Association Between PFNA Trochanteric Protrusion Height and Hip Pain in Geriatric Patients with Pertrochanteric Fractures

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ABSTRACT

Introduction: Per-/intertrochanteric femur fractures in the elderly are commonly treated surgically, with the Proximal Femoral Nail Antirotation (PFNA) system being a frequent implant choice. However, concerns exist about its compatibility with the proximal femur geometry in Asian patients, potentially leading to post-operative hip pain. This study aimed to assess the association between PFNA trochanteric protrusion height and post-operative hip pain, functional outcomes, and the development of trochanteric bursitis in geriatric patients.

Materials and methods: Patients aged 60 and older with per-/intertrochanteric fractures treated with the PFNA system were recruited. Subjects were categorised by trochanteric protrusion height (<1cm, 1-1.5cm, >1.5cm). The association between protrusion height and post-operative hip pain (measured by the Numeric Rating Scale), functional outcomes (assessed by the modified Harris Hip Score : mHHS), and trochanteric bursitis was evaluated at one- and three-months post-surgery.

Results: Among 101 patients, 92% had trochanteric protrusion with a median height of 0.96cm, and 53.47% experienced lateral hip pain. Protrusion heights >1.5cm were associated with significantly higher pain scores at one and three months ($p = 0.008$ and $p = 0.001$, respectively) and a higher likelihood of developing trochanteric bursitis (OR = 9.49, $p = 0.001$). Protrusion heights >1 cm was associated with poorer functional outcomes (mHHS) at one and three months.

Conclusion: Greater PFNA trochanteric protrusion height is associated with increased hip pain, a higher risk of trochanteric bursitis, and poorer functional outcomes. These findings emphasise the need for thorough pre-operative planning and review of proper surgical techniques to optimise outcomes and reduce complications.

Keywords:
trochanteric protrusion height, hip pain, trochanteric bursitis, pertrochanteric fracture, intertrochanteric fracture

INTRODUCTION

Per-/intertrochanteric fractures of the femur represent a prevalent occurrence in the elderly, typically resulting from low-energy trauma. Cephalomedullary nailing is a frequently employed surgical technique for the treatment of per-/intertrochanteric fractures of the femur, with one notable option being the Proximal Femoral Nail Antirotation (PFNA) system. Introduced in 2004 as a variant of the PFN device, the PFNA system features a singular head-neck helical blade[1]. Originally tailored for the Western population with larger skeletal frames, the PFNA system underwent modifications to suit Asian anatomical characteristics, resulting in the PFNA-II. These modifications included reducing the proximal nail diameter from 17mm to 16.5mm, decreasing the mediolateral angulation from 6° to 5°, and flattening the proximal lateral surface of the nail[1-2]. Despite these adaptations, studies have revealed continued incompatibility with the proximal femur geometry in Asians[1-2]. Moreover, the limited availability of this device locally poses a challenge.

While the PFNA has been established as generally effective in treatment of per-/intertrochanteric fractures, some patients may still experience persistent or new-onset hip pain, potentially attributable to geometric incompatibilities of the device[1-4]. In a study conducted by Hu *et al*, post-operative hip pain emerged as a prominent symptom following PFNA device fixation. The investigation revealed a notably high incidence of this symptom among patients with a PFNA protrusion height averaging 11.13mm[1]. Similarly, Kim *et al* observed hip pain around the greater trochanteric region in a

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cohort with an average protrusion height of 9.01mm[2]. Tang *et al* identified trochanteric bursitis as a potential contributor to post-operative hip pain[3].

Trochanteric bursitis is the inflammation of the bursa on the lateral aspect of the hip, superficial to the hip abductor muscles and deep to the iliotibial band[5-7]. This inflammatory response can be the result of repetitive microtrauma, gross trauma, or idiopathic causes[5-6]. The proximal end of the PFNA may contribute to the development of trochanteric bursitis, creating a "nail-point effect" where the protruding nail abuts the adjacent bursa[8].

Presently, the PFNA has been gaining traction as the preferred implant for the treatment of trochanteric femur fractures. However, as mentioned, complications can still arise, prompting a need for further investigation. While studies have evaluated the anatomic compatibility of the current system for the Asian population, specific research on the association between PFNA trochanteric protrusion height and post-operative hip pain is scarce. Such an inquiry holds potential significance in pre-operative planning for patients with trochanteric femur fractures and may inform future designs of the PFNA system for the Asian population.

This primary objective of this study is to assess the association between PFNA trochanteric protrusion height and post-operative hip pain among geriatric patients with pertrochanteric and intertrochanteric femur fractures. Specifically, the objective is to measure PFNA trochanteric protrusion height using the Picture Archiving and Communication System (PACS) measuring tools and evaluate its association with post-operative hip pain using the Numeric Rating Scale (NRS), functional outcome assessed via the modified Harris Hip Score (mHHS), and the presence of trochanteric bursitis.

