Similarities between Inferior-Center and Center-Center Lag Screw Positions in Femoral Intertrochanteric Fracture Surgeries

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Research article

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Abstract

Background: The center-center lag screw position has been widely accepted as the optimal lag screw/helical blade position in femoral intertrochanteric fracture surgery to achieve a tip-apex distance (TAD) less than 25 mm. Despite the inferior-center lag screw/helical blade position having some biomechanical advantages, and the emergence of calcar-referenced tip-apex distance (CalTAD), the clinical differences between the two commonly placed lag screw/helical blade positions remain unclear.

This study aimed to (1) report radiological outcomes in managing geriatric femoral intertrochanteric fractures, (2) identify the influences of positions of lag screw/helical blade, and (3) identify the relationship between implants and the values of TAD and CalTAD.

Methods: We retrospectively assessed the clinical and radiographic findings of geriatric patients (age $\geq$ 55 years) who underwent surgery for acute closed femoral intertrochanteric fractures during 1-year period and were followed up a minimum of 6 months. The radiographic parameters and incidences of fixation failure were compared between the different lag screw and helical blade positions (center-center vs. inferior-center). Subgroup analyses of different implant types (extramedullary and intramedullary) were also performed for comparisons for different lag screw positions, and TAD and CalTAD beyond the normal standard value of 25 mm.

Results: A total of 206 patients were included during the study period, with a 7.8% fixation failure. There were no differences in incidences of fixation failure between the commonly inserted lag screw/helical blade positions (center-center vs. inferior-center), regardless of the implant types. Those with a TAD > 25 mm had significantly higher incidence of fixation failure than those with a TAD $\leq$ 25 mm in the extramedullary plate (17.0% vs. 1.2%, p = 0.001), but not in the intramedullary nails (16.1% vs. 4.4%, p = 0.08). There were no significant differences in incidences of fixation failure between CalTAD $\leq$ 25 mm and CalTAD > 25 mm in either extramedullary or intramedullary implants.

Conclusion: Although TAD > 25 mm might increase the fixation failure rate in extramedullary plates, an inferior-center lag screw/helical blade position could achieve comparable radiographic results as a center-center position after osteosynthesis for geriatric femoral intertrochanteric fractures.

Background

Intertrochanteric fracture is a common osteoporotic fracture among elderly populations in an aging society [1–3]. Multiple comorbidities result in high rates of morbidity and mortality, which makes intertrochanteric fractures challenging to treat for orthopedic surgeons [4–6]. Early surgical fixation on these aging patients has been proposed recently for early rehabilitation and has had a positive impact on reducing comorbidities [7–9].

Baumgaertner et al. [10] proposed the concept of tip-apex distance (TAD), which describes the optimal position of the lag screw in intertrochanteric fracture surgery. It has been widely accepted that a lag screw or helical blade with a TAD $\leq$ 25 mm has a lower risk of devastating complications, like screw cutout or fixation failure [11, 12]. In order to achieve a TAD $\leq$ 25 mm, the lag screw or helical blade should be inserted close to the bisector of the femoral head and femoral neck, which could be termed as the center-center position. However, several biomechanical studies showed non-inferior fixation strength and failure rate when a lag screw or helical blade was placed within the lower third of the femoral neck and femoral head under the theory of calcar-referenced tip-apex distance (CalTAD) [13, 14]. Under this theory, the inferior deviation of the lag screw from the bisector of the femoral head would increase the likelihood of TAD > 25 mm.

On the other hand, the fixation implants for femoral intertrochanteric fractures could be divided into extramedullary and intramedullary fashions, which both consist of a lag screw or helical blade inserted into the femoral neck and femoral head [15–17]. Compared to the extramedullary plate, intramedullary nails provide more biomechanical advantages in treating unstable femoral intertrochanteric fractures [16]. Under carefully selected indications among different implants, satisfactory surgical outcomes could be achieved by following the principles of fracture reduction for these fractures [18, 19]. Although some studies emphasized CalTAD as a better indicator than TAD [13, 20], TAD > 25 mm was still found to be one of the independent risk factors for fixation failure in intramedullary nails [20, 21]. However, the relationships between positions of a lag screw or helical blade, TAD, and CalTAD affecting radiological outcomes are still undetermined.

