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INTRAVERTEBRAL EXPANDABLE IMPLANTS IN THORACOLUMBAR VERTEBRAL COMPRESSION FRACTURES

IMPLANTES INTRAVERTEBRAIS EXPANSÍVEIS NAS FRATURAS VERTEBRAIS DORSOLOMBARES EM COMPRESSÃO

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ABSTRACT

Current scientific evidence enhances the importance of the anatomic restauration of vertebral bodies with compression fractures aiming, as with other human body joints, to obtain a biomechanic and functional spine as close as the one prior to the fracture as possible. We consider that anatomic reduction of these fractures is only completely possible using intravertebral expandable implants, restoring vertebral endplate morphology, and enabling a more adequate intervertebral disc healing. This enables avoiding disc and osteodegenerative changes to that vertebral segment and its adjacent levels, as well as the anterior overload of adjacent vertebral bodies in older adults — a consequence of post-traumatic vertebral flattening — thus minimizing the risk of adjacent vertebral fractures. The ability of vertebral body fracture reduction and height maintenance over time and its percutaneous transpedicular application make the intravertebral expandable implants a very attractive option for treating these fractures. The authors show the direct and indirect reduction concepts of vertebral fractures, review the biomechanics, characteristics and indications of intravertebral expandable implants and present a suggestion for updating the algorithm for the surgical treatment of vertebral compression fractures which includes the use of intravertebral expandable implants. ***Level of Evidence V, Expert Opinion.***

Keywords: Prostheses and Implants. Spinal Fractures. Spine. Fractures, Compression. Fracture Fixation.

RESUMO

A evidência científica atual aponta para a importância de obter restauração anatómica dos corpos vertebrais com fraturas em compressão, tal como acontece em outras articulações do corpo humano, de modo a garantir uma coluna biomecânica e funcionalmente mais próxima da prévia à fratura. Consideramos que a redução anatómica destas fraturas apenas se consegue na totalidade com a aplicação de implantes intravertebrais expansíveis, restaurando a morfologia das plataformas vertebrais e assim proporcionando uma cicatrização do disco intervertebral mais adequada. Isto permite minimizar a progressão para alterações disco e osteodegenerativas desse segmento vertebral e dos níveis adjacentes, bem como em idosos evitar a sobrecarga anterior dos corpos adjacentes consequente ao achatamento pós-traumático e assim minimizar o risco de fraturas vertebrais adjacentes. A capacidade de redução da fratura e de manutenção da altura do corpo vertebral ao longo do tempo, bem com a sua aplicação percutânea transpedicular, torna os implantes intravertebrais expansíveis uma opção muito atrativa no tratamento destas fraturas. Os autores apresentam os conceitos de redução direta e indireta de fraturas vertebrais, revêm a biomecânica, características e indicações dos implantes intravertebrais expansíveis, finalizando com uma proposta de atualização do algoritmo de tratamento cirúrgico das fraturas vertebrais em compressão que inclui a aplicação de implantes intravertebrais expansivos. ***Nível de Evidência V, Opinião do Especialista.***

Descritores: *Próteses e Implantes. Fraturas da Coluna Vertebral. Coluna Vertebral. Fraturas por Compressão. Fixação de Fratura.*

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INTRODUCTION

The treatment of fractures of the thoracolumbar spine, in particular the compression fractures, has evolved rapidly over the past 30 years, having considerably changed the indications, techniques and surgical implants. The morbidity of anterior approaches to anterior spine reconstruction has caused an exaggerated tendency to treat vertebral compression fractures by pedicular fixation, often increasing the number of fixed levels. However, loss of support in the anterior spine, a region that receives 80% of all axial loads, will inevitably overload the posterior instrumentation, sometimes

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resulting in instrumentation failure, loss of vertebral body height, and local and post-traumatic segmental kyphosis, with clinical and functional repercussions.[1-6] In view of this, the minimally invasive techniques of augmenting the fractured vertebral body have gained increasing popularity due to their ability to stabilize the anterior spine through the percutaneous posterior pathway, enabling good results in symptomatic relief, convalescence speed, functional and quality of life indices, and spine anatomy and biomechanics restoration.[7-9] Expanding intravertebral implants are devices capable of controlled self-expansion applied percutaneously via posterior access transpedicular. They are introduced inside the fractured vertebral body, which usually shows a compression fracture. Their expansion can reduce the fracture of the vertebral body, restoring its height, integrity, and stability. The application of *expansive intravertebral implants*, also known as *armed kyphoplasty*, in addition to allowing the immediate analgesia and stabilization benefits of vertebroplasty and kyphoplasty, also allow the maintenance of the restored vertebral height, which is demonstrated in several studies with medium and long-term follow-up.[7-23] This is because, after vertebral platforms height is restored, they are mechanically supported by the expanded device (functioning as a interior support or sustentaculum), decreasing or preventing vertebral flattening, minimizing the risk of local and post-traumatic segmental kyphosis, and ensuring the stable anterior support of vertebral body height.[7,8,24-27] In this way, expansive intravertebral implants have gained popularity in the treatment of vertebral body compression fractures due to its guarantee of stable anterior support at the level of the vertebral body performed percutaneously, transpedicularly, reserving the high invasibility of corpectomy and reconstruction with spacers or massive allograft for cases requiring anterior neurological decompression of the vertebral canal.[24,25,28]