MATERIALS AND METHODS

The study adheres to the ethical considerations and ethical principles set out in relevant guidelines, including the Declaration of Helsinki, WHO guidelines, International Conference on Harmonization-Good Clinical Practice, Data Privacy Act of 2012, and National Ethics Guidelines for Health Research 2017. The study protocol was reviewed and approved by the Review Board and Research and Ethics Committee of the institution.

The study follows a prospective cohort design. Patients were recruited through purposive sampling, targeting individuals aged 60 years and older with per-/intertrochanteric fractures classified as AO 31A1-A3, who underwent surgery using a short or long PFNA system, and achieved acceptable post-operative reduction with a neck-shaft angle of 130 ± 7°. To ensure comparability, inclusion was limited to surgeries performed using the Kanghui NeoGen AR Nail system with the following specifications: 16.5° proximal diameter, 5° proximal bend, flat proximal lateral surface, 130 caput-collum-diaphyseal (CCD) angle; and Sharma Elegant® New Gama Nail system with the following specifications: 14° proximal diameter, 5° proximal bend, flat proximal lateral surface, 135° caput-collum-diaphyseal (CCD) angle. Recent studies have demonstrated no significant difference in functional outcome and post-operative pain between short and long PFNA systems, hence inclusion of both nail lengths[9,10]. Exclusion criteria included patients with multiple injuries, non-ambulatory status, pathologic proximal femur fractures, pre-operative history of trochanteric bursitis, and those treated with PFNA for femoral neck or subtrochanteric fractures.

On recruitment, informed consent was obtained from each patient, and demographic and clinical data were collected, which included age, sex, admitting diagnosis, and dates of injury and surgery. Anteroposterior pelvic radiographs were obtained at one-month post-surgery, with measurements conducted using the digital ruler within the institution's Picture Archiving and Communication System (PACS), by a single examiner. To ensure accuracy, measurements were calibrated based on the diameter of nail used. PFNA trochanteric protrusion height was determined in accordance with the methodology established by Hu *et al*, involving the measurement of the distance from the lateral proximal tip of the nail to the tip of the greater trochanter connecting the lateral border of the nail (Fig. 1)[1].

Patients were categorised into three groups based on measurements: <1cm, 1-1.5cm, and >1.5cm (Fig. 2). Pain level was assessed using the Numeric Rating Scale (NRS) (Fig. 3), while functional outcome was evaluated using the modified Harris Hip Score (mHHS) (Fig. 4) by orthopaedic surgeons who were blinded on patient group, with assessments conducted at both one- and three-months post-surgery. Initial assessment was done at the first post-operative month to mitigate the influence of acute post-surgical pain. The mHHS assesses function based on 8 domains: pain, limp, support, distance walked, stairs, shoes and socks, sitting, and public transport which is scored in total from 0-100 and is interpreted as poor (<70), fair (70-79), good (80-89) and excellent (>90)[11]. The presence of trochanteric bursitis was determined if all three of the following physical examination findings were present: (1) localised pain with deep palpation over the greater trochanter on the lateral aspect of the proximal femur, (2) positive Ober's test, and (3) negative isometric abduction test, resisted abduction test, hip lag sign, and single leg stance test[7,12]. Data collected were recorded in an Excel spreadsheet, with each patient assigned identifiers to ensure confidentiality.

Patients diagnosed with trochanteric bursitis were initiated on treatment, which included pharmacological management with nonsteroidal anti-inflammatory drugs (NSAIDs), along with rehabilitation management focusing on quadriceps

Table I: Demographic and clinical characteristics according to proximal femoral nail antirotation (PFNA) trochanteric protrusion height classifications among the participants (N = 101).

Characteristics	PFNA Trochanteric Protrusion Height (N = 101)				Test Statistic[a]	p-value (Two-Tailed)
	<1cm (n = 53)	1 to 1.50cm (n = 26)	>1.50cm (n = 22)	Total (N = 101)		
Age (Years; $\bar{x}$, SD)	74.30 (8.53)	72.73 (7.83)	77.45 (7.39)	74.58 (8.21)	2.08	0.130
Sex (f, %)					1.12	0.571
Male	12 (22.64%)	8 (30.77%)	4 (18.18%)	24 (23.76%)		
Female	41 (77.36%)	18 (69.23%)	18 (81.82%)	77 (76.24%)		
Laterality (f, %)					5.79	0.055
Left	33 (62.26%)	14 (53.85%)	7 (31.82%)	54 (53.47%)		
Right	20 (37.74%)	12 (46.15%)	15 (68.18%)	47 (46.53%)		
Greater Trochanter Protrusion Height (Centimeters; Md, IQR)	0.61 (0.25 – 0.80)	1.24 (1.13 – 1.37)	1.75 (1.64 – 1.98)	0.96 (0.61 – 1.46)	82.88†	0.001
Neck-Shaft Angle (Degrees; Md, IQR)	130 (125 – 135)	130 (128 – 133)	128 (126 – 130)	130 (126 – 134)	1.67	0.434
Type of Implant (f, %)					1.62	0.602
Short Implant	50 (94.34%)	24 (92.31%)	22 (100.00%)	96 (95.05%)		
Long Implant	3 (5.66%)	2 (7.69%)	0 (0.00%)	5 (4.95%)		
Lateral Hip Pain Status (f, %)					5.67	0.060
Without Pain	30 (56.60%)	11 (42.31%)	6 (27.27%)	47 (46.53%)		
With Pain	23 (43.40%)	15 (57.69%)	16 (72.73%)	54 (53.47%)		
Pain Medications (f, %)						
Celecoxib	3 (5.66%)	1 (3.85%)	2 (9.09%)	6 (5.94%)	0.60	0.736
Tramadol	8 (15.09%)	9 (34.62%)	8 (36.36%)	25 (24.75%)	5.60	0.057
Mefenamic Acid	0 (0.00%)	2 (7.69%)	1 (4.55%)	3 (2.97%)	3.82	0.104

