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Research article

Comprehensive Approach of the Diagnosis, Treatment, and Medical Rehabilitation of Patients with Spondylolisthesis

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Abstract: Spondylolisthesis represents the slippage of one vertebra over another, and is widely diagnosed among patients accusing low back pain. Despite most patients being asymptomatic, spondylolis-thesis can be the cause of extremely severe, irreversible, and invalidating symptoms. The most frequent types of spondylolisthesis are isthmic, degenerative, dysplastic, traumatic, pathologic, and iatrogenic. While numerous classification systems have been used to describe spondylolis-thesis, the descriptive Wiltse classification and the Meyerding classification based on the severi-ty of slippage are the most commonly used in current practice. The clinical evaluation is focused on the degree of pain, the presence of radiculopathy, and other neurological deficits, and is fol-lowed by diagnostic imaging, including standing anteroposterior and lateral spine radiographs, computed tomography, and magnetic resonance imaging. Therapeutic options include conserva-tive methods comprising symptomatic medication and physical therapy for low-grade spondy-lolisthesis with good to excellent results in the long term, as well as surgical treatment with a variety of possible techniques that allow for the reduction of the grade of slippage and obtaining the fusion of the affected level, followed by a well-tailored physical therapy program. The most important role for a patient's long-term satisfactory result is adequate medical rehabilitation, with consequent and properly designed regimens that the patients will adhere to for the rest of their lives.

Keywords: spondylolisthesis; diagnosis; treatment; orthopedics; medical rehabilitation; radiology; magnet-ic resonance imaging

1. Introduction

In the latest European health reports, cardiovascular diseases remain a significant challenge for healthcare systems worldwide, across Europe, and specifically in Romania. This is underscored by the high mortality rates attributable to cardiovascular causes – aprox 57% from the total annual deaths positioning Romania at the forefront of European negative statistics. Despite extensive research, numerous projects, and policies at various levels aimed at controlling risk factors and promoting health, global progress in reducing the incidence of cardiovascular diseases seems to be plateauing. There's a notable improvement in survival rates after cardiovascular events, prompting a focus on reducing overall mortality, rehospitalization rates, and enhancing the quality of life post-event(1–3).

Spondylolisthesis is a term generally used to describe any kind of displacement of one vertebral body over another. The origin of this word dates back to Ancient Greek, where spondyl (from the word "spóndylos") is referring to vertebrae, and oliothesis (from the word "olisthánein") means to slip [1]. The slippage can occur at any age, with different underlying causes. The presentation of spondylolisthesis can vary from asymptomatic, in an incidental finding, to lower back pain with a wide variety of degrees of pain, to radiculopathy accompanied or not by other neurologic deficits, to extremely severe cases. Treatment includes conservative methods, but can also require a surgical approach, followed by a well-designed and personalized recovery plan [2].

2. Epidemiology

The epidemiology of different types of spondylolisthesis, caused by various factors, remains a topic of controversial discussion. The incidence of spondylolysis in adults varies across different ethnic groups and is reported to be 6.4% in caucasian males, 2.8% in African-American males, 2.3% in caucasian females, and 1.1% in African-American females [3]. Furthermore, the highest incidence of spondylolysis of the lumbar spine was reported in the Eskimo skeletons from Alaska, Canada, and Greenland with a prevalence of 45-54%, suggesting a genetic factor involved [4]. The fifth lumbar vertebra is most frequently involved.

Spondylolisthesis is less frequent than spondylolysis, with a prevalence of 3.1% in the general asymptomatic population [5]. Most of these patients are asymptomatic. Moreover, young athletes have a higher incidence of spondylolysis and rates of progression to spondylolisthesis than the general population, especially in sports that require hyperextension and torsion of the lumbar spine [6].

Degenerative spondylolisthesis has a higher prevalence in women, with African-American women being the most affected by this disease. The L4-L5 level is usually affected by degenerative modifications of the spine, leading to instability. Pregnancy has a possible influence on the development of degenerative spondylolisthesis, with a higher incidence of 28% in women who had borne children, than 16.7% in nulliparous women [7].

