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Radiological evaluation of fusion patterns after lateral lumbar interbody fusion: institutional case series

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Abstract

Introduction There is no consensus on how to evaluate segmental fusion after lateral lumbar interbody fusion (LLIF). Bone bridges (BB) between two contiguous vertebra are reported as pathognomonic criteria for anterior fusion. However, to the best of our knowledge, there are no radiological investigations on zygapophyseal joints (ZJ) status after LLIF. The aim of this radiological study was to investigate the different fusion patterns after LLIF.

Materials and methods This is a retrospective single-centre radiological study. Patients who underwent LLIF and posterior percutaneous screw fixation for degenerative spondylolisthesis, on a single lumbar level, were considered for eligibility. Complete radiological data and a minimum follow-up of 1 year were the inclusion criteria. Intervertebral BB were investigated for evaluating anterior fusion and ZJ ankylotic degeneration was evaluated according Pathria et al., as a matter of proof of posterior fusion and segmental immobilization.

Results Seventy-four patients were finally included in the present study. Twelve months after surgery, intervertebral BB were recognized in 58 segments (78.3%), whereas ZJ Pathria grade was I in 8 (10.8%) patients, II in 15 (20.3%) and III in 51 (68.9%) that were considered posteriorly fused. The overlapping rate between anteriorly and posteriorly fused segments was 72.4% (42 segments), whereas 10 (13.5%) did not achieve any fusion, anterior or posterior, and 6 (8.1%) were posteriorly fused only.

Conclusions Our results seem to suggest that anterior fusion is not sufficient to achieve segmental immobilization. Further properly designed investigations are needed to investigate eventual clinical–radiological correlations.

Keywords Spine · Instrumentation · Fusion · LLIF · Spondylolisthesis · Minimally invasive spine surgery

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Abbreviations

BB	Bone bridges
CT	Computer tomography
LL	Lateral lumbar interbody fusion
PACS	Picture archiving and communication system
PEEK	PolyEther ether ketone
SD	Standard deviation
ZJ	Zygapophyseal joints

Introduction

Nowadays, many minimally invasive surgical techniques for spinal degenerative conditions are routinely performed, such as the lateral lumbar interbody fusion (LLIF) [1, 2]. It allows restoring the sagittal and the coronal alignments, indirectly enlarging the nerve roots foramina, and providing higher primary stability that leads to secondary fusion [3–6].

Computer tomography (CT), with fine-cuts axial images and multiplanar views, represents the gold standard exam for investigating the presence of bone bridges (BB) between two contiguous vertebrae [7, 8], reported by many authors as pathognomonic criteria for anterior fusion [6, 9–12]. On the other hand, the intervertebral disc is just part of the articular complex, together with the posterior zygapophyseal joints (ZJ). However, to the best of our knowledge, there are no radiological investigations on ZJ joints status after LLIF.

This radiological study aimed to investigate the different fusion patterns after LLIF and posterior percutaneous instrumentation for single-level lumbar degenerative spondylolisthesis.

Materials and methods

Study design and settings

The present study consists of a single-centre retrospective investigation, collecting data from the institutional Picture archiving and communication system (PACS), in a time range from April 2015 to September 2018. Data collection was approved by the IRB.

Inclusion and exclusion criteria

The institutional database was screened for patients who underwent LLIF and posterior percutaneous screw fixation on a single level for degenerative lumbar spondylolisthesis. Only cases with complete clinical and radiological data, pre-collected informed consent for scientific investigations, and a minimum follow-up of 12 months were considered for eligibility.

The exclusion criteria were:

1. Preoperative bone density (studied by Dual Energy X-Ray Absorptiometry, DEXA) with t-score < 2.0;
2. Ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis;
3. Previous lumbar spinal surgery;
4. Pre- or postoperative abnormal spinopelvic parameters [13, 14];
5. Postoperative infection;
6. Neoplastic diseases.
7. Intraoperative evidence of cage subsidence.

