cases used a soft cervical collar for 4-6 weeks postoperatively.

DISCUSSION

In this study, we evaluated the clinical and radiological outcomes of ACCF and plating in subaxial cervical spine traumas. We explored ways to further enhance ACCF procedures based on the results obtained from our own cases.

Surgical treatment is the generally accepted rule in patients with unstable spine fractures and neurologic deficits secondary to the fracture[1]. Surgery should be performed with an approach that has low risks and high effective results. The preferred surgical approach and timing are important in terms of functional outcomes[10]. The type of surgical method should be decided by considering the patient's health status, type of trauma, preoperative radiologic imaging data, expectations and possibilities. In this study, we applied ACCF and plating approach to prevent neural compression and provide spinal stability in selected cases.

ACCF is a commonly preferred method for the surgical treatment of spinal instability caused by traumatic, infectious, neoplastic, and other factors[11-13]. In the case of traumatic fractures, it is necessary to use bone grafts to enable the union of adjacent segments[1]. After corpectomy, spinal reconstruction can be performed using autograft and allograft materials[14]. In cases where autografts are used, fusion occurs more naturally and quickly[14,15]. However, the literature has reported issues related to the donor site and the target region[8,14,16]. Alternative reconstruction methods such as titanium mesh cage, expandable cage and peek cage have been developed as alternatives to problems such as donor site issue, graft resorption and kyphotic angulation[15,17-19]. We do not prefer this method in reconstruction in our clinical practice due to

problems with autografts. We used expandable titanium cage in all of our cases (Figure 3). Bones collected during corpectomy were placed into and to the sides of the cage to facilitate fusion. It was supported with anterior plating. In the literature, high fusion rates have been found in single level anterior cervical corpectomy procedures performed in this way[4,15]. For example, Dorai achieved fusion in 97.5%, Majd achieved 97% fusion and Das achieved a 100% fusion rate[15,18,20]. We found a fusion rate of 100% in the minimum 6-month follow-up of our case series of 20 patients. Despite the high fusion rates of ACCF, we added posterior fusion in 3 cases due to the damage of posterior elements. The issue of supporting anterior corpectomy with posterior fusion has been evaluated on a case-by-case basis and has not been clarified[16,21,22]. Many authors believe that additional posterior stabilization should be performed after corpectomy in the spine, especially in the thoracolumbar region[23]. Studies emphasize that anterior fusion alone is more likely to fail after multilevel corpectomy[1,23].

Considering the biomechanics of the spine, ACCF is a procedure with direct access to the target and without damaging the

Table 1. The epidemiologic, demographic and clinical characteristics of the patients

Patient	Age (year)	Sex	Etiology	Corpectomy level	Time until the operation (hour)	Duration of ACCF (minute)	Hospitalization period (day)
1	54	M	FA	C5	10	145	6
2	30	M	MVA	C5	7	145	4
3	37	M	FA	C7	5	170	4
4	78	F	MVA	C7	8	103	5
5	51	M	FA	C6	4	140	3
6	69	F	FA	C7	10	80	15
7	46	M	MVA	C6	6	105	4
8	67	M	MVA	C6	5	145	4
9	56	M	MVA	C6	7	135	30
10	65	M	FA	C6	4	200	4
11	25	M	DA	C6	16	115	4
12	26	M	MVA	C5	192	160	7
13	23	M	DA	C4	24	180	5
14	69	M	MVA	C6	48	180	6
15	78	M	MVA	C5	9	157	6
16	75	M	FA	C5	6	150	4
17	45	M	FA	C3	10	120	4
18	29	F	MVA	C7	7	90	4
19	36	M	MVA	C7	36	110	4
20	39	F	MVA	C7	20	100	5
ASIA scores	**Preoperative (n)**				**Postoperative (n)**		
	ASIA A: 1				ASIA A: 1		
	ASIA B: 0				ASIA B: 0		
	ASIA C: 4				ASIA C: 3		
	ASIA D: 5				ASIA D: 4		
	ASIA E: 10				ASIA E: 12		

MVA: Motor vehicle accident, FA: Fall accident, DA: Diving accident, ASIA: American Spinal Injury Association, ACCF: Anterior cervical corpectomy and fusion

Table 2. Preoperative and postoperative measurements

	Preoperative (mean ± SD)	Postoperative (mean ± SD)	P value
Sagittal Cobb	6.6000±7.52952	13.8350±6.80103	<0.001*
LBAV	1.8275±0.39975	2.2280±0.36913	<0.001⁺
CCW	0.9995±0.36227	1.5225±0.20486	<0.001⁺

*Wilcoxon rank sum test, ⁺Paired samples t-test, SD: Standard deviation, LBAV: Length between adjacent vertebrae, CCW: Cervical canal width

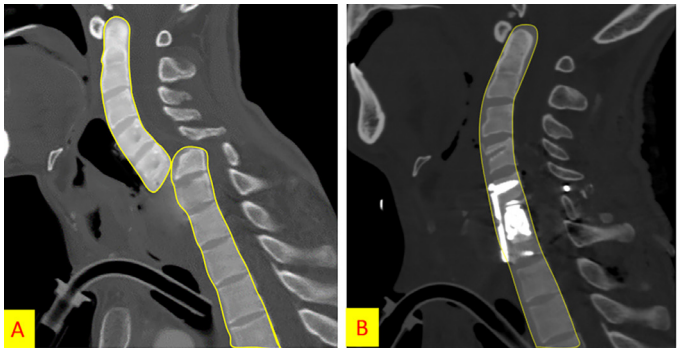

Figure 3. Expandable titanium cage and anterior cervical plate with screws

connective tissue elements involved in spinal stability. This technique minimally disrupts normal cervical muscles and is associated with a low risk of injuring surrounding structures[11]. In this way, segmental instability is also prevented. Kyphosis did not develop in our patients in whom we performed only anterior cervical corpectomy. Although anterior interventions are superior in preserving spinal biomechanics compared to posterior approaches, and the likelihood of neural damage is low, various complications have been reported in the literature[4,11,24]. These complications include wound site infections, dural injury, dysphagia, cerebrospinal fluid fistula, and nerve root damage. In addition to these, major complications such as VA rupture, esophageal injury, and damage to the recurrent laryngeal nerve have also been reported[19,22,25,26].

The incidence of VA injury, which is one of the destructive complications of anterior corpectomy, has been reported at around 3% in studies[26]. Eleraky et al.[11], in their study involving 185 ACCF cases, mentioned 4 cases of iatrogenic VA injury. They emphasized that 2 of the cases had VA anomalies, one case had a tumor adhering to the VA artery, and the fourth case had a loss of midline orientation. They indicated that direct repair was performed in two cases, ligation in the other two, and that all patients started postoperative aspirin. They also noted that none of the cases experienced postoperative neurological problems[11]. The identification of the UVJ plays an important role in avoiding VA injury[11,26,27]. In our own cases, we measured the height, width, and depth of the vertebral body using preoperative tomography. CT Angiography was performed to assess the VA in all cases. During corpectomy, we continuously monitored our measurement data along with anatomical landmarks to prevent neural and vascular injuries. In a case consulted 10 hours after trauma, left VA occlusion was identified on preoperative CT angiography. Posterior fossa infarction was present on preoperative CT. The patient had facet locking and accompanying dislocation. The patient was operated under aspirin treatment and later referred to a palliative care center.

Wound site problems were observed in 2 out of 20 cases, and they healed with local debridement in our study. Transient recurrent laryngeal nerve injury occurred in 2 patient. Medical treatment was applied, and at the postoperative 3-month follow-up, complete recovery was observed. Transient dysphagia was seen in 4 cases. In approximately 7-10 days, all cases completely recovered. The root damage was detected in one patient. There were no dural injury and postoperative cerebrospinal fluid fistula. No collections were observed at the wound site. Due to early postoperative complications, 1 patient required reoperation. A patient with tracheal compression and dyspnea due to prevertebral hematoma was urgently re-operated at the 8th hour for hematoma evacuation. The patient's follow-ups did not indicate any neurological problems. While the literature reports cases that lead to instrument insufficiency in the late period, we did not observe similar situations during the follow-up of our cases.

We adjusted the cage height to not exceed 5-10 mm beyond the height of the corresponding vertebral body to prevent neural damage due to cage distraction. In cases with burst fractures, this measurement might not be effective, so we perform distraction based on lateral X-rays and cervical alignment, guided by neuromonitoring data. Control CT was performed in all cases at 24 hours postoperatively.

One of the goal of surgery is preserving normal spinal axis, including cervical lordosis, related segment height. We detected postoperatively patients mean Cobb angle were improved. Cage distraction improved the Cobb angle and increased the distance between adjacent vertebrae by 0.4 cm. At the same time, a 0.5 cm enlargement of the spinal canal diameter was achieved. We found improvement in 40% of cases with neurological deficit. Our results demonstrate that ACCF is good choice for subaxial cervical fractures and providing high fusion rates and biomechanical stability

Study Limitations

The limitations of our study include a small sample size and a restricted follow-up period. Additionally, since the cases encompass a selected patient group, the results may differ from those of larger general groups undergoing ACCF.

CONCLUSION

After cervical trauma, the preferred surgical approach is still a topic of ongoing debate. Anterior approaches are gaining popularity due to their minimally invasive nature. Also ACCF may be preferred for the reconstruction of cervical lordosis. We found significant changes in postoperative radiological evaluations. To avoid perioperative complications in the anterior approach, thorough preoperative radiological assessment is crucial. Intraoperative assistance techniques should also be utilized. We believe that ACCF and plating is a safe and suitable approach for subaxial spinal trauma in appropriate cases.

Ethics

Ethics Committee Approval: The study was initiated after obtaining the University of Health Sciences, Gülhane Training and Research Hospital Ethical Committee approval (decision no: 2021-238, date: 20.05.2021).

Informed Consent: Retrospective study.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: M.C.E., G.K., Concept: M.C.E., G.K., Design: M.C.E., G.K., Data Collection or Processing: M.C.E., G.K., Analysis or Interpretation: M.C.E., G.K., Literature Search: M.C.E., G.K., Writing: M.C.E., G.K.

Conflict of Interest: The authors have no conflicts of interest to declare.

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COMPARISON OF TWO ANESTHESIA METHODS IN PERCUTANEOUS VERTEBROPLASTY FOR THE TREATMENT OF SINGLE-LEVEL OSTEOPOROTIC VERTEBRAL FRACTURES

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ABSTRACT

Objective: Vertebroplasty (VP) is a commonly used technique for the treatment of osteoporotic vertebral fractures (OVF). The aim of the study is to compare general anesthesia (GA) and local anesthesia (LA) applications for VP.

Materials and Methods: Patients who underwent VP for a single-level OVF were included in to the study. Visual analog scale (VAS), demographic characteristics, operative time, mean arterial pressure (MAP), heart rate, length of stay in intensive care and hospital, complications, side effects, kyphotic angle (KA) and anterior vertebral height (AVH) of the vertebral body were compared between groups.

Results: Eighty patients (52 female, 28 male) were included and divided into two groups: As GA, group 1, and as LA, group 2. There was statistical significant differences between preoperative VAS scores, KA, AVH compared to postoperative period in both groups ($p<0.05$). There was no difference between the groups in terms of recovery rates of these variables, complications and side effects ($p>0.05$). Heart rate and MAP was lower in group 1 ($p<0.05$).

