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About Us

Journal of Turkish Spinal Surgery (www.jtss.org), is the official publication of the Turkish Spinal Surgery Society. 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 the development of the spinal knowledge. The journal publis¬hes original scientific research articles, invited reviews and case reports that are accepted by the Editorial Board, in English.

The journal is published once in every three months and a volume consists of four issues. Journal of Turkish Spinal Surgery is published four times a year: on January, April, July, and October.

Journal of Turkish Spinal Surgery is indexed in TÜBİTAK ULAKBİM TR Index, EBSCO, J-Gate, GALE, ProQuest, Türkiye Atıf Dizini, Index Copernicus and Europub.

The Turkish Spinal Surgery Society was established in 1989 in Izmir (Turkey) by the pioneering efforts of Prof. Dr. Emin Alıcı and other a few members. The objectives of the society were to: - establish a platform for exchange of information/experience between Orthopedics and Traumatology Specialists and Neurosurgeons who deal with spinal surgery - increase the number of physicians involved in spinal surgery and to establish spinal surgery as a sophisticated medical discipline in Turkey - follow the advances in the field of spinal surgery and to communicate this information to members - organize international and national congresses, symposia and workshops to improve education in the field - establish standardization in training on spinal surgery - encourage scientific research on spinal surgery and publish journals and books on this field - improve the standards of spinal surgery nationally, and therefore make contributions to spinal surgery internationally.

The main objective of the Journal is to improve the level of knowledge and experience among Turkish medical society in general and among those involved with spinal surgery in particular. Also, the Journal aims at communicating the advances in the field, scientific congresses and meetings, new journals and books to its subscribers. Journal of Turkish Spinal Surgery is as old as the Turkish Spinal Surgery Society.

The first congress organized by the Society took place in Çeşme, Izmir, coincident with the publication of the first four issues. Authors were encouraged by the Society to prepare original articles from the studies presented in international congresses organized by the Society every two years, and these articles were published in the Journal. The Journal publishes clinical or basic research, invited reviews, and case presentations after approval by the Editorial Board. Articles are published after at least two reviewers review them. Editorial Board has the right to accept, to ask for revision, or to refuse manuscripts.

The Journal is issued every three months, and one volume is completed with every four issue. Associate Editors and Editor in Chief are responsible in reviewing and approving material that is published. Responsibility for the problems associated with research ethics or medico-legal issues regarding the content, information and conclusions of the articles lies with the authors, and the editor or the editorial board bears no responsibility. In line with the increasing expectations of scientific communities and the society, improved awareness about research ethics and medico-legal responsibilities forms the basis of our publication policy.

Citations must always be referenced in articles published in our journal. Our journal fully respects to the patient rights, and therefore care is exercised in completion of patient consent forms; no information about the identity of the patient is disclosed; and photographs are published with eye-bands. Ethics committee approval is a prerequisite. Any financial support must clearly be disclosed. Also, our Journal requests from the authors that sponsors do not interfere in the evaluation, selection, or editing of individual articles, and that part or whole of the article cannot be published elsewhere without written permission.

Journal of Turkish Spinal Surgery is available to the members of the society and subscribers free of charge. Membership fees, congresses, and the advertisements appearing in the journal meet the publication and distribution costs.

The advertisement fees are based on actual pricing. The Editorial Board has the right for signing contracts with one or more financial organizations for sponsorship. However, sponsors cannot interfere in the scientific content and design of the journal, and in selection, publication order, or editing of individual articles.

Journal of Turkish Spinal Surgery agrees to comply with the "Global Compact" initiative of the UN, and this has been notified to the UN. Therefore, VI our journal has a full respect to human rights in general, and patient rights in particular, in addition to animal rights in experiments; and these principles are an integral part of our publication policy.

Recent advances in clinical research necessitate more sophisticated statistical methods, well-designed research plans, and more refined reporting. Scientific articles, as in other types of articles, represent not only an accomplishment, but also a creative process.

The quality of a report depends on the quality of the design and management of the research. Well-designed questions or hypotheses are associated with the design. Well-designed hypotheses reflect the design, and the design reflects the hypothesis. Two factors that determine the efficiency of a report are focus and shortness. Drawing the attention to limited number of subjects allows the author to focus on critical issues. Avoidance from repetitions (apart from a few exceptions), a simple language, and correct grammar are a key to preparing a concise text. Only few articles need to exceed 3000 words, and longer articles may be accepted when new methods are being reported or literature is being reviewed.

Although authors should avoid complexity, the critical information for effective communication usually means the repetition of questions (or hypotheses or key subjects). Questions must be stated in Abstract, Introduction and Discussion sections, and the answers should be mentioned in Abstract, Results, and Discussion sections. Although many journals issue written instructions for the formatting of articles, the style of the authors shows some variance, mainly due to their writing habits.

Journal of Turkish Spinal Surgery adopts the AMA style as a general instruction for formatting. However, not many authors have adequate time for learning this style. Thus, our journal is tolerant to personal style within the limitations of correct grammar and plain and efficient communication.

JOURNAL OF TURKISH SPINAL SURGERY

Instructions to Authors

Journal of Turkish Spinal Surgery (www.jtss.org), is the official publication of the Turkish Spinal Society. 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 the development of the spinal knowledge. The journal publishes original scientific research articles, invited reviews and case reports that are accepted by the Editorial Board, in English.

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PEER REVIEW

Article is reviewed by secretaries of the journal after it is uploaded to the web site. Article type, presence of the all sections, suitability according to the number of words, name of the authors with their institutions, corresponding address, mail addresses, telephone numbers and ORCID numbers are all evaluated and shortcomings are reported to the editor. Editor request the all defect from the authors and send to vice editors and native English speaker editor after completion of the article. Vice editors edit the blinded article and this blinded copy is sent to two referees. After reviewing of the article by the referees in maximum one month, the review report evaluating all section and his decision is requested, and this blinded report is sent to the author. In fifteen days, revision of the article is requested from the authors with the appreciate explanation. Revised blinded copy is sent to the referees for the new evaluation. Editor if needed may sent the manuscript to a third referee. Editorial Board has the right to accept, revise or reject a manuscript.

-Following types of manuscripts related to the field of "Spinal Surgery" with English Abstract and Keywords are accepted for publication: I- Original clinical and experimental research studies; II- Case presentations; and III- Reviews.

AUTHOR'S RESPONSIBILITY

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 participated in the study to a significant extent. All authors should confirm that they have read the study and agreed to the submission to 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.

It is the author's responsibility to ensure that a patient's anonymity be carefully protected and to verify that any experimental investigation with human subjects reported in the manuscript was performed upon the informed consent of the patients and in accordance with all guidelines for experimental investigation on human subjects applicable at the institution(s) of all authors.

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.

CONFLICTS OF INTEREST

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 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".

ARTICLE WRITING

Clinically relevant scientific advances during recent years include 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 rigor of 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 the 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 written permission letter and it should be submitted along with the manuscript.

Review articles: The format for reviews substantially differs 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 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 which 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 by 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.

-Key Words: 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.

The first paragraph should introduce the general topic or problem and emphasized 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 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 historic 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 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 escribe 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 a 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 be long. 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 so-mething else (different in what way? the readermay 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 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 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 the 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 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 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:

1. 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 (1): 5-9.

Book chapter:

2. 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:

3. 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:

4. 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:

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

Book in press:

6. 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:

7. 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:

8. 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 abbrevia-tions.

-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 Acknowledgments section.

Authors are requested to apply and load including the last version of their manuscript to the manuscript submission in the official web address (www.jtss.org). The electronic file must be in Word format (Microsoft Word or Corel Word Perfect). Authors can submit their articles for publication via internet using the guidelines in the following address: www.jtss.org.

- 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 historical precedent. Instead, indicate the point in the manuscript by providing citation by superscripting.

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 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 ignificance 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

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

Morphometric analysis

Anesthesiology

Animal study

Basic Science

Biology

Biochemistry

Biomaterials

Bone mechanics

Bone regeneration

Bone graft

Bone graft sustitutes

Drugs

Disc

Disc Degeneration

Herniated Disc

Disc Pathology

Disc Replacement

IDET

Disease/Disorder

Congenital

Genetics

Degenerative disease

Destructive (Spinal Tumors)

Metabolic bone disease

Rheumatologic

Biomechanics Cervical Spine

Cervical myelopathy

Cervical reconstruction

JOURNAL OF TURKISH SPINAL SURGERY

Cervical disc disease
Cervical Trauma
Degenerative disease
Complications
Early
Late
Postoperative
Deformity
Adolescent idiopathic scoliosis
Kyphosis
Congenital spine
Degenerative spine conditions
Diagnostics
Radiology
MRI
CT scan
Others
Epidemiology
Etiology
Examination
Experimental study
Fusion
Anterior
Posterior
Combined
With instrumentation
Infection of the spine
Postoperative
Rare infections
Spondylitis
Spondylodiscitis
Tuberculosis
Instrumentation
Meta-Analysis

Osteoporosis
Bone density
Fractures
Kyphoplasty
Medical Treatment
Surgical Treatment
Outcomes
Conservative care
Patient Care
Primary care
Quality of life research
Surgical
Pain
Chronic pain
Discogenic pain
Injections
Low back pain
Management of pain
Postoperative pain
Pain measurement
Physical Therapy
Motion Analysis
Manipulation
Non-Operative Treatment
Surgery
Minimal invasive
Others
Reconstructive surgery
Thoracic Spine
Thoracolumbar Spine
Lumbar Spine
Lumbosacral Spine
Psychology
Trauma

Fractures

Dislocations

Spinal cord

Spinal Cord Injury

Spinal stenosis

Cervical

Lumbar

Lumbosacral

Tumors

Metastatic tumors

Primary benign tumors

Primary malign tumors

APPLICATION LETTER EXAMPLE:

Editor-in-Chief

Journal of Turkish Spinal Surgery

Dear Editor,

We enclose the manuscript titled '.....' for consideration to publish in Journal of Turkish Spinal Surgery.

The following authors have designed the study (AU: Parenthetically insert names of the appropriate authors), gathered the data (AU: Parenthetically insert names of the appropriate authors), analyzed the data (AU: Parenthetically insert names of the appropriate authors), wrote the initial drafts (AU: Parenthetically insert initials of the appropriate authors), and ensure the accuracy of the data and analysis (AU: Parenthetically insert names of the appropriate authors).

I confirm that all authors have seen and agree with the contents of the manuscript and agree that the work has not been submitted or published elsewhere in whole or in part.

As the Corresponding Author, I (and any other authors) understand that Journal of Turkish Spinal Surgery requires all authors to specify any contracts or agreements they might have signed with commercial third parties supporting any portion of the work. I further understand such information will be held in confidence while the paper is under review and will not influence the editorial decision, but that if the article is accepted for publication, a disclosure statement will appear with the article. I have selected the following statement(s) to reflect the relationships of myself and any other author with a commercial third party related to the study:

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Dear Colleagues,

Once again, it is my great honor to be able to publish the Journal of Turkish Spinal Surgery for you, my esteemed colleagues. 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. 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. Without your munificent contributions our journal would cease to exist.

The Journal of Turkish Spinal Surgery (www.jtss.org), is the official publication of the Turkish Spine Society. We are very happy to announce that JTSS is currently indexed in eight Indices: Ulakbim, Türkiye Atıf Dizini, Index Copernicus, J-Gate, Europub, Proquest, Gale Cengage Learning and Ebsco Host.

This issue includes six clinical research studies, and two case reports. Please take the time to review it carefully, and make use of any new information or insights that you glean from it.

The first study is A Bibliographic Analysis of the 50 Most Cited Articles in Adolescent Idiopathic Scoliosis. In the second, one can read about The Relationship Between TLICS 1-3, and Functional and Radiological Outcomes, in Conservative Treatment of Thoracolumbar Vertebrae Fractures. The third article is A Radiological Study about Morphometry of the Subaxial Cervical Spine Pedicles in the Anatolian Population. The authors of the fourth study evaluated Radiological Normal Sagittal Vertebral Pelvis, and Global Vertebral-Pelvic Parameters, in a Young Adult Turkish Population. The fifth study is A Retrospective Investigation, in Army Officer Candidates, of Lumbosacral Transitional Anomalies, and any Relation with Sagittal Spinal Alignment and Coronal Spinal Asymmetry.

The authors of the sixth study wrote about Effects of Lumbar Microdiscectomy on Spinopelvic Parameters. While, in the seventh, a pilot study about Functional Recovery after Wharton's Jelly-Derived Mesenchymal Stem Cell Administration in a Patient with Traumatic Spinal Cord Injury. The eighth article is A Case Report about a Lumbar Intramedullary Dermoid Tumor in an Adult.

I hope you found this issue thought provoking and informative. I am dedicated to trying to provide our members with information regarding the latest developments in our field. It is only by doing this that we can stay abreast of the most current and ground breaking developments in our field.

I pray that all our Turkish spinal surgeons and their families will remain safe during these difficult times, and that the vaccines which are currently being administered will help bring this pandemic under control.

With kindest regards,

Editor in Chief

Metin Özalay, M.D.

JOURNAL OF TURKISH SPINAL SURGERY

Contents

ORIGINAL ARTICLES

CASE REPORTS

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ORIGINAL ARTICLE
1

ADOLESCENT IDIOPATHIC SCOLIOSIS: A BIBLIOGRAPHIC ANALYSIS OF THE 50 MOST CITED ARTICLES

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ABSTRACT

Objective: Although adolescent idiopathic scoliosis (AIS) is the most commonly observed spinal deformity, there is limited bibliographic analysis of AIS in the literature. The aims of this study were to identify and analyze the top 50 most cited articles on AIS.

Materials and Methods: On February 6th, 2020, we searched the Thomson Reuters Web of Science-Science Citation Index Expanded database using the term, "AIS". We listed the articles by their number of citations. The titles of the articles, citation number, citation density, article content, journal of publication, author name, publishing country, institute, publishing specialty, and year of publication were noted.

Results: The mean citation number was 210.4±148 (range: 117-873); the mean citation density was 12.8±14 (range: 3-46). The contents of 25 articles (50%) were related to surgical treatment outcomes. Most of the articles (74%) were published in "Spine", and the total citation number was 6978. Most of the articles (67%, 33 articles) were published from the United States (USA). The first specialty of the primary authors of 46 articles was orthopedic surgery; LG Lenke and YJ Kim had the most citations for AIS-related articles. There was only one level 1 study.

Conclusion: Our bibliographic analysis showed that most studies were based on surgical treatment for AIS in the USA, and that "Spine" had published more than 50% of these studies. Although the number of publications has increased rapidly over the years, prospective randomized trials for AIS treatment are still lacking.

Keywords: Adolescent idiopathic scoliosis, citation analysis, bibliographic analysis, classic papers

INTRODUCTION

The most common type of scoliosis is adolescent idiopathic scoliosis (AIS) that develops in otherwise healthy children, mainly female, around puberty(1). Epidemiological studies estimate that 2-4% of the at-risk population (10-16-year-old females) will develop some degree of spinal curvature(2). AIS causes many problems, such as cosmetic, respiratory, and mobilization problems(3). Bracing for 23 hours per day is the conservative treatment of choice when the Cobb angle is between 20 and 40 degrees with remaining growth potential, whereas spinal fusion is in order when the Cobb angle is >40 degrees with remaining growth potential or >45 degrees at skeletal maturity(4,5). Studies reporting conservative treatment emphasize the importance of early diagnosis and treatment(6). Both the indications and procedures used for conservative treatment are clear. However, surgical treatment is complex and requires operative experience in scoliosis surgery. Lenke et al.(7) described a new classification for AIS to guide spinal surgery(7). There have been many studies describing surgical treatment and techniques, especially the pedicle screw technique and fusion levels according to the type of deformity(7-10).

The number of publications on AIS has continued to increase over the years. Bibliographic analysis can provide access to basic articles on popular topics, such as AIS, and identify the most influential journals, clinics, and authors for a given subject. In addition, it helps to identify the subjects that could inspire young surgeons to contribute to the literature with their own studies.

Examining the most cited articles is a frequently used method for bibliographic analysis(11). The number of citations of an article is an objective tool that shows how much the article is appreciated by the scientific community and determines the relevance of an article at the academic level(12). For this reason, bibliographic studies of popular topics have increasingly focused on the top 50 most cited articles in the literature. In orthopaedic literature, analyses of most cited papers have been performed

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for shoulder and hip arthroscopy, knee and hip arthroplasty, wrist surgery, spine surgeries, and some special topics such as anterior cruciate ligament, lumbar spondylolisthesis, and cervical dyspathy[13-21]. In the spine deformity topic, bibliographic analyzes were made with different study protocols such as 100 top-cited Articles on Spinal Deformity and scoliosis research for 10 year period[22-24].

Although AIS is the most common spinal deformity, the aims of this study were to identify and analyze the top 50 most cited articles on AIS in the Thomson ISI Web of Science® Database.

MATERIALS AND METHODS

Study Design

Institutional review board approval was not required given the public availability of the data. On February 6th, 2020, we searched the Thomson Reuters Web of Science-Science Citation Index Expanded database using the term, "AIS" and web of science categories of orthopaedics. Publications were sorted according to the citation numbers. The articles published in the English language between 1970 and 2020 were included in the present study. The articles published in languages other than the English language, before 1970, in the non-orthopaedics journal or with contents not related to AIS were excluded from the present study (Figure 1).

Variables

We noted the titles of the articles, citation number, citation density (citation number/duration of publication), article content, journal of publication, author name, publishing country, institute (institution), publishing branch (speciality), and year of publication.

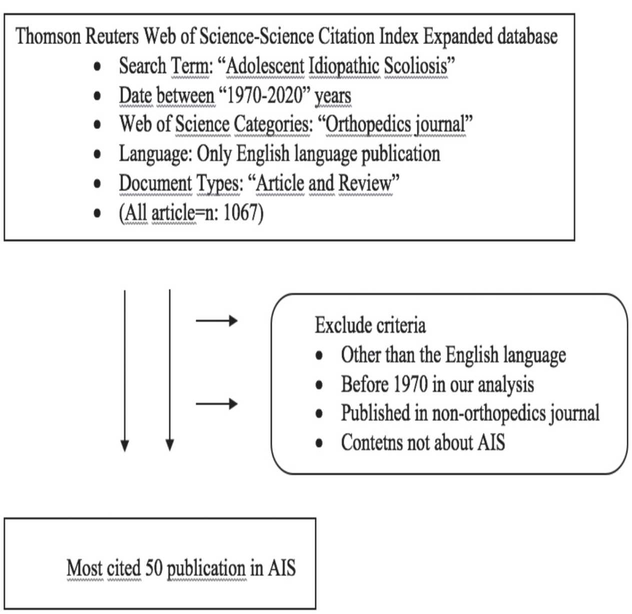

Figure 1. Study flow chart

AIS: Adolescent idiopathic scoliosis

Categorization for Some Variables

Article content: Surgical treatment outcomes, classification score system, radiological imaging, non-surgical treatment brace, surgical technique, progression, and complications.

Author name: For more than two first-author publications.

Institute: Institutes with more than two publications.

Decades between 1970 and 2020: 1970s, 1980s, 1990s, 2000s, and 2010s.

Study design: Randomized controlled, non-randomized controlled, prospective study, case-control, meta-analysis review, retrospective cohort, and retrospective cohort without a control group.

Levels of study: Level 1, level 2, level 3, level 4, and level 5.

Statistical Analysis

Data were analyzed statistically using SPSS v.22 software at a confidence interval of 95%. Qualitative data are described as frequency distributions, and quantitative data are presented as mean, minimum, and maximum values.

RESULTS

Citation Vount and Citation Density

The mean citation number was 210.4±148 (range: 117-873). The mean citation density was 12.8±14 (range: 3-46). The total number of citations and citation density of the articles are listed in Table 1.

Article Contents

The content of 25 articles (50%) was related to surgical treatment outcomes. The contents of other studies were as follows: radiology-imaging (n=6), classification-scoring systems (n=4), progression (n=4), complications (n=4), surgical techniques (n=4), and conservative treatment brace (n=4) (Figure 2).

Journals and Total Citation Number of the Journal

All articles appear to be published in a total of 4 journals (Table 2). The spine was the journal in which most of the articles (74%) were published; the total citation number was 6978. The second-highest number of articles (n=9) was published in the Journal of Bone and Joint Surgery; the total citation number is 2400. The other articles were published in the European Spine Journal (3 articles; total citation number of 1080) and Acta Orthopaedica Scandinavica (1 article; total citation number of 136).

Analysis of Authors

LG Lenke and YJ Kim were the authors who had participated in the highest number of scientific studies on AIS. LG Lenke was the first author in 5 articles and a co-author in 9 articles. YJ Kim was the first author in 7 articles and a co-author in 2 articles.

Countries

Most of the articles (67%, 33 articles) were published from the USA, followed by Sweden (13%, 6 articles), and Canada (8%, 4 articles). The remaining 8 articles were published from other countries (Figure 3).

