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BIOMECHANICAL CHANGES IN CERVICAL SPINE SEQUENCING AFTER RIGID LUMBAR STABILIZATION

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ABSTRACT

Objective: Surgical stabilization of the thoraco-lumbar spine can induce biomechanical changes in other spinal regions, potentially influencing postoperative outcome. This study detected biomechanical changes in cervical spine sequencing and identify preoperative parameters associated with these changes following rigid stabilization surgery for degenerative lumbar spinal disease.

Materials and Methods: Twenty patients (10 males and 10 females, mean age 64.6 years) with lumbar degeneration receiving rigid stabilization (polyaxial screws and titanium rods) were included in the study. Preoperative and postoperative anterioposterior and sagittal scoliosis x-rays were retrospectively evaluated by an independent researcher using SurgimapR (Nemaris Inc., USA). Preoperative and postoperative cervical spine parameters were compared using Wilcoxon test. A $p<0.05$ was considered statistically significant for all tests.

Results: Among the 20 patients enrolled, 4 each were treated for degenerative disc disease, 5 had spinal stenosis, and 3 had spondylolisthesis, while 5 were treated for the previously operated spinal instability and 3 for spondylolysis. The highest instrumentation level was L1 and the lowest was L5. Radiological measurements were obtained by calibrating Surgimap for each patient using standard techniques. The T1 slope angle was significantly reduced post-surgery ($p<0.05$), and the magnitude of this reduction was enhanced by greater improvement in the lumbar long segment angle after rigid stabilization ($p<0.05$).

Conclusion: Rigid stabilization for degenerative lumbar spine disease can also affect sagittal balance and alter biomechanical loads in postoperative cervical spine sequencing.

Keywords: Rigid stabilization, sagittal balancing, cervical spine, SurgimapR

INTRODUCTION

Curvilinear alignment of the spine is essential for sagittal and coronal balance, and permits intricate movements with minimal energy consumption. Computer-aided measurements have revealed that optimal alignment maintains efficient spinopelvic sequencing by balancing the effects of pelvic and head compensator mechanisms[1,2].

In contrast, spinal deformity due to degenerative bone disease impairs sagittal balance, thereby disrupting motor activity, and may lead to chronic pain and disability[3-5]. Rigid stabilization of the thoraco-lumbar spine is frequently conducted to correct sagittal imbalance, but may also alter the biomechanical properties of other spine segments[6-8]. These reciprocal changes lead to reorganization of the axial load distribution for restoration of sagittal balance, causing the cervical-vertebral balance to approach the gravity line[9].

This study aimed to reveal the effects of rigid stabilization surgery for degenerative lumbar disease on cervical spine alignment and biomechanical parameters, and to evaluate whether these changes are influenced by preoperative sagittal spine alignment disorder. Second, we aimed to identify preoperative parameters that trigger these changes in cervical spine alignment after corrective surgery.

MATERIALS AND METHODS

Patient Population

Ethics committee approval was obtained from İstanbul Medipol University Non-Invasive Clinical Research Ethics Committee (approval no: E-10840098-772.02-5820, date: 11.11.2021). Informed consent was obtained from our patients for our study. Between January 2019 and April 2021, adult patients receiving rigid stabilization surgery (using polyaxial screws and titanium rods) for sequential lumbar spinal degenerative disease were recruited according to the following inclusion criteria: over 50 years of age, with spinal deformity of at least one segment, and receiving two-way scoliosis flat X-rays in the normal standing position both before and after surgery. Patients with neuromuscular disorders, ankylosing

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spondylitis, or spinal deformity due to tumors or infection were excluded. Clinical, surgical, and radiographic records were examined retrospectively (Table 1).

Radiological Measurements

Full-length antero-posterior and lateral scoliosis radiographs were acquired in the standard upright position with arms folded horizontally forward and per shoulder. Radiographic measurements were obtained by calibrating Surgimap (Nemaris Inc., USA) for each patient in accordance with standard techniques. Scoliosis X-rays were acquired 1-2 days before surgery and 2-3 days after surgery (when the patients were mobilized). The C2 occiput angle (Occ-C2) was measured from the line drawn between the line drawn along the C1 front belt and the lower margin of the C2 body and the occiput inferior tip. The C1-C2 angle (C1-2) was measured from the line between the front arcus of C1 and the rear arcus of C2 to the line along the lower margin of body C2. The C2-C7 angle (C2-7) was measured along the line along the rear body of C2 extending to the back body of C7. The T1 slope angle was measured between the upper endplate of T1 and the horizontal reference line. The C7 sagittal vertical angle (C7 CSB) and C2 sagittal vertical angle (C2 CSB) were defined as horizontal distances from the back end of the upper sacral endplate to the center of the C7 corpus and C2 corpus respectively (Figures 1, 2).