Conclusion: VP is a minimally invasive method that provides pain relief and restoration of the fractured vertebrae. Our study showed there is no difference in the success, complication and side effect rates of VP surgeries performed with both anesthesia methods. LA may be an alternative method to GA as the primary anesthetic option for VP operations. VP can be performed under local anesthesia to avoid complications of GA and shorten the length of stay in the hospital especially in high-risk patients.

Keywords: Vertebroplasty, kyphosis angle, osteoporotic vertebral fractures, general anesthesia, local anesthesia

INTRODUCTION

Osteoporosis ranks as the second most significant public health concern worldwide, following cardiovascular diseases, according to the World Health Organization[1]. Among the various fractures associated with osteoporosis, vertebral compression fractures are the most prevalent[2]. When considering conservative treatment, concerns arise regarding the prolonged use of non-steroidal anti-inflammatory drugs, which may affect the gastrointestinal system and kidneys, as well as the potential for pressure ulcers due to extended bed rest. This raises the importance of exploring alternative approaches to expedite patient treatment and mobility[3].

In addressing osteoporotic vertebral fractures (OVFs), two commonly employed surgical techniques are vertebroplasty (VP) and kyphoplasty[4]. VP, a minimally invasive method for OVF treatment, involves the percutaneous injection of cement into the fractured vertebra[3,5]. The main goal is to promptly alleviate pain and facilitate patient mobility. VP can be performed under either local or general anesthesia. Local anesthesia is the safer and more cost-effective choice, particularly for older patients, due to its reduced risk of anesthesia-related complications[6]. However, the administration of local anesthesia provides effective communication with the patient during the procedure. Prolonged operative time, discomfort caused by body positioning, and potential toxic effects from excessive local anesthetic use are factors that may unexpectedly compromise vital functions and necessitate the termination of surgery. Conversely, the use of general anesthesia in elderly patients introduces an increased risk of complications and multiple organ dysfunction[7]. This study aimed at comparing the outcomes of VP for OVFs under both local and general anesthesia, shedding light on the optimal approach for this patient population.

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MATERIALS AND METHODS

Study Design

This retrospective controlled study received approval from the Clinical Research Ethics Committee of University of Health Sciences Turkey Trabzon Faculty of Medicine, and informed consent was obtained from all participating patients. The study involved a review of medical records for patients who underwent VP for single-level OVF between January 2018 and December 2021. Among the 125 patients who underwent percutaneous VP, inclusion criteria comprised having undergone bone densitometry examination within one year before or after the surgery, sustaining a fracture due to low-energy trauma, having no history of previous malignancy, trauma, vertebra surgery, chronic rheumatological or neurological diseases, and possessing the ability to mobilize independently before surgery. Patients without relevant medical record data, those with fractures resulting from high-energy trauma, those who underwent VP at multiple levels, or those who had concurrent surgeries were excluded from the study. Ultimately, the eligible patients were categorized into two groups: group 1, consisting of 40 patients who underwent general anesthesia, and group 2, comprising 40 patients who underwent local anesthesia.

Measurement Method

Prior to surgery, all patients underwent thoracolumbar spinal anteroposterior and lateral X-ray examinations. Postoperative thoracolumbar X-rays were conducted on the first day following the procedure. The study assessed the impact of different anesthesia methods on intraoperative mean arterial pressure (MAP) and mean heart rate, and operative time. The operative time was determined from the moment the guide needle was inserted until wound closure. VP levels were categorized into three regions: T7-T10 as the first region, T11-L2 as the second region, and L3-L5 as the third region.

Visual analogue scale (VAS) scores, ranging from 0 to 10 (with 0 indicating no pain and 10 indicating severe pain), were recorded both before and after surgery. Additionally, measurements of anterior vertebral height (AVH) and kyphotic angle (KA) were obtained from direct lateral radiographs before and after the operation. To assess the clinical effectiveness of different anesthesia methods, improvements in these parameters were calculated using the following formulas and then compared between the two groups:

1. Improvement in VAS scores (%) = [(preoperative VAS score - postoperative VAS score)/preoperative VAS score] X 100.
2. Recovery rate of AVH (%) = [(postoperative AVH - preoperative AVH)/*mean AVH] X 100.

(*mean AVH = [AVH of the upper level + AVH of the lower level]/2)

3. Recovery rate of KA (%) = [(preoperative KA - postoperative KA)/preoperative KA] X 100.

Abbreviations: *(mean AVH= [AVH of upper level+ AVH of lower level]/2).

Surgical Technique

All procedures were conducted using sterile equipment. Patients were positioned face down on the operating table after sterile preparation. Fluoroscopy was employed to pinpoint the fracture line. With the assistance of fluoroscopy, anteroposterior and lateral imaging was performed to access the vertebral body, which was then cemented using the transpedicular method. The distribution of cement within the vertebral body was verified using fluoroscopy. Once the cement had fully set, patients were repositioned to the supine position, concluding the procedure. Throughout the process, patients were continuously monitored for the risk of neurological deficits, and notably, none of the patients required a cast.

Anesthesia Method

Patients received either general or local anesthesia for the procedure. General anesthesia was performed on patients who had high anxiety levels with concerns about local anesthesia and in whom sedation in the prone position poses risks to airway safety. All patients underwent standard monitoring with electrocardiography, heart rate, MAP, and peripheral oxygen saturation. Following preoxygenation with 100% oxygen for 3 minutes, anesthesia induction was provided to all patients with intravenous 2 mg/kg propofol (propofol vial 1%) and 1 mcg/kg fentanyl. After muscle relaxation was achieved with 0.6 mg/kg rocuronium bromide, endotracheal intubation was performed. Anesthesia was maintained by inhaling a mixture of sevoflurane at 2% concentration and 60% nitrogen oxide + 40% oxygen.

Prior to local anesthesia, sedation was administered with 1 mg/kg of intravenous midazolam. Local anesthesia was performed administering 2% prilocaine hydrochloride (8 cc) to the subcutaneous tissue from the pedicle of the fractured vertebra. Various parameters were compared between the groups based on the medical records, including age, gender, fracture level, the American Society of Anesthesiologists (ASA) classification, body mass index (BMI), pre- and post-operative VAS scores, operative time, MAP, heart rate, and length of intensive care and hospital stay. Adverse anesthetic reactions were defined as vomiting, hypotension (MAP <60 mmHg), bradycardia (heart rate <60/min), and hypoxemia.

Additionally, pre- and post-operative KA and AVH measurements were derived from X-rays. The study also compared perioperative and postoperative complications between the two anesthesia groups.

Statistical Analysis

The data analysis was conducted using the SPSS software (version 22.0, Chicago, USA, 2013). Categorical data were expressed as percentages, while continuous variables were presented as mean values along with their standard deviations. Group comparisons were assessed using the Pearson chi-square test for categorical data. The normality of data distribution was examined using the Shapiro-Wilk test, Skewness, and Kurtosis

Histogram values. The relationship between non-normally distributed continuous variables and groups was analyzed using the Mann-Whitney U test.

For within-group assessments of percentage changes in VAS, KA, and AVH before and after surgery, the related samples Wilcoxon signed-rank test was employed.

RESULTS

The two groups showed no significant differences in demographic data (p>0.05). In group 1, the mean age was 77.80±4.9, consisting of 27 (67.5%) females and 13 (32.5%) males. Group 2 had a mean age of 78.55±5.94, with 25 (62.5%) females and 15 (37.5%) males (Table 1).

Table 1. Demographic data

Variables	Group 1 (n=40)	Group 2 (n=40)	p-value
Age	77.80±4.9	78.55±5.94	0.689[a]
Female Male	27 (67.5%) 13 (32.5%)	25 (62.5%) 15 (37.5%)	0.815[b]

The mean BMI was 28.60±4.77 in group 1 and 27.98±3.71 in group 2. There was no significant difference between the groups in terms of VP levels (p>0.05). Importantly, significant differences were observed in the ASA score, length of hospital stay, and operative time (p<0.05). The mean length of hospital stay was 1.93±0.764 days in group 1 and 1.55±0.749 days in group 2. The mean operative time was 45.03±9.29 minutes in group 1 and 55.28±8.44 minutes in group 2 (Table 2). The mean follow-up period of the patients after the operation was 16 months.

Parameters such as hypotension, vomiting, cement leakage, and the requirement for intensive care did not exhibit significant differences between the groups (p>0.05). Hypotension occurred in 6 (15%) patients in group 1 and 10 (25%) patients in group 2. Vomiting was observed in 9 (22.5%) patients in group 1 and 7 (17.5%) patients in group 2. Intensive care was required for 16 (40%) patients in group 1 and 11 (27.5%) patients in group 2. Cement leakage was noted in 6 (15%) patients in group 1 and 4 (10%) patients in group 2. Desaturation was absent in the general anesthesia group but affected 4 patients in the local anesthesia group. Additionally, there were significant

Table 2. Intergroup comparison

Variables	Group 1 (n=40)	Group 2 (n=40)	p-value
BMI	28.60±4.77	27.98±3.71	**0.779[a]**
Length of hospital stay (days)	1.93±0.764	1.55±0.749	**0.023[a]**
Operative time (minutes)	45.03±9.29	55.28±8.44	**0.000[a]**
VP level			
T7-T10 T11-L2 L3-L5	12 (30%) 18 (45%) 10 (25%)	12 (30%) 17 (42.5%) 11 (27.5%)	**0.978[b]**
ASA			
2 3 4	10 (25%) 26 (65%) 4 (10%)	0 20 (50%) 20 (50%)	**0.001[b]**
Hypotension (<60 mmHg)			
No Yes	34 (85%) 6 (15%)	30 (75%) 10 (25%)	**0.876[b]**
Desaturation			
No Yes	40 (100%) 0	36 (90%) 4 (10%)	**0.116[b]**
Vomiting			
No Yes	31 (77.5%) 9 (22.5%)	33 (82.5%) 7 (17.5%)	**0.781[b]**
Intensive care requirement			
No Yes	24 (60%) 16 (40%)	29 (72.5%) 11 (27.5%)	**0.344[b]**
Cement leakage			
No Yes	34 (85%) 6 (15%)	36 (90%) 4 (10%)	**0.737[b]**
MAP (mmHg)	113.75±18.90	130.25±19.28	**0.000[a]**
Heart rate	71.1±10.90	87.83±7.92	**0.000[a]**

[a]: Statistical significance between groups according to the Mann-Whitney U test, [b]: Statistical significance between groups according to the Pearson chi-square test, BMI: Body mass index, VP: Vertebroplasty, ASA: American Society of Anesthesiologists, MAP: Mean arterial pressure

differences in heart rate and blood pressure values between the groups (p<0.05). In group 1, the mean blood pressure was 113.75±18.90, while in group 2, it was 130.25±19.28. The mean heart rate in group 1 was 71.1±10.90, whereas in group 2, it was 87.83±7.92 (Table 2).

Both groups displayed significant improvements in VAS scores following surgery (p<0.05). In group 1, VAS scores shifted from 8.33±1.38 before surgery to 2.1±1.08 after surgery, while in group 2, they changed from 8.10±1.48 to 2.17±1.21 (Table 3).

The mean improvement rates in VAS scores were 72.59±19.87% in the general anesthesia group and 70.94±20% in the local anesthesia group, with no statistically significant difference (p>0.05) (Table 4).

