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LITERATURE REVIEW

A Novel Technique for Spondylolysis Repair With Pedicle Screws, Rod and Polyester Band

Case Report With Technical Note and Systematic Literature Review

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Study Design. Systematic review and case report.

Objective. Our study aims to present a new technique using three components to repair the pars defect: pedicle screws, rod and polyester band. Furthermore, we perform a systematic literature review of the previously described techniques.

Summary of Background. Spondylolysis is a common condition in children and adolescents. Depending on the severity it may be treated either nonoperatively or surgically. Surgery is required if nonoperative treatment failed to give sustained pain relief. Several surgical techniques have been described.

Methods. The literature review investigates the database (MEDLINE-EMBASE-Cochrane-ScienceDirect) up to May 2019 for studies presenting a surgical technique for spondylolysis.

The Screw-Rod-Band (SRB) technique combines the use of pedicle screws, a rod and a polyester band to repair the spondylolysis. The horizontal rod connects the pedicle screws. The polyester band linked to the rod passes below the spinous process to apply compressive forces on the pars.

Results. Twenty-one out of 982 studies described a surgical procedure. Eight main different techniques were identified: Isthmic Screw, Wiring, Butterfly-Plate, Hook-Screw Construct, Shaped-Rod, Laminar-Screw, and two combination technique (Lag Screw and Tension Band Fixation and Cortical Screws and Spinous-Process ModularLink). Our technique showed immediate postoperative clinical improvement. No surgical or perisurgical complication occurred.

Conclusion. The systematic literature review revealed a great number of surgical techniques for the spondylolysis, demonstrating the lack of consensus.

SRB technique is an effective and simple treatment for pars fixation. The surgical procedure puts the pars under strong compression. The results are comparable with procedures present in the literature and seems capable to reduce the invasiveness and the risk of neurological injury.

Key words: fixation, isthmic repair, pars interarticularis, spondylolysis, surgery.

Level of Evidence: 2

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Spondylolysis is defined as a defect or fracture of the pars interarticularis, or isthmus, located in the transition area between the superior and inferior articular processes of the vertebral arch. Described in the mid-1800s by Kilian, Neugebauer, and Lambl,[1–4] its incidence varies considerably depending on ethnicity, sex, age, level of the sporting activity, occupation, and certain disease.[5]

Fredrickson *et al*[6] reported in a prospective study that the incidence of spondylolysis at the age of 6 years was 4.4% and increased to 6% in adults, and to 15% in adolescents who practice sports involving repeated hyperextension and rotation of the lumbar spine.[7,8]

The etiology of spondylolysis remains unknown, but current opinion is that there is an element of weakness that is genetically determined, or a degree of dysplasia at the pars interarticularis that renders it susceptible to injury even under the stresses of regular activity, resulting in a stress fracture.[9] High pelvic incidence has been shown to be a risk factor for spondylolysis and spondylolisthesis.[10,11] Patients with spondylolysis can be asymptomatic[12,13] or develop initial symptoms during late childhood, at a period of increased athletic activity.

The treatment of spondylolysis varies from nonoperative (rest, analgesia, physiotherapy, brace, or local injections), to surgical when pain is resistant to nonoperative treatment after at least 6 months.[14] If a painful spondylolysis occurs in a young patient with a still intact disc,[15] without a relevant

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The device(s)/drug(s) is/are FDA-approved or approved by corresponding national agency for this indication.

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spondylolisthesis,[16] a direct repair of the spondylolysis without fusing the segment may be the treatment of choice. The goals are to obtain the isthmus reduction and fusion, to restore the spinal stability, and to preserve the mobility of the segment concerned. Many surgical techniques are reported, varying from fixation with screws or hooks, wiring or a combination of the above. Results are generally acceptable, but a percentage of implant failure is reported and can lead to the non-union of the isthmus.

Our study aims to review the techniques previously described and present a case treated with a new surgical procedure. This new technique, a modification of Scott wiring method,[17] combines the use of pedicle screws, a rod and a polyester band to repair the spondylolysis.

MATERIALS AND METHODS

Case Report: Screw-Rod-Band (SRB) Technique

In July 2016, a 14-year-old male (50 kg, 155 cm) affected by L5 spondylosis with history of persistent low back pain (Oswestry Disability Index (ODI) 24, Visual Analog Scale (VAS)-back 6, and VAS-leg 0) underwent a L5 isthmic reconstruction. The patient gave an informed consent for the modified procedure aimed to preserve the spinal mobility, reduce the surgical invasiveness and the potential risks of neurological injury. The procedure combines the use of pedicle screws, a rod and a polyester band to repair the spondylolysis. The pedicle screws serve as anchors in the anterior part of the vertebra. A horizontal rod connects the pedicle screws. The polyester band links to the rod and passes below the spinous process of the spondylolytic vertebra. Tensioning of the band compresses the pars defect to create stability and promote fusion.

Intraoperatively, the patient was placed under general anesthesia in a prone position. Through a median longitudinal posterior approach, with limited paravertebral muscle splitting, the pars interarticularis is exposed bilaterally. The pars defect is prepared by removing the interposed soft tissue and curetting the bony ends. Two polyaxial pedicle screws of 6 to 6.5 mm in diameter and of appropriate length are inserted into the lytic vertebra utilizing a standard technique. A rod is inserted horizontally connecting the two screws and piercing the interspinous ligament above the lytic vertebra, and the nuts are locked definitively. A commercially available polyester band is passed from the right under the base of the spinous process of the lytic vertebra, around to the left side of the rod, again under the base of the spinous process from left to right, and finally connected to the right side of the rod. The tensioning of the band results in a compressive force across the pars interarticularis. This step is completed when the gap, created by Gill body resection, is completely closed. If a minimal residual gap is still present, it can be filled with autologous bone graft, which is also used when the opposed bone surfaces are sclerotic (in such case, the end surfaces are refreshed with a sharp curette or a low speed burr). The band is locked after tensioning, providing stability (Figure 1). The final positioning of the implants is checked by intraoperative radiography. The wound is thoroughly washed and closure performed as per routine.