[a]Note: Comparative analyses were conducted using Chi-Square Test of Homogeneity, for nominal data; Kruskall-Wallis H Test for ordinal and non-normal, continuous data; or, One-Way Analysis of Variance (ANOVA), for normally-distributed, continuous data.
*Significant at 0.05
†Significant at 0.01

Table II: Between-group comparisons of the first month outcomes (pain score, tenderness, trochanteric bursitis, modified harris hip score, and functional outcome) according to proximal femoral nail antirotation (PFNA) trochanteric protrusion height classification among the participants (N = 101).

First Month Outcomes	PFNA Trochanteric Protrusion Height (N = 101)				Test Statistic	p-value (Two-Tailed)
	<1cm (n = 53)	1 to 1.5cm (n = 26)	>1.5cm (n = 22)	Total (N = 101)		
Pain Score ($\bar{x}$, SD)	1.92 (2.52)	2.85 (2.80)	3.82 (3.16)	2.57 (2.82)	3.89*	0.024
Positive tenderness (f, %)	10 (18.87%)	10 (38.46%)	14 (63.64%)	34 (33.66%)	14.31†	0.001
Positive Trochanteric Bursitis (f, %)	7 (13.21%)	7 (26.92%)	13 (59.09%)	27 (26.73%)	16.71†	0.001
Modified Harris Hip Score (mHHS; $\bar{x}$, SD)	70.72 (11.59)	61.88 (15.03)	52.59 (16.60)	64.50 (15.42)	14.23†	0.001
Functional Outcome (f, %)						
Poor (Scores <70)	18 (33.96%)	16 (61.54%)	18 (81.82%)	52 (51.49%)	15.67†	0.001
Fair (Scores 70 to 79)	22 (41.51%)	8 (30.77%)	4 (18.18%)	34 (33.66%)	3.92	0.154
Good (Scores 80 to 89)	13 (24.53%)	2 (7.69%)	0 (0.00%)	15 (14.85%)	8.82*	0.011
Excellent (Scores ≥90)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	–	–

[a]Note: Comparative analyses were conducted using Chi-Square Test of Homogeneity, for nominal data; Kruskall-Wallis H Test for ordinal and non-normal, continuous data; or, One-Way Analysis of Variance (ANOVA), for normally-distributed, continuous data.
*Significant at 0.05
†Significant at 0.01

strengthening, iliotibial band stretching, and hip abduction exercises[5,7,13]. The study subjects adhered to a single post-operative rehabilitation treatment protocol post-surgery[14] (Fig. 5).

Statistical analyses were conducted using STATA-MP Parallel Edition Statistical Software, Version 18, College Station, TX: StataCorp LP. A p-value ≤0.05 was considered statistically significant. Descriptive statistics included frequency and percentage for nominal data; median and interquartile range for ordinal and non-normal, continuous

Table III: Between-group comparisons of the third month outcomes (pain score, tenderness, trochanteric bursitis, modified harris hip score, and functional outcome) according to proximal femoral nail antirotation (PFNA) trochanteric protrusion height classification among the participants (N = 101).

Third Month Outcomes	PFNA Trochanteric Protrusion Height (N = 101)				Test Statistic	p-value (Two-Tailed)
	<1cm (n = 53)	1 to 1.50cm (n = 26)	>1.50cm (n = 22)	Total (N = 101)		
Pain Score ($\bar{x}$, SD)	0.96 (1.68)	1.12 (1.61)	2.18 (1.74)	1.27 (1.73)	4.28*	0.017
Positive tenderness (f, %)	7 (13.21%)	7 (26.92%)	10 (45.45%)	24 (23.76%)	9.12*	0.012
Modified Harris Hip Score (mHHS; $\bar{x}$, SD)	79.49 (12.35)	71.08 (12.20)	66.64 (12.92)	74.52 (13.47)	9.64†	0.001
Functional Outcome (f, %)						
Poor (Scores <70)	11 (20.75%)	11 (42.31%)	12 (54.55%)	34 (33.66%)	9.12†	0.010
Fair (Scores 70 to 79)	11 (20.75%)	8 (30.77%)	7 (31.82%)	26 (25.74%)	1.46	0.492
Good (Scores 80 to 89)	17 (32.08%)	6 (23.08%)	3 (13.64%)	26 (25.74%)	2.90	0.254
Excellent (Scores ≥90)	14 (26.42%)	1 (3.85%)	0 (0.00%)	15 (14.85%)	11.93†	0.002