KAs showed a significant improvement in both groups (p<0.05). In group 1, KA changed from 29.35±4.73 before surgery to 16.55±4.32 after surgery, while in group 2, it shifted from 29.65±5.74 to 15.15±4.22 (Table 3). The percentage improvement in KA showed no significant difference between the groups, with mean values of 43.42±12.31% in group 1 and 48.44±12.62% in group 2 (p>0.05) (Table 4).

Improvements in AVH collapse ratios were significant in both groups post-surgery (p<0.05). In group 1, the collapse ratio changed from 34.85±8.02% before surgery to 22.53±6.32% after surgery. In group 2, the pre- and post-operative values were 33.52±7.75% and 23.8±6.2%, respectively (Table 2). There were no significant differences between the groups regarding AVH collapse recovery rates (p>0.05), with mean values of 12,32±1.80% in group 1 and 9,87±1.32% in group 2 (Table 4).

Notably, no patients developed infection or neurological deficits, but cement leakage occurred in 7 cases into the upper and lower discs and in 3 cases into the epidural space.

DISCUSSION

The results of this study revealed no statistically significant differences in age, gender, BMI, or VP levels between the two groups. Both groups underwent the surgical procedures using the current anesthesia method, without the need for any alternative methods. Furthermore, there were no discernible distinctions between the two groups in terms of improvements in the VAS scores, correction ratios of the kyphosis angle, or anterior vertebra height. Notably, the length of hospital stay was significantly longer in the general anesthesia group. While the need for intensive care was slightly higher in group 1 (40%) compared to group 2 (27.5%), this difference did not reach statistical significance. Moreover, there were no statistically significant variations between the groups in parameters such as hypotension, desaturation, cement leakage during surgery, postoperative vomiting, and the requirement for intensive care. In essence, our study revealed that the success rates, complication rates, and side effect profiles of VP surgeries remained consistent regardless of the chosen anesthesia method.

In a separate study comparing local and general anesthesia for percutaneous kyphoplasty, the VAS scores decreased from a mean postoperative value of 6.6 to a mean postoperative 1-day value of 1.7[8]. In another study focused on percutaneous VP under local anesthesia, patient satisfaction was evaluated, with 76% of patients reporting a very good or good experience[9]. Additionally, a cohort that underwent VP using local anesthesia combined with oral sedation exhibited significantly lower level-specific verbal pain scores at the postoperative follow-up compared to preoperative scores[10]. Balkarli et al.[3] reported an 83% postoperative improvement in pain levels for patients undergoing VP under local anesthesia. Ge et al.[8] found no statistically significant differences between the local anesthesia and general anesthesia groups in patients undergoing kyphoplasty. In our series, the mean preoperative and postoperative VAS scores for the general anesthesia group were 8.33±1.38 and 2.1±1.08, respectively. In the group operated under local anesthesia, the corresponding scores were 8.10±1.48 and 2.17±1.21, respectively (p<0.05). Additionally, there were no significant differences in VAS score improvement rates between the two anesthesia methods (p<0.05). The statistical significance of this change

Table 3. Pre-and post-operative clinical and radiological findings

	Group 1 (n=40)			Group 2 (n=40)		
	Preop	Postop	p-value	Preop	Postop	p-value
VAS	8.33±1.38	2.1±1.08	0.000	8.10±1.48	2.17±1.21	0.000
KA	29.35±4.73	16.55±4.32	0.000	29.65±5.74	15.15±4.22	0.000
AVH collapse (%)	34.85±8.02	22.53±6.32	0.000	33.52±7.75	23.8±6.26	0.000

Related-samples Wilcoxon signed-rank test. VAS: Visual analog scale, KA: Kyphotic angle, AVH: Anterior vertebral height

Table 4. Comparison of recovery percentages of VAS, KA and AVH

Percentages of recovery	VAS (%)	KA (%)	AVH (%)
Group 1 (n=40)	72.59±19.87	43.42±12.31	12.32±1.80
Group 2 (n=40)	70.94±20.87	48.44±12.62	9.87±1.32
p-value	0.481	0.088	0.467

Mann-Whitney U test. VAS: Visual analog scale, KA: Kyphotic angle, AVH: Anterior vertebral height

underscores that VP is an effective method for patients with OVFs, whether performed under general anesthesia or local anesthesia.

Nerve injury arising during VP operations can be identified earlier in patients who opt for local infiltration anesthesia, as these patients remain awake and alert[8,11]. However, it is important to note that if patients are not eligible for local anesthesia, they may inadvertently move during the procedure, making surgery more challenging and prolonged, potentially leading to postoperative complications. In such cases, sedo-analgesia is often required in conjunction with local infiltration anesthesia[12]. General anesthesia with endotracheal intubation is more commonly chosen when deep sedation in the prone position poses risks to airway safety[11]. Common complications associated with VP procedures include pulmonary embolism, epidural cement extravasation leading to spinal cord or nerve root compression, infections, and adjacent vertebral fractures. In a study by Ge et al.[8], it was noted that the general anesthesia group had the highest incidence of adverse anesthetic effects, with 29.1% of patients experiencing postoperative vomiting and 38.2% reporting pharyngalgia as a secondary effect of intubation. Patients who underwent surgery with general anesthesia also had a higher requirement for intensive care[12]. Interestingly, there was no significant difference in the rate of nerve injuries between the general anesthesia group and other groups[8]. In our study, the general anesthesia group exhibited 22.5% incidence of vomiting, and a 40% need for intensive care unit (ICU) admission, whereas the local anesthesia group experienced lower rates of 17.5%, and 27.5%, respectively. Cement leakage occurred in 15% of cases in the general anesthesia group and 10% in the local anesthesia group. Desaturation was observed in only four patients who received local anesthesia. Importantly, no significant complications such as infection or neurological deficits were observed in any patient. Cement leakage occurred in 10 cases, extending into the upper and lower disc in seven cases and into the epidural space in three cases, yet it did not result in any neurological complications. These results underscore the reliability of VP when administered using both anesthesia methods for the treatment of OVFs.

Patients who receive general anesthesia tend to exhibit more stable MAP and heart rates compared to those under local anesthesia[8]. In our study, there was a notable difference in heart rate and blood pressure between the two groups ($p<0.05$), with the group undergoing general anesthesia showing lower values of mean MAP and heart rate.

Of note, patients positioned prone during surgery after local anesthesia might experience discomfort. This discomfort can sometimes result in unintended patient movements, potentially prolonging the operative time. Consequently, surgeries performed under local anesthesia generally have longer durations compared to those under general anesthesia[6,8]. Our study aligns with existing literature, revealing longer operative times in the local anesthesia group.

Studies have indicated that vertebral augmentation procedures, such as VP and kyphoplasty, can lead to improvements in AVH and correction of kyphosis[13,14]. While some studies suggest that kyphoplasty is more effective in restoring anterior height and correcting kyphosis, clinical outcomes often do not significantly differ between the two procedures[15,16]. In a study evaluating VP with different anesthesia methods, it was noted that although the degree of improvement in the kyphosis angle and AVH did not reach statistical significance, the procedure's ability to prevent the progression of kyphotic deformity was emphasized. This prevention, in turn, mitigated lung volume reduction and reduced the risk of damage to intra-abdominal organs[3]. In our study, consistent with existing literature, we observed a significant reduction in postoperative vertebral collapse rates in both the general anesthesia and local anesthesia groups.

In a study where no differences were observed between the groups concerning ASA classification, the authors reached the conclusion that the variance in postoperative ICU stay and postoperative hospital stay might be linked to the anesthesia method employed. They noted that the length of ICU and hospital stay was longer in the group receiving general anesthesia[12]. In our study, the mean length of hospital stay was shorter in the local anesthesia group, despite the longer operative times ($p<0.05$). Additionally, a significant difference existed between the groups regarding ASA scores, with a higher number of patients having higher scores in the local anesthesia group ($p<0.05$). However, there was no difference between the groups regarding the requirement for ICU admission ($p>0.05$).

Study Limitations

This study has several limitations. Firstly, the study had a retrospective nature which means that data were collected from past records, potentially introducing inherent biases and limitations associated with retrospective research. Additionally, the evaluation of VAS scores was restricted to assessments before and after surgery, with no real-time evaluations during the surgical procedure. The absence of intraoperative assessments could hinder our understanding of pain management and patient comfort during surgery. Furthermore, the study did not specify separate anesthesia durations when calculating the overall operative time, which could have provided a more precise measure of the time spent in the operating room. Lastly, the study's limited sample size may impact the generalizability of its results. To strengthen the study's conclusions and facilitate more robust statistical analyses, future research should consider larger cohorts.

CONCLUSION

In a vast number of VP patients, general anesthesia is not the first choice anesthesia method. Instead, local anesthesia serves as a potential alternative as the primary choice for

anesthesia during VP procedures. This approach can help circumvent the complications associated with general anesthesia and reduce hospital stays, particularly in cases involving high-risk patients.

Ethics

Ethics Committee Approval: This retrospective controlled study received approval from the Clinical Research Ethics Committee of University of Health Sciences Turkey Trabzon Faculty of Medicine (number: 2023/32, date: 28.09.2023).
Informed Consent: Informed consent was obtained from all participating patients.
Peer-review: Internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: G.P., İ.A., E.K., F.S., Concept: G.P., İ.A., E.K., F.S., Design: G.P., İ.A., E.K., F.S., Data Collection or Processing: G.P., İ.A., B.S., Analysis or Interpretation: G.P., İ.A., B.S., Literature Search: G.P., B.S., Writing: G.P., İ.A.
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LONG-TERM CLINICAL AND RADIOLOGICAL RESULTS OF VERTEBRAL AUGMENTATION TECHNIQUES IN OSTEOPOROTIC LUMBAR COMPRESSION FRACTURES: VERTEBROPLASTY OR KYPHOPLASTY?

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ABSTRACT

Objective: This study aimed to compare long-term segmental deformity and clinical manifestations associated with vertebroplasty and kyphoplasty in treating single-level vertebral compression fractures.

Materials and Methods: The patients were categorized into four groups based on corpus height loss and surgical procedures: VP1 and KP2 for ⩽50% and VP2 and KP1 for >50%. Corpus height losses, restoration rates, segmental kyphotic angle values, visual analogue scale (VAS), and Oswestry disability index (ODI) scores were recorded at the 5-year follow-up.

Results: There was a significant difference in the distribution of cases with corpus height loss ⩽50% (VP1 and KP2) and ⩾50% (KP1 and VP2) ($p<0.05$). Statistically significant decreases were observed in the restoration rates between the first day and the 60th month of postoperative follow-up for VP1, VP2, and KP1 ($p<0.001$). The restoration rate decreased in KP2 ($p=0.023$). There were no statistically significant changes in the segmental kyphotic angles for VP1, VP2, and KP1 from the first day to the 30th month. The angle of KP2's angle remained unchanged until the 60th month. VAS scores were significantly decreased for VP1, VP2, and KP1 on both the first and sixth day and the sixth (month <0.001). A significant difference was found in ODI values between the pre-operative period and the 5th year for VP1, VP2, and KP1 ($p<0.001$) but not for KP2 ($p=0.003$), indicating better results for KP2.

Conclusion: Vertebroplasty is sufficient in patientscases with a height loss of ⩽50%, whereas kyphoplasty is superior in patients with a height loss of >50%.

