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Research article

Assessment of frailty, performance and functional independence in patients with periprosthetic fractures associated with total hip arthroplasty

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Abstract: Periprosthetic fractures (PFs) associated with total hip arthroplasty are significant postoperative complications after hip prosthesis implantation surgery. The aim of this study was to evaluate the fragility, performance and functional independence of patients with PFs associated with total hip arthroplasty. A cross-sectional study was conducted between January and October 2024. The 101 patients evaluated were divided into 3 groups: the group consisting of hip arthroplasty patients - named ATS group (n=36), the group consisting of periprosthetic fractures patients - named PF group (n=11), the group consisting of stage III and IV coxarthrosis patients - named OAH group (n=42). Mean scores fall in the range of pre-fragility - mild frailty for ATS and OAH groups (7.098 ± 2.289 vs. 6.939 ± 1.405), with no significant differences between them, while the mean score of PF group falls in the range of moderate-severe frailty (11.727 ± 3.289). Our data analysis suggests a marked impairment of functional independence in more than 90% of PF patients versus 32% of patients in the ATS group and about 20% of patients in the OAH group; about 75% of patients in the PF group have a significant impairment of functional perfomance. Periprosthetic hip fractures are associated with advancing age and increased fragility. Functional performance and independence of patients with periprosthetic fractures, more than 3 months after fracture, is significantly impaired and is associated with frailty status and advanced age.

Keywords: periprosthetic fractures, fragility, functional performance, functional independence

1. Introduction

Periprosthetic fractures (PFs) associated with total hip arthroplasty represent fractures in the proximity of implants and constitute a significant postoperative complication after hip prosthesis implantation surgery due to their anatomic and biomechanical complexity. These fractures can have various causes, the most common being minor trauma in elderly patients with osteoporosis, or as a result of

falls from the same level. Other identified risk factors are obesity, intense physical exertion and prosthesis design (1).

The prevalence of PFs is increasing, as predicted by Della Rocca et al., with the increasing life expectancy of the population and the increasing incidence of total hip arthroplasty in recent decades. The ageing population and the increasing number of patients with degenerative joint diseases make familiarization with these complications increasingly relevant. PFs can lead to reduced mobility, significant pain and, in many cases, may require additional complicated surgery (2).

Therapeutic management is in accordance with the Vancouver classification (1995) and the Unified Classification System for Periprosthetic Fractures (UCS-PF). PF can range from minor injuries with little impairment of function to major injuries requiring reconstructive treatment. The goals of PF treatment are to achieve anatomic alignment, prosthesis stability, and early mobilization to prevent bone and muscle loss (3).

The population affected by these injuries often consists of older patients who may present with comorbidities and osteopenia, thus emphasizing the need for rigorous preoperative assessment and appropriate surgical planning. The management of these periprosthetic fractures can be complex and requires an individualized approach, given the variability of available techniques, including internal fixation or prosthesis revision. Postsurgical complications represent another major concern, and the associated morbidity and mortality rates have increased interest in studying and improving treatment protocols (4).

Frailty, in the context of health, is a syndrome characterized by a reduction in a person's physical, psychological and social reserves, which makes the individual more vulnerable to stressors and adverse events. It is a common condition among older adults, but can also occur in younger people, depending on various health conditions or lifestyle. Definitions of frailty vary, but usually include clinical criteria such as decreased strength and muscle mass, fatigue, reduced physical activity, impaired mobility, and an overall frail health status (5). In most research, frailty is associated with an increased risk of falls, hospitalizations, functional disability, and mortality. Numerous scores and instruments have been developed to assess frailty, which take into account five key dimensions: unintentional weight loss, muscle weakness, fatigue, reduced physical activity and walking speed. Three of these criteria are sufficient for diagnosis (6). An accurate assessment of frailty allows the development of personalized interventions that can help improve quality of life and reduce associated risks.

The studies show that the incidence of osteoporosis (changes in bone mass and microarchitecture) is increasing in the general population, leading to an increased risk of fracture. More than 25% of osteoporosis is associated with total hip arthroplasty (THA) (7). Associated sarcopenia, a syndrome defined as osteosarcopenia, increases the risk of fragility fractures (8, 9).

The studies published in 2019 by Rebecca L Johnson and collaborators (N=9818 patients undergoing primary and revision total knee arthroplasty) suggest the presence of fragility in one-fifth of recruited patients (10) and that, increased preoperative fragility will lead to perioperative complications after primary and revision total hip arthroplasty (N= 8640 patients) (11). An increased fragility score determined in revision patients after total hip arthroplasty correlates with an increased incidence of complications (12).