Pre and postoperative radiographs of the patient are shown in Figure 2. The drain is removed on the first postoperative day. The patient is allowed to stand up 2 days after surgery. No brace is required but extension and torsion movements are to be avoided for 4 months after the procedure. To confirm bone union, a low-dose Conventional Tomography scan 3D reconstruction[18] and a lateral radiograph is performed at the 4-month follow-up. At the 4-year follow-up, no complications occurred, the patient was satisfied good clinical (ODI 4, VAS-Back 1, VAS-Leg 0) and radiographic outcome achieved (Figure 3).

Systematic Literature Review

Study Design

A computer-based literature search was performed to identify all studies examining original techniques for surgical spondylolysis repair. Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines were followed during the design, search, and reporting stages of this systematic review.[19]

The PubMed database was searched from its inception point to June 2020. The search terms were ''spondylolysis,'' ''pars interarticularis,'' ''surgery,'' ''repair,'' ''fixation,'' or ''reconstruction.''

The search string was: ((((((((((spondylolysis) AND surgery)) OR spondylolysis) AND repair)) OR spondylolysis) AND fixation)) OR ((((((((spondylolysis[MeSH Terms]) AND surgery)) OR spondylolysis[MeSH Terms]) AND repair)) OR spondylolysis[MeSH Terms]) AND fixation)) OR ((((((((pars interarticularis) AND surgery)) OR pars interarticularis) AND repair)) OR pars interarticularis) AND fixation). Similar search strategies were used in MEDLINE, EMBASE, Cochrane-Register, and ScienceDirect database.

Two authors (M.I. and G.R.) performed the search and evaluated the abstracts independently for potential eligibility and subsequently full-text publications for eligibility. A third author (F.L.) resolved discrepancies. Each researcher reviewed the title and abstract of all the articles and selected the relevant ones according to inclusion and exclusion criteria. The list of references of each article was screened in order to find any additional original articles. In addition to the computer search, an independent hand search including scanning of reference lists from other studies was performed.

Study Selection

The following criteria were applied for article inclusion to ensure that the question was addressed: articles presenting original research (observational studies or clinical trials) or technical note in peer-reviewed journals without language restriction. The patients included were both male and female and underwent primary surgery for a lumbar spondylolysis. After identification and removal of duplicates, studies were

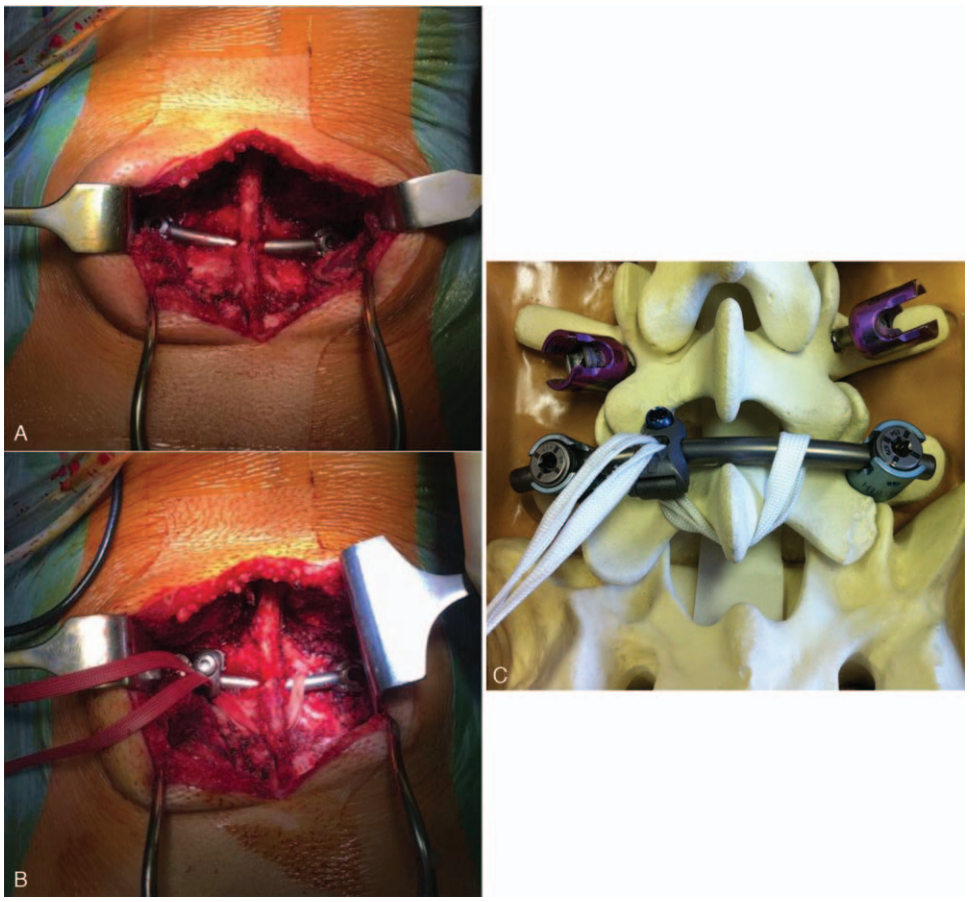


Figure 1. Case example. This is a case of L5 Isthmic spondylolysis. The image shows the surgical field after (**A**) the implant of L5 pedicle screw with polyaxial tulip and (**B**) after the isthmus fixation using Screw-Rod-Band (SRB) Technique. The Sawbones model (**C**) illustrates the SRB Technique.

excluded in the screening process (title and abstract) if (1) no abstract was available, (2) if title and abstract indicated that the focus of the article was outside the scope of the article, (3) the patients were not affected by spondylolysis, or (4) the authors proposed spinal arthrodesis. When screening for eligibility (full text), articles were excluded if the authors proposed a non-original procedure. Additional subject definition and exclusion criteria were applied to allow for the most homogeneous comparisons across studies. We excluded editorials and commentaries, review articles and meta-analysis, cervical spondylolysis, spondylolisthesis cases. Figure 4 shows the search strategy used according to PRISMA guidelines to generate the final study list.