In order to determine the relationships among implants, positions of the lag screw or helical blade, and radiographic references, we hypothesized that despite a TAD > 25 mm being common for the inferior-center position of the lag screw or helical blade while treating the femoral intertrochanteric fracture, the radiographic results following the inferior-center position might be at least compatible to those with the center-center position.

Methods

Patients

The present study enrolled a consecutive series of patients with femoral intertrochanteric fractures who received osteosynthesis at our institute between January and December in 2015. The inclusion criteria of this study were 1) skeletally matured patients aged over 55 years old, 2) acute closed femoral intertrochanteric fractures as the single fracture of the body, 3) received osteosynthesis either with extramedullary or intramedullary implants, and 4) were followed up for at least 6 months postoperatively. The clinical management for the patients proceeded prospectively and the data were recorded retrospectively. This study protocol was approved by the Institutional Review Board of Chang Gung Memorial Hospital (IRB No. 201601598B0). All methods were performed in accordance with the relevant guidelines and regulations of the institution.

Surgical procedure

Once the patient was admitted to the hospital, the osteosynthesis was arranged as soon as possible after their medical condition had been optimized. All the osteosynthesis was conducted on a radiolucent traction table under real-time fluoroscopic examination throughout the surgical procedure. We used the Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification as the reference to determine a “stable” or “unstable” femoral intertrochanteric fracture[9,18]. According to the AO classification, type 31-A1.1, 1.2, 1.3, and 2.1 were classified as stable fracture patterns while the rest types of 31-A were classified as unstable ones. We usually used an extramedullary plate (dynamic hip compression screw/plate [DHS], Depuy Synthes, Raynham, MA) for stable fracture patterns and intramedullary nails (Gamma 3 nail, Stryker, Kalamazoo, MI) and Proximal femoral nail anti-rotation II (PFNA II, Depuy Synthes, Raynham, MA) for unstable ones. However, intramedullary nails might occasionally be applied to the stable femoral intertrochanteric fracture for those with potentially unstable patterns.

Radiographic assessments

Standard X-ray assessments consisted of anteroposterior (AP) and lateral views before and after the osteosynthesis were applied. Patients were assessed at intervals of 1, 3, 6, 12 months after discharge. Thereafter, annual follow-ups were conducted annually. Routine radiographic follow-ups were arranged immediately after the surgery and on each clinic visit. Several parameters were applied during radiographic assessments, including:

1. TAD: Sum of the distances between the tip of the lag screw to the apex of the femoral head on the AP and lateral views (Figure 1a & 1c) [10]. The true implant diameters were used for the correction of image magnification.
2. CalTAD: Sum of the distance between the tip of the lag screw to the intersection of the femoral head contour and the tangential line of the medial femoral neck cortex on the AP view (Figure 1b), and the distance between the lag screw tip to the apex of the femoral head on the lateral view (Figure 1c) [13].
3. The quality of the reduction was categorized into three grades based on a modification of the method developed by Baumgaertner et al [10]. The first criterion used was a normal or slightly valgus neck-shaft angle (130° to 150°) on the AP view and an angulation < 20° on the lateral view. The second criterion used was the presence of a < 4 mm displacement of any fragments in the AP and lateral views. A reduction was categorized as good if both criteria were met, acceptable if only one criterion was met, and poor if neither criteria were met.
4. The lag screw tip position in the femoral head was classified by the Cleveland index (Figure 2a) [22].
5. Femoral neck shortening: The femoral neck shortening distance was measured between the last follow-up and the immediate postoperative radiographs with the correction of the true implant diameters.
6. Fixation failure was defined as lag screw cutout or progressive varus collapse of the femoral head that needs revision surgery.

Two surgeons (Y.-C. Y. and C.-H. L.) interpreted the postoperative AP and lateral plain films at each radiographic follow-up to evaluate the applied parameters. Regarding continuous data during assessments, such as TAD, CalTAD, and femoral neck shortening, the average value from the measurements of the 2 surgeons was recorded. For categorical data, the data was directly recorded when both surgeons had a similar opinion. When the result was different between the 2 main evaluators, a senior surgeon (Y.-H. H.) was consulted for the final decision.