[a]Note: Comparative analyses were conducted using Chi-Square Test of Homogeneity, for nominal data; Kruskall-Wallis H Test for ordinal and non-normal, continuous data; or, One-Way Analysis of Variance (ANOVA), for normally-distributed, continuous data.
*Significant at 0.05
†Significant at 0.01

Table IV: Univariate linear and binary logistic regression analyses for the association of proximal femoral nail antirotation (PFNA) trochanteric protrusion height classification with the first- and third-month outcomes among the participants (N = 101).

Proximal femoral nail antirotation (PFNA) trochanteric protrusion height	First Month Outcome							
	Pain Score		Modified Harris Hip Score		Tenderness (Positive)		Trochanteric Bursitis (Positive)	
	β Coefficient	p-value (Two-Tailed)	β Coefficient	p-value (Two-Tailed)	Odds Ratio (OR)	p-value (Two-Tailed)	Odds Ratio (OR)	p-value (Two-Tailed)
<1cm	Referent	–	Referent	–	Referent	–	Referent	–
1 to 1.5cm	0.14	0.163	–0.25†	0.008	2.69	0.064	2.42	0.141
>1.5cm	0.28†	0.008	–0.49†	0.001	7.53†	0.001	9.49†	0.001

Proximal femoral nail antirotation (PFNA) trochanteric protrusion height	Third Month Outcome					
	Pain Score		Modified Harris Hip Score		Tenderness (Positive)	
	β Coefficient	p-value (Two-Tailed)	β Coefficient	p-value (Two-Tailed)	Odds Ratio (OR)	p-value (Two-Tailed)
<1cm	Referent	–	Referent	–	Referent	–
1 to 1.5cm	0.04	0.703	–0.27†	0.006	2.42	0.141
>1.5cm	0.29†	0.005	–0.40†	0.001	5.48†	0.004

*Significant at 0.05
†Significant at 0.01

data; and mean and standard deviation for normally distributed, continuous data. Data normality was analysed using Shapiro-Wilk's Test[15]. Between-group comparisons of the demographic characteristics, first month outcomes, and third month outcomes (pain score, tenderness, trochanteric bursitis, and mHHS) according to PFNA trochanteric protrusion height classifications (<1cm, 1-1.5 cm, and >1.5cm) were conducted using Chi-Square Test of Homogenity for nominal data; Kruskall-Wallis H Test for ordinal and non-normal, continuous data; and, one-way Analysis of Variance (ANOVA) for normally-distributed, continuous data. For statistically significant comparisons, post-hoc pairwise comparisons were conducted using Bonferroni adjustments[15]. The association of PFNA trochanteric protrusion height with the first- and third-month outcomes were conducted using univariate linear and binary logistic regression analyses. Linear regression was utilised to determine the association of the PFNA trochanteric protrusion height with the first- and third-month pain scores and mHHS. Binary logistic was used for the association of the PFNA trochanteric protrusion height with the presence of tenderness and trochanteric bursitis status[15].

RESULTS

The study had a dropout rate of 17% (n=21) after initial recruitment of 122 subjects. Among these dropouts, 11 were due to mortality from causes unrelated to the surgery, while

Fig. 1: PFNA protrusion height (PPH) = distance from lateral proximal tip of nail (A) to tip of greater trochanter connecting the lateral border.

