Iatrogenic Spinal Deformities

İatrojenik Spinal Deformiteler

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ABSTRACT

Iatrogenic spinal deformities can cause either sagittal or coronal imbalance. They consist of flat back syndrome, post-laminectomy kyphosis, proximal junctional kyphosis, failing of a spinal instrument, pseudoarthrosis, infection and using of instruments that cause anterior compression. We discuss the iatrogenic spinal deformities and alternatives for treatment in this review.

KEYWORDS: Spinal deformity, Flat back syndrome, Post-laminectomy kyphosis, Proximal junctional kyphosis, Fusion, Osteotomies

ÖZ

İatrojenik spinal deformiteler ya sagital yada koronal denge bozukluğu yaparlar. İatrojenik spinal deformiteler düz bel sendromu, postlaminektomi kifozu, birleşme yeri kifozu, enstrüman yetersizliği, psödoartroz, enfeksiyon ve anterior kompresyon yapan enstrümanların kullanımını içerir. Bu bölümde iatrojenik spinal deformiteler ve tedavi alternatifleri tartışıldı.

ANAHTAR SÖZCÜKLER: Omurga deformitesi, Düz bel sendromu, Postlaminektomi kifozu, Proksimal bileşke kifozu, Füzyon, Osteotomiler

INTRODUCTION

Spinal deformity is a dynamic and complex entity. To describe spinal deformity, destructions in the sagittal and coronal plate are used. As a general overview of spinal deformity, rigid deformities are most likely to be seen in adults, while adolescent patients tend to encounter more flexible spinal deformities (14). Deformities in adult patients are more likely to show up with pain and neurological deficits, while those in adolescent patients tend to be more cosmetic, including obvious aesthetic abnormalities (9,14,55). Deformity operations are highly complicated surgeries (14,51,55); and the risk of pre-operative and post-operative complications remains high even with an experienced surgery team (6,51,55). The surgical procedure, post-operative results and expectations of the patient should be thoroughly explained during the decision-making period. The main aim of deformity surgery is to relieve the patient's pain. A decompression might be performed to repair or ameliorate a neurological deficiency or to correct an incorrect alignment in the sagittal and coronal plates of the vertebrae by means of a properly done fusion (9). Additionally, this procedure may be necessary to achieve a stable, balanced, pain-free spine. A secondary aim of deformity surgeries is to correct and support the spine's cosmetic appearance (6,50,55).

Spine deformities can be classified into 2 general groups: scoliosis, including coronal plate deformities, and kyphosis, including sagittal plate deformities. These deformities can be either flexible or rigid and are classified according to age, with infantile scoliosis occurring between the ages of 0 and 2; juvenile, between 3 and 9 years, adolescent, between 10 and 17 years; and adult, at 18 years and older. (44). Idiopathic adolescent scoliosis, adult idiopathic scoliosis, degenerative scoliosis, congenital scoliosis and complex rigid multi-planar deformities, as classified into these 5 groups, represent pathologies that also affect a coronal imbalance (38).

Scheuermann kyphosis, post-traumatic kyphosis and congenital kypho-scoliosis are included as sagittal plate deformities.

Degenerative disc disease, facet joint disease, ankylosing spondylitis, trauma and post-laminectomy syndrome/kyphosis, and flat-back syndrome are other iatrogenic causes of sagittal plate deformities (45). As the present topic is iatrogenic deformities, we will expand upon each of these in greater depth within this review. Our description of the general principles of deformity will also be targeted toward our main focus, iatrogenic spinal deformities.