Surgical technique

The LLIF, according to the technique originally described by Ozgur et al. [2], was always the first stage, and the instrumentation system was the XLIF (Nuvasive, San Diego, CA, US) in all cases. An accurate discectomy was always performed, avoiding endplates violation. All the implants, made by either PolyEther Ether Ketone (PEEK) or titanium, were filled with graft material (Synthetic bone Nuvasive AttraX Putty, 25 × 9 × 13.5 mm, 6 cc).

The posterior percutaneous fixation with pedicle screws and rods, all made by titanium (Precept, Nuvasive, San Diego, CA, US), was then performed in prone position, as the second stage, carefully avoiding to violate the ZJ.

Radiological outcomes

Preoperative and 12-months postoperative CT scans and X-Ray images were retrieved and reviewed, using a dedicated workstation (Advantage Windows Workstation; GE Medical Systems, Milwaukee USA), by a senior radiologist (A.L.).

Interbody BB inside or around the cage, characterized by trabeculae connecting the cancellous bone of the two vertebrae with no longer evidence of the endplate cortical rim, were considered as pathognomonic criteria for segmental fusion [6, 9–12], and their distribution patterns database.

ZJ were evaluated preoperatively and 12 months after surgery, and their fusion patterns were classified according to Pathria et al. [15]. They were considered fused when Pathria grade III and non-fused for lower grades. Posterior fusion due to the ankylotic degeneration was used as segmental immobilization criteria [16]. CT images were independently evaluated by three authors, two senior spinal surgeons (L.P. and F.C.T) and one senior radiologist (A.L.).

Clinical outcomes

The clinical status was evaluated preoperatively and 12 months after surgery, using a ten-points itemized visual analogue scale (VAS) for leg (VAS-l) and back (VAS-b) pain, and the Oswestry Disability Index (ODI) score. Intraoperative and postoperative complications were recorded.

Statistical analysis

Data are reported as means and standard deviations (SD). Data normality was tested. Categorical variables were compared using the 2-tales Fisher exact test, whereas continuous variables were compared using the T-tests. The inter-rater reliability (IRR) between the three evaluators was calculated using a Fleiss' kappa statistic. An alpha value of 0.05 was set for statistical significance. SPPS ± statistical calculation software (SOSS Inc, Chicago, IL) was used for data analysis.

Results

Participants

Seventy-four patients (41F,33 M) were finally included in the present study. The mean age was 65.1 (±7.7, range 32–77) years and the mean follow-up was 17.1 (±3.5, range 13–22) months. The patients data are summarized in Table 1.

Surgical data

A total of 74 cages were implanted, made by PEEK 39 (52.7%) or titanium 35 (47.3%) and the left side was used for the lateral stage in 56 patients (82.4%). The mean ileal-psoas muscle retraction duration was 22 min (±6.3, range 19–29). The mean intraoperative blood loss was 91.2 (±56.8, range 63–170) ml, and no cases required postoperative blood transfusions. We recorded 7 cases (9.45%) of asymptomatic cage subsidence, 10 cases (13.5%) of transient dysesthesia on the anterior-medial surface of the thigh (ipsilateral to the surgical approach), 7 cases (9.4%) of postoperative paralytic ileus (spontaneously recovered within 3 days), and 3 cases (4%) of abdominal wall twitching. There were no cases requiring reoperation.

Radiological findings

Intervertebral BB was recognized in 58 segments (78.3%), which were considered anteriorly fused, and their topographical distribution patterns are summarized in Fig. 1. One or more BB inside the cage was found in every anteriorly fused segment, whereas in 31 (53.4%), there was evidence of at least one BB also outside of the implant.

On regards of the ZJ evaluation, the preoperative Pathria grade was 0 in 8 (10.8%) patients, I in 58 (78.3%), II in 5 (6.7%) and III in 3 (4%); whereas 12 months after surgery, it was grade I in 8 (10.8%) patients, II in 15 (20.3%) and III in 51 (68.9%) (Fig. 2) that were considered posteriorly fused. The IRR was calculated using the Fleiss' kappa (0.791, 95% CI: 0.613–0.869).

