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Apical instrumentation alters the rotational correction in adolescent idiopathic scoliosis

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Abstract The aim of this study was to retrospectively evaluate the effect of apical vertebral instrumentation in the axial plane in the surgical treatment of idiopathic scoliosis. Seventy-six consecutive patients with King type II idiopathic scoliosis, treated with posterior spinal instrumentation, were included in the study. The mean age of the patients was 14.5 years (range 10–18 years), and the mean follow-up was 49 (range 28–74) months. Preoperative radiological evaluation was performed with postero-anterior, lateral, traction and side-bending radiographs. Vertebral rotation was measured with a Perdriolle torsion meter. Patients were retrospectively divided into two groups according to the presence of apical vertebra instrumentation. Group 1 consisted of 43 patients in whom the upper and lower neutral and intermediate vertebrae of thoracic curves had been instrumented on the concave side. Group 2 consisted of 33 patients who had received instrumentation of the apical vertebra on the concave side

in addition to the instrumentation configuration of group 1. Posterior fusion was added in all patients. Cobb and Perdriolle measurements were compared between the two groups preoperatively and at the last follow-up. Preoperative age and gender distribution, Cobb angle and rotational measurements, and correction ratios on side-bending films were similar in the two groups. Although the differences between the two groups in preoperative mean values of both Cobb angle and apical rotation were not statistically significant ($P>0.05$), mean values of apical rotation were significantly different postoperatively ($P<0.05$). At the same time, apical derotation ratios differed significantly between the two groups ($P=0.000$). We conclude that instrumentation of the apical vertebra provides better derotation at the apex.

Keywords Scoliosis · Apical vertebra · Rotational correction · Surgery

Introduction

Adolescent idiopathic scoliosis is a three-dimensional deformity, and the goals of the instrumentation include a balanced spine in the frontal, sagittal, and axial planes and sufficient fixation to achieve rigid fusion. In recent years, the importance of vertebral rotation in the etiology of scoliosis and in the surgical correction of rotation has become

well recognized [7]. The rotation at the apex of a scoliosis appears to contribute most to the rib hump deformity; therefore, it may decrease pulmonary function in untreated patients. Proper selection of fusion levels and correction of deformity in the coronal and sagittal planes are necessary to establish a well-balanced spine, whereas correction of rotational deformity improves vertebral column alignment and increases thoracic volume by correction of costal deformities [23].

Harrington distraction rods, which were used in the surgical treatment of scoliosis for many years, have no significant corrective effect on the rotational deformity [1, 13, 20, 22]. A small correction can be obtained with Harrington distraction rods, but this effect is mostly secondary to the correction of frontal plane deformity, rather than being a result of any direct derotational force [25].

Fig. 1A,B Schematic drawing of construct pattern. In group 1 (A), only intermediate and neutral vertebrae on the concave side were instrumented, while apical vertebra instrumentation was added in group 2 (B)

Fig. 2 Preoperative (A) and postoperative (B) standing postero-anterior radiographs of a patient in group 1. The arrow indicates the apex of the curve

Since the introduction of Cotrel-Dubousset instrumentation in the mid-1980s, attempts at three-dimensional correction of idiopathic scoliosis have been theorized. Segmental instrumentation provides better axial plane correction than Harrington instrumentation. In segmental instrumentation systems, a rod rotation maneuver may decrease the apical rotation, and the rib hump deformity may improve.

The aim of apical vertebral instrumentation is correction of the apical vertebra in the axial plane as well as in the frontal plane. In this study, the effect of apical vertebral instrumentation on the correction of the rotational deformity of the apical vertebra is assessed and compared with non-instrumented constructions.

Materials and methods

Seventy-six consecutive patients with King type II idiopathic scoliosis, treated with posterior spinal instrumentation in Dokuz Eylül University Hospital between 1989 and 1995, were included in the study. There were 44 girls and 32 boys, with a mean age of 14.5 years (range 10–18 years), and a mean follow-up of 49 (range 28–74) months.

Preoperative radiological evaluation was performed with postero-anterior (PA), lateral, traction and side-bending radiographs.