3. Pathogenesis

Isthmic spondylolisthesis is absent or extremely rare in newborns and individuals who are nonambulatory [8]. The risk of progressive slippage is higher during rapid growth spurts, and as the patient ages, the risk of progression decreases. The defect in the pars interarticularis weakens the structural elements of the adiacent vertebrae, which progresses into a translational instability, that will further affect posterior stability elements. This can lead to global sagittal imbalance, compensatory posture, and altered gait [9].

Degenerative spondylolisthesis is defined by the presence of an intact pars. Facet joints are affected by chronic degenerative modifications, along with the disc space narrowing that influence the normal segmental stability. Anatomic variants of the lumbar spine, including lumbar lordosis, lumbosacral angle, sagittal orientation of the facet joints, pelvic inclination angle, and sacralization of the L5 are considered risk factors for the development of degenerative spondylolisthesis [10].

Other causes for spondylolisthesis are rare and include congenital or dysplastic spondylolisthesis (due to abnormalities at the lumbosacral level, either of the upper sacrum or the neural arch of L5), traumatic spondylolisthesis (with an acute instability due to trauma that can fracture the facet complex or can rupture different ligamentous structure), pathological spondylolisthesis (affecting the posterior column of the spine due to generalized or local bone disease such as neoplasm of infection) [11,12].

4. Classification

Wiltse et al. separate spondylolisthesis into five groups, based on their etiology [13]. Type I is a congenital or dysplastic spondylolisthesis, where a congenital dysplasia is present, either of the upper sacrum or the neural arch of L5, allowing the last lumbar vertebra to slip forward. Type II is an isthmic spondylolisthesis when the lesion is found in the pars interarticularis. This type is further divided into three subtypes: IIA – lytic, or separation of the pars, IIB – elongation of the pars, but without separation, IIIC – acute pars fracture. Type III is a degenerative spondylolisthesis, most frequently caused by arthritic changes, with weakening of the ligamentum flavum, permitting the slippage of vertebrae [14]. Type IV spondylolisthesis is post-traumatic, after a severe injury that leads to a fracture in a region of the vertebra, other than the pars. Type V is a pathologic spondylolisthesis, that can be caused by generalized or local bone disease [15]. There is also described a type VI spondylolisthesis, iatrogenic, usually seen in patients who had other spinal surgery in the past, such as laminectomy [16].

The Wiltse classification is a descriptive one, not offering information related to the severity or the progression of the disease. To address this need, Meyerding developed a classification, grading spondylolisthesis from I to V according to the severity of slippage, on standing lateral lumbar spine radiographs. Drawing a line that goes through the posterior wall of the two adjacent vertebral bodies to assess the translation of the two vertebrae in comparison with the length of the vertebral body below. The grading scale of Meyerding is as follows: grade I – 0-25% slippage, grade II – 25-50% slippage, grade III - 50-75% slippage, grade IV – 75-100% slippage, grade V – greater than 100%, also known as spondyloptosis. Grades I and II are low-grade slips and grades III, IV, V are considered high-grade slips [17]. Two illustrative cases are shown in Figures 1 and 2.