Patients with a commonly placed lag screw or blade positions (center-center vs. inferior-center) were compared for radiographic statistics and incidences of fixation failure. The modes of fixation failure, which include screw cutout and progressive varus collapse, were recorded specifically. Subgroup comparisons in patients who received either extramedullary or intramedullary implants were also made for different lag screw positions, and TAD and CalTAD comparisons (TAD $\leq$ 25 mm vs. TAD > 25 mm and CalTAD $\leq$ 25 mm vs. CalTAD > 25 mm).

Statistical analysis

Statistical analysis was conducted using SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). Continuous variables are presented as the mean and standard deviation. Categorical variables are reported as frequency and percentage. Parametric Student t-test and nonparametric Mann-Whitney U-test was used on continuous dependent variables. Pearson's chi-squared test was used on categorical variables. A two-tailed *p*-value of 0.05 was considered significant.

Results

As the demographic data in Table 1 shows, a total of 206 patients (71 males and 135 females) with a mean age of 78.7 ± 15.7 years old were enrolled, and all of the patients suffered from a fall from a standing height. The mean follow-up length was 11.8 ± 7.5 months. As for the fracture pattern, 136 patients (66%) were classified as stable-fracture patterns, whereas the rest, 70 patients (34%), were classified as unstable. DHS was used in 130 patients (63%), and intramedullary nails were applied to the rest of the patients, which was 76 patients (37%). The tip position of the lag screw or helical blade distribution was classified according to Cleveland index [7] and presented in Fig. 2b with the incidences of fixation failure in specific positions. Among all the implants, the average TAD was 23.1 ± 7.4 mm and the average CalTAD was 27.3 ± 6.1 mm. Fixation failure occurred in 16 patients (7.8%). Nonetheless, 35 patients (17%) had femoral neck shortening > 1 cm until the fracture healed.

Table 1
Demographic data of the 296 patients.

Patient number	**206 (71M & 135F)**
Age	78.7 ± 15.7 (55–105)
Side	
Left	117 (56.8%)
Right	89 (43.2%)
Unstable fracture pattern	70 (34.0%)
Fracture reduction quality	
Good	91 (44.2%)
Fair	108 (52.4%)
Poor	7 (3.4%)
Implant	
Dynamic Hip Screw (DHS)	130 (63.1%)
Gamma 3 Nail	63 (30.6%)
Proximal Femoral Nail Anti-rotation II (PFNA II)	13 (6.3%)
PostOP Neck shaft angle	140.2° ± 7.5°
Bilateral neck shaft angle difference	1.0° ± 8.8°
TAD (mm)	23.1 ± 7.4
CalTAD (mm)	27.3 ± 6.1
TAD in AP (mm)	11.0 ± 3.7
CalTAD in AP (mm)	15.2 ± 4.6
TAD in lateral (mm)	12.1 ± 4.1
Follow up length (months)	11.8 ± 7.5
Last follow-up neck shaft angle	136.8° ± 10.8°
Neck shaft angle loss	3.5° ± 7.5°
Femoral neck shortening > 1 cm	35 (17.0%)
Fixation failure	16 (7.8%)
Screw cutout	11 (5.3%)
Varus collapse	5 (2.4%)

Center-center vs. inferior-center of the lag screw or helical blade position

Comparisons of the most commonly two placed lag screw or helical blade positions, center-center (Cleveland index area 5) vs. inferior-center (Cleveland index area 8) were listed in Table 2 for all patients, Table 3 for patients using the extramedullary plate, and Table 4 for patients using intramedullary nails.

Table 2
Comparisons between 2 common positions of the lag screw or helical blade.

