The effectiveness of a low implant density in Scheurmann kyphosis in correcting the lumbar lordosis -pelvic incidence mismatch

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Purpose
To evaluate the effectiveness of using a low implant density in surgical treatment of Scheurmann Kyphosis (SK) in correcting the lumbar lordosis (LL)- Pelvic incidence (PI) mismatch.
Methods
Patients that were surgically treated for SK by a low screw density with multiple Ponte osteotomies at two institutions from January 2021 to January 2022 were identified and included in the study. Preoperative/postoperative/1- and 2-year follow-up measurements were analyzed from full-spine standing radiographs.
Results
Thirty patients were enrolled in our study, mean age 20.5 (13–37) years, mean preoperative kyphosis was 85.9 (75–108), a mean preoperative lumbar lordosis-pelvic LL-PI mismatch was 25.9 (23–28). The maximum kyphosis was corrected to 46.2 (37–63) and the LL-PI mismatch was reduced to 7.7. The correction was maintained at 1- and 2-years follow-up with no statistical change in the sagittal angles.
Conclusion
Surgical correction of SK using low-density implants and multiple Ponte osteotomies is an effective method of correcting the kyphotic deformity and reducing the LL-PI mismatch to normal physiological values.

Keywords:
low density implant, lumbar lordosis, pelvic incidence, ponte osteotomy, scheurmann kyphosis

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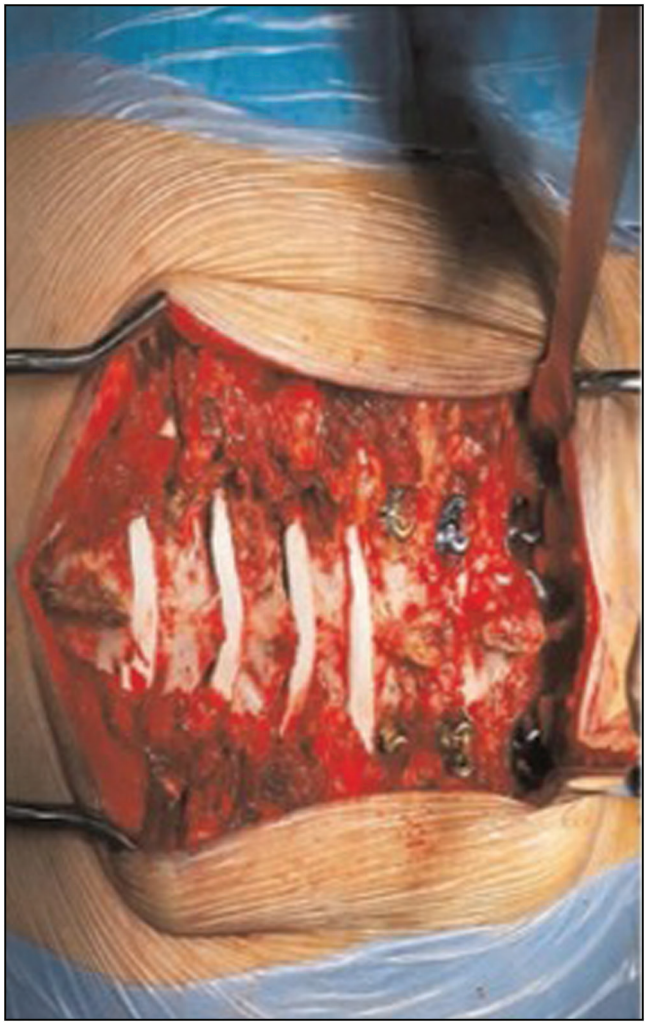
Introduction

Scheurmann Kyphosis (SK) is a developmental thoracic or thoracolumbar hyper-kyphosis that could cause chronic back pain, cosmetic problems to the patients, and rarely neurologic impairment [1]. SK is considered the most common sagittal angular spinal deformity with an incidence of 4–8% with no gender predomination [2]. There could be a genetic contribution to the pathology as well as some role of mechanical factors supported by the thickening of the anterior longitudinal ligament across the area of kyphosis and in another theory, asymmetric osteonecrosis of the vertebral endplates [3].

