Association between Sacral Fractures and Pelvic Ring Injuries: A Correlative Study of Fracture Morphologies

Associação entre fraturas sacrais e lesões de anel pélvico: Estudo correlativo entre as morfologias

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Abstract

Objective To investigate, in a retrospective cohort, the association between sacral fractures and pelvic ring injuries (PRIs) by correlating their respective classification subtypes.

Methods We selected 45 patients admitted to a tertiary trauma center between March 2023 and May 2025. Imaging studies were evaluated for the presence of PRIs and sacral fractures, followed by their classification according to the Tile and Denis systems. Then, a statistical analysis was performed using the McNemar–Bowker test and the Cramér's V coefficient to assess the strength of the association.

Results Among the PRIs classified according to the Tile system, type B was predominant (62.22%), followed by type C (35.56%), and type A (2.22%). Among the sacral fractures classified according to the Denis system, type I was the most prevalent (50%), followed by type II (28.57%), and type III (21.43%). When the classifications were correlated, Tile type-B PRIs showed an 85.7% incidence of associated sacral fractures, 66.6% of which were Denis type I. For Tile type-C PRIs, the incidence of associated sacral fractures was of 100%, with 50% classified as Denis type II. There was a significant association between the Tile and Denis classifications ($p < 0.001$), with a moderate correlation (Cramér's $V = 0.27–0.35$).

Conclusion The study suggests correlations between PRIs and sacral fracture subtypes, with Tile B-Denis I and Tile C-Denis II representing the most frequent associations. This relationship may facilitate diagnostic investigation and improve patient outcomes.

Keywords
- classification
- pelvic bones
- sacrum

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Resumo

Objetivo Investigar, por meio de coorte histórica, a associação entre fraturas sacrais e lesões do anel pélvico (LAPs), por meio da correlação entre seus subtipos classificatórios.

Métodos Foram selecionados 45 pacientes internados em um centro traumatológico terciário entre março de 2023 e maio de 2025. Foram avaliados exames de imagem quanto à presença de LAPs e fraturas sacrais. Em seguida, os pacientes foram classificados segundo as classificações de Tile e de Denis. Então, foram submetidos à análise estatística seguindo a metodologia do teste de McNemar–Bowker e para avaliar a força da associação por meio do coeficiente V de Cramér.

Resultados Na classificação das LAPs por Tile, encontrou-se predominância do tipo B (62,22%), seguido do tipo C (35,56%) e do tipo A (2,22%). Quanto às fraturas sacrais classificadas por Denis, o tipo mais prevalente foi I (50%), seguido do tipo II (28,57%) e do tipo III (21,43%). Ao associar os dados, observou-se que nas LAPs Tile B houve uma incidência de 85,7% de fratura sacral associada, sendo que, destas, 66,6% eram Denis I. Já nas LAPs Tile C, a incidência de fratura sacral associada foi de 100%, sendo 50% descritas como Denis II. Houve associação significativa entre as classificações de Tile e de Denis ($p < 0{,}001$), com correlação moderada (V de Cramér: 0,27–0,35).

Conclusão O estudo sugere correlações entre subtipos de LAP e fraturas sacrais, sendo mais frequentes as associações Tile B-Denis I e Tile C-Denis II. Essa associação pode acelerar a investigação e melhorar os desfechos dos pacientes.

Palavras-chave

- classificação
- ossos pélvicos
- sacro

Introduction

Pelvic ring injuries (PRIs) and their variants have been the subject of academic debate for over a century, from Malgaigne's descriptions in 1859[1] to more recent systematic reviews.[2,3]

These injuries encompass a broad spectrum and present several classifications and subtypes; PRIs occur across all age groups and account for approximately 3% of all fractures. They are more common in male subjects aged 18 to 44 years.[4] Traumatic disruptions of the pelvic ring are most commonly the result of high-energy trauma mechanisms and represent an important cause of morbidity and mortality.[5–7] In the literature,[2,8] mortality rates range from 10 to 40%, depending on the trauma mechanism, the previous clinical status of the patient, and the therapeutic management instituted.