	Center-center	Inferior-center	*p*-value
Patient number	99 (32M & 67F)	36 (13M & 23F)	0.68
Age	78.3 ± 17.0	78.5 ± 15.4	0.96
Unstable fracture pattern	36 (36.4%)	9 (25.0%)	0.22
Fracture reduction quality			0.24
Good	51 (51.5%)	17 (47.2%)	
Fair	48 (48.5%)	18 (50.0%)	
Poor	0 (0%)	1 (2.8%)	
Implant			0.61
DHS	61 (61.6%)	21 (58.3%)	
Gamma 3 Nail	31 (31.3%)	14 (38.9%)	
PFNA II	7 (7.1%)	1 (2.8%)	
PostOP NSA	140.2° ± 7.1°	144.7° ± 7.3°	0.002*
Bilateral NSA difference	0.3° ± 8.8°	5.1° ± 9.7°	0.007*
TAD (mm)	19.0 ± 5.0	26.9 ± 6.6	< 0.001*
CalTAD (mm)	25.7 ± 3.9	24.4 ± 5.2	0.12
TAD in AP (mm)	9.0 ± 2.5	13.5 ± 3.2	< 0.001*
CalTAD in AP (mm)	15.7 ± 2.6	11.0 ± 2.6	< 0.001*
TAD in lateral (mm)	10.0 ± 2.7	13.4 ± 3.9	< 0.001*
Follow up length (months)	10.8 ± 6.6	13.9 ± 8.6	0.03*
Last follow-up NSA	137.2° ± 9.0°	142.3° ± 9.7°	0.005*
Neck shaft angle loss	3.0° ± 6.1°	2.4° ± 6.2°	0.65
Femoral neck shortening > 1 cm	16 (16.2%)	4 (11.1%)	0.47
Fixation failure	3 (3.0%)	2 (5.6%)	0.49
Screw cutout	2 (2.0%)	1 (2.8%)	0.79
Varus collapse	1 (1.0%)	1 (2.8%)	0.45

Table 3
Comparisons between 2 common positions of the lag screw of extramedullary plate.

	Center-center	**Inferior-center**	***p*-value**
Patient number	61 (20M & 41F)	21 (9M & 12F)	0.41
Age	80.0 ± 16.0	79.8 ± 14.7	0.96
Unstable fracture pattern	13 (21.3%)	1 (4.8%)	0.08
Fracture reduction quality			0.16
Good	37 (60.7%)	10 (47.6%)	
Fair	24 (39.3%)	10 (47.6%)	
Poor	0 (0%)	1 (1.2%)	
PostOP NSA	141.5° ± 7.5°	145.9° ± 7.1°	0.02*
Bilateral NSA difference	2.3° ± 8.9°	7.0° ± 9.1°	0.04*
TAD (mm)	18.6 ± 4.5	25.6 ± 5.0	< 0.001*
CalTAD (mm)	25.5 ± 3.6	23.6 ± 3.8	0.04*
TAD in AP (mm)	8.8 ± 2.4	12.8 ± 2.5	< 0.001*
CalTAD in AP (mm)	15.7 ± 2.5	10.9 ± 2.5	< 0.001*
TAD in lateral (mm)	9.8 ± 2.4	12.7 ± 3.2	< 0.001*
Follow up length (months)	9.8 ± 5.7	11.2 ± 6.0	0.36
Last follow-up NSA	139.6° ± 9.1°	145.0° ± 10.3°	0.03*
Neck shaft angle loss	1.9° ± 6.5°	0.9° ± 7.0°	0.53
Femoral neck shortening > 1 cm	13 (21.3%)	3 (14.3%)	0.48
Fixation failure	1 (1.6%)	1 (4.8%)	0.42
Screw cutout	1 (1.6%)	1 (4.8%)	0.42
Varus collapse	0 (0%)	0 (0%)	-

Table 4
Comparisons between 2 common positions of the lag screw of intramedullary nails.