The frontal Cobb angles of both the thoracic and the lumbar curves were measured on the standing PA radiographs both preoperatively and at the last follow-up. The frontal Cobb angle was also measured on side-bending radiographs, and flexibility ratios of the thoracic and lumbar curves were calculated preoperatively in order to detect a possible variation in flexibility of the curves between the two groups. Sagittal plane analysis was assessed by kyphosis and lordosis angles. The measurement from T5 to T12 was used as a standard measurement for kyphosis, because these levels, most con-

Fig. 3 Preoperative and postoperative postero-anterior radiographs of a patient in group 2. The apical vertebra was instrumented on the concave side. Apical instrumentation is indicated by an arrow

sistently seen on radiographs, were usually in the instrumented area of the spine [4, 10]. Similarly, measurement between L1 and L5 was used for the lordosis angle. The junctional kyphosis between the thoracic and lumbar curves was noted with reference to the distal hook site. The rotation deformity of the apical vertebra was measured with a Perdriolle torsion meter [16]. Balance was assessed on the PA radiograph by measuring the distance of T1 to the midsacral line. Acceptable balance was defined as a translation of less than 10 mm. Using this criterion, comparisons between the preoperative and postoperative measurements of balance were made. All measurements were carried out by the same author (O.A.).

Upper and lower fusion levels were determined by analysis of plain radiographs. Neutral and intermediate vertebrae were marked on PA standing films, and mobile intervertebral disc segments were detected on side-bending films. Patients were retrospectively divided into two groups according to the presence of apical vertebra instrumentation. Group 1 consisted of 43 patients with instrumentation of the upper and lower neutral and intermediate vertebrae of thoracic curves on the concave side, with hook-screw combinations. On the convex side, one or two upper and lower adjacent segments of the apex were instrumented in addition to the upper and lower neutral vertebral instrumentation (Fig. 1A, Fig. 2A,B). In group 2, there were 33 patients in whom instrumentation of the apical vertebra on the concave side was added to the configuration of group 1 (Fig. 1B, Fig. 3A,B). The neutral vertebra was located at the thoracolumbar junction in both groups. Distal reverse hooks were placed between the neutral and stable vertebrae on the left side or on both sides for preventing junctional kyphosis. The rod was bent to fit to the curve. Derotation maneuver was performed, and compression and distraction were then applied to the concave and convex side respectively, in both groups. Posterior fusion was added in all patients, with autogenous bone graft harvested from the posterior iliac spine. A soft corset was used for 3–6 months.

Cobb and Perdriolle measurements were compared between two groups, both preoperatively and at the last follow-up. Correction ratios of rotation and Cobb measurements were calculated and compared within groups. Independent *t*-tests and paired *t*-tests were used for statistical analysis.

Results

Preoperative age and gender distribution, Cobb angles, rotational measurements, and correction ratios on side-bending films were similar in the two groups (Table 1).

Preoperatively, the mean Cobb angle of the thoracic curves in group 1 was 52.8° (±14°), and it was 50.6° (±16.5°) in group 2. The mean lumbar Cobb angles in group 1 and

Table 1 Demographic data of groups 1 and 2. Preoperative measurements are almost same in the two groups

	Group 1 (n=43)	Group 2 (n=33)
Mean age (range)	14.7 (10–18)	14.3 (10–17)
Male	20	12
Female	23	21
Preop thoracic Cobb	52.8°	50.6°
Postop thoracic Cobb	16.9°	12.7°
Preop lumbar Cobb	33.6°	34.7°
Postop lumbar Cobb	9.9°	11.8°
Preop rotation	21.9°	20.6°
Postop rotation*	13.7°	6.7°
Preoperative thoracic correction ratio (on side-bending films)	34.1%	31%
Preoperative lumbar correction ratio (on side-bending films)	46%	48.7%

*The difference is statistically significant ($P<0.05$)

group 2 were 33.6° ($\pm 12.1^\circ$) and 34.7° ($\pm 12.5^\circ$), respectively. The differences in the preoperative mean values of both the thoracic and the lumbar Cobb angles between group 1 and 2 were not statistically significant ($P=0.702$).

The preoperative mean kyphosis angle was 24.8° ($\pm 15.8^\circ$) in group 1, and 26.5° ($\pm 11.5^\circ$) in group 2. Mean lordosis angles in groups 1 and 2 were 21.4° ($\pm 12.3^\circ$) and 25.1° ($\pm 8^\circ$), respectively. The differences in kyphosis angle and lordosis angle between groups 1 and 2 were not statistically significant ($P=0.6$ for kyphosis and $P=0.19$ for lordosis).