INTRODUCTION to IATROGENIC DEFORMITY

The modern surgical practices used to correct spinal deformities first emerged with improvements in the utility and ubiquity of Harrington rods (15,21). The next generation after Harrington rods was heavily influenced by Dwyer, Zilke, Luque and Cotrel-Dubousset, whose improvements to the instruments used during spinal surgeries contributed to the progression of deformity operations (11,17,39,40,64). These developments resulted in the Harrington rod system being better equipped to avoid the distractions of the vertebrae and have become commonly used to treat flat back syndrome in this population of patients (60). With the development of posterior segmental stabilization, the rates of flat back syndrome decreased (7,35,36,56,60). A pathology known as junctional kyphosis also commonly calls for the use of instrumentation above the level of fusion in the thoraco-lumbar or cervico-thoracal vertebrae (29). Fusions that end at the level of the 7th and 8th thoracic vertebrae are known as the apex of thoracic kyphosis and may lead to junctional kyphosis. Post-laminectomy kyphosis is mostly seen after multi-level laminectomy procedures, especially in the cervical region and in cases of facetectomies with facet capsule destruction (13). After cervical laminectomies in pediatric patients with incomplete bone development, post-laminectomy kyphosis is seen more commonly than in adult patients (13,28). The rate of post-laminectomy kyphosis may become much greater in the population of pediatric patients with malignant intramedullary pathologies following radiotherapy treatment. (13,63). Related iatrogenic spinal deformities can be classified as post-laminectomy kyphosis, flat-back syndrome and junctional kyphotic deformity. In the following sections, we will discuss these deformities and the treatment choices.

POST-LAMINECTOMY KYPHOSIS

Post laminectomy kyphosis is a sagittal plate deformity that occurs after multiple laminectomy procedures. Not often seen in early onset patients, such cases of kyphosis usually arise after a long period of time, alongside increased loading in the anterior corpus of the vertebrae and the absence of posterior tension bands. Facet articulation destructions may coincide, depending on the selected surgical technique and atrophy of the posterior cervical muscles. With the progression of kyphotic deformity facet articulation, destruction and insufficiency will lead to increased neck pain and the progression of cervical angulation, which may cause cervical myelopathy with progressive neurological deficits. Cases of symptomatic post-laminectomy kyphotic deformities are among the most important reasons for complex surgical procedures in iatrogenic spinal deformity cases (2,13,49).

Cervical post-laminectomy kyphosis rarely occurs in cases with multiple laminectomy levels. The incidence of cervical post-laminectomy kyphosis after multiple laminectomies is 20% (27), although this value may be higher in patients with pre-operative flattened lordosis and tendencies toward angulation, with decreased lordosis in the cervical region (27).

Another important factor is the resection of facets greater than 50%, which involves the destruction of facet articulation capsules, increasing instability and creating an insufficient posterior tension band. Ultimately, this technique will lead to the anterior angulation of the cervical vertebrae. Biomechanical studies also support these data (13,46).

Post-laminectomy kyphosis, which arises after multiple levels of laminectomy, is seen in pediatric patients much more commonly than in elderly patients; the incidences of partial fusions and degenerated spines further increase to 50% in patients who have undergone an intramedullary glial tumor operation, including a large laminectomy and radiotherapy. The application of radiotherapy to pediatric patients with malignant cervical tumors causes the destruction of bone tissue and leads to the destruction of bone development. Thus, the incidence of cervical sagittal deformities is increasing (31). Posterior instrumentation should be used as a supportive procedure for patients with lordosis who will undergo multiple level laminectomies with posterior fusion. For pediatric patients with incomplete bone development, posterior instrumentation is not a popular choice; however, if the patient has an operable, malignant spinal tumor with multiple levels of laminectomies but without the conservation of facet joints, posterior instrumentation following radiotherapy treatment should be applied. In patients with cervical lordosis, if possible, the first choice for treatment should be an anterior approach. Patients with post-laminectomy kyphosis should undergo a conservative treatment with a cervical collar and close follow-up. Corset-based treatments remain controversial (13). During the close follow-up of these patients, an operation should be performed if the kyphosis continues to progress.

In the cervical spine, cervical lordosis is classified between 14 and 20 degrees; thus, all cases of cervical kyphosis are believed to be pathological conditions (19). Before the operation, in addition to the cervical x-ray, hyperextension and hyperflexion x-rays should be taken. These will give us clues indicating whether the deformity is rigid or flexible. Cervical and 3-D cervical CTs should be taken to evaluate cervical deformities. Facet joints and their fusion are best evaluated by 3D-CTs; these images aid the decision-making process regarding the surgical procedure. Cervical magnetic resonance imaging provides details about the spinal cord in patients with kyphotic deformities but will also show any myelopathy or atrophy in the spinal cord.