The aim of the study was to assess fragility in patients with periprosthetic fractures associated with total hip arthroplasty.

2. Results

2.1. Baseline characteristics

The general characteristics of the patients included in the study are shown in Table 1. Data analysis suggests no significant differences associated with background, gender (p=0.732) among the three groups. Data on the frequency of osteoporosis, osteopenia and frailty are presented.

Table 1. General characteristics for the study groups.

Parameters		Group ATS	Group OAH	Group PF	p-value
Age, M, SD		66.61 ± 7.72	66.06 ± 8.98	74.36 ± 8.77	0.014
Urban, n (%)		17 (41.46)	21 (42.85)	6 (54.54)	0.207
Female, n (%)		21 (41.00)	22 (44.89)	7 (63.63)	0.511
Weight		40 (100)	48 (100)	11 (100)	0.003
	Normal	13 (32.50)	17 (35.42)	4 (36.36)	
	overweight	4 (10.00)	21 (43.75)	1 (9.09)	
	Obesity grade I	11 (27.50)	8 (16.67)	4 (36.36)	
	Obesity grade II	9 (22.50)	1 (2.08)	12 (12.12)	
	Obesity grade III	3 (7.50)	1 (2.08)	4 (4.04)	
Bone density, n (%)					0.537
	Normal limits	10 (25.00)	10 (20.40)	2 (18.19)	
	osteopenia	11 (27.50)	19 (38.77)	6 (54.54)	
	osteoporosis	19 (47.50)	20(40.81)	3 (27.27)	
Frailty staging					p<0.001
	Normal limits	13 (31.70)	3 (6.12)	0 (0.00)	
	Pre-frailty	11 (26.82)	36 (73.47)	1 (9.09)	
	Mild frailty	2 (4.88)	3 (6.12)	0 (0.00)	
	Moderate frailty	13 (31.70)	6 (12.25)	2 (18.18)	
	Severe frailty	2 (4.88)	1 (2.04)	8 (72.72)	

Figure 1 suggests the mean age values for each study group; it can be seen that the mean age in the PF group is higher than the means of the other two groups.

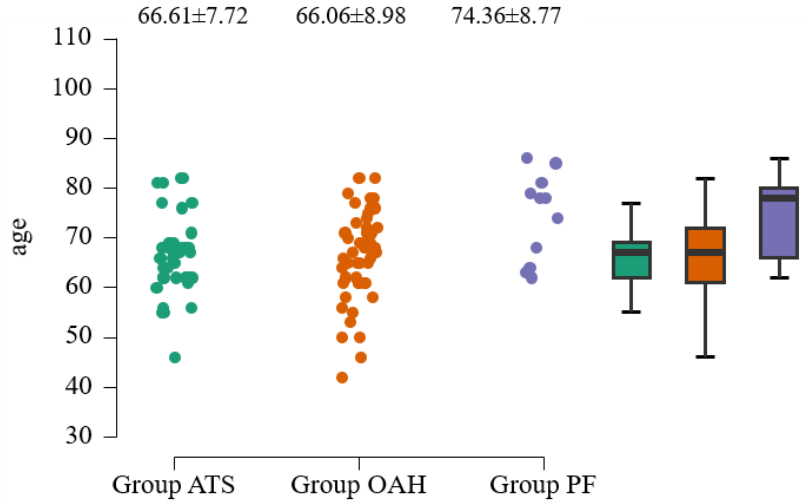

Figure 1. Mean age values in the 3 groups.

Levene's test was applied to assess the homogeneity of dispersion. We can consider that the groups have a homogeneous dispersion (p=0.372). Next, post hoc analysis (ANOVA) was applied to identify differences between groups. Significant differences were observed in the mean age of patients in the 3 groups, namely between the ATS and PF group (p = 0.022) and between the OAH and PF group (p = 0.011) (table 2).

Table 2. Comparative analysis of the mean age of the 3 study groups (ANOVA).

Group		Mean Difference	SE	t	p_{tukey}
Group ATS	Group OAH	0.5409	1.793	0.306	0.950
	Group PF	-7.754	2.876	-2.696	0.022
Group OAH	Group PF	-8.302	2.826	-2.938	0.011

P-value and confidence intervals adjusted for comparing a family of 3 estimates (confidence intervals corrected using the tukey method).