Importance of anatomical reduction in vertebral compression fractures

The authors of this article defend the importance of obtaining, as indicated for the other joints of the human body, an anatomical restoration (or the closest to it) of vertebral bodies which suffered compression fractures (by correcting the vertebral kyphosis angle, vertebral height, and the morphology of vertebral platforms) in order to ensure a biomechanically and functionally spine closer to the one prior to the fracture. Thus, it is sought in young individuals to avoid progression to disc alterations and osteodegenerative disorders of this vertebral segment and adjacent levels and in older adults to avoid the anterior overload of adjacent bodies and thus minimize the risk of adjacent vertebrae fractures.[8,11,16,24,28] Restoring the original anatomy of vertebral platforms enables the recreation of the original position of the often injured intervertebral disc, promoting its proper healing and pressurization and minimizing the invagination of the nucleus pulposus to the interior of the vertebral body, possibly compromising bone healing. This allows a better physiological load damping, potentially minimizing accelerated degeneration and reducing the overload of the suprajacent vertebral body and, thus, the risk of adjacent fractures.[2,6,29-33] A study showed, by functional magnetic resonance, that the apparent diffusion coefficient of the intervertebral disc suprajacent to vertebral compression fractures, after a mean 2.67 years, was significantly higher in fractures treated with expandable intravertebral implants, in which the anatomy of the vertebral platform is restored (thus showing coefficients similar to normal control discs), than fractures subjected to conservative treatment, which maintains the central flattening of the vertebral platform.[34] The diffusion coefficient of suprajacent discs decreased as the post-fracture degree of vertebral kyphosis increased. This coefficient represents the water and nutrient diffusion levels to the nucleus pulposus, thus suggesting the importance of anatomically reducing the vertebral platform supporting the disc to ensure its adequate water and nutritional intake. This study also demonstrates that the application of intravertebral cement has minimal influence on the diffusion of nutrients and water through the vertebral platforms for discs. Thus, the traumatic deformation of the vertebral platform compromises its diffusion circuits to the nucleus pulposus, promoting its dehydration, malnutrition, and the accelerated progression to post-traumatic disc degeneration. Moreover, suprajacent discs, after a mean 2.67 years, were in a significantly more advanced state of degeneration after conservative treatment (83.33% of which with Pfirrmann grades II and III) than those which had undergone intravertebral implant treatment (78.57% showed a Pfirrmann grade I, and the others, a grade II).[7,10,28,34] In particular case of osteoporotic fractures, it is currently recognized that it is essential to restore vertebral body height at the time of the first fracture to prevent the domino effect of the disease, i.e., the consecutive occurrence of osteoporotic fractures in adjacent vertebrae due to anterior spine overload after the first uncorrected vertebral flattening. Vertebral flattening progressively diverts the load axis to a more anterior position, exposing the osteoporotic vertebral bodies to excessive anterior loads and favoring spine kyphotization and a cascade of consecutive pathological fractures.[9,35]