Sacral fractures are relatively rare injuries. However, in PRIs, it is estimated that 10 to 45% of the cases are associated with such fractures,[9,10] with up to 30% of the cases not diagnosed in the first evaluation, resulting in poor outcomes for these patients.[11,12]

Several classification systems have been developed to better understand and characterize this group of injuries. Among them, the most widely used are the Tile classification, which addresses pelvic ring stability,[13] and the Denis classification, which describes the morphology of sacral fractures.[4]

Some studies have addressed the association between sacral fractures and PRIS. However, the literature remains scarce regarding correlations involving their respective subtypes in an attempt to determine the incidence of these synchronous injuries.[14–16]

The objective of the current study was to investigate, through a retrospective evaluation, the association between sacral fractures and PRIs by correlating their respective subtypes.

Materials and Methods

We conducted a retrospective cohort evaluation through a comprehensive review of the database of a tertiary trauma referral hospital to identify PRIs and sacral fractures between March 2023 and May 2025. The evaluation identified 55 cases of PRIs, sacral fractures, and both in patients who required hospitalization.

The inclusion criteria were the presence of PRIs, with or without associated sacral fractures, of traumatic etiology, as well as the availability of radiographic (X-ray) and computed tomography (CT) examinations for injury classification. The exclusion criteria were patients with incomplete complementary studies, non-traumatic etiology, or skeletal immaturity.

After screening, 10 patients were excluded from the study: 1, due to skeletal immaturity, 5, due to incomplete complementary examinations, and 4, because their imaging studies were not available in the radiological archive. As such, 45 participants were eligible for analysis.

Following patient selection, digital pelvic radiographs were retrieved in anteroposterior, inlet, and outlet views, as well as CT scans with reconstructions in axial, sagittal, and coronal planes, all performed in a standardized manner at