Preoperative apical vertebral rotation values in groups 1 and 2 were 21.9° ($\pm 10.7^\circ$) and 20.6° ($\pm 8.7^\circ$), respectively. Differences between the two groups in the preoperative mean values of both the Cobb angle and apical rotation were not statistically significant ($P=0.542$).

Postoperatively, the mean thoracic and lumbar Cobb angles in group 1 were 16.9° ($\pm 11.8^\circ$) and 9.9° ($\pm 9.3^\circ$). In group 2, the mean thoracic and lumbar Cobb angles were 12.7° ($\pm 9.9^\circ$) and 11.8° ($\pm 9^\circ$). The differences in Cobb angles between the two groups were not significant for either the thoracic or the lumbar curves ($P=0.105$ for thoracic measurements, $P=0.353$ for lumbar measurements).

The postoperative mean kyphosis angle was 23.7° ($\pm 10.6^\circ$) in group 1 and 27.2° ($\pm 8.3^\circ$) in group 2. Postoperative mean lordosis angles in groups 1 and 2 were 18.5° ($\pm 11.7^\circ$) and 25.8° ($\pm 7.9^\circ$), respectively. Although there was no significant difference in kyphosis between the two groups ($P=0.117$), the mean lordosis angle was increased in group 2 ($P<0.05$).

Postoperative mean apical vertebral rotations were 13.7° ($\pm 8.6^\circ$) and 6.7° ($\pm 6.6^\circ$) in groups 1 and 2, respectively, which represented a significant difference between the two groups ($P<0.05$).

The thoracic and lumbar Cobb angles and rotational measurements from apical vertebra were significantly decreased on the postoperative radiographs in both groups ($P=0.000$). However, kyphosis and lordosis remained unchanged. Although postoperative thoracic and lumbar Cobb correction ratios did not differ significantly between group 1 and group 2, apical derotation ratios were statistically different ($P=0.000$).

Twenty patients (46%) in group 1 had presented with an imbalanced spine on the frontal plane preoperatively. T1 was tilted to the right side in 11, and to the left side in 9 of these 20 patients. An imbalanced spine was detected in 10 of the 43 patients (23%) postoperatively, with T1 being translated to the right side in half of them. Six of the ten group 1 patients with a postoperative frontal imbalance had presented with an imbalanced spine preoperatively, whereas the imbalance had developed postoperatively in four patients. Revision was performed for one patient in whom the preoperative frontal plane imbalance progressed postoperatively.

Preoperative imbalance was detected in 9 of 33 patients (37.5%) in group 2. Seven of these preoperatively

imbalanced patients had right tilt of T1, and two had left tilt. Eight patients (24.2%) in group 2 had a frontal imbalance postoperatively. The preoperative frontal balance of the spine had been normal in five of these eight patients. Revision surgery was not required for the balance problem in this group. No significant difference was detected in cardiopulmonary function and clinical appearance in the postoperative period.

Discussion

Idiopathic scoliosis is a three-dimensional deformity, and the clinical importance of these deformities in relation to each other is controversial. Although frontal plane deformity was accepted as the primary problem for many years, evidence showed the multiplanar features of the scoliotic spine, especially in the sagittal plane [2, 4]. At the same time, many authors have described the axial plane rotational deformity that accompanies the coronal and sagittal abnormalities and the importance of its correction [5, 11, 19, 27]. Several different instrumentation systems have been used in attempts to correct the rotational deformity of scoliosis. Harrington instrumentation has been shown to be limited in its ability to derotate the spine and correct the rib hump deformity [5, 6, 11]. Although rotational correction can be achieved by selective segmental instrumentation, some authors have suggested that this derotation does not dramatically correct the rib-hump deformity [27].

Various radiographic techniques have been described to quantify the rotational component of the scoliotic curve. Although Cobb's technique for measurement of rotation based on the position of the tip of the spinous process in relation to the underlying vertebral body was used for years, Nash and Moe, in 1969, proposed a simplified method, which correlates the amount or percentage of convex pedicle displacement seen on radiographs with the approximate degrees of rotation present in that vertebra [14]. Perdriolle used a special template (torsion meter) to measure the degree of rotation, based on the location of the convex-side pedicle relative to the lateral borders of the vertebral body [16]. Recently, the reliability and accuracy of the torsion meter was found to be questionable [15, 17, 24]. Richards states that an error of 2 mm in identifying the pedicle would result in a difference of apparent rotation of approximately 5° . He found that the intraobserver error from the actual value averaged 6° , and he suggested that the measurements may be more accurate when the actual rotation was mild [17]. Ideally, computed tomography (CT) might provide the most accurate measure of rotation; however, CT scan studies add additional expense. At the same time, during the CT examination, the spine is unloaded in a lying position, and the curve may be corrected spontaneously to some degree on both planes [18, 28]. On the other hand, Yazıcı et al. found that Perdriolle's method is a simple, convenient and reliable

