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# *Analysis of the causes of proximal junctional kyphosis following spinal instrumented fixation in patients with bone mineral density deficiency*

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**Objective** To explore causes of proximal junctional kyphosis (PJK) following instrumented fixation of lumbar spine in patients with degenerative scoliosis due to mineral bone density deficiency. **Material and methods** A retrospective analysis was conducted on 308 patients with degenerative lumbar scoliosis surgically treated with decompression of neural elements, deformity correction and stabilization of FSU using rigid transpedicular fixation systems. The patients were followed up for 2 years of surgery and were subdivided into 2 groups, those who developed PJK (n=132) and those who did not (n=176). Variable risk factors for PJK described in the literature were analyzed. They could be categorized into patient related factors (age, gender, osteoporosis, body mass index (BMI), smoking habits), surgical factors (type of osteotomy performed, a magnitude of lordosis correction, long fixation to the sacrum) and radiographic parameters (PI, TK, LL, SVA, PI-LL, PJA). **Results** Osteoporosis (53–33 %, p = 0.032), BMI >25 (51–37 %, p = 0.042) and greater than 30° lordosis correction (51–34 %, p = 0.038) were found to be statistically significant for PJK. Lumbar lordosis restored in more than 30% increases the risk of PJK by 2.3 times. The proximal junctional angle (PJA) ⩾ 11° is a statistically significant risk factor for PJK and associated with increased occurrence of PJK by 2.9 times (p = 0.022). An increase in PJA by 1° increases the risk of PJK by 11.8 % (making the risk 1.118 times higher). Osteoporosis coupled with PJA entails a statistically significant impact on PJK (p = 0.002) with PJA increased by 1° in osteoporosis scenario increasing the risk of PKJ by 66.4 % (making the risk 1.664 times higher). **Conclusion** Osteoporosis, body mass index > 25 and a surgical correction of lumbar lordosis by more than 30° have been shown to be significantly associated with PJK in patients with lumbar curves. PJA of 11° is the significant risk factor for PJK making the occurrence of PJK 2.9 times higher (p = 0.022). Osteoporosis coupled with PJA entails a statistically significant impact on PJK (p = 0.002) with PJA increased by 1° in osteoporosis cases increasing the risk of PKJ by 66.4 %.
**Keywords**: spine, osteoporosis, proximal junctional kyphosis (PJK), proximal junctional angle (PJA)

## BACKGROUND

Degenerative lumbar scoliosis is a common condition occurring in 6–68 % [1, 2] of older individuals. Common symptoms associated with the condition include vertebrogenic syndrome, intermittent claudication, mono- or polyradiculopathy [3, 4]. Combination of the above symptoms is observed in 33–95 % of the cases [5, 6]. Degenerative lumbar scoliosis is found in older adults with medical comorbidities. Operative intervention is met with the challenge of bone mineral density deficits [4, 7, 8]. The treatment needs to be tailored individually accounting for a number of variables. Osteoporosis is a compounding factor in relation to securing fixation points with instrumentation to the structurally weak bone [9, 10, 11]. However, critical forms of degenerative scoliosis are indication to reconstructive surgical intervention with the use of metal implants to stabilize the spine. Although the major goal is pursued at early postoperative period long-term outcomes are not always up to expectations of a patient and operating surgeon. Proximal junction kyphosis (PJK) is one of the factors contributing to unfavorable outcomes. PJF has important clinical implications with issues of reduced bone density. PJF has important clinical implications especially for elderly patients with issues of reduced bone mineral density [4, 12, 13, 14].

The purpose of the study was to explore causes of proximal junctional kyphosis (PJK) following instrumented fixation of lumbar spine in patients with degenerative scoliosis due to bone mineral density deficiency.

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## MATERIAL AND METHODS

A retrospective analysis was conducted on 308 patients with degenerative lumbar scoliosis surgically treated between 2009 and 2015. The mean age of the patients was 61.1 ± 6.9 years. There were 208 (67.5 %) females and 100 (32.5 %) males. Surgical intervention included decompression of neural elements, deformity correction and stabilization of FSU using rigid transpedicular fixation systems. The stages of surgical treatment were performed at one session using posterior approach. There were at least 5 FSU fixed. The proximal fixation level included Th10–L1 vertebrae. The distal fixation level reached L5–S1 with/without screws placed in the iliac bones. The choice of the cranial and caudal fixation level is dependent on vertebral position in relation to the curve in coronal plane considering the stability and neutral position.