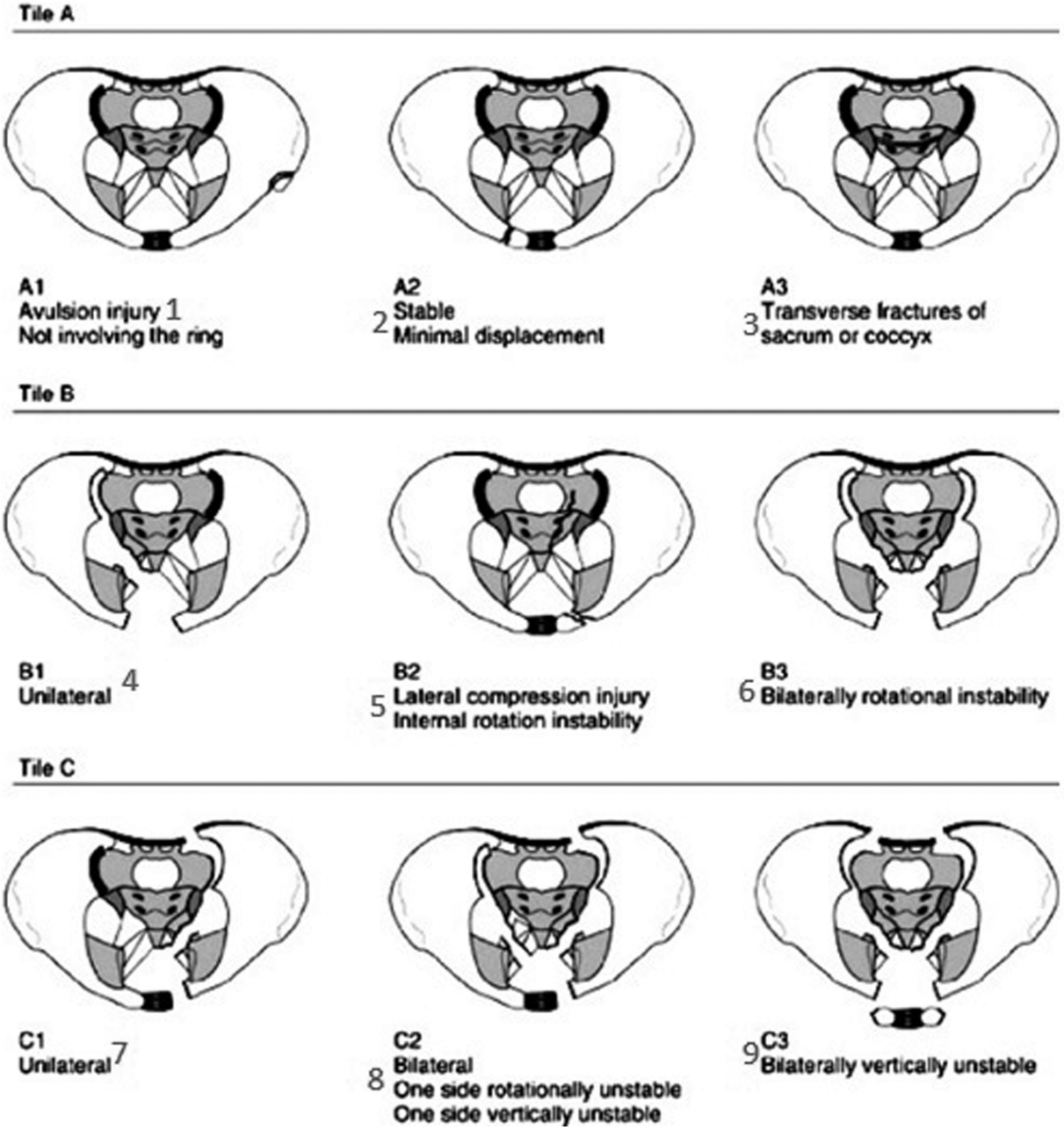

Fig. 1 Tile classification of pelvic ring injuries.

the same radiology center. The PRIs were subsequently evaluated and classified according to the Tile algorithm[13] (►**Fig. 1**), and the sacral fractures, according to the Denis classification (►**Fig. 2**),[11] by four independent examiners (JPLS, AAAJ, JVJS, TCA—resident physicians of the Orthopedic Trauma Unit). In cases of disagreement, a fifth senior examiner (EGF—orthopedic trauma and spine surgeon with 25 years of experience) reassessed the classification.

The data were stored in the Research Electronic Data Capture (REDcap, Vanderbilt University) application, maximizing data security and facilitating subsequent statistical analysis.

A descriptive analysis of the data presented measures of central tendency and dispersion for the numerical variables, as well as absolute and relative frequencies for the categorical variables (Tile and Denis classifications). The McNemar–Bowker test evaluated the associations involving these variables, with paired data arranged in a 3×3 contingency table and subsequently submitted to the Bowker function of the ANSM5 package (version 1.1.1) in the R (R Foundation for Statistical Computing) software. Cramér's V coefficient quantified the strength of the association. The institutional Research Ethics Committee, affiliated with Plataforma Brasil, approved the current study under CAAE number 85686924.9.0000.5553.

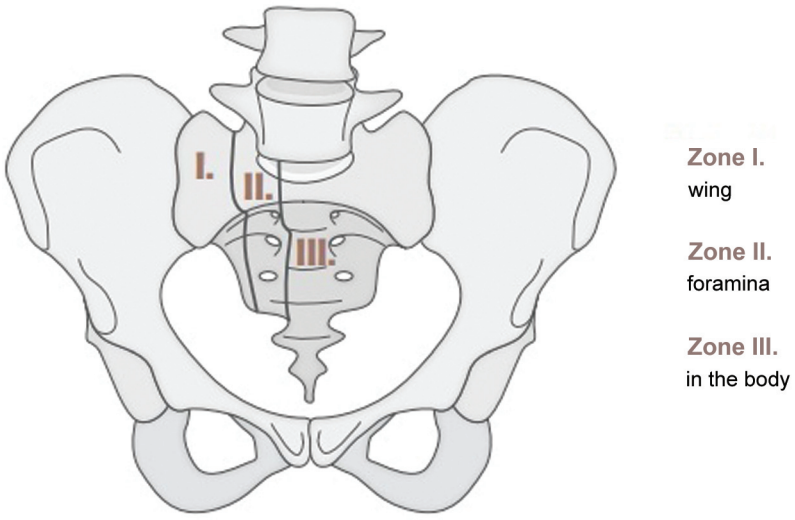

Fig. 2 Denis classification of sacral fractures.

Results

A total of 45 patients were evaluated regarding their radiographic and tomographic presentation of PRIs and sacral fractures (►**Table 1**).

The mean age of the participants was of 44 (range: 18–84) years. The sample consisted of 75.56% (n = 34) of male and 24.44% (n = 11) of female patients.

Regarding the trauma mechanism, pedestrian run-over was the most prevalent, accounting for 37.78% (n = 17), followed by falls from height (24.4%, n = 11), motorcycle falls (22.22%, n = 10), and motor vehicle accidents (15.56%, n = 7).

