SACRAL FRACTURE TREATMENT WITH A VARIATION OF THE LUMBOPELVIC FIXATION TECHNIQUE

TRATAMENTO DA FRATURA SACRAL COM UMA VARIAÇÃO DA TÉCNICA DE FIXAÇÃO LOMBOPÉLVICA

TRATAMIENTO DE LA FRACTURA SACRAL CON UNA VARIACIÓN TÉCNICA DE LA FIJACIÓN LUMBOPÉLVICA

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ABSTRACT

Spinopelvic instability is an uncommon injury that is caused by high-energy traumas. Surgical treatment is used, in the majority of cases, to restore stability and enable early mobilization. Various stabilization techniques have been used in the treatment of spinopelvic instability, and lumbopelvic fixation (LPF) is currently the technique of choice due to its biomechanical superiority. One of its limitations is the fact that the technique does not directly address the lower sacral segment, permitting a residual kyphotic deformity. This deformity has been attributed to unsatisfactory outcomes, including late development of pelvic floor muscle defects and complications during childbirth. We report a case of a patient with spinopelvic instability due to sacral fracture, which was treated using a variation of the LPF technique, in which rods and screws originally developed for cervicothoracic fixation were adapted to correct sacral deformity in the sagittal plane. The upper sacral segment was reduced indirectly using hip extension and femoral traction manoeuvres, associated with distraction manoeuvres via rods. Bone reduction forceps were used to reduce the kyphotic deviation in the lower sacral fragment, enabling its fixation to the lumbopelvic rod and screws system. There were no complications of infection, suture dehiscence, or breakage of the implants, and at the end of the first year of follow-up, the sacral kyphosis was normal and radiographic consolidation was confirmed. Our technique provides a viable and promising alternative to traditional LPF, making it especially useful in fractures with accentuated deviations of the lower sacral fragment. ***Level of Evidence: 4.Type of study: Case series***

Keywords: Sacrum; Wounds and injuries; Kyphosis.

RESUMO

A instabilidade espino-pélvica (IEP) é uma lesão rara, decorrente de traumas de alta energia. O tratamento cirúrgico é empregado, na maioria dos casos, para restaurar a estabilidade e permitir mobilização precoce. Diferentes técnicas já foram empregadas no tratamento da IEP e, atualmente, a fixação lombo-pélvica (LPF) é a preferida devido à sua superioridade biomecânica. Uma de suas limitações é o fato de a técnica não abordar diretamente o fragmento sacral inferior, permitindo uma deformidade residual em cifose. Esta deformidade tem sido atribuída a resultados insatisfatórios, tais como defeitos do assoalho pélvico e complicações durante o parto. Relatamos o caso de uma paciente com IEP por fratura sacral que foi tratada com uma variação da técnica de LPF, na qual hastes e parafusos originalmente desenvolvidos para a fixação cervicotorácica foram adaptados para corrigir a deformidade sacral no plano sagital. O fragmento sacral superior foi reduzido indiretamente por manobras de extensão dos quadris e tração femoral, associadas a manobras de distração através de hastes. Pinças de redução foram usadas para reduzir o desvio cifótico do fragmento sacral inferior, permitindo sua fixação à montagem lombo-pélvica. Não houve complicações infecciosas, deiscência de suturas ou quebras dos implantes e, ao término do primeiro ano de acompanhamento, a cifose sacral estava normal e a consolidação radiográfica confirmada. Nossa técnica acrescenta um recurso à LPF tradicional, tornando-a especialmente útil em fraturas com desvios acentuados do fragmento sacral inferior. ***Nível de Evidência: 4. Tipo de estudo: Série de casos***

Descritores: Sacro; Ferimentos e lesões; Cifose.

RESUMEN

La inestabilidad espinopélvica es una lesión poco frecuente causada por traumas de alta energía. El tratamiento quirúrgico se utiliza en la mayoría de los casos para restablecer la estabilidad y permitir la movilización temprana. Diferentes técnicas se han empleado en el tratamiento de la inestabilidad espinopélvica, y la fijación lumbopélvica (FLP) es actualmente la técnica de elección debido a su superioridad biomecánica. Una de sus limitaciones es el hecho de que la técnica no aborda directamente el segmento sacro inferior, lo que permite una deformidad cifótica residual. Esta deformidad se ha atribuido a resultados insatisfactorios, incluido el desarrollo tardío de defectos musculares del piso pélvico y complicaciones durante el parto. Presentamos el caso de un paciente con inestabilidad espinopélvica por fractura del sacro, que fue tratada mediante una variación de la técnica de FLP, en la que se usaron vástagos y tornillos adaptados, desarrollados originalmente para la fijación cervicotorácica para corregir la deformidad sacra en el plano sagital. El segmento sacro superior se redujo