Table 1. The most cited 50 articles in adolescent idiopathic scoliosis

Rank	Article	Number of cite (cite density)
1	Lenke LG, Betz RR, Harms J, et al. Adolescent idiopathic scoliosis: a new classification to determine extent of spinal arthrodesis. J Bone Joint Surg Am. 2001;83(8):1169-1181.	873 (46)
2	Kim YJ, Lenke LG, Bridwell KH, Cho YS, Riew KD. Free hand pedicle screw placement in the thoracic spine: is it safe?. Spine (Phila Pa 1976). 2004;29(3):333-342.	417 (26)
3	Nachemson AL, Peterson LE. Effectiveness of treatment with a brace in girls who have adolescent idiopathic scoliosis. A prospective, controlled study based on data from the Brace Study of the Scoliosis Research Society. J Bone Joint Surg Am. 1995 Jun;77(6):815-22.	386 (15)
4	Kosmopoulos V, Schizas C. Pedicle screw placement accuracy: a meta-analysis. Spine (Phila Pa 1976). 2007;32(3):E111-E120.	311 (24)
5	Kim YJ, Lenke LG, Cho SK, Bridwell KH, Sides B, Blanke K. Comparative analysis of pedicle screw versus hook instrumentation in posterior spinal fusion of adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 2004;29(18):2040-2048.	285 (18)
6	Cochran T, Irstam L, Nachemson A. Long-term anatomic and functional changes in patients with adolescent idiopathic scoliosis treated by Harrington rod fusion. Spine (Phila Pa 1976). 1983;8(6):576-584.	276 (7)
7	Haher TR, Gorup JM, Shin TM, et al. Results of the Scoliosis Research Society instrument for evaluation of surgical outcome in adolescent idiopathic scoliosis. A multicenter study of 244 patients. Spine (Phila Pa 1976). 1999;24(14):1435-1440.	267 (12)
8	Kim YJ, Lenke LG, Kim J, et al. Comparative analysis of pedicle screw versus hybrid instrumentation in posterior spinal fusion of adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 2006;31(3):291-298	255 (18)
9	Richards BS, Bernstein RM, D'Amato CR, Thompson GH. Standardization of criteria for adolescent idiopathic scoliosis brace studies: SRS Committee on Bracing and Nonoperative Management. Spine (Phila Pa 1976). 2005;30(18):2068-2077.	230 (15)
10	Lee SM, Suk SI, Chung ER. Direct vertebral rotation: a new technique of three-dimensional deformity correction with segmental pedicle screw fixation in adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 2004;29(3):343-349.	229 (14)
11	Pehrsson K, Larsson S, Oden A, Nachemson A. Long-term follow-up of patients with untreated scoliosis. A study of mortality, causes of death, and symptoms. Spine (Phila Pa 1976). 1992;17(9):1091-1096.	226 (8)
12	Glattes RC, Bridwell KH, Lenke LG, Kim YJ, Rinella A, Edwards C 2nd. Proximal junctional kyphosis in adult spinal deformity following long instrumented posterior spinal fusion: incidence, outcomes, and risk factor analysis. Spine (Phila Pa 1976). 2005;30(14):1643-1649.	222 (15)
13	Betz RR, Harms J, Clements DH 3rd, et al. Comparison of anterior and posterior instrumentation for correction of adolescent thoracic idiopathic scoliosis. Spine (Phila Pa 1976). 1999;24(3):225-239.	213 (15)
14	McDonnell MF, Glassman SD, Dimar JR 2nd, Puno RM, Johnson JR. Perioperative complications of anterior procedures on the spine. J Bone Joint Surg Am. 1996;78(6):839-847.	203 (8)
15	Smith JS, Shaffrey CI, Sansur CA,et. al. Rates of infection after spine surgery based on 108,419 procedures: a report from the Scoliosis Research Society Morbidity and Mortality Committee. Spine, 2011; 36(7), 556-563.	199 (22)
16	Hicks JM, Singla A, Shen FH, Arlet V. Complications of pedicle screw fixation in scoliosis surgery: a systematic review. Spine,2010 35(11), E465-E470.	197 (20)
17	Lonstein JE, Winter RB. The Milwaukee brace for the treatment of adolescent idiopathic scoliosis. A review of one thousand and twenty patients. J Bone Joint Surg Am. 1994;76(8):1207-1221.	190 (7)
18	Stokes IA, Spence H, Aronsson DD, Kilmer N. Mechanical modulation of vertebral body growth. Implications for scoliosis progression. Spine (Phila Pa 1976). 1996;21(10):1162-1167.	185 (8)
19	Schwartz DM, Auerbach JD, Dormans JP, et al. Neurophysiological detection of impending spinal cord injury during scoliosis surgery. J Bone Joint Surg Am. 2007;89(11):2440-2449.	184 (14)
20	Coe JD, Arlet V, Donaldson W, et al. Complications in spinal fusion for adolescent idiopathic scoliosis in the new millennium. A report of the Scoliosis Research Society Morbidity and Mortality Committee. Spine (Phila Pa 1976). 2006;31(3):345-349.	183 (13)
21	Goldberg CJ, Moore DP, Fogarty EE, Dowling FE. Adolescent idiopathic scoliosis: the effect of brace treatment on the incidence of surgery. Spine (Phila Pa 1976). 2001;26(1):42-47. doi:10.1097/00007632-200101010-00009	182 (10)
22	Danielsson AJ, Wiklund I, Pehrsson K, Nachemson AL. Health-related quality of life in patients with adolescent idiopathic scoliosis: a matched follow-up at least 20 years after treatment with brace or surgery. Eur Spine J. 2001;10(4):278-288.	179 (9)
23	Lenke LG, Bridwell KH, Baldus C, Blanke K, Schoenecker PL. Cotrel-Dubousset instrumentation for adolescent idiopathic scoliosis. J Bone Joint Surg Am. 1992;74(7):1056-1067.	169 (6)
24	Mac-Thiong JM, Labelle H, Berthonnaud E, Betz RR, Roussouly P. Sagittal spinopelvic balance in normal children and adolescents. Eur Spine J. 2007;16(2):227-234.	163 (12)
25	Horton WC, Brown CW, Bridwell KH, Glassman SD, Suk SI, Cha CW. Is there an optimal patient stance for obtaining a lateral 36" radiograph?: a critical comparison of three techniques. Spine,2005 30(4), 427-433.	159 (10)

26	Reames DL, Smith JS, Fu KM, et al. Complications in the surgical treatment of 19,360 cases of pediatric scoliosis: a review of the Scoliosis Research Society Morbidity and Mortality database. Spine (Phila Pa 1976). 2011;36(18):1484-1491.	151 (17)
27	Lenke LG, Edwards CC 2nd, Bridwell KH. The Lenke classification of adolescent idiopathic scoliosis: how it organizes curve patterns as a template to perform selective fusions of the spine. Spine (Phila Pa 1976). 2003;28(20):S199-S207.	149 (9)
28	Lowenstein JE, Matsumoto H, Vitale MG, et al. Coronal and sagittal plane correction in adolescent idiopathic scoliosis: a comparison between all pedicle screw versus hybrid thoracic hook lumbar screw constructs. Spine (Phila Pa 1976). 2007;32(4):448-452.	148 (11)
29	Dobbs MB, Lenke LG, Kim YJ, Kamath G, Peelle MW, Bridwell KH. Selective posterior thoracic fusions for adolescent idiopathic scoliosis: comparison of hooks versus pedicle screws. Spine (Phila Pa 1976). 2006;31(20):2400-2404.	144 (10)
30	Nuttall GA, Horlocker TT, Santrach PJ, Oliver Jr WC, Dekutoski MB, Bryant S. Predictors of blood transfusions in spinal instrumentation and fusion surgery. Spine, 2000; 25(5), 596-601.	144 (7)
31	Kesling KL, Reinker KA. Scoliosis in twins. A meta-analysis of the literature and report of six cases. Spine (Phila Pa 1976). 1997;22(17):2009-2015.	142 (6)
32	Mac-Thiong JM, Labelle H, Charlebois M, Huot MP, de Guise JA. Sagittal plane analysis of the spine and pelvis in adolescent idiopathic scoliosis according to the coronal curve type. Spine (Phila Pa 1976). 2003;28(13):1404-1409.	127 (7)
33	Little DG, Song KM, Katz D, Herring JA. Relationship of peak height velocity to other maturity indicators in idiopathic scoliosis in girls. J Bone Joint Surg Am. 2000;82(5):685-693.	137 (6)
34	Lenke LG, Betz RR, Bridwell KH, Harms J, Clements DH, Lowe TG. Spontaneous lumbar curve coronal correction after selective anterior or posterior thoracic fusion in adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 1999;24(16):1663-1672.	137 (6)
35	Sahlstrand T, Ortengren R, Nachemson A. Postural equilibrium in adolescent idiopathic scoliosis. Acta Orthop Scand. 1978;49(4):354-365.	136 (3)
36	Kim YJ, Lenke LG, Bridwell KH, et al. Proximal junctional kyphosis in adolescent idiopathic scoliosis after 3 different types of posterior segmental spinal instrumentation and fusions: incidence and risk factor analysis of 410 cases. Spine (Phila Pa 1976). 2007;32(24):2731-2738.	134 (10)
37	Peterson LE, Nachemson AL. Prediction of progression of the curve in girls who have adolescent idiopathic scoliosis of moderate severity. Logistic regression analysis based on data from The Brace Study of the Scoliosis Research Society. J Bone Joint Surg Am. 1995;77(6):823-827.	134 (5)
38	Levy AR, Goldberg MS, Mayo NE, Hanley JA, Poitras B. Reducing the lifetime risk of cancer from spinal radiographs among people with adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 1996;21(13):1540-1548.	132 (5)
39	Barr SJ, Schuette AM, Emans JB. Lumbar pedicle screws versus hooks. Results in double major curves in adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 1997;22(12):1369-1379.	131 (6)
40	Dolan LA, Weinstein SL. Surgical rates after observation and bracing for adolescent idiopathic scoliosis: an evidence-based review. Spine (Phila Pa 1976). 2007;32(19 Suppl):S91-S100.	129 (10)
41	Vora V, Crawford A, Babekhir N, et al. A pedicle screw construct gives an enhanced posterior correction of adolescent idiopathic scoliosis when compared with other constructs: myth or reality. Spine (Phila Pa 1976). 2007;32(17):1869-1874.	129 (10)
42	Nault ML, Allard P, Hinse S, et al. Relations between standing stability and body posture parameters in adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 2002;27(17):1911-1917	129 (7)
43	O'Brien MF, Lenke LG, Mardjetko S, et al. Pedicle morphology in thoracic adolescent idiopathic scoliosis: is pedicle fixation an anatomically viable technique?. Spine (Phila Pa 1976). 2000;25(18):2285-2293.	125 (5)
44	Kim YJ, Lenke LG, Bridwell KH, Kim KL, Steger-May K. Pulmonary function in adolescent idiopathic scoliosis relative to the surgical procedure. J Bone Joint Surg Am. 2005;87(7):1534-1541.	124 (8)
45	Kim YJ, Bridwell KH, Lenke LG, Kim J, Cho SK. Proximal junctional kyphosis in adolescent idiopathic scoliosis following segmental posterior spinal instrumentation and fusion: minimum 5-year follow-up. Spine (Phila Pa 1976). 2005;30(18):2045-2050.	123 (8)
46	Kuklo TR, Lenke LG, O'Brien MF, Lehman RA Jr, Polly DW Jr, Schroeder TM. Accuracy and efficacy of thoracic pedicle screws in curves more than 90 degrees. Spine (Phila Pa 1976). 2005;30(2):222-226.	123 (8)
47	Guo X, Chau WW, Chan YL, Cheng JC, Burwell RG, Dangerfield PH. Relative anterior spinal overgrowth in adolescent idiopathic scoliosis--result of disproportionate endochondral-membranous bone growth? Summary of an electronic focus group debate of the IBSE. Eur Spine J. 2005;14(9):862-873	122 (8)
48	Lehman RA Jr, Lenke LG, Keeler KA, et al. Operative treatment of adolescent idiopathic scoliosis with posterior pedicle screw-only constructs: minimum three-year follow-up of one hundred fourteen cases. Spine (Phila Pa 1976). 2008;33(14):1598-1604.	117 (8)
49	Luhmann SJ, Lenke LG, Kim YJ, Bridwell KH, Schootman M. Thoracic adolescent idiopathic scoliosis curves between 70 degrees and 100 degrees: is anterior release necessary? Spine (Phila Pa 1976). 200515;30(18):2061-7.	117 (8)
50	Moreau A, Wang DS, Forget S, Azeddine B, Angeloni D, Fraschini F, Labelle H, Poitras B, Rivard CH, Grimard G. Melatonin signaling dysfunction in adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 2004 Aug 15;29(16):1772-81.	117 (8)

Institutions

There were 31 institutions that featured in all 50 articles, and 7 institutes were associated with more than 2 articles (Table 3). Washington University School of Medicine ranked first with 11 articles and Columbia University Medical Center followed with 4 articles each, Göteborg University with 3 articles and 4 institutes each associated with 2 articles.

The speciality of the primary authors

The highest number of publications (46) was by orthopaedic surgeons. The remaining 4 articles were associated with the following specialities: Neurosurgery (n=2), anaesthesia (n=1), and health care research (n=1).

Decade-wise number of citations

The articles were spread over a total of 40 years (1978-2011) despite cumulative to the 2000s (Figure 4).

Study design of the articles

A total of 7 study designs were observed in the articles in this analysis (Table 4): Meta-analysis review (n=6), randomized controlled (n=2), non-randomized controlled (n=2), prospective cohort (n=6), retrospective cohort (n=20), retrospective without control group cohort (n=13), and case series (n=1).

Level of evidence of the articles

Most studies had level 3 (n=19) and level 4 (n=18) evidence, other studies one study level 1, 12 studies level 2, none study level 5 (Figure 5).

DISCUSSION

Although AIS is the most discussed topic among scoliosis deformities[15], in this study, we listed the most cited 50 articles on AIS and determined the citation number, citation density, article count, country, institution, author, journal, study design, and level of evidence. In addition, we found that the most of the contents of these articles on AIS were based on surgical treatment outcomes and had been published by institutions in the USA; more than 50% of the articles had been published in "Spine".

Scoliosis is a 3D spinal deformity and has the following subtypes: congenital, juvenile, adolescent idiopathic, neurogenic, and adult scoliosis. Two studies on spinal deformities had the highest number (100) of citations[22,23]. The study by Zhang et al.[22] had examined deformity types in detail, including sagittal deformities; among its 100 citations, 37 articles were on AIS and 20 articles on adult scoliosis. In the other study, Tao et al.[24] presented a 10-year bibliographic analysis of scoliosis.

In our analysis, the mean number of citations was 210.4±148 (range: 117-873) for AIS. A higher mean citation count was observed for spondylolisthesis (range: 68-586) and thoracolumbar fracture (range: 81-267) compared to similar lumbar disease analyses[17,18]. In contrast, there were fewer citations for sports surgeries related to the anterior cruciate ligament (range: 315-1670) and rotator cuff tear (range: 137-677).

Most of the articles' contents were related to surgical treatment outcomes. In contrast, the most cited article title described AIS classification. For an article to be appreciated, it must fill a knowledge gap in the literature.

The most cited study was the study that described the classification developed by Lenke et al.[7] in 2001 to determine the level of spinal arthrodesis[7]. Before the Lenke classification, the King classification presented in 1983 was used for AIS[25]. The most important difference in the Lenke classification is its 2D examination of the deformity, which provides a better understanding of the deformity without having sharp limits for fusion levels.

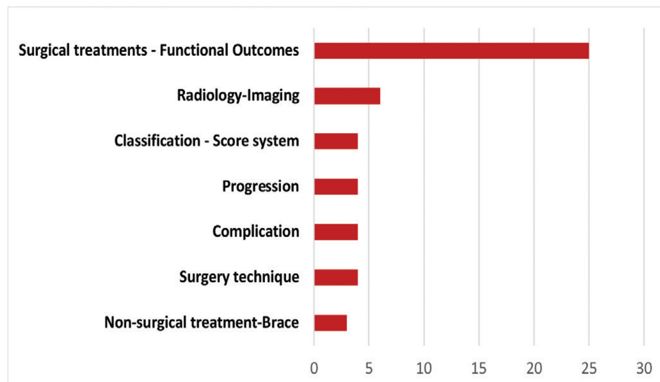

Figure 2. Frequences of the article contents

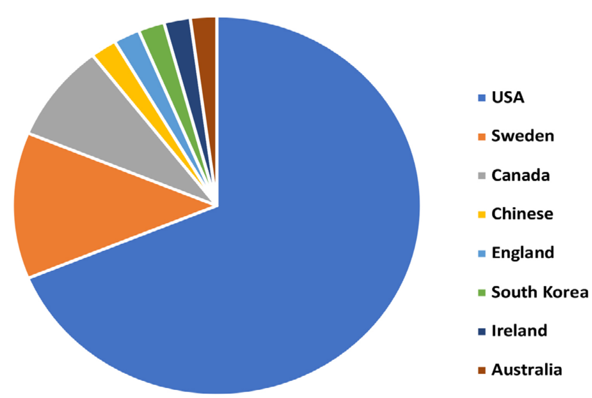

Figure 3. List of the countries of publication

Table 2. List of the journal with article number and total citation counts

Journal name	Article number	Total cite counts
Spine	37	6978
The Journal of Bone and Joint Surgery	9	2400
Europian Spine Journal	3	1080
Acta Orthopaedica Scandinavica	1	136

The second most cited study was by Kim et al.[8] published in 2004 wherein the authors described free pedicle screw placement in the thoracic spine for which they used anatomical marks and specific entry points in 3204 patients over 10 years. In addition, Lenke and Kim were the most prolific authors in AIS research.

In our study, each of 3 countries-USA, Sweden, and Canada-was associated with more than 2 publications, with USA being more active with more than 50% of the publications in our analysis. The scientific leadership of the USA was also evident in other bibliographic analyses of lumbar and non-lumbar pathology[15-20]. Washington University School of Medicine was affiliated with 11 studies. More than 50% of the institutions were English-speaking institutions. For AIS and other lumbar pathologies, "Spine" was the journal that had published the most number of articles in our analysis;[18-20] it was followed by the Journal of Bone and Joint Surgery and the European Spine Journal. Less and specific journals came to the fore for lumbar pathologies. From our analysis, it would appear that for an article to be highly cited, it is most likely to be published from an English-speaking institution in the USA in a subject-specific journal.

Similar to the findings of many bibliographic studies, very few articles in our analysis contained level 1 evidence[16,17], with only four randomized controlled studies in our study.

Study Limitation

Our bibliographic analysis has some limitations, as stated in similar studies[26]. The search term used in such bibliographic analyses needs to be clearly identified, and the content of the articles should be checked. Although we used a specific search term, "AIS" in our study, 9 studies were still excluded because of their unsuitable content. On the other hand, some of the publications published in prestigious journals such as Lancet and The new England Journal of Medicine and receiving high citation are excluded from the evaluation because they do not meet the study criteria[27,28]. Another limitation was that as older studies have an advantage with respect to the number of citations, mean citation number (total number citations/years

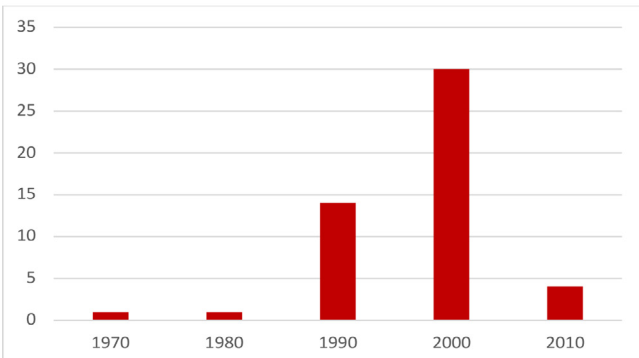

Figure 4. Number of most cited article according to decade of publication

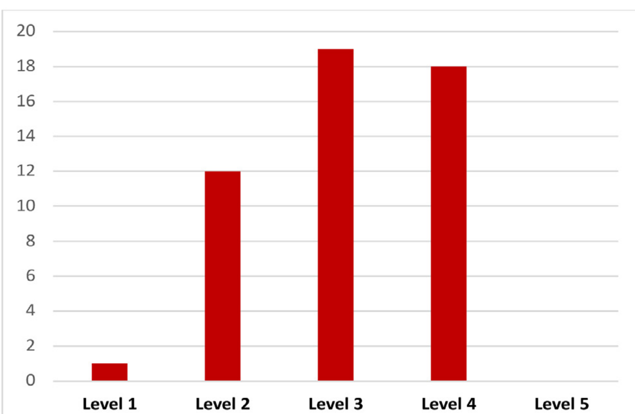

Figure 5. Level of evidence in the articles

Table 4. Study design of articles

Clinical articles of study type	Number of articles
Meta-analyses and review	6
Non-randomize controlled	2
Randomize controlled	2
Prospective cohort	6
Retrospective cohort	20
Retrostective cohort without control group	13
Case series	1

Table 3. Institutions with 2 or more publications

Name of Institution	Number of articles
Washington University School of Medicine	11
Columbia University Medical Center	4
Göteborg university	3
University of Virginia	2
Hopital Sainte-Justine	2
Sahlgrenska University Hospital	2
University of Iowa	2
Others*	24

*: Hospital Orthopedique de la Suisse Romande, St. Vincent's Hospital Medical Center, Texas Scottish Rite Hospital for Children, Seoul Spine Institute, Renströmska and Sahlgrenska Hospitals, Shriners Hospital and Temple University Hospital, University of Louisville School of Medicine, University of Virginia Medical Center, Emory Orthopaedics and Spine Center, Morgan Stanley Children's Hospital of New York Presbyterian, MAYO clinic, Triple Army Medical Center, Royal Alexandra Hospital for Children, Maisonneuve-Rosemont Hospital, Harvard Medical School, Penn State College of Medicine, Laboratoire d'E´ tude du Mouvement Research Center Sainte-Justine Hospital, *University of Colorado and Woodridge Orthopedic and Spine Clinic, Walter Reed Army Medical Center, The Chinese University of Hong Kong, Walter Reed Army Medical Center

since publication) must be calculated. The level of evidence and study design were difficult to find for some articles.

CONCLUSION

In this bibliographic analysis of AIS, most articles described the surgical treatment and had been published from the USA; more than 50% of the articles were published in "Spine". Although the number of publications has increased rapidly over the years, we found that there were few prospective randomized trials.

Ethics

Ethics Committee Approval: Institutional review board approval was not required given the public availability of the data.

Informed Consent: The study does not contain patient data by design.

Peer-review: Internally peer-reviewed.

Authorship Contributions

Concept: Y.U.Y., B.H., Design: Y.U.Y., B.H., Data Collection or Processing: Y.U.Y., B.H., Analysis or Interpretation: Y.U.Y., Literature Search: B.H., Writing: Y.U.Y.

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

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ORIGINAL ARTICLE
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THE RELATIONSHIP BETWEEN TLICS 1-3 AND FUNCTIONAL AND RADIOLOGICAL OUTCOMES IN CONSERVATIVE TREATMENT OF THORACOLUMBAR VERTEBRAE FRACTURES

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ABSTRACT

Objective: There is almost no controversy about the conservative treatment of patients with fractures with a Thoracolumbar injury classification and severity score (TLICS) of 1-3. External thoracolumbosacral orthosis is the recommended method. However, it is still controversial to support the TLICS with radiological parameters. The aim of this study was to evaluate the correlation between TLICS scores of 1-3 and clinical and radiological results of patients with stable thoracolumbar and lumbar vertebrae fractures, who were followed up conservatively.

Materials and Methods: This retrospective study included patients diagnosed as having TLICS 1 to 3 thoracolumbar or lumbar vertebrae fractures who were followed up conservatively. Data were gained from the patient files. Outcome measures and classification parameters used were; visual analogue scale (VAS) and Turkish version of Oswestry disability index (ODI). The radiological parameters were measured. The recovery rates of all patients were evaluated, and correlation between clinical and radiological outcomes of the patients and TLICS scores was analyzed.

Results: The mean duration of hospitalization and time to return to work were 1.61 and 126 days, respectively. Both VAS and ODI values steadily decreased over time. However, local kyphotic angle (LKA) and vertebra height loss (VHL) percentage values increased over time. TLICS did not correlate with the time to return to work. However, LKA at admission and VHL percentage at admission correlated significantly with the time to return to work.

Conclusion: The TLICS classification seems to be effective in decision making in the conservative treatment of thoracolumbar and lumbar vertebral fractures, but it would be noteworthy to take into account the clinical and radiological parameters in this classification to predict the treatment period and time to return to work.

Keywords: TLICS, thoracolumbosacral orthosis, vertebrae fracture, conservative treatment

INTRODUCTION

The conservative approach is the generally accepted treatment method in stable thoracolumbar and lumbar fractures[1-5]. In this sense, an external thoracolumbosacral orthosis (TLSO) is recommended according to the level of injury[1,2]. Herewith, in recent years, the thoracolumbar injury classification and severity score (TLICS) have been frequently used to determine management[2,4,6-8] (Table 1). There is almost no controversy about the conservative treatment of TLICS 1-3 fractures and operative treatment of TLICS ≥5 fractures, whereas TLICS 4 is controversial[2,8-11]. However, the lack of predicting radiological progress and time to return to work are the main challenges of TLICS. For instance, the progressive kyphotic deformity was shown in comminuted burst fractures with a TLICS score of 2 treated non-operatively[12]. Moreover, it has been suggested that worsening radiographic findings are associated with an increase in the incidence of permanent pain[4,11]. There are also studies showing no correlation between the local kyphosis angle (LKA) and vertebral height loss (VHL) and clinical results. From this point of view, it was claimed that radiological parameters should be excluded from the TLICS[13]. However, it is still controversial to support the TLICS with radiological

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Table 1. Thoracolumbar injury classification and severity score (TLICS)

Morphology	
Compression fracture	1 point
Burst fracture	2 points
Translation/rotation	3 points
Distraction	4 points
Posterior ligamentous complex	
Intact	0 points
Suspected injury or indeterminate	2 points
Injured	3 points
Neurologic involvement	
Intact	0 points
Nerve root	2 points
Cord/conus medullaris (incomplete)	3 points
Cord/conus medullaris (complete)	2 points
Cauda equine	3 points

1-3: Usually treated non-operatively, 4: May be treated operatively or non-operatively, ≥5: Usually considered for operative management
TLICS: Thoracolumbar injury classification and severity score

parameters[8,10,13,14]. Based on our experience, although TLICS is an effective method to choose the treatment method, it is still insufficient in predicting radiological changes and returning to work. Therefore, we aimed to evaluate the correlation between TLICS scores (1 to 3) and clinical and radiological results of patients with stable thoracolumbar and lumbar vertebrae fractures, who were followed up conservatively.

MATERIALS AND METHODS

Study Design and Participants

This retrospective study was conducted after the approval of the Clinical Research Ethics Committee. Between January 2013 and December 2017, the patients diagnosed with TLICS 1 to 3 thoracolumbar or lumbar vertebrae fractures, and who followed up conservatively in a tertiary hospital were enrolled. Inclusion criteria were; traumatic thoracolumbar and lumbar fractures (compression and burst) between T11-L5, only score of TLICS 1 to 3, without neurologic deficit, age at 18 to 65 years, within 24 hours of presentation and a minimum 24 months of follow-up period. Exclusion criteria were other TLICS scores such as ≥4, patients with follow-up period of less than 24 months, pregnancy, having pathological fractures (cancer, infection) or osteoporotic fractures, previous history of spine surgery, and any missing data regarding the fracture. The patients were divided into three groups according to the scores obtained in TLICS classification. The recovery rates of all patients were evaluated, and the correlation between clinical and radiological outcomes of the patients and TLICS scores were compared. Informed consent was obtained from the patients.