RESULTS

Study Selection

We identified 982 studies through database searching. No additional eligible studies were identified through other sources. After screening titles and abstracts of all remaining unique articles, 26 full-text articles needed to be assessed to verify their eligibility for the inclusion in the present study. Ultimately, five of them were excluded for various reasons (two preliminary studies: Roca in 1989 and Songer in 1988; three studies presented the same procedure of Buck and Morscher techniques), resulting in the inclusion of 21 studies.

Levels of Evidence and Types of Study

The literature research reached level of evidence (LoE) IV as the best result. The review included 28.6% (6/21) technical note or biomechanical studies (LoE V)[20–25] and 71.4% (15/21) case series (LoE IV).[17,26–39] All papers were included if they presented original surgical methods. All the techniques of spondylolysis direct repair are summarized and grouped on the basis of the main implant used in Table 1.

Data From Studies

Isthmic Direct Screwing

In 1970, Buck[30] first introduced a surgical technique aimed to create a direct fixation of the pars defect. The original method places the screws from the ipsilateral lamina directly through the pars interarticularis defect. Intending to increase the accuracy and safety of screw placement, in 2008, Brennan *et al*[21] introduced a variation based on the O-arm (3D) navigation. In 2016, Wilson *et al*[24] proposed the percutaneous pars fixation combined with the use of compression screws.

Wiring

In 1987, Scott proposed the first wiring technique.[17] The loose posterior arch is fixed by cerclage wiring of the transverse process to the spinous process of the involved vertebra with the defect fusion.

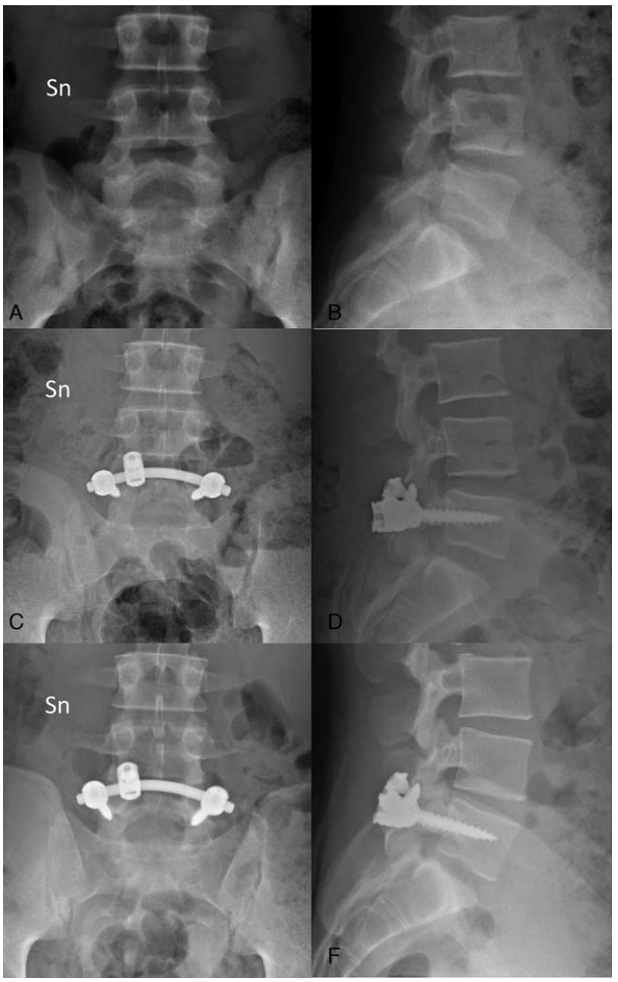


Figure 2. Case example. Screw-Rod-Band (SRB) Technique. Preoperative coronal (**A**) and Sagittal (**B**) x-ray. Postoperative coronal (**C**), and sagittal (**D**) x-ray. X-ray, 4 years follow-up (**E**) coronal and sagittal (**F**).

Hambly proposed a variation in 1989.[22] He described an intersegmental wiring technique, where one end of the loop is tightened under the spinous process of the same vertebra and the other end is tightened under the spinous process of the segment below.

Salib and Pettine[29] described another modification of the original wiring technique: a tension band wiring around the spinous process combined with pedicle screws of the same vertebra.

Songer and Rovin[40] replaced the wire for a cable passing underneath the lamina, fixed on a pair of pedicle screws. Later, Bozart *et al*[28] proposed to pass a cable around a pedicle screw on each side, rather than the transverse process, and modified the Songer technique to pass the cable around the base of the spinous process and not beneath the lamina.

Butterfly Plate

In the 1980s, a segmental fixation of spondylolytic vertebra and the vertebra below was proposed by Louis.[34] The author developed a properly designed butterfly plate to fix temporarily the lumbosacral junction and the pars interarticularis defect. The plate offered a wide area for bone graft and not required the application of compressive forces across the pars interarticularis with the possible consequences of pars shortening.

Figure 3. Case example. Screw-Rod-Band (SRB) Technique. Preoperative CT scan, (**A**) left and (**B**) right side. Low dose CT scan at 4-month follow-up, (**C**) left, and (**D**) right side. CT scan at 4 years follow-up, (**E**) left and (**F**) right side.

Hook-Screw Construct

In 1984, Morscher *et al*[41] described a new repair technique that used a laminar hook positioned in the defect and a compressive force placed upon it with a spring held against a screw within the articular process to achieve approximation of the pars defect.