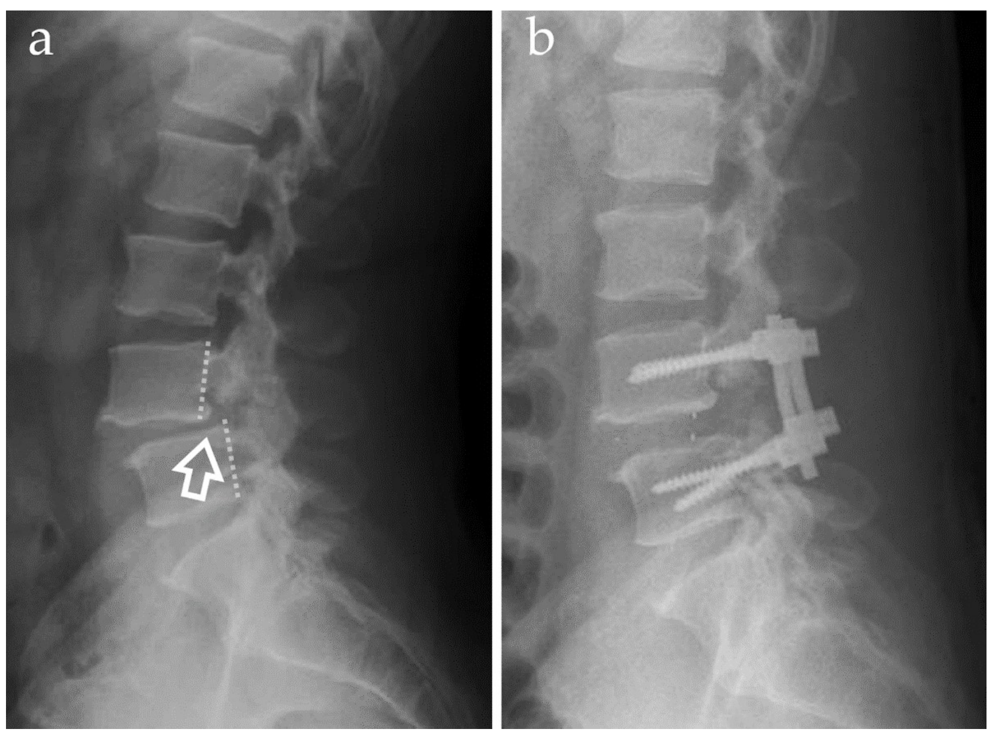

Figure 1 The case of a patient with a low-grade L4-L5 spondylolisthesis, Meyerding grade I (a), and the postoperative result after decompression and PLIF in the L4-L5 level (b).

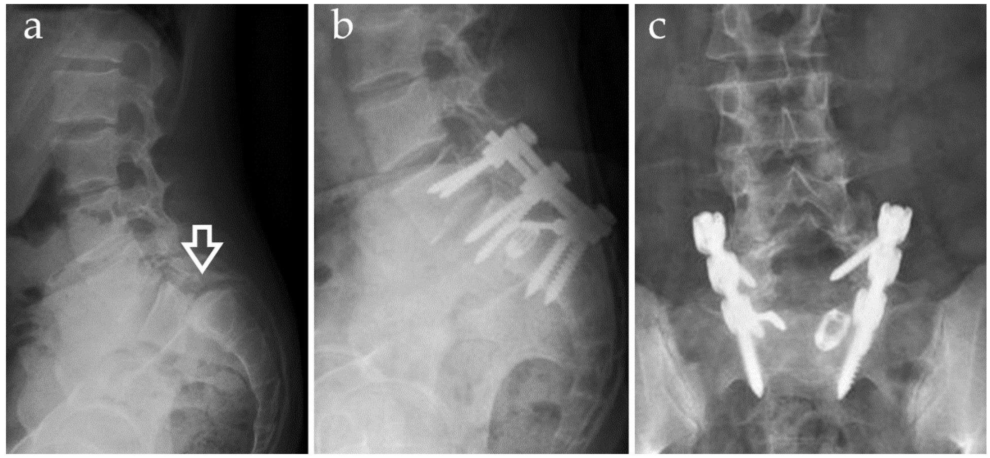

Figure 2. The case of a young adult with a high-grade dysplastic spondylolisthesis, Meyerding grade IV (a), and the postoperative result after posterior approach (b,c).

5. Clinical evaluation

The presentation of spondylolisthesis can vary from asymptomatic, in an incidental finding, to lower back pain with a wide variety of degrees of pain, to radiculopathy accompanied or not by other neurologic deficits, to extremely severe cases, such as cauda equina syndrome. The majority of patients who are diagnosed with spondylolysis or spondylolisthesis are asymptomatic, their diagnosis being an incidental finding on X-rays performed for other conditions [18]. The most frequent symptom is lower lumbar back pain, which can vary from daily to seldom in terms of frequency, and from just a minor pain to disabling, severe pain in terms of intensity. The differential diagnosis should include other sources of lower back or buttock pain as well as peripheral neuropathy regardless of the cause [19-24].