For the PRIs, there were no statistically significant differences between radiographic and tomographic results. Tile type B was the most frequent (62.22%, n = 28), followed by type C (35.56%, n = 16), and type A (2.22%, n = 1) (►**Fig. 3**).

For sacral fractures, relevant differences were observed between the imaging methods. On the radiographic evaluation, Denis type I accounted for 53.85% of the cases (n = 21), followed by type II (41.03%, n = 16), and type III (5.13%, n = 2), totaling 39 evaluations. On the tomographic evaluation, type I accounted for 50.00% of the cases (n = 21), type II, for 28.57% (n = 12), and type III, for 21.43% (n = 9), totaling 42 evaluations (►**Fig. 4**). Sacral fractures were not identified in six radiographic evaluations; in three of these cases, they also remained undetected on the tomographic evaluation. These cases were excluded from the final statistical analysis for each imaging modality.

A statistically significant association between the Tile and Denis classifications was observed for CT scans and X-rays. For the CT scans, the McNemar–Bowker test showed $\chi^2_{df=3} = 20.33$, $p < 0.001$, with a moderate strength of association (Cramér's V = 0.35; 3 × 3 table). For the X-rays, the McNemar–Bowker test showed $\chi^2_{df=3} = 26.4$, $p < 0.001$, also with a moderate strength of association (Cramér's V = 0.27; 3 × 3 contingency table).

Among Tile type-B PRIs, the incidence of associated sacral fractures was of 85.7%, 66.6% of which were Denis type I. Among Tile type-C PRIs, the incidence of associated sacral fractures was of 100%, with 50% classified as Denis type II. Thus, in both imaging modalities, there was a relative concentration of Denis type-I fractures associated with Tile type-B injuries, and Denis type-II fractures associated with Tile type-C injuries (►**Table 2**).

Discussion

Pelvic ring injuries represent approximately 3% of traumatic skeletal injuries. Up to 80% of PRIs considered unstable result from high-energy trauma.[3] Sacral fractures are estimated to occur in 10 to 45% of these pelvic fractures.[9]

In 1859, Malgaigne described the first recognized classification of PRIs, reporting the *double vertical fracture*.[1] However, the first comprehensive classification of these injuries was proposed only a century later by Tile.[13] who classified PRIs as stable (type-A fractures), rotationally-unstable (type-B), and vertically-unstable (type-C)[13] (►**Fig. 1**).

Sacral fractures are rare injuries and usually result from high-energy trauma. Their incidence remains debated in the literature[17] due to the difficulty in identifying these fractures during the acute phase. Among the reasons for this difficulty are limitations in imaging assessment caused by the overlap of soft tissues and intestinal gas on radiographs, as well as insufficient diagnostic suspicion, since patients often do not present evident neurological deficits during the initial evaluation.[16]

Denis et al.[11] classified sacral fractures into three types according to their anatomical location (►**Fig. 2**): lateral to the foramina (zone I), foraminal (zone II), and medial to the foramina (zone III).

In the present study, the prevalence of PRIs was of 62% for Tile type B, 35% for Tile type C, and 2.2% for Tile type A, differing from the values originally reported by Tile.[13] Denis type-I fractures were the most prevalent (50%), followed by type II (28.6%) and type III (21.4%). Gänsslen et al.[18] observed 42% injuries to zone I, 47% to zone II, and 11% to zone

Table 1 Clinical cases

Case	Age (years)	Gender	Trauma mechanism	Treatment center	Tile classification (X-ray)	Tile classification (CT)	Denis classification (X-ray)	Denis classification (CT)
1	67	Female	Pedestrian run-over	HBDF	C	B	2	2
2	74	Female	Pedestrian run-over	HBDF	C	C	2	1
3	47	Male	Pedestrian run-over	HBDF	C	C	2	2
4	22	Male	Motorcycle fall	HBDF	B	B	1	1
5	23	Female	Motorcycle fall	HBDF	B	B	1	1
6	54	Male	Pedestrian run-over	HBDF	C	C	1	2
7	18	Male	Motorcycle fall	HBDF	C	C	1	2
8	56	Female	Pedestrian run-over	HBDF	B	B	1	1
9	26	Female	Fall from height	HBDF	C	C	2	3
10	46	Female	Pedestrian run-over	HBDF	A	B	Fracture not detected	1
11	40	Female	Pedestrian run-over	HBDF	B	C	2	2
12	27	Male	Fall from height	HBDF	A	A	1	1
13	56	Male	Motorcycle fall	HBDF	C	C	1	2
14	34	Male	Fall from height	HBDF	C	C	2	3
15	61	Male	Fall from height	HBDF	C	C	2	3
16	NA	Male	Motor vehicle accident	HBDF	C	C	2	2
17	39	Male	Motorcycle fall	HBDF	B	B	2	2
18	56	Male	Motorcycle fall	HBDF	B	B	2	3
19	37	Male	Pedestrian run-over	HBDF	B	B	1	1
20	50	Male	Motorcycle fall	HBDF	C	C	Fracture not detected	3
21	20	Male	Pedestrian run-over	HBDF	B	B	1	2
22	44	Male	Motorcycle fall	HBDF	B	B	Fracture not detected	3
23	32	Male	Pedestrian run-over	HBDF	B	B	2	1
24	23	Male	Fall from height	HBDF	B	B	2	1