Potential surgical approaches include anterior, posterior and combined anterior and posterior approaches (2,13). If cervical rigid deformities are not present, 5 days of pre-operative traction may be beneficial; however, this by itself will not be sufficient to correct the cervical kyphosis (13). An anterior release with an anterior approach can be applied in anterior corpectomies and multi-level discectomies (2,25). Later, during the distraction, the placement of allografts, cages filled with osteografts or allografts, or anterior plaques can also help to correct the cervical kyphosis (2,13,25). Much of the deformity correction can be managed by anterior corpectomy or discectomy during the distraction procedure (2,25).

If anterior releasing, multi-level fusion and corpectomy are performed for more than 2 levels, posterior instrumentation and fusion should be applied (2,48). Steady stabilization is achieved as the anterior approach is able to allow the correction of deformities with posterior instrumentation.

Smith–Peterson osteotomies or pedicle subtraction osteotomies can be performed to facilitate deformity correction in the posterior approach. Smith-Peterson osteotomy, which is achieved by posterior resection, provides only limited correction of deformities. Cervical pedicle subtraction can be applied to the C7 and T1 vertebra, although with a high rate of morbidities. Pedicle subtraction procedures carry a high risk of neurological deficiency, such as C8 nerve root injuries; quadriparesis should be avoided (13). Osteotomies will contribute to the deformity correction, decrease the load on the screws and support the stabilization system. Posterior cervical stabilization can be applied with lateral mass screws, especially at the C2 and C7 levels with pedicle screws. Posterior stabilization is achieved according to the features of the kyphotic deformity, although usually in cervical kyphotic deformity cases, C2-C7 are included in the posterior stabilization to achieve a steady construction. Some authors add T1 pedicle screws in this procedure (2). Cervical deformity surgery is a complex procedure, and the surgical plan and decision-making period will directly affect the result. A delayed cervical kyphotic deformity is most likely to be a rigid deformity; generally, the anterior approach alone will not be sufficient for such corrections.

In such cases, a 540-degree approach might be called for, including the anterior release of vertebrae, the use of posterior osteotomies to apply posterior fusion and stabilization, and the anterior fusion and plate insertion to support the system with anterior stabilization. As with all deformities, cervical kyphotic deformities should be analyzed according to each individual patient and only then should an approach be decided on (Figure 1A-H).

The development of kyphosis after laminectomy can also be seen in the thoracic spine. As in the cervical vertebrae before the completion of vertebral development, any laminectomies in the thoracic vertebrae may lead to kyphosis. Thoracal canal tumor excision, aneurysmal bone cysts, pediatric chondromas, osteoma and sarcoma excision can all lead to such deformities (Figure 2A-C). Patients with these conditions should be frequently followed up. If kyphotic deformities occur, the patient should undergo stabilization during the earliest onset possible. In delayed cases, the most important problem in the thoracic region is related to the rapid progression of kyphosis, which decreases the volume of the thoracic cavity, thoracic inspiration and expiration and leads to potential pulmonary complications, such as recurrent pulmonary infections and pulmonary insufficiencies related to cardiac insufficiency. These complications can be prevented with early recognition and deploying simple surgical procedures. In delayed cases, an anterior releasing and posterior correction is performed. Anterior releasing can be achieved with an endoscope. In the thoracic region, an anterior vertebrectomy may be performed to correct rigid deformities, and facet joints may be used for posterior unit resections. Depending on the severity of a posterior deformity, one or more pedicle subtraction osteotomies may also be sufficient for the kyphotic correction. The necessity completely depends on the surgeon's preferences and decision-making process. However, during an osteotomy and correction procedure, surgeons should be aware of a narrow spinal canal or the presence of the spinal cord in the thoracic region during every single step. Monitoring during correction is an important issue.