In isthmic spondylolisthesis, symptoms can occur anytime from early childhood to adult life. Low back pain is the most frequent symptom experienced by patients. Previous trauma is not usually acknowledged. The physical examination can identify the loss of the lumbar lordosis, or flattening of the lower back, muscle spasm, hamstring muscle tightness, a prominent sacrum, or low back or buttock pain worsened by spinal flexion and extension [25]. Aggravating pain through extension is due to facet joints or pars pathology, whereas pain with flexion or sitting is caused by intervertebral disc pathology. Insidious onset of symptoms can progress, with worsening pain over time and symptoms of nerve root compression, such as radiculopathy or neurogenic claudication. Compression of the exiting nerve root will cause radiating leg pain, that can be associated with paresthesia or weakness during different activities [26]. In extremely severe cases, progressive spondylolisthesis can lead to worsening radicular pain, associated with bowel and bladder dysfunction and other neurologic deficits, such as in cauda equina syndrome.

Degenerative spondylolisthesis occurs with chronic degenerative modifications represented by hypertrophy and subluxation of the facet joints, accompanied by ligamentous hypertrophy, intervertebral space narrowing, and disc degeneration, leading to exiting root compression and symptoms of central canal stenosis. Symptoms of degenerative spondylolisthesis include back pain, leg pain, neurogenic claudication, radiculopathy with motor weakness, sensory deficits, and changes of the specific reflexes with bowel and bladder dysfunction [27].

In congenital or dysplastic spondylolisthesis, the most affected level is L5-S1, where a congenital dysplasia is present, either of the upper sacrum or the neural arch of L5, allowing the last lumbar vertebra to slip forward. Due to the fact that the pars interarticularis is intact, the progressive slippage will cause symptoms of central spinal stenosis, with specific clinical findings, in early adolescence or young adulthood.

In traumatic spondylolisthesis, because a high-energy trauma is necessary for the displacement to take place, other injuries that involve the bony parts of the spine, ligamentous system, soft tissue surrounding the spine, and neurovascular elements are present. The clinical findings can vary from severe back pain to radiculopathy with hypoesthesia, to bowel and bladder dysfunction or cauda equina, to paraplegia [28].

In pathologic spondylolisthesis, most symptoms occur insidiously and are accompanied by other general symptoms, depending on the original cause. Usually, nighttime pain is highly suggestive of a malignant cause. Osteoporosis is associated with generalized bone-related pain and fractures with no significant trauma [11]. Various serum parameters may be altered depending on disease severity, duration, and comorbidities [29].

6. Diagnostic imaging

The first imaging tool used for the diagnosis of spondylolisthesis in most patients is represented by standing anteroposterior and lateral radiographs. Supine radiographs should be avoided, as they can allow the slipped vertebra to be temporarily reduced, generating a false-negative diagnostic. On the anteroposterior view, the pars region is analyzed and the "Napoleon's hat" sign can be identified, suggested by the lucency in the pars region that is fractured and compensatory sclerosis on the contralateral side. On the standing lateral view, the degree of anterior slippage can be identified and the pars fracture will become more visible [30]. Another characteristic sign in spondylolisthesis is the "Scotty dog" sign, introduced by Millard, visible in an oblique profile view, resembling a Scottish Terrier, where the collar of the dog is represented by the bilateral defect or fracture in the pars [31]. Flexion and extension lateral images are used for assessing hypermobility. The Ferguson anteroposterior view can be used to assess the L5-S1 disc space and the posterior elements of L5 and S1. Scoliosis films can be used for evaluating the global sagittal balance.