Treatment Method

Patients were hospitalized for observation a minimum of 24 hours after diagnosis. Bed rest in a supine position, analgesic, and subcutaneous anticoagulant (enoxaparin sodium 40 mg=4000 anti-Xa IU) therapy was administered. All patients were encouraged to be mobilized with a TLSO (Biofix® BA-287) one day after the hospitalization. After discharge, the patients after were advised to comply with bed rest (at nights in supine position), to use TLSO (in sitting and standing position), anticoagulant therapy, and analgesic drugs. All patients were examined clinically with 2 weeks of intervals and radiologically 4 weeks of intervals, for 12 weeks. Thereafter, the follow-up was continued three months of intervals for 24 months.

Data Collection and Radiographic Evaluation

The data were obtained from the medical records of the patients. Clinical and demographic features (age, gender, level of fracture, and return to work) were noted. All patients had images of the two-plan radiograph, computed tomography scan, and magnetic resonance imaging on admission. Angular measurements were performed on the lateral spine radiographs at the first admission and at the final follow-up. LKA was measured as the angle from the superior end-plate to the inferior end-plate[13]. Normalized VHL was calculated as a percentage of the height loss normalized to the average of the vertebral bodies above and below the injured segment[13]. Radiographic evaluations were performed by a blinded senior spine surgeon.

Outcome Measures

The primary functional outcome measure was the oswestry disability index (ODI) that was validated for the Turkish population[15]. The ODI is a functional, disease-specific instrument comprising ten questions on limitations in the activities of daily living, caused by low back pain. Each question is scored 0 to 5. The ODI score is multiplied by two to acquire the percentage. The total score ranges 0 (best health state) to 100 (worst health state).

Secondary outcome measures included back pain visual analogue scale (VAS)[16] score, and time for the return to work. Records of VAS scores for back pain were collected and compared between the groups. VAS is a well-known, validated instrument to let patients score their daily pain. We used a 0 to 10 scale as scored 0=no pain and 10=unbearable pain. Time for a return to work was determined from self-reported at last follow-up time.

Statistical Analysis

SPSS software package program (SPSS Inc., version 16, Chicago, IL, USA) was used for statistical analysis. Descriptive data were given as mean, standard deviation, median, number, or percentage. Baseline and after-surgery data were compared using the Paired t-test or Wilcoxon signed-rank test. Pearson correlation analyses were performed for the correlation analyses. A value of $p<0.05$ was accepted as statistically significant. In the calculation of the post hoc sample size, the power of the study with 0.05 alpha value was found over 80%. The standard effect size for quantitative data was set at 0.81 %, and the power of the study was 99%.

RESULTS

This study included a total of 153 patients (102 males, 51 females) with a mean age of 44.50±13.3 years (ranges 18 to 65 years). Clinical and demographic properties of the patients are summarized in Table 2. Seventy-five patients (49.0%), 71 patients (46.4%), and 7 patients (4.6%) patients were scored as TLICS 1, 2, and 3, respectively. The mean duration of hospitalization and time for the return to work was 1.61 and 126 days, respectively. The mean VAS score at admission was 8.29±1.1, and the mean ODI was 21.38±8.1 at the 3rd month. Both VAS and ODI values steadily decreased over time (Figure 1). However, LKA and VHL values increased over time (Figure 2). The mean LKA increased from 26.75±6.7 to 30.80±6.9 (p<0.001). The mean VHL increased from 39.84±8.7 to 47.81±8.6. Correlation analyses are shown in Table 3. TLICS did not correlate with the time for the return to work (r=0.124, p=0.127). However, LKA at admission (r=0.427, p<0.001) and VHL at admission (r=0.254, p=0.002) correlated significantly with the time for the return to work. As the LKA or VHL increased, time for the return to work did prolong. Similarly, the VAS scores (r=0.288, p<0.001) and ODI values (r=0.167, p=0.039) significantly correlated with the time for the return to work.

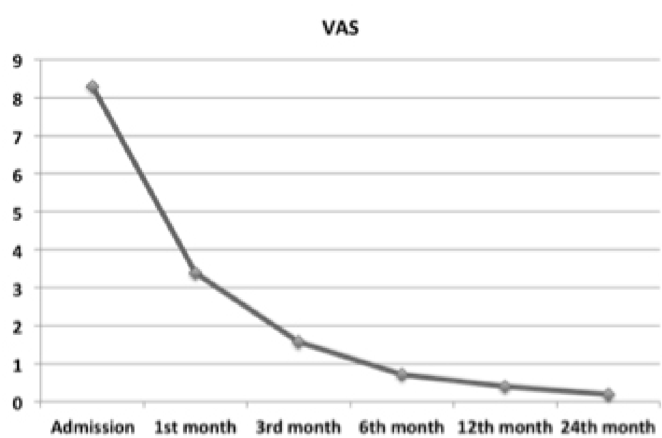
DISCUSSION

The purpose of this study was to evaluate the relationship between TLICS scores (1 to 3) and clinical and radiological outcomes of patients with stable thoracolumbar and lumbar vertebrae fractures and treated conservatively. Three main findings emerged from this study. First, the conservative treatment showed satisfactory outcomes. ODI and VAS scores values steadily decreased over time and significantly correlated with the time for the return to work. Second, both LKA and VHL values increased over time and were associated with prolonged

Table 2. Descriptive features of the patients

	Mean ± SD or N (%)
Age (years)	44.50±13.3 46 (18-65)
Gender	
Male Female	102 (66.7) 51 (33.3)
Fracture Region	
Thoracolumbar Lumbar	131 (85.6) 22 (14.4)
Level of Fracture	
T11 T12 L1 L2 L3 L4 L5	5 (3.3) 38 (24.8) 48 (31.4) 41 (26.8) 7 (4.6) 10 (6.5) 4 (2.6)
Trauma Type	
Fall from height Basic falls In-vehicle traffic accident Out-vehicle traffic accident	58 (37.9) 14 (9.2) 48 (31.4) 33 (21.6)
TLICS	
1 2 3	75 (49.0) 71 (46.4) 7 (4.6)
Hospitalization (days)	1.61±0.8 2 (1-7)
Return to work (days)	130±20 126 (90-180)

SD: Standard deviation, TLICS: Thoracolumbar injury classification and severity score



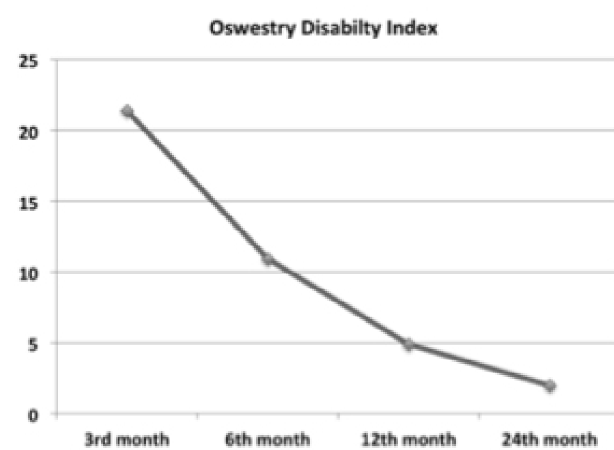


Figure 1. Visual analogue scale pain scores and Oswestry disability index values
The mean VAS score at admission was 8.29±1.1 and the mean ODI was 21.38±8.1 at the 3rd month. Both VAS and ODI values steadily decreased over time.

VAS: Visual analogue scale; ODI: Oswestry disability index time for the return to work. Third, TLICS values did not predict the return to work and radiological or clinical outcomes.

The generally accepted management in stable thoracolumbar and lumbar fractures is conservative treatment, and an external TLSO is recommended according to the level of injury(1-5). There has been debate about the effectiveness of bracing in stable fractures(17). Bailey et al.(18) concluded that using brace in burst fractures with neurologically stable patients did not affect the outcome regarding pain control and function. Therefore, TLSO was routinely used for conservative treatment in the present study. According to our results, all patients had improved satisfaction in terms of pain and disability. Herein, we would like to highlight once again that conservative treatment, including TLSO, bed rest, and analgesics, seems to be effective in TLICS 1-3 patients. Our findings were consistent with the literature as regards the effectiveness(1,3-5). However, the TLICS did not predict a return to work. Thus, compatible with the literature (2,9), both ODI and VAS scores correlated with earlier return to work.

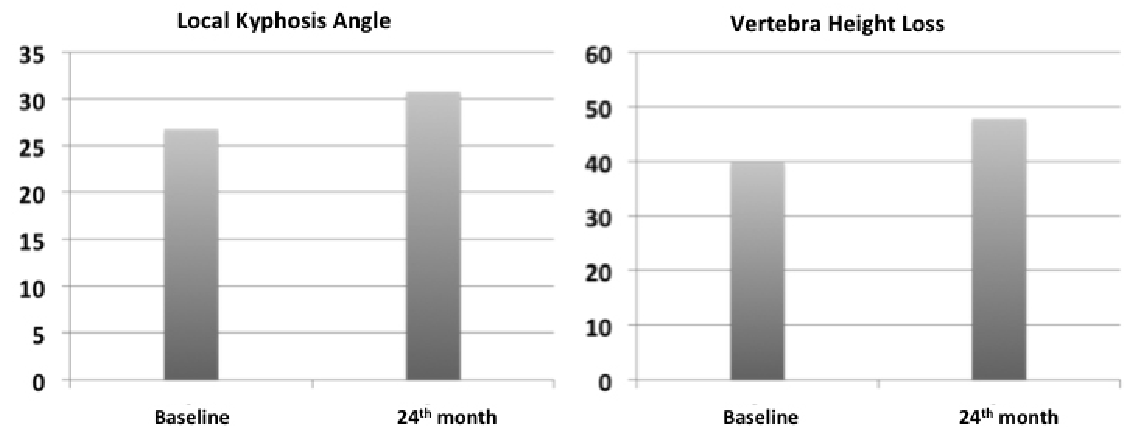


Figure 2. Local kyphosis angle and vertebrae height loss
The mean LKA increased from 26.75±6.7 to 30.80±6.9 (p<0.001). The mean VHL increased from 39.84±8.7 to 47.81±8.6.
LKA: Local kyphotic angle, VHL: Vertebrae height loss

Table 3. Correlation analyses

Variables		Age	VAS admission	ODI 3rd month	TLICS	LKA before	VHL before	LKA after	VHL after	Return to work
Age	r	1	-0.077	-0.053	-0.091	0.136	0.037	0.132	0.050	0.102
	p	-	0.347	0.512	0.264	0.095	0.647	0.103	0.541	0.209
VAS admission	r	-0.077	1	0.210**	0.068	0.130	0.140	0.105	0.065	0.288**
	p	0.347	-	0.009	0.403	0.110	0.084	0.197	0.421	0.000
ODI 3rd month	r	-0.053	0.210**	1	-0.010	0.263**	0.191*	0.251**	0.229**	0.167*
	p	0.512	0.009	-	0.902	0.001	0.018	0.002	0.004	0.039
TLICS	r	-0.091	0.068	-0.010	1	0.004	-0.043	-0.003	-0.068	0.124
	p	0.264	0.403	0.902	-	0.965	0.602	0.972	0.406	0.127
LKA before	r	0.136	0.130	0.263**	0.004	1	0.572**	0.948**	0.561**	0.427**
	p	0.095	0.110	0.001	0.965	-	0.000	0.000	0.000	0.000
VHL before	r	0.037	0.140	0.191*	-0.043	0.572**	1	0.529**	0.927**	0.254**
	p	0.647	0.084	0.018	0.602	0.000	-	0.000	0.000	0.002
LKA after	r	0.132	0.105	0.251**	-0.003	0.948**	0.529**	1	0.550**	0.350**
	p	0.103	0.197	0.002	0.972	0.000	0.000	-	0.000	0.000
VHL after	r	0.050	0.065	0.229**	-0.068	0.561**	0.927**	0.550**	1	0.188*
	p	0.541	0.421	0.004	0.406	0.000	0.000	0.000	-	0.020
Return to work	r	0.102	0.288**	0.167*	0.124	0.427**	0.254**	0.350**	0.188*	1
	p	0.209	0.000	0.039	0.127	0.000	0.002	0.000	0.020	-

Correlation is significant at the **0.01 level (2-tailed) or *0.05 level (2-tailed).
VAS: Visual analogue scale, ODI: Oswestry disability index, TLICS: Thoracolumbar injury classification and severity score, LKA: Local kyphotic angle, VHL: Vertebrae height loss

The time for the return to work is a significant determinant of the efficacy of the management, and this issue was previously studied in several studies in the literature. Wood et al.[19], in a prospective and randomized trial, enrolled 47 patients (24 surgery vs. 23 orthoses) with thoracolumbar burst fractures without neurological deficit. At the final follow-up (minimum two years), there were no statistical differences in terms of return to work between the two groups, with a tendency to better results in the conservative group. Shamji et al.[20] compared bracing with no-bracing groups in their randomized controlled trial whereby there was no difference in terms of LKA and VHL progression or clinical outcomes during the sixth months of the follow-up period. However, the effectiveness of orthosis was investigated and was reported to be a safe method with acceptable functional and radiographic results in the treatment of thoracolumbar fractures[1]. Studies also showed that chronic back pain and VHL were associated with patients with thoracolumbar vertebrae fractures[21]. In our study, although TLICS 1 to 3 patients improved clinically over time, their radiological parameters, i.e., LKA and VHL, worsened. Besides, the radiological parameters significantly correlated with delayed return to work. Previous reports also reported that TLICS classification had limitations to predict clinical and radiological outcomes in patients who needed surgery for permanent pain or progressive deformity (TLICS score less than 4 points)[3,6,10,22].

The retrospective design is the main limitation. Although the follow-up period (24th months) is acceptable compared with the previous studies, it could be longer. In addition, the absence of a control group or a surgery group is another limitation of this study.

CONCLUSION

According to the data revealed by the present study, TLICS classification seems to be effective on decision making in the conservative treatment of thoracolumbar and lumbar vertebral fractures, but it would be noteworthy to take into account the clinical and radiological parameters in this classification to predict the treatment period and return to work. Further studies on this matter in prospective designs are awaited.

Ethics

Ethics Committee Approval: All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards (58-911/06.2020).

Informed Consent: Informed consent was obtained from the patients.

Peer-review: Internally peer-reviewed.

Authorship Contributions

Concept: E.K., F.S., O.Ç., A.D., G.P., M.İ., H.M.G., Design: E.K., F.S., O.Ç., A.D., G.P., M.İ., H.M.G., Data Collection or Processing: E.K., F.S., O.Ç., A.D., G.P., M.İ., H.M.G., Analysis or Interpretation: E.K., F.S., O.Ç., A.D., G.P., M.İ., H.M.G., Literature Search: E.K., F.S., O.Ç., A.D., G.P., M.İ., H.M.G., Writing: E.K., F.S., O.Ç., A.D., G.P., M.İ., H.M.G.

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MORPHOMETRY OF THE SUBAXIAL CERVICAL SPINE PEDICLES IN THE ANATOLIAN POPULATION

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ABSTRACT

Objective: Transpedicular screw fixation for the subaxial cervical spine is considered to be more stable than other posterior fixation techniques despite its technical challenges. Thorough understanding of cervical pedicle anatomy and morphometric parameters is essential to avoid neurovascular injury during screw placement.

To evaluate subaxial cervical spine pedicle dimensions, screw starting points, and screw trajectories to provide data that might be representative of the entire Anatolian peninsula.

Materials and Methods: This retrospective study included 200 patients (2000 cervical pedicles). The distance from the junction of the lamina and spinous process to the entry point (DEP), pedicle width (PW), pedicle maximum axis length (PAL), pedicle transverse angle (PTA) in the axial plane, and pedicle height (PH) in the sagittal plane were measured from C3 to C7 on computed tomography (CT) by two blinded observers.

Results: The mean values for DEP, PW, PAL, PTA and PHA ranged between 22.92 mm-23.75 mm, 4.99 mm-6.26 mm, 28.24 mm-36.01 mm, 33.52°-34.60° and 6.36 mm-7.03 mm, respectively. The PW significantly increased in the rostrocaudal direction. The PAL was significantly different between the right and left sides at C3 in male patients. The PTA was significantly different between the right and left sides at C3 in female patients. The PH was greater than the PW at all levels on both sides.

Conclusion: Although surgical planning should be carried out on a case-by-case basis, the findings of the present study might be helpful for Turkish spine surgeons in decision-making for the accurate placement of cervical pedicle screws.

Keywords: Anatomy, computed tomography, morphometric analysis, pedicle, pedicle screw, subaxial cervical spine

INTRODUCTION

Numerous cervical spinal disorders, such as infections, tumours, traumatic injuries, and degenerative diseases, may result in instability and require cervical spinal instrumentation. The armamentarium for posterior cervical spine fixation includes interspinous wiring, laminar hooks, and screw fixation with rods and/or plates[1]. For the past two decades, lateral mass screw fixation has been the most preferred technique among spine surgeons as this technique is associated with lower complication risks and higher fusion rates[2]. Transpedicular screw fixation for the subaxial cervical spine, initially reported by Abumi et al.[3] and Jeanneret et al.[4] in 1994, is considered to be more stable than other posterior fixation techniques. However, the approach is technically demanding. The diameter of the pedicle is narrow, and there is a potential risk for serious neurovascular complications, including injuries to the vertebral artery, nerve root, and spinal cord[3,5]. Recently, spine surgeons are reporting a lower incidence rate of complications than initially considered, and are attempting to perform transpedicular screw fixation more frequently[6]. Thorough understanding of cervical pedicle anatomy and morphometric parameters is essential to avoid neurovascular injury during screw placement.

Subaxial cervical spine morphometric values vary among different populations in the literature[5,7-15]. To our knowledge, four morphometric studies with small sample sizes from Turkey have been reported in the English literature[7-9,11]. As various ethnic groups are present and immigration to big cities and interethnic marriage are common, Anatolia has a highly

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heterogeneous population. Thus, data obtained from a small group may not represent the entire Anatolian peninsula. The present study aimed to evaluate subaxial cervical spine pedicle dimensions, screw starting points, and screw trajectories, using computed tomography (CT), for providing data that might be representative of the entire Anatolian peninsula.

MATERIALS AND METHODS

This retrospective research, designed to investigate morphological properties of subaxial cervical spine in Anatolian population, included 200 consecutive patients (100 male and 100 female; 2000 cervical pedicles) who underwent standard CT for various reasons at a tertiary academic care unit between 2015 and 2017. The CT scans were obtained from radiology archive of the institution, and no clinical data of patients were retrieved. The informed consent for academic research had been taken. The inclusion criteria were fine quality images of subaxial cervical spine and age >18 years at the time of imaging. The exclusion criteria were evidence of any pathology related to a severely degenerative, congenital, traumatic, infectious, metabolic, or neoplastic spinal disease and prior cervical spine surgery since these conditions may have caused structural changes. The study population included patients who have origins in central, eastern and western Anatolian peninsula.

All cervical spine CT scans were performed using the Somatom Sensation 16 (Siemens Medical Solutions, Erlangen, Germany) tomography system. Axial images were taken in 2 mm slice thickness, and then sagittal reconstructions with 2 mm thickness were obtained. The distance from the junction of the lamina and spinous process to the entry point (DEP), pedicle width (PW), pedicle maximum axis length (PAL), pedicle transverse angle (PTA) in the axial plane, and pedicle height (PH) in the sagittal plane were measured for morphometric analysis of the subaxial cervical pedicles as was described in the literature[13] (Table 1) (Figure 1). All measurements were performed by two blinded observers on one occasion.

Statistical Analysis

The mean and standard deviation values of the parameters were calculated at each level without considering sex initially and then considering sex (male and female patients separately). Normal distributions of numerical variables were calculated using the Shapiro-Wilk normality test and Q-Q graphics. Differences in measurements between the right and left pedicles were evaluated using the paired t-test, and comparisons of the measurements at different cervical vertebra levels were performed using the one-way repeated-measures analysis of variance. The Bonferroni test was used as a Post-hoc test. An independent samples t-test was used to determine sex differences with regard to IPD. All statistical analyses were performed using IBM SPSS Statistics software, version 22.0 (IBM Corp., Armonk, NY, USA). A p-value <0.05 was considered statistically significant.

RESULTS

The study involved 200 Anatolian patients (100 of each sex) aged 18-78 years (mean 52 years). The mean age of the male patients was 47±20 years, and the mean age of the female patients was 56±18 years. Although the difference in age was statistically significant (p<0.05), no correction was performed as age is not considered to be related to the measured parameters. The mean values of measured subaxial cervical pedicle

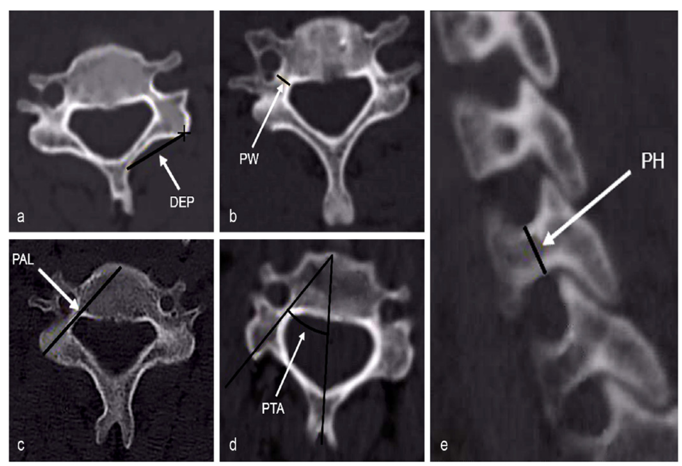

Figure 1. Parameters measured on computed tomography. Distance from the junction of the lamina and spinous process to the entry point (DEP) (a). Pedicle width (PW) (b). Pedicle axis length (PAL) (c). Pedicle transverse angle (PTA) (d). Pedicle height (PH) (e)

Table 1. Parameters measured on computed tomography

Measurement	Abbreviation	Description
Distance from the junction of the lamina and spinous process to the entry point	DEP	Distance between the junction of the lamina and spinous process and the pedicle screw entry point
Pedicle width	PW	Mediolateral diameter of the pedicle at its narrowest part
Pedicle axis length	PAL	Distance between the posterior cortex of the lateral mass to the anterior wall of the vertebral body along the pedicle axis
Pedicle transverse angle	PTA	Angle between the transverse pedicle axis and median sagittal axis of the vertebra
Pedicle height	PH	Rostrocaudal diameter of the pedicle at its narrowest part

DEP: Distance from the junction of the lamina and spinous process to the entry point, PW: Pedicle width, PAL: Pedicle maximum axis length, PTA: Pedicle transverse angle, PH: Pedicle height morphological parameters are summarized in Table 2 and Table 3. The overall mean DEP ranged from 22.92 mm to 23.75 mm, and the minimum DEP was 19.94 mm. There were no significant differences between the right and left sides, except for C6. No statistical significance associated with gender was found for DEP. Post-hoc analysis revealed that the DEP was not significantly different between C3 and C5, C4 and C5, and C6, and C7 on the right side; and the DEP was significantly lower at C7 than at the other levels on the left side.

The overall mean PW ranged from 4.99 mm to 6.26 mm, and the minimum PW was 4.11 mm at C6. There was no significant difference between the right and left side, except for C3 in the whole study group and for C4 in male patients. When comparing male and female patients, the PW was found to be larger at C3 and C4 but smaller at C5, C6, and C7 in male patients; however, the differences were found to be significant at C3, C4, and C6 on the right and at C3 and C6 on the left side. Post-hoc analysis revealed that the PW significantly increased in the rostrocaudal direction, except between C4 and C5, on both sides.