Table 1. Demographic information and diagnosis of patients

Patient no	Age	Sex	Level	Diagnosis
1	71	M	L4- L5	Spinal stenosis
2	70	M	L3- L4	Spondylolysis
3	65	M	L2- L5	Spinal instability (operated)
4	61	F	L4- L5	Degenerative disc disease
5	68	F	L4- L5	Spinal stenosis
6	52	M	L3- L4	Spondylolisthesis
7	68	F	L4- L5	Spinal stenosis
8	62	M	L3- L5	Spinal instability (operated)
9	73	F	L4- L5	Spinal stenosis
10	66	M	L3- L4	Degenerative disc disease
11	72	F	L2- L5	Spondylolysis
12	56	F	L4- L5	Spondylolisthesis
13	58	M	L4- L5	Spondylolisthesis
14	72	F	L3- L5	Spinal instability (operated)
15	56	M	L4- L5	Degenerative disc disease
16	69	F	L1- L5	Spinal instability (operated)
17	53	M	L2- L5	Spinal instability (operated)
18	72	F	L4- L5	Spinal stenosis
19	67	F	L3- L5	Spondylolysis
20	62	M	L4- L5	Degenerative disc disease

Study Design and Statistical Analysis

All data were analyzed using IBM SPSS Statistics 25. Datasets were first tested for normality using the Kolmogorov-Smirnov test, Shapiro-Wilk test, histogram observation, or coefficient of variation. Parameters were compared before and after surgery by the Wilcoxon signed-rank test. A $p<0.05$ was considered statistically significant for all tests.

RESULTS

The demographic characteristics and diagnoses of the 20 enrolled patients are summarized in Table 1. The study group included 10 males and 10 females of mean age 64.6 years, of which 4 were diagnosed with degenerative disc disease, 5 with spinal stenosis, 5 with previously operated spinal instability, 3 with spondylolisthesis, and 3 with spondylolysis. The highest stabilized spinal level was L1 and the lowest level was L5. There was a significant difference in T1 slope angle post-surgery compared to preoperative baseline ($p<0.05$) and the change appeared proportional to the improvement in global lumbar angle (Tables 2 and 3). Therefore, the relationship between the single-segment T1 slope angle and the angle of the long segment with rigid stabilization was examined. We speculated that a greater improvement in global lumbar angle within the long segment would result in a larger reduction in T1 slope angle. Indeed, a larger global lumbar angle after rigid stabilization was associated with a smaller postoperative T1 slope angle ($p<0.05$) (Table 3 and Figure 3).

DISCUSSION

Deterioration of one spinal segment may alter the biomechanical properties of other segments. In bipedal animals, lordotic and kyphotic slopes balance the spine load[10]. During daytime, the spine is usually maintained in the balanced sagittal position, so deterioration of the lower spine will naturally affect upper spine posture. Similarly, patients with pathologies of the pelvis, hip joints, or lower extremities may adopt an alternate spinal posture as a compensatory mechanism to maintain balance. If this adaptation is small (within normal physiological limits) and successfully helps maintain balance, gait, and movement, no symptoms are likely to develop. If the required compensation is extreme or unsuccessful, however, spinal balance may be disturbed[11,12]. For instance, substantial deterioration or deformity of the lumbar region will alter the positions of the thoracic spine, cervical spine, and head, while pathologies of the thoracic region usually affect the cervical spine and head, and cervical abnormalities will affect the position of the head.

Various lumbar, thoracic, and cervical spine parameters have been defined for diagnosis and treatment evaluation. Further, lumbar-thoracic parameters changes at lower levels. For instance, the sacral slope angle is replaced by the thoracic slope angle and pelvic tilt by the thoracic tilt angle. The thoracaal groan angle corresponds to the pelvic incision and is calculated as the sum of the thoracaal slope and neck tilt angle. These parameters are critical for evaluation of lumbar and thoracic pathologies and effects on the cervical spine[3,8].

Thoracic and cervical regions are greatly affected by lumbar degeneration and ensuing alterations in sagittal equilibrium[3,13]. A similar sagittal equilibrium disorder occurs after instrumentation surgery if lumbar lordosis is not protected[3]. In cases where the underlying movement is disrupted, the upward effect is clearly visible. However, the effects of lumbar stabilization on the cervical region has not been investigated until now. When posture is disrupted, the C0-C2 angle of the upper cervical region may be increased[14-16], but we found no significant differences between cases with and without postural disorder, suggesting that posture distortion alone is insufficient to affect this area.