Keywords: Vertebral augmentation, vertebroplasty, kyphoplasty, osteoporosis, compression fracture

INTRODUCTION

Osteoporosis is a condition that affects the entire skeletal system and is characterized by an increased susceptibility to fractures in multiple areas of the body. This susceptibility is primarily due to the degradation of bone microarchitecture and a reduction in bone mass[1,2]. Vertebral compression fractures (VCF) are the most common complication of osteoporosis, affecting around 50% of individuals aged 50 and above with the condition[3,4]. The annual incidence in the UK is roughly 120,000, while it ranges from 1 to 1.5 million in the US[5,6]. With the aging population and increased life expectancy, the prevalence of osteoporosis and VCF is steadily rising[7,8].

While conservative treatment methods such as pain management and immobilization are initially employed, some cases may benefit from vertebral augmentation (VA) techniques like vertebroplasty (VP), balloon kyphoplasty (KP), and stentoplasty. These procedures aim to improve quality of life by reducing pain and optimizing vertebral alignment, thereby preventing further damage[3,4,9-11].

Existing literature has extensively discussed these procedures' short to medium-term outcomes, benefits, and drawbacks. However, there needs to be more sufficient data on long-term outcomes and changes in treatment preferences. This study aims to offer a new perspective by conducting a comparative analysis of the long-term segmental deformity and clinical manifestations associated with VP and KP, the two commonly used minimally invasive VA techniques for VCF treatment.

MATERIALS AND METHODS

Study Design

This study investigated patients admitted to our hospital's trauma center between 2010 and 2017. All procedures followed were following ethical standards and guidelines, including the Helsinki Declaration of 1975, as revised in 2008. Approval

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was obtained from the University of Health Sciences Turkey, İstanbul Medeniyet University Göztepe Training and Research Ethics Committee (date: 21.06.2023, number: 2023/0402). The study involved a retrospective analysis of cases treated at our clinic using the KP or VP techniques for single-level osteoporotic VCFs. The inclusion criteria were patients diagnosed with osteoporotic VCF who had undergone four weeks of conservative treatment with no sufficient clinical improvement, had no spinal cord compression, and had completed radiological imaging and five-year follow-ups. The acceptance criteria for our osteoporotic VCF diagnosis were that the cases' previous bone mineral density (BMD) values were less than -2.5 (T-score <-2.5) and that they had a previous diagnosis of osteoporosis. BMD was not repeated in our cases who were already diagnosed with osteoporosis. In terms of VCF morphology, Osteoporotic Fracture (OF)2 and OF3 cases were included in our study based on the "AO Spine-DGOU OF Classification System"[12]. The exclusion criteria included bleeding disorder, surgical site infection, absence of BMD, not having a diagnosis of osteoporosis, allergy to bone cement, failure to complete cement (polymethylmethacrylate) injection for any reason, VCF due to causes other than osteoporosis, treatment with a technique other than VP or KP, being morphologically OF1, OF4, OF5, failure to complete the 5-year follow-up or missing records. One hundred-twenty one cases were included in the study and categorized into four groups based on variations in corpus height loss and surgical procedures. The VP1 and KP2 groups included individuals with corpus height losses ⩽50%, while the VP2 and KP1 groups included individuals with corpus height losses >50%. BMD values of the patients or any other demographic factors did not play a decisive role in the selection of surgical technique.

Chart Data and Radiological Features

Demographic information of all cases, including age, gender, localization data, preoperative corpus height losses, postoperative restoration rates, segmental kyphotic angle values, visual analogue scale (VAS) scores, and Oswestry disability index (ODI) scores, were documented. These variables were measured at various time points, including day 1, 6-month intervals, and up to the 60th month. Radiological measurements were performed using standing lateral X-rays covering the entire spine, including the height of the upper vertebral body, lower vertebral body, fractured vertebral body, and the angle of segmental kyphosis. Essential calculations were performed based on these measurements. The estimated vertebral height (EVH) was calculated by adding the upper vertebral body height to the lower vertebral body height and dividing the sum by two. Vertebral corpus height loss (VCHL) was determined by subtracting the fractured vertebral body height from the EVH, dividing the result by the EVH, and multiplying by 100. The restoration rate was calculated using the formula: 100 - (postoperative VCHL divided by preoperative VCHL, multiplied by 100) (Figure 1)[13].

A conventional surgical method was employed in all of the cases included in our study. The bipedincular approach was chosen as the standard strategy in this study. In each case, a volume of 3 cm^3 of cement, specifically polymethylmethacrylate, was administered by injection from both sides. Cases in which the administration of a complete 6 cm^3 volume of cement (polymethylmethacrylate) injection was not feasible for whatever reason were excluded from the research evaluation.

Statistical Analysis

Statistical analysis was performed using the SPSS 15.0 for Windows software. Descriptive statistics were calculated, including numbers and percentages for categorical variables and mean and standard deviation for numeric variables. The Kruskal-Wallis test was used for independent comparisons of numerical variables among more than two groups, as the normal distribution condition was not met in groups. Subgroup analyses were conducted using the Mann-Whitney U test with Bonferroni correction. The Wilcoxon test was used to analyze numerical variables independent groups, as the differences did not meet the normal distribution condition. The chi-squared test was used to analyze ratios in the groups. The significance level was set at $p<0.05$.

RESULTS

Our study was conducted with a total of 121 osteoporotic VCF cases who met our inclusion criteria. VP technique was applied to 64 (52.9%) of our cases, and KP technique was applied to 57 (47.1%) cases. The mean age was 66 years. While 104 (85.95%) of our cases were female, 17 (14.05%) of our cases were male. There was no statistically significant difference in age and gender distributions between the groups.

From a morphological standpoint, no statistically significant difference was observed between the cases of OF2 (n=60) and

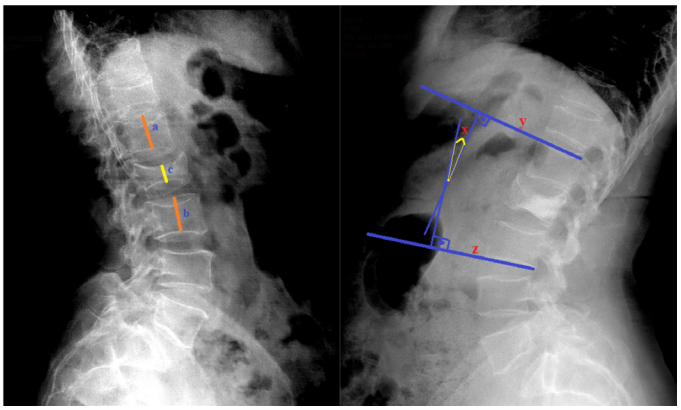

Figure 1. a: Upper vertebral body height, b: Lower vertebral body height, c: Fractured vertebral body height, x: Segmental kyphosis angle, y: Parallel line to the upper end plate of the upper vertebra, z: Parallel line to the lower end plate of the lower vertebra
Estimated vertebral height (EVH): a + b / 2
Vertebral corpus height Loss (VCHL): (EVH - c / EVH) x 100
Restoration rate: 100 – (postop VCHL / preop VCHL x 100)

OF3 (n=61). No statistically significant difference was detected in the prevalence of OF2 and OF3 cases among the various categories. The most common localization of VCF was at TH12 (21.5%), L1 (19.8%), and L3 (17.3%) levels (Table 1).

The distribution of preoperative corpus height losses according to the groups and the statistical differences between the groups are presented in Table 2. There was a significant statistical difference in the distribution of cases with corpus height loss ⩽50% (VP1 and KP2) and ⩾50% (KP1 and VP2) (p<0.05).

The statistically significant decreases were observed between the first day and the 60th month of postoperative restoration rates in the VP1, VP2, and KP1 (p<0.001). The restoration losses observed in the KP2 did not exhibit statistical significance (p=0.023) (Table 3, Figure 2).

The change in segmental kyphotic angles was statistically insignificant in the KP2 group, but statistically significant in the other groups on the first day after the surgery. There was no statistically significant change observed in the segmental kyphotic angles for the VP1, VP2, and KP1 during the postoperative 1st day to 30th month follow-up period. Nevertheless, statistically significant alterations were noted in the follow-up measurements at 36 and 30 months across all three groups. The KP2 showed statistically significant preservation of the observed change from the initial day up to the 60th month (Figure 3).

When comparing the values of segmental kyphotic angle change between the groups, no statistically significant difference was observed between the KP1 and KP2 throughout the follow-up periods. Although there was no statistically significant disparity in the change value of the segmental kyphotic angle between KP1 and VP2 during the preoperative period, a significant difference was observed in favor of KP1 throughout all subsequent months of follow-up. A similar association was similarly noted between the VP1 and VP2. A small level of statistical significance was observed in the comparison between VP1 and KP2, with the results favoring KP2 (Table 4).

A significant statistical difference was observed between the preoperative and 5th-year VAS values for all cases, regardless of the type of surgical procedure performed (p<0.001). The study findings indicate a statistically significant decrease in preoperative VAS values for VP1, VP2, and KP1 on both the first day and the sixth month (p<0.001). The KP2 showed a statistically significant decrease, although with decreased power on the

Table 1. Distribution of demographic data by groups

		Surgical procedure				
VP 1 **n (%)** **43 (35.5)**		**VP 2** **n (%)** **21 (17.4)**	**KP 1** **n (%)** **46 (38.0)**	**KP 2** **n (%)** **11 (9.1)**		**p** **(<0.05)**
Age (mean ± SD)		65.9±3.0	64.6±2.8	66.0±3.9	67.7±4.2	0.385
Gender n (%)	Female	40 (93.0)	17 (81.0)	40 (87.0)	7 (63.6)	0.081
	Male	3 (7.0)	4 (19.0)	6 (13.0)	4 (36.4)	
Localization	**L1**	14 (32.6)	4 (19.0)	5 (10.9)	1 (9.1)	
	L2	4 (9.3)	0 (0.0)	5 (10.9)	3 (27.3)	
	L3	1 (2.3)	4 (19.0)	15 (32.6)	1 (9.1)	
	L4	5 (11.6)	0 (0.0)	1 (2.2)	2 (18.2)	
	L5	6 (14.0)	0 (0.0)	0 (0.0)	0 (0.0)	
	T8	4 (9.3)	0 (0.0)	0 (0.0)	0 (0.0)	
	T9	1 (2.3)	1 (4.8)	2 (4.3)	0 (0.0)	
	T10	1 (2.3)	2 (9.5)	1 (2.2)	0 (0.0)	
	T11	0 (0.0)	2 (9.5)	7 (15.2)	3 (27.3)	
	T12	7 (16.3)	8 (38.1)	10 (21.7)	1 (9.1)	

VP1: Vertebroplasty group 1, VP2: Vertebroplasty group 2, KP1: Kyphoplasty group 1, KP2: Kyphoplasty group 2, SD: Standard deviation

Table 2. Distribution of preop corpus height loss by groups and comparison between groups

	VP 1 **⩽50%** **Mean ± SD**	**VP 2** **⩾50%** **Mean ± SD**	**KP 1** **⩾50%** **Mean ± SD**	**KP 2** **⩽50%** **Mean ± SD**
Preop corpus height loss	42.8±3.8	57.2±4.2	58.5±3.8	35.0±4.7
	VP 1 / KP 1 (p)	**KP 2 / KP 1** (p)	**VP 1 / VP 2** (p)	**KP 2 / VP 2** (p)
	<0.001	<0.001	<0.001	<0.001

VP1: Vertebroplasty group 1, VP2: Vertebroplasty group 2, KP1: Kyphoplasty group 1, KP2: Kyphoplasty group 2, SD: Standard deviation

Table 3. Statistical analysis of postop restoration rates of groups according to follow-up times