Several modifications of this technique were proposed based on different instrumentation used. Tokuhashi and Matsuzaki[27] used the Isola pediculolaminar system; Kakiuchi[35] used the Texas Scottish Rite Hospital (TSRH) system, with a variable-angle pedicle screw; Roca *et al*[32] used the Diapason system that presents a hook bent at an angle of 30° to grasp the lamina in a very close-fitting way; Debusscher and Troussel[37] used the Bone and Joint Research (BJR) system, which was made up of a standard pedicle screw and a rod-laminar hook complex.

Shaped Rod

In 1999, Gillet and Petit[31] described direct repair by placing screws on the pedicles of the involved vertebra and fixing the loose posterior arch with a solid rod bent into a V-shape,

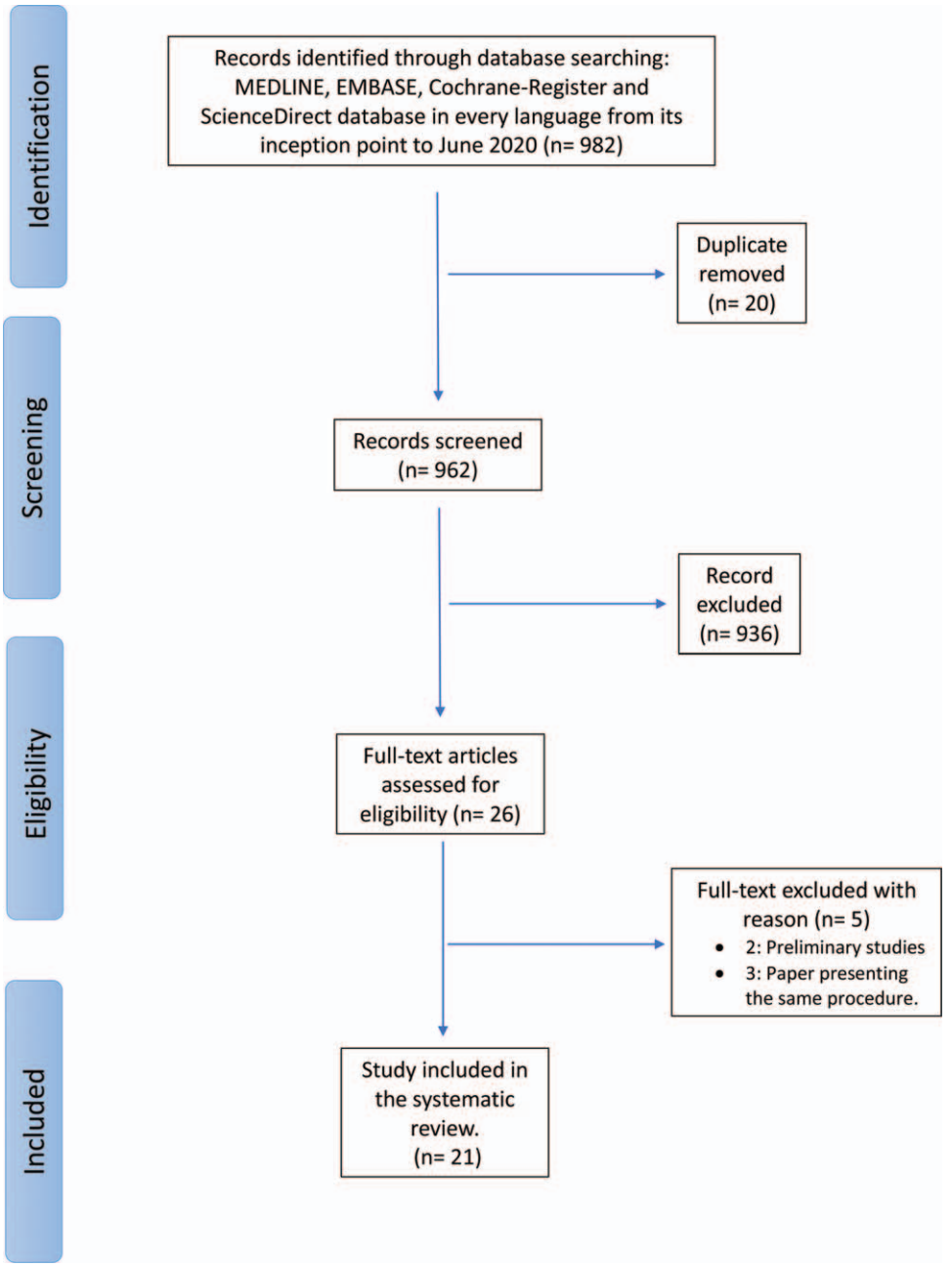


Figure 4. Flow diagram of studies through the different phases of the review. Literature review search algorithm performed using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. After the application of all exclusion criteria, 21 studies were identified for the final analysis.

taking purchase on the spinous process and laminae. In 2006, Ulibarri *et al*[23] reported a minimal variation of the Gillet technique using a U-shaped modular linkage in association with multiaxial pedicle screws. In 2012, Mohi[26] presented a minimally invasive variation with image-guided screw positioning.

Laminar Screw

In 2012, Patel *et al*[25] introduced a combination of the pedicle screw and laminar screw system to fix the posterior arch and the anterior portion of the spondylolytic vertebra. The compressive forces are applied across the pars without the reduction of the fusion surface. Furthermore, the surgical procedure is performed entirely outside the spinal canal and preserves the spinal motion.