Usually, conservative measures are applied, but surgical correction is indicated in kyphosis over 70–75 especially if it causes pain, respiratory problems and/or neurologic compromise [4]. The treatment approach evolved over the last two decades from a combined approach (anterior release followed by posterior correction and fusion) to a posterior-only approach as the latter proved to be as effective in terms of deformity correction with fewer complications and reduced operative time [5].

With the development of modern posterior instrumentations, achieving and maintaining deformity correction has been easier to attain especially if supplemented with multiple posteriorly-based shortening osteotomies [6]. All screws or high-density constructs through the posterior approach have been considered the gold standard [5]. The senior author had previously published his technique of using low-density construct to achieve similar radiological and clinical results when compared with the gold standard technique [7]. The main purpose of this study is to evaluate the effectiveness of the low implant density in correcting the Lumbar Lordosis-Pelvic Incidence (LL-PI) mismatch in patients with SK.

Figure 1



Multiple Ponte Osteotomies.

Patients and methods

This is a prospective study of patients who had undergone surgical correction of SK by a low implant density by two surgeons in two institutions from January 2021 to January 2022. Institutional review board approval was obtained from the research ethics committee, Cairo University, faculty of medicine, Egypt (Approval number MD-413-2021) and the IRB committee in Zagazig Faculty of medicine (IRB# 118.10.03.2024) for this study. 30 patients were enrolled in the study. All patients or their legal guardians (if age below 18) signed an informed consent agreeing to be enrolled in the study.

All patients underwent a posterior approach through which pedicle instrumentation was done only at the 3–4 most proximal levels and the three most distal levels in the fusion area. Multiple Ponte osteotomies were done across the apex and peri-apical levels and correction was achieved through a cantilever rod reduction from proximal to distal (Fig. 1).

The Upper instrumented level was either T3 or T2 according to the extent of the deformity. The lower instrumented vertebra was chosen to be the sagittal stable vertebra. Intraoperative neuromonitoring was used in all patients. Exclusion criteria were previous spine surgeries, any neuromuscular disorder, and patients with incomplete radiographic data. For each patient the following characteristic data were analyzed; age, sex, radiographic measurements, and duration of follow-up.

Radiographic measurements were done on whole spine standing radiograph obtained preoperatively, 1 month postoperatively and 1 and 2 years follow-up. The radiographic parameters measured were: Maximum Kyphosis angle, Lumbar Lordosis (L1-S1), PI. Radiographic measurements were done independently by two of the research team, a spine fellowship-trained surgeon and a spine fellow using the Surgimap program. Surgical details were also recorded and assessed including operative time, blood loss, fusion levels, screw density, and a number of Ponte Osteotomies. Screening for postoperative complications in the form of proximal junctional kyphosis and distal junctional kyphosis was carried out (Figs 2 and 3).