The overall mean PAL ranged from 28.24 mm to 36.01 mm. There were no significant differences between the right and left sides for all vertebrae, except C3 in male patients. No significant differences were noted with regard to sex. Post-hoc analysis revealed that the PAL significantly increased from C3 to C7.

Table 2. The evaluated morphological parameters of pedicles in subaxial cervical spine

		DEP (mm)	PW (mm)	PAL (mm)	PTA (°)	PH (mm)
		(Mean ± standard deviation)				
C3	Overall	23.70±1.39	5.00±0.15	28.28±1.13	33.90±1.33	7.02±0.21
	Right	23.75±1.40	4.99±0.16	28.24±1.14	33.96±1.36	7.01±0.24
	Left	23.65±1.38	5.02±0.15	28.33±1.12	33.84±1.31	7.03±0.17
C4	Overall	23.52±1.40	5.37±0.26	30.44±1.54	33.53±1.35	6.88±0.40
	Right	23.48±1.43	5.36±0.24	30.42±1.55	33.52±1.34	6.87±0.41
	Left	23.55±1.36	5.38±0.29	30.46±1.53	33.53±1.36	6.90±0.40
C5	Overall	23.47±1.46	5.31±0.58	32.11±0.62	33.71±1.39	6.68±0.45
	Right	23.41±1.46	5.26±0.58	32.11±0.61	33.73±1.40	6.71±0.46
	Left	23.53±1.45	5.36±0.58	32.11±0.63	33.69±1.38	6.66±0.44
C6	Overall	23.29±1.53	5.62±0.80	34.30±0.94	34.59±1.90	6.43±0.63
	Right	22.94±1.57	5.65±0.81	34.33±1.00	34.57±1.92	6.36±0.67
	Left	23.65±1.42	5.60±0.80	32.26±0.89	34.60±1.88	6.49±0.58
C7	Overall	22.96±1.62	6.23±0.86	36.00±0.93	34.02±2.46	6.65±0.61
	Right	22.92±1.63	6.20±0.86	35.99±0.94	33.96±2.44	6.65±0.60
	Left	23.00±1.62	6.26±0.80	36.01±0.93	34.08±2.49	6.65±0.61

DEP: Distance from the junction of the lamina and spinous process to the entry point, PW: Pedicle width, PAL: Pedicle maximum axis length, PTA: Pedicle transverse angle, PH: Pedicle height

Table 3. The summary of evaluated morphological parameters based on genders

		DEP (mm)	PW (mm)	PAL (mm)	PTA (°)	PH (mm)
		(Mean ± standard deviation)				
C3	Male	23.77±1.38	5.08±0.14	28.29±1.13	33.83±1.39	7.03±0.21
	Female	23.63±1.40	4.92±1.12	28.28±1.13	33.97±1.27	7.01±0.20
C4	Male	23.55±1.41	5.44±0.26	30.46±1.55	33.45±1.37	6.89±0.37
	Female	23.49±1.38	5.29±0.25	30.42±1.54	33.60±1.33	6.88±0.43
C5	Male	23.55±1.45	5.30±0.50	32.08±0.59	33.76±1.39	6.68±0.44
	Female	23.39±1.45	5.32±0.65	32.14±0.64	33.66±1.40	6.69±0.46
C6	Male	22.27±1.57	5.48±0.70	34.36±0.94	34.54±1.84	6.43±0.65
	Female	23.32±1.51	5.77±0.87	32.23±0.94	34.63±1.96	6.43±0.61
C7	Male	23.02±1.60	6.19±0.89	36.04±0.96	34.02±2.50	6.60±0.59
	Female	22.91±1.64	6.27±0.82	35.97±0.91	34.02±2.43	6.69±0.62

DEP: Distance from the junction of the lamina and spinous process to the entry point, PW: Pedicle width; PAL: Pedicle maximum axis length, PTA: Pedicle transverse angle, PH: Pedicle height

The overall mean PTA ranged from 33.52° to 34.60°. There were no significant differences between the right and left sides for all vertebrae, except for C3 in female patients. Significant gender-specific differences were found at C3 on the right and C5 on the left. Post-hoc analysis revealed significant differences in the PTA between C6 and other vertebrae above. There were no significant differences with regard to C7. The values for C5 and other vertebrae above were similar.

The overall mean PH ranged from 6.36 mm to 7.03 mm. The PH was greater than the PW at all levels on both sides. There were no significant differences between the right and left sides for all vertebrae, except C6 in male patients. Gender was not found to have a significant effect on PH. Post-hoc analysis revealed that the PH significantly decreased from C3 to C6 and then increased slightly from C6 to C7, but this change was not statistically significant.

DISCUSSION

Among the spinal segments, the cervical spine has the greatest range of motion, and this makes it more susceptible to degenerative or traumatic pathologies. Other issues, such as infections, tumours, and metabolic diseases, may also affect the cervical spine and may reduce stability; thus, cervical instrumentation with or without fusion may be unavoidable in the setting of instability under such circumstances. The most commonly used posterior instrumentation technique in current practice is lateral mass fixation(2). For the subaxial cervical spine, Abumi et al.(3) and Jeanneret et al.(4) described transpedicular screw fixation in 1994. Several biomechanical studies have demonstrated that cervical pedicle screw fixation is more stable than other posterior fixation methods, but its use is limited owing to the risk of serious injury to adjacent neurovascular structures(16).

Unlike the thoracic and lumbar vertebrae, the cervical vertebrae, with the exception of C7, have transverse foramina on the transverse process, allowing passage of the vertebral artery and vertebral veins. Owing to their small size and unique anatomical features, the most severe complications associated with transpedicular screw fixation are injuries to the vertebral arteries, spinal cord, and nerve roots. To avoid complications, detailed knowledge of pedicle anatomy, including the pedicle width, PH, and anteroposterior trajectory, is required during transpedicular screw fixation.

Several cadaveric and radiological studies on cervical spine morphology have been conducted(6,10,17). Although some similarities were noted, there were differences that may be attributed to the different study populations. Even ethnic problems can be seen now in any city, and one should not exclude this variable totally, Turkey includes several ethnic populations. Thus, it is difficult to generalize the findings of previous publications on the Turkish population with small sample sizes(7-9,11). We have performed this study on a larger group of individuals who have origins from the central to eastern and western Anatolian peninsula.

Right vs. Left and Male vs. Female

There is a limited amount of studies analysing the right and left sides in the literature. The pedicle-spinous process distance, PW, and PAL were shown to be statistically significant(8,14). In our study, every parameter showed differences between the right and left sides at least in one spinal segment, and the calculated amount of differences were highest at C3, followed by C6. Although there was no general pattern, the differences in results can be attributed to the following: 1) a larger sample size in this study than in previous studies, which may have resulted in small differences becoming apparent, 2) differences in demographics of the study population, and 3) differences in inter-rater reliability.

There have been reasonably consistent reports on differences according to gender. Although some researchers found out differences between sexes in the measurement of PW, PH, and PAL, there were also others reporting no differences(7,13,14). To our knowledge, only Uğur et al.'s(7) study demonstrated a statistically significant difference in the PTA between male and female patients(7). We found differences in the PW and DEP according to sex. However, contradictory to previous findings, there were no significant differences in the PH and PAL according to sex. Moreover, there were significant differences in the PTA at some levels between male and female patients, as reported by Uğur et al.(7). We do not believe that the absence of significance for the PH and PAL can be attributed to sample size, as the sample size was large enough to demonstrate differences. However, it might be associated with population characteristics, as the inter-rater reliability for the PAL has been shown to be intermediate to good and that for the PH has been shown to be good to very good(13,14).

DEP

We found a decreasing tendency from the caudal to rostral direction, similar to the finding in the study by Herrero et al.(13). However, statistical significance was only noted for C7 on the left side, DEP with the lowest value. There is no generally accepted entry point for cervical pedicle screw insertion in the literature. As considering the mean DEP ranged between 22.92-23.75 mm and the smallest DEP was noted as 19.94 mm in the present study, pedicle screws at least 20mm lateral to spinous process-lamina junction could be safely placed in the Anatolian population.

PW

The smallest PW in our study was 4.11mm, which is greater than the width reported in previous studies, except the study by Herrero et al.(13). Additionally, the PW had an increasing tendency in the distal direction, although the change was not significant at each level. Jones et al.(5) found no difference in the pull-out strengths of 2.7-mm and 3.5-mm pedicle screws. Thus, a width of 4.11 mm is sufficient to safely insert a 2.7-mm pedicle screw. However, 2.7 mm pedicle screws are not widely available. Considering the majority of commercially available pedicle screws have the smallest width of 3.5 mm, they seem to be safe at all levels. Moreover, considering the smallest PW being 4.11 mm in 2000 measurements, 4mm pedicle screws can be safely used as rescue screws.

PAL

We found a significant increase in the PAL from C3 to C7, which is not consistent with the results in other morphometric studies. Additionally, this finding is in contrast to the finding in the study by Herrero et al.[13]. As the cohort sizes of our study and the study by Herrero et al.[13] were similar, the differences in PAL might be associated with population differences or inter-rater reliability, which has been reported to be moderate to good by Herrero et al.[13] and Westermann et al.[14], and good by Rao et al.[15]. In accordance with the current study's PAL values, it can be said that inserting longer screws with increasing dimensions of 2 mm as progressing caudally through the cervical spine starting from C3 with an 18 mm screw could be performed securely in the Anatolian population.

PTA

The mean overall PTA ranged from 33.52° to 34.59°. The PTA at C6 was significantly higher than that at the above levels, but there was no significant difference with regard to C7. This finding is in contrast to the findings of studies that reported the smallest PTA at C7. Moreover, to our knowledge, the PTA range in our study is one of the smallest among similar studies[5,7,9,10,12,14,15]. Similar findings were reported by Panjabi et al.[18]. As such a low trajectory angle might result in perforation of the transverse foramina, we highly recommend preoperative evaluation of cervical pedicle trajectories individually.

PH

Although the PH had a decreasing tendency from the rostral to caudal direction, with the exception of C7, it was greater than the PW at all levels, which is consistent with previous findings. Thus, the screw diameter can be safely determined according to only the PW.

Study Limitations

This study has several limitations. First, single-centre nature of the study might not necessarily represent the whole Anatolia. However, the study was performed in a government-owned academic tertiary referral care centre with ease of access by the public. The hospital is located in İzmir, which aside from being 3rd largest city in Turkey, also has been the 3rd city that receives domestic immigration the most for the last decade[19]. The location of the centre is close to where most of those immigrants settled, and the patient population mostly consists of those people. As the power analysis was resulted in over 90% for all evaluated parameters, the study population is considered as sufficient. Second, we included only a limited range of individuals and excluded the patients with the occurrence of any pathology related to any kind of spinal disease and prior cervical spine surgery. So, some modifications might be needed in terms of such circumstances. Third, a statistically significant difference was found between the mean ages of the genders; no correction was performed as age is not considered to be related to the measured parameters. Fourth, this was a radiomorphometric study, and clinical assessment was absent. And finally, all measurements were performed by two blinded observers in one occasion; no reliability analysis was performed. However, we believe that this study supplies useful information about radiomorphometric parameters for the Turkish spine surgeons in the accurate placement of cervical pedicle screw.

CONCLUSIONS

We performed a detailed CT-based morphometric analysis of the subaxial cervical spine in the Anatolian population. Based on these findings, pedicle screws with 3.5 mm width seems to be safe at all levels. A distance from 2 mm lateral to spinous process-lamina junction appears to be a valid screw entry point. Furthermore, it is not necessary to measure PH, and finally, the findings regarding the pedicle insertion angle should be taken cautiously until they are supported by further studies. As a consequence, although surgical planning should be carried out on a case-by-case basis, the findings of the present study might help Turkish spine surgeons in decision-making for the accurate placement of cervical pedicle screws.

Ethics

Ethics Committee Approval: The study protocol was approved by the local institutional review board. (Date: 20.06.2017, decision no: 521).

Informed Consent: The informed consent for academic research had been taken.

Peer-review: Internally peer-reviewed.

Authorship Contributions

Concept: M.S., C.T., Design: M.S., İ.D.C., C.T., Data Collection or Processing: İ.D.C., Analysis or Interpretation: M.S., İ.D.C., C.T., S.B., S.A., Literature Search: S.B., S.A., Writing: S.B., S.A.

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RADIOLOGICAL EVALUATION OF NORMAL SAGITTAL VERTEBRAL, PELVIS AND GLOBAL SPINOPELVIC PARAMETERS IN A YOUNG ADULT TURKISH POPULATION

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ABSTRACT

Objective: Normal values of sagittal vertebral, pelvis and global spinopelvic parameters have been reported to vary from society to society. The aim of this study was to determine these parameters in a young adult Turkish population and to evaluate the relationship between the sagittal spinopelvic measurements. This was the first study on this subject in a Turkish population.

Materials and Methods: The study included a total of 170 subjects comprising 137 (80.6%) males and 33 (19.4%) females, with a mean age of 24.1±4.9 years. Anteroposterior and lateral spine X-rays and pelvis X-rays were performed to evaluate the sagittal vertebral, pelvis and global spinopelvic parameters. Patients were classified according to the Roussouly classification system to classify normal variations of the vertebrae, pelvis and sacrum in the sagittal plane. Normal distribution of the variables was examined with the Shapiro-Wilk test. The Independent Samples t-test was used in the comparison of mean values.

Results: The mean and standard deviation values for sagittal vertical axis (SVA), spinopelvic inclination (T1Slop, T1SPi) , thoracic kyphosis, lumbar lordosis (LL), pelvic tilt, pelvis incidence (PI) and sacral slope values were 2.7±3.8, 13.5±7.5, -6.3±7.5, 29.6±9.8, 49.7±12.2, 11.6±7.3, 45.1±12.4 and 36.2±8.5, respectively. According to the Roussouly classification, 15.9% of the participants were classified as type 1, 32.3% type 2, 34.7% type 3, and 17.1% type 4. A statistically significant weak negative correlation was found between PI and T1SPi and a weak positive correlation was determined between PI and LL. No statistically significant correlation was determined between T1SPi and SVA.

Conclusion: One hundred and eighty-seven asymptomatic young adult Turkish volunteers were evaluated in terms of some pelvic angles and the physiological standard ranges of spinal parameters defining spinal balance and the ratios were determined according to the Roussouly sagittal morphological classification. The results showed a negative correlation between T1SPi and PI.

Keywords: Sagittal pelvic parameters, radiological evaluation, spine, Roussouly classification

INTRODUCTION

The Dubousset cone of economy concept illustrates the importance of spinopelvic balance to minimize the energy spent while standing and walking(1). This is due to the harmonic relationship of the normal sagittal curves and the pelvic anatomy. Sagittal radiological evaluations of a healthy population could provide new information about normal sagittal alignment, and this information could contribute to the treatment of spine deformities.

In the evaluation of spinal curves, some authors have placed anatomic limit points on regional spinal curves. Berthonnaud et al. (2) named the point between lumbar lordosis (LL) and TK (thoracic kyphosis) at which lordosis becomes kyphosis as the "inflexion point" and defined it as a limited functional variable(2). Based on the Berthonnaud concept of spinal segmentation, Roussouly et al. (3) recommended the classification of common variables according to the spinopelvic (SP) curve in sagittal spinal alignment by defining the spinopelvic shape in 4 types(3). Thus for the classification of normal variations of the vertebrae, pelvis and sacrum in the sagittal plane, the Roussouly classification is used(3). When planning deformity treatment, in particular, taking the 4 types of variants of the Roussouly classification into consideration can provide useful information. In addition, it can be useful to make recommendations to the patients according to the sagittal anatomy of the lumbar spine.

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The aim of this study was to radiologically evaluate the sagittal pelvis, vertebral and global SP parameters in a young adult, asymptomatic Turkish population, to evaluate the relationships between the pelvic parameters and the global SP parameters and to determine variants of sagittal spinal alignment using the Roussouly classification[4].

MATERIALS AND METHODS

Power analysis was applied to calculate the minimum number of participants for the study. The results showed that a minimum of 170 subjects was necessary to be able to provide mean 0.05 error, 95% confidence interval (CI), standard deviation (SD) estimation 10 and at least 1.5 margins of error (total width 3). Adding 10% substitute volunteers, it was deemed necessary to examine at least 187 participants. Following the power analysis, approval for the study was granted by the Ankara Yıldırım Beyazıt University Faculty of Medicine Clinical Research Ethics Committee (decision no: 54, dated: 05/03/2018).

The participants were selected from subjects applying for military service who had routine radiographs taken during the health screening. A total of 187 subjects were enrolled in the study, then a total of 17 were excluded for various reasons; inadequate axial radiograph in 10 cases, vertebral anomaly determined in 4 cases, and pelvic obliquity in 3 cases. The study was conducted between 2018-2019. Criteria for inclusion in the study were 1) healthy voluntary adult aged 17-40 years, 2) no clinical or radiological spinal, pelvic, or hip pathology, 3) no lower limb length discrepancy, 4) no back pain, leg pain or arm pain thought to be related to the spine in the anamnesis in the anamnesis, 5) both femoral heads visible on the lateral radiograph, 6) no vertebral anomaly, 7) no contra-indication for the taking of radiographs, 8) Body mass index (BMI) <30.

Informed consent was obtained from all the participants. A record was made for each patient of demographic data including age, gender, height, weight and BMI.

For all the subjects, the radiographic protocol applied as a standard 90x35 cm anteroposterior and left lateral radiograph including the whole spine from the occipital condyles to the sacrum, taken vertically at a distance of 2 metres from the radiography tube onto a single cassette. The radiographs were taken in the comfortable position described by Faro and Horton to minimise postural changes in the sagittal plane[5,6]. The subjects were instructed to stand with the knees and hips in full extension, shoulders at 90° and elbows in full flexion with the hands on the shoulders.

The measurements were taken by an experienced spine surgeon using Surgimap software vn 2.2.15.5 (Surgimap; Nemaris Inc., New York, USA). Previous sagittal spinal alignment measurement studies made with Surgimap were used for reference[7,8]. This computer-assisted sagittal alignment measurement is extremely fast and sensitive, is acceptable in the determination of reference points and has inter and intra-observer reliability[9]. To evaluate the sagittal vertebral, pelvis and global SP parameters, measurements were taken of the sagittal vertical

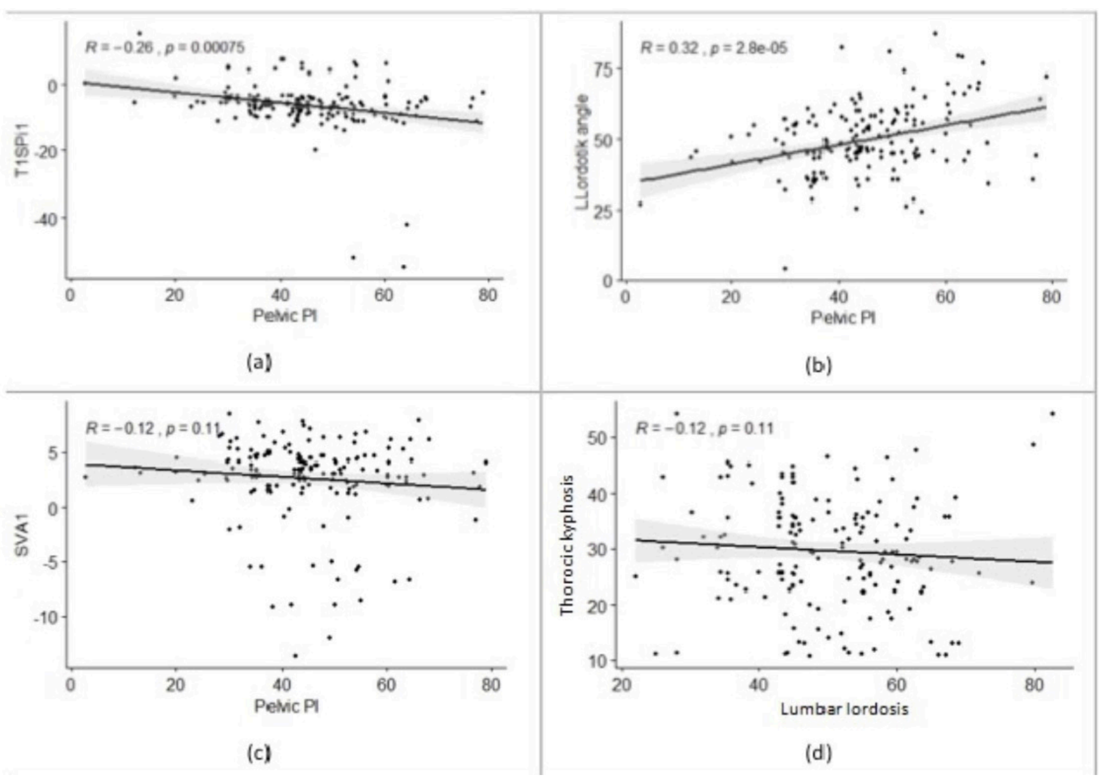

Figure 1. The measurements were made on the Surgimap software, in a; PT, PI, SS, L1-L4, PI-LL and in b; PT and PI

PT: Pelvic tilt, PI: Pelvic incidence, SS: Sacral slope, LL: Lumbar lordosis, T1SPi: T1 spino pelvic inclination, SVA: Sagittal vertical axis

axis (SVA), the T1 slope, T1SP inclination (T1SPi), TK, LL, pelvic tilt, sacral slope (SS), and pelvic incidence (PI) (Figure 1). Patients were classified according to the Roussouly classification system to classify normal variations of the vertebrae, pelvis and sacrum in the sagittal plane[3]. In the Roussouly classification system, type 1 and type 2 are characterized by low-grade SS and low-grade PI and differ from each other by the number of lordotic vertebrae. Type 3 has high-grade SS and high-grade PI, whereas type 4 is defined as the type with the largest SS in combination with high-grade PI[3].

Statistical Analysis

Data obtained in the study were analysed statistically using SPSS for Windows vn. 21.0 software (IBM Corpn, Armonk, NY, USA). To obtain a 95% CI in the R program, "DescTools" package was used, and "ggpubr" package in the drawing of the scatter pilot[10,11]. Conformity of the variables to normal distribution was examined with the Shapiro-Wilks test. The Independent Samples t-test was used in the comparisons of mean values obtained from the Turkish population and mean values obtained in other studies[12]. Quantitative variables were stated as mean ± SD, median, minimum and maximum values, and a 95% CI was used in the relationships of each pair of measurements. Categorical variables were stated as number (n) and percentage (%). A value of $p<0.05$ was accepted as statistically significant. Correlations between PI and LL, sagittal vertebral axis, and T1SPi were examined with the Spearman rho correlation test. The correlation coefficients were interpreted as 0.00-0.19=no correlation or at a negligible level, 0.20-0.39=weak correlation, 0.40-0.69=moderate correlation, 0.70-0.89=strong correlation, and 0.90-1.00=very strong correlation[13].

RESULTS

The 170 subjects evaluated in the study comprised 137 (80.6%) males and 33 (19.4%) females with a mean age of 24.1±4.9 years (range, 17-39 years). According to the BMI classification, 5 (3.0%) subjects were underweight (BMI <18.5 kg/m^2), 132 (77.6%) were of normal weight and 33 (19.4%) were overweight. The distribution of the subjects according to the Roussouly classification, is shown in Table 1.

The descriptive statistics of the variables examined in the study are shown in Table 2.

A weak negative correlation was determined between PI and T1SPi (rho= -0.256; p=0.001). A statistically significant weak positive correlation was determined between PI and LL (rho=0.315) (Figure 2). No statistically significant correlation was determined between T1SPi and SVA (p=0.830). There was no statistical correlation between height-weight and measured parameters.