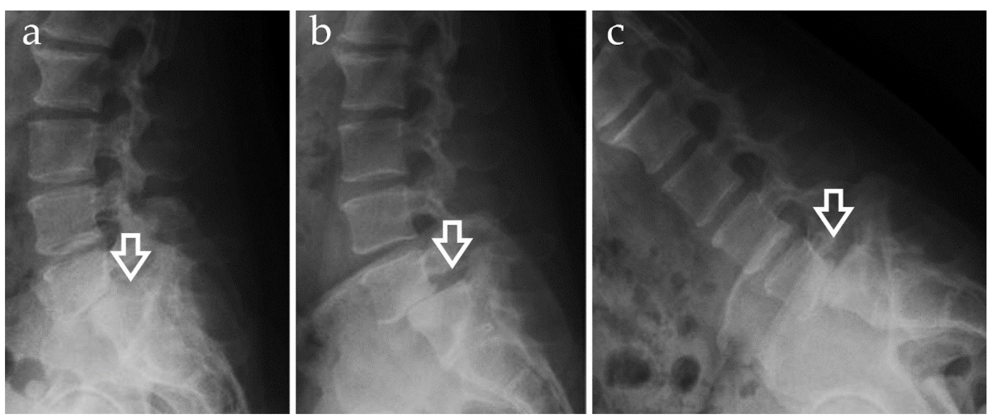

Figure 3. The radiographic diagnosis of spondylolisthesis starts with standing radiographs centered on the affected level (a). In order to assess the mobility of the level and the instability of the spine segment, flexion (b) and extension lateral (c) views are obtained.

The computed tomography (CT) examination can be used whenever there is a high clinical suspicion of spondylolysis or spondylolisthesis with negative radiographs, or as a preoperative tool in order to assess the anatomy of severe cases of spondylolisthesis with the help of 2D- and 3D- reconstructions [32].

Magnetic resonance imaging (MRI) is useful for patients with neurologic deficits, in order to evaluate the grade of compression on the neural elements. T2-weighted images offer information about the level of hydration of the intervertebral discs or changes occurring in the vertebral endplates, suggesting degenerative processes, and can help the surgeon to preoperative assess the levels of the spine to be fused.

Transitional vertebrae or any numeric variants of the spine should be thoroughly recorded alongside any anatomic variation of the surrounding tissues and vessels, as they can be of relevance in the surgical approach [33-35]. It is advisable to use international nomenclature when reporting imaging findings to achieve a good understanding between radiologists and clinicians [36].