At this point, proximal junctional kyphosis is important. Especially when using instrumentation that ends at the cervico-thoracic junction level, the cervical vertebrae can slide anteriorly, relative to the bilateral facet subluxation, due to the hypermobility of the degenerated facet joints in the vertebrae above the level of the instrumentation. The most common clinical symptoms are neck pain and C7-T1 root compression symptoms (Figure 2D, E).

FLAT BACK SYNDROME

Flat back syndrome is usually iatrogenic and is mostly seen in patients with long thoraco-lumbar instrumentation and fusion (1,32,33,60). Flat back syndrome most commonly occurs after distractive instrumentation that elongates to the lumbo-sacral junction.

This syndrome is characterized by diminished lordosis in the lumbar area and causes pain, difficulty standing up straight and a forward-leaning body posture. Usually, in the process of supporting this body posture, these patients may experience neck and knee pain.

Such a scenario reflects a sagittal balance distortion. Flattened lordosis in the lumbar area causes the leaning forward of a patient's body. Distortion of the sagittal place constitutes a reason for a patient to flex his knees and extend his pelvis to preserve the standing posture, as both acts are commonly encountered compensation mechanisms against the disturbed sagittal balance (22,52,60). The lumbar lordosis ratio ranges between 31 and 79 degrees (45). The mean value of the lumbar lordosis is measured at 44 degrees (4). Patients with decreased lumbar lordosis to 30 degrees and flat back syndrome would present an anterior decompensation of the spine (18). A positive sagittal balance is seen in the flat back syndrome (22,60). To evaluate the whole spine and its sagittal balance, a 36-inch lateral x-ray including the cervical and lumbar vertebrae and the pelvic joints should be taken (18,22,60). In this x-ray, the patient's knees and pelvis should be in the extended position. The line that can be drawn from the middle of the C7 vertebrae to the back of the L5-S1 disc interspace is called the plumb line (22,45). Inside this line, 2 cm sliding is accepted as normal, while sliding greater than 2 cm is accepted as pathological (42). Inthe flat back syndrome, sliding generally moves forward in what is called a positive sagittal imbalance. Flat back syndrome was first seen after the application of Harrington rods during scoliosis operations using long segmental thoracolumbar instrumentation; distraction surgery was recognized to cause postural changes in patients (43,54). Flat back syndrome was first described by Doherty as a diminished physiological lumbar lordosis (16). The most important cause of flat back syndrome is the use of distractive instrumentation reaching the lower lumbar and sacral region. To prevent flat back syndrome caused by Harrington rods, new, square-shaped rods were developed and called square-ended Harrington rods (Moe Rods). Unfortunately, they too were unable to prevent flat back syndrome (42,60). After fusion operations, pseudoarthrosis was found to be responsible for the post-operative diminution in lumbar lordosis (45). During the operation, the patient's posture is important, especially given that the patient's pelvis should be in the complete extended position. In addition, no instruments should be used in the flexion position of the lumbar region. If flat back syndrome is to be prevented, the decompression portion of surgeries in the lumbar region should be in the neutral position (60). In spinal surgery, segmental distraction can be applied with pedicle screws and cages or bone grafts, which can be used for posterior lumbar interbody fusion and transforaminal lumbar interbody fusion. Focal kyphosis can arise as a result of segmental fusion (60). In elderly patients with decreased compensation mechanisms due to focal kyphosis and diminished lumber lordosis, sagittal imbalances may occur (32,60).

The prevention of flat back syndrome in the perioperative period is essential due to the 60% rate of complications in deformity surgeries aiming to ameliorate flat back syndrome (33). After the long-term usage of Harrington rods, which are mostly used in distractive surgery for scoliosis, flat back syndrome is commonly seen. However, the recent increase in the usage of pedicle screwing systems and posterior segmental instrumentation has decreased the incidence of flat back syndrome by supporting lumbar lordosis and preventing its flattening (7,35,36,60).

Conservative treatment remains the first treatment method. Conservative treatment includes non-steroid anti-inflammatory medications, exercises to increase pelvis and back extension, and corsets. If conservative treatment is not effective and symptoms increase, especially with a concurrent increase in the sagittal imbalance, surgery should be considered. Suitable surgical treatments include the Smith–Peterson osteotomy (SPO), polysegmental osteotomy and pedicle subtraction osteotomy (Figure 3A-C).