	Center-center	Inferior-center	*p*-value
Patient number	38 (12M & 26F)	15 (4M & 11F)	0.73
Age	75.7 ± 18.6	76.7 ± 16.9	0.95
Unstable fracture pattern	23 (60.5%)	8 (53.3%)	0.63
Fracture reduction quality			0.51
Good	14 (36.8%)	7 (46.7%)	
Fair	24 (63.2%)	8 (53.3%)	
Poor	0 (0%)	0 (0%)	
Implant			0.28
Gamma 3 Nail	31 (81.6%)	14 (93.3%)	
PFNA II	7 (18.4%)	1 (6.7%)	
PostOP NSA	138.1° ± 6.0°	143.1° ± 7.6°	0.02*
Bilateral NSA difference	-2.8° ± 7.8°	2.5° ± 10.0°	0.07
TAD (mm)	19.6 ± 5.8	28.7 ± 8.3	0.001*
CalTAD (mm)	26.0 ± 4.4	25.6 ± 6.7	0.75
TAD in AP (mm)	9.2 ± 2.8	14.3 ± 3.9	< 0.001*
CalTAD in AP (mm)	15.7 ± 2.8	11.2 ± 2.8	< 0.001*
TAD in lateral (mm)	10.3 ± 3.3	14.4 ± 4.7	0.004*
Follow up length (months)	12.4 ± 7.7	17.7 ± 10.4	0.06
Last follow-up NSA	133.4° ± 7.4°	138.5° ± 7.7°	0.04*
Neck shaft angle loss	4.6° ± 5.1°	4.6° ± 4.0°	0.90
Femoral neck shortening > 1 cm	3 (7.9%)	1 (6.7%)	0.88
Fixation failure	2 (5.3%)	1 (6.7%)	0.84
Screw cutout	1 (2.6%)	0 (0%)	0.53
Varus collapse	1 (2.6%)	1 (6.7%)	0.49

Among all the used implants, there were no differences in patient numbers, fracture patterns, reduction quality, implant choices, and CalTAD. A greater postoperative neck-shaft angle was found in the inferior-center group compared to that in the center-center group (144.7° ± 7.3° vs. 140.2° ± 7.1°, $p = 0.002$). The TAD was significantly smaller in the center-center group than that in the inferior-center position group (19.0 ± 5.0 vs. 26.9 ± 6.6, $p < 0.001$). However, there were no differences in the neck-shaft angle loss, femoral neck shortening, and fixation failure along with follow-up between the 2 groups.

While the different implants were analyzed separately, similar results shown in Table 2 were found in either extramedullary or intramedullary implants despite the increased CalTAD in the center-center group when analyzing the patients who underwent extramedullary plate treatment.

TAD and CalTAD comparisons between extramedullary and intramedullary implants

In order to further discover the effect of TAD and CalTAD in different types of implants, the authors compared the two parameters with a cutoff value of 25 mm in either extramedullary or intramedullary implants. The results are listed in Table 5 for the extramedullary plate and Table 6 for intramedullary nails.

Table 5
TAD and CalTAD comparisons of extramedullary plate.

	TAD ≤ 25	TAD > 25	*p*-value	CalTAD ≤ 25	CalTAD > 25	*p*-value
Patient number	83 (31M & 52F)	47 (18M & 29F)		54 (19M & 35F)	76 (30M & 46F)	
Age	80.9 ± 13.7	79.6 ± 15.7	0.62	79.6 ± 16.0	81.0 ± 13.2	0.57
Unstable fracture pattern	15 (18.1%)	10 (21.3%)	0.66	7 (13.0%)	18 (23.7%)	0.13
Fracture reduction quality			0.006			0.01*
Good	49 (59.0%)	15(31.9%)		33 (61.1%)	31 (40.8%)	
Fair	33 (39.8%)	29 (61.7%)		18 (33.3%)	44 (57.9%)	
Poor	1 (1.2%)	3 (6.4%)		3 (5.6%)	1 (1.3%)	
PostOP NSA	141.7° ± 7.5°	140.1° ± 8.2°	0.26	142.9° ± 7.7°	139.8° ± 7.6°	0.03*
Bilateral NSA difference	3.3° ± 7.8°	2.5° ± 8.7°	0.60	3.9° ± 8.3°	2.4° ± 8.0°	0.33
TAD (mm)	18.6 ± 3.8	29.8 ± 3.9	< 0.001*	19.4 ± 5.5	25.0 ± 6.3	< 0.001*
CalTAD (mm)	25.0 ± 3.9	30.8 ± 6.3	< 0.001*	22.3 ± 1.8	30.5 ± 4.8	< 0.001*
TAD in AP (mm)	8.8 ± 2.1	14.5 ± 2.2	< 0.001*	9.5 ± 3.2	11.8 ± 3.3	< 0.001*
CalTAD in AP (mm)	15.2 ± 3.4	15.5 ± 6.3	0.73	12.4 ± 2.7	17.4 ± 4.6	< 0.001*
TAD in lateral (mm)	9.8 ± 2.2	15.3 ± 2.7	< 0.001*	9.9 ± 2.7	13.2 ± 3.4	< 0.001*
Follow up length (months)	10.5 ± 5.9	10.6 ± 6.3	0.87	10.2 ± 5.4	10.7 ± 6.4	0.63