Concepts of anatomical reduction of vertebral compression fractures

Expandable intravertebral implants introduce the concept of *direct fracture reduction* (Figure 1), that is, performed by an expanded implant at the exact fracture location within the vertebral body. If the fracture occurs by mechanism in compression, these implants will do the opposite, they expand the vertebral body, the reverse mechanism to the one that caused the fracture, being therefore a very effective method of fracture reduction. The classic indirect reduction by distraction and lordosis maneuvers through pedicle instrumentation of adjacent vertebrae reduces the cortical ring of the vertebral body due to the effects of containment of the anterior and posterior longitudinal ligaments and the peripheral portions of the vertebral platforms because of containment of the fibrous ring of the intervertebral disc. In turn, only direct reduction by expandable intrasomatic implants enables the restoration of the central part of the vertebral platforms, showing their importance in post-traumatic anatomical reduction and the promotion of adequate disc healing (Figure 1).[2,6,36-37] Moreover, these implants, in view of the integrity of common longitudinal anterior and posterior ligaments and the insertion of the fibrous ring in vertebral platforms, also enable anterior and posterior bone fragments to effectively return to their original positions, respectively, by ligamentotaxis and anulotaxis. Thus, they also reduce the peripheral parts of vertebral platforms and cortical rings.[1,7-22,27,28,30,34,36,38-41] Therefore, we consider that, to obtain the complete desired anatomical reduction of a vertebral compression fracture, direct reduction with expandable intravertebral implants is always necessary to correct the central depression of vertebral platforms. Moreover, in some fractures, this maneuver is sufficient for total fracture reduction and stabilization. Thus, when an initial indirect reduction by adjacent pedicular instrumentation is required, in order to also anatomically restore the central part of vertebral platforms it is necessary to associate it with a direct reduction by expandable intravertebral implants. Several studies have shown that, if expandable intravertebral implants are correctly positioned, the fear that they increase posterior wall retropulsion in burst compression fractures is unverified. On the contrary, by performing ligamentotaxis and anulotaxis at the time of implant expansion, the increased vertebral body height causes the posterior wall to move anteriorly, moving away from the vertebral canal and approaching its original position, restoring the posterior vertebral body height and making an indirect decompression of the vertebral canal.[1,7,11,12,18,36,38,40,41]

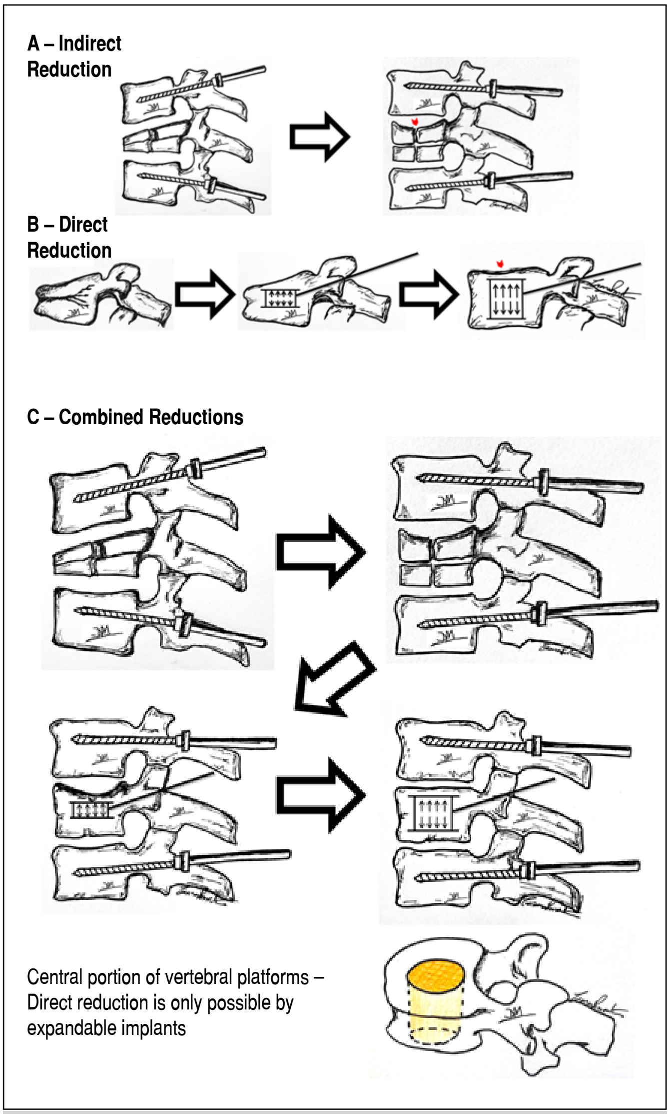
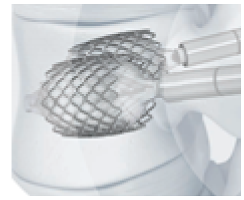


Figure 1. A: Indirect fracture reduction by distraction and lordosis maneuvers performed through instrumentation in the pedicles of adjacent vertebrae. Note the reduction of posterior wall retropulsion and restoration of anterior and posterior sagittal heights of the vertebral body. However, central flattening of the upper vertebral platform persists with no complete restoration of the middle sagittal height of the vertebral body (red arrowhead); B: Direct reduction of the fracture via expandable intravertebral implants. Note the elevation of the entire upper vertebral platform (arrowhead); C: Indirect reduction and direct reduction combined. Notice how direct reducion complements the indirect reduction manouvers, allowing the total anatomical restoration of the vertebral body, that is, the reduction of the cortical ring and also of the central portion of the vertebral platforms.