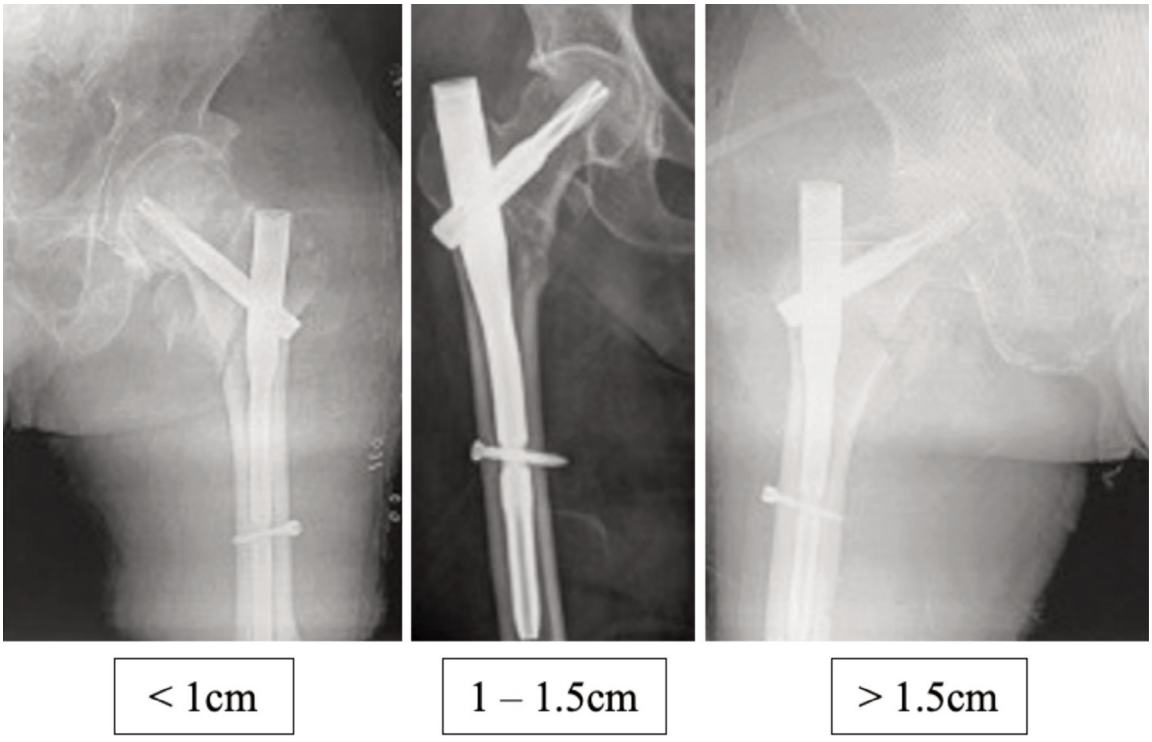

Fig. 2: Sample radiographs with different PFNA protrusion heights.

10 were lost to follow-up. Mean age of the participants was 74.58 years old (SD=8.21), majority of which were females (76.24%). 53.47% of participants had left extremity affectation. Additionally, a short PFNA was used in 95.05% of participants. Ninety-three out of 101 (92%) subjects presented with PFNA trochanteric protrusion. The median greater trochanteric protrusion height was 0.96cm (IQR = 0.61 – 1.46), and the median neck-shaft angle was 130° (IQR = 126 – 134°). A total of 53.47% of the participants had lateral hip pain, and the most common pain medication given was Tramadol (24.75%). Demographic and clinical characteristics were not statistically different across the comparison groups (p>0.05) (Table I).

At one month, the mean pain score was significantly higher among those with a trochanteric protrusion height >1.5cm compared to those with <1cm (3.82±3.16 vs. 1.92±2.52, p=0.023) (Table II). At three months, the mean pain score of those with a trochanteric protrusion height of >1.5cm (2.18±1.74 vs. 0.96±1.68) remained significantly higher than

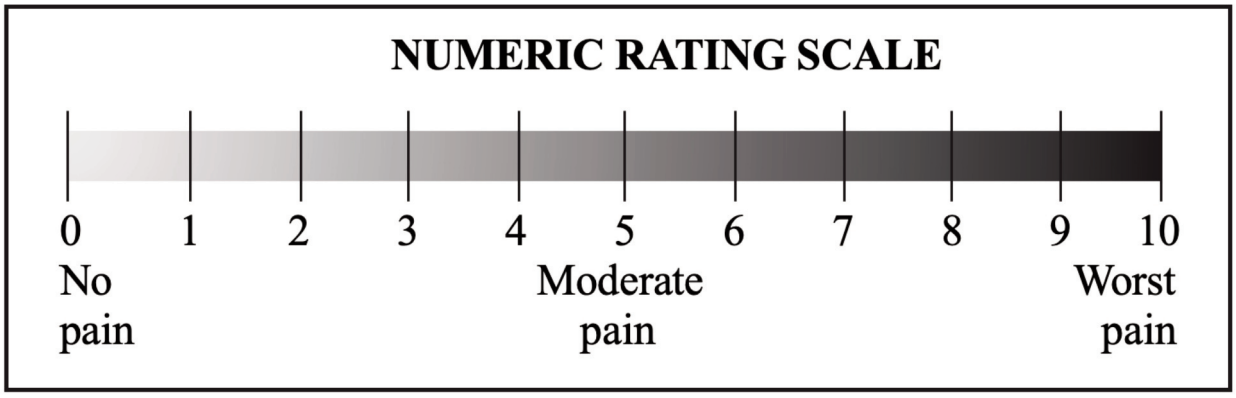

Fig. 3: Numeric rating scale (NRS).