		VP 1 (p)	VP 2 (p)	KP 1 (p)	KP 2 (p)
Postop. restoration rate (%)	**1. day/6. month**	**<0.001**	**0.001**	**<0.001**	0.023
	6. month/12. month	1.000	0.083	0.046	1.000
	12. month/18. month	**<0.001**	0.083	0.014	1.000
	18. month/24. month	1.000	1.000	0.046	0.046
	24. month/30. month	1.000	1.000	0.012	0.157
	30. month/36. month	**<0.001**	0.317	0.206	0.102
	36. month/42. month	**0.001**	**<0.001**	**<0.001**	0.020
	42. month/48. month	**0.001**	0.214	0.029	0.102
	48. month/54. month	0.038	0.096	**<0.001**	0.083
	54. month/60. month	0.025	**<0.001**	0.007	0.317
	1. day/60. month	**<0.001**	**<0.001**	**<0.001**	**0.0034**

VP1: Vertebroplasty group 1, VP2: Vertebroplasty group 2, KP1: Kyphoplasty group 1, KP2: Kyphoplasty group 2

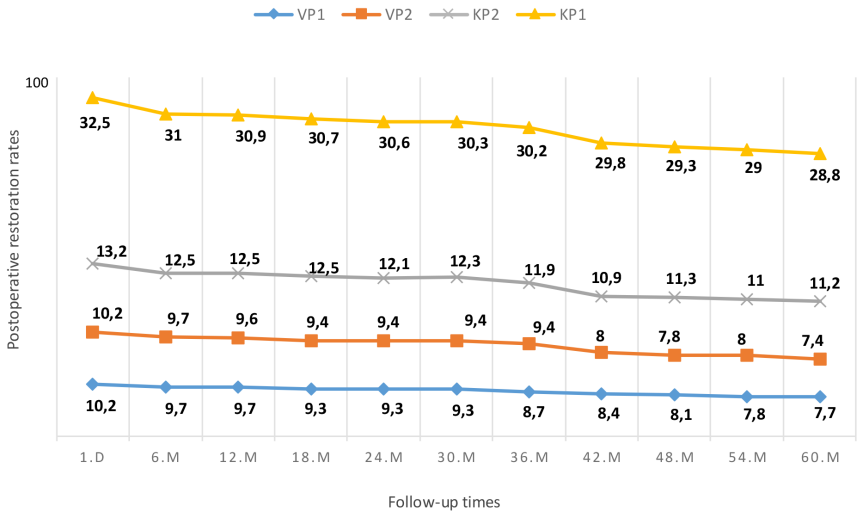

Figure 2. Analysis of postop restoration rates of groups according to follow-up times
VP1: Vertebroplasty group 1, VP2: Vertebroplasty group 2, KP1: Kyphoplasty group 1, KP2: Kyphoplasty group 2, D: Day, M: Month

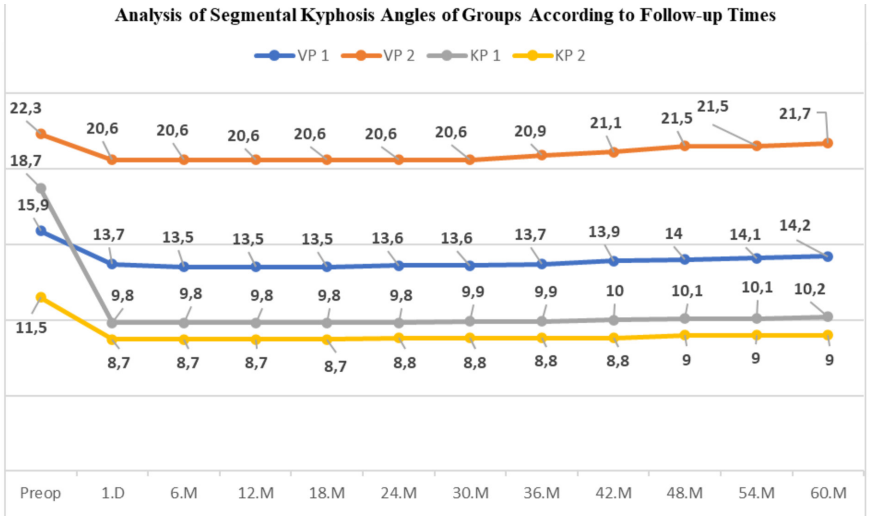

Figure 3. Analysis of segmental kyphosis angles of groups according to follow-up times
VP1: Vertebroplasty group 1, VP2: Vertebroplasty group 2, KP1: Kyphoplasty group 1, KP2: Kyphoplasty group 2, D: Day, M: Month

first day (p=0.003). Although the alterations were noted in the data about subsequent months of observation, they did not exhibit statistical significance. Statistically significant increases in VAS values were observed exclusively in the VP2 following the 36th month (Figure 4). When comparing the VAS values of the groups, there was no statistically significant difference observed between KP1 and KP2, as well as between VP1 and KP2 throughout the duration of the study. Nevertheless, there was no statistically significant difference in preoperative VAS scores between the two groups, KP1 and VP2. However, a significant difference in VAS scores in favor of KP1 was observed during all follow-up months. A similar relationship was noted between the VP1 and VP2 (Table 5).

A statistically significant difference was found between the ODI values, preoperative and the 5th year (p<0.001). While this difference was significant in VP1, VP2 and KP1 (p<0.001), it was significant but relatively lower in KP2 (p=0.003). Preoperative ODI values decreased in KP1 with a statistically significant difference in the first day and the first 12 months (p<0.001). While this decrease for VP1 and VP2 was realized with a high statistical difference on the 1st day (p<0.001), it continued with a statistically lower rate in the first 6 months (for VP1; p=0.001, for VP2; p=0.003). After the 6th month for VP1 and after the 12th month for KP1, the ODI change values showed a statistically stable course. However, a statistically significant increase was observed for VP2 after 36 months (Figure 5). The 1st day data for KP2 was relatively lower than the other groups (p=0.003).

Table 4. Statistical comparison of segmental kyphosis angles of groups according to follow-up periods

		VP1/VP2	VP1/KP2	KP1/VP2	KP1/KP2
		(p)	(p)	(p)	(p)
Segmental kyphosis angle	Preop	**0.002**	0.062	0.107	**0.005**
	1. day	**<0.001**	**0.004**	**<0.001**	0.401
	6. month	**<0.001**	**0.005**	**<0.001**	0.401
	12. month	**<0.001**	**0.006**	**<0.001**	0.406
	18. month	**<0.001**	**0.006**	**<0.001**	0.401
	24. month	**<0.001**	**0.006**	**<0.001**	0.401
	30. month	**<0.001**	**0.006**	**<0.001**	0.401
	36. month	**<0.001**	**0.006**	**<0.001**	0.407
	42. month	**<0.001**	**0.004**	**<0.001**	0.430
	48. month	**<0.001**	**0.005**	**<0.001**	0.430
	54. month	**<0.001**	**0.004**	**<0.001**	0.418
	60. month	**<0.001**	**0.004**	**<0.001**	0.418

VP1: Vertebroplasty group 1, VP2: Vertebroplasty group 2, KP1: Kyphoplasty group 1, KP2: Kyphoplasty group 2

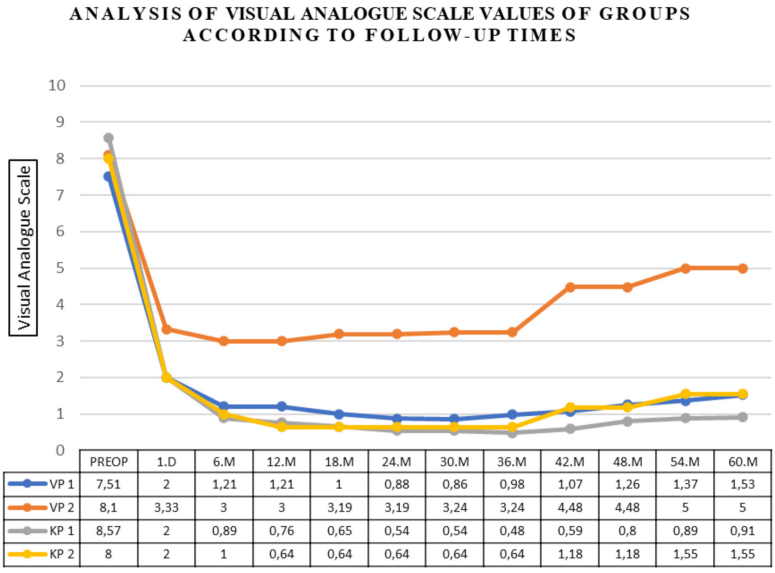

Figure 4. Analysis of visual analogue scale values of groups according to follow-up times
VP1: Vertebroplasty group 1, VP2: Vertebroplasty group 2, KP1: Kyphoplasty group 1, KP2: Kyphoplasty group 2, D: Day, M: Month

This decline continued for the first 6 months and then remained stable (Figure 5).

In the comparison of ODI values between groups; no statistically significant difference was observed between KP1 and KP2 and between VP1 and KP2 during the follow-up periods. However, while there was no significant preoperative ODI difference between KP1 and VP2, a significant difference was observed in favor of KP1 in all follow-up months. Similar relationship was observed between VP1 and VP2 (Table 6).

DISCUSSION

Osteoporosis is a pathological condition affecting the skeletal system, which is defined by a decrease in bone mass, degradation of the microarchitecture of bone tissue, and an elevated vulnerability to fractures[14]. There is a widely accepted consensus that osteoporosis predominantly impacts women. Specifically, women aged 50 years or older exhibit a significantly higher prevalence of osteoporosis, with a fourfold increase compared to males. Additionally, women in this age group also experience a twofold higher incidence of osteopenia in comparison to their male counterparts[15]. Concurrently, our data exhibits a prevalence of female patients. The current scenario aligns with the existing body of literature.

The primary consideration in determining the treatment method for VCF is the assessment of spinal instability, neural compression, and associated neurological symptoms. Decompression and stabilization surgeries are recommended in cases of instability and neurological deficits[4]. However, if patients experience pain without neurological impairment, a trial of conservative treatment with VA techniques may be considered after 4-6 weeks of follow-up[3,4]. VA techniques should also be prioritized in cases where prolonged analgesic therapy and immobilization may lead to vertebral demineralization or when adequate immobilization cannot be achieved due to respiratory and cardiogenic risks[9,10].