Table 1. Distribution of the subjects in different studies according to the Roussouly classification

Roussouly classification	Current study (%)	Roussouly et al.[14]	Cho[15]	Araujo et al.[16]
1	15.9	12	23	4.9
2	32.3	22	13.1	31.3
3	34.7	30	49.6	42.3
4	17.1	20	14.3	21.5

Table 2. Descriptive statistics of the variables examined

Variables	Min; max	Median	95% CI for median lower limit; upper limit	Mean ± SD	95% CI for mean lower limit; upper limit
Age (years)	17; 39	23.0	22; 24	24.1±4.9	23.3; 24.8
Height (cm)	153; 195	175.0	174; 176	175.1±6.8	174.1; 176.1
Weight (kg)	40; 97	70.0	69; 72	70.1±9.5	68.7; 71.6
BMI (kg/m^2)	17.1; 27.5	22.7	22.1; 23.3	22.8±2.2	22.5; 23.1
SVA	-13.7; 8.6	3.5	3.1; 4.0	2.7±3.8	2.1; 3.3
T1 Slope	-3.0; 40.4	12.1	11.2; 13.2	13.5±7.5	12.4; 14.6
TK	10.7; 54.3	29.3	27.5; 32.4	29.6±9.8	28.1; 31.1
LL	4.0; 87.2	47.9	45.5; 51.2	49.7±12.2	47.9; 51.5
PT	-9.0; 35.3	12.3	10.9; 13.4	11.6±7.3	10.4; 12.7
PI	2.7; 79.1	43.9	43.2; 45.5	45.1±12.4	43.2; 47.0
SS	11.7; 62.9	35.6	33.2; 38.7	36.2±8.5	34.9; 37.5
T1SPi	-55.0; 15.2	-6.0	-6.7; -5.5	-6.3±7.5	-7.4; -5.2

CI: Confidence interval, SD: Standard deviation, BMI: Body mass index, SVA: Sagittal vertical axis, TK: Thoracic kyphosis, LL: Lumbar lordosis, PT: Pelvic tilt, PI: Pelvic incidence, SS: Sacral slope, T1SPi: T1 spino pelvic inclination

Figure 2. Scatter plot graph showing correlations between absolute PI and T1SPi, and absolute LL and SVA: a) T1SPi-absolute PI; r=0.256, p<0.001 b) LL-absolute PI; r=0.315, p<0.001 c) SVA-absolute PI; r= -0.125 p>0.001 d) TK-absolute LL PI; r= -0.12, p=0.11

PI: Pelvic incidence, T1SPi: T1 spino pelvic inclination, LL: Lumbar lordosis, SVA: Sagittal vertical axis, TK: Thoracic kyphosis, PT: Pelvic tilt, SS: Sacral slope

DISCUSSION

The aim of this study was to present the relationships of sagittal spinal radiographic parameters with some sagittal radiological values in a young adult Turkish population. By determining the normal distribution of these parameters, abnormal sagittal parameters will be able to be diagnosed. This is of importance as incompatibility in this plane can lead to spinal deformation and decreased quality of life. This is the first study to have presented normative sagittal radiological parameters in the Turkish population. In literature, there can be seen to be an extremely wide range of distribution of the sagittal SP parameters. This is because a great many factors affect these values. For example, in the current study subjects, the TK angle ranged from 10° to 54° (mean 30°), and the lordosis angle from 4° to 87° (mean 49°). In a study of asymptomatic subjects aged >40 years, Gelb et al.[17] reported the TK angle as mean 34°, and LL angle as means 64°[17]. In that study, no relationship was determined between height-weight and measured parameters, as in the current study.

Stagnara et al.[18] found the TK angle to be mean 37°, and the LL angle to be mean 50° in a study of 100 subjects in France. As the range of these values is very wide, the mean values of the normal kyphotic and lordotic curves are meaningless, and Stagnara et al.[18] emphasised the importance of determining the normal range[18]. Factors affecting these parameters in healthy individuals include BMI, age, race, genetic and environmental factors. When the results of the current study are compared with those of other studies, it can be seen that the findings are closer to those of studies conducted on Far East Asian populations, such as in Japan, Korea and China (Figure 3).

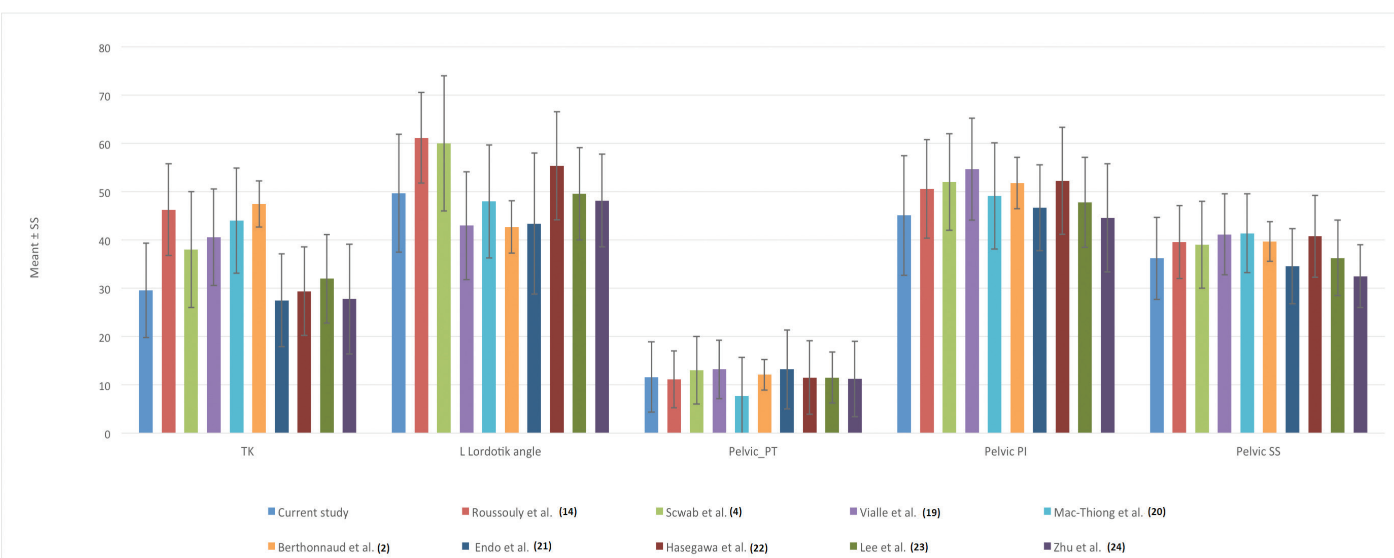

Figure 3. The mean ± SD values of the TK, lordotic angle (L), PT, PI and SS variables obtained from the current study and previous studies. *: p<0.05 as a result of comparisons with the values obtained from the current study

SD: Standard deviation, TK: Thoracic kyphosis, PT: Pelvic tilt, PI: Pelvic incidence, SS: Sacral slope

When compared with studies conducted in Europe and the USA, there can be seen to be a more significant statistical difference between sagittal parameters (Figure 2). When the TK is examined, while there was no significant difference with Asian populations, there was found to be a significant difference in the studies of European and American populations. In respect of the PI value, the current study values were closer to those of Asian populations. Although these studies were conducted on healthy individuals, the differences in demographic characteristics such as BMI, age, and male/female ratio limit the comparisons with these studies.

Common variations of lumbar sagittal alignment of the spine are classified in the Roussouly classification(14). By refining the previously existing anatomic segmentation of L1-S1 LL, the concept of short and long LL was established(14). The lumbar spine was separated into 4 according to the anatomic shape in the sagittal plane. Understanding the variation patterns in sagittal alignment reveals the relationship between sagittal balance and degenerative changes. It can also be important to bear in mind that there could be a need for different sagittal alignment when planning the operations necessary to recover sagittal alignment in patients with spinal pathology. In other words, it can be said that the same sagittal curve should not be given to all patients. Furthermore, specific recommendations can be made according to the LL type in patients with LL classified at an older age. As seen in Table 1 of the current study and other studies, the highest rate was the neutral postural position (Type 3). In the Roussouly study, it was stated that type 3 was the average spine shape, and it was not characterised by specific degeneration of the spine(25,26). In the current study, type 3 was followed by type 2 (flat lordosis). As there is greater pressure on the discs in type 2, this has been associated with early disc degeneration and subsequent multi-level central discopathies(27,28).

The high pressure formed on the spine by activities and sports in individuals with type 2 LL can accelerate the discopathy mechanical process(27-30). Therefore, even before the degenerative process develops, patients with type 2 LL should be advised not to undertake activities which can cause pressure on the spine. In the current study, type 4 LL was determined at the rate of 17%. Type 4 LL is known to be associated with L5 facet arthritis, a narrow canal and spondylolisthesis(27). In these individuals, recommendations of isometric strengthening or flexion exercises may be of benefit in preventing spondylolisthesis(14). Type 1 LL was determined at the lowest rate in the current study. In this group, retrolisthesis may develop between thoracolumbar kyphosis and the LL region(27). Facet arthrosis L5 spondylolysis may be seen in the hyperlordotic area(27). Flexion and strengthening exercises can be recommended again for this group to prevent the development of spondylolisthesis(31).

As in several previous studies in literature, a significant positive correlation was found in the current study between LL and PI(26,27). No significant correlation was determined between PI and SVA. No relationship was found between PI and SVA in a study by Endo et al.(21) While there are some studies in the literature showing a relationship between PI and SVA, no study could be found which showed a relationship between PI and T1SPi. In the current study, a weak negative correlation was determined between PI and T1 SPi, showing global sagittal balance. T1SPi represents the angular relationship in the sagittal plane of the centre of both femoral heads with thoracic 1 spine(25). PI represents the angular relationship in the sagittal plane of the centre of the two femoral heads according to the sacrum and is a morphologically stable parameter(25).

In previous studies, the T1SPi normal values have been reported as 7°-29°(13). Bakouny et al.(32) reported these values as -5.5°±2.6°. In the current study, the normal values were found to be -6.3°±7.5°. As PI increases, so LL and TK together increase. There are compensation mechanisms of the pelvis shape to be able to provide global sagittal balance. Thus, the global sagittal balance can be held within a certain range(27,33). In the current study, with the negative correlation between T1SPi and PI, it can be said that as PI increased, the global sagittal balance was compensated in a narrower range, and as PI decreased, the normal values of the sagittal balance were in a wider range.

When PI decreases, the spine takes on a flatter shape in the sagittal plane, and as PI increases, the spine in the sagittal plane becomes more angular(14,33). This can be evaluated as global sagittal balance in a wider range in a flatter spine, and a narrower range of global sagittal balance in a more angulated spine. However, there is a need for further studies to support this view.

CONCLUSION

In this study, 185 asymptomatic young adult Turkish population were evaluated in respect of some pelvic angles and the standard physiological ranges of spinal parameters defining spinal balance, and the ratios were determined of the types seen in the Roussouly sagittal morphological classification. The results showed a negative correlation between T1SPi and PI. When comparisons were made with studies of other populations, the sagittal values of the Turkish population were observed to be closer to those of Asian populations.

Ethics

Ethics Committee Approval: Approval for the study was granted by the Ankara Yıldırım Beyazıt University Faculty of Medicine Clinical Research Ethics Committee (decision no: 54, dated: 05/03/2018).

Informed Consent: Informed consent was obtained from all the participants.

Peer-review: Internally peer-reviewed.

Authorship Contributions

Concept: M.A.E.A., Design: M.A.E.A., Data Collection or Processing: M.A., S.A., Hİ.A., Analysis or Interpretation: M.A., Hİ.A., P.D., Literature Review: H.A., Hİ.A., Manuscript Writing: M.A.E.A., M.A.

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

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DO LUMBOSACRAL TRANSITIONAL ANOMALIES HAVE ANY RELATION WITH SAGITTAL SPINAL ALIGNMENT AND CORONAL SPINAL ASYMMETRY: A RETROSPECTIVE INVESTIGATION IN ARMY OFFICER CANDIDATES

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ABSTRACT

Objective: Lumbosacral transitional vertebrae (LSTV) are commonly seen congenital anomalies of the lumbosacral spine, and named according to the transition type as sacralization or lumbarization. The aim of this study was to determine whether LSTV have influence on sagittal spinal alignment and coronal spinal asymmetry.

Materials and Methods: Anteroposterior and lateral full-length standing X-rays of young adult army officer candidates, who were admitted for health screening between January 2018 and January 2019, were extracted from the medical electronic database. Among these X-rays, those belonging to participants with sacralization and lumbarization were identified. The cervical lordosis, thoracic kyphosis and lumbar lordosis were measured on lateral X-rays and coronal spinal angle, if exist, were measured on anteroposterior X-ray with Cobb angle. Sagittal and coronal parameters were compared among participants with lumbarization, participants with sacralization and that of age- and sex-matched controls without LSTV.

Results: Of the 179 X-rays extracted from the database, 30 (16.8%) were participants with sacralization, 69 (38.5%) were participants with lumbarization and 90 (50.3%) were controls. Participants with lumbarization had significantly greater cervical and lumbar lordosis angles than those without LSTV (controls). However, thoracic kyphosis angle did not differ among three groups. Based on coronal spinal measure, controls had higher spinal asymmetry values than participants with sacralization and participants with lumbarization. Curve patterns found in this study were single thoracic and single lumbar patterns.

Conclusion: The finding of this study demonstrated that individuals without LSTV were more likely to develop coronal spinal asymmetry. This study also suggested considering lumbarization for increase in physiological cervical and lumbar sagittal angles.

Keywords: Lumbarization, sacralization, sagittal spinal alignment, coronal spinal asymmetry, lumbosacral transitional vertebrae

INTRODUCTION

Lumbosacral transitional vertebrae (LSTV) are commonly seen congenital anomalies of the lumbosacral spine. The lumbosacral junction may be renamed according to the transition type: sacralization defines the assimilation of the fifth lumbar vertebra to the sacrum (fusion between the L4 and S1 segment), and lumbarization shows the transition of a sacral vertebra to a lumbar configuration (L6-S1). Men (4.7% prevalence) are more likely to have transitional vertebrae compared to women (2.7% prevalence)[1]. LSTV has been reported to be associated with low back-related symptoms. The presence of LSTV has been reported to be one of the factors for patients who apply with low back pain to orthopedics and traumatology departments in some clinical studies[2,3]. Some other studies have claimed that the LSTV anomaly may predispose patients to certain clinical disorders, such as smaller disk height, increased risk of lumbar disc herniation, early disc degeneration above the transitional segment, and spinal stenosis[4,5]. Sagittal and coronal spinal disorders are recognized as important in selecting army officer candidates in Turkey. Individuals with LSTV, or with sagittal spinal curves outside of the normal limits or coronal spinal asymmetry above 10°, will not be accepted for army officer positions as the rule.

Previously, abnormal torque moments at the vertebral segment above the transitional segment were reported as being responsible for disc degeneration[4]. Relative hypermobility

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above LSTV and the inability to distribute loads equally and, thereby, an increase in local stress in a vertebral segment is suggested to occur in the presence of LSTV[6]. Price et al.[7] showed alterations in spinopelvic parameters in subjects with LSTV. They reported increased pelvic tilt, pelvic incidence, sacral slope, and lumbar lordosis in subjects with lumbarization compared to healthy controls. Yokoyama et al.[8] showed increased spinopelvic parameters in asymptomatic individuals with lumbarization, like Price et al.[7], and they also found positive sagittal balance in that group of patients. These biomechanical changes with LSTV reported in the literature made us think that physiological sagittal curves might be affected by the LSTV and coronal spinal asymmetries may occur.

Lee et al.[5] reported LSTV prevalence as 12.2% in adolescents with idiopathic scoliosis. The presence of LSTV has been considered important in determining surgical levels for the curve correction, because it affects spinal stability and compensation in idiopathic scoliosis[5]. Furthermore, Zhou et al.[1] found that LSTV significantly affected spinal alignment parameters, except for thoracic kyphosis and truncal tilt. They found an increase in the magnitude of sagittal pelvic (pelvic incidence and pelvic tilt), spinopelvic (sacral slope), and global spinal alignment (sagittal vertical axis, T1-pelvic angle, and lumbar lordosis) parameters.

We noticed the lack of retrospective studies that might help to define the relationship between LSTV and physiological sagittal spinal curves and the possible risk of coronal spinal asymmetry. The aim of this study was first to investigate whether sagittal spinal curves change in participants with LSTV, and, secondly, to analyze the relationship between LSTV and coronal spinal asymmetry. The third aim was to compare these spinal parameters between two different LSTV groups, namely participants with sacralization and participants with lumbarization.

MATERIALS AND METHODS

This study is retrospective radiographics analysis of hospital records, approval was obtained from the local ethics committee of University of Health Turkey, Ankara Bilkent City Hospital Ethics Board (date: 25.03.2020/16, decision no: 72300690-790). The data of young adult army officer candidates in Turkey, who applied to the our hospital Department of Orthopedics and Traumatology for the purpose of health screening between January 2018 and January 2019, were extracted from the electronic database of the hospital. All anteroposterior and lateral radiographs were evaluated regarding the presence of LSTV. Among participants who had LSTV, those with sacralization or lumbarization were included in the study. Assimilation of the fifth lumbar vertebra to the sacrum was called sacralization, while transition of the first sacral vertebra to a lumbar configuration was called lumbarization[9]. In addition, an age-matched control group with no signs of lumbosacral transitional anomalies was constituted. Participants were excluded if they had a history of spinal trauma/surgery, spondylolisthesis, spondylodiscitis, scoliosis, chronic inflammatory arthritis predominantly affecting the axial skeleton (e.g., ankylosing spondylitis, psoriatic arthritis), vertebral fracture, aseptic necrosis of the vertebra, and/or radiographs of inappropriate image quality.

On the standing full-length [36-in (91-cm)] lateral radiograph of the spine, sagittal spinal curves including cervical lordosis, thoracic kyphosis, and lumbar lordosis and on the standing full-length anteroposterior radiograph, lateral curvature of the spine, if present, were measured with imaging software (RadiAnt DICOM Viewer version 5.5) using the Cobb method by a single examiner. Cervical lordosis was measured from vertebrae C2 through C7[10]. Thoracic kyphosis was measured in a similar manner using a line drawn along the superior endplate of T1/T2 and the inferior endplate of T11/12[10]. Lumbar lordosis was measured from the top of L1 to the top of the sacrum[10]. For cervical and lumbar sagittal spinal measures, extension (lordosis) angles were considered as positive numbers, whereas flexion (kyphosis) angles were considered as negative numbers. For thoracic sagittal spinal measures, flexion (kyphosis) angles were considered as positive numbers.

Straight or symmetrical spines in the coronal plane were called normal spines in this study. Curves of ≥10° in the coronal plane were accepted as scoliosis, whereas curves of less than 10° were accepted as spinal asymmetry[11]. Curve patterns were classified according to the Scoliosis Research Society's classification[12]. They divided curves into single (thoracic or lumbar), double (both thoracic and lumbar), and triple patterns (upper thoracic, middle thoracic, and lumbar).

Statistical Analysis

Statistical analysis was performed with SPSS 15.0 for Windows (SPSS Inc., Chicago, IL, USA). The normality of the variables was checked by Kolmogorov-Smirnov test. Because the variables were normally distributed ($p>0.05$), parametric tests were performed. One-Way ANOVA was used for between-group comparisons of continuous variables. For significant interactions, post-hoc pairwise comparisons were made using Tukey's method. The relationship between variables was assessed using Pearson's correlation analysis. Following Cohen's classification, the magnitude of the Pearson correlation coefficient was categorized as follows: 0.10 to 0.29, low; 0.3 to 0.49, moderate; and 0.5 or above, large[13]. The alpha level was 0.05 for all tests of statistical significance.

RESULTS

A total of 277 participants with both anteroposterior and lateral spine radiographs were identified from the electronic database. Of these participants, 254 who had proper radiographs were included in the study. After the assessment of the radiographs and medical records of these participants, 75 of them were excluded from the study for several different reasons as illustrated in the flowchart diagram (Figure 1). Analyses were undertaken of the remaining participants, including [1] participants with sacralization (n=30), [2] participants with lumbarization (n=59), and [3] age-matched control participants with no signs of lumbosacral transitional anomalies (n=90).

The mean ages of participants with sacralization, with lumbarization, and with no signs of lumbosacral transitional anomalies were 18.8±1.2, 18.8±1.2, and 18.8±0.8 years, respectively. There was no difference between the three groups regarding age (p=0.988). Body mass index differed among the groups. Both participants with sacralization [mean difference, -0.86 (0.36); 95% confidence interval (CI), -1.7 to -0.02, p=0.043] and lumbarization (mean difference, -1.4 (0.28); 95% CI, -2.09 to -0.75, p<0.001) had higher body mass indexes than the controls. Demographic characteristics are shown in Table 1.

For sagittal spinal alignment parameters, there was a difference between the three groups in cervical lordosis (p=0.034) and

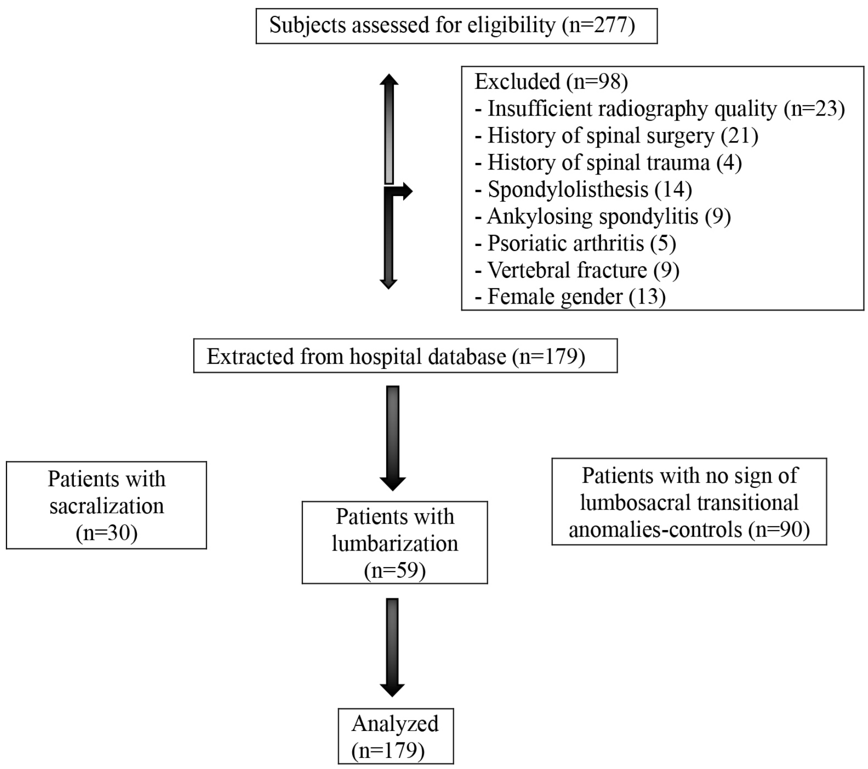

Figure 1. Flow diagram for participants of the study

Table 1. Comparison of demographic and clinical characteristics of the participants among groups

Participant characteristics	Participants with LSTV		Controls (n=90)	P value
	Participants with sacralization (n=30)	Participants with lumbarization (n=59)		
Age (years)	18.8±1.21	18.8±1.21	18.82±0.83	0.988
BMI (kg/m²)	21.74±2.09	22.29±2.04	20.87±1.23	<0.001**
Sagittal spinal parameters (°)				
Cervical lordosis	8.93±8.47	9.29±7.0	6.36±6.81	0.034*
Thoracic kyphosis	34.50±10.64	36.84±10.18	35.23±8.77	0.469
Lumbar lordosis	41.96±14.71	45.76±10.23	38.87±11.65	0.010*
Coronal spinal asymmetry presence n (%)	9 (30%)	11 (18.6%)	78 (86.7%)	N/A
Coronal spinal asymmetry angle (°)	2.07±3.24	1.24±2.64	6.42±2.46	<0.001**
Coronal spinal curve pattern n (%)				
Single thoracic	6 (20%)	6 (10.2%)	48 (53.3%)	N/A
Single lumbar	3 (10%)	5 (8.5%)	30 (33.3%)	N/A

Data shown as mean ± standard deviation or n (%), Statistically significance, * p<0.05, ** p<0.001
LSTV: Lumbosacral transitional vertebrae, BMI: Body mass index, N/A: Not available

lumbar lordosis (p=0.010) angles, whereas thoracic kyphosis did not differ among the groups (p=0.469) (Table 1). Both cervical (mean difference, -2.93 (1.20); 95% CI, -5.78 to -0.09, p=0.041) and lumbar lordosis (mean difference, -6.89 (2.25); 95% CI, -12.2 to -1.57, p=0.007) angles were greater in participants with lumbarization than in controls.