TAD: Tip-apex distance; CalTAD: Calcar referenced tip-apex distance; NSA: Neck shaft angle; AP: Anteroposterior view

*Statistical significance

	TAD ≤ 25	TAD > 25	*p*-value	CalTAD ≤ 25	CalTAD > 25	*p*-value
Last follow-up NSA	140.5° ± 9.0°	136.7° ± 11.9°	0.04*	140.6° ± 9.3°	138.1° ± 10.8°	0.17
Neck shaft angle loss	1.2° ± 6.2°	3.4° ± 7.7°	0.10	2.3° ± 7.7°	1.8° ± 6.2°	0.66
Femoral neck shortening > 1 cm	21 (25.3%)	8 (17.0%)	0.28	16 (29.6%)	13 (17.1%)	0.09
Fixation failure	1 (1.2%)	8 (17.0%)	0.001*	2 (3.7%)	7 (9.2%)	0.22
Screw cutout	1 (1.2%)	6 (12.8%)	0.005*	2 (3.7%)	5 (6.6%)	0.47
Varus collapse	0 (0%)	2 (4.3%)	0.04*	0 (0%)	2 (2.6%)	0.23
TAD: Tip-apex distance; CalTAD: Calcar referenced tip-apex distance; NSA: Neck shaft angle; AP: Anteroposterior view						
*Statistical significance						

Table 6
TAD and CalTAD comparisons of intramedullary nails.

	TAD ≤ 25	TAD > 25	*p*-value	CalTAD ≤ 25	CalTAD > 25	*p*-value
Patient number	45 (7M & 38F)	31 (15M & 16F)		25 (1M & 24F)	51 (21M & 30F)	
Age	79.8 ± 14.7	70.2 ± 19.7	0.02*	79.4 ± 12.8	74.1 ± 19.2	0.21
Unstable fracture pattern	27 (60.0%)	18 (58.1%)	0.87	16 (64.0%)	29 (56.9%)	0.55
Fracture reduction quality			0.10			0.05
Good	17 (37.8%)	10 (32.3%)		10 (40.0%)	17 (33.3%)	
Fair	28 (62.2%)	18 (58.1%)		15 (60.0%)	31 (60.8%)	
Poor	0 (0%)	3 (9.7%)		0 (0%)	3 (5.9%)	
Implant			0.29			0.41
Gamma 3 Nail	39 (86.7%)	24 (77.4%)		22 (88.0%)	41 (80.4%)	
PFNA II	6 (13.3%)	7 (22.6%)		3 (12.0%)	10 (19.6%)	
PostOP NSA	137.0° ± 5.9°	141.2° ± 7.7°	0.009*	139.6° ± 6.8°	138.4° ± 7.1°	0.48
Bilateral NSA difference	-2.4° ± 8.7°	-2.4° ± 9.3°	0.99	-2.2° ± 9.6°	-2.5° ± 8.6°	0.89
TAD (mm)	18.1 ± 4.3	32.5 ± 5.7	< 0.001*	18.3 ± 5.5	26.7 ± 8.6	< 0.001*
CalTAD (mm)	24.6 ± 4.7	32.2 ± 6.9	< 0.001*	21.0 ± 3.0	31.1 ± 5.5	< 0.001*
TAD in AP (mm)	8.6 ± 2.0	15.5 ± 2.9	< 0.001*	9.2 ± 2.9	12.5 ± 4.3	< 0.001*
CalTAD in AP (mm)	15.2 ± 4.1	15.2 ± 5.4	0.99	11.8 ± 3.1	16.8 ± 4.4	< 0.001*

TAD: Tip-apex distance; CalTAD: Calcar referenced tip-apex distance; AP: Anteroposterior view; PFNA II: Proximal femoral nail anti-rotation II; NSA: Neck shaft angle;