Table 5. Statistical comparison of visual analogue scale values between groups according to follow-up periods

		VP1/VP2	VP1/KP2	KP1/VP2	KP1/KP2
		(p)	(p)	(p)	(p)
Visual analogue scale	**Preop**	0.008	0.078	0.027	0.032
	1. day	**<0.001**	1.000	**<0.001**	1.000
	6. month	**<0.001**	0.614	**<0.001**	0.703
	12. month	**<0.001**	0.099	**<0.001**	0.542
	18. month	**<0.001**	0.314	**<0.001**	0.963
	24. month	**<0.001**	0.314	**<0.001**	0.501
	30. month	**<0.001**	0.314	**<0.001**	0.501
	36. month	**<0.001**	0.279	**<0.001**	0.350
	42. month	**<0.001**	0.944	**<0.001**	0.162
	48. month	**<0.001**	0.532	**<0.001**	0.477
	54. month	**<0.001**	0.646	**<0.001**	0.091
	60. month	**<0.001**	0.964	**<0.001**	0.091

VP1: Vertebroplasty group 1, VP2: Vertebroplasty group 2, KP1: Kyphoplasty group 1, KP2: Kyphoplasty group 2

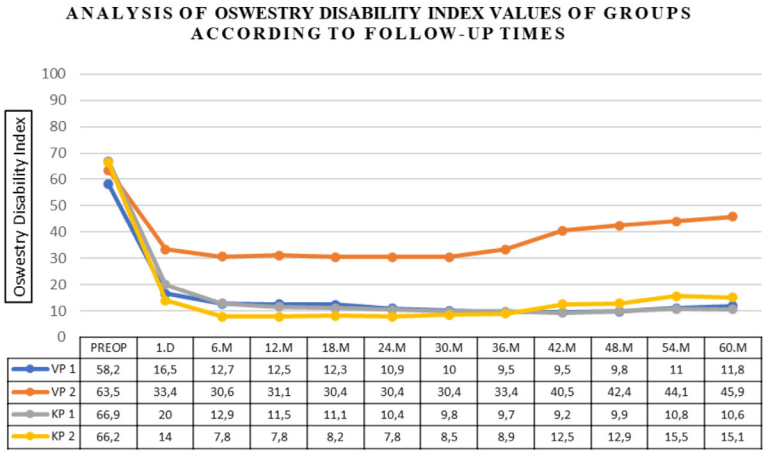

Figure 5. Analysis of Oswestry disability index values of groups according to follow-up times
VP1: Vertebroplasty group 1, VP2: Vertebroplasty group 2, KP1: Kyphoplasty group 1, KP2: Kyphoplasty group 2, D: Day, M: Month

Table 6. Statistical comparison of Oswestry disability index values between groups according to follow-up periods

		VP1/VP2	VP1/KP2	KP1/VP2	KP1/KP2
		(p)	(p)	(p)	(p)
Oswestry disability index	**Preop**	0.035	0.037	0.169	0.469
	1. day	**<0.001**	0.454	**<0.001**	**<0.001**
	6. month	**<0.001**	0.228	**<0.001**	0.009
	12. month	**<0.001**	0.496	**<0.001**	0.074
	18. month	**<0.001**	0.496	**<0.001**	0.095
	24. month	**<0.001**	0.393	**<0.001**	0.087
	30. month	**<0.001**	0.770	**<0.001**	0.200
	36. month	**<0.001**	0.737	**<0.001**	0.174
	42. month	**<0.001**	0.222	**<0.001**	0.250
	48. month	**<0.001**	0.204	**<0.001**	0.420
	54. month	**<0.001**	0.382	**<0.001**	0.203
	60. month	**<0.001**	0.418	**<0.001**	0.132

VP1: Vertebroplasty group 1, VP2: Vertebroplasty group 2, KP1: Kyphoplasty group 1, KP2: Kyphoplasty group 2

Galibert et al.[16] introduced VP, the first VA technique, in 1987 to treat painful vertebral hemangioblastoma. Since then, VP has been used a lot to treat osteoporotic VCFs caused by things like trauma, primary vertebral tumors, multiple myeloma, metastatic vertebral involvement, and angiomas[5,6]. Numerous studies have established the efficacy of VP in managing pain and improving functional quality of life[3,4,17]. However, VP alone is insufficient for restoring vertebral alignment, especially in cases with significant loss of vertebral body height[3,4].

The KP technique was developed in 1998 to address this limitation[18]. Studies comparing different VA techniques have consistently reported positive outcomes[11,19-22]. KP has shown a relative superiority in restoration rates and gain in segment kyphotic angle during the early and mid-term follow-up periods. However, there has yet to be a consensus on the long-term outcomes of different VA techniques, possibly due to variations in technique preference[11,19,20,23,24].

Our study examined the restoration rates of VP and KP groups and segmental kyphotic angle changes. We observed a statistically significant decline in restoration during the initial postoperative period in all groups. This aligns with previous research findings[25]. Bo et al.[26] demonstrated the efficacy of addressing vertebral sagittal alignment disorders in addressing persistent pain following VP. Lin et al.[27] demonstrated a correlation between sagittal imbalance and the potential occurrence of new VCFs in individuals with osteoporosis. Accordingly, one of the primary goals of VA techniques is to restore lost vertebral alignment[3,4,28]. The general opinion is that KP is more effective than VP in restoring lost vertebral alignment[4,11,20,23]. However, long-term studies have reported mixed results, with some showing no significant difference between the two techniques[19].

Our study found a statistically weak change in segmental kyphotic angles in the KP group compared to a statistically significant increase in the VP groups at postoperative day 1. This pattern continued during the initial and middle follow-up periods (up to 30 months) for all groups except KP2. From the 30th month onwards, a statistically significant change was observed in all groups except KP2. We also observed variations in data expression based on follow-up periods, in line with the literature.

Furthermore, during the comparative analysis of the groups, there was a notable disparity in favor of KP1 in cases with a height loss of 50% or more. KP should be preferred in cases with ≥50% height loss. In cases with ≤50% height loss, although our study showed a statistically significant correlation favoring KP2 when considering the percentage of change in data, there was no significant difference with VP. Therefore, we cannot declare significant superiority for either technique in cases with ≤50% height loss.

The mechanisms underlying the analgesic effects of VA techniques are still debated[4]. The mechanical power of segmental corpus reconstruction, stabilization, and the impact of cement hardening on endplates are proposed hypotheses[4,29]. Empirical investigations have shown positive outcomes regarding analgesic properties and functional quality of life improvements for both VP and KP[3,4,11,17,19,21,22].

Many studies have compared VP and KP and found no significant difference in pain control and functional quality of life, especially in the early and mid-term results[11,17,19-22,24,30]. However, some studies have reported a superior functional outcome with KP[31-33]. Our study also showed no significant difference in pain control and functional quality of life between the VP and KP groups, except for the VP2 group after 36 months. These findings align with the existing literature.

In terms of indications, VP is generally recommended for cases with minimal deformity, while KP is preferred for cases with ≥30-40% loss of anatomical morphology[34-40]. However, there is no absolute standardization in these recommendations.

Our study analyzed and interpreted the long-term results of both techniques without preconception. We found that KP was significantly more effective than VP in cases with >50% height loss, based on improvement rates in segmental kyphotic angle changes and functional quality of life. However, in cases with ⩽50% height loss, both radiological and clinical data showed similar outcomes for both techniques. Considering the cost difference between the two techniques, VP may be an adequate and effective choice in this group of cases.

Study Limitations

This study had several limitations. First, it was a retrospective study without a control group and no comparison was made with conservative treatments and other treatment methods. Secondly, only cases diagnosed with osteoporotic vertebral compression fracture were included in our study, but other pathologies for which VA techniques are indicated, especially trauma, were not included in our study. Thirdly, the acceptance criteria for our osteoporotic VCF diagnosis were that the cases' previous BMD values were less than -2.5 (T-score <-2.5) and that they had a previous diagnosis of osteoporosis. Therefore, BMD was not repeated in our cases who were already diagnosed with osteoporosis. Fourthly, among the VA techniques, only data on VP and KP techniques were compared; as a handicap, our study does not include new generation VA methods such as stentoplasty. Finally, although our study makes recommendations based on the radiological and clinical results of the cases, it does not include data on the complications of the compared techniques. It is obvious that there is a need for prospective studies in different indications, including new techniques and differences in complications between techniques.

CONCLUSION

The effectiveness and benefits of KP and VP techniques differ depending on the length of the follow-up period. It is essential to consider the specific indications for each technique when choosing the most appropriate option. In cases where the height loss is ⩽50%, VP may be sufficient, as there is no significant difference in superiority between the two techniques. However, in cases where there is a height loss greater than 50%, a comparison of the improvement rates in segmental kyphotic angle alterations and sagittal alignment with their impact on long-term functional quality of life revealed that KP was much more effective than VP. Therefore, KP may offer more significant advantages for cases with a height loss of >50%.

Ethics

Ethics Committee Approval: Approval was obtained from the University of Health Sciences Turkey, İstanbul Medeniyet University Göztepe Training and Research Ethics Committee (date: 21.06.2023, number: 2023/0402).

Informed Consent: Informed consent was obtained from patients.

Peer-review: Internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: A.Y.Y., M.V.A., Concept: A.Y.Y., M.V.A., Design: A.Y.Y., M.V.A., Data Collection or Processing: A.Y.Y., M.V.A., Analysis or Interpretation: A.Y.Y., M.V.A., Literature Search: A.Y.Y., M.V.A., Writing: A.Y.Y., M.V.A.

Conflict of Interest: No conflict of interest was declared by the authors.

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SURGICAL OUTCOME OF FULL-ENDOSCOPIC INTERLAMINAR BILATERAL DECOMPRESSION WITH UNILATERAL APPROACH FOR LUMBAR SPINAL STENOSIS: A CLINICAL STUDY OF 24 PATIENTS

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ABSTRACT

Objective: This study aimed to evaluate the surgical outcomes of 24 patients with lumbar spinal stenosis (LSS) treated by full-endoscopic interlaminar bilateral decompression using a unilateral approach.

Materials and Methods: Twenty-four patients (seven males and 17 females) treated for LSS by the senior author and followed up for 18 months were included in the study. The pre-operative and postoperative clinical statuses were assessed using a neurological examination, a visual analog scale (VAS) score, and the Oswestry disability index (ODI). Preoperative lumbar magnetic resonance imaging, computed tomography (CT), and postoperative lumbar CT were performed.

Results: Eight patients had isolated lateral recess stenosis, six had central lumbar stenosis, and 10 had both. A total of 31 spinal levels were treated using full endoscopic percutaneous interlaminar decompression. In patients undergoing a single-level procedure, the pre-operative mean VAS score was 9 and the postoperative mean VAS score was 2.5. The mean ODI was 43.5 before surgery and decreased to 11 after surgery. In patients with multi-level intervention, the mean VAS score was 8.5 and the mean ODI was 40 before surgery. Postoperatively, both decreased to 3.5 and 14.5, respectively. All pre- and postoperative values were significantly different.

Conclusion: Full-endoscopic interlaminar bilateral decompression using a unilateral approach provided adequate decompression in selected patients. It also prevents unnecessary surgical trauma and tissue damage and enables better preservation of spine stability, even in patients operated on at multiple spinal levels.

Keywords: Spinal stenosis, endoscopic decompression, interlaminar approach

INTRODUCTION

Lumbar spinal stenosis (LSS) is characterized by sensory dysfunction, gait disturbance, and pain, mostly due to degenerative alterations around the spinal canal and compression of the thecal sac and nerve roots[1,2]. The prevalence of degenerative LSS is approximately 25% and the incidence rate increases after age 50[3]. Moreover, LSS is the most common cause of spinal surgery over the age of 65[4]. This intervention aims to relieve the compression of neural structures, which constitutes the actual purpose of the intervention. Although several surgical techniques have been developed, a laminectomy with partial or total facetectomy, usually followed mainly by spinal stabilization and fusion, remains the traditional approach[5-7].

In patients who have not yet developed segment instability, the traditional surgical method may cause instability of the spinal structure. Many surgeons prefer minimally invasive procedures to avoid increasing the risk of significant complications and to decrease the need for spinal stabilization. Different laminotomy techniques have been introduced to prevent destabilizing the level operated[5-10]. Various authors have advocated bilateral microscopic decompression using a unilateral approach as a less invasive technique[11-16]. As endoscopic tools for spinal surgery are becoming more prevalent, different endoscopic methods for spinal decompression have been described to minimize surgical complications[1,17,18].