A primary cohort of patients was grouped on inclusion and exclusion criteria. The study included patients aged older than 18 years who developed spinal deformity due to progressing degeneration and were treated with the above surgical interventions. Exclusion criteria were systemic diseases of connective tissues, previous spinal surgeries, absence of comprehensive radiography and densitometry, minimum follow-up period of 2 years, history of infection and signs of unstable metal construct (MC). Radiological assessment included two views of full-length standing spine-hip radiographs prior to surgery, at early postoperative period (the first week) and at 3, 6, 12 and 24 months. Parameters determined with the radiographs included Sagittal Vertical Axis (SVA), Thoracic Kyphosis (TK): Th5–Th12), Lumbar Lordosis (LL): L1–L5), Pelvic Incidence (PI), Pelvic Tilt (PT) and Proximal Junctional Angle (PJA) between the lower endplate of uppermost instrumented vertebra and the upper endplate of 2 supra-adjacent vertebra.

Statistical multifactorial analysis was performed to identify risk factors for PJK and their role. Variable risk factors that are frequently described in the literature were included in the analysis. They can be categorized into patient-related (age, gender, osteoporosis, body mass index, smoking habits), surgical (type of osteotomy, amount of lumbar lordosis corrected, fixation to sacrum) and radiographic (PI, TK, LL, SVA, PI-LL, PJA) risk factors.

## RESULTS AND DISCUSSION

Patients were subdivided into 2 groups at primary stage of analysis with regard to PJK with no signs of unstable MC. PJK group consisted of 132 patients (34.6 %) and non-PJK group included 176 patients (65.4 %) followed over the period of two years. Clinical and radiological assessment of PJK was produced following instrumentation fixation of lumbar and thoracolumbar spine identifying major mechanisms, specific manifestations and onset of PJK (Table 1).

Major risk factors for PJK were compared in both groups of patients using Pearson's Chi2 test (Tables 2, 3). Standard methods of nonparametric statistical analysis were primarily applied to identify significance of the mean radiological parameters in patients of both groups (Table 4).

Potential risk factors for PJK were determined with Pearson's Chi2 test to evaluate significant differences between certain parameters in cross tables. The test showed statistical significance for patient related, surgical and several radiological risk factors. A higher rate of PJK was identified in patients with osteoporosis (53–33 %; p = 0.032), body mass index of more than 25 (51–37 %; p = 0.042 and change in lumbar lordosis more than 30° (51–34 %; p = 0.038). Statistical significance of radiological risk factors was identified with pelvic incidence (PI; p = 0.031), difference in pelvic incidence and lumbar lordosis (PI–LL; p = 0.018) and proximal junctional angle (PJA; p = 0.019). Factors with statistical significance were included in the Cox regression analysis to identify independent significance of all variables, their correlation and the effect as risk factors with PJK (Tables 5, 6).

Table 1

Mechanisms causing PJK

| | PJK (n = 132) | Mean time to development of PJK, months | Mean angle of PJA° |
|---|---|---|---|
| Degeneration of intervertebral disc | 12 (9 %) | 12.2 ± 5.7 | 14.4° ± 3.2° |
| Fracture of supra adjacent vertebra | 64 (49 %) | 4.2 ± 3.8 | 34.2° ± 6.2° |
| Fracture of the vertebra of the proximal fixation point | 56 (42 %) | 3.3 ± 4.1 | 32.1° ± 7.1° |

Table 2

Comparison of patient related risk factors in study groups

| Risk factor | PJK group (n = 132) | Non-PJK group (n = 176) | Frequency of PJK | p value (significance) |
|---|---|---|---|---|
| Age | 61.3 ± 6.4 | 60.8 ± 7.2 | | 0.126 |
| Gender | | | | |
| female | 96 | 112 | 46 % | 0.244 |
| male | 36 | 64 | 36 % | |
| Osteoporosis | | | | |
| yes | 82 | 74 | 53 % | 0.032 |
| no | 50 | 102 | 33 % | |
| Smoking habits | | | | |
| yes | 44 | 52 | 46 % | 0.676 |
| no | 88 | 124 | 42 % | |
| BMI >25 | | | | |
| yes | 69 | 67 | 51 % | 0.042 |
| no | 63 | 109 | 37 % | |

Table 3

Comparison of surgical risk factors in study groups

| Risk factor | PJK group (n = 132) | Non-PJK group (n = 176) | Frequency of PJK | p value (significance) |
|---|---|---|---|---|
| Type of osteotomy | | | | |
| SPO | 85 | 112 | 43 % | 0.342 |
| PSO / VCR | 38 | 48 | 44 % | |
| none | 9 | 16 | 36 % | |
| Correction of LL > 30° | | | | |
| yes | 82 | 80 | 51 % | 0.038 |
| no | 50 | 96 | 34 % | |
| Fixation to sacrum | | | | |
| yes | 76 | 104 | 42 % | 0.829 |
| no | 56 | 72 | 44 % | |