Table 1. Features of the two main expandable intravertebral implants currently available. Indications of each implant according to the authors' preference.[42,43]

Implant name	VBS® (*Vertebral Body Stenting*)	SpineJack®
Illustration		
Morphology	Cylindrical shape network (stent). Two implants by bipedicular access	Similar to a carjack with upper and lower lamellae. Two implants by bipedicular access
Material	Chromium-cobalt	Titanium
Expansion direction	Circumferential and centrifugal in the coronal plane (craniocaudal + lateral)	Bidirectional in craniocaudal or vertical direction
Expansion mechanism	Hydraulic, by a kyphoplasty ballon (pressure and volume controlled)	Mechanic
Expansion force	Maximum pressure of 30 Atm; Maximum expansion volumes: #Small stent = 4 ml; #Medium stent = 4.5 ml; #Large stent = 5 ml	Expansion force of 500 Newtons; Maximum expansion heights: #Small implant, 4.2 size = 12.5 mm; #Medium implant, 5.0 size = 17 mm; #Large implant, 5.8 size = 20 mm
Goal	Fracture reduction and space filling – Indicated for osteopenia, lithic injuries, and A4 burst traumatic fractures	Fracture reduction, preservation of non-fractured trabeculae – Indicated for A1, A2, and A3 fractures with healthy bones
Rationale	VBS® is a reduction and space-filling implant system since it can multidirectionally expand (vertically and laterally). It is indicated for reconstructing or replacing the vertebral body without waiting for vertebral fracture healing. Stents are implants that form two cavities, coated by a casing of impacted trabeculae, within the vertebral body by expanding and impacting surrounding bony trabeculae. These implants form cavities that, after being filled with cement or bone graft, replace much of the vertebral body, filling and stabilizing it. Moreover, they minimize cement extravasation by recreating the walls of the vertebral body via impaction of bony trabeculae containing the cement.	SpineJack® is a more powerful reduction implant and preserver of non-fractured native bone trabeculae, rather than a filler, as it has only vertical expansion and not lateral. In these cases, fracture reduction and healing is intended, rather than replacing the vertebral body. This implant only reduces and sustains the vertebral body since it shows neither cavitary shape nor lateral expansion. It is incapable of destroying intact lateral trabeculae and does not create significant empty space inside the vertebral body. Thus, it is useful when it is intended to reduce the fracture and obtain bone healing, preserving as much of healthy bone as possible. Therefore, we consider this implant not ideal for replacing the comminuted vertebral body, lytic or porotic, a vertebra that does not have content and needs intrasomatic filling in addition of fracture reduction.

Biomechanics of expandable intravertebral implants

Table 1 shows the features of the two main expandable intravertebral devices currently available, the VBS® (Vertebral Body Stenting) and the SpineJack® systems, the most commonly used worldwide.[42-44] Technological evolution will certainly bring expandable intravertebral implants with different mechanisms and morphology which will effectively ensure the anatomical restoration of vertebral platforms. In short, according to the authors' opinion and according to Table 1, the VBS® implant reduces and replaces the flattened and destroyed vertebral body, does not intending to wait for bone healing, while the SpineJack® implant reduces and preserves the flattened vertebral body, intending to bone healing.