Pain	
None or ignores it	44
Slight, occasional	40
Mild pain, rarely moderate	30
Moderate pain	20
Marked pain	10
Totally disabled, pain in bed	0
Function	
Limp	
None	11
Slight	8
Moderate	5
Severe	0
Support	
None	11
Cane, long walks	7
Cane, most of the time	5
One crutch	3
Two canes	2
Two crutches	0
Not able to walk	0
Distance walked	
Unlimited	11
Six blocks	8
Two or three blocks	5
Indoors only	2
Bed and chair	0
Stairs	
Normally without railing	4
Normally with railing	2
In any manner	1
Unable to do	0
Shoes and socks	
With ease	4
With difficulty	2
Unable	0
Sitting	
Ordinary chair for 1 h	5
High chair for 1 h	3
Unable to sit in any chair	0
Public transport	
Able to use	1
Unable to use	0

Fig. 4: Modified Harris hip score (mHHS) .

those with <1cm (Table III). A protrusion height of >1.5cm was associated with a pain score 0.28-units higher than the <1cm group (β=0.28, p=0.008) (Table IV). Similarly, protrusion heights of >1.5cm was associated with a pain score 0.29-units higher than those with a protrusion height of <1cm (β=0.29, p=0.005) (Table IV).

The mean mHHS scores among those with trochanteric protrusion height >1.5cm (52.59±16.60 vs. 70.72±11.59 p=0.001) and between 1 to 1.5cm (61.88±15.03 vs. 70.72±11.59, p=0.025) had significantly lower scores compared to those with a trochanteric protrusion height of <1cm, indicating poor functional outcome at one month (Table II). Those with a PFNA trochanteric protrusion height of 1cm to 1.5cm (β=–0.25, p=0.008) and >1.5cm (β=–0.49, p=0.001) had mHHS scores which were 0.25-units and 0.49-units significantly lower than those with a PFNA trochanteric protrusion height of <1cm, respectively (Table IV). At three

	Post-operative positioning	Additional limb support	Exercise, weight bearing	Comment
Intertrochanteric/Pertrochanteric Femur Fracture	Leg extended in slight abduction (cushion between legs)	May use cane/walker as support	Younger patient: Partial weight bearing (toe touch): 15kg week 0-6 30kg week 4-10 Full weight bearing: when comfortable Elderly: Full weight bearing as tolerated	Full weight bearing can start immediately (within 24 hours)

Fig. 5: Post-operative rehabilitation protocol

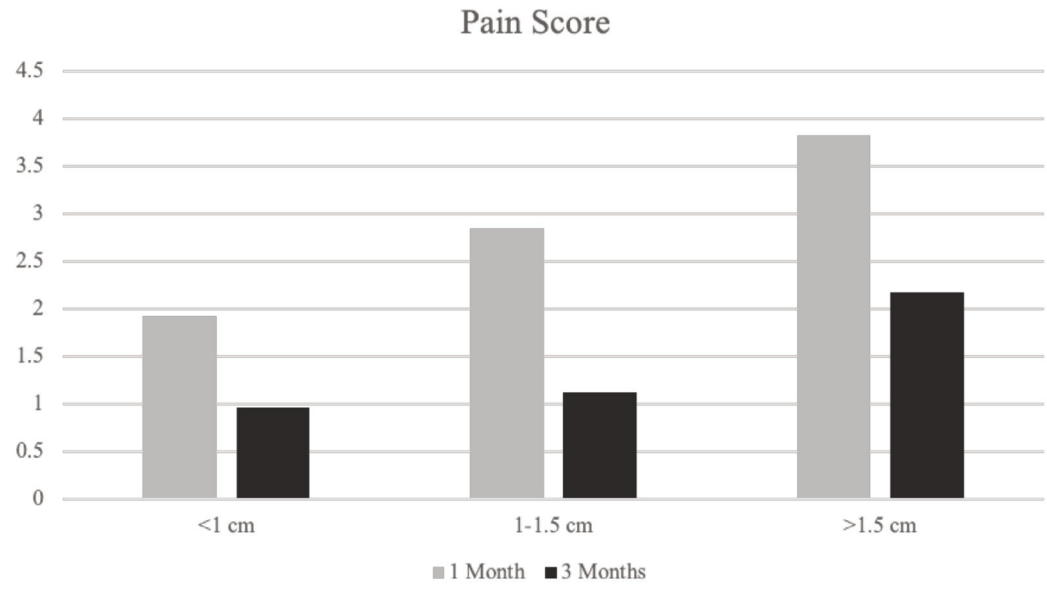

Fig. 6: Pain scores at one and three months according to trochanteric protrusion height group.