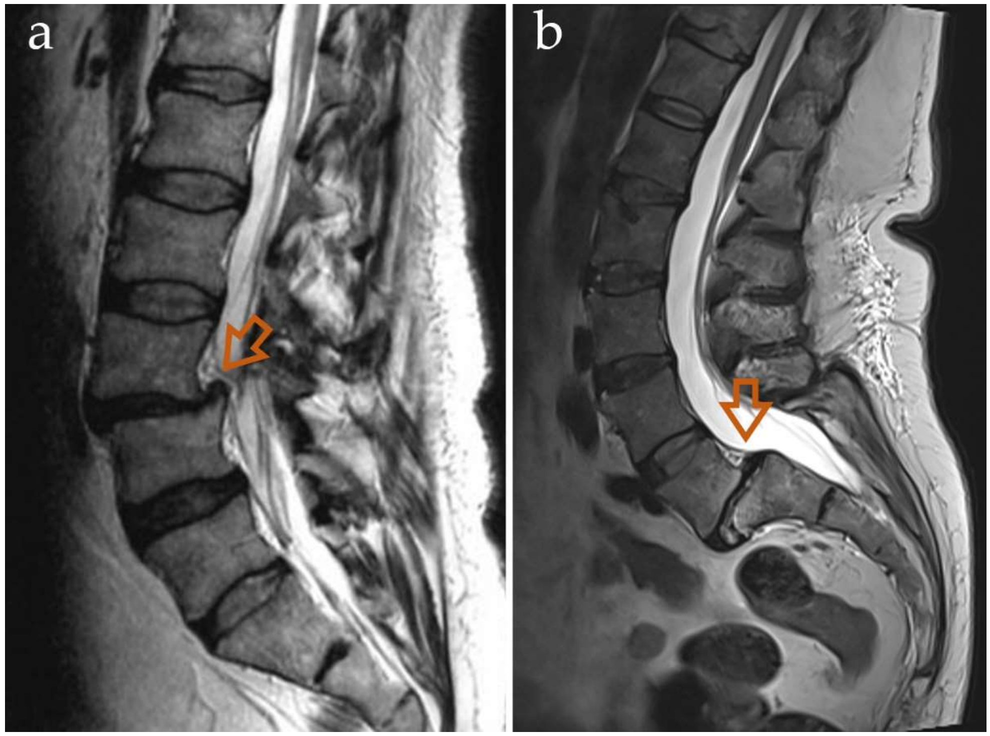

Figure 4. Sagittal images of MRI investigations in T2-weighted sequences, used for evaluation of the neural elements in two patients. A certain degree of slippage can be seen (orange arrows), but as the MRI is performed in a supine position, the slippage can be temporarily reduced, therefore the evaluation of the vertebral slip is best assessed on standing radiographs.

6. Therapeutic options

6.1. Conservative or nonsurgical treatment

The first line of treatment in most cases of spondylolysis, low-grade spondylolisthesis, and every diagnosed new case of spondylolisthesis, except for those with severe and progressive neurologic deficit, is represented by conservative treatment. Spondylolysis is a frequent diagnostic in children, with a prevalence of 12.3% in pediatric patients with back pain [37]. The majority of young adults diagnosed with spondylolysis or isthmic spondylolisthesis can be treated with conservative treatment, with positive results. In a meta-analysis study, it has been stated that over 83.9% of patients who were treated using nonsurgical treatment had a successful clinical outcome after at least one year, despite most defects remaining unhealed, with pars defect still visible [38]. Moreover, the majority of athletes with low-grade isthmic spondylolisthesis treated with conservative methods are expected to return to their activities within 3-6 months [39].

The initial treatment of spondylolisthesis will include a short period of rest or sports activity restriction and the use of medication in order to control the pain (usually this can be achieved with a nonsteroidal antiinflammatory, acetaminophen, or narcotics, associated with muscle relaxants) for two weeks. After this period, if symptoms have not resolved, physical therapy should be considered as the next step of treatment [40]. Within the physical therapy program, exercises that require trunk stabilization, flexion-extension strengthening exercises, avoiding hyperextension, core stabilization exercises, cycling, swimming, and elliptical machines, weight reduction and activity modifications have all been shown to have a positive response in the treatment of low back pain. Furthermore, Arima et al. have studied the effects of low-intensity pulsed ultrasound (LIPUS) on the union rate of spondylolysis, and the results were satisfactory, with patients receiving LIPUS daily having a higher union rate than patients who only received conservative treatment [41].

Spondylolisthesis symptoms can also benefit from steroidal injection therapy, whether they are pars injections, epidural injections, facet joint injections with or without guidance.

6.2. Operative treatment

Non-surgical treatment has a successful rate in most patients, especially those with low-degree slippage and mild symptoms. However, there are a number of patients with symptoms that do not improve or even worsen during conservative treatment. The indications for surgical treatment can be synthesized within the following: patients with persistent symptoms after a 3-month trial of conservative treatment, progressive neurologic deficit or extremely severe neurologic involvement at diagnosis, a high-grade slippage from the start, a high degree of instability, neurogenic bladder or bowel symptoms [42].

There is a lack of consensus regarding the technique in the surgical treatment of spondylolisthesis in regard to providing the fusion of the affected level with or without the use of instrumentation, reducing the slippage to 100% or 50%, or in-situ fusion, the importance of decompression and other topics. Patient selection is crucial: smokers, patients with a low educational level, obese females, patients with psychiatric pathology, patients receiving compensation, and others have lower levels of satisfaction after surgery [43,44]. Extreme care and preparation must be taken in the surgical treatment of a spondylolisthesis that associates other pathologies of the spine, such as osteoporosis, congenital deformities of the spine, spinal tumors, spinal canal stenosis, scoliosis, and many others. Preoperative digital planning is usually performed in order to accurately predict the extent of the surgery and the necessary osteosynthesis devices [45].