Indications of expandable intravertebral implants

The problem of vertebral compression fractures is located at the vertebral body, it is the one that is fractured, so it makes sense that some direct reduction and stabilization action on this same vertebral body is necessary. Indirect reduction by adjacent pedicular instrumentation, in addition to failing to correct vertebral platform depression, is incapable of providing vertebral bodies with sufficient integrity to receive loads. Indirect reduction maneuvers increase cortical ring height. However the interior of the vertebral body, previously filled with a resistant bony trabecular meshwork is now weak, showing only crushed bony trabeculae, which often results in progressive vertebral flattening and can lead to non-union situations. As such, we consider that the application of expansive intravertebral implants is indicated when an anatomical and sustained reduction of the fracture is intended, as such in most vertebral compression fractures. The purpose of anatomical reduction is in traumatic compression fractures to avoid an early development of degenerative discoarthropathies caused by the persistence of vertebral flattening, and in osteoporotic compression fractures to avoid domino effect of anterior overload caused by vertebral flattening, decreasing thus the risk of adjacent vertebral fractures and the progression of pathological kyphotization of the spine. The literature lacks well-defined flattening and kyphotic values for vertebral bodies which would justify their reduction. Yet, some authors point to the flattening of about one third of the vertebral body height, vertebral kyphoses equal to or greater than 15° and/or Beck sagittal indices equal to or lower than 0.7.[9,11,24,28,35] It is increasingly considered that the reconstruction of the anterior column, particularly the vertebral body, an important support for axial loads predominant in bipedal gait, is essential to rebuilding a spine both biomechanically and physiologically more similar to the one prior to the fracture.[1,8,16] Therefore, it is currently considered that reducing and stabilizing vertebral bodies with expandable intravertebral implants is indicated in compression fractures of the vertebral body, i.e., in type-A fractures in the AO Spine classification, whether traumatic, osteoporotic or tumoral.[3,5,24,38,44,45] Attention is drawn that there may be room for conservative treatment, especially in A1-, A2-, and A3-type fractures, particularly in cases with flattening of less than one third of the vertebral body height and vertebral kyphoses below 15° whose patients can verticalize their trunk without relevant pain.[28,44] However, treatment should always be analyzed on a case-by-case basis, considering that more pronounced deformities may be acceptable in cases in which life-expectancy is short and patients' reduced functionality fail to justify surgical reduction and stabilization. Despite this, it is important to verify that pain relief, standing up, gait, and remaining recovery are usually faster in patients who undergo augmentation of the vertebral body with cement ("up and go" in a few hours and unrestricted activity in 24 hours, often without any pain).[44,46] Kyphoplasty and expandable intravertebral implants have also shown promising results in face of fractures subjected to conservative treatment which had symptomatically and chronically evolved to post-traumatic necrosis, often with associated flattening and kyphosis.[47] Initially, expandable intravertebral implants were considered a reduction and stabilization method complementary to pedicular instrumentation. Nevertheless, several recent studies have shown that most vertebral compression fractures (type-A fractures in the AOSpine classification), i.e., those with intact posterior ligament complexes, can be effectively treated only with these intravertebral implants, which work, at the same time, as a reduction and stabilization device of the vertebral body, with no need for pedicular instrumentation if anterior stabilization is effective.[8,24,25,38,40,44] This is very relevant insofar as most dorsolumbar fractures are compression ones. Thus, they are included in the indication for expandable intravertebral implants, many of which dispense pedicular screws.[10] We highlight below the two special situations in which compression fractures require pedicular screw instrumentation. In complete A4 burst fractures, we recommend, in addition to intravertebral implants, the application of pedicular screws above and below the fracture due to the complete separation of the vertebral body from posterior elements. The fractured vertebra can also be instrumented with short intermediate pedicular screws, as shown by Cianfoni A et al. who published a circumferential vertebral fixation technique without arthrodesis in which fenestrated intermediate screws are inserted inside the stents, working, after cement filling, as anchorage of the posterior elements to the vertebral body, stabilizing all Denis columns.[48] Regardless of the comminution degree of the A4 fracture, if expandable intravertebral implants support the vertebral body, pedicular instrumentation of only one level above and below the fracture is sufficient for a safe construction, consisting in a circumferential stabilization (posterior + anterior), dispensing fixation of further levels due to stable anterior support.[49] We also highlight the cases in which the fracture caused important segmental kyphosis. In these cases, segment reduction is impossible with only intravertebral implants in the fractured body. Thus, we initially recommend reducing segmental kyphosis by distraction and lordosis maneuvers via the pedicular instrumentation of adjacent levels, followed by applying intravertebral implants in the fractured body aiming to complement the reduction of its platforms and maintain this reduction over time. In summary, most compression vertebral fractures may dispense stabilization with pedicle screws since the immediate stabilization of the vertebral body by expansive intravertebral implants enables avoiding the need for discharge that segment with pedicle screws at adjacent levels until there is vertebra healing. The advantage of being able to dispense pedicle fixation is the maintenance of mobility of the segments adjacent to the fractured vertebra, allowing a more physiological biomechanics of the discs and the spine in general, which in theory accelerates patient rehabilitation and minimizes progression of discoarthropathies degenerative changes by compensatory hypermobility of the following unfixed levels. Moreover, it enables avoiding the risk of screw pull-out in the porotic bone and the eventual need to cement them or use expandable screws, as well as eliminating the need for a second surgery to extract the instrumentation. Intravertebral expansive implants also have place in those type B and C fractures of the AOSpine classification associated with a compression component at the vertebral body, however, in these cases it is mandatory to be associated with pedicular screws instrumentation because the posterior elements are compromised and need stabilization.[7,44]

Authors' algorithm for treating vertebral compression fractures

In this section, we present the algorithm followed by the authors for treatment of vertebral compression fractures, applying the referred principles of importance of anatomical reduction and the use of expansive intravertebral implants (Figures 2 and 3).