Study conducted at the Instituto Nacional de Traumatologia e Ortopedia (INTO/MS) Rio de Janeiro, RJ, Brazil.
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indirectamente utilizando la extensión de la cadera y las maniobras de tracción femoral, asociadas con maniobras de distracción a través de vástagos. Pinzas de reducción fueron utilizadas para reducir la desviación cifótica del fragmento sacro inferior, lo que permite su fijación al sistema lumbopélvico de vástago y tornillos. No hubo complicaciones de infección, dehiscencia de la sutura o ruptura de implantes y al final del primer año de seguimiento, la cifosis sacral estaba normal y se confirmó la consolidación radiográfica. Nuestra técnica proporciona una alternativa viable y prometedora al FLP tradicional, por lo que es especialmente útil en las fracturas con desviaciones acentuadas del fragmento sacro inferior. ***Nivel de Evidencia: IV. Tipo de estudio: Serie de caso***

Descriptores: Sacro; Heridas e lesiones; Cifosis.

INTRODUCTION

Sacral fractures with spinopelvic instability are rare, and are the result of high-energy trauma with axial overload through the sacrum.[1,2] The injury is characterized by the presence of two longitudinal fractures through the sacral foramina, in combination with a transverse fracture, and the association with brain or spinal cord traumas and/or cavity organ injuries, besides being common, are potentially serious and should be considered in the initial evaluation of the trauma.[1-4]

Another important aspect is the high rate of underdiagnosis of spinopelvic instability.[5] The panoramic radiography of the pelvis, used in the routine evaluation of patients with multiple trauma, is insufficient to identify fractures of the sacrum with spinopelvic instability. The intestinal loops and sacral tilt can hinder the visualization of the transverse fracture.[6] In addition, the pain originating from coexisting lesions can mask complaints coming from the sacropelvic region, contributing to underdiagnosis.[4]

The objective in the treatment of these injuries should be resolution of the spinopelvic instability.[7-9] The conservative approach has been related to the worsening of the sacral deformity, aggravation of neurological symptoms, and higher mortality rates. As a result, surgery is the initial choice in most cases.[1,10] Different stabilization techniques have already been used in the surgical treatment of spinopelvic instability, such as Harrington rods, iliosacral screws, transiliac and transsacral rods or plates, or pedicle screws.[7-16] The rarity of sacral fractures, which may evolve with spinopelvic instability, makes standardization of techniques and evaluation of the postoperative results difficult.[9]

Lumbopelvic fixation (LPF) is currently a widely used method in the treatment of spinopelvic instability.[1,9,13] The technique provides posterior stabilization of the pelvic ring, with stable realignment between the ilium, upper sacral fragment, and lumbar spine. Early mobilization is an advantage of the technique, allowing walking in the immediate postoperative period, which reduces the occurrence of complications related to bed restriction in patients with multiple traumas.[15,17]

The lack of adequate implants for the sacral anatomy is a limitation of the LPF technique. Around 20% of patients were reoperated due to prominence of the screws or breakage of the synthesis material used in the stabilization.[1,18] Another problem related to suboptimal outcomes in LPF is the occurrence of residual kyphosis by anteriorization of the sacral fragment below the transverse fracture, when it is used in the treatment of sacral fracture with spinopelvic instability.[3,19-23]

METHODS

Introducing a variation of the LPF used in the treatment of a multiplanar fracture of the sacrum with spinopelvic instability. The study was approved by the Institutional Review Board where it was conducted (CAAE: 51609815.1.0000.5273) and the patient agreed to participate voluntarily, by signing the informed consent form.

Case Description

A female patient, 21 years of age, admitted after a fall from 12 meters of height, with longitudinal trauma on the lower limbs. After initial clinical stabilization, physical examination revealed perianal hypoesthesia, absence of anal wink and bulbocavernosus reflex, and pain upon palpation of the lumbosacral bony prominences. The strength and deep reflexes of the lower limbs were normal. Radiological evaluation showed multiplanar fracture in the sacral 'H' (variant of 'U' fracture), with longitudinal fractures extending beyond the lower sacral fragment. There was 60° kyphosis at the level of the transverse fracture, causing a narrowing of the spinal canal. Fractures of the pubic branch and transverse processes of L5 were also identified (Figure 1).