6.3. Decompression alone

Decompression is used to relieve symptoms of radiculopathy and neurogenic claudication. Decompression alone should not be used in children, because of the risk of progressive slippage. It is also not recommended for people with dynamic instability, for the same mechanical reasons [30]. In cases of degenerative spondylolisthesis, where spinal stenosis and degenerative facet joints are present, decompression is useful. The most frequent decompression technique is the Gill laminectomy, with resection of all bone and fibrous soft tissue that lies distally from the pars affected. Care must be taken to prevent the progression of slippage by an iatrogenic instability. In a comparative study of three surgical approaches in the treatment of spondylolisthesis, the result showed that posterior decompression with preservation of the articular processes offers good to excellent results over time [46].

6.4. Decompression with posterior and posterolateral fusion

Because of the risks of iatrogenic instability after decompression alone, along with a higher rate of pseudarthrosis and poor clinical outcome, posterior and posterolateral in-situ fusion have been proposed, usually done with autogenous cancellous bone graft. The number of fused vertebrae depends on the degeneration processes at adjacent levels of the spondylolisthesis. The autogenous cancellous bone graft is most frequently used from the iliac crest. The recipient site for grafting needs to be prepared with subperiosteal dissection of the facet joints and removing all cartilage from the facet joints that will need to be fused. The cancellous bone grafts prepared will be introduced in the recipient site, from the pars interarticularis to the tip of the transverse process, on both sides [30].

In a prospective, randomized study by Herkowitz and Kurz, patients treated with both decompression and fusion had better results regarding the relief of back pain and pain in the lower limbs, than those treated by decompression alone [47].

6.5. Posterior lumbar interbody fusion - PLIF

The role of adding instrumentation to the surgical plan of spondylolisthesis was to achieve better rates of fusion and therefore improve most clinical outcomes, with the specific disadvantages of possible complications of the instrumentation and, of course, higher economic costs. Yuan et al. reported a significantly higher and faster fusion rate, better functional and clinical results, along with superior spine alignment in the group of patients with pedicle screws implants [48].

Using a posterior approach to the spine, pedicle screws are placed bilaterally, followed by a Gill decompression. With the use of retractors, the nerve roots and the dural sac are retracted medially in order to expose the disc space and remove the disc. After the disk space is freed, cancellous autograft, cages, or interbody fusion devices are placed in the anterior third of the disc space, from both sides of the dura, followed by compression in the posterior instrumentation, in order to allow the restoration of the anatomic lordotic segment of the spine [30].

TLIF – or unilateral PLIF, described by Blume, is a technique that approaches the disc space in the foraminal region, with preservation of the ligamentum flavum and all the stability elements from the contralateral side [49]. Anterior placement of the cage or interbody fusion device is the key to restoring the lordosis of the spine segment.

6.6. Anterior lumbar interbody fusion – ALIF

ALIF, or anterior lumbar interbody fusion, is a procedure that provides access to the anterior part of the spine, via a transabdominal or retroperitoneal approach, in which the degenerated disc is removed and the disc height is restored with the use of a graft, cage or interbody fusion device. An ALIF procedure will help decompress the posterior neural elements and relieve the symptoms of compression. A study comparing patients with degenerative spondylolisthesis treated with ALIF or posterior decompression suggested the use of ALIF only in the early stages of degenerative spondylolisthesis, when the main compression factor is the slipping vertebra and the use of posterior decompression in the late stages of degenerative spondylolisthesis, when stenosis is aggravated by the presence of articular processes osteophytes [50]. ALIF can be used as a sole procedure or it may be combined with a posterior procedure for better support, depending on the complexity of the spondylolisthesis case and the experience of the surgeon. Robotic surgery is also a viable option and is increasingly applied for a variety of orthopedic procedures, including spinal surgery [51-53].

Among the complications of the approach are vascular injuries, visceral injuries, incisional hernia, temporary dietary changes like ileus or constipation, retrograde ejaculation in males, and deep vein thrombosis.

Recent advancements in biomaterials, including 3D printing of personalized grafts for osseous reconstruction have allowed for improved healing and faster recovery, with the advantage of optimal pre-planning in regard to patient anatomy [54-56].