Statistical analysis

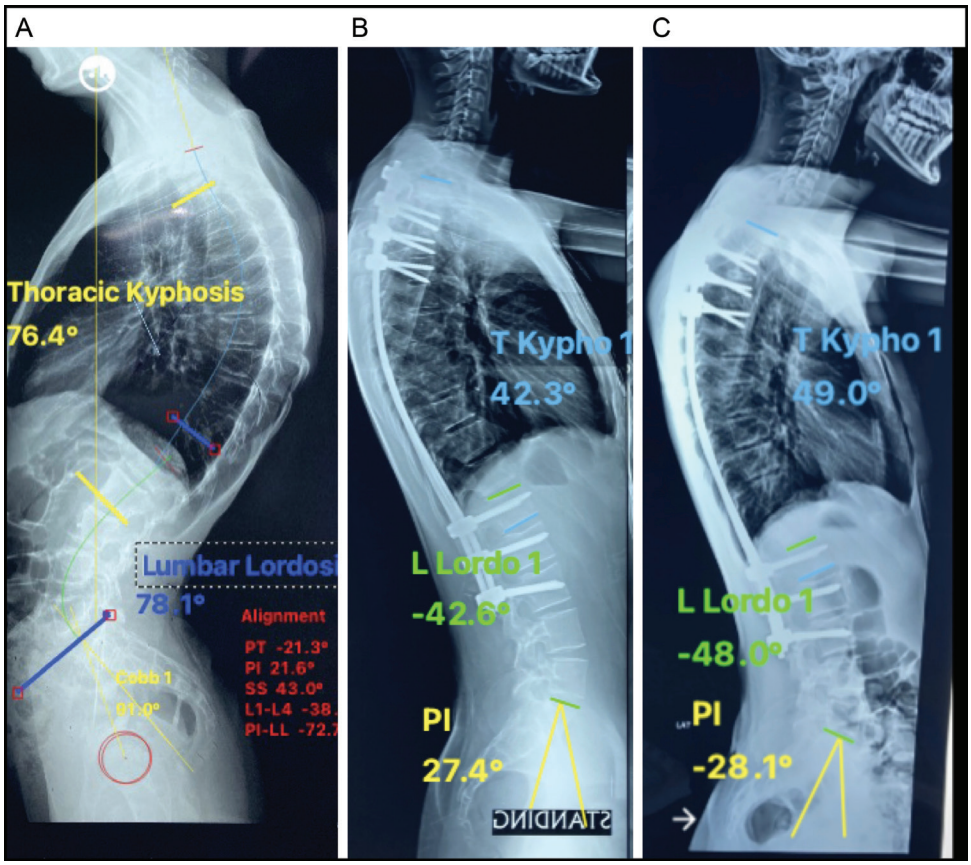
Statistical analysis was done by SPSS v26 (IBM Inc., Armonk, NY, USA). Quantitative variables were presented as mean and standard deviation (SD) and Intra group comparison was performed using the Paired Student *t* Test. Qualitative variables were presented as frequency and percentage (%). A two tailed *P* value less than 0.05 was considered statistically significant.

Results

Thirty patients with SK underwent a posterior spinal fusion with low-density construct with a mean age of 20.5 (range 13–37), 19 males and 11 females. The preoperative maximum kyphosis ranged from 75 to 108° with a mean of 85.9 ± 10.01. The preoperative LL range was 40–82° with a mean of 65.2 ± 12.15°. The mean preoperative LL-PI mismatch was 25.96 (range 23–28).

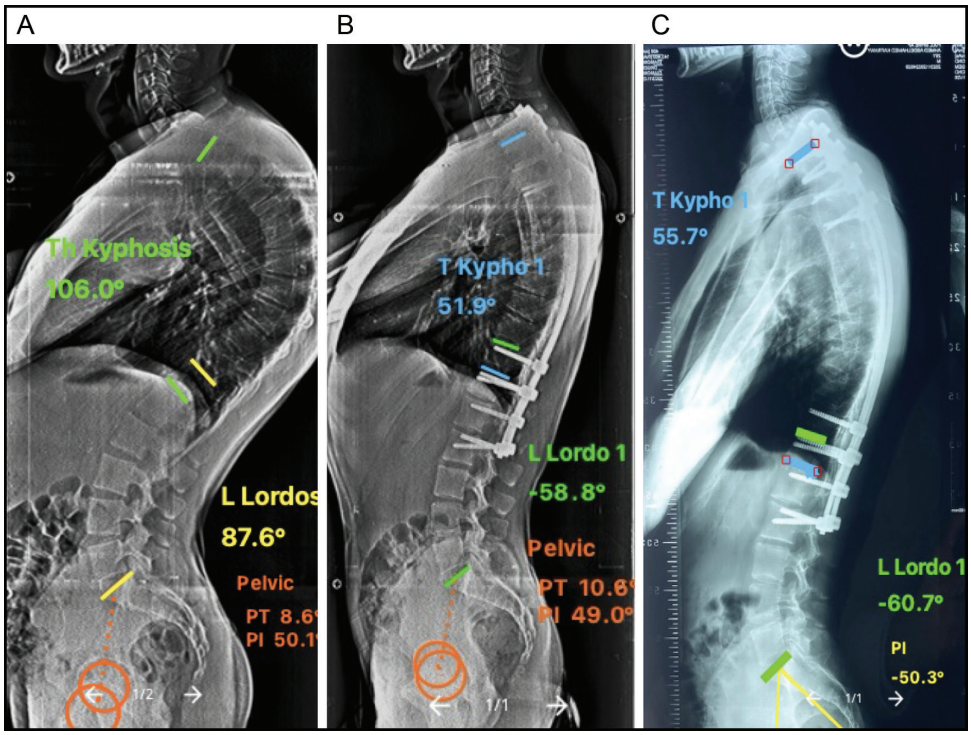
The mean operative time was 155 min (120–180), average blood loss was 450 ml (200–600). The average number of pedicle screws per case was 12.4 (12–14). The mean screw/implant density per case - calculated by dividing the number of screws on the total amount of pedicles available in the fusion area- was 0.5 (0.45–0.63). The average number of peri-apical Ponte Osteotomies done was 4.3(3–6) per surgery.