The correction of kyphotic deformities with surgery was first described by Smith–Peterson in 1945 (53). An osteotomy to resect the posterior units, thus undercutting the adjacent spinous processes, was proposed, after which the osteotomy would be closed posteriorly. Thus, the extension osteotomy

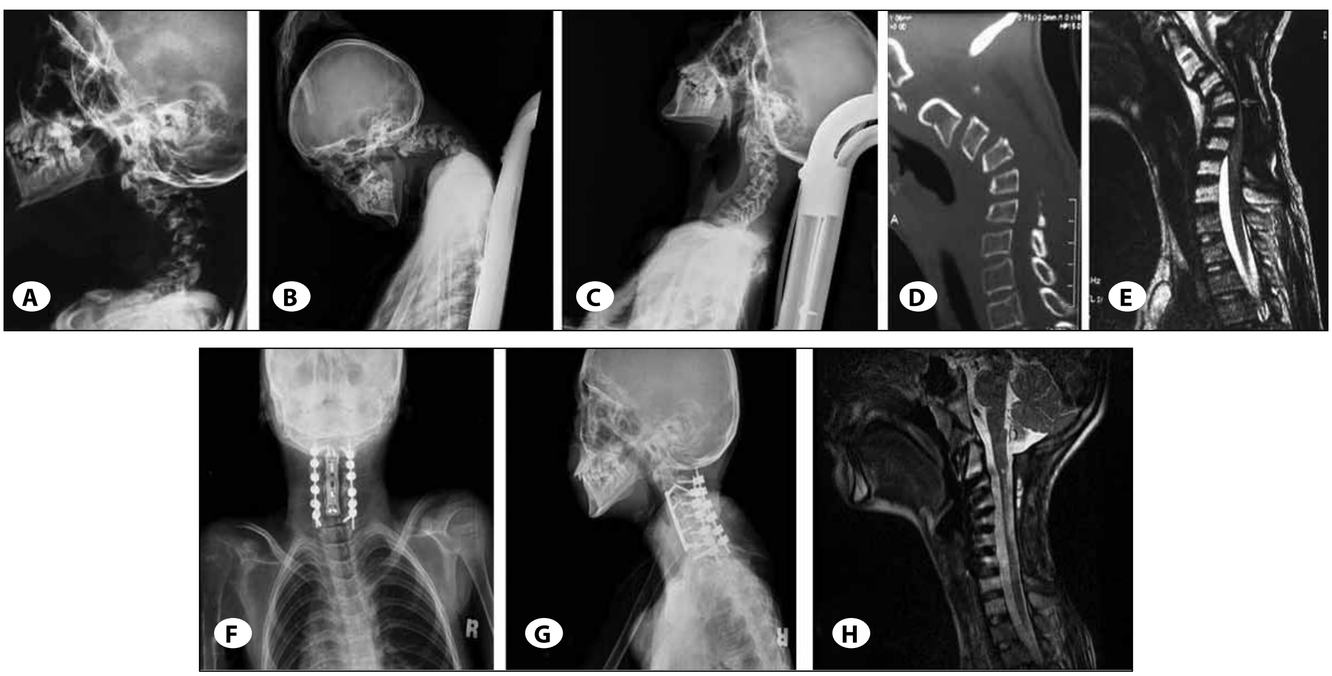

Figure 1: An 11-year-old male patient had a C1-C6 intradural intramedullary malignant tumor, and a C1-C6 laminectomy and gross total tumor resection were performed. Post-operative radiotherapy was administered due to a glioblastoma multiforme pathological result. After the 6th month follow up after the laminectomy, kyphosis was noted in the patient, and a re-operation was performed to treat the kyphotic deformity. At the patient's follow-up at the sixth post-operative month, he had neck pain and demonstrated a regression in his neurological status (tetra paresis). No correction of the deformity was evident in the pre-op x-rays, and fusion was observed at the level of the lower cervical laminectomy. Thus, anterior releasing, posterior osteotomy, instrumentation and fusion, anterior fusion and instrumentation were planned surgically. First, an anterior approach was used for the C2-C3, C3-C4, C4-C5 and C5-6 discectomies to achieve the anterior release (preserving the posterior longitudinal ligament). Next, the position was switched for a posterior approach, from which the lower cervical segments were fused. Polysegmental Smith–Peterson osteotomies were performed with C2 pars screws, C3-6 lateral mass screws and C7 pedicle screws, which were applied to restore the sagittal balance and posterior stabilization. Fusion was also performed. Then, the patient's position was again altered for an anterior approach, and a peek cage filled with osteografts was inserted. Fusion was performed at the C2-C7 region using anterior plaques. The patient underwent this procedure as a 540-degree surgery. No complications arose peri-operatively, and the patient's neurological status recovered rapidly. At the post-operative 6 month follow–up, fusion was observed. **A)** Pre-operative (deformity surgery) lateral x-ray. **B)** Pre-operative hyperflexion x-ray. **C)** Pre-operative hyperextension x-ray. **D)** Pre-operative sagittal CT image. **F)** Post-operative 6th month AP x-ray. **G)** Post-operative 6th month lateral x-ray. **H)** Post-operative 6th month MRI.