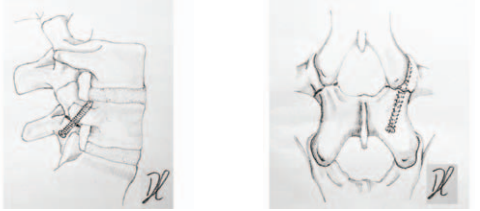
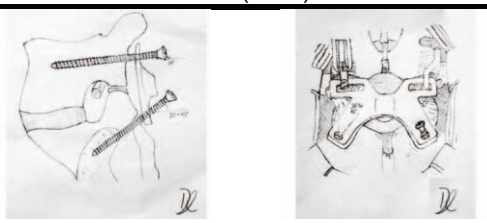
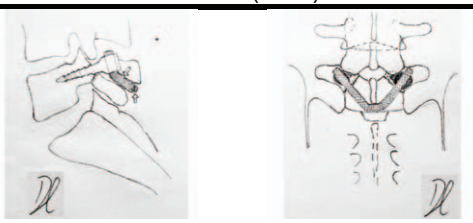
Combination Techniques

Some papers presented a combination of various techniques.

In 2002, Tan *et al*[33] introduced a combination of Buck and Scott techniques: a lag screw is placed across the pars defect and a tension band cerclage is performed between this screw and the transverse process.

In 2016, Goldstein *et al*[36] combined the Buck and Gillet techniques. Cortical bone trajectory screws were placed across the fracture lines using navigation. A rod was contoured in a curvilinear fashion, passed through the inferior

TABLE 1. The Table Illustrates the Surgical Procedures Identified for Spondylolysis Direct Repair

	Original Techniques	Variation
Isthmic Screw	 Buck (1970)	• Higashino (2007) • Brennan (2008) • Wilson (2016)
Wiring	 Scott (1987)	• Hambly (1989) • Salib (1993) • Songer (1998) • Bozarth (2007)
Butterfly Plate	 Louis (1988)	
Hook-Screw Construct	 Morscher (1992)	• Taddonio (1991) • Tokuhashi (1996) • Kakiuchi (1997) • Roca (2005) • Debusscher (2007)
Shaped Rod	 Gillet (1999)	• Ulibarri (2006) • Mohi Eldin (2012)

interspinous ligament, and finally connected to the screw tulip heads.

DISCUSSION

In case of spondylolysis, surgery is indicated when nonoperative measures have failed, after an attempt of at least 6 months. Direct repair of a spondylolysis by direct pars osteosynthesis is the widely preferred method of treatment in absence of severe disc degeneration or instability.

The novel SRB technique presented in this paper is a modification of the Scott technique with additional advantages. It utilizes three components to form a construct to repair the spondylolysis: pedicle screws, rod and polyester band. Polyester is a synthetic polymer made of purified terepthalic acid (PTA) or dimethyl terephthalate (DMT) and monoethylene glycol (MEG). Soft, woven, and flat polymeric bands, which are secured to the metal rod using a metal clamp, have been introduced in the last decade improving the sublaminar wiring technique.[38,31,42]

Unlike the Scott technique, which demands extensive muscle stripping and excising the iliolumbar ligament to expose the transverse process during the procedure,[23,43] the SRB technique requires minimal soft tissue dissection and reduces blood loss. Easy surgical access to the spinous

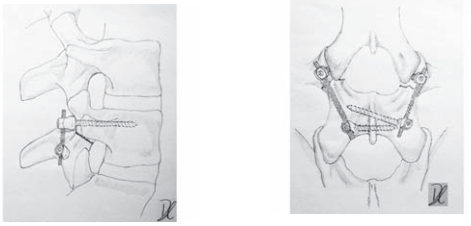
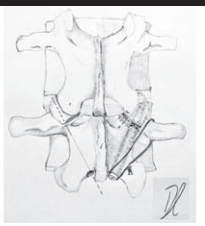
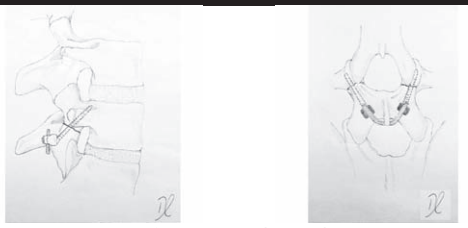
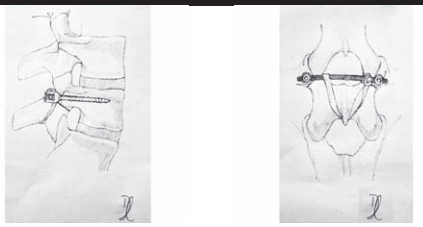
Laminar Screw	 Patel (2012)	
Combination Technique Lag screw and tension band fixation	 Tan (2002)	
Combination Technique Cortical Screws and Spinous-Process Modular Link.	 Goldstein (2016)	
Combination Technique Screw-Rod-Band (SRB) Technique	 Berjano (2020)	

Table 1 continued. For each group is described the name of the surgical procedure (Left Column), the proposing author and the modifying authors (Right Column).

process allows the surgeon to pass the polyester band under the base of the spinous process. There is no penetration of the band into the canal, and by looping the band over a transverse rod, instead of transverse processes, the risk of neurological injuries is reduced.

In earlier techniques utilizing wire as part of the construct for the repair of the spondylolysis, the variable strength of the bone, and the relatively small surface area of the wire can cause cut through of the spinous process or transverse process and bone absorption, leading to loosening of the construct and loss of stability.[44,45]

The flat profile and soft, flexible nature of polyester systems distributes contact forces over a greater area lowering the risk of cable pull-out in comparison to metal cables.[46] The gradual application of tension intraoperatively to the band allows for progressive compression across the isthmus.

In a mechanical study,[47] the tensile strength and stiffness of a polymer cable were found to be substantially greater than a titanium. These mechanical properties can potentially reduce the risk of implant failure. The other disadvantages of using metal wire as cerclage wires for the repair of spondylolysis, potentially include the low fatigue strength, cable fraying, and fragmentation that can lead to nonunion.[48] There will not be any metal wear particles generated from the polymer band.

Using the SRB technique, the construct will also not be prone to dislodgement unlike a construct that utilizes hooks.[49,50] Furthermore, there are no screws across the pars defect. This allows for a greater area of bony contact as well as not hindering the bone graft to promote higher fusion rate.[37]

The application of the horizontal rod and polyester band outside the spinal canal and away from the transverse processes is relatively straightforward, making the procedure potentially easy to learn.