With technical advances and increased experience, spinal endoscopic procedures have become a promising method for primary interventional treatment. The endoscopic technique

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allows the exploration of both sides of the spinal canal through undercutting with minimal skin incision and muscle retraction. Visual control, supported by a high-definition camera and constant irrigation, enables a minimally invasive intervention for sufficient bone and ligament resection. Additionally, the surrounding joint structures can be protected[1,17,18]. Therefore, we considered that the endoscopic technique provides favorable short and long-term benefits for decompression in patients with LSS. Our study presents the clinical outcomes of patients with LSS treated with bilateral decompression using a unilateral full-endoscopic interlaminar approach.

MATERIALS AND METHODS

The study was approved by İstanbul University, İstanbul Faculty of Medicine, and the Ethics Committee for Clinical Trials (reference no: 655, date: 15.04.2014). Informed consent was obtained from each patient and their parents. It included 24 patients with LSS subjected to bilateral decompression using the unilateral endoscopic interlaminar approach by a surgeon having experience more than five years of full-endoscopic spinal surgery. The patients were followed up for 18 months. Demographic data were collected, and physical, neurological, and radiological investigations were conducted for all patients. A computed tomography (CT) scan and magnetic resonance imaging (MRI) were used preoperatively to identify the lumbar region pathology. Patients with clinical or radiological instability revealed during their preoperative assessment were excluded from the study. Additionally, all patients were evaluated using the visual analog scale (VAS) and the Oswestry disability index (ODI). After surgery, all patients underwent lumbar CT, and spinal stability was evaluated clinically and radiologically (Figure 1). The physical, neurological, and radiological examination data, VAS score, and ODI obtained postoperatively were noted and compared with the preoperative findings.

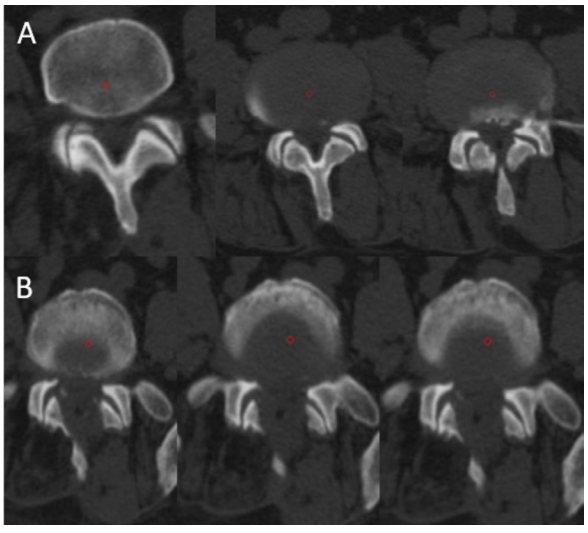

Figure 1. Preoperative **(A)** and postoperative **(B)** CT scans showing bone resection for unilateral access for bilateral recess stenosis

Surgical Procedure

The patient was placed in the prone position using thorax and pelvis support pillows. Endoscopic and optical instruments were set. A C-arm was required for the procedure. All operations were performed using a Vertebris Spine and Endoscopy System produced by Richard Wolf GMHB, Knittlingen, Germany. The intended interlaminar space was determined using the C-arm (Figure 2). The entry point had to be close to the midline to achieve lateral visualization. A deep 8 mm incision was made through the fascia of the paraspinal muscle. The dilator was placed just above the ligamentum flavum, toward the facet joint, using the C-arm (Figure 3). The working sleeve was inserted over the dilator with the beveled edge facing medially. The C-arm was fixed laterally to check the position of the working sleeve in the craniocaudal axis (Figure 4). Then, the dilator was removed, and the endoscope was introduced through the working sleeve. The operation was performed under visual control and continued irrigation with a physiological saline solution. Paravertebral muscles and soft tissues were removed using a rongeur and a bipolar radiofrequency device to expose the ligamentum flavum and the inferior tip of the descending facet (Figure 5). Bone was removed from the medial side of the inferior tip of the descending facet up to the cranial lamina using an oval burr with lateral protection (Figure 6). Then, the ascending facet and its superior tip were exposed. A round burr and an oval burr with lateral protection were used for thinning the ascending facet. Then, the flaval ligament was resected with a punch starting from the midline. The resection of the

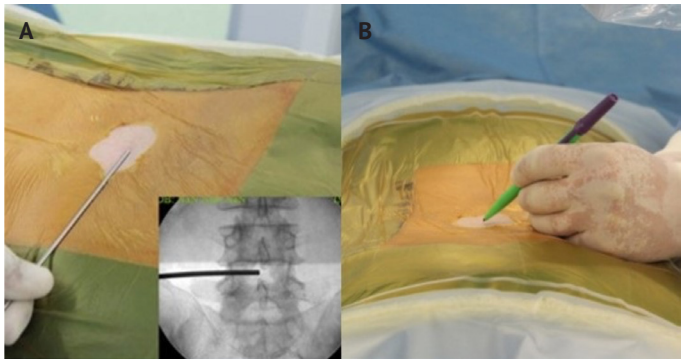

Figure 2. Detection **(A)** and marking **(B)** of the interlaminar space

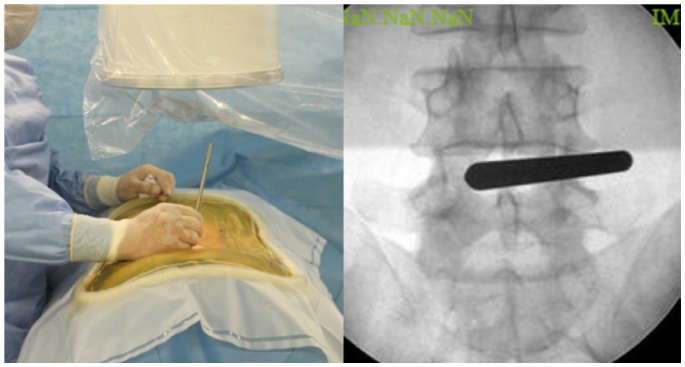

Figure 3. Positioning of the dilator under C-arm guidance

ligamentum flavum was performed in the towards the lateral and caudal directions to access the lateral recess (Figure 7). A Kerrison punch was used to further remove the ascending facet toward the lateral portion. A resection from the tip of the ascending facet to the caudal pedicle and the caudal lamina is recommended. The contralateral facet joint was accessed under the spinous processes. The same procedure for removing bone and ligamentum flavum was performed on the contralateral side. Then, decompression was completed (Figure 8). After hemostasis, the procedure was terminated by removing the endoscopic system. A single suture without any drainage was sufficient for closure.

Statistical Analysis

IBM SPSS Statistics version 28.0 was used for statistical analysis. The normality of the distribution was assessed using kurtosis and skewness tests. Non-parametric tests were conducted because the number of patients was limited. The Mann-Whitney U test was used to analyze the preoperative and postoperative pain scores. A value of $p<0.05$ was considered statistically significant.

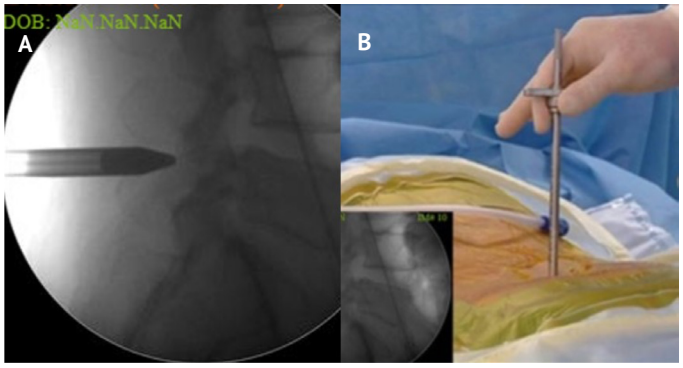

Figure 4. Positioning **(A)** and manipulation **(B)** of the working sleeve

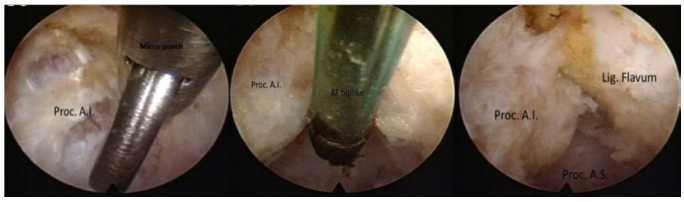

Figure 5. Exposure of the ligamentum flavum and facet joint. (Lig. Flavum: Ligamentum flavum, Proc. A. I.: Inferior articulating process, Proc. A. S.: Superior articulating process)

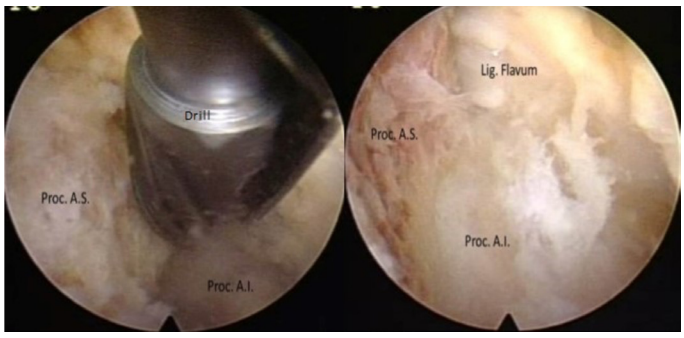

Figure 6. Bone resection. (Lig. Flavum: Ligamentum flavum, Proc. A. I.: Inferior articulating process, Proc. A. S.: Superior articulating process)

RESULTS

Twenty-four patients (seven males and 17 females) underwent surgery for LSS. The mean age of the patients was 61, and the age range was 44-85. At admission, all patients experienced leg pain and gait disturbance. Four patients also described paresthesia in their lower extremities. All patients had neurological claudication, and four presented paresis in distal myotomes of the lower extremities on clinical examination. The femoral nerve stretch test results of two patients were positive. One patient also had spasticity due to a previous cervical spondylosis operation. Lumbar MRI revealed isolated lateral recess stenosis in eight patients, central lumbar stenosis in six patients, and both entities in 10 patients.