Figure 2: A 36-year-old female patient. Thoracic kyphosis developed due to a thoracic aneurysmal cyst (25 years ago), for which she received radiotherapy. The patient underwent an operation related to her back pain and her thoracic kypho-scoliosis. First T4, T5 and T6 corpectomy and anterior releases were performed during a thoracotomy; next, using a posterior approach, the C7-T9 posterior instrumentation and fusion were performed to correct the kyphotic angulation. Then, switching to an anterior approach, an expandable cage and fusion were applied between T3 and T7. A 540-degree approach deformity surgery was performed for the patient. Two months after the operation, a fractured vertebra was observed in the upper junctional area, and kyphosis was observed at the proximal junctional area. A second operation was performed to elongate the fusion to the cervical region, and the proximal junctional kyphosis was treated. **A)** The thoracic kyphosis that arose after the laminectomy was related to the thoracic aneurysm cyst treated 25 years prior to the present operation, shown in a lateral MRI image. **B)** AP and lateral x-rays after the deformity surgery; the posterior instrumentation and expandable cage and correction in the deformity can be observed. **C)** Post-operative correction of the thoracic kyphotic deformity can be observed on CT. **D)** Proximal junctional kyphosis after the deformity surgery and a C6-C7 cervical posterior unit separation and fracture can be observed above the fusion and proximal junctional kyphosis. **E)** After the second correction operation, an elongated cervical instrumentation to the C5-C6 cervical vertebrae can be seen in AP and lateral x-rays.

provides closure by extending to the posterior units and opening to the anterior units and anterior disc interspaces. Serious complications, such as aortic rupturs and, as a result of the tension in the cauda equina, paraplegia, have been related to anterior spinal column elongation (37,41,59,60). With the Smith–Peterson osteotomy, the shared aim of all of the modifications is to shorten the posterior column, elongating the anterior column to preserve lumbar lordosis. Most of the authors recommend polysegmental SPO over monosegmental SPO, the latter of which can lead to serious, long-term complications (3,10,23,60,61). Polysegmental SPO was first described by Wilkon and Turkel (61). In this technique, facet joints are resected on different levels, providing a posterior unit compression to preserve the lordosis. Thus, 10-15 degrees of segmental correction is gained with every SPO (5,23). With an SPO resection of 1 mm bone tissue, 1 degree of lordosis can be expected to be corrected (5,23).