Operative technique

On a radiotransparent table, with the patient in ventral decubitus, a median longitudinal incision was made, followed by subperiosteal dissection of the paravertebral muscles to expose the posterior elements of L5 to the sacrum. Facet osteotomies were performed at the level of L5-S1, to allow the insertion of pedicle screws in L5 and S1. Iliac screws were also inserted bilaterally. The left lateral pedicle of S2 was instrumented using the Mirkovic technique.[24] Screws were inserted in S3, with medial orientation. In this vertebra, the intersection between a vertical line through the sacral foramina and a transverse line between the dorsal foramen of S2 and S3 was used as the entry point for the screw (Figure 2). Laminectomias of S1 and S2 were performed, allowing good visualization of the dural sac and sacral roots, which were intact. An initial attempt was made to reduce the sacral kyphosis the through hip extension. Additional longitudinal distraction and cantilever manoevers were performed through rods fixed to the screws of L5, S1 and iliac screws to reduce the upper sacral fragment. The smallest fragment of the sacrum (below the transverse fracture) was realigned with the sacral fragment, using bone tweezers, enabling the screws of S2 and S3 to be connected to the rods (Figure 2). The cartilage of joints L5-S1 and the sacroiliac joints was removed, and autologous bone obtained from the sacrum was grafted between the transverse processes of L5 and the sacral wings, between facets L5-S1 and between the sacroiliac joints, aiming at arthrodesis between them. The musculature was approached by planes, ensuring good coverage of the implants. Suction drains were inserted into the subcutaneous tissue, and the skin was sutured

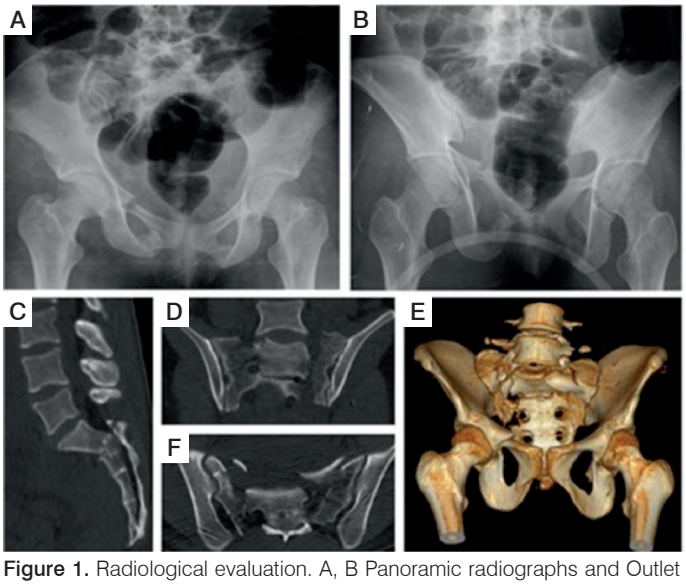

Figure 1. Radiological evaluation. A, B Panoramic radiographs and Outlet View - gaseous shadows of the intestines and the sacral tilt, hindering visualization of the fracture; C-F. Computed Tomography - better visualization of the fracture pattern.

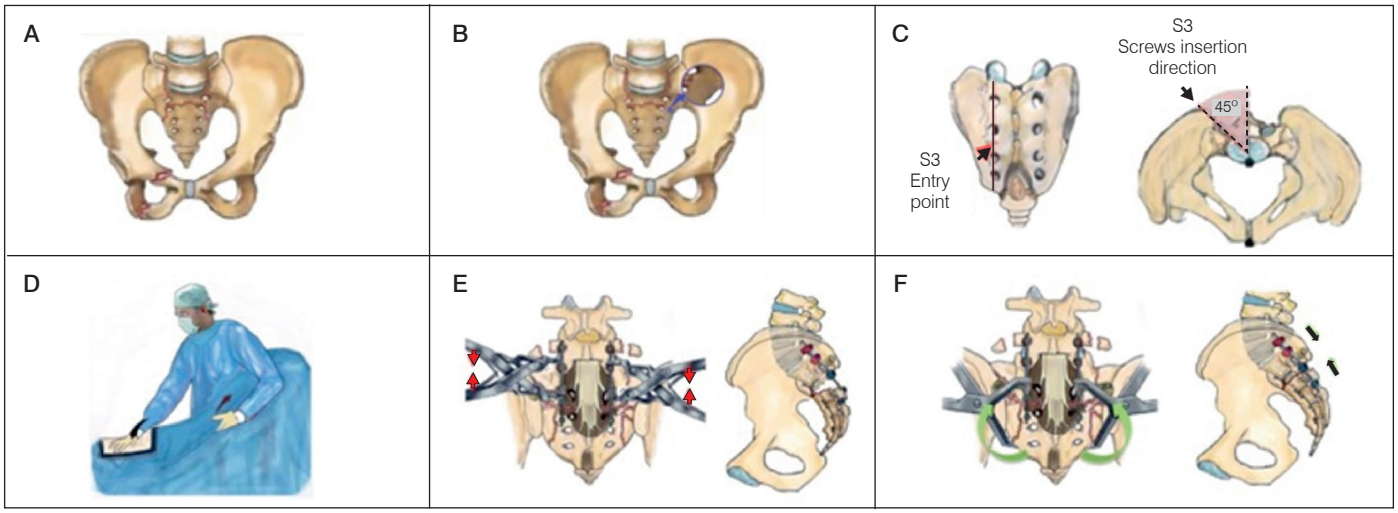

Figure 2. Illustrations of the fracture pattern and technique performed. A. variant in 'H' seen in the presented case; B. sacral fracture in 'U', with emphasis on the bone bridge between the lower sacral fragment and the sacroiliac joint; C. entry point for the insertion of the screws in S3; D. maneuver of hip extension used in the reduction of the sacral fragment; E. compression maneuvers used to complement the reduction of upper sacral fragment; F. Compression maneuvers used to complement the reduction of the lower sacral fragment.