Based on coronal spinal measures, there were participants with spinal asymmetry in all groups, whereas there was no participant with scoliosis. However, spinal asymmetry intensity differed among groups (p<0.001) (Table 1). Pairwise comparisons revealed that controls had higher spinal asymmetry values than participants with sacralization (mean difference, 4.35 (0.56); 95% CI, 3.02 to 5.67, p<0.001) and participants with lumbarization (mean difference, 5.18 (0.44); 95% CI, 4.13 to 6.24, p<0.001). Curve patterns found in this study were single thoracic and single lumbar

Correlation analysis established that coronal spinal asymmetry negatively correlated with cervical lordosis and lumbar lordosis and positively correlated with thoracic kyphosis. Both cervical lordosis and thoracic kyphosis were positively correlated with lumbar lordosis. Correlations were found to be low or moderate. Correlations between sagittal spinal parameters and coronal spinal asymmetry are summarized in Table 2.

DISCUSSION

This paper explores whether sagittal spinal curves change in young male participants with LSTV, analyzes the relationship between LSTV and coronal spinal asymmetry, and compares sagittal and coronal spinal parameters between two different LSTV groups, namely participants with sacralization and participants with lumbarization. The study showed that participants with lumbarization had greater cervical and lumbar lordosis angles than controls without LSTV. Presence of LSTV was not seen to affect the thoracic kyphosis angle. Interestingly, controls without LSTV were found to have higher spinal asymmetry prevalence and mean values than participants with LSTV.

According to Panjabi[13] , the mechanical stability of the spine is necessary to maintain spinal functions such as load carrying and core stabilizing for movements of the extremities. The spinal stabilizing system consists of active (muscles and tendons surrounding the spinal column), passive (vertebrae, facet articulations, intervertebral discs, spinal ligaments, joint capsules, passive mechanical properties of the muscles), and neural (various force and motion transducers, located in ligaments, tendons, and muscles, and the neural control centers) subsystems. Both hypomobility and hypermobility of the spine as measured by the range of motion have been reported as predisposing factors of spinal instability. When spinal stability is deteriorated, the capacity in resisting torsional loads is reported to weaken and compensatory changes occur[13]. We determined in the present study that, compared to individuals without LSTV, those with lumbarization presented with different sagittal alignment. As expected, with an extra lumbar vertebra, lumbar lordosis was on average 7° greater in subjects with lumbarization than controls. In the presence of lumbarization, separation of the first sacral segment from the sacral corpus results in the number of lumbar vertebrae increasing to six. Lumbarization could probably result in a more mobile lumbar segment, thereby increasing the physiological lumbar curve. Similarly, Price et al.[7] found an average 8° increase in patients with lumbarization when compared with an asymptomatic population: Yokoyama et al.[8] also showed that lumbar lordosis tended to be greater by an average of 3° in individuals with lumbarization. They noted positive sagittal balance when lumbarization occurred. In the present study, there was an increase in cervical lordosis of about 3° in the lumbarization group, whereas thoracic kyphosis did not differ among groups. Similarly, Zhou et al.[1] found that LSTV significantly affected lumbosacral sagittal spinal alignment parameters, but no difference in the physiological curvature of the spine above the lumbar spine existed between patients with LSTV and healthy controls. Alterations in structures resulting in biomechanical adjustments of these segments may change the muscular efforts around the spine in order to achieve optimal movement without compromising stability.

Previously, possible variations in the number of thoracic and lumbar vertebrae were investigated in individuals with adolescent idiopathic scoliosis because of their importance in surgical correction[14]. Atypical vertebral anatomy has been proposed as a risk factor for wrong-site spine surgery in coronal spinal deformities and it was suggested that vertebrae variation occurs with considerable frequency (10% of prevalence) in this population. Lee et al.[5] suggested considering LSTV with 12.2% prevalence in patients with adolescent idiopathic scoliosis. On the other hand, Seçer et al.[15] transitional vertebra detected in 18 (4.5%) of a total of 401 young male patients with low back

Table 2. Correlation between sagittal spinal parameters, coronal spinal asymmetry and body mass index

N=179	All participants			
	Cervical lordosis	Thoracic kyphosis	Lumbar lordosis	Coronal spinal asymmetry
Cervical lordosis	1	r=-0.031, **p=0.676**	r=0.229, **p=0.002***	r=-0.260, **p<0.001****
Thoracic kyphosis		1	r=0.201, **p=0.997***	r=0.219, **p=0.003***
Lumbar lordosis			1	r=0.186, **p=0.013***

Significance is indicated by p-values; * p<0.05, ** p<0.001

pain without scoliosis. In contrast, higher spinal asymmetry values were seen in controls without LSTV than participants with LSTV (both in sacralization and lumbarization groups) in the present study. Comparative studies investigating the relation between coronal spinal asymmetry and LSTV are limited. Given the methods used in the current study, it is not possible to determine which mechanisms were responsible for the high prevalence of coronal spinal asymmetry in controls without transitional vertebrae.

Kiel et al.[9] defined the alteration of sagittal curves in patients with low magnitude idiopathic scoliosis as coronal spinal asymmetry (average Cobb angle of 5°). They reported backward vertebral tilt between T7 and L3 and forward tilt at T5 and L5. Segmental sagittal angulation was found to be more common in patients with greater Cobb angles[9]. Clement et al. found that the low kyphosis in idiopathic scoliosis has a trend of accompanying low lordosis[16]. Yu et al.[17] highlighted that the sagittal cervical angle is correlated with global sagittal and coronal alignment in young patients with idiopathic scoliosis. They emphasized that cervical kyphosis was related to coronal spinal deviation. On the contrary, Hu et al.[18] found that coronal and sagittal parameters were not significantly correlated, and the coronal deformity types did not change the global sagittal postural patterns. Concerning coronal and sagittal spinal parameters, our study identified an association between coronal spinal asymmetry (Cobb angle below 10°) and sagittal spinal parameters. Coronal spinal asymmetry was negatively correlated with cervical lordosis and lumbar lordosis and positively correlated with thoracic kyphosis. In addition, both cervical lordosis and thoracic kyphosis were positively correlated with lumbar lordosis. These relations may be explained by the flexible spine characteristics of young people and the spontaneous adaptation mechanism of the spinal-pelvic system.

Study Limitations

The present study has some limitations. First, this study had a retrospective design. Second, the subject population consisted of young male participants. Therefore, results cannot be generalized to other age groups or to females. Body mass index distribution among the groups was different. Clinical measurements such as pain, function, and health-related quality of life of the participants might have been beneficial to explain the relations between the findings of this study.

CONCLUSION

The results of this study showed that young male participants with lumbarization had increased cervical and lumbar lordosis curves in the sagittal plane compared to controls without LSTV, whereas thoracic kyphosis was not affected by the presence of transitional vertebrae. LSTV was not found to have any effect on the risk of coronal spinal asymmetry development in this study. Therefore, the detailed investigation of the relation between LSTV and sagittal spinal alterations and factors that might affect this relationship is suggested for future studies, because these could cause symptoms in the long term.

Ethics

Ethics Committee Approval: Universtiy of Health Sciences Turkey, This study was approved by the local ethics committee of Ankara Bilkent City Hospital Ethics Board (date: 25.03.2020/16, decision no: 72300690-790).

Informed Consent: The patients were informed regarding the treatment and its potential benefits as well as evaluation methods; and thereby, signed informed consent forms were obtained.

Peer-review: Internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: F.İ., U.G., E.C., Concept: F.İ., G.Y., U.G., Design: G.Y., U.G., E.C., Data Collection or Processing: F.İ., U.G., Analysis or Interpretation: G.Y., E.C., Literature Search: F.İ., G.Y., U.G., E.C., Writing: F.İ., G.Y., U.G., E.C.

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ORIGINAL ARTICLE
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EFFECTS OF LUMBAR MICRODISCECTOMY ON SPINOPELVIC PARAMETERS

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ABSTRACT

Objective: One of the causes which accelerates spinal degeneration process is lumbar disc hernia (LDH). In this study, we observed the changes in spinopelvic parameters one month after single-level lumbar microdiscectomy (LM).

Materials and Methods: Standardized bilateral standing scoliosis radiography images of 19 patients, which were performed before and 1 month after LM operation, were evaluated retrospectively. Sagittal vertical axis and coronal vertical axis distances, thoracic kyphosis, lumbar lordosis, pelvic incidence, sacral slope and pelvic tilt angles were measured with Surgimap software.

Results: There was a positive correlation between pre-and post-LM values of all spinopelvic parameters included in the study. In comparative tests however, the difference was found to be not statistically significant. As a result, despite LM operation slightly improved spinopelvic parameters in the first month, there was not a significant change overall.

Conclusion: LDH is known to worsen the degenerative process in spine. LM as a treatment option is seen to alleviate this degenerative process by slowing down the deterioration in spinopelvic parameters.

Keywords: Lumbar microdiscectomy, spinopelvic parameters, spinal balance

INTRODUCTION

Back pain, which has an incidence of 80% in the general population, is the most common complaint amongst patients who received a lumbar disc herniation (LDH) diagnosis[1,2]. The most common symptom after the pain is neurological losses due to radiculopathy. For every 100,000 patients diagnosed with lumbar disc disease, an average of 14-70 lumbar microdiscectomies (LM) are performed[3]. The pain can be either directly discogenic, caused by straining of local anatomical structures or paraspinal muscle spasms, and this situation results in a significant productivity loss[4]. Besides the spasm of muscles forming lumbar anatomical area, intervertebral disc degeneration and degeneration in facet joints are also shown to affect spinopelvic parameters and cause scoliosis[5]. This deterioration in spinopelvic parameters also results in straining of muscles which are responsible for standing straight and ultimately causes pain[6]. In another study, it was shown that spinopelvic parameters were deteriorated in these patients[7]. It is known that the severity of pain lessens after the correction of spinopelvic parameters[2,8]. Deterioration in spinopelvic parameters makes it difficult for patients to live a healthy life and reduces their quality of life[9]. Inpatient that underwent instrumentation, the changes in these parameters were studied extensively, and it was found that patients, who were brought closer to the global balance due to these changes, had an increased quality of life[10-13].

However, it is seen that the number of studies, which show the changes in these spinopelvic parameters in patients who underwent LM, is fairly low in the literature[11]. For this reason, it was aimed to define possible changes in spinopelvic parameters by comparing LM measurement before and after LM in our study. The sagittal vertical axis (SVA), coronal vertical axis (CVA) measurement and lumbar lordosis (LL), thoracal kyphosis (TK), pelvic incidence (PI), pelvic tilt (PT) and sacral slope (SS) angles, which were shown to affect standing posture and global balance[9,12], were included in the study. Surgimap program was used in the measurement of angles and distances[14].

MATERIAL AND METHODS

Patients who underwent LM operation in Çanakkale Onsekiz Mart University, Department of Neurosurgery, between 01.10.2017 and 1.11.2020 were included in our study. Ethical board approval was received with the (11.11.2020/2020-13) decision of Çanakkale Onsekiz Mart University, Faculty of Medicine, Ethical Board of Clinical Studies. Permission to use

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medical records for clinical studies were present on the routine patient consent forms received before the operation. Patient data used in the study were analyzed retrospectively. It was shown in the literature that the measurement of spinopelvic angles gave the ideal results when made on simultaneous bilateral scoliosis radiographs which include the area between cranium and femur[15].

Data from 19 cases, whose radiographs were taken in adequate resolution with the proper format for standard angle and parameter measurements, were used in our study. Additionally, cases with radiographs from before and 1 month after the LM operation as routine follow-ups, were chosen. Radiographs which include spinal and pelvic anatomy in proper format were taken from picture archiving and communication system anonymously. Anatomical landmarks, which were used in the measurement of spinopelvic parameters, were determined according to standardized studies[16,17]. Parameters PI, PT, SS were used as pelvic parameters and LL, PI-LL mismatch, TK in T4-12 level were used in the thoracolumbar measurement. And for the global alignment parameters, SVA and CVA were used (Figure 1).

For the measurements, Surgimap software (Surgimap, Nemaris, New York, 133 USA) was used[14]. The software is distributed for free on the internet. Images of the first cervical vertebra, head of femur and sacrum were inserted to the software before the measurement process (Figure 2). Measurement of spinopelvic

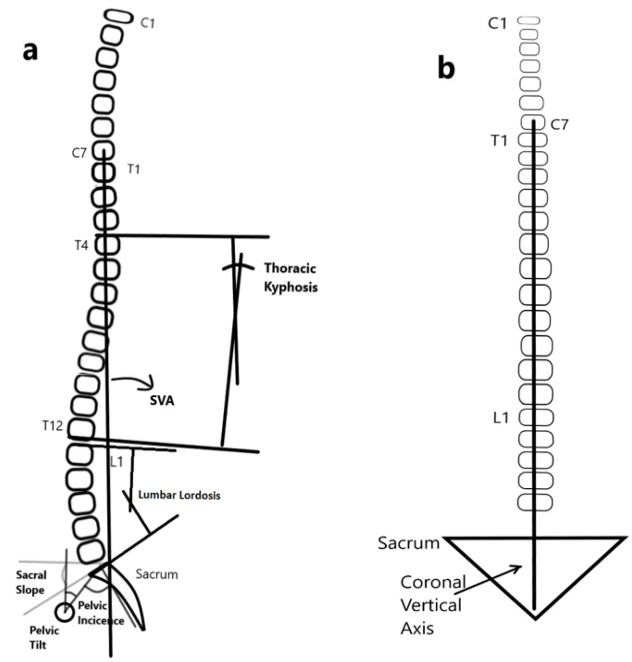

Figure 1. Schematical drawings of the anatomical landmarks that were used a reference for spinopelvic parameters. a) Sagittal plane. b) Coronal plane.

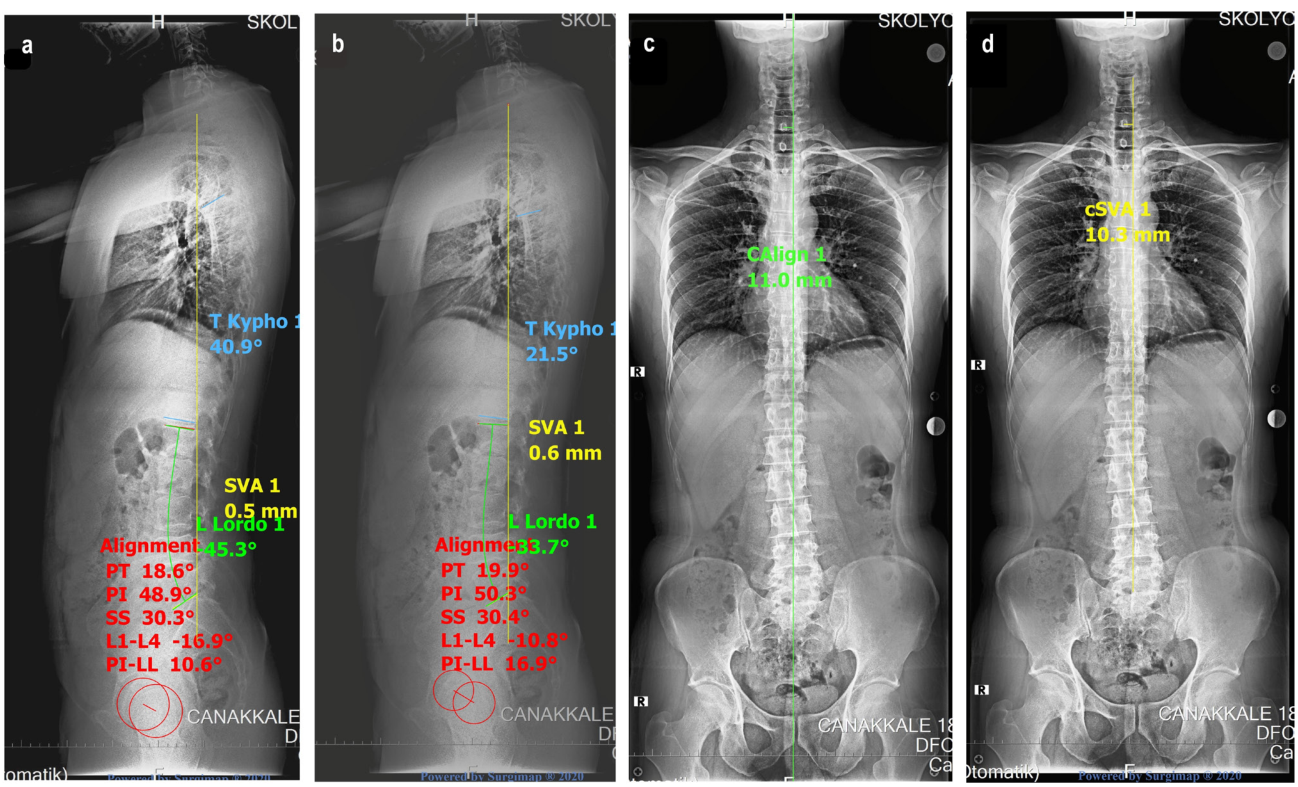

Figure 2. Spinopelvic parameters and measurement techniques. Standing scoliosis radiographs are on a) Pre-operative sagittal, b) Post-operative sagittal, c) Pre-operative coronal, d) Post-operative coronal plane.

SVA: Sagittal vertical axis, CVA: Coronal vertical axis, TK: Thoracic kyphosis, PT: Pelvic tilt, SS: Sacral slope, LL: Lumbar lordosis, PI: Pelvic incidence parameters was performed as described in Surgimap user guide[18]. Those whose radiographs were not adequate for measurements, who had de-novo or congenital scoliosis, lower extremity asymmetry, congenital hip dislocation, pelvic imbalance, gait deformities, loss of function in peripheral nerves of the lower extremity, advanced lumbar spondylolisthesis, spinal tumour or infection in the lumbar area were omitted from the study. Measurement made on pre-and post-operative radiographs were interpreted by analyzing with comparison and correlation tests.

Statistical Analysis

Data acquired from patients were transferred to SPSS. First, lost data inspection was made. It was determined that there was no lost data. Pre-and post-operative "SVA, LL, TK, CVA, PT, PI and SS" data of 19 cases were tested for normal distribution through "Shapiro-Wilk test", and it was seen that the data did not have a normal distribution. Bivariate two-sided Spearman correlation coefficient test and Partial two-sided test were used to analyze the existence and direction of correlation. The correlation value (r) calculated between two variables was determined as 0.01-0.29=very weak, 0.20-0.39=weak, 0.40-0.59=moderate, 0.60-0.79=high and 0.80-1=very high correlation. For "r" value, (+) shows positive and (-) shows a negative correlation. Comparative statistical analysis was performed with the Wilcoxon paired two-sample test. The statistical significance threshold was determined as $p<0.05$.

RESULTS

Nineteen cases that were adequate for spinopelvic parameters were comprised of 11 females (%57.8) and 8 males (%42.1). In terms of age, it was seen that there were 5 cases between the ages of 20-40, 9 cases between 41-60, and 5 cases above the age of 61. The mean age was 49.5 for females and 50.1 for males. It was seen that the L4-5 level (n=10) was operated most frequently. Information about age, gender and disc level of the operated cases was given in Table 1.

Between pre-and post-operative means of all spinal parameters, there was a change towards a neutral balance in all groups with the exception of the SS group (Table 2). There was an average of 1.7 increase in SS angle. Despite this change being in the opposite direction of neutral balance, the change was found to be not statistically significant ($p>0.05$).

Comparative statistical tests were performed to determine whether the difference forming in spinopelvic parameters was related to LM operation. To determine the relation between parameters that could affect each other, bivariate correlation method was used. Moreover, relations between parameter clusters and other parameter were analyzed using Partial correlation method.

Table 1. Demographic spread of cases

	n=19	%
Age		
20-40	5	26.3
41-60	9	47.4
61-80	5	26.3
Gender		
Female	11	57.9
Male	8	42.1
Level		
L3-4	2	10.5
L4-5	10	52.6
L5-S1	7	36.8

Table 2. Pre-and post-operative spinopelvic parameter measurements

Variable		Mean	Minimum	Maximum	SD±
SVA (mm)	Pre-operative	-5.1	-115.9	56.6	41.6
	Post-operative	9.1	-60.1	109,3	34.6
CVA (mm)	Pre-operative	10.2	-25.9	54.3	16.8
	Post-operative	6.7	-14.0	44.3	15.0
LL (°)	Pre-operative	51.0	26.1	74.2	13.8
	Post-operative	52.5	29.1	70.2	12.9
TK (°)	Pre-operative	41.5	25.8	72.9	13.5
	Post-operative	40.8	0.5	63.8	17.3
PT (°)	Pre-operative	18.5	3.1	42.2	11.7
	Post-operative	19.8	4.0	39.9	11.4
PI (°)	Pre-operative	52.6	36.2	70.3	10.2
	Post-operative	55.6	35.8	72.8	11.7
SS (°)	Pre-operative	34.1	19.4	54.3	8.6
	Post-operative	35.8	23.9	49.8	7.2

Mean, minimum and maximum standard deviation values of the measured parameters (n=19).
SVA: Sagittal vertical axis, CVA: Coronal vertical axis, TK: Thoracic kyphosis LL: Lumbar lordosis, PT: Pelvic tilt, PI: Pelvic incidence, SS: Sacral slope

It was seen that there was a strong positive relation between pre-operative (-5.12±41.59 mm) and post-operative (9.08±34.61 mm) SVA measurements (r=0.63, p<0.01). CVA measurements, which were 10.22±16.17 mm before the operation, became 6.71±15.03 mm afterwards, and there was no statistically significant relation between two values (r=0.32, p>0.05). There is a moderately strong positive relation between post-LM LL angles and previous angles, which was statistically significant (r=0.53, p<0.05). There was a statistically significant, strong positive relation between TK angles (r=0.64, p<0.05). There was a strong, positive correlation between PT angles (r=0.74, p<0.001). The correlation between PI angles was very strong and positive in a statistically significant way (r=0.83, p<0.001). Correlation between changes in SS angles was positive, moderately strong and statistically significant. In relation analysis of spinopelvic parameter measurements, there was a statistically significant, positive change on all planes except CVA (Table 2, 3). All these statistically significant, positive changes show the correctional and protective effect of spinopelvic parameters on global balance, following LM operation.

The PI correlation was determined as the control reference value. A partial correlation test was applied to post-operative values. When the resulting SVA, CVA, TK, PT, SS and LL values were compared with Bivariate test results, the difference was found to be not significant. Similar results were also acquired when LL correlation was determined as a control reference value (Table 4). LL&PI and LL correlations were determined as control reference parameters. The partial test was applied to pre-and post-operative values. When the way and r values of SVA, PT and SS correlations were compared with Bivariate and partial correlation test results, the difference was found to be not significant (Table 5).

There was no statistically significant difference between "r" values acquired from direct and indirect correlation tests. It was seen that the post-LM measurements were closer to optimal values. These results showed in a statistically significant way that LM operation was effective in bringing spinopelvic parameters closer to the optimum values.