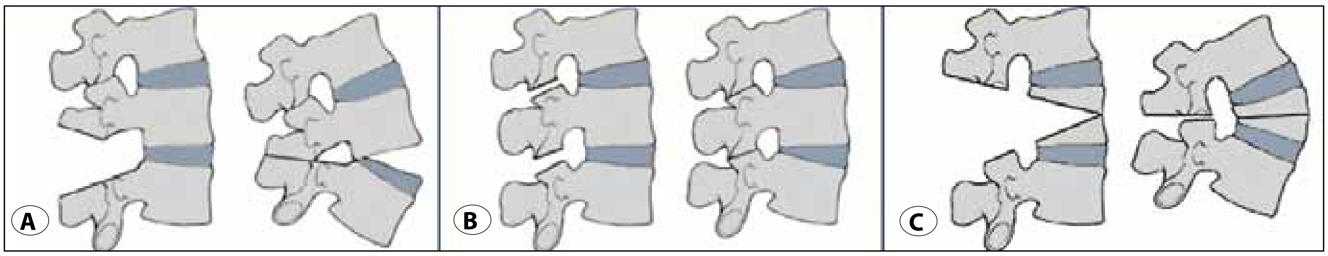

Figure 3: Osteotomy figures; **A)** Smith–Peterson osteotomy (SPO) with ruptured anterior longitudinal ligaments and resection of the posterior units; the anterior spinal column was elongated and the posterior column shortened for the correction. **B)** Polysegmental osteotomy. **C)** Pedicle subtraction osteotomy or closing wedge osteotomy (PSO).