A total of 31 spinal levels were targeted using the full-endoscopic percutaneous interlaminar approach. The number of endoscopic decompression procedures was two for the L2-L3 level, 10 for the L3-L4 level, 17 for the L4-L5 level, and two for the L5-S1 level. A decompression on two levels occurred in five patients, and one underwent the procedure on three levels. The average skin-to-skin operation time was 62 min for patients treated at a single level (51-74 min), 96 min for patients undergoing a two-level procedure (83-110 min) and

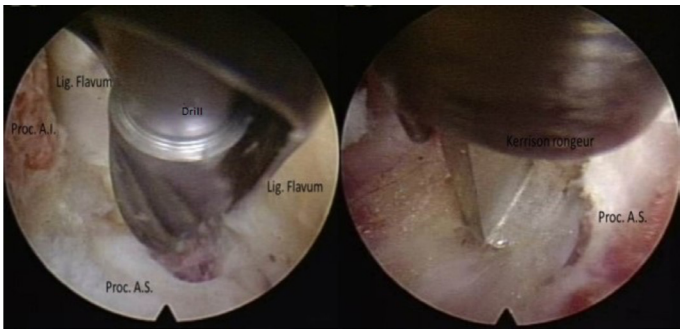

Figure 7. Completion of the ipsilateral bone resection. (Lig. Flavum: Ligamentum flavum, Proc. A. I.: Inferior articulating process, Proc. A. S.: Superior articulating process)

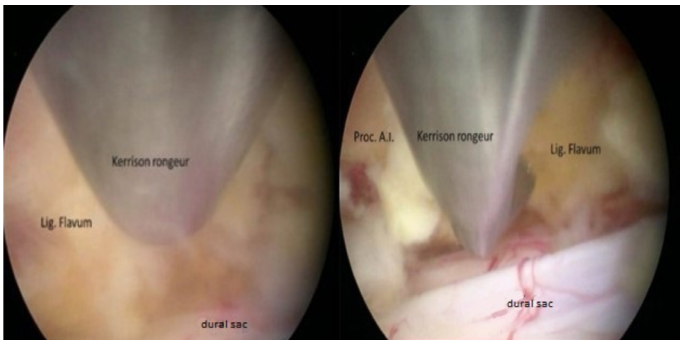

Figure 8. Contralateral bone and ligament resection. (Lig. Flavum: Ligamentum flavum, Proc. A. I.: Inferior articulating process)

163 min for the patient treated at three levels. No complication or neurological deterioration was observed after surgery. In one of the four patients with preoperative paresis, the neurological status improved during the early postoperative period. One patient who underwent a single-level surgery and another subjected to a multi-level intervention reported pain in both legs of the same severity as before surgery. No evidence of spinal instability was detected during the postoperative assessments. The comparison between pre- and postoperative pain scores revealed a significant decrease in pain levels after treatment of patients with endoscopic interlaminar decompression at single or multiple spinal levels. In patients subjected to a single-level intervention, the preoperative mean VAS score was 9, and the postoperative score was 2.5. Their mean ODI was 43.5 and decreased to 11 in the postoperative evaluation. The difference between both scores was statistically significant (p=0.001). Before surgery, the mean VAS score was 8.5, and the mean ODI score was 40 for patients subjected to a multilevel resection. Both scores were significantly decreased to 3.5 and 14.5, respectively (p=0.002), after surgery. At an individual level, the pain scores of two patients who did not report any postoperative improvement remained similar to those before surgery. After clinical and radiological evaluation, we proposed to perform a second operation, but both patients declined an additional intervention.

DISCUSSION

Although the most common surgical treatment for LSS is laminectomy, frequently accompanied by stabilization, less invasive surgical options have become popular recently. Classical decompression surgeries require extensive soft tissue dissection and bone removal. Because excessive bone and facet removal leads to instability, even in cases without preoperative instability, stabilization usually complements classical decompression procedures. This may cause additional morbidity and chronic persistent low back pain in patients with LSS, particularly older ones. Low patient satisfaction has been reported after these surgeries due to persistent or recurrent pain[19-32]. For example, Amundsen et al.[19] evidenced the positive outcomes of the surgical management of lumbar stenosis and mentioned a certain dissatisfaction of some patients during the early postoperative period. Another study found that surgical intervention was more effective than conservative treatment, but the relative benefit faded with time[20]. Iguchi et al.[23] suggested spinal fusion after adequate decompression by laminectomy to avoid long-term deterioration in neurological status. Mayer et al.[32] proposed that paravertebral muscle dissection and retraction cause atrophy in traditional decompression procedures. Electromyographical anomalies and chronic denervation can also be observed after extreme decompressing operations[33]. Young et al.[6] were among the first surgical teams to perform bilateral microscopic laminotomy. They treated 32 patients and aimed to cause as little damage as possible while preserving stability by protecting the spinous process and interspinous and supraspinous ligaments[6]. However, a study by Thomas et al.[26] showed that laminotomy was insufficient to decompress the spinal canal, as spondylolisthesis rates were similar to those of laminectomy. On the other hand, Aryanpur and Ducker[5] observed no complications after laminotomy in their lateral stenosis study. Additionally, a few reports on less invasive procedures indicated that these procedures also caused instability despite the minimal tissue damage and bone removal[34,35]. However, most studies on bilateral laminectomy and unilateral or bilateral decompression have not described any instability[16,36-41].

Weiner et al.[16] suggested bilateral microdecompression using a unilateral route to successfully treat lower back pain by causing minimal tissue damage. Orpen et al.[42] published a similar study in 2010. Four patients developed symptomatic instabilities in their two-year follow-up of 100 patients with "grade 1" spondylolisthesis and no instability symptoms. Thomé et al.[35] compared bilateral decompression using bilateral laminotomy, unilateral laminotomy, and laminectomy in patients without disc herniation and instability symptoms. Although all three methods effectively treated symptoms and resulted in greater distances walked by patients, the bilateral laminotomy seemed superior to the other methods. Instability symptoms were reported in three out of 40 patients treated with laminectomy and two out of 40 patients treated with unilateral laminotomy and bilateral decompression[35].

In 2005, Ikuta et al.[18] compared microendoscopic and traditional microscopic laminectomy methods. Short-term analysis showed that the microendoscopic approach was better at treating lower back pain and restoring functionality. Additionally, the microendoscopic method prevented blood loss and the excessive administration of painkillers. Ikuta et al.[18] reported a longer operation time for the microendoscopic method than that of the traditional method; however, they attributed this difference to the novelty and lack of mastery of the approach. Wada used a single tubular retractor to perform bilateral decompression. Although they stated that this method achieved adequate decompression, working through a narrow tube is disadvantageous. Moreover, in his study, they reported only one surgical field hematoma as a complication[43].

Here, we treated all patients using a full-endoscopic percutaneous interlaminar approach. This method was first described by Ruetten in 2006 and modified for spinal stenosis in 2009. The comparison of full-endoscopic and microscopic decompression methods in 161 patients with unilateral single-level lateral recess stenosis revealed that the full-endoscopic approach resulted in an increased walking distance and less pain. Moreover, the full-endoscopic approach allowed better surgical field vision, shorter operation time, and faster rehabilitation. Because of minimal tissue damage, there was less scar tissue and a lower need for blood transfusion. The only reported disadvantage of the full-endoscopic method is the long and arduous learning process[1]. In a study by Komp

et al.[17], 74 patients, including those with radicular pain and single-level stenosis, underwent unilateral full-endoscopic surgery. The authors reported an average operation time of 44 min (35-61 min) and no significant blood loss. They listed transient dysesthesia, transient urinary retention, dural injury, and motor deficit as possible complications. They also observed an increased kyphotic angle at the operated level in three patients (4.2%) and decreased intervertebral disc space height in eight patients (11.1%). Additionally, grade 1 spondylolisthesis progressed to grade 2 in one patient. No additional instability findings were reported[17]. Siepe et al.[44] used the endoscopic interlaminar over-the-top technique for bilateral decompression of both nerve roots.

McGrath et al.[45] compared the outcomes of minimally invasive and endoscopic unilateral laminotomies for bilateral decompression. They showed that the operation time was significantly longer for the endoscopic group, but the hospital stay was shorter. At the first-year follow-up, the VAS scores for leg pain and back pain disability index scores were significantly lower in the endoscopic group. The endoscopic technique was the first to introduce a tubular retractor and replace the trocar with an endoscope[45]. A similar study by Chen et al.[46] compared full-endoscopic and microscopic unilateral laminotomies for bilateral decompression of LSS at the L4-L5 level. A 9-mm endoscope with a 5.7-mm working channel was used (Vertebris stenosis, RIWOSpine, GmbH, Knittlingen, Germany). There were no significant differences in postoperative disc height, translational motion, or facet preservation rate. No findings of instability were reported for both groups. The use of analgesics, blood loss, and hospitalization time were significantly lower in the endoscopic group. Furthermore, the endoscopic group had a lower VAS score for back pain, whereas there was no significant difference in leg pain and ODI[46]. A study by Lee et al.[47] on 213 patients (232 lumbar levels) subjected to decompression for treating spinal canal and lateral recess stenoses reported significantly lower VAS scores for leg and back pain and mean ODIs. Kim et al.[48] included 48 patients in their study, showing that full-endoscopic bilateral decompression for LSS decreased the VAS score and ODI. Macnab outcome grade was good to excellent in 96% of patients. Kim et al.[48] used an iLESSYS Delta Endoscopic System (Joimax GmbH, Karlsruhe, Germany). This system has a working cannula with a 13.7-mm outer diameter and a 10.2-mm inner diameter. The endoscope has a 10-mm outer diameter and a 6-mm working channel. Dural tear occurred in 3 patients (6.25%), and 2 patients (4.17%) required a transforaminal interbody fusion procedure. There were no findings of instability during the follow-up period[48]. In another study, 450 patients with single- and multiple-level lumbar stenosis were operated on using a full-endoscopic approach with a single-entry point. No evidence of instability was found in the postoperative dynamic imaging modalities[49]. However, most of the aforementioned studies involved patients with single-level pathologies. In our study, all patients had neurological claudication, and none presented spinal instability, even those subjected to a multilevel resection. Postoperative decreases in the ODI and VAS scores were statistically significant. There was a poor outcome for two patients, one undergoing a two-level intervention and one undergoing a single-level resection. One of these patients had previously undergone surgery after a diagnosis of acromegaly. Postoperative evaluation of both patients suggested insufficient decompression, and the patients were offered a second intervention that they declined.

In the present study, four patients had neurological deficits before surgery. The neurological deficit improved in one of these patients, whereas the condition of the other three patients remained unchanged during the early postoperative period. No additional neurological deficits or complications were encountered. Contrary to many other studies[19-31,35], no spinal instability was detected in patients after a one-year follow-up. The mean operation time was 62 min in cases of single-level intervention, which was longer than that reported by Komp et al.[17]. Because of constant irrigation, the actual bleeding could not be quantified, but the hemoglobin levels of patients were not significantly decreased.

Study Limitations

The retrospective nature of the study, limited patient population, and inability to compare microscopic spinal decompression and endoscopic technique of the same surgeon were some of the study's limitations.

CONCLUSION

Endoscopic procedures are increasingly used for spinal surgery, and the application areas of endoscopy are also expanding. Endoscopic treatment of LSS is relatively new, but its advantages are increasingly reported. Persistent pain and instability are severe problems occurring after decompression surgeries, and endoscopic approaches might allow for avoiding the complications encountered after traditional interventions. Lesser tissue damage and lower blood loss seem to be definite advantages of endoscopic surgeries, and operation time shortens as experience increases. Moreover, the endoscopic approach enables better preservation of the spine's stability, even in patients operated on at multiple spinal levels.

Ethics

Ethics Committee Approval: The study was approved by İstanbul University, İstanbul Faculty of Medicine, and the Ethics Committee for Clinical Trials (reference no: 655, date: 15.04.2014).

Informed Consent: Informed consent was obtained from each patient and their parents.

Peer-review: Internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: İ.D., A.G.Y., A.S., Concept: İ.D., T.C.Ü., A.G.Y., P.A.S., A.A., Y.A., A.S., Design: İ.D., T.C.Ü., A.G.Y., P.A.S., A.A., Y.A., A.S., Data Collection or Processing: İ.D., A.G.Y.,

Analysis or Interpretation: İ.D., T.C.Ü., A.G.Y., D.D., O.Ö., P.A.S., A.A., Y.A., A.S., Literature Search: İ.D., A.G.Y., D.D., O.Ö., C.İ.G., D.Ş., Writing: İ.D., C.İ.G., D.Ş.

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