2.2. Total EFS score

The Leneve test of homogeneity of dispersion, when analyzing the total EFS score, suggested an inhomogeneity of the 3 groups ($p<0.05$), thus the Welch test, $p<0.001$, was used for testing. Figure 2 shows that the mean scores fall in the pre-fragility - mild frailty range for the ATS and OAH groups, with no significant differences between them, while the mean score of the PF group falls in the moderate - severe frailty range.

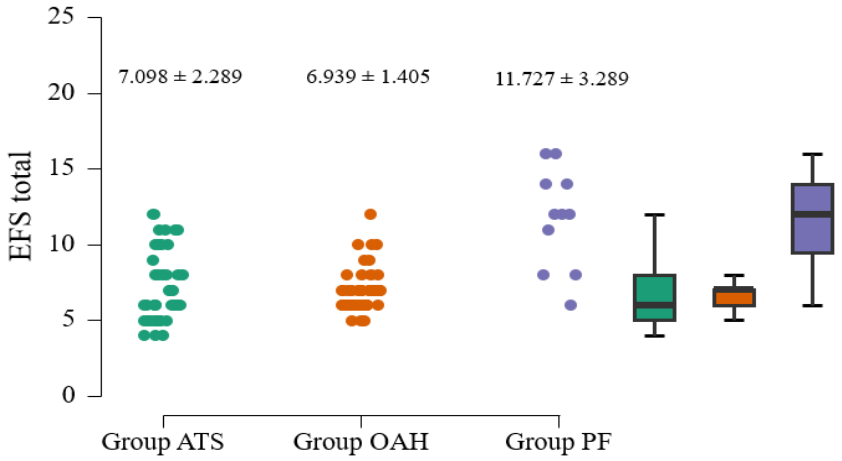

Figure 2. Comparative mean values of the three groups.

In the cohort evaluated, the incidence of severe frailty is about 11%, of which 72.72% is present in the PF group (Table 3). Approximately 63.5% of the total recruited patients fall within normal values or show scores belonging to the pre-frailty or mild frailty domains, of which only 9.09% (N=1) belong to the PF group.

Table 3. Distribution of patients by severity stage.

Frailty staging	Group ATS	Group OAH	Group PF	Total
Normal limits, n (%)	13 (31.70)	3 (6.12)	0 (0.00)	16 (15.84)
Pre-frailty, n (%)	11 (26.83)	36 (73.47)	1 (9.09)	48 (47.52)
Mild frailty, n (%)	2 (4.88)	3 (6.12)	0 (0.00)	5 (4.95)
Moderate frailty, n (%)	13 (31.70)	6 (12.24)	2 (18.18)	21 (20.79)
Severe frailty, n (%)	2 (4.87)	1 (2.04)	8 (72.72)	11 (10.89)

n- number of patients

2.3. Physical performance

Functional performance assesses the time needed for the patient to get up from the chair, walk a distance of 3 m at a brisk pace, turn around and sit down again. A

duration between 0-10 sec is scored 0 points, between 11-20 sec is scored 1 point, a duration of more than 20 sec or the need for assistance is scored 2 points. The mean values obtained for the three groups are shown in figure 3.

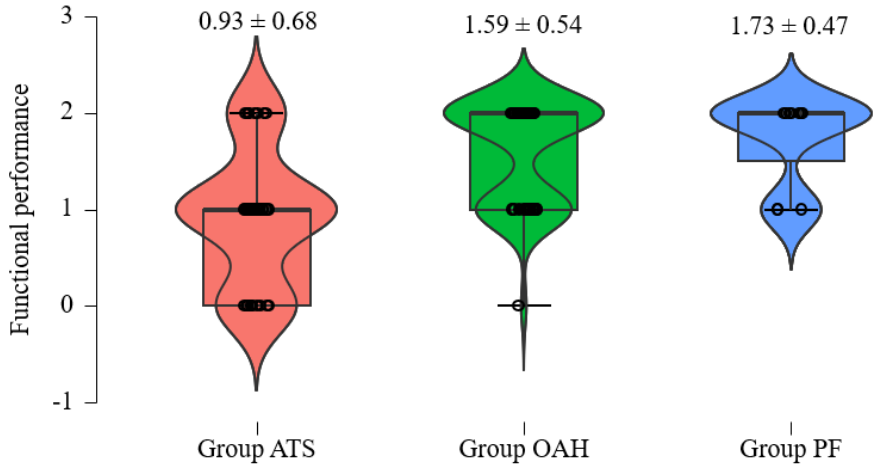

Figure 3. Mean values of functional performance scores.