*Statistical significance

	TAD ≤ 25	TAD > 25	*p*-value	CalTAD ≤ 25	CalTAD > 25	*p*-value
TAD in lateral (mm)	9.5 ± 2.6	17.0 ± 3.9	< 0.001*	9.1 ± 2.9	14.3 ± 4.8	< 0.001*
Follow up length (months)	13.2 ± 8.4	15.2 ± 10.0	0.36	11.5 ± 8.4	15.3 ± 9.2	0.09
Last follow-up NSA	132.0° ± 7.3°	134.0° ± 14.3°	0.42	135.0° ± 8.2°	131.7° ± 11.6°	0.21
Neck shaft angle loss	5.0° ± 5.2°	7.2° ± 10.9°	0.31	4.5° ± 5.1°	6.6° ± 9.1°	0.29
Femoral neck shortening > 1 cm	4 (8.9%)	2 (6.5%)	0.70	2 (8.0%)	4 (7.8%)	0.98
Fixation failure	2 (4.4%)	5 (16.1%)	0.08	1 (4.0%)	6 (11.8%)	0.27
Screw cutout	1 (2.2%)	3 (9.7%)	0.15	1 (4.0%)	3 (5.9%)	0.73
Varus collapse	1 (2.2%)	2 (6.5%)	0.35	0 (0%)	3 (5.9%)	0.22

TAD: Tip-apex distance; CalTAD: Calcar referenced tip-apex distance; AP: Anteroposterior view; PFNA II: Proximal femoral nail anti-rotation II; NSA: Neck shaft angle;

*Statistical significance

For the extramedullary plate, the initial postoperative fracture reduction quality was worse in patients with a TAD > 25 mm and a CalTAD > 25 mm as compared to patients who had a TAD ≤ 25 mm and a CalTAD ≤ 25 mm. Patients with a TAD ≤ 25 mm had significantly lower incidence of fixation failure than those with TAD > 25 mm (1.2% vs. 17.0%, $p = 0.001$), whereas the fixation failure rates were comparable between patients with a CalTAD ≤ 25 mm and a CalTAD > 25 mm (3.7% vs. 9.2%, $p = 0.22$).

For intramedullary nails, patients with a TAD ≤ 25 mm were significantly older (79.8 ± 14.7 vs. 70.2 ± 19.7, $p = 0.02$), and had a significantly smaller initial postoperative neck-shaft angle (137.0° ± 5.9° vs. 141.2° ± 7.7°, $p = 0.009$) than those with TAD > 25 mm. However, there were no significant differences in terms of the incidences of fixation failure either between TAD ≤ 25 mm and TAD > 25 mm (4.4% vs. 16.1%, $p = 0.08$), or between CalTAD ≤ 25 mm and CalTAD > 25 mm (4.0% vs. 11.8%, $p = 0.27$).

Discussion

We retrospectively reviewed the surgical outcomes of osteosynthesis for femoral intertrochanteric fractures using extra- or intramedullary implants of aging patients at a single institute within a one-year period. The results of our study revealed that the overall failure rate was 7.8%. The majority of failures were lag screw or helical blade cut-out (5.3%), the rest of the failures were due to the varus collapse in the neck-shaft angle with an impending lag screw or helical blade cut-out. An inferior-center lag screw or helical blade position achieved similar radiographic results at the center-center position despite the TAD being significantly greater in the inferior-center group. However, a TAD > 25 mm significantly increased the failure rate in the extramedullary plate, while for intramedullary implants, neither TAD nor CalTAD had a significant impact on the incidence of fixation failure.

Surgical treatment is often warranted for femoral intertrochanteric fracture owing to its anatomic position as insertions of multiple musculotendinous and the mechanical roles for weight-bearing. Although a highly successful rate can be achieved following standard surgical principles [11, 12], a certain percentage of failures were reported [23–26]. The TAD was first proposed by Baumgaertner et al [10], and for more than 2 decades, a TAD less than 25 mm was thought to be the golden rule for surgical treatment on femoral intertrochanteric fracture either with extra- or intramedullary implants [11, 27]. From the results of our study, we observed that a TAD greater than 25 mm significantly increased the failure rate by using the extramedullary plate but not the intramedullary nail. Similar findings were reported in previous reports [28–30]. Therefore, we postulate that the intramedullary nail provides more stability in treating unstable femoral intertrochanteric fractures than the extramedullary plate by restoring the femoral lateral wall, thus preventing the varus reduction/fixation and avoiding the medialization of the distal fragment [20, 30, 31]. Hence, a TAD > 25 mm might have less affect the failure rate in the intramedullary nail group.