In healthy bones and AOSpine A1-type traumatic fractures with values equal to or higher than 15° kyphosis and flattening of one third of the height, or A2- and A3-type fractures, we prefer reduction and stabilization with SpineJack® implants. In these fractures, typically in younger patients, in which most of the intrasomatic bony trabeculae are still preserved, the goal is to maintain them, restore vertebral body height and the

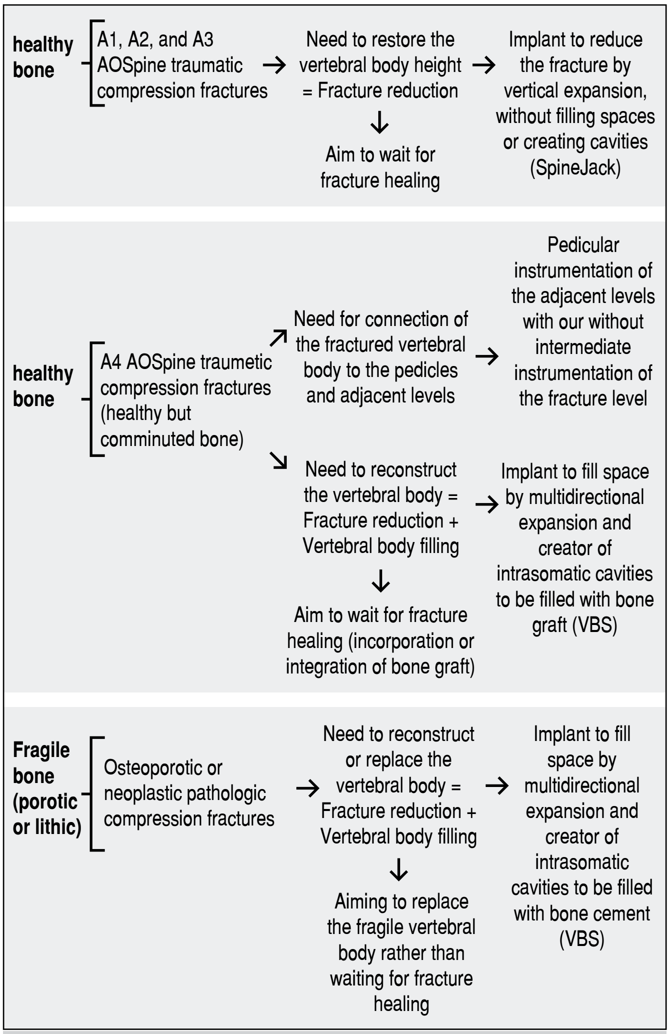


Figure 2. Schematic representation of the objectives for each type of vertebral compression fracture, according to bone quality and the AOSpine classification, as well as the justification for choosing the expandable intravertebral implant to be applied and the need or not for pedicular instrumentation.