The overlapping rate between anteriorly and posteriorly fused segments was 72.4% (42 segments), whereas 10 (13.5%) did not achieve any fusion, anterior or posterior, and 6 (8.1%) were posteriorly fused only.

The spinopelvic parameters, measured preoperatively and at last radiological follow-up, were: Lumbar Lordosis (LL) 42.9° (±8.1)–48.6° (±9.3) ($p=0.08$); Sacral Slope (SS) 30.7° (±6.4)–32.1° (±7.7) ($p=0.71$); Pelvic Tilt (PT) 19.7° (±4.9)–17.2° (±6.1) ($p=0.46$). The mean disc angle changed from 2.9° (±1.8) to 6.7 (±2.2) ($p=0.00342$). No statistically significative differences, in terms of spinopelvic parameters modification, were found between immobilized and non-immobilized segments, or between fused, partial fused and non-fused levels.

Clinical outcomes

The mean VAS-b score changed from 7.9 (±1.6) preoperatively to 2.4 (±1.9) after 12 months ($p=0.00118$) in fused group, from 8.2 (±0.9) to 3.1 (±1.2) ($p=0.0021$) in partial fused group, and from 8.4(±1.7) to 5.2 (±2.1) in non-fused group ($p=0.0132$). The mean VAS-b score in non-fused group at last follow-up was significatively higher than in fused ($p=0.0023$) and in partial fused (p=0.0043) ones.

The mean preoperative VAS-l changed from 6.8 (±1.6) preoperatively to 2.1 (±1.3) after 12 months ($p=0.0043$) in fused group, from 7.2 (±1.1) to 1.9 (±1.1) ($p=0.0014$) in partial fused group, and from 7.7 (±1.9) to 3.3 (±1.8) in non-fused group ($p=0.0047$). The were no statistically significative differences between the three groups preoperatively or at last follow-up measurements.

The mean ODI score changed from 42% (±9) preoperatively to 18% (±6) after 12 months ($p=0.0001$) in fused group, from 44% (±12) to 22% (±8) ($p=0.0032$) in partial fused group, and from 49% (±10) to 39% (±11) in non-fused group ($p=0.029$). The mean ODI score was statistically higher in non-fused than in fused ($p<0.001$) and in partial fused ($p=0.0067$) groups.

In immobilized and non-immobilized patients, the mean VAS-b scores were, respectively, 8.1 (±1.6) and 8.3 (±1.3) preoperatively ($p=0.32$), then 2.6 (+/1.4) and 4.7 (±1.8)

Table 1 Patients data

Demographical	
Age	65.1±7.7
Sex (F/M)[a]	41 (55.4%)/33 (44.5%)
BMI	25.6±1.1
Diabetes[a]	16, 21.6%
Smokers[a]	31, 41.8%
Instrumentated level[a]	
L1-2	3 (4%)
L2-3	19 (25.7%)
L3-4	21 (28.4%)
L4-5	31 (41.9%)
Mean follow-up (months)	17.1±3.5

Values are reported as mean±standard deviation

[a]Values are reported as number of patients (percentage)