Table 4

Comparison of mean radiological parameters in patients of study groups

| Risk factor | PJK group (n = 132) | Non-PJK group (n = 176) | p value (significance) |
|---|---|---|---|
| PI (°) | 61.2 ± 7.8 | 54.1 ± 8.2 | 0.031 |
| PT (°) | | | |
| pre-op | 25.6 ± 7.3 | 27.3 ± 8.4 | 0.114 |
| post-op | 19.4 ± 7.1 | 21.1 ± 6.7 | 0.082 |
| difference | 6.2 ± 6.9 | 6.2 ± 7.2 | 0.921 |
| LL (°) | | | |
| pre-op | 26.3 ± 12.1 | 28.4 ± 10.2 | 0.127 |
| post-op | 59.6 ± 7.2 | 51.2 ± 7.8 | 0.032 |
| difference | 33.3 ± 9.2 | 22.8 ± 8.8 | 0.021 |
| PI-LL (°) | | | |
| pre-op | 34.9 ± 7.4 | 25.7 ± 8.6 | 0.018 |
| post-op | 1.6 ± 8.2 | 2.9 ± 11.8 | 0.082 |
| SVA (mm) | | | |
| pre-op | 96.6 ± 64.2 | 88.2 ± 58.4 | 0.146 |
| post-op | 32.2 ± 28.3 | 25.6 ± 32.3 | 0.246 |
| difference | 64.4 ± 42.3 | 62.6 ± 74.6 | 0.459 |
| PJA (°) | | | |
| pre-op | 13.8 ± 4.1 | 8.2 ± 5.3 | 0.019 |
| post-op | 12.5 ± 4.8 | 7.1 ± 6.0 | 0.024 |
| difference | 1.3 ± 1.8 | 1.1 ± 2.1 | 0.213 |
| TK (°) | | | |
| pre-op | 34.2 ± 8.1 | 31.8 ± 7.9 | 0.097 |
| post-op | 38.4 ± 8.6 | 33.1 ± 7.1 | 0.178 |
| difference | 4.2 ± 6.7 | 1.3 ± 3.4 | 0.089 |

Table 5

Correlation of major variables (risk factors) in the development of PJK

| Correlation matrix of regression coefficients | | | | | |
|---|---|---|---|---|---|
| | Osteoporosis | PJA | BMI | PI-LL | PI |
| PJA | .443 | | | | |
| BMI | .309 | –.263 | | | |
| PI-LL | –.300 | –.084 | –.019 | | |
| PI | .152 | .421 | –.223 | .091 | |
| Corr. LL> 30° | –.158 | .049 | –.428 | –.478 | –.223 |

A binding force of two variables is characterized by an absolute value of correlation coefficient. A coefficient of correlation measuring up to 0.2 is considered to be very weak, up to 0.5 weak, up to 0.7 moderate, up to 0.9 strong and 0.9 very strong. The analysis showed the variables being in weak correlation that could be used as independent variables for regression.

The test showed statistical significance for risk factors associated with change in lumbar lordosis more than 30° and proximal junctional angle. A ROC curve was used to identify a threshold value for PJA being statistically significant as a risk factor for PJK (**Fig. 1**). The ROC curve showed statistically significant PJA for PJK as a risk factor. The area under the curve (AUC) measured 0.891 with 95 % confidence interval from 0.817 to 0.966 that indicated to a high prognostic accuracy of the model. The threshold PJA measured with maximum sensitivity of 90.5 % and specificity of 82.6 % was 11°. The PJA variable of 11° characterizing distribution of patients depending on the angle (either < 11° or ≥ 11°) was included in the Cox proportional hazards regression model to determine PJA as a risk factor for PJK (Table 7).

Table 6

Analysis of major variables (risk factor) for PJK using the Cox proportional hazards regression model

| The Cox proportional hazards regression model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | B | ex. er. | Wald | st. sv. | Significance | Exp (B) | CI 95.0 % for Exp (B) | |
| | | | | | | | lower | upper |
| Osteoporosis | 1.181 | .487 | 5.884 | 1 | .055 | 2.258 | 1.255 | 8.462 |
| BMI > 25 | 1.021 | .256 | 3.613 | 1 | .078 | 1.566 | .457 | 6.712 |
| Corr. LL> 30° | 1.342 | .414 | .051 | 1 | .006 | 2.365 | .635 | 5.611 |
| PI | .533 | .311 | 2.754 | 1 | .234 | 1.332 | .077 | 4.126 |
| PI-LL | -.198 | .069 | 5.884 | 1 | .385 | .887 | .045 | 7.132 |
| PJA | 1.223 | .323 | 2.075 | 1 | .003 | 1.671 | 0.402 | 4.241 |