without tension. After sacropelvic stabilization, the patient was placed in the supine position and the pubic branch fixed with a percutaneous screw. The devices used in the osteosynthesis are listed in Table 1.

Postoperative care and Follow-up

On the third postoperative day, walking was started with partial support. A week after surgery, the patient was already walking with only one crutch, and was discharged to outpatient follow-up. On discharge, radiographic images were obtained to evaluate the fracture alignment, position of the implants and decompression of the spinal cord. During outpatient follow-up, pelvic and lumbosacral radiographs were taken at six-week intervals during the first six months, to evaluate the kyphotic angle at the level of the transverse fracture line. The clinical results were evaluated by the Majeed and Gibbons scores, and by the Visual analogue scale (VAS) for pain.[25-29]

RESULTS

The surgical procedure lasted three hours, with estimated blood loss of 380 ml. The total length of hospital stay was 10 days, and there were no complications, such as infection or dehiscence of the suture. The local pain and perineal paresthesia improved gradually, and after discharge, opioid analgesics were no longer needed. A favorable prognosis was confirmed based on the positive results listed in Table 2. In the second outpatient follow-up consultation, the patient was already walking without crutches and was able to bear full weight while standing on one leg (Figure 3). There were no reports of lumbar or pelvic pain during walking or lying down.

Table 1. Implants used in osteosynthesis.

L5	6.0 x 45 mm – Expedium® Spine System (DePuy Synthes - Johnson & Johnson, Massachusetts, EUA)
S1	6.0 x 40 mm – Expedium® Spine System (DePuy Synthes - Johnson & Johnson, Massachusetts, EUA)
Ilium	7.5 x 70 mm – CD Horizon® System (Medtronic - Sofamor-Danek, Tennessee, EUA)
S2	3.5 x 20 mm – Vertex® (Medtronic - Sofamor-Danek, Tennessee, EUA)
S3	3.5 x 20 mm – Vertex® (Medtronic - Sofamor-Danek, Tennessee, EUA)
Rods	Transition rods 5.5 x 3.5 mm – SUMMIT® (DePuy Synthes - Johnson & Johnson, Massachusetts, EUA)
Pubic bone screw	3.5 x 80 mm – Synthes® (DePuy Synthes - Johnson & Johnson, Pennsylvania, EUA)

Table 2. Clinical and functional assessment scores.

	Before surgery	Before discharge	3rd Month postoperative	6th Month postoperative	12th Month postoperative
Gibbons[A]	2	2	1	1	1
Majeed[B]	Not applicable	Not applicable	74	90	98
VAS[C]	8	9	3	2	0

A. Gibbons neurological evaluation score (I- normal neurological examination, II- Paresthesias only, III- Motor deficit, IV- Sphincter dysfunction). B. Majeed functional evaluation score after pelvic lesions (varies from zero [worse] to 100 [normal function]); C. Visual Analogue Scale indicating the patient's pain status (varies from zero [without pain] to 10 [worst possible pain]).

Sexual function, competence sphincteric and perineal sensitivity were normal. The patient's only complaint was discomfort in the areas where the implants were prominent, especially when sitting down. The postoperative showed imaging study showed no loss of correction of kyphosis or pelvic instability; evidence of consolidation was identified on the twelfth postoperative day (Figure 3). The patient returned to regular activities three months after surgery, and even with prominence of the implants, did not undergo repeat surgery to remove them.

DISCUSSION

Roy-Camille was the first to describe sacral 'U' fracture as a multiplane lesion: a transverse fracture in the axial plane combined with bilateral longitudinal fractures in the sagittal plane.[30] The most widely used classification system for spinopelvic instability was been proposed by Roy-Camille and subsequently modified by Strange-Vognsen And Iebech.[30,31] This system evaluates the relationship between the upper and lower sacral fragments, but does not address possible variations in the components of the multiplane fracture.