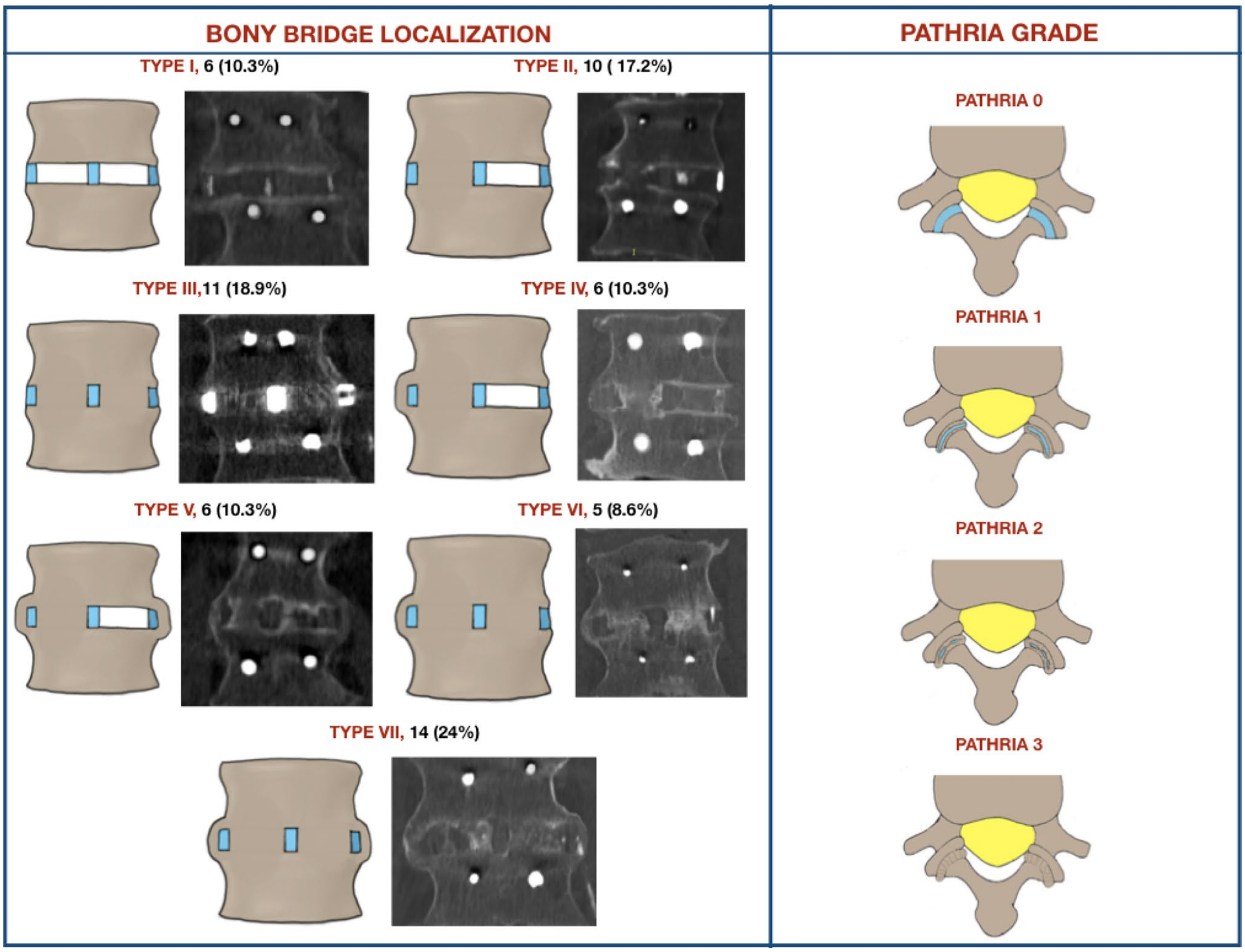

Fig. 1 The topography of intervertebral bone bridges and Pathria classification system. Type I: no bone bridges (no fusion). Type II: bone bridges inside one of the two internal spaces of the cage. Type III: bone bridges in both internal spaces of the cage. Type IV: bone bridges inside one of the two internal spaces of the cage and on one side. Type V: bone bridges inside one of the two internal spaces of the cage and on both sides. Type VI: complete fusion of the inside spaces of the cage, and bone bridge on one lateral side of the cage. Type VII: bone bridges inside the cage bilaterally and on both sides. Right column: Pathria classification system for zygapophyseal joints: grade 0, normal facet joints; grade I, narrowing joint rim, small osteophyte or mild hypertrophy of the articular process; grade II, narrowing joint rim with mild subarticular bone erosions; grade III, ankylosis

after 12 months ($p = 0.0044$); the mean VAS-l scores were, respectively, 6.7 (± 1.6) and 6.9 (± 2) preoperatively ($p = 0.127$), then 2 (± 1.3) and 4.9 (± 1.5) after 12 months ($p < 0.001$); the mean ODI scores were, respectively, 43% (± 11) and 47% (± 9) preoperatively ($p = 0.654$), then 21%(± 5) and 36%(± 8) after 12 months ($p = 0.0076$).