The potential disadvantages of performing the SRB technique for the repair of spondylolysis include the cost and

availability of the polyester band compared with other previous techniques. Furthermore, if the polyester band is passed under the tip, instead of the base of the spinous process, it can introduce rotation forces across the posterior elements that potentially affect the facet joint. Further studies should be necessary to evaluate the cost-effectiveness and the clinical outcomes of this technique.

Previous Techniques Review

The purpose of this systematic review was to provide an overview of all the original surgical techniques historically described to treat spondylolysis. The research identified 21 studies describing new surgical procedures suggesting, on the one hand, a wide range of possibilities, on the other hand, the lack of scientific consensus. In particular, the research highlighted six main approaches and two combinations of original techniques. The results vary from good to excellent for all methods.

Isthmic Direct Screwing

In 1970, Buck[30] described an internal fixation with screws penetrating directly through the pars interarticularis, with good or excellent outcomes in 88% of cases. Achieving accurate placement of the screws was challenging, with a lengthy learning curve, and complications occurred in up to 40% of cases, most commonly related to screw loosening or misplacement. In this technique, the screw itself occupied much of the space of the defect in the region of the isthmus, decreasing the available area for bone grafting and fusion.[51]

In the last decades, minimally invasive surgery and modifications of the original techniques have been described. These techniques employ similar muscle sparing approaches that are more likely to maintain the continued function of the multifidus muscle. Muscle degeneration, an undesirable complication especially for sports players, can therefore be reduced.

The first author to describe a minimally invasive technique was Higashino,[20] who in 2007 added the use of a spinal endoscope to Buck screwing procedure.

In 2008, Brennan *et al*[21] reported a minimally invasive variation of Buck technique, by using intraoperative 3D imaging and frameless navigation. In a similar manner, Wilson *et al*[24] in 2016 reported a percutaneous variation using a compression screw to achieve maximal compression over the defect.

Wiring

In 1987, the Scott technique showed good subjective results reported in 80% of cases. This technique requires greater surgical exposure, with extensive stripping of the muscle in order to expose the transverse process completely. A complication rate of 14% is reported in the literature. The fragility of the fixation method and anchors obliged patients to wear a postoperative brace for 3 months to avoid wire or anchor breakage, reported in several cases.[52–54]

Several modifications of Scott technique were proposed. In particular, Salib and Pettine[29] and Songer and Rovin[40] using a combination of tension band wiring and pedicle screws, eliminated the need to pass the wire around the transverse process providing at the same time a solid fixation with excellent results and less surgical exposure.

Butterfly Plate

In the 1980s, Louis developed a technique of temporary fixation of the lumbosacral junction.[34] The advantages are a large area available for the bone graft and the avoidance of possible shortening of the pars interarticularis, as could happen with techniques that apply compression over this area. The authors reported 86% of good results and a fusion rate of 95% of the cases. Implant removal 1 year later as a secondary procedure is mandatory and postoperative bracing is advised for 3 months.

Hook-Screw Construct

With the introduction of ''Hook-Screw'' construct, Morscher *et al*[41] introduces several advantages. The fixation did not depend on the shape of the isthmus defect; it allowed for maximal grafting of the defect and it would exert a compressive force across the lamina. Despite this, numerous problems were reported such as the difficulty in screw placement with a 15% risk of error, screw loosening and breakage,[55] a high risk of non-healing, with a complication rate of up to 44%. The small screw purchase in the base of the superior articular process seems responsible for the many cases of screw pullout and consequent non fusion.

A biomechanical evaluation shows that interbody flexion, extension, and torsional stiffness were the highest for the pedicle screw-hook construct, in respect to other fixation systems.[23] The first to introduce pedicle screw-hook fixation was Taddonio[56] using the Cotrel-Debousset system. Later, different authors presented their own device variations: Tokuhashi and Matsuzaki,[27] with the Isola pediculolaminar system, reported with good clinical results, without implant failure or breakage and Kakiuchi,[35] with the Texas Scottish Rite Hospital (TSRH) system, proposed a more rigid fixation.

Shaped Rod

Firstly Gillet and Petit[31] and later Ulibarri *et al*[23] proposed the association of pedicle screws and V- or U-shaped rod, respectively. The authors reported good to excellent results in 70% of cases, without significant complications. The biomechanical evaluation of Ulibarri variation, based on U-shaped modular linkage with multiaxial pedicle screws, revealed the least displacement across the pars defect.

Laminar Screw

In an attempt to provide a stiffer construct for higher defect-healing rates, in 2012 Patel *et al*[25] devised a pedicle screw–intralaminar screw construct. This relatively simple system also presented the advantage of being entirely outside of the spinal canal, decreasing the chance of a neurological injury. There was not a significant difference in stiffness between the pedicle screw–hook and pedicle screw–intralaminar screw techniques in any of the testing modes.

Combination Techniques

In the past decades, a combination of screws, rod and band cerclage were performed to offer multiple modifications aimed to reduce the invasiveness and improve the fusion rate. In particular, Tan *et al*[33] in 2002 and Goldstein *et al*[36] in 2016 provided muscle-sparing procedures reporting excellent safety and reliability.

The vast majority of the published studies presenting a new surgical technique, or its modification, are based on clinical case reports and technical note studies that reduce the quality of our research for their low level of evidence. To ascertain the validity of eligible study, only papers describing original surgical procedures were included in the systematic process. We did not perform the quality assessment of the selected studies since the inclusion criteria were strict enough to avoid the inclusion of low-quality papers. All these biases, along with the retrospective nature of studies, may influence the evaluation and the power of results.