DISCUSSION

The idea that spinal posture should be mathematically and statistically analyzed was first hypothesized by Beck and Killus in 1973[19]. Later in 1989, Duval-Beaupere described the economy cone concept, where minimal energy is spent while standing[20]. The same author has defined global balance as the position of center of gravity in relation to coccygeal femoral joints[21]. Nowadays, despite surgeons continuing to analyze and use the biomechanical effects of global balance and spinal parameters in surgical planning, a consensus can still not be reached on this subject. Global balance concept was refined by further evaluating all these parameters simultaneously, and the importance of these parameters has increased further due to degenerative scoliosis surgery becoming widespread[8,13]. Since

Table 3. Correlation in spinopelvic parameters between pre- and post-LM measurements

(n=19)	SVA (mm)	CVA (mm)	LL (°)	TK (°)	PT (°)	PI (°)	SS (°)
r	0.63	0.32	0.53	0.64	0.74	0.83	0.57
p	<0.01	>0.05	<0.05	<0.05	<0.001	<0.001	0.05

Bivariate correlation test analysis of parameter measurements, (n=19).
SVA: Sagittal vertical axis, CVA: Coronal vertical axis, TK: Thoracic kyphosis, LL: Lumbar lordosis, PT: Pelvic tilt, PI: Pelvic incidence, SS: Sacral slope

Table 4. Relation between values when compared with post-operative ones

SVA (mm)		Post-operative					
		CVA (mm)	TK (°)	PT (°)	SS (°)	LL (°)	
Pre-operative and post-operative	PI&PI	0.58*	0.08	0.61**	0.67**	0.67**	0.7**
	LL&LL	0.69**	0.12	0.53*	0.71**	0.52*	

"r" values of parameter measurements from two-sided Partial correlation test analysis. n=19, *p<0.05, **p<0.01.
SVA: Sagittal vertical axis, CVA: Coronal vertical axis, TK: Thoracic kyphosis, PT: Pelvic tilt, SS: Sacral slope, LL: Lumbar lordosis, PI: Pelvic incidence

Table 5. Relation between correlation of pre-and post-operative measurement groups and different measurement groups

Pre-operative and post-operative# (n=19)	SVA	SS	PT
PT&SS	0.71**	-	-
LL&PI	0.71**	0.56*	0.56*
LL	0.70**	0.51*	0.71**
PT	-	0.64**	-

In this table, correlations between several spinopelvic parameters are shown. (#r=Spearman Multiplication of Moments Correlation Coefficent) *p<0.05, **p<0.01 values were accepted to be statistically significant.
SVA: Sagittal vertical axis, PT: Pelvic tilt, SS: Sacral slope, LL: Lumbar lordosis, PI: Pelvic incidence

asymmetrical disc degeneration is responsible for scoliosis, it is expected for spinopelvic parameters to be affected in patients undergoing LM operation[5]. In literature, there are too few studies in which changes in spinopelvic parameters following LM are analyzed. To discover new information regarding this subject, in our study, we have analyzed SVA and CVA distance, LL, TK, PI, SS and PT angles, which are claimed to change following LM.

SVA, which shows sagittal balance, passes through the posterosuperior corner of S1 when in a neutral position. A positive value is assigned when it passes through the front of this point, and a negative value is assigned when it passes through the back of this point. SVA distance, which is a valuable determinant of balance even by itself, was seen to change towards neutral axis following LM operation, compared to its pre-operative state. It is expected for this change to lighten degenerative loads on the disc and to slow down the degenerative process. It is considered a neutral global balance when CVA passes through posterosuperior of S1 vertebrae.

CVA is assigned a positive value when it passes through the right side of the patient and a negative value when it passes through the left side (Figure 1b). When a spinal pathology is on multiple levels and is advanced, coronal balance becomes disrupted. We have reached the conclusion that the effect of LM on CVA was not statistically significant in our series. However, the difference between post-(6.7±15) and pre-LM (10.2±16.2) CVA values we obtained was slightly in favour of global balance (Table 3).

All loads that are transferred through the spine are transmitted to lower extremities by the pelvis, and the direction of these force vectors change according to pelvic parameters. PI, which is one of these parameters, was shown to not change for the entire life of a person after bone growth was completed, unless the pelvic structure was disrupted by a pathology[9]. In a study made by no relation was found between the severity of disc degeneration and PI values in both surgical intervention group and conservative treatment groups[22]. Moreover, they also reached the conclusion that there was no statistically significant difference between PI values of patients that underwent LM or instrumented spinal fusion surgery.

It is known that PI=PT+SS (Figure 1)[9]. Since it is not possible for the PI angle to change under normal circumstances, it should be considered that the change might be resulting from the researcher who made the measurements or measurements on non-standard radiographs. In our measurements, the mean 3-degree difference seen in PI angles was thought to be a result of the aforementioned phenomena (Table 2). The strong relation we saw between pre-and post-LM PI angles when they were statistically compared showed that there was no statistically significant difference. On top of this, the strongly positive result from the comparison of pre-and post-operative PT&SS and LL&PI relation coefficients with SVA relation coefficients showed that LM operation did not cause a statistically significant change on these angles. SS and PT measurements, which are part of the pelvic parameters, were seen to have stayed the same. When correlations of different measurement groups were analyzed, it was clear that the relation between PI and other angles were not disrupted. Moreover, the post-LM change in PT and SS angles was seen to be in favour of global balance. However, in another study, it was determined that pathologies, which caused a decreased lumbar disc distance, changed LL and as an extension, SS and PT[23]. It is known that the flattening in LL is related to LDH, and this decrease in lordosis is known to increase disc degeneration, and trigger compensation mechanisms such as increased thoracic kyphosis[24]. Between pre-and post-operative LL and TK angles of patients who underwent single-level LM, a moderately strong, positive correlation was found (Table 3). Despite a minimal change in angles following discectomy, this difference was found to be not statistically significant after comparative statistical tests ($p>0.05$). To sum up, all changes in spinopelvic parameters were seen to be in favour of global balance following LM.

Study Limitations

Further studies made on large series which also include sixth month and first-year parameters, not just early post-operative period, are needed to further clarify the relation between spinopelvic parameters and LM. Additionally, studies that include a control group comprised of patients who needed LM operation but were unable to be operated would also be helpful.

CONCLUSION

One of the pathological elements that play a role in degenerative spinal process is LDH, and LM is commonly used as a treatment option. In our study, we aimed to determine whether the spinopelvic parameters changed with LM treatment in LDH cases which required surgical treatment. The data we collected showed that there was a positive correlation between pre-operative and post-operative first-month measurement. These results show that spinopelvic parameters are protected, or even improved towards global balance following LM. Moreover, it supports the hypothesis that LM alleviates and slows down the deterioration in spinopelvic parameters related to disc degeneration.

Ethics

Ethics Committee Approval: Ethical board approval was received with the (11.11.2020/2020-13) decision of Çanakkale Onsekiz Mart University, Faculty of Medicine, Ethical Board of Clinical Studies.

Informed Consent: Permission to use medical records for clinical studies were present on the routine patient consent forms received before the operation.

Peer-review: Internally peer-reviewed.

Authorship Contributions

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

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

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CASE REPORT
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FUNCTIONAL RECOVERY AFTER WHARTON'S JELLY–DERIVED MESENCHYMAL STEM CELL ADMINISTRATION IN A PATIENT WITH TRAUMATIC SPINAL CORD INJURY: A PILOT STUDY

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ABSTRACT

The use of stem cells in the treatment of traumatic spinal cord injury (SCI) in recent years has provided promising results. Different sources of cells for transplantation have been used, including mesenchymal stem cells [MSCs; e.g., Wharton's jelly-derived (MSCs WJ-MSCs)]. Here, we reported on a 29-year-old man who was treated with WJ-MSCs in the course of therapy for blunt, traumatic SCI due to a work accident. He was operated on within 6 hours of the injury. Three and a half months later, he underwent intrathecal, intramuscular, and intravenous administrations of WJ-MSCs at a target dose of 1x106/kg for each application route (twice a month for 2 months). All the procedures were tolerated well by the patient. In parallel to this, we have not seen any application-related complications so far. After stem cell infusions, progressive improvements were shown in the patient's neurological examination and neurophysiological and neuroradiological findings.

Keywords: Stem cell, transplantation, traumatic spinal cord injury, Wharton's jelly

INTRODUCTION

Spinal cord injury (SCI) is a serious, debilitating condition affecting mostly young individuals. There have been many advances in the early surgical management and rehabilitation of these patients, resulting in improved survival but a lesser degree of functional improvement and independence[1]. The exact pathomechanism of SCI in humans remains blurry because most data about SCI have been acquired from animal models. An extensive interplay between various cells and molecules of the central nervous system (CNS), such as adhesion molecules, immune cells, and scar-forming cells, seems to be involved. It has been suggested that the extents of the astrocytic response and demyelination process are different between the pathomechanisms in humans and animal models; however, the fundamental events are similar[2]. SCI is a bi-phasic assault. In the first phase of SCI, mechanical damage to the spinal cord results in the rupture of neuronal membranes and axonal damage[3]. Decreased blood flow causes hypoxia and diffuse swelling of the cord[4]. The secondary phase causes prolonged and widespread tissue damage resulting from interlinked events like excitotoxicity, ionic imbalance, oxidative stress, and immune and inflammatory responses[5,6]. But setting off of a multitude of vascular, biochemical, cellular, and molecular events exaggerates the inflammatory response and aggravates the lesion[7]. The current treatment for traumatic SCI is surgical decompression of the spinal cord and medical treatment, such as methylprednisolone steroid therapy[8]. Recent advances in neuroscience and regenerative

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treatments, along with an intense focus on cell-based therapy, have yielded promising results. Karaoz et al.[9] suggested that transplantation of rat pancreatic islet-derived stem cell (rPI-MSCs) in the contused spinal cord improved locomotor recovery. Reduction of inflammation factors after rPI-SCs transplantation might be effective for functional outcomes following traumatic injuries to the spinal cord[9].

CASE PRESENTATION

The presented pilot study was a prospective, longitudinal medical experiment. The study was performed at the University of Health Sciences Turkey, Gaziosmanpaşa Training and Research Hospital, İstanbul, Turkey. The MSC trial was approved by the Turkish Ministry of Health (protocol number: 56733164-203-E.2569). The patient was informed of the procedure, and a written informed consent form was obtained per the Helsinki Declaration. The general data collected before the experimental therapy consisted of age, gender, cause of the SCI, length of time since the SCI, previous medical treatment for the SCI, and past medical history.

Medical History

The patient was a 29-year-old male who had fallen from a power pole and was admitted to a private hospital's emergency room in a paraplegic condition. He had been diagnosed with a T5-6 fracture dislocation and blunt, traumatic SCI, which can be stated as a mid-thoracic (T6) American Spinal Injury Association (ASIA) Impairement scale grade-A SCI. He had no motor or sensory function below T6 or in his sacral area. He had undergone operation within 6 hours after the injury and had a T5-7 total laminectomy and T3-11 posterolateral fusion (Figure 1). Postoperatively, his neurological status had not changed. One week after the operation, he reported a crude touch sensation between the T6 and T8 levels, but he was unable to discriminate the examining needle in his detailed neurological examination. No motor recovery or sacral sensory changes were noted. He had been admitted to physical therapy for 3 months, which increased the patient's level of participation in therapy without any improvement in the neurological function (Figure 2A, B; Table 1 and 2). At this stage, the patient was referred to our tertiary level hospital for the MSC trial.

Enrollment Criteria

The pilot study included the patient with SCI, with contusions (preserved anatomical integrity of the spinal cord) confirmed by imaging studies [magnetic resonance imaging (MRI), etc.] and neurological examination and neurophysiological findings. Focal CNS lesions (e.g., neoplastic lesions) or chronic diseases (e.g., systemic diseases) that would require long-term pharmacotherapy would be exclusion criteria. Prior to the treatment, the patient was examined by the doctors in the neurosurgery and physical therapy and rehabilitation departments. The Wharton's jelly mesenchymal stem cells (WJ-MSC) implantation procedure was performed when the patient was stable, without contraindications for sedo-/general anesthesia from the viewpoint of internal medicine and without any serious infectious diseases, including sepsis, immediately prior to the procedure.

PROCEDURE

Umbilical cords were obtained from the Good Manufacturing Practice facility of LivMedCell (İstanbul, Turkey). All the umbilical cords were obtained from various donors after informed consent, as approved by an institutional regulatory board (LivMedCell). Postnatal umbilical cords were obtained from donors of full-term pregnancies. Recently, we represented the umbilical cord processing and quality control, characterization of WJ-MSCs by flow cytometry, cell differentiation and karyotyping, pre-transplantation process, and surgical procedure and WJ-MSC transplantation procedure in our previous publications (Table 3)[10,11].

Clinical Evaluation and Statistical Analysis Pretreatment Neurological Examination

The pretreatment assessment included extensive evaluation by a team of medical and rehabilitation experts (Suppl. Video 1). Detailed neurological and functional evaluation was documented in each step of the procedure (e.g., ASIA). Spasticity

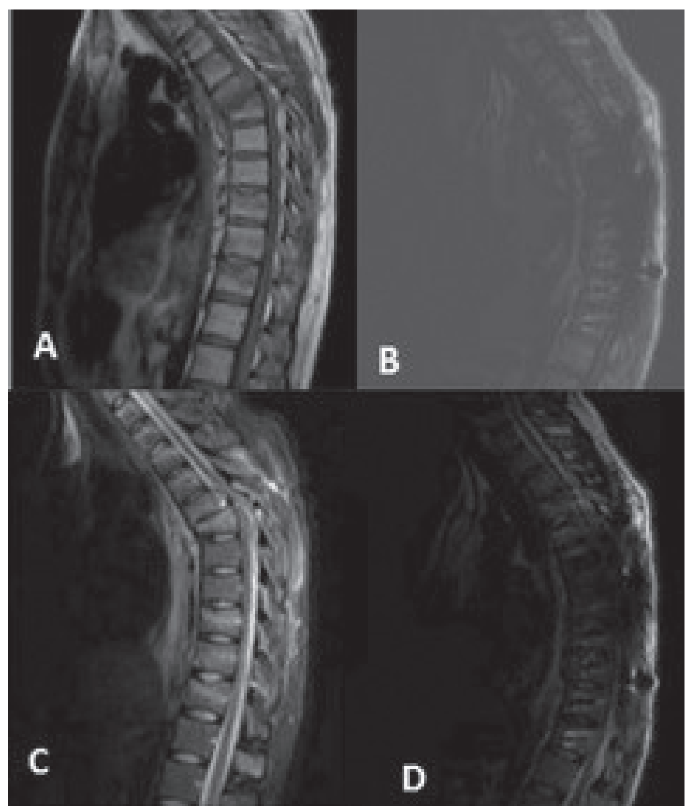

Figure 1. Spinal cord MRI including T1 sequences; (A) postop early, (B) 6 months a.f.i, spinal cord MRI including T2 sequences; (C) post-op early and (D) 6 months a.f.i. showed bilateral myelomalacia

MRI: Magnetic resonance imaging

was assessed using the Modified Ashworth scale, and quality of life was assessed based on parental evaluation according to the Functional Independence Measure (FIM) scale[12].

Safety Evaluation Criteria

The safety criteria for the transplantation procedure included the appearance of infection, fever, headache, pain, an increased level of C-reactive protein, increased leukocytosis, allergic reaction/shock, and perioperative complications (anesthesia-and analgesia-related complications, infections of the wound) for 7-14 days after the procedure. The safety criteria for using WJ-MSC included infection, neuropathic pain, cancer development, and deterioration of the neurological state, and they were assessed for a 1-year follow-up period.

Follow-up Assessment of Treatment Success

The follow-up evaluation consisted of a neurological examination evaluating motor function according to the Medical Research Council (MRC) Muscle Strength scale. The progression of the patient's sense was evaluated by detailed sensory examination. Clinical signs of efficacy were observed at 1 week, 1, 2, 3, and 9 months following the injection in both motor and sensory scores based on International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI)[13]. Spasticity was assessed using the Modified Ashworth scale, and quality of life was assessed based on the functional recovery estimated by the FIM scale[14]. In addition, an evaluation of the development of neuropathic pain, secondary infections, urinary tract infections, or pressure ulcers of the skin was performed.

RESULTS

Safety and Adverse Events

The patient tolerated the procedure well and did not experience any severe adverse events related to the injection. Our patient showed only early, transient complications, such as subfebrile fever, mild headache, and muscle pain due to intramuscular (i.m.) injection, which resolved in 24 hours (Table 4). Throughout the 1 year follow-up, no other safety issues or adverse events were reported.

Table 1. Sensory examination

Dermatomes (0: absent, 1: altered, 2: normal)		Time of SCI (06.06.2017)		Post-op. 1st week (13.06.2017)		At discharge (07.09.2017)		After 1st MSC administration (27.09.2017)		After 2nd MSC administration (11.10.2017)		After 3rd MSC administration (25.10.2017)		After 4th MSC administration (29.11.2017)		After 6 months from the final application (08.06.2018)	
		Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
T5	5th Intercostal space	2+C4:R10	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
T6	6th Intercostal space	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
T7	7th Intercostal space	0	0	1	1	2	2	2	2	2	2	2	2	2	2	2	2
T8	8th Intercostal space	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2
T9	Between 8th intercostal space and umbilicus	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2
T10	Umbilicus	0	0	0	0	0	0	1	1	2	2	2	2	2	2	2	2
T11	Between umbilicus and inguinal ligament	0	0	0	0	0	0	0	0	1	1	2	2	2	2	2	2
T12	Inguinal ligament	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2
L1	Anterosuperior of thigh	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2
L2	Anteromedial of thigh	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2
L3	Medial condyl of femur	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	2
L4	Medial malleolus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
L5	Dorsal foot at 3rd metatarsophalangeal joint	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

SCI: Spinal cord injury, MSC: Mesenchymal stem cell

Table 2. Motor and sensory scores according to International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI)

	Time of SCI (06.06.2017)	Post-op. 1st week (13.06.2017)	At discharge (07.09.2017)	After 1st MSC administration (27.09.2017)	After 2nd MSC administration (11.10.2017)	After 3rd MSC administration (25.10.2017)	After 4th MSC administration (29.11.2017)	After 6 months from the final application (08.06.2018)
Lower right extremity motor score	0	2	3	8	9	14	16	20
Lower left extremity motor score	0	2	3	7	8	12	14	17
Total lower extremity motor score	**0**	**4**	**6**	**15**	**17**	**26**	**30**	**37**
Right pinprick sensory score	24	27	28	35	36	42	43	45
Left pinprick sensory score	24	27	28	35	36	42	43	45
Total pinprick sensory score	**48**	**54**	**56**	**70**	**72**	**84**	**86**	**90**
Right light touch sensory score	25	28	29	33	35	43	44	47
Left light touch sensory score	25	28	29	33	35	43	44	47
Total light touch sensory score	**50**	**56**	**58**	**66**	**70**	**86**	**88**	**94**

SCI: Spinal cord injury, MSC: Mesenchymal stem cell

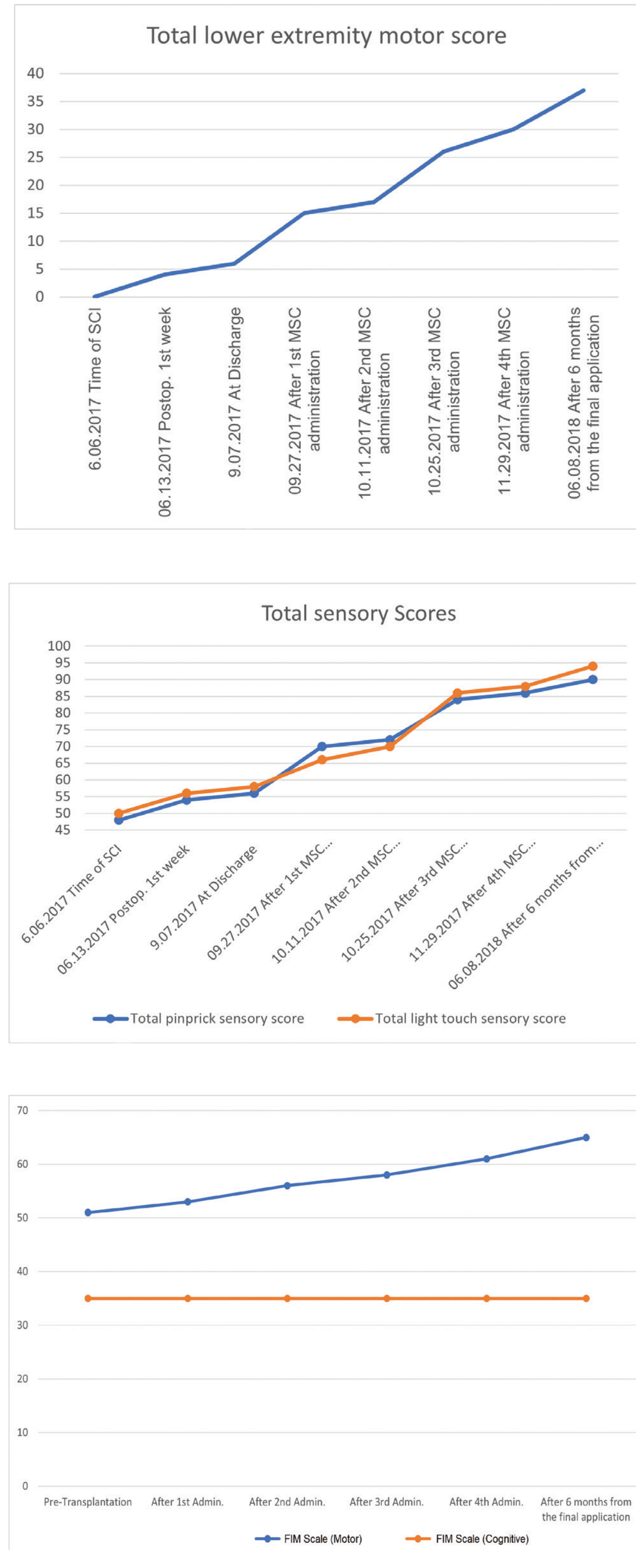

Figure 2. A, The total lower extremity motor score at all time points. B, Total pinprick and light touch sensory score at all time points. C, FIM scale scores at all time points.

FIM: Functional independence measurement, ISNCSCI: International Standards for Neurological Classification of Spinal Cord Injury

ASIA Motor Score

The total lower extremity motor score progressively improved from 6 at baseline to 37 at 9 months, with more marked improvement on the right (3 at baseline to 20 at 9 months) with the left side (3 at baseline to 17 at 18 months) (Figure 2A; Table 2).

ASIA Sensory Score

The total pinprick score improved consistently at each time point from 56 at baseline to 90 at 9 months of follow-up. The improvement was similar on both sides, improving from 28 at to 45 at 9 months of follow-up. Similarly, total light touch score also improved on both sides 58 at baseline to 94 at 9 months of follow-up (Figure 2B; Table 2). We also examined the improvement in each dermatomal region. In the lower thoracic level, the improvement was substantially pronounced in the T10 region bilaterally after the first WJ-MSC application and so on. In the lower extremity, the patient experienced improvement in L4, L5 (Table 1).