(*Continued*)

Table 1 (*Continued*)

Case	Age (years)	Gender	Trauma mechanism	Treatment center	Tile classification (X-ray)	Tile classification (CT)	Denis classification (X-ray)	Denis classification (CT)
25	84	Male	Pedestrian run-over	HBDF	B	B	1	1
26	58	Male	Motorcycle fall	HBDF	B	B	1	3
27	23	Female	Pedestrian run-over	HBDF	C	C	2	1
28	23	Male	Pedestrian run-over	HBDF	C	C	1	2
29	32	Male	Motor vehicle accident	HBDF	B	Fracture not detected	1	1
30	61	Female	Fall from height	HBDF	B	B	1	1
31	82	Male	Pedestrian run-over	HBDF	B	B	Fracture not detected	Fracture not detected
32	66	Male	Fall from height	HBDF	B	B	1	1
33	58	Male	Motor vehicle accident	HBDF	B	B	3	3
34	63	Male	Fall from height	HBDF	B	B	1	1
35	44	Female	Motor vehicle accident	HBDF	B	C	1	1
36	75	Male	Fall from height	HBDF	C	C	2	2
37	56	Male	Pedestrian run-over	HBDF	B	B	Fracture not detected	1
38	41	Male	Motorcycle fall	HBDF	B	B	1	1
39	35	Male	Motor vehicle accident	HBDF	B	B	1	Fracture not detected
40	50	Male	Fall from height	HBDF	B	B	1	1
41	19	Female	Motor vehicle accident	HBDF	B	B	2	2
42	49	Male	Pedestrian run-over	HBDF	B	B	1	1
43	22	Female	Motor vehicle accident	HBDF	B	B	Fracture not detected	Fracture not detected
44	19	Female	Pedestrian run-over	HBDF	B	B	2	1
45	26	Male	Fall from height	HBDF	C	C	3	3

Abbreviations: CT, computed tomography; HBDF, Hospital de Base do Distrito Federal, Brazil; X-ray, radiography.

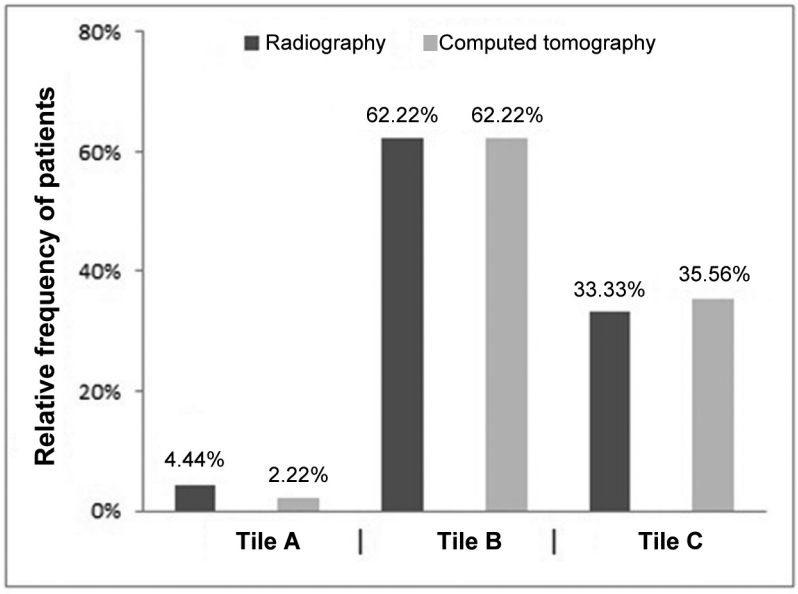

Fig. 3 Radiographic and computed tomography evaluation of pelvic ring injuries.