Figure 2



A: preoperative lateral radiograph of a 15-year-old male with SK showing the Maximum kyphosis, Lumbar lordosis angle, pelvic tilt (PT) and pelvic incidence (PI) measured on Surgimap program. B: 1 year follow-up image showing the deformity correction C: 2 years follow-up showing maintenance of the deformity correction.

Figure 3



A: preoperative lateral radiograph of a 27-year-old male with SK showing the maximum kyphosis and Lumbar lordosis angle measured on Surgimap program. B: 1 year follow-up image showing the deformity correction. C: 2 years follow-up showing maintenance of the deformity correction.

Table 1 Showing pre and postoperative pelvic incidence, lumbar lordosis and maximum kyphosis angle

	N=30	Normal
Pelvic Incidence		
Mean±SD	39.57±9.46	35–85
Range	21–61	
Preoperative lumbar lordosis		
Mean±SD	65.2±12.15	20–45
Range	40–82	
Preoperative maximum kyphosis angle		
Mean±SD	85.9±10.1	20–40
Range	75–108	
Pelvic incidence		
Mean±SD	39.57±9.46	35–85
Range	21–61	
Post-operative lumbar lordosis		
Mean±SD	46.8±10.51	20–45
Range	24–76	
Post-operative maximum kyphosis angle		
Mean±SD	46.2±7.83	20–40
Range	37–63	

Postoperatively the maximum kyphosis was reduced to a mean value of 46.2 (37–63) (P<0.001*), mean LL was reduced to 46.8(24–76) (P<0.001*), The mean LL-PI mismatch was 7.73 (6–10) (P<0.001*), The maximum kyphosis correction was maintained at 1 and 2 years follow up with a very minor increase at 1 year to reach 47.1(37–65) and at 2 years to reach 47.6 (34-64) which was not statistically significant (Table 1).

Discussion

The purpose of this study is to evaluate the effectiveness of the low implant density in achieving similar results upon comparing to the standard high-density implant in terms of deformity correction, maintaining of the correction and correction of LL-PI mismatch.

The surgical approach was as described by the senior author [7], classic posterior approach, pedicle screw instrumentation in the 3–4 proximal levels and the three most distal levels in the fusion area. The upper instrumented vertebra was either T2 or T3 according to the extent of the deformity, the lower instrumented vertebra was selected to coincide with the sagittal stable vertebra, multiple periapical Ponte osteotomies and deformity correction primarily by cantilever method.

Multiple periapical Ponte osteotomies done effectively and accurately as described by Ponte *et al.* [8] will cause enough flexibility of the hyperkyphotic segment and allow deformity correction through shortening of the posterior column without inducing significant stretch of the anterior section of the spinal cord enabling safer correction [9–12].