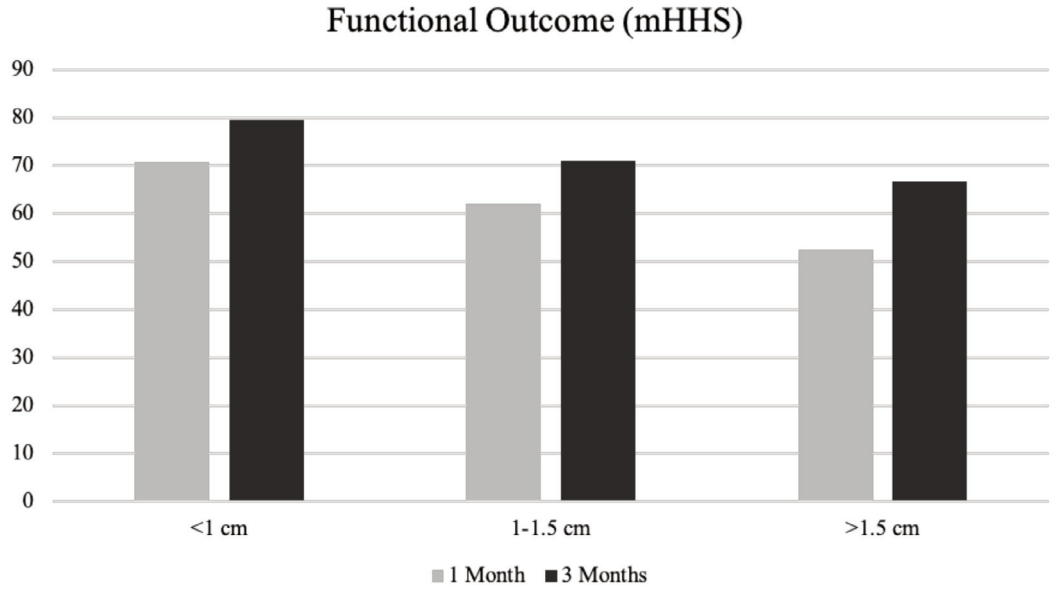

Fig. 7: Functional outcome scores (mHHS) at one and three months according to trochanteric protrusion height group.

months, the mean mHHS scores of those with a trochanteric protrusion height of >1.5cm (66.64±12.92 vs. 79.49±12.35, p=0.001) and 1 to 1.5cm (71.08±12.20 vs. 79.49±12.35, p=0.017) remained significantly lower than those with a trochanteric protrusion height <1cm (Table III). Participants with a PFNA trochanteric protrusion height of 1 to 1.5cm (β=–0.27, p=0.006) and >1.5cm (β=–0.40, p=0.001) had a significantly lower mHHS score by 0.27-units and 0.40-units, respectively (Table IV).

Participants with a trochanteric protrusion height >1.5cm had a significantly higher proportion who tested positive for tenderness at one month (63.64% vs. 18.87%, p=0.002) and with persistent tenderness over the greater trochanter at three months (45.45% vs. 13.21%, p=0.002) when compared to those with a trochanteric protrusion height of <1cm (Tables II & III). Similarly, the proportion of participants diagnosed with trochanteric bursitis was significantly higher among those with a trochanteric protrusion height >1.5cm compared to those with <1cm (59.09% vs. 13.21%, p=0.001) (Table II). PFNA trochanteric protrusion height of >1.5cm increased the odds of testing positive for tenderness by 7.53-times at one-month (OR=7.53, p=0.001), developing trochanteric bursitis by 9.49-times (OR=9.49, p=0.001), and persistent tenderness over the greater trochanter by 5.48-times at three months (OR=5.48, p=0.004) (Table IV).

DISCUSSION

Studies on per-/intertrochanteric fractures report excellent post-operative outcomes after treatment with PFNA, regardless of fracture stability. However, the use of PFNA in Asian patients has led to reports of various complications, including iatrogenic femoral cortex fracture due to the larger femoral curvature, as well as lateral wall fracture resulting from the pressure exerted by the circular proximal outer side wall of the PFNA[16]. Additionally, hip and thigh pain have been observed, particularly in patients with a short stature, as the long proximal tip of the implant abuts against the surrounding soft tissue[16]. Consequently, revisions were made to the implant design specifically with the Asian population in mind. These modifications included decreasing the outer angle of the nail from 6° to 5° to prevent the distal tip impacting the anterior femoral cortex, shortening the proximal end to 45mm and reducing the proximal diameter from 17mm to 16.5mm to alleviate friction between the proximal tip and surrounding soft tissue, and flattening the proximal lateral wall to decrease the likelihood of iatrogenic proximal femoral fracture and reduction loss[1,2,16].

Following the changes made, early reports on the revised PFNA system among Asian patients showed excellent post-operative results with limited post-operative hip pain[17,3]. More recent findings, however, present a shift in this pattern[1-3]. Hu *et al* observed that 60.8% (31/51) of patients exhibited protrusion heights of more than 5mm, with 31.7% (13/41) reporting lateral hip pain with a mean protrusion height of 11.13 ± 3.75mm over a one-year follow-up period[1]. Another study by Kim *et al* noted post-operative pain over the greater trochanter in patients with and without trochanteric protrusion. Their results highlighted a significantly higher incidence of post-operative hip pain among patients with greater trochanteric nail protrusion, averaging 9.01mm (ranging from 3.44-20.36mm)[2]. These align with our findings, where a majority of our subjects presented with trochanteric protrusion. Among these subjects, trochanteric protrusion heights >1.5cm had significantly higher pain scores. All groups exhibited a downward trend in pain from one to three months, but pain scores remained significantly higher for trochanteric protrusion heights >1.5cm (Fig. 6).