Table 4 contains the frequency of responses by each group. Analysis of the data shows that approximately 75% of patients in the PF group have a significant impairment in functional perfomance.

Table 4. Frequency of responses by each group.

Group	Functional Performance Score	N (%)
Group ATS	0	11 (26.83)
	1	22 (53.66)
	2	8 (19.51)
Group OAH	0	1 (2.04)
	1	18 (36.73)
	2	30 (61.22)
Group PF	1	3 (27.27)
	2	8 (72.73)

Applied Levene's test indicates homogeneity of dispersion (p=0.628). Post hoc analysis (ANOVA), performed to identify differences between groups, suggests(table 5) that there are no differences between the PF Group and the OAH Group (p=1.00), but differences between the PF Group and the ATS Group are reported (p<0.001).

Table 5. Post hoc analysis (ANOVA) of functional performance scores.

Group		MD	95% CI for Mean Difference		SE	t	p_{tukey}
			Lower	Upper			
Group ATS	Group OAH	-0.665	-0.965	-0.365	0.126	-5.273	<0.001
	Group PF	-0.800	-1.282	-0.319	0.202	-3.956	<0.001
Group OAH	Group PF	-0.135	-0.609	0.338	0.199	-0.681	0.775

MD - Mean Difference; P-value and confidence intervals adjusted for comparing a family of 3 estimates (confidence intervals corrected using the tukey method).

2.4. Functional independence

The mean values of the functional independence score are presented in figure 4. The data analysis shows that the mean value of the score determined for the PF Group is much higher than that of the other two groups, values determined by the difficulties encountered by the patients in shopping, transportation, and housekeeping.

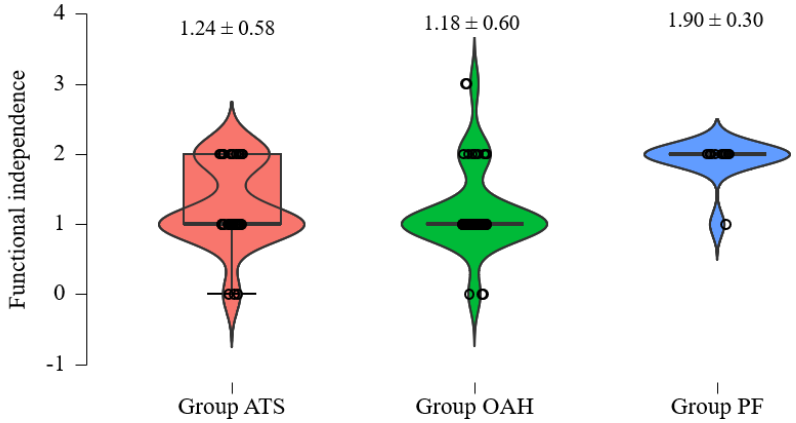

Figure 4. Mean values of functional independence scores.

Frequency Table 6 suggests a marked impairment of functional independence in more than 90% of patients in PF group versus 32% of patients in the ATS group and about 20% of patients in the OAH group.

Table 6. Contingency table on functional independence scores.

Group	Functional Independence Score	N (%)
Group ATS	0	3 (7.31)
	1	25 (60.97)
	2	13 (31.70)
Group OAH	0	3 (6.12)
	1	36 (73.47)
	2	10 (20.40)
Group PF	1	1 (9.09)
	2	10 (90.90)

The post hoc ANOVA (Table 7) on the differences in functional independence scores confirms the differences between the PF and OAH ($p < 0.001$), respectively ATS ($p = 0.003$) groups.

Table 7. Post hoc analysis on the differences between functional independence scores.

Group		Mean Difference	SE	t	p_{tukey}
Group ATS	Group OAH	-0.060	0.121	-0.499	1.000
	Group PF	-0.665	0.193	-3.438	0.003
Group OAH	Group PF	-0.725	0.190	-3.816	$p < 0.001$

3. Discussion

Retrospective assessment of the number of arthroplasties between January and October 2024 shows the incidence of periprosthetic fractures of 3.55% of all hip arthroplasties performed during this period.