Upon the advancement of spinal instrumentations, namely pedicle screws enabling a rigid three column spinal fixation, the posterior only approach with all pedicle screws has become the preferred surgical management modality for patients with SK [3,13]. Of course, this came with a cost, either financially or an increase in the complication rate. Considering the various financial constraints on different aspects of health care, there is a continuous demand on the evaluation of proper implant usage. Therefore, having evidence supporting that low implant density constructs in SK will achieve similar results compared with a high-density construct will redeem the earlier construct more cost effective. Additionally, each pedicle screw does not increase only the cost but increases as well the surgical time, blood loss, and the incidence of potential complications [14].

Behrbalk *et al.* [15] concluded a comparative study as they compared a high-density construct (all pedicles instrumented) to a low-density construct (54–69% of available pedicles) and their results showed similar correction in both groups with a significant cost-reduction in the low-density group.

The senior author published his surgical technique [7] where he uses a low-density construct (only instrument the three most caudal and cephalic levels – 12 screws totally), leaving the periapical area without instrumentation and relying mainly on a cantilever technique for deformity correction. Counter-intuitively, this construct achieved similar hyper-kyphosis correction when compared with all screw constructs and maintained that correction with an average of 2 years follow-up.

This study was in concordance with the previous study [7] in terms of kyphosis correction and maintenance of that correction. The primary focus of this study was to evaluate the effectiveness of this low implant density construct to correct the PI-LL mismatch in patients with SK. The preoperative PI-LL mismatch was corrected from a mean value of 25.96 (23–28) to a mean postoperative value of 7.73 (6–10), and the correction was maintained for 2 years follow-up.

As well noted in the literature, SK is always accompanied by a compensatory hyper-lordosis [16]. There are several studies that have documented the spontaneous correction of the LL after surgical correction of the SK [17,18]. Jansen *et al.* [19] have outlined in their study

that there is a predicable reduction of the lumbar hyperlordosis after surgical correction of SK. Moreover, the main correction occurs in the upper segment of LL and there is a strong correlation between the degree of SK correction and the spontaneous LL correction.

Numerous studies had stressed on the importance of radiographic parameters (namely PI-LL mismatch) and its association with health-related quality of life outcomes [20–23]. Additionally, one of the international spine study group publications [20] defined the ideal PI-LL for individuals under 35 years of age to be around 10.5°. Moreover, Aoki *et al.* [24] reported the influence of PI-LL mismatch on residual low back pain after short segment fusion in the Lumbar Spine and advised spine surgeons to strongly consider the reduction of PI-LL mismatch even in short fusions. Consequently, we believe that the low-density implant could efficiently achieve the alignment goals of the spinal deformity corrective surgery in terms of reducing the thoracic hyperkyphosis and reducing the PI-LL mismatch to physiological levels.

The limitation of this study is mainly the small number of patients and the lack of long-term follow-up. We understand that this low-density construct is biomechanically weaker compared with the standard all pedicle screw construct. However, we were able to demonstrate its efficiency in the deformity correctio and the reduction of PI-LL mismatch without a single biomechanical failure up to two years follow-up.

Conclusion

Surgical treatment of SK is mostly an all-posterior approach with segmental pedicle screws and multiple Ponte osteotomies. The low implant density construct is an economically and surgically efficient way in achieving deformity correction. The low implant density construct succeeded in achieving proper deformity correction in terms of Kyphosis correction, Lordosis normalization, and reducing the PI-LL mismatch to physiological levels. The correction was maintained with no loss of correction or mechanical failures up to 2 years follow-up.

Ethical approval

This study was approved by our Institutional Ethics Review Board.

Consent to Participate

All patients provided informed consent to participate in this study.

Consent to Publish

All participants provided informed consent for the publication of this study.

Authors' contributions

All authors whose names appear on the submission (1) made substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data; or the creation of new software used in the work; (2) drafted the work or revised it critically for important intellectual content; (3) approved the version to be published; and (4) agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Abbreviations

SK, Scheurmann Kyphosis;
LL, Lumbar Lordosis;
PI, Pelvic Incidence

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