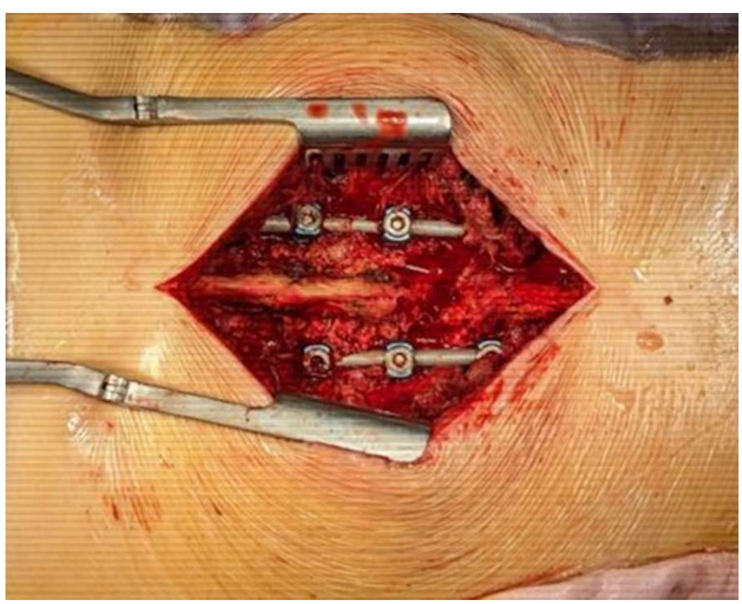

Figure 5. Intraoperative photo of a L4-L5 degenerative spondylolisthesis, in which L2-S1 posterior fixation along with L4-L5 decompression were performed.

6.7. Postoperative care after spinal surgery for spondylolisthesis

After surgery, the patient is mobilized on the first post-operative day, under the supervision of a physical therapist. Most people are able to return home 3-5 days after surgery. The most important aspect of postoperative rehabilitation and care is to keep the spine aligned correctly, thus the workload on the spine is minimal, and the healing process is ensured. The patient gets out of bed and starts walking starting from the first – postoperative day, to the point of minor-moderate aching [57].

In the first six weeks after surgery, the patient is advised to avoid bending forward or backward, twisting of the spine and lifting weights that are more than 2 – 4 kg. During this period, walking is the main form of physical activity and plays an important role in the rehabilitation of an operated spine.

Six weeks to three months post-operative, patients will begin a tailored physical therapy program. The first exercises are static stabilization exercises, that can be performed in bed, only moving the arms or legs, without the need to involve the trunk. After strength build-up, more and more exercises will be added. The next set of exercises will include dynamic exercises, first with body weight only and after strength is built up, resistance bands or exercise therapy balls can be added. Stretching activities are as important as strengthening activities and should be included in the recovery program.

In three months after surgery, most of the patients progressively return to their daily activities, continuing their physical therapy program. Low-impact aerobic exercises should be added, swimming is recommended at this point. High-impact exercises should be avoided, such as jogging or running, and contact sports [58].

Bending, lifting, and twisting are allowed as soon as some form of fusion is confirmed on radiographs. This is expected to happen somewhere between 6 and 12 months after surgery. However, patients are advised to use all the techniques learned during recovery and apply them to everyday life, such as not forgetting about stretching, bending the knees when lifting heavier weights, and continuing the strengthening exercises for the back musculature.

Postoperative care is continued long-term with patient monitoring and regular scheduled follow-up visits. These aim to ensure that the patient has a proper recovery and to prevent the onset of complications which may include infection, non-union, and neurological deficits [59]. Implant failure is a possible occurrence in all orthopedic surgeries, regardless of the treated site, implant type or size [60,61].

7. Conclusion

The presentation of spondylolisthesis can vary from incidental to extremely severe cases such as cauda equina syndrome. A thorough history and physical examination, followed by the use of imaging tools such as standing radiographs, CT, and MRI will certify the diagnosis. Initial treatment is conservative, with symptomatic therapy using NSAIDs and muscle relaxants, steroid injections, and a well-conducted physical therapy program. Some cases may benefit from operative treatment from the start or after conservative treatment has failed and will require surgical decompression, with or without instrumented fusion. Recovery programs are extremely important in patients with spondylolisthesis and require progressive strengthening of the back musculature, stretching exercises and aerobic low-impact exercises.

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