We found no changes in other subaccesive parameters except lumbar rigid stabilization, such as in cervical slope angle, thoracic inlet angle, and cervical tilt angle, among individuals without sagittal equilibrium problems. Naturally, cervical tilt and thoracic moment angle are increased, while cervical slope angle is reduced in these cases, possibly to maintain horizontal gaze. This may have caused a biomechanical improvement in

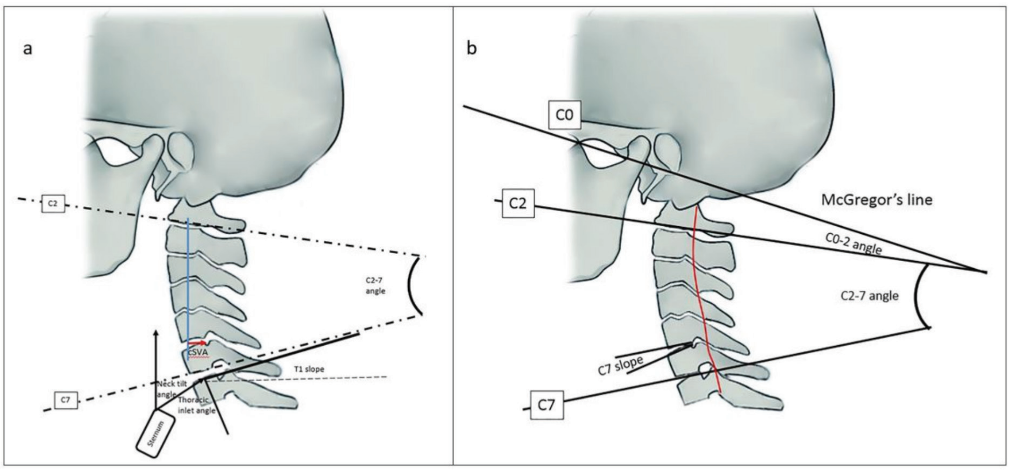

Figure 1. a) Thoracic kyphosis angle. C0-C2 angle and C7 slope angle are shown b) thoracic inlet angle, cervical tilt angle, cSVA and C2-7 angle measurements