CONCLUSION

The literature review has revealed a great number and variety of surgical techniques for the spondylolysis repair, demonstrating the lack of consensus on a satisfactory procedure. The pars defect repair we propose using a construct consisting of pedicle screws, a transverse rod and a polyester band seems to be a technically simple and safe procedure that presents the advantage of placing the spondylolysis under strong compression to help ensure fusion. The clinical case presented good clinical outcomes at the 4-year follow-up and significant pain reduction with an early return to daily life and sports. Further studies, both biomechanical and clinical, must be conducted to validate the procedure.

➢ Key Points

- ❑ The SRB is a novel technique for spondylolysis treatment consisting of pedicle screws, a transverse rod, and a polyester band.
- ❑ The procedure is performed by looping the band over a transverse rod fixed at L5 pedicle screws.
- ❑ Requires minimal soft tissue dissection and reduced blood loss. The implant places the spondylolysis under strong compression to ensure fusion.

Acknowledgments

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References

1. Wiltse LLR, Milanowska K, Hanley EN, Bradford DS. Lumbar and lumbosacral spondylolisthesis.*The Lumbar Spine*. Philadelphia: Saunders; 1990; 471–499.
2. Neugebauer FI. The classic: a new contribution to the history and etiology of spondyl-olisthesis by F. L. Neugebauer. *Clin Orthop Relat Res* 1976;4–22.
3. Kilian HF. Schilderungen neuer Beckenformen und ihres Verhaltens in Leven, Mannheim. Mathy Verlag von Vassermann. 1854 [DE].
4. Kilian HF. De spondilolisthesi gravissimae pelvangustiae causa nuper detecta, commentatio anatomico-obstetrica. Lit c Georg Bonnae. 1854 [LA].
5. Sakai T, Sairyo K, Suzue N, et al. Incidence and etiology of lumbar spondylolysis: review of the literature. *J Orthop Sci* 2010;15:281–8.
6. Fredrickson BE, Baker D, McHolick WJ, Yuan HA, Lubicky JP. The natural history of spondylolysis and spondylolisthesis. *J Bone Jt Surg Am* 1984;66:699–707.
7. Debnath UK, Freeman BJC, Gregory P, et al. Clinical outcome and return to sport after the surgical treatment of spondylolysis in young athletes. *J Bone Joint Surg Br* 2003;85:244–9.
8. Rossi F, Dragoni S. Lumbar spondylolysis: occurrence in competitive athletes. Updated achievements in a series of 390 cases. *J Sports Med Phys Fitness* 1990;30:450–2.
9. Tezuka F, Sairyo K, Sakai T, et al. Etiology of adult-onset stress fracture in the lumbar spine. *Clin spine Surg* 2017;30:E233–8.
10. Roussouly P, Pinheiro-Franco JL. Biomechanical analysis of the spino-pelvic organization and adaptation in pathology. *Eur Spine J* 2011;20 (suppl):609–18.
11. Lamartina C, Berjano P, Petruzzi M, et al. Criteria to restore the sagittal balance in deformity and degenerative spondylolisthesis. *Eur Spine J* 2012;21 (suppl):S27–31.
12. Sedney CL, McConda DB, Daffner SD. Natural history of spondylolysis and spondylolisthesis. *Semin Spine Surg* 2014;26:214–8.
13. Vanti C, Ferrari S, Villafañe JH, et al. Responsiveness and minimum important change of the Oswestry Disability Index in Italian subjects with symptomatic lumbar spondylolisthesis. *J Orthop Traumatol* 2017;18:145–50.
14. Aebi M. Direct screw fixation of the spondylolysis without fusion. *Eur Spine J* 2010;19:1803–5.
15. Pfirrmann CW, Metzdorf A, Zanetti M, et al. Magnetic resonance classification of lumbar intervertebral disc degeneration. *Spine (Phila Pa 1976)* 2001;26:1873–8.
16. Meyerding HW. Spondylolisthesis; surgical fusion of lumbosacral portion of spinal column and interarticular facets; use of autogenous bone grafts for relief of disabling backache. *J Int Coll Surg* 1956;26:566–91.
17. Scott J. The Edinburgh repair of isthmic (Group II) spondylolysis. *J Bone Jt Surg Br* 1987;69:491.
18. Langella F, Villafañe JH, Damilano M, et al. Predictive accuracy of surgimap surgical planning for sagittal imbalance: a cohort study. *Spine (Phila Pa 1976)* 2017;42:E1297–304.
19. Moher D, Liberati A, Tetzlaff J, et al., PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA Statement. *Ann Intern Med* 2009;151:264–9.
20. Higashino K, Sairyo K, Katoh S, et al. Minimally invasive technique for direct repair of the pars defects in young adults using a spinal endoscope: a technical note. *Minim Invasive Neurosurg* 2007;50:182–6.
21. Brennan RP, Smucker PY, Horn EM. Minimally invasive image-guided direct repair of bilateral L-5 pars interarticularis defects. *Neurosurg Focus* 2008;25:E13.
22. Hambly M, Lee CK, Gutteling E, et al. Tension band wiring-bone grafting for spondylolysis and spondylolisthesis. A clinical and biomechanical study. *Spine (Phila Pa 1976)* 1989;14:455–60.
23. Ulibarri JA, Anderson PA, Escarcega T, et al. Biomechanical and clinical evaluation of a novel technique for surgical repair of spondylolysis in adolescents. *Spine (Phila Pa 1976)* 2006;31:2067–72.
24. Wilson L, Altaf F, Tyler P. Percutaneous pars interarticularis screw fixation: a technical note. *Eur Spine J* 2016;25:1651–4.
25. Patel RD, Rosas HG, Steinmetz MP, et al. Repair of pars interarticularis defect utilizing a pedicle and laminar screw construct: a new technique based on anatomical and biomechanical analysis. *J Neurosurg Spine* 2012;17:61–8.
26. Mohi Eldin M. Minimal access direct spondylolysis repair using a pedicle screw-rod system: a case series. *J Med Case Rep* 2012;6:396.