On the other hand, CalTAD was proposed as an alternative predicting factor for the fixation failure in intertrochanteric fracture surgeries when the lag screw or helical blade was positioned inferiorly [13, 29]. Analyzing 77 pertrochanteric fractures, Kashigar et al.[29] demonstrated that CalTAD was the only significant predictor in the multivariate regression analysis, and thus recommended an inferior lag screw placement in cephalomedullary nails of intertrochanteric fracture surgeries. In another study[32] that analyzed 67 intertrochanteric fractures treated with biaxial cephalomedullary nails, CalTAD was proposed as a better predictor for the cutout than TAD. However, the CalTAD did not demonstrate any effect in predicting the fixation failure in both extramedullary and intramedullary implants in our study.

Despite TAD and CalTAD being commonly used in failure prediction in treating femoral intertrochanteric fractures, the position of the lag screw or helical blade might be another important factor that needs to be addressed and a simpler method needs to be examined during osteosynthesis. To meet the criteria of the TAD ≤ 25 mm, the lag screw or blade should be inserted in the center position of the femoral neck, and its tip should be closed to the apex of the femoral head in the AP and lateral views of plain radiographs. An inferior deviation of the lag screw from the apex of the femoral head significantly increases the likelihood of the TAD being > 25 mm in both AP and lateral radiographs, which may be a negative influence according to the previous TAD theory. However, biomechanical evidence revealed that an inferior-center position of the lag screw or helical blade had comparable strength to the center-center position in both extramedullary and intramedullary implants [13, 14, 28]. In our study, an inferior-center position of the lag screw or blade with an increased TAD would not increase the fixation failure rate irrespective of the types of implants used, as compared with the center-center position. We postulated that the reason for this was that a greater postoperative neck-shaft angle (valgus reduction) was found for those with the lag screw or blade placed inferiorly. A valgus reduction might produce a biomechanically stable environment for the hip joint; this was also proved by the result of the comparable percentages of femoral neck shortening between inferior-center and center-center positions.

Despite efforts made to avoid bias, there were limitations to this study. First, this study is retrospective. Heterogeneous implant types and image results solely based on radiological findings are potential causes that might affect the study results. However, the strength of this study is that all evaluations and measurements from X-rays were processed by at least 2 independent surgeons, which could minimize the evaluation bias. Second, there was no objective osteoporosis measurement nor patient-report outcome for the included patients, which may be a confounding factor in our study. Lastly, the intramedullary nail was originally favored in treating unstable fracture patterns, which might increase the failure rate in using this implant. However, the results of this study did not directly compare the radiological outcomes of the chosen 2 implants.

Conclusion

In conclusion, following surgical principles during osteosynthesis in a geriatric femoral intertrochanteric fracture has remained the gold standard. Overall, an inferior-center position of the lag screw or blade had a comparable radiological result to the center-center position. However, the TAD rule should be kept in mind as a TAD > 25 mm might increase the incidence when using the extramedullary plate for a geriatric femoral intertrochanteric fracture, even in a stable type. Further prospective studies are needed to address more conclusive evidence in terms of lag screw or positions in different implant types of femoral intertrochanteric fracture surgeries.

Abbreviations

CalTAD: Calcar-referenced tip-apex distance; DHS: Dynamic hip screw.plate; PFNA II: Proximal femoral nail anti-rotation II; TAD: Tip-apex distance.

Declarations

Ethics approval and consent to participate: The study protocol was approved by the institutional review board of Chang Gung Medical Foundation (IRB No. 201601598B0). Informed consent was obtained verbally from all participants included in the study due to this study was proceeded only by medical records and images review with the minimal risk nature of their participation, which is an approved process by the IRB.

Consent to publish: Not applicable.

Availability of data and materials: All data generated or analyzed during this study are included in this published article. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