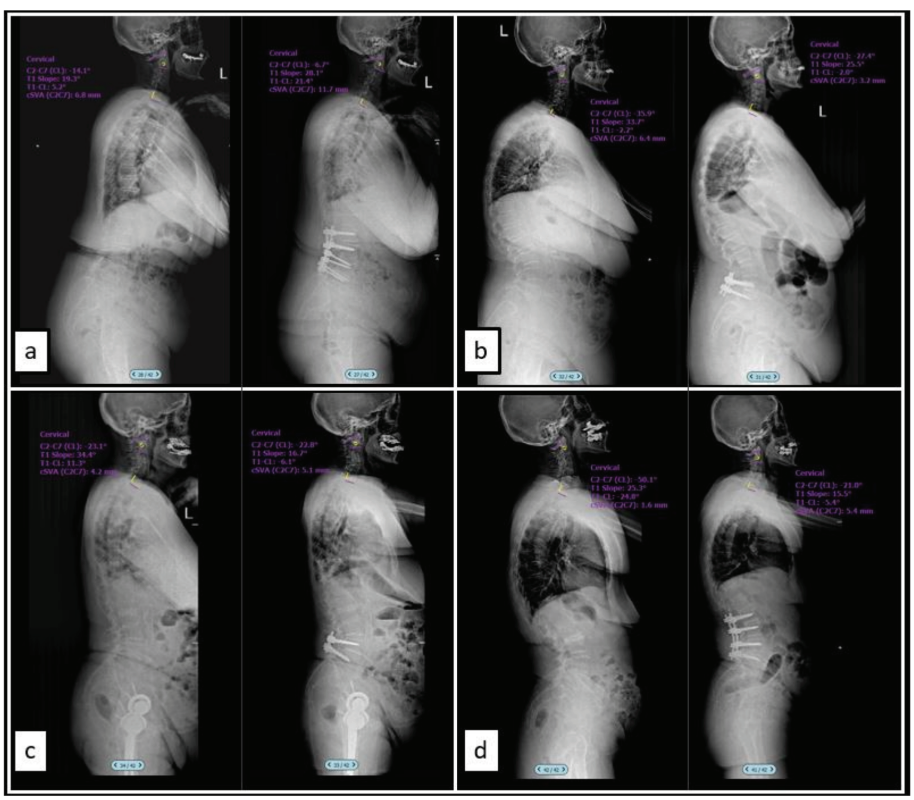

Figure 2 a-d. Preoperative and postoperative cervical biomechanical measurements

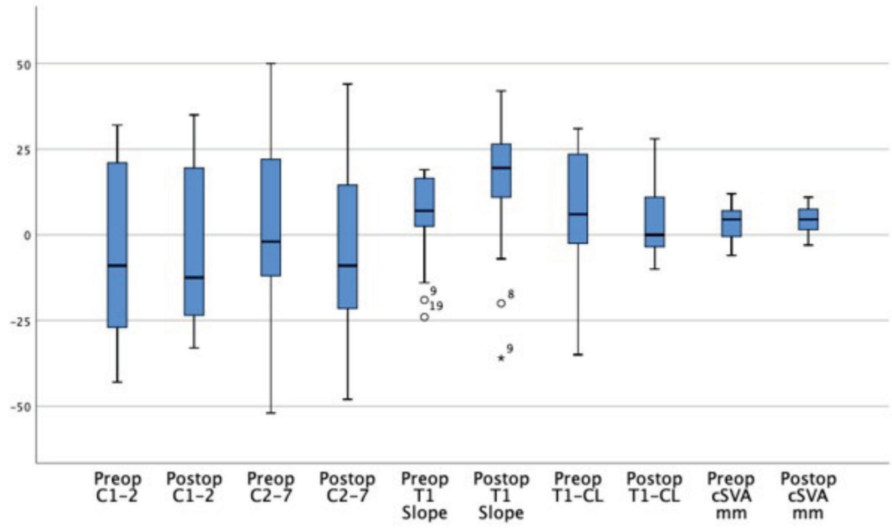

Figure 3. Statistical result cervical biomechanical parameters of patients

Table 2. Examined cervical biomechanical parameters of the patients

Patient no	Preop C1-2	Postop C1-2	Preop C2-7	Postop C2-7	Preop T1 Slope	Postop T1 Slope	Preop T1-CL	Postop T1-CL	Preop cSVA mm	Postop cSVA mm
1	-16	-32	23	20	7	22	31	28	6	5
2	-22	-13	-5	-31	11	33	23	1	9	2
3	-6	-12	-16	-19	7	17	-5	-2	5	8
4	-29	-14	1	-1	16	28	25	28	10	9
5	-12	-22	-37	-36	19	25	-18	-10	-4	8
6	-5	10	-52	44	3	17	-35	10	-1	-3
7	-43	-33	-11	-4	5	15	26	11	12	3
8	28	31	21	15	-14	-20	7	-5	3	7
9	21	16	6	40	-19	-36	-12	4	-1	-3
10	28	35	5	-18	17	34	18	11	5	1
11	-41	-13	10	-12	4	14	24	-1	5	4
12	-12	-30	-11	14	11	8	0	22	0	5
13	-25	21	-13	-21	13	24	0	0	0	4
14	-29	-29	-14	-6	17	28	5	21	6	11
15	-38	20	-11	8	19	7	7	0	8	0
16	21	-25	35	-27	3	25	2	-2	-6	3
17	24	-12	23	-22	2	23	-11	-6	1	5
18	32	19	-8	28	19	-7	10	-2	8	0
19	21	32	26	-48	-24	42	2	-5	-3	8
20	9	-16	50	-21	2	15	24	-5	4	5

Table 3. Significant difference in T1 slop angle

Test statistics[a]

	Postop C1-2 - Preop C1-2	Postop C2-7 - Preop C2-7	Postop T1 Slope - Preop T1 Slope	Postop T1-CL - Preop T1-CL	Postop cSVA mm - Preop cSVA mm
Z	-0.081[b]	-0.765[c]	-2,186[b]	-0.624[c]	-0.542[b]
Asymp. Sig. (2-tailed)	0.936	0.444	0.029	0.532	0.588

There is a significant difference between Postop T1 Slope and Preop T1 Slope ($p<0.05$). There is no significant difference between other parameters.
[a]: Wilcoxon Signed Ranks Test, [b]: Based on negative ranks, [c]: Based on positive ranks
Asymp. Sig.: Asymptotic significance

cervical spine sequencing. These values changed in parallel as the level of rigid stabilization increased. When the global lumbar lordosis angle was optimally configured, the T1 slope angle was reduced, resulting in improved cervical spine structure.

Study Limitations

This study has several limitations. First, the sample size was small. Second, the retrospective design does not allow for assessment of causality. Larger-scale prospective studies are warranted. Patient global CSB changes were not examined and will be the subject of another article. By measuring lordosis angle in each segment, it may be possible to evaluate how each change contributes to the decrease in cervical T1 slope angle. Dynamic systems could also be considered in a separate patient group, or such patients could be evaluated together with patients receiving rigid system stabilization.

CONCLUSION

It is essential to preserve lumbar lordosis in the rigidly stabilized spine, even if it is in the segmenter. Although loss of lordosis may not impair back function in youth, it can lead to serious problems in older age. Such effects emerge first in the cervicothoracic region, likely to protect neck posture.

Ethics

Ethics Committee Approval: Ethics committee approval was obtained from İstanbul Medipol University Non-Invasive Clinical Research Ethics Committee (approval no: E-10840098-772.02-5820, date: 11.11.2021).

Informed Consent: Informed consent was obtained from our patients for our study.

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Authorship Contributions

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

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