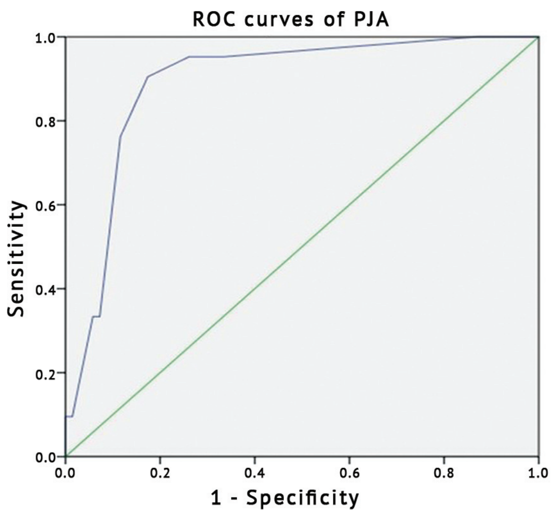


**Fig. 1** ROC curve of PJA

Table 7

Analysis of major variables (risk factor) for PJK using the Cox proportional hazards regression model with incorporated variable PJA of 11°

| The Cox proportional hazards regression model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | B | Ex. er. | Wald | st. sv. | Significance | Exp (B) | CI 95.0 % for Exp (B) | |
| | | | | | | | lower | upper |
| Osteoporosis | 1.162 | .488 | 5.871 | 1 | .062 | 2.223 | 1.241 | 8.453 |
| BMI > 25 | 1.047 | .254 | 3.622 | 1 | .086 | 1.527 | .473 | 6.724 |
| Corr. LL> 30° | 1.323 | .413 | .085 | 1 | .011 | 2.331 | .621 | 5.625 |
| PI | .538 | .315 | 2.732 | 1 | .253 | 1.364 | .056 | 4.133 |
| PI-LL | –.191 | .061 | 5.876 | 1 | .366 | .856 | .034 | 7.143 |
| PJA | 1.281 | .324 | 2.024 | 1 | .004 | 1.118 | 0.413 | 4.254 |
| PJA 11° | 1.411 | .129 | 11.035 | 1 | .022 | 2.974 | 1.355 | 7.633 |

Therefore, the multifactorial statistical analysis revealed statistical significance of PJA and greater correction of LL as risk factors for PJK. The risk of PJK was likely to increase by 2.3 times with LL corrected more than 30° (p = 0.011). PJA being equal or greater than 11° was shown to be statistically significant risk factor for PJK increasing the likelihood of the development by 2.9 times (p = 0.022). The risk of PJK appeared to increase by 1.118 times or by 11.8 % with PJA increased by 1°. There was a tendency of osteoporosis impacting the development of PJK although its role as an independent risk factor for PJK was not confirmed statistically. The correlation of osteoporosis and the study variables for the development of PJK demonstrated statistical significance with incorporated PJA parameter (Table 8).

Thus, osteoporosis and PJA showed statistically significant correlation for PJK (p = 0.002) with PJA increased by 1° in osteoporotic patients resulting in the increase in risk factor for PJK by 1.664 times or by 66.4 %.

Table 8

Analysis of risk factor correlation for PJK using the Cox proportional hazards regression model

| The Cox proportional hazards regression model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | B | Ex. er. | Wald | st. sv. | Significance | Exp (B) | CI 95.0 % for Exp (B) | |
| | | | | | | | lower | upper |
| Osteoporosis | 1.218 | .474 | 3.401 | 1 | .287 | 2.628 | 1.431 | 9.655 |
| PJA | 1.151 | .329 | 7.694 | 1 | .029 | 1.131 | 0.561 | 3.932 |
| Osteoporosis *PJA | .511 | .128 | 4.309 | 1 | .002 | 1.664 | 0.855 | 3.621 |

## CONCLUSION

1. Osteoporosis (53–33 %; p = 0.032), body mass index of more than 25 (51–37 %; p = 0.042) and correction of LL more than 30° (51–34 %; p = 0.038) were found to play a significant role for the development of PJK.

2. Lumbar lordosis restored in more than 30 % increases the risk of PJK by 2.3 times.

3. The proximal junctional angle (PJA) ⩾ 11° is a statistically significant risk factor for PJK and associated with increased occurrence of PJK by 2.9 times (p = 0.022). An increase in PJA by 1° increases the risk of PJK by 11.8 % (making the risk 1.118 times higher).

4. Osteoporosis coupled with PJA entails a statistically significant impact on PJK (p = 0.002) with PJA increased by 1° in osteoporosis scenario increasing the risk of PKJ by 66.4 % (making the risk 1.664 times higher).

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