The mean age of patients in the PF group was significantly higher than the other groups, comparable with the mean age of patients in the COMPOSE study, 79.9 years, (2022) and the mean age of patients in the PIPPAS [Peri-Implant PeriProsthetic Survival Analysis] study (84 years) (14). The higher incidence in females was also determined in our study (63.63%) similar to the COMPOSE study (63.2%) (15). Furthermore, female gender was the only significant predictor of fracture type (Vancouver classification) for periprosthetic fractures associated with hip arthroplasty.

The causes identified were trauma in approximately 50% of patients. The risk factors identified were altered mineral density (osteopenia/osteoporosis/ pathologic bone) in 75% of patients, obesity in over 60% of patients, similar to other published studies (16). Therapeutic management, correlated with Vancouver staging (54.55% stage B, 45.54% stage C), consisted mostly of plate fixation (72%), with the remaining cases benefiting from prosthesis revision.

The prevalence of Vancouver B PF found in the study correlates with the study by Liu, B et al. suggesting an incidence of 61.29% (16); in the study published by Seung-Jae Lim et al, (N=36), Vancouver B PF are in excess of 80% (17).

The moderate to severe fragility is present in 80% of patients in the PF group versus an incidence of less than 40% in the ATS group, which supports the statement that most PF associated with hip arthroplasty are associated with fragility (18); the increased incidence of fragility in patients with periprosthetic fractures was also determined in the PIPPAS study, a multicenter study published by the PIPPAS Study Group in 2024 (n=1387) (14).

The importance of determining fragility is also supported by the study performed by Rebecca L Johnson and collaborators on 9818 patients with TKA and PF. The risk of periprosthetic fracture increases 4-fold in the first 90 days after total hip arthroplasty; thus, this category of patients should benefit from special surveillance and a particularized recovery program, depending on the factors that favor fragility (10).

The incidence of osteoporosis is increased in the frail patient, as are fragility fractures, which are more common in females (19), emphasizing the importance of BMI and FRAX determination (20).

The functional performance of PF patients is significantly decreased compared to the other two groups. A study published by J. Moreta and co-workers (2015), in which walking ability was monitored for 58 patients, shows that more than 50% of patients did not return to the status before the periprosthetic fracture (21). Results of a comparative study performed on patients with uncomplicated joint arthroplasty versus PF patients, published by A. Luzzi and co-workers (2024) suggested significantly lower WOMAC - function scores in the group of patients with periprosthetic fracture, similar to our study (22).

Strengths and Limitations of the Study

The novelty of this study is the multidimensional assessment (9 domains) of patients with PF compared to patients with hip arthroplasty and stage III/IV coxarthrosis. Also, this study is the first study in Romania, to our knowledge, that followed the impact of PF on functional performance and functional independence in Romanian patients. Functional performance is assessed by lifting, walking, turning and sitting ability.

We consider as limitations of the study the single-center evaluation, the cross-sectional design of the study and the lack of long-term evaluation, the relatively small number of the study group, the lack of identification of the prosthesis design.

4. Materials and Methods

4.1. Study Design

A cross-sectional study was conducted between January and October 2024, in Ploiesti County Hospital to evaluate the incidence of frailty, performance and functional independence in patients with periprosthetic fractures associated with total hip arthroplasty. For comparative evaluation, patients with coxarthrosis stages III and IV (preoperative status), patients with total hip arthroplasty at minimum 3 months after prosthesis, patients with diagnosis of periprosthetic fracture associated with total hip arthroplasty (stages A, B, C Vancouver) at minimum 3 months after fracture treatment were recruited.

A total of 125 consecutive patients with the mentioned osteo-articular hip pathology were evaluated for inclusion in the study.

4.2. Inclusion/Exclusion Criteria

Patients with osteo-articular hip pathology (stages III-IV coxarthrosis, total hip arthroplasty, periprosthetic fractures associated ATS) with compensated associated comorbidities were considered eligible.

Exclusion criteria were:

- Patients with coxarthrosis stages I and II,
- Patients with recent surgical revision, including arthroplasty or prosthesis revision, less than 3 months.
- Patients with decompensated associated pathologies, patient refusal.

After applying inclusion/exclusion criteria, patients were divided into three groups (Figure 5):

- The group consisting of hip arthroplasty patients - named ATS group (n=36),
- Group consisting of periprosthetic fracture patients - named PF group (n=11),
- The group of patients with coxarthrosis stage III and IV - called OAH group (n=42).