There were no differences in terms of clinical outcomes (VAS-l, VAS-b, ODI) comparing fused and immobilized patients at last follow-up. Clinical data are summarized in Table 2.

Subgroups analysis

Dividing the patients in 2 groups, according to the material of the implanted cage (PEEK or Titanium), those who achieved neither anterior nor posterior fusion were 6 (15.6%)

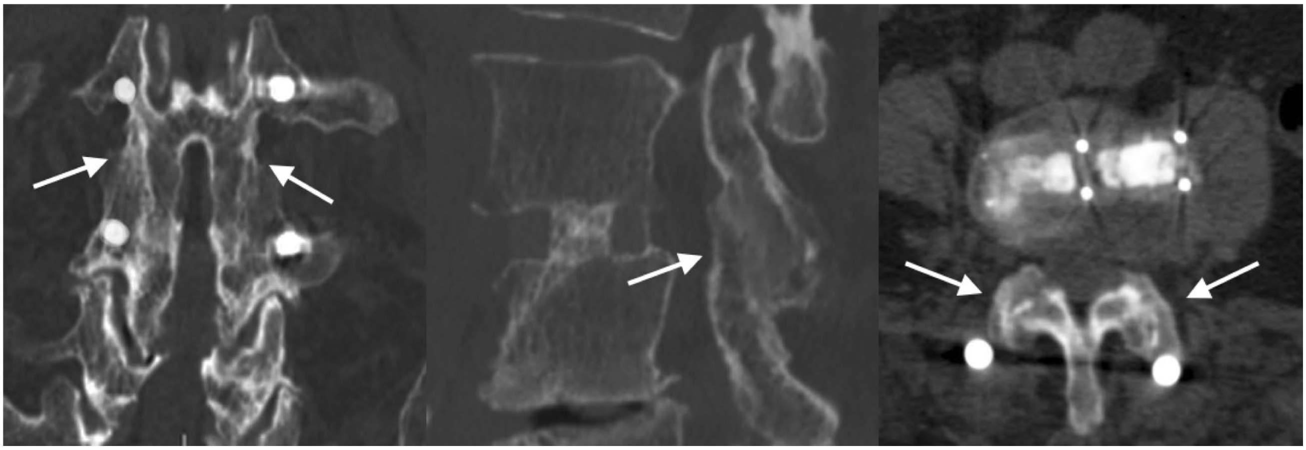

Fig. 2 Zygapophyseal joints ankylosis degeneration. The coronal (left), sagittal (middle) and axial (right) cuts figuring out the zygapophyseal joints ankylotic degeneration (white arrows) rated as Pathria grade III

in the first and 4 (11.6%) in the second group ($p=0.12$); those who achieved only anterior fusion were 9 (23.4%) and 7 (20.3%), respectively ($p=0.44$); posterior fusion only was observed in 4 (10.4%) and 2 (5.8%) patients, respectively ($p=0.23$); finally, anterior and posterior fusions were contemporary found in 20 (52%) patients in the first and 22 (63.8%) in the second group ($p=0.02$).

Discussion

Although even more innovations, in terms of instrumentations and technologies, have been improving surgical and clinical outcomes in spinal procedures, the "pursuit of fusion" still represents the main challenge for surgeons. However, a consensus on how to evaluate segmental fusion is still missing [6, 10–12]. Different methods have been reported, mainly investigating the presence of bone connections between adjacent vertebrae, inside or around the implants [9, 12, 17–20].

Fusion is usually searched for on behalf of the segmental immobilization [9, 20], which prevents those residual micro-movements underlying mechanical stress and fatigue, often leading to systems failures [9, 21], the persistence of back pain and instability related disorders [21, 22]. On the other hand, to evaluate the immobilization is as difficult as it is for the micro-instability, thus indirect radiological signs are usually searched for instead. Accordingly, a way to even indirectly evaluate the segmental immobilization would help in defining the success rate in spinal fusion surgeries.