Table 3. Administration schedule

Date Route WJ-MSC
Round 1
09.20.2017 IT 1x10$_6$/kg in 3 mL
09.20.2017 IV 1x10$_6$/kg in 30 mL
09.20.2017 IM 1x10$_6$/kg in 20 mL
Round 2
10.11.2017 IT 1x10$_6$/kg in 3 mL
10.11.2017 IV 1x10$_6$/kg in 30 mL
10.11.2017 IM 1x10$_6$/kg in 20 mL
Round 3
10.18.2017 IT 1x10$_6$/kg in 3 mL
10.18.2017 IV 1x10$_6$/kg in 30 mL
10.18.2017 IM 1x10$_6$/kg in 20 mL
Round 4
11.22.2017 IT 1x10$_6$/kg in 3 mL
11.22.2017 IV 1x10$_6$/kg in 30 mL
11.22.2017 IM 1x10$_6$/kg in 20 mL

IT: Intratekal, IV: Intravenous, IM: Intramuscular, WJ-MSC:Wharton's jelly-derived mesenchymal stem cell

Table 4. Early and late complications of the proces

Complications	09.20.2017	10.04.2017	10.18.2017	11.22.2017
Early				
Infection	-	-	-	-
Fever	+	+	-	+
Pain	+	-	+	-
Headache	+	+	-	-
Increased level of C-reactive protein	-	-	-	-
Leukocytosis	-	-	-	-
Allergic reaction or shock	-	-	-	-
Perioperative complications	-	-	-	-
Late				
Secondary infections	-	-	-	-
Urinary trackt infections	-	-	-	-
Deterioration of neurologiacal status	-	-	-	-
Carcinogenesis	-	-	-	-

-: Not present, +: Present

Table 5. Quailty-of-life improvement and spasticity evaluated with the use ot the FIM scale, modified ashworth grading and MRC muscle strength scale

Evalualuation periods (Pre and post-transplantation)	FIM scale		Modified ashworth scale						MRC muscle strength scale					
			Hips		Knees		Ankles		Hips		Knees		Ankles	
	Motor	Cognitive	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Pre-transplantation	51	35	2	2	2	2	2	2	0	0	0	0	0	0
After 1st admin.	53	35	2	2	2	2	2	2	0	0	0	0	0	0
After 2nd admin.	56	35	2	2	2	2	2	2	1	1	0	0	0	0
After 3rd admin.	58	35	1+	1+	1+	1+	1+	1+	2	2	1	1	0	0
After 4th admin.	61	35	1+	1+	1+	1+	1+	1+	2	2	1	1	0	0
After 6 months from the final application	65	35	1	1	1	1	1	1	2	2	2	2	1	1

Admin: Administration, FIM: Functional independence measurement, MRC: Medical research council

Table 6. Quality of life improvement evaluated with the use of the FIM scale

Measurement	Pre-transplantation	After 1st administration	After 2nd administration	After 3rd administration	After 4th administration	After 6 months from the final application
Self care						
Eating	7	7	7	7	7	7
Grooming	7	7	7	7	7	7
Bathing	6	6	7	7	7	7
Dressing-upper body	6	6	7	7	7	7
Dressing-lower body	6	6	6	6	7	7
Toileting						
Sphincter control						
Bladder management	1	1	1	1	1	1
Bowel management	1	1	1	1	3	4
Transfer						
Bed, chair, wheelchair	5	5	5	5	5	7
Toilet	5	5	6	6	6	7
Tub, shower	5	5	5	6	6	6
Locomotion						
Walk/wheelchair	1	2	2	3	3	4
Starrs	1	1	1	1	1	1
Motor subtotal score	**51**	**52**	**56**	**58**	**61**	**65**
Communication						
Comprehension	7	7	7	7	7	7
Expressionr	7	7	7	7	7	7
Social cognition						
Social interaction	7	7	7	7	7	7
Problem solving	7	7	7	7	7	7
Memory	7	7	7	7	7	7
Cognitive subtotal score	**35**	**35**	**35**	**35**	**35**	**35**
Total FIM score	**86**	**88**	**91**	**93**	**96**	**100**

FIM: Functional independence measurement, FIM scale in detail; 7 Points: Complete independence, 6 Points: Modified independence, 5 Points: Supervision, 4 points: Minimal assistance, 3 Points: Moderate assistance, 2 Points: Maximal assistance and 1 Point: Total Assistance or not testable. Total motor score: 91 points, total cognitive score: 35, and total FIM score is 126

FIM Scale Score

Substantial improvement in quality of life was observed, as assessed using the FIM scale 6 main questionnaire including motor and cognitive scores. The total FIM Scale score improved from 86/126 at baseline to 100/126 at 9 months. The total motor score improved consistently at each time point from 51 at baseline to 65 at 9 months of follow-up. The total cognitive score was 35 and remained stable at 9 months of follow-up (Figure 2C; Table 5, 6).

Modified Ashworth and MRC Muscle Strength Scale

The Modified Ashworth Scale score was similar on both sides, improving from 2 at baseline to 1 at 9 months of follow-up. Similarly, MRC Muscle Strength scale score also improved on both sides from 0 at baseline to 2 in his knees and hips at 9

Table 7. Summary of the neuroradiological and neurophysilogical findings using MRI and EMG before and after treatment

	Date	MRI appearance of cord
MRI	Pre-t.p.	Ischemia (T2 hyperintensity)
	Post-t.p.	Bilateral myelomalacia
	Date	**EMG findings**
EMG	Pre-t.p.	Upper motor neuron involvement
	Post-t.p.	Not present

MRI: Magnetic resonance imaging, EMG: Electomyography, t.p.: transplantation months of follow-up. On the other hand, MRC Muscle Strength scale score improved on both sides from 0 at baseline to 1 in his ankles at 9 months of follow-up (Table 5).

Neuroradiological and Neurophysilogical Findings

In the early postoperative spinal cord MRI, there was ischemia (T2 hyperintensity) in the injured thoracic spinal cord (T6). On repeating spinal cord MRI at 3 months after the first intervention (a.f.i.), there was bilateral myelomalacia in the injured thoracic spinal cord (T6). In the electromyographic (EMG) a.i.f readings showed normal motor and sensory transmission without firing of motor unit potentials, revealing an upper motor neuron lesion in accordance with the original spinal cord lesion at T6. Post-transplantation EMG wasn't presented due to clinical improvement of the patient (Data not shown) (Figure 1; Table 7).

Physical Therapy

We also observed considerable improvement in physical therapy at follow-up. Starting from the first transplantation, the patient underwent intensive neurorehabilitation that included physiotherapy as a part of the treatment program. The patient was placed on a personalized exercise program that emphasized techniques for facilitating mobility and the multiplication of the injected stem cells, thereby giving enhanced results. The personalized program comprised one session (50 min.) per day, 5 times a week, including posture, balance, range of motion and strength and stretch exercises. On the stem cell application days, the exercise program was interrupted. After 1 week following the initial administration of MSCs, the patient mentioned that he had gained some sensation back in previously numb areas (T6-10 dermatomes). Two weeks later, a 2nd administration of MSC resulted in improved sensation between the T6 and T11 dermatomes, just below the umbilicus. A 3rd MSC administration resulted in sensory extension down to the L2-3 dermatomes (Table 1; Suppl. Video 2). After the 4th MSC administration, the patient began to show marked improvements. His trunk balance and control improved; the patient could walk with bilateral push knee splints and elbow crutches (Suppl. Video 3). The patient has been followed up every 6 months thereafter to further assess his progress. He was walking with a walker and his motor functions improved in this time frame. According to the ASIA scale assessment, he had changed from ASIA A to ASIA C during a 1 year period (Suppl. Video 4).

DISCUSSION

SCI is a severe, debilitating injury, not just because of the loss of neurological function but also the psychological and social burdens the patients, families, and society as a whole have to face. Previously, it was thought that the CNS was unable to regenerate; however, several studies have suggested that alterations to the local environment of the injury site may aid the regeneration of nerve cells[15]. These alterations include transplantation of fetal spinal cord tissue, peripheral nerves, Schwann cells, and fibroblasts, as well as removal of nerve growth inhibitory factors[16-18].

Aras et al.[19] suggested that the transplantation of MSCs derived from different tissues improved the locomotor recovery following SCI, and the capacity of rat adipose tissue-derived (rAT)-MSCs to differentiate into the oligodendrocyte lineage improved the functional recovery. An important point of this study was the determination of the ideal transplantation time: The results revealed that the local conditions at the time of the transplantation were important for the cell behavior[19]. Moreover, Kabatas et al.[20] suggested that the MSCs can be isolated from the dental pulp and cultured and passaged *in vitro*. After transplantation of the passaged MSCs into rats with SCI, the isolated MSCs can survive in rat bodies without any immune rejection. The implanted MSCs can differentiate into nerve cells, and they are involved in the recovery of the damaged spinal cord. This improves the scores of motion behavior and promotes the recovery of motor function after SCI[20]. All these results provide a theoretical and experimental basis for MSC transplantation applied in the treatment of SCI. Previously, we reported on the safety and feasibility of both the triple route and multiple WJ-MSC implantations, using this treatment strategy in a patient with hypoxic-ischemic encephalopathy[10]. As the studies have been further improved and deepened, it is now possible to apply WJ-MSC transplantation to the clinical treatment of SCI. In this article, we present a patient with a blunt, traumatic SCI who was treated with WJ-MSC therapy. MSCs, also known as mesenchymal progenitor cells, are self-renewing, multipotent progenitor cells that can differentiate into different mesodermal tissues ranging from bone and cartilage to cardiac muscle[21]. They have been advocated as a promising novel treatment strategy for patients with SCI[22]. Previously, bone marrow (BM) was considered a good candidate as a source of MSCs. However, since BM aspiration is an invasive procedure and the proliferation and differentiation capacity of cells decreases with donor age, alternative sources of stem cells were pursued. Fetal-derived MSCs, which are more primitive and have less immune reactivity, have recently been suggested as better alternatives for BM-MSCs.

The primitive connective tissue of the umbilical cord between the umbilical vessels and amniotic membrane is known as "Wharton's jelly," and it protects fetal umbilical vessels from compression and torsion. During embryogenesis, hematopoietic and mesenchymal cells migrate through the WJ, and some of them become trapped, making this tissue a good source of MSCs[23-25]. Stem cell therapy (SCT) for SCI involves acquiring endogenous stem cells *in vivo*, harvesting or altering them *ex vivo* and transplanting them into the injured site, thereby promoting neuronal regeneration and the secretion of neurotrophic molecules[26]. Harvesting protocols and isolation methods may vary among different institutes. Animal studies using transplanted human umbilical MSC-derived neurospheres on transected SCI rat models have shown recovery of hindlimb motor function at 5 weeks compared with control groups without MSC therapy[27].

Various studies have demonstrated that MSCs display their therapeutic benefits via paracrine regulation with growth factors and cytokines[28]. In a previous study, we suggested that, after performing SCI, the injection of rPI-SCs is likely to prevent immune cell activation, and especially, to reduce the secretion of proinflammatory cytokines (e.g., interleukin-6) as possible direct markers of spinal cord inflammation. Inhibition of these inflammation factors positively affects the SCI healing process[9]. In addition, Németh et al.[29] demonstrated that anti-inflammatory mediators (e.g., IL-1ra) increased after MSC treatment. We also demonstrated that rPI-SC administration was found to be effective for increasing the intensity of IL-1ra in the injured area of the spinal cord, suggesting an anti-inflammatory role for these cells[9,29]. Our patient had four cycles of intrathecal (i.t.), intravenous (i.v.) and i.m. MSC injections at 2 week intervals starting 3 and a half months after SCI from a fall. With SCT and intensive neurorehabilitation, he showed moderate improvements in bowel control. His physical examination revealed gradual improvement in sensation down to 11 levels (9 levels a.f.i) below the level of his lesion, and his motor function improved in stages. On the other hand, treatment involving SCT combined with physiotherapy (as a supportive therapy) offers a tremendous opportunity for patients with neurological disorders, e.g., after SCI. The rehabilitation itself could prevent the process of muscle atrophy and joint stifness, but it cannot repair the damaged nerve function[30]. This improvement is thought to be related to the migration of MSCs to the injury site and promotion of neuroregenerative mechanisms there. On the other hand, it is important in such cases to distinguish gains attributable to therapy from spontaneous recovery following the injury[31]. In the current report, we have presented both subjective (physical therapy reports) and objective (ISNCSCI, FIM, Modified Ashworth and MRC Muscle Strength Scales' scores) measures to demonstrate that the patient, after reaching a plateau of spontaneous improvement at 3 and a half months postinjury, experienced improvement in neurological and functional status.

CONCLUSION

Therapeutic administration of stem cells has a theoretical role in the treatment of SCI, and this is supported by many preliminary clinical studies in the literature; no serious adverse effects of this therapy have been documented to date. Although promising results from many publications have been reported, there is still no consensus on which cellular therapy should be administered to which patient at what time after SCI. There seems to be a need for a tremendous amount of work to elucidate the underlying mechanisms of how MSCs interact with damaged host tissues and how this interaction results in a cascade of events that lead to some functional neuronal recovery. These findings suggest that quality of the cells, optimization of the cell dose, standardization of the cell processing, the timing, route of administration and patient selection as well as the role of clinical experience of the physcisian are critical to the success of SCT in SCI patients.

Ethics

Ethics Committee Approval: Ethical approval to report this case was obtained from the IRB of Turkish Ministry of Health, Department of Organ, Tissue Transplant and Dialysis Services' Scientific Committee (protocol number: 56733164-203-E.2569), Ankara, Turkey.

Informed Consent: The patient was informed of the procedure, and a written informed consent form was obtained per the Helsinki Declaration.

Peer-review: Internally peer-reviewed.

Authorship Contributions

Concept: S.K., E.K., Design: S.K., E.K., Data Collection or Processing: S.K., E.C., E.C.S., N.K., E.Ç., F.D., O.B., G.G., Analysis or Interpretation: S.K., E.C., E.C.S., N.K., E.Ç., F.D., O.B., G.G., Literature Search: S.K., E.C., E.K., Writing: S.K., E.C., E.C.S., N.K.

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Video 1.
https://www.doi.org/10.4274/jtss.galenos.2021.363.video1

Video 2.
https://www.doi.org/10.4274/jtss.galenos.2021.363.video2

Video 3.
https://www.doi.org/10.4274/jtss.galenos.2021.363.video3

Video 4.
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LUMBAR INTRAMEDULLARY DERMOID TUMOR IN AN ADULT: A CASE REPORT

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ABSTRACT

The intramedullary dermoid tumors are very rare tumors in adults. They are usually seen in pediatric age and usually with spinal dysraphism. Here, we present a surgical video apperances of a very rare case of lumbar intramedullary dermoid tumor in an adult.

Keywords: Adult, dermoid tumor, anesthesia

INTRODUCTION

The intramedullary dermoid tumors are very rare tumors in adults and counts 0.8-1.1% of all intraspinal tumors(1,2). Spinal cord dermoid tumors are common in pediatric age with or without spinal dysraphism. Dermoid tumors originate from totipotent ectodermal cells of congenital or acquired ectodermal inclusions(3). Generally, symptoms develop slowly as back pain, motor deficits in lower limbs, sphincter dysfunctions. It was also reported that cyst might rupture and acute symptoms such as meningitis or meningeal irritation may occur, and dissemination of tumor content to subdural space and ventricles may also cause hydrocephalus(4,5).

We present a very rare case of lumbar intramedullary dermoid tumor in an adult without spinal dysraphism.

CASE REPORT

Thirty-one-year old female patient referred to our clinic with back pain and left lower limb weakness. On examination, left foot weakness on dorsal flexion (1/5) and left L5 hypoesthesia were found. The patient had a childbirth history 2 months ago with epidural anesthesia. Symptoms appeared a few days after birth. Laboratory findings were normal. The lumbar magnetic resonance imaging (MRI) revealed a tumoral mass in medullary conus. T1 weighted images (Figure 1a) showed hypointense, T2 weighted images (Figure 1b) showed a hyperintense intramedullary mass at the level of L1-L2 above the filum terminale. The tumor showed no enhancement after contrast injection (Figure 1c). No additional pathology was observed on cervical, thoracic and cranial MRI.

Video section (2 min 39 sec, X2 time-lapse)

On operation, the spinal cord was markedly expended in conus area. Median myelotomy was performed after bipolar cauterization, and the pearly whitish-grey tumor was seen under the surgical microscope (11 sec). We first thought it was an epidermoid tumor, but we saw hair follicles during tumor excision (1 min 45 sec). Tumor was removed piecemeal, and local adhesions made tumor removal difficult especially in rostral and caudal ends, and also lateral tumor recesses (1 min 26 sec). After tumor removal, a semi lucent-thin pseudomembrane covering tumor bed was observed (1 min 24 sec). The pseudomembrane was firmly adherent to the neural tissue in tumor bed, and it was difficult to remove it. After dural closure (2 min 17 sec), bony closure was done by osteoplastic laminotomy using microplate and micro screws (Figure 2). Postop period was uneventful and left foot motor strength (3/5) was better (2 min 24 sec).

Neuromonitorization was done throughout the operation with EMG, somatosensory evoked potential and motor evoked potential, and no abnormal changes were detected. Control MRI showed no residual tumor in the second month (Figure 3a, 3b).

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DISCUSSION

Although there are comparative articles on the diagnosis and surgery of dermoid and epidermoid tumors(6,7), and reports on cases that spread by bursting into the central canal, syrinx cavity, subdural area and into the ventricle in the literature(4,5,8), no lumbar intramedullary tumor cases with clinical findings after epidural anesthesia have been reported in an adult.

Preliminary diagnosis in this case example was ependymoma considering the age of the patient, the absence of dermal sinus tract and other spinal dysraphisms, and according to MRI findings. Ependymomas may show different enhancement patterns according to their grades. As in our case, ependymomas, oligodendrogliomas and epidermoid tumors should be considered in the differential diagnosis as examples of non-enhancing tumors. If dermoid tumor is suspected such as a child with dysraphism with the non-enhancing tumor, diffusion MRI should be performed. Hyperintensity can be observed in the dermoid tumors in diffusion in MRI, which is important for preoperative diagnosis. In addition, hypointense areas can be seen in fat-saturated MRI(9). Thus, knowing the diagnosis before the operations may worn us against the chemical meningitis, and we may take more precautions during the operations.

Although spinal dermoid tumors usually develop from ectopic embryonic rest inclusions during embryonic development(10), they may rarely develop after interventional procedures such as lumbar puncture, spine surgery(11-13). In our case, the patient's history of epidural anesthesia was a few days. This may suggest that the dermoid tumor is associated with this procedure, but it is not possible for these slowly developing tumors in 2 months. Because the foot drop developed a few days after epidural anesthesia, the drug volume given for epidural anesthesia may have squeezed the lumbar nerve roots in the lower part of the tumor and therefore creates a clinical picture. The fact that there is a paraplegia case that develops after myelography(14) and that this complication is associated with the pressure gradient that develops after substance administration. The patient waited some weeks for resolution of foot drop. Then MRI revealed the tumor. Although epidural anesthesia may aggravate clinical symptoms on it was just a coincidence, we need urgent MRI when there is a neuro deficit after a procedure. The walls of the tumor consist of the epidermis within the lining of stratified squamous epithelium and cutaneous appendages (sebaceous glands with keratins, cholesterol crystals and hair follicles)(11). Thus, as logical thought, the membrane (or pseudomembrane) of tumor may cause recurrence when left behind, although it is not the wall of the tumor and there is no proof in the literature. The authors have attempted to remove it during the surgery, but it was so adherent to spinal cord neural tissue that they did not take a risk to injure the spinal cord. Tumor was totally removed except pseudomembrane, and the patient will be on close and long term follow-up.

CONCLUSION

In conclusion, the possibility of the dermoid tumor should be kept in mind in adult patients.

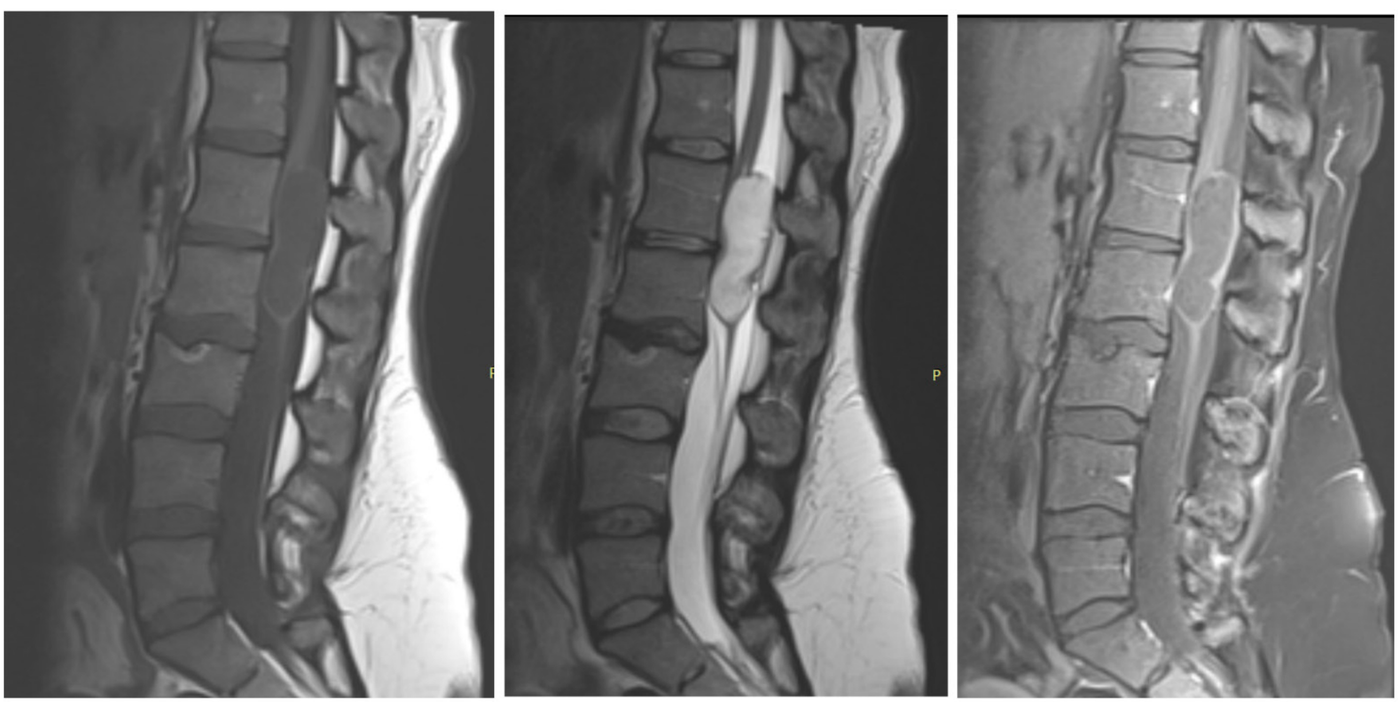

Figure 1. Preoperative T1 (a), T2 (b) and T1 contrast (c) weighted sagittal MRI shows spinal cord conus tumor with no enhancement at lumbar 1 and 2 level.

MRI: Magnetic resonance imaging

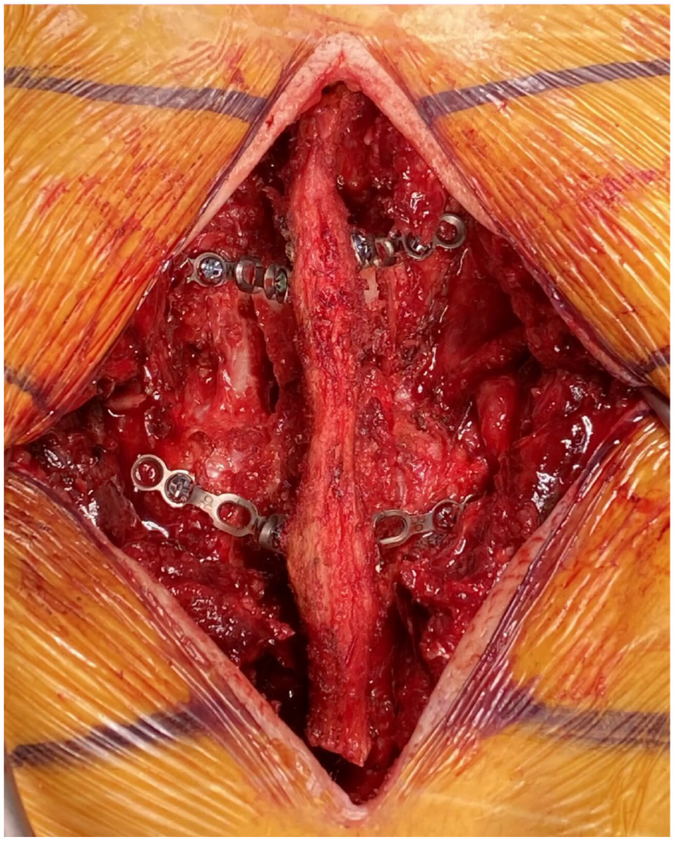

Figure 2. Bony closure with osteoplastic laminotomy using microplate and microscrews, perioperative view

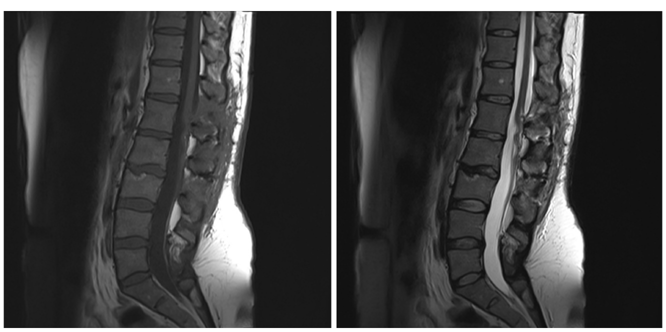

Figure 3. Postoperative T1 (a) weighted and T2 (b) sagittal MRI shows no residual tumor. Posterior vertebral elements are also seen intact

MRI: Magnetic resonance imaging

Ethics

Informed Consent: Informed consent was taken from patient and her husband.

Peer-review: Internally peer-reviewed.

Authorship Contributions

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

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

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Video 1.
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