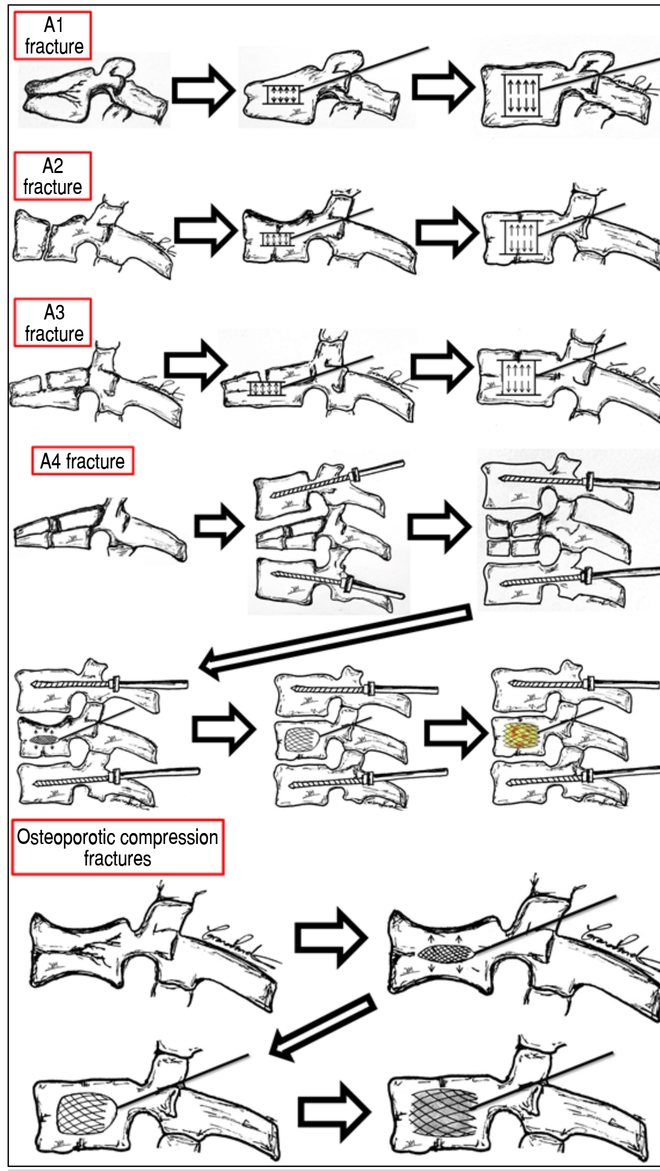


Figure 3. Graphic algorithm of the surgical options for reducing and stabilizing each type of vertebral compression fracture according to the AOSpine classification. A1, A2, and A3 fractures according to AOSpine[44] — reduction and stabilization with SpineJack® expandable intravertebral implants; A4 AOSpine fractures — initial reduction with maneuvers by pedicular instrumentation, additional reduction and replacement of the vertebral body with expansive intravertebral VBS®-type implants filled with bone graft. Note the reduced central depression of the upper vertebral platform after expansion of intravertebral implants and its final filling with bone graft (final image in yellow/brown represents the bone graft inside the stents); Osteoporotic compression fractures – reduction and stabilization with expansive intravertebral VBS®-type implants filled with bone cement. Note the reduced depressions of the upper and lower platforms after expansion of the implants. Final image in gray represents the cement inside the stents.

morphology of the vertebral platforms, and wait for fracture healing, thus obtaining an anatomical and biomechanical vertebra similar to the one prior to the fracture. The implants used for this purpose are SpineJack®, which by its exclusively vertical expansion, elevate the vertebral platforms without destroying many surrounding bone trabeculae (it does not occupy relevant space), then requiring only a minimal amount of bone cement to stabilize the implants. In these fractures, the objective is to wait for their bone healing in an anatomic position. The minimum amount of injected cement does not affect the bone healing process. In A1-, A2-, and A3-type fractures, we consider that direct reduction by expandable implants is sufficient to achieve anatomical restoration and fracture stabilization, except in cases of segmental kyphosis greater than 15°, which require indirect reduction by pedicular instrumentation. Due to the frequent body-pedicle dissociation of type A4 fractures, we initially perform percutaneous pedicle instrumentation at the adjacent levels above and below, then indirect reduction by distraction and lordosis maneuvers through this instrumentation, followed by further direct reduction of the vertebral body and stabilization of the restored height with VBS® implants. Thus, in these fractures with severe destruction of the vertebral body, we subjected the fracture to both types of reduction, initially indirect (pedicular instrumentation) and then direct (expandable implant), seeking to obtain the best possible anatomical restoration. We believe intraosseous vascularization of the vertebral body to be compromised in A4-type fractures. Thus, in these fractures, bone healing is not expected, as such we immediately move toward reconstructing/replacing the vertebral body with cylindrical implants, the stents. These make further reduction of the vertebral body through multidirectional impaction of the surrounding bone trabeculae, in particular by elevation of the central portion of the vertebral platforms, and guarantee the maintenance of this reduction as interior supports (interior sustentaculum). As we recommend for fractures with porotic bone, some authors indicate the intrasomatic application of polymethylmethacrylate cement for A4 burst fractures with healthy bone (even for young patients), arguing that fracture healing takes place even in the presence of cement, as fracture gaps between bone trabeculae and cement are filled by bone callus.[2,6,24,25,35,50-52] However, in view of this type of fractures in healthy bone and young ages, we prefer to fill the stents with bone graft, usually cancellous allograft granules from bone bank. We apply the graft with minimal impaction so as to not compromise bone matrix structure or nutritional diffusion until its revascularization, aiming at its colonization by osteoprogenitor cells, vascular invasion, and bone incorporation. With this filling, we intend to obtain a vertebra biomechanically similar to unfractured ones, i.e., more physiological in the distribution of loads than those filled with polymethylmethacrylate, a biologically inert cement, which makes difficult the future pedicular instrumentation of the vertebra, as well as somehow influencing its biological activity, healing, and remodeling. We consider this option important especially for active young and middle-aged individuals who would request their spine in long term, in which a more rigid vertebra, caused by intrasomatic filling with polymethylmethacrylate cement, can alter the normal balance of the rachis in terms of elasticity and segmental stiffness, which can lead to discovertebral degeneration and adjacent body fractures. Another option could be the intra-stent application of the biologically active and osteoconductive calcium phosphate cement, which is slowly reabsorbed and replaced by bone, unlike the inert polymethylmethacrylate. This biological version of a cement shows its progressive osteointegration while the structure, consistency, and height of the vertebral body, as well as the calcium phosphate cement itself, are mechanically protected by expandable intravertebral impl ants.[2,3,6,24,25,35,39,45,53-56] Still, we prefer for an intrasomatic filling with bone graft, aiming to provide a bone matrix capable of osteoconduction and osteoinduction, thus favoring consolidation to obtain a vertebral body whose morphology and biomechanics are similar to those pre-fracture with a metallic interior endoskeleton filled with the incorporated graft. Several studies have assessed the isolated intrasomatic application of bone graft (without intravertebral expandable implants) in fractures. However, they found a progressive flattening of these vertebrae and graft resorption, probably due to the insufficient mechanical support capacity of the isolated bone graft which suffered excessive loads compromising its integrity and incorporation.[4,31,57-60] Thus, we consider the application of bone graft inside the stents to be fundamental, ensuring not only the maintenance of vertebral height but also protecting the bone graft and minimizing its resorption until its incorporation, obtaining a vertebra with a metallic endoskeleton which is fully filled by bone. The limited histological evidence of cases of isolated intrasomatic application of bone graft (without intravertebral expandable implants) showed, in some patients, the absence of intrasomatic graft incorporation and microscopic findings of partial graft necrosis are frequent even in the presence of clinical evidence and bone healing imaging. This suggests a probable excessive load on the graft to be incorporated (not protected by intravertebral implants) and a weak relation between histology and clinic. However, long-term prospective studies are needed to show the advantages of intrasomatic bone graft application, or its substitute, associated with intravertebral implants in these fractures.[4,31,57-60]