It has been reported that some segmental motion may exist even after circumferential instrumentations, using LLIF and posterior bilateral pedicle screws [23, 24]. Ankylosis due to immobilization has been widely reported in synovial joints [25–29]. In fact, even lumbar ZJ experience a not reversible ankylotic degeneration when immobilized longer than 5 months on canine models [30], and within 12 months in posterior fixations, with percutaneous screws and rods, for thoracolumbar vertebral fractures [16, 31].

Since the disc and the ZJ constitute an articular complex, once the anterior fusion is achieved posterior ankylosis is expected, as a matter of proof of the segmental immobilization. Accordingly, we used the Pathria classification system to evaluate the ZJ status [15].

Our results showed how not each anteriorly fused segment is immobilized, as well as not each immobilized segment is anteriorly fused. It seems to suggest that the presence of BB is not sufficient for immobilizing the segment. On the other hand, anterior fusion or a solid fixation of the segment due to the implants can determine immobilization and ZJ ankylosis.

Our results suggest that 3 grades of segmental fusion may be obtained after LLIF:

- Non-fusion: no evidence of BB between the two vertebrae or posterior ZJ ankylosis (Pathria grade ranging from 0 to II);

Table 2 Clinical outcomes, trend overtime

	No. of pt	Pre-op VAS-b	12 m VAS-b	*p* value	Pre-op VAS-l	12 m VAS-l	*p* value	Pre-op ODI %	12 m ODI %	*p* value
Fused (F)	42	7.9 ± 1.6	2.4 ± 1.9	0.00118	6.8 ± 1.6	2.1 ± 1.3	0.0043	42 ± 9	18 ± 6	0.0001
Partial fused (PF)	22	8.2 ± 0.9	3.1 ± 1.2	0.0021	7.2 ± 1.1	1.9 ± 1.1	0.0014	44 ± 12	22 ± 8	0.0032
Non-fused (NF)	10	8.4 ± 1.7	5.2 ± 2.1*	0.0132	7.7 ± 1.9	3.3 ± 1.8	0.0047	49 ± 10	39 ± 11*	0.029
Immobilized (I)	48	8.1 ± 1.6	2.6 +/1.4	0.0037	6.7 ± 1.6	2 ± 1.3	0.00481	43 ± 11	21 ± 5	0.00732
Non-immobilized (NI)	26	8.3 ± 1.3	4.7 ± 1.8*	0.0295	6.9 ± 2	4.9 ± 1.5*	0.0189	47 ± 9	36 ± 8*	0.0167

*p value statistical significant: VAS-b 12 m F versus NF $p = 0.0023$, PF versus NF $p = 0.0043$, I versus NI $p = 0.0044$; VAS-l 12 m I versus NI $p \geq 0.001$; ODI 12 m F versus NF $p < 0.001$, PF versus NF $p = 0.0067$, I versus NI $p = 0.0076$

- Partial fusion: either interbody BB or ZJ ankylotic degeneration (Patria grade III);
- Circumferential fusion: both anterior BB and ankylotic ZJ.

On the other hand, the segment could be easier classified as immobilized or non-immobilized, according to the ZJ status. The possible scenarios are summarized in Fig. 3. Our results suggested that there are higher chances for achieving a circumferential fusion using cages made by titanium.

Going through the clinical data, it seems that immobilized segments provide better clinical outcomes, in terms or residual low back and legs pain and disability grade, than non-immobilized ones. Furthermore, this differences is more significative than when comparing fused with partial fused or non-fused segments. Our results seem to suggest that immobilization could influence the clinical outcomes stronger than fusion. Nevertheless, these data should be carefully evaluated, according to the non-negligible limitations of the present study.