Different surgical techniques have been applied in the treatment of 'U' fractures, among which LPF is becoming increasingly important.[1,9] In this technique, realignment between the lumbar spine, sacrum and pelvis is obtained through the use of rods and screws, positioned bilaterally in L5 and the iliac crest.[1-9,15] In LPF, it is possible to stabilize the lumbopelvic transition even without the instrumentation of the sacrum, which may be fragmented, without areas for anchoring the implants. In classical 'U' fracture, the realignment of the upper and lower sacral fragments is obtained indirectly through the reduction maneuvers by the rods, thanks to the existence of a bone connection

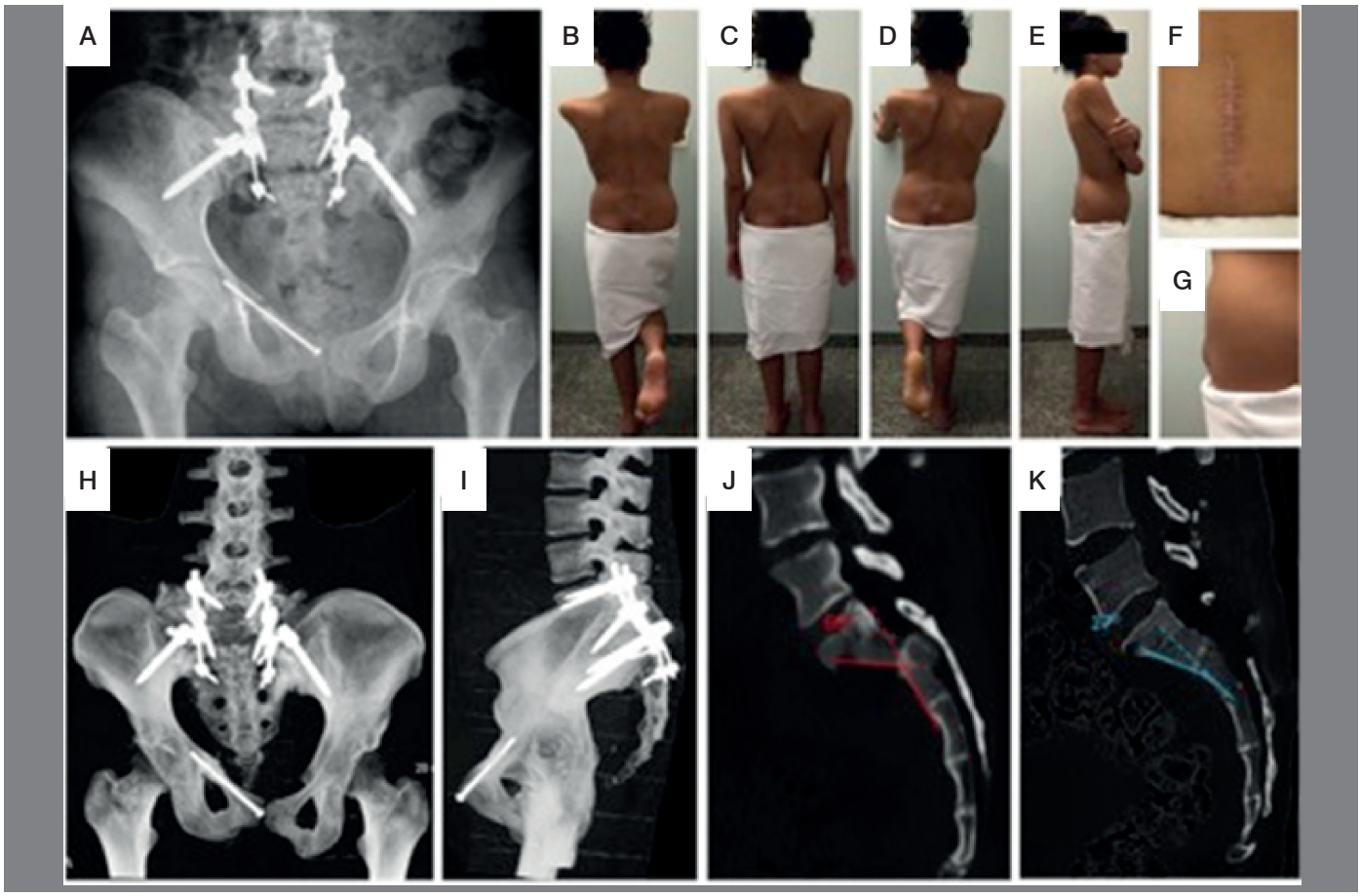

Figure 3. Imagens do pós-operatório. A. Radiografia panorâmica da pelve; B-E. Imagens clínicas da paciente em ortostase com mono e bipedestação; F, G. Imagem da cicatriz cirúrgica destacando a proeminência dos implantes; H, I. Tomografias computadorizadas revelando o bom posicionamento dos implantes e a consolidação da fratura; J, H. Redução da cifose sacral e descompressão adequada do canal.

between the lower fragment and the pelvis (Figure 2). The rarity of the sacral fractures with spinopelvic instability, as well as their morphological diversity, makes it difficult to standardize techniques for correcting and stabilizing these lesions.