method to measure rotation on standing radiograms [28]. In our study, the Perdriolle template was used because it is simple, avoids the risk of additional X-ray exposure and avoids additional expense.

Jarvis and Greene reported their results with the use of a hybrid system comprising Harrington distraction rods, Luque rods, and button-wire constructs. In their study, all of their patients showed improvement in the coronal plane, and this derotation was most pronounced in type II curves. They suggested that rotational correction in their study is similar with the results in the literature [8]. In our study, both frontal, sagittal and axial plane corrections were achieved in all groups postoperatively. However, rotational correction was more evident in group 2 than group 1. Rotational differences between the two groups may be explained by apical implantation.

Wood et al. noted more segmental rotation beyond the levels of instrumentation. They found that Cotrel-Dubousset instrumentation does not consistently derotate the thoracic apex relative to the pelvis, especially in single thoracic curves. King-Moe type II curves were more likely to derotate, and these curves may be better suited to absorb the transmitted rotational force, and preserve a balanced spine. They reported that Cotrel-Dubousset instrumentation can achieve derotation of scoliosis by changing the curve from relative lordosis to kyphosis, producing a rotational force opposite to that of the initial deformity, which is then augmented by the insertion of the convex rod [26]. In our study, instrumentation principles were similar to those of Cotrel-Dubousset instrumentation. On the other hand, the main difference with group 2 was the instrumentation of apex on concave side. Thus, the apical vertebra may be more likely to derotate between the upper and lower intermediate vertebrae. Derotation maneuver of the pre-bent rod can increase the transfer of rotational forces to the apex via apical implants. In our study, King Type II curves were selected to standardize the effect of instrumentation on the axial plane. In idiopathic scoliosis, rotational deformity is more prominent in the apical vertebra, and for that reason rotational measurements were performed only at the apex. Apical rotation was not correlated to the pelvis, because this correlation requires CT examination.

Postoperatively, a decrease in lumbar curves was detected as well as a correction in thoracic curves. However, no significant difference in lumbar correction was observed between the two groups. Many authors showed

that spontaneous lumbar curve correction could occur consistently after both selective thoracic anterior and posterior fusions [3, 10, 12]. Besides, it was also stated that thoracic derotational forces might have negative effects on lumbar curves. Thompson et al. stressed the importance of overcorrection relative to the preoperative deformity producing decompensation [21].

There was no significant difference in kyphosis angle between the two groups postoperatively. However, the lordosis angle was slightly decreased in group 1 after thoracic fusion. In the literature, sagittal plane alterations were demonstrated after selective thoracic fusions [4, 9].

Postoperative coronal decompensation after selective posterior fusion of King type II curves was an occasional complication, and the common pattern with postoperative decompensation [10, 21]. In this study, 20 patients (46%) in group 1 had an imbalanced spine preoperatively. This ratio improved to 23% after selective instrumentation. The decompensation rate was found to be 9% in patients with a normal preoperative balance. In the literature, a reversed hook pattern between distal neutral and stable vertebra was recommended in King type II curves to prevent this problem [3, 10]. Distally, a reversed hook pattern was used in all of our cases.

In the present study, postoperative frontal and coronal measurements were significantly lower than the preoperative values. This is an expected result, because the spinal curves can be corrected with rigid instrumentation. However, postoperative rotational correction was better in group 2 than in group 1. Differences in postoperative correction ratios of Cobb angle and rotation between the two groups are also important. The difference in Cobb angle correction ratios was found not to be statistically significant between the group 1 and 2, but rotational correction ratios were significantly different. Apical instrumentation on the concave side of the curves is the only difference in instrumentation between two groups. For that reason, the more prominent rotational correction in group 2 may have been resulted from this instrumentation pattern.

We conclude that instrumentation of apical vertebra provides better derotation at the apex in type 2 curves. The effects of this improvement in correction remain to be determined.

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