A high trochanteric protrusion height and hip pain may greatly affect functional outcome of patients, seen in our results as consistently poor mHHS scores among subjects with greater trochanteric protrusion height >1cm (Fig. 7). This is in contrast to findings by Kim *et al*, which did not report any significant association between trochanteric protrusion height and hip pain, and functional outcome[2]. This may be due to a lower mean trochanteric protrusion height (9.01mm) reported in their study, compared to our study with trochanteric protrusion heights exceeding 1cm. The resultant higher pain scores among these patients may have also contributed to the lower mHHS, specifically affecting the pain domain (Fig. 6 and 7).

Historically, trochanteric bursitis has been identified as the most common diagnosis among individuals presenting with lateral hip pain[5,6,7,18]. Studies by Koyuncu *et al* and Chang *et al* have associated post-operative hip pain with soft tissue irritation caused by nail protrusion, potentially leading to trochanteric bursitis[8,19]. Additionally, Koyuncu *et al* describe a "nail-point effect," suggesting that the protruding nail directly irritates the adjacent bursa[8]. However, to date, no study has conclusively confirmed this association through imaging studies in patients undergoing fixation with PFNA. Our results support these findings showing significant association between trochanteric protrusion height and clinical diagnosis of trochanteric bursitis, with protrusion heights >1.5cm, which persisted until the third month. On the other hand, Pianka *et al* and Williams *et al* have reported that isolated trochanteric bursitis is relatively uncommon and is often associated with abductor tendinopathy, particularly involving the gluteus medius and minimus[7,18]. A retrospective analysis by Long *et al* involving sonograms of 877 patients with greater trochanteric pain syndrome found that almost 50% of patients with gluteal tendinopathy also exhibited trochanteric bursitis[20]. Additional studies suggest that the clinical diagnosis of trochanteric bursitis often coexists with hip abductor pathology, manifesting as persistent lateral hip pain and tenderness at the greater trochanter, with supporting signs such as pain on resisted hip abduction or positive Patrick-FABERE test[18]. This explains the proportion of

patients in our study initially diagnosed with trochanteric bursitis based on clinical findings and later exhibit positive results on the resisted abduction and single leg stance tests. This implies that trochanteric bursitis develops earlier in patients with PFNA trochanteric protrusion heights as high as 1cm, and later on, these patients develop abductor tendinopathy as well. We attribute these findings to weakness and inflammation of the hip abductor muscles from irritation from the protruding nail more so than the surgical incision and trauma from nail insertion, as suggested in the aforementioned studies. Furthermore, a definite conclusion that trochanteric bursitis is unlikely to develop with trochanteric protrusion heights within 1-1.5cm cannot be made, despite non-significant findings in our study, since isolated diagnosis is said to be uncommon.

Achieving anatomic reduction and proper implant placement remains crucial in mitigating potential post-operative complications, including proximal nail protrusion. Parker *et al* demonstrated a positive correlation between nail protrusion height and the Parker ratio, indicating that superior positioning of the helical blade in the femoral head corresponds with greater protrusion height over the trochanter[21]. Similarly, Hu e*t al* showed that valgus reductions, while biomechanically superior to varus reductions, may result in increased nail protrusion height[1]. They recommend aiming for central placement of the helical blade in both the anteroposterior and lateral views, along with achieving anatomical reduction of the femoral fracture, as essential steps to decrease trochanteric protrusion height and potentially minimise other post-operative complications such as cut-out and cut-through[1]. In contrast, a by Pu *et al* noted greater trochanteric protrusion when the helical blade is positioned more centrally. They observed that the proximal end of the nail was inserted fully when the helical blade was placed inferiorly[22]. It is important to note that our study consisted of subjects with acceptable post-operative reductions. However, we failed to note implant placement, whether the nail and helical blade sits too superior, centre or too inferior.

CONCLUSION

Several key conclusions can be drawn from the study. Firstly, the study revealed a significant association between trochanteric protrusion height and post-operative hip pain. Specifically, a greater trochanteric protrusion height >1.5cm resulted to higher post-operative hip pain scores. Secondly, there is a significant association between trochanteric protrusion height and trochanteric bursitis, with higher likelihood of developing trochanteric bursitis seen with trochanteric protrusion heights (>1cm). Lastly, the study demonstrated a significant association between PFNA trochanteric protrusion height and functional outcome, where subjects with greater trochanteric protrusion heights (>1cm) exhibited poor mHHS scores at one and three months.

CONFLICT OF INTEREST

There are no conflicts of interest.

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