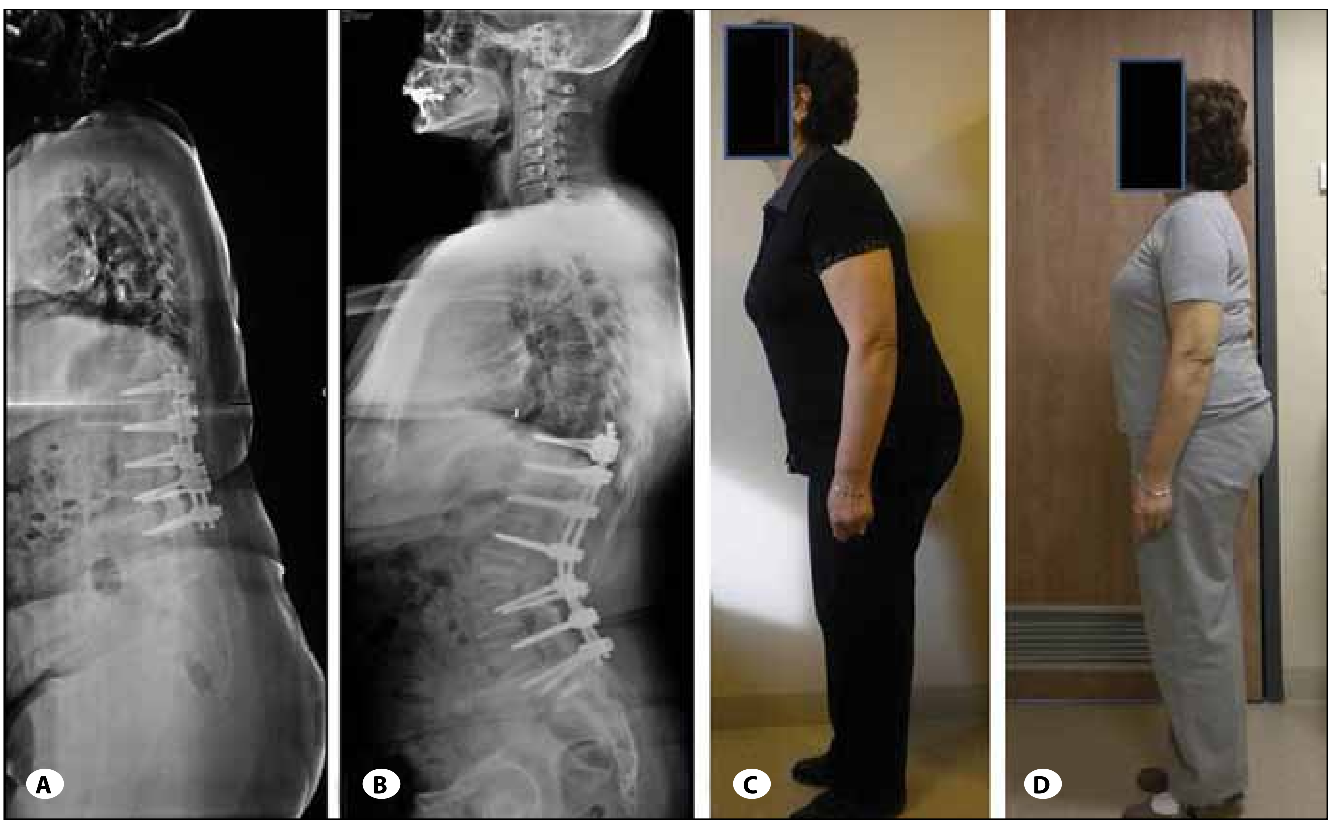

Figure 4: A 59-year-old female patient had undergone two operations related to degenerative spinal stenosis, but a year after these surgeries, the patient experienced progressive back pain and a leaning forward posture (flat back syndrome). The patient submitted to an operation for the flat back syndrome. An L2 pedicle subtraction osteotomy and a T10-L5 posterior instrumentation were performed to restore the sagittal balance. **A)** Pre-operative lateral x-ray showing lumbar region flat back syndrome; distortion in the sagittal balance is observed. **B)** Post-operative lateral x-ray showing a restored sagittal balance after L2 pedicle subtraction osteotomy and T10-L5 posterior instrumentation. A plumb line from the C7 corpus is shown vertically passing the sacrum. **C)** Pre-operative flat back syndrome and the related posture distortion, observed in a lateral x-ray. **D)** Post-operative correction of patient posture and restored sagittal balance, as observed in a lateral x-ray.

Pedicle resection (subtraction) osteotomy was first described by Heinig (24) as an eggshell osteotomy; later, Thomasen (57) modified and described it as a circumferential wedge excision osteotomy of the corpus. Both of these closing wedge osteotomies are based on the correction of the anterior apex at the same times as the spine is shortened posteriorly. In pedicle osteotomy subtraction, the posterior units, pedicles and transverse processes are resected. Through the pedicle, spongiotic bone tissue is extracted from the corpus; and through the posterior compression, the posterior column is shortened. With each osteotomy, 30-50 degrees of sagittal correction is attained (25,57,62) (Figure 4A-D).

JUNCTIONAL KYPHOSIS and OTHERS

Proximal junctional kyphosis is an important complication that is seen most commonly in adult patients after the application of long segmental instrumentation and fusion (29,62). In adult patients with long segmental instrumentation during fusion operations, the incidence of junctional kyphosis is 35% (58); however, the incidence in adolescent patients is low. Proximal junction kyphosis is mostly seen in posterior instrumented fusion surgeries, rather than in anterior spinal fusions. In symptomatic patients, pain, neurological deficits, gait disturbances, social isolation and distortion in the sagittal balance preservation can be observed (34,58).

Risk factors that lead to junctional kyphosis include the last vertebral choice for instrumentation; the last instrumented vertebrae on top and the destruction of the facet joint below it; muscle, ligament distortion; decreased support of the posterior structures; dissection of the muscles in the junctional area; and weakness of the posterior tension band (12,29,58,62). During the operation, sparing and preserving the posterior muscle tissue can be helpful to prevent proximal junctional deformities (20). Proximal junctional deformities and the changes in stress may cause proximal junctional kyphosis or the subluxation of a superior vertebra; segmental angulation can also be seen. Proximal junctional deformity usually arises in the first few months after surgery (30,58). Related to junctional deformity, the sagittal balance can be disturbed. Patients with junctional kyphosis and symptoms related to deformities generally require osteotomy with revision surgery. These surgeries are complex and have an increased risk of complications (20) (figure 2).

Another reason for an iatrogenic sagittal imbalance is the postoperative displacement of screws after a posterior segmental spinal instrumentation or instrumentation insufficiency.(20) Pseudoarthrosis arising after fusion surgeries and infected cases may also affect the formation of iatrogenic deformities (8,45). Other reasons for flat back syndrome can include the use of anterior compression instruments, such as those of Dwyer and Zielke. When using these instruments for anterior spinal colon compression, the preservation of lumbar lordosis might not be possible.

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