27. Tokuhashi Y, Matsuzaki H. Repair of defects in spondylolysis by segmental pedicular screw hook fixation. A preliminary report. *Spine (Phila Pa 1976)* 1996;21:2041–5.
28. Bozarth GR, Fogel GR, Toohey JS, et al. Repair of pars interarticularis defect with a modified cable-screw construct. *J Surg Orthop Adv* 2007;16:79–83.
29. Salib RM, Pettine KA. Modified repair of a defect in spondylolysis or minimal spondylolisthesis by pedicle screw, segmental wire fixation, and bone grafting. *Spine (Phila Pa 1976)* 1993;18: 440–3.
30. Buck JE. Direct repair of the defect in spondylolisthesis. Preliminary report. *J Bone Joint Surg Br* 1970;52:432–7.
31. Gillet P, Petit M. Direct repair of spondylolysis without spondylolisthesis, using a rod-screw construct and bone grafting of the pars defect. *Spine (Phila Pa 1976)* 1999;24:1252–6.
32. Roca J, Iborra M, Cavanilles-Walker JM, et al. Direct repair of spondylolysis using a new pedicle screw hook fixation: clinical and CT-assessed study: an analysis of 19 patients. *J Spinal Disord Tech* 2005;18 (suppl):S82–9.
33. Tan J, Jia L, Xu J, et al. Bone graft repair of adolescence spondylolysis with lag screw and tension band fixation. *Zhonghua Wai Ke Za Zhi* 2002;40:727–9.
34. Louis R. Pars interarticularis reconstruction of spondylolysis using plates and screws with grafting without arthrodesis. Apropos of 78 cases. *Rev Chir Orthop Reparatrice Appar Mot* 1988;74:549–57.
35. Kakiuchi M. Repair of the defect in spondylolysis. Durable fixation with pedicle screws and laminar hooks. *J Bone Joint Surg Am* 1997;79:818–25.
36. Goldstein MJ, Bruffey J, Eastlack RK. New minimally invasive technique for direct pars interarticularis osteosynthesis using cortical screws and spinous-process modular link. *Spine (Phila Pa 1976)* 2016;41:E1421–4.
37. Debusscher F, Troussel S. Direct repair of defects in lumbar spondylolysis with a new pedicle screw hook fixation: clinical, functional and Ct-assessed study. *Eur Spine J* 2007;16:1650–8.
38. Hefti F, Seelig W, Morscher E. Repair of lumbar spondylolysis with a hook-screw. *Int Orthop* 1992;16:81–5.
39. Songer M. Repair of the pars interarticularis defect with a cable-screw construct. *Spine (Phila Pa 1976)* 1998;23:284.
40. Songer MN, Rovin R. Repair of the pars interarticularis defect with a cable-screw construct. A preliminary report. *Spine (Phila Pa 1976)* 1998;23:263–9.
41. Morscher E, Gerber B, Fasel J. Surgical treatment of spondylolisthesis by bone grafting and direct stabilization of spondylolysis by means of a hook screw. *Arch Orthop Trauma Surg* 1984;103: 175–8.
42. Hensinger RN. Spondylolysis and spondylolisthesis in children and adolescents. *J Bone Joint Surg Am* 1989;71:1098–107.
43. Aihara T, Takahashi K, Yamagata M, et al. Biomechanical functions of the iliolumbar ligament in L5 spondylolysis. *J Orthop Sci* 2000;5:238–42.
44. Bernard TN, Johnston CE, Roberts JM, et al. Late complications due to wire breakage in segmental spinal instrumentation. Report of two cases. *J Bone Joint Surg Am* 1983;65:1339–45.
45. Fan J, Yu G, Liu F, et al. A biomechanical study on the direct repair of spondylolysis by different techniques of fixation. *Orthop Surg* 2010;2:46–51.
46. Crawford RJ, Sell PJ, Ali MS, et al. Segmental spinal instrumentation. A study of the mechanical properties of materials used for sublaminar fixation. *Spine (Phila Pa 1976)* 1989;14:632–5.
47. Roth AK, Boon-Ceelen K, Smelt H, et al. Radiopaque UHMWPE sublaminar cables for spinal deformity correction: preclinical mechanical and radiopacifier leaching assessment. *J Biomed Mater Res B Appl Biomater* 2018;106:771–9.
48. Silverton CD, Jacobs JJ, Rosenberg AG, et al. Complications of a cable grip system. *J Arthroplasty* 1996;11:400–4.
49. Polly DW, Potter BK, Kuklo T, et al. Volumetric spinal canal intrusion: a comparison between thoracic pedicle screws and thoracic hooks. *Spine (Phila Pa 1976)* 2004;29:63–9.
50. van Laar W, Meester RJ, Smit TH, et al. A biomechanical analysis of the self-retaining pedicle hook device in posterior spinal fixation. *Eur Spine J* 2007;16:1209–14.
51. Giudici F, Minoia L, Archetti M, et al. Long-term results of the direct repair of spondylolisthesis. *Eur Spine J* 2011;20 (suppl): S115–20.
52. Johnson GV, Thompson AG. The Scott wiring technique for direct repair of lumbar spondylolysis. *J Bone Joint Surg Br* 1992;74:426–30.
53. Bradford DS, Iza J. Repair of the defect in spondylolysis or minimal degrees of spondylolisthesis by segmental wire fixation and bone grafting. *Spine (Phila Pa 1976)* 1985;10:673–9.
54. Askar Z, Wardlaw D, Koti M. Scott wiring for direct repair of lumbar spondylolysis. *Spine (Phila Pa 1976)* 2003;28:354–7.
55. Sales de Gauzy J, Vadier F, Cahuzac JP. Repair of lumbar spondylolysis using Morscher material: 14 children followed for 1–5 years. *Acta Orthop Scand* 2000;71:292–6.
56. Taddonio R. Isthmic spondylolisthesis.*The Textbook of Spinal Surgery*. Philadelphia, PA: Lippincott; 1991; 565–584.