Limitations

The present investigation has some limitations to be disclosed. The retrospectively collected data, the absence of any control group and the small patients' sample may affect level of evidence of the present study; we were not able to conduct any comparison with data retrieved from the literature, since there are no studies reporting ZJ fusion patterns, according Pathria et al., in patients suffering from degenerative spondylolisthesis, who underwent surgical treatments; the radiological outcomes were evaluated on images collected 12 months after surgery only, thus, we were not able to detect any trend over time; a delayed fusion or immobilization is still possible later than 1 year from surgery; we did not collect dynamic X-rays during the follow-up, and this may represent a limitation in evaluating clinical–radiological correlations.

Conclusions

Although the fusion rate is a commonly reported outcome after spinal fusion surgeries, the real surgical goal might be the segmental immobilization, which reduces the mechanical stress on the instrumentation system, thus the risk for its failure. Properly designed trials are needed to evaluate the reliability of the ZJ ankylosis as an indirect sign of segmental immobilization and eventually its clinical correlations.

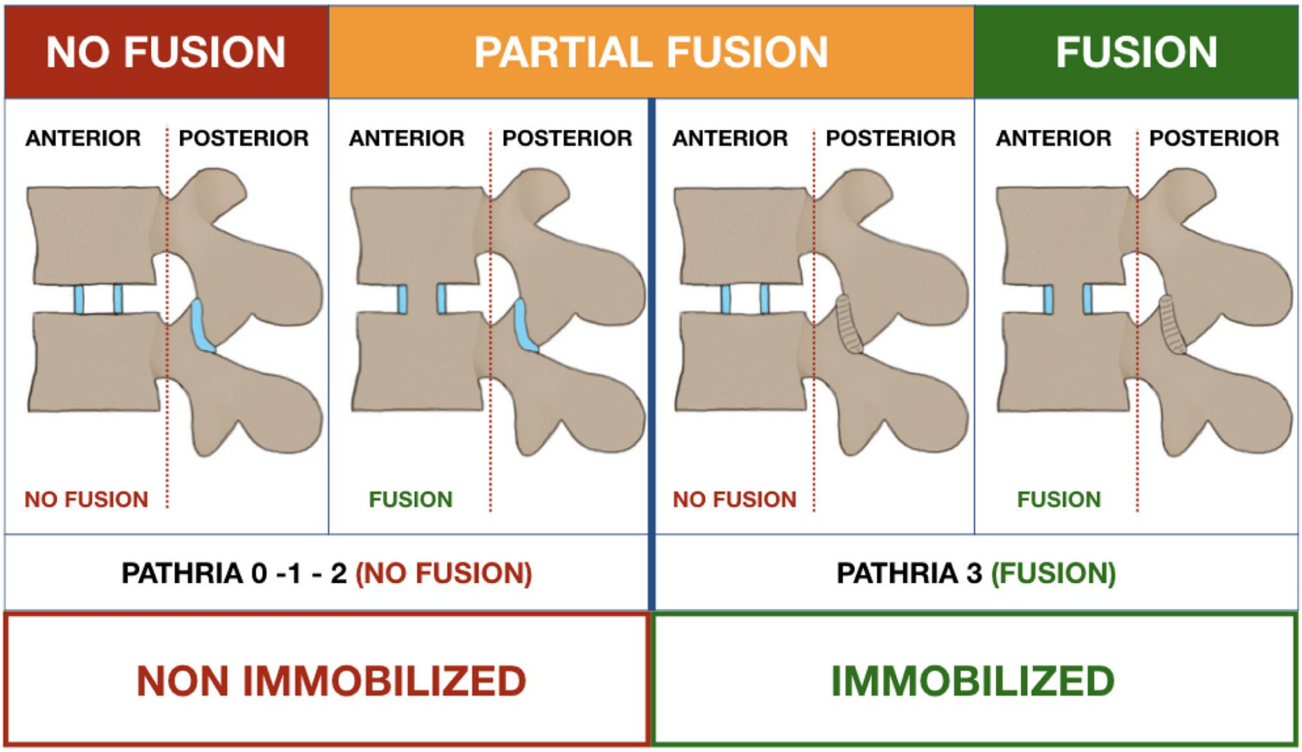

Fig. 3 Fusion grades and immobilization status

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Compliance with ethical standards

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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