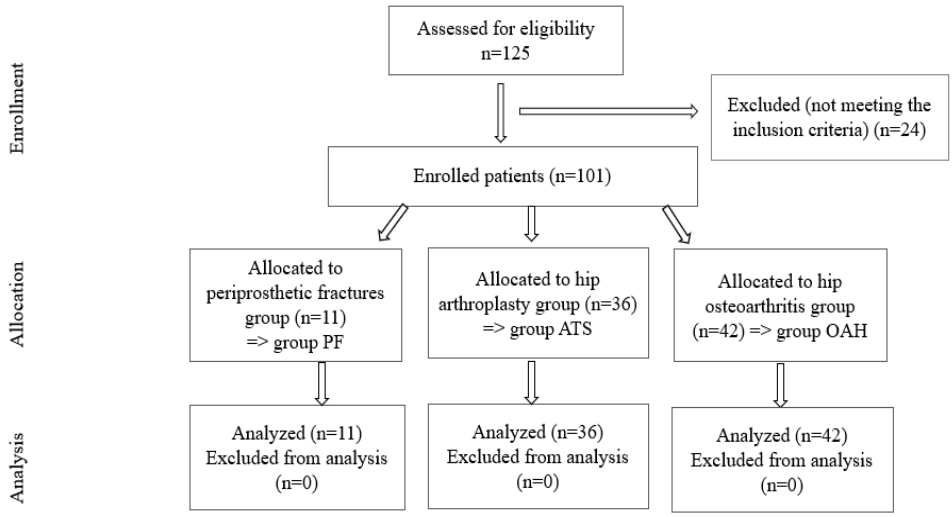

Figure 5. CONSORT flow diagram of the study.

4.3. Sample size

The formula used to calculate the sample size of the subjects included in the study was n = t2 pq/(x2 + t2 pq/N), where (p - probability of occurrence of the phenomenon, 0p1, q - counterprobability, q = 1-p, t - probability factor, x - error limit, N - community size). The result obtained by applying the above formula is N = 96.

4.4. Study tools

The patients enrolled in the study were administered the Edmonton Frail Scale (EFS) questionnaire by 2 independent team members. The frailty questionnaire, EFS, (translated by a certified translator) assesses nine dimensions that characterize patients' quality of life and are associated with frailty (cognition, general health, functional independence, social support, medication use, nutrition, mood, continence, functional performance) (13). Each of the assessed domains are scored from 0 to 2 (0 - best performance and 2 - significant impairment). The total score ranges from 0 to 17; values below 5 indicate no frailty, 6-7 express pre-frailty, 8 and 9 indicate mild frailty, 10-11 moderate frailty. A value above 12 suggests severe frailty.

4.5. Ethical Approval

The study was approved by the Institutional Review Committee of the County Hospital of Ploiești, Prahova County, Romania. The research was conducted in accordance with the Declaration of Helsinki of the World Medical Association. Participation in the study was voluntary.

2.6. Statistical Analysis

Data processing was performed using JASP version 0.18.1.0. The means and the standard deviations were determined. Levene's test was used to assess the homogeneity of variances between the different groups. If the data were homogeneous, parametric tests (ANOVA) were subsequently used. Statistical significance was set for $p < 0.05$.

5. Conclusions

Periprosthetic hip fractures are associated with advancing age and increased fragility. The functional performance of patients with periprosthetic fractures, more than 3 months after the fracture, is impaired in more than 75% of cases. Also marked reduction in functional independence is present in more than 90% of patients. This research can be a starting point for the development/implementation of optimal public health policies on the identification of risk factors associated with periprosthetic fractures. Early diagnosis, appropriate treatments and preventive measures can significantly reduce the impact of these injuries on patients' mobility and quality of life.

Author Contributions: Conceptualization, V.N., R.E., and R.D.N; methodology, V.N., R.D.N., S.T.; software, V.N., R.D.N., S.T.; validation, S.T., C.M., M.G.P., R.D.N. and V.N.; formal analysis, V.N., R.E., A.L.D., S.T.; investigation, V.N., S.T., R.D.N.; resources, V.N.; data curation, X.X.; writing—original draft preparation, V.N., R.E., A.L.D., S.T., C.M., M.G.P., R.D.N.; writing—review and editing, V.N., R.E., A.L.D., S.T., C.M., M.G.P., R.D.N.; visualization, V.N., R.E., A.L.D., S.T., C.M., M.G.P., R.D.N.; supervision, R.D.N., R.E., A.L.D.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee (no. 54150/31.10.2024) for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

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