In this study, we present a morphological variation of a 'U' fracture, classified as Roy-Camille type 2. The transversal component of the lesion was located between S1 and S2, while the longitudinal components extended below sacroiliac joints, forming an 'H' pattern (Figures 1 and 2). There was no bone connection between the lower sacral bone fragment and the remaining portions of the sacrum, or pelvis, making it impossible to correct the kyphosis at the level of the transverse fracture using the original LPF technique alone.

The decision to reduce the kyphosis deformity in sacral fractures with spinopelvic instability is based on well-established principles of the spinopelvic balance. Kyphotic deformity of the sacrum increases the pelvic incidence (IP), a radiographic parameter of sagittal spinopelvic balance related to dissatisfactory functional outcomes in the long term.[32-34] In addition, reducing the deformity restores the diameter of the rachidian canal, the obliteration of which was attributed to neurological deficits and chronic pain in the medium and long terms. Another advantage of correcting sacral deformity is the restoration of the pelvic dimensions, especially its anteroposterior diameter. This restoration recovers the bone canal of labor and the tension in the components of the pelvic floor, reducing the chance of obstetric complications in women of childbearing age, and late gynecological complications, such as the genital dystopias.[35,36]

To correct the sacral kyphosis of fractures in 'U', we combined the LPF technique with a sacro-sacral technique. After the insertion of screws in L5, S1, S2, S3 and iliac screws, reduction of the upper sacral fragment was performed using maneuvers of hip extension and femoral traction. Additional maneuvers of compression and distraction were also performed through the rods, using the screws in L5 and the iliac crest as points of support (Figure 2). These maneuvers were not sufficient to achieve complete reduction of the kyphosis. Therefore, it was essential to vary the technique presented.

Transition rods originally developed for use in the cervicothoracic transition were adapted for LPF, allowing the use of smaller-diameter screws (originally developed for the cervical spine) in the lower sacral fragment (Table 1), which was reduced with the aid of bone tweezers, to be subsequently fixed in the pre-molded rods through the screws in S2 and S3 (Figure 2). This adaptation allowed the direct reduction and stabilization of the kyphosis, connecting the lower sacral fragment to the LPF after reduction.

The need for decompression of the spinal canal is another controversial issue in the surgical treatment of sacral fractures in general.[1,12,37,38] As a rule, we performed decompression in all unconscious patients or those with neurological deficits whenever there was impairment of the spinal canal or foraminal comminution. In the case presented here, performing adequate clinical evaluations was a particular challenge. Despite the complaint of perineal hypoesthesia in the first clinical evaluation, the patient's depressive mood and lack of cooperation hindered topographic characterization of the findings, and follow-up. Given that the imaging exams showed obliteration of the spinal canal, and that open surgery was to be performed, we opted for decompressive laminectomy of S1 and S2.

Another important aspect of the LPF technique is performing arthrodesis of the sacroiliac joints. The residual mobility in these joints has been related to breakage of the implants, residual pain, and the need for reoperation.[1,39,40] Bearing in mind the unfavorable psychosocial profile of the patient for subsequent procedures, it was decided to perform the sacroiliac arthrodesis. The patient did

not report any pain, limitations in movement of the hip and lumbar spine, or changes in gait during the follow-up, but we agree that other clinical and biomechanical studies are needed to clarify the importance of this stage in LPF.

Protrusion of the implant is the most common problem related to LPF.[35,36] This was also observed in our patient. Even without continuity lesions or ulcers resulting from pressure on the prominent areas, the patient complained about the aesthetic appearance in all the postoperative visits. The development of implants more suitable for use in LPF may reduce this problem, prompting even more surgeons to use this technique.

A greater number of cases and longer follow-up times are needed to evaluate the complications related to LPF.[3,8-10,19] The same reasoning should be applied to the variation of the technique presented in our case. Until now, the standardization of a technique for the treatment of sacral fractures with spinopelvic instability has not been possible, whether due to the low incidence of these injuries, or to the great morphological heterogeneity of sacral involvement.

The variation of the LPF technique presented here proved to be a viable and promising alternative for the treatment of sacral fractures with spinopelvic instability, especially in cases where the sacral kyphosis cannot be treated by the classical LPF technique alone.

CONCLUSIONS

We present a variation of the LPF technique that aims to combine realignment and spinal-pelvic stabilization in a morphological variant of 'U' fracture. Our technique is a promising alternative to anatomical reduction of kyphosis deformity at the level of the transverse fracture, combining all the benefits of the classical LPF technique.

All authors declare no potential conflict of interest related to this article.

CONTRIBUTION OF THE AUTHORS: Each author made significant individual contributions to this manuscript. VMR(0000-0001-5441-0679)*, ALLB (0000-0002-6517-4285)* and JAMG (0000-0002-5647-2248)* were the main contributors to the writing of the manuscript. VMR, FMC(0000-0002-3773-6914)* and ALLB designed the surgical technique and performed the procedure. VMR, ALLB, AEPAJ(0000-0001-5186-1239)*, APOF (0000-0003-4079-6659)*, and FMC followed-up the patient and gathered clinical data. VMR, ALLB (0000-0002-6517-4285)*, AEPAJ, DPA (0000-0002-5341-3779)* and JAMG conducted the bibliographic research, revision of the manuscript, and contributed to the intellectual concept of the study. *ORCID (Open Researcher and Contributor ID).

REFERENCES

1. Yi C, Hak DJ. Traumatic spinopelvic dissociation or U-shaped sacral fracture: a review of the literature. Injury. 2012;43(4):402-8.
2. Bydon M, Fredrickson V, De la Garza-Ramos R, Li Y, Lehman RA, Jr., Trost GR, et al. Sacral fractures. Neurosurg focus. 2014;37(1):E12.
3. Murray JRD, Erskine JH, Misra RR. ATLS – Advanced Trauma Life Support. In: Murray JRD, Erskine JH, Misra RR. A–Z of Musculoskeletal and Trauma Radiology.Cambridge: Cambridge University Press; 2008. p. 179-80.
4. Hussin P, Chan CY, Saw LB, Kwan MK. U-shaped sacral fracture: an easily missed fracture with high morbidity. A report of two cases. Emerg Med J. 2009;26(9):677-8.
5. Rommens PM, Vanderschot PM, Broos PL. Conventional radiography and CT examination of pelvic ring fractures. A comparative study of 90 patients. Unfallchirurg. 1992;95(8):387-92.
6. Atici Y, Akman YE, Erdogan S, Sari S, Yavuz U, Carkci E et al. The effect of growing rod lengthening technique on the sagittal spinal and the spinopelvic parameters. Eur Spine J. 2014;24(6):1148-57.
7. Halawi MJ. Pelvic ring injuries: Surgical management and long-term outcomes. Journal of clinical orthopaedics and trauma. J Clin Orthop Trauma. 2016;7(1):1-6.
8. Ricci WM, Mamczak C, Tynan M, Streubel P, Gardner M. Pelvic inlet and outlet radiographs redefined. J Bone Joint Surg Am. 2010;92(10):1947-53.
9. Schicho A, Schmidt SA, Seeber K, Olivier A, Richter PH, Gebhard F. Pelvic X-ray misses out on detecting sacral fractures in the elderly - Importance of CT imaging in blunt pelvic trauma. Injury. 2016;47(3):707-10.
10. Konig MA, Jehan S, Boszczyk AA, Boszczyk BM. Surgical management of U-shaped sacral fractures: a systematic review of current treatment strategies. Eur Spine J.2012;21(5):829-36.
11. Schildhauer TA, Bellabarba C, Nork SE, Barei DP, Routt ML Jr., Chapman JR. Decompression and lumbopelvic fixation for sacral fracture-dislocations with spino-pelvic dissociation. J Orthop Trauma. 2006;20(7):447-57.
12. Sagi HC, Militano U, Caron T, Lindvall E. A comprehensive analysis with minimum 1-year follow-up of vertically unstable transforaminal sacral fractures treated with triangular osteosynthesis. J Orthop Trauma. 2009;23(5):313-9.
13. Dudda M, Hoffmann M, Schildhauer TA. [Sacrum fractures and lumbopelvic instabilities in pelvic ring injuries: classification and biomechanical aspects]. Unfallchirurg. 2013;116(11):972-8.
14. Soultanis K, Karaliotas GI, Mastrokalos D, Sakellariou VI, Starantzis KA, Souca cos PN. Lumbopelvic fracture-dislocation combined with unstable pelvic ring injury: one stage stabilisation with spinal instrumentation. Injury. 2011;42(10):1179-83.
15. Sullivan MP, Smith HE, Schuster JM, Donegan D, Mehta S, Ahn J. Spondylopelvic dissociation. Orthop Clin North Am. 2014;45(1):65-75.
16. Janusz P, Tyrakowski M, Monsef JB, Siemionow K. Influence of lower limbs discrepancy and pelvic coronal rotation on pelvic incidence, pelvic tilt and sacral slope. Eur Spine J.2016;25(11):3622-29.
17. Pytiak A, Bomar JD, Peterson JB, Schmitz MR, Pennock AT, Wenger DR et al. Analysis of spinal alignment and pelvic parameters on upright radiographs: implications for acetabular development. J Hip Preserv Surg. 2016;3(3):208-14.
18. Denis F, Davis S, Comfort T. Sacral fractures: an important problem. Retrospective analysis of 236 cases. Clin Orthop Relat Res. 1988;227:67-81.
19. Roy-Camille R, Saillant G, Gagna G, Mazel C. Transverse fracture of the upper sacrum. Suicidal jumper's fracture. Spine (Phila Pa 1976). 1985;10(9):838-45.
20. Hsieh PC, Ondra SL, Wienecke RJ, O'Shaughnessy BA, Koski TR. A novel approach to sagittal balance restoration following iatrogenic sacral fracture and resulting sacral kyphotic deformity. Technical note. J Neurosurg Spine. 2007;6(4):368-72.
21. McLaren AC, Rorabeck CH, Halpenny J. Long-term pain and disability in relation to residual deformity after displaced pelvic ring fractures. Can J Surg. 1990;33(6):492-4.
22. McCarthy ML, MacKenzie EJ, Bosse MJ, Copeland CE, Hash CS, Burgess AR. Functional status following orthopedic trauma in young women. J Trauma. 1995;39(5):828-36; discussion 836-7.
23. Tan GQ, He JL, Fu BS, Li LX, Wang BM, Zhou DS. Lumbopelvic fixation for multiplanar sacral fractures with spinopelvic instability. Injury. 2012;43(8):1318-25.
24. Chaudhary K, Potdar P, Bapat M. Complex multilevel lumbar spine fractures with transverse sacral fracture. Indian J Orthop. 2011;45(6):576-80.
25. Lindahl J, Makinen TJ, Koskinen SK, Soderlund T. Factors associated with outcome of spinopelvic dissociation treated with lumbopelvic fixation. Injury. 2014;45(2):1914-20.
26. Gibbons KJ, Soloniuk DS, Razack N. Neurological injury and patterns of sacral fractures. J Neurosurg. 1990;72(6):889-93.
27. Faiz KW. VAS - visual analog scale. Tidsskrift Nor Laegeforen. 2014;134(3):323.
28. Hoeymans N, van Lindert H, Westert GP. The health status of the Dutch population as assessed by the EQ-6D. Qual Life Res. 2005;14(3):655-63.
29. Lee KJ, Min BW, Oh GM, Lee SW. Surgical Correction of Pelvic Malunion and Nonunion. Clin Orthop Surg. 2015;7(3):396-401.
30. Kanakaris NK, Angoules AG, Nikolaou VS, Kontakis G, Giannoudis PV. Treatment and outcomes of pelvic malunions and nonunions: a systematic review. Clin Orthop Relat Res. 2009;467(8):2112-24.
31. Korhonen U, Taipale P, Heinonen S. Assessment of bony pelvis and vaginally assisted deliveries. ISRN obstetrics and gynecology. 2013;2013:763782.
32. Cannada LK, Barr J. Pelvic fractures in women of childbearing age. Clin Orthop Relat Res. 2010;468(7):1781-9.
33. Hart RA, Badra MI, Madala A, Yoo JU. Use of pelvic incidence as a guide to reduction of H-type spino-pelvic dissociation injuries. J Orthop Trauma. 2007;21(6):369-74.
34. Rhee WT, You SH, Jang YG, Lee SY. Lumbo-sacro-pelvic Fixation Using Iliac Screws for the Complex Lumbo-sacral Fractures. J Korean Neurosurg Soc. 2007;42(6):495-8.
35. He S, Zhang H, Zhao Q, He B, Guo H, Hao D. Posterior approach in treating sacral fracture combined with lumbopelvic dissociation. Orthopedics. 2014;37(11):e1027-32.
36. Sagi HC. Technical aspects and recommended treatment algorithms in triangular osteosynthesis and spinopelvic fixation for vertical shear transforaminal sacral fractures. J Orthop Trauma. 2009;23(5):354-60.
37. Ruatti S, Kerschbaumer G, Gay E, Milaire M, Merloz P, Tonetti J. Technique for reduction and percutaneous fixation of U- and H-shaped sacral fractures. Orthop Traumato Surg Res. 2013;99(5):625-9.
38. Phelan ST, Jones DA, Bishay M. Conservative management of transverse fractures of the sacrum with neurological features. A report of four cases. The Journal of bone and joint surgery British volume. 1991;73(6):969-71.
39. Totterman A, Glott T, Madsen JE, Roise O. Unstable sacral fractures: associated injuries and morbidity at 1 year. Spine (Phila Pa 1976). 2006;31(18):E628-35.
40. Bellabarba C, Schildhauer TA, Vaccaro AR, Chapman JR. Complications associated with surgical stabilization of high-grade sacral fracture dislocations with spino-pelvic instability. Spine (Phila Pa 1976). 2006;31(11 Suppl):S80-8; discussion S104.