In our opinion, the comminution of both vertebral platforms of A4-type fractures makes in these cases the SpineJack® reduction mechanism less effective since it is based on metal lamelae applied against vertebral upper and lower platforms. If these platforms show comminuted fractures, there is an increased risk of the metallic lamelae either crossing fracture lines and entering the disc space or of them raising only one platform fragment, resulting in an incomplete reduction. In turn, an implant with greater trabecular impaction surface, such as VBS®, enables a more effective direct reduction of A4 fractures, as it impacts the bone trabeculae around them, reinforcing the bone casing of the vertebral body. On the other hand, in fractures with adjacent segmental kyphosis greater than 15°, we prefer to start by indirect reduction maneuvers via pedicular instrumentation, followed by direct reduction by intravertebral implants. If neurological deficits are present, nervous decompression, most often laminectomy, is associated with the aforementioned steps. Corpectomy and filling with massive spacers or allografts is reserved for situations requiring anterior decompression of the vertebral canal.

In turn, in *fragile bone fractures*, i.e., osteoporotic or neoplastic pathological fractures and traumatic fractures in porotic bone, we usually prefer VBS reduction and stabilization filled with polymethylmethacrylate cement. The rarefaction and marked destruction of intrasomatic bony trabeculae in this type of fracture entails the replacement of most of the inner empty vertebral body with another material. In these fractures, typical of an older population, immediate stabilization is sought for rapid symptomatic relief and functional recovery, rather than waiting for fracture healing or a vertebra biomechanically similar to the others. Thus, the marked bone rarefaction of the vertebral body is compensated by applying two VBS® cement-filled cylindrical implants that occupy a considerable space, to obtain a rigid and stable vertebral body. SpineJack® is mainly a reduction implant and not a space-filler. Thus, we usually do not use it in osteoporotic fractures, in which we intend to occupy and immediatly stabilize the intrasomatic space.

CONCLUSION

Current scientific evidence points to the need for the anatomical reduction of compression vertebral body fractures, what can only be achieved in totality with the application of expansive intravertebral implants, restoring the morphology of the vertebral platforms. Percutaneous transpedicular posterior access, the ability to fracture reduction and maintenance of vertebral body height, makes these implants a very attractive option in the treatment of compression fractures of the vertebral bodies, whether of a traumatic, osteoporotic or tumoral nature. Currently, there is no scientific evidence regarding comparative studies on the preferential use of an expandable implant over another. So, for now, the decision is made based on surgeons' opinion. Large prospective studies are needed to consolidate treatment efficacy and elucidate how each expandable intravertebral implant is to be indicated.

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