III, differing from our results. However, studies[10] evaluating the relationship between trauma mechanism and sacral fracture patterns reported discrepant values for zone-II and zone-III injuries. These studies demonstrated that, in anteroposterior compression trauma, sacral fractures to zone III may account for up to 25% of the cases, which is consistent with the data herein presented. The current study identified a positive association between Tile type-B and Denis type-I fractures. Previous investigations have reported similar findings. Beckmann and Cai.[19] observed that, in vertically-stable subtypes, 48% of the lesions were to zone I, corroborating our results.

The present study also identified an association between Tile type-C and Denis type-II fractures. Previous studies[18,19] have reported a high incidence of zone-II and zone-III involvement in vertically-unstable injuries (Tile type C). Tötterman et al.[20] reported fractures to zone II in 72% and to zone III in 22% of the patients with this injury profile, which is consistent with our findings.

The current study has some limitations. As the sample consisted of patients who required admission to a tertiary hospital, there are epidemiological limitations resulting from the relatively-small number of eligible patients. Although statistical significance was achieved, the sample may reflect a tendency toward polytraumatized patients with complex cases and biomechanically-unstable pelvic injuries.

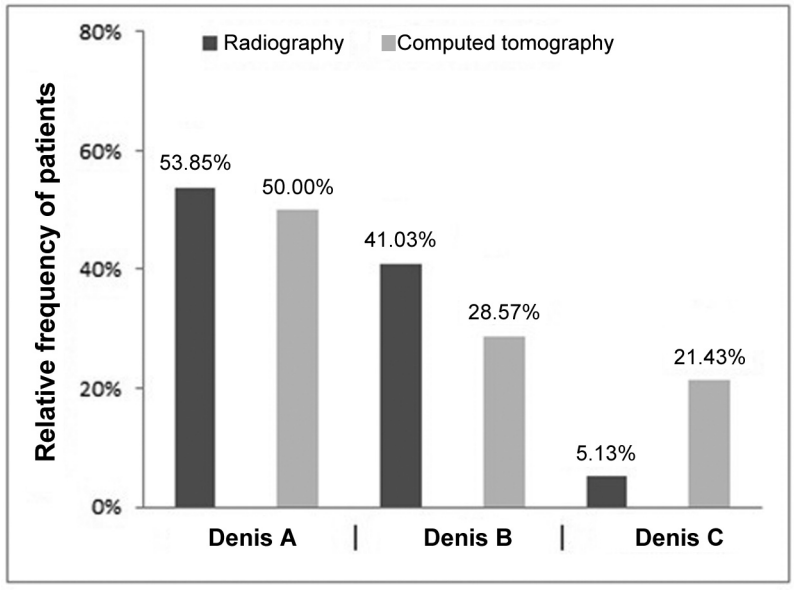

Fig. 4 Radiographic and computed tomography evaluation of sacral fractures.

Table 2 Contingency table

Radiography				
		DENIS		
		1	*2*	*3*
TILE	*A*	1	0	0
	B	16	7	1
	C	4	9	1
McNemar–Bowker test	$\chi^2 = 26.4$	$p < 0.001$		
Cramér's V	0.279			
Computed tomography				
		DENIS		
		1	*2*	*3*
TILE	*A*	1	0	0
	B	16	4	4
	C	3	8	5
McNemar–Bowker test	$\chi^2 = 20.33$	$p < 0.001$		
Cramér's V	0.352			

Conclusion

Sacral fractures and PRIs are associated with high morbidity and mortality, making accurate and early diagnosis essential to enable appropriate management. We can be concluded that there are associations involving specific PRI subtypes and the most prevalent sacral fracture morphologies, particularly Tile B-Denis I and Tile C-Denis II. Recognizing these patterns may help guide diagnostic investigation and support clinical diagnosis.

Data Availability

Data will be available upon request to the corresponding author.

Authors' Contributions

Each author contributed individually and significantly to the development of this article. JPLS: data analysis, writing – original draft, and writing – review & editing. JVJS: methodology and data analysis. AAAJ and TCA: data collection and literature review; and EGF: conceptualization and writing – review & editing.

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Conflict of Interests

The authors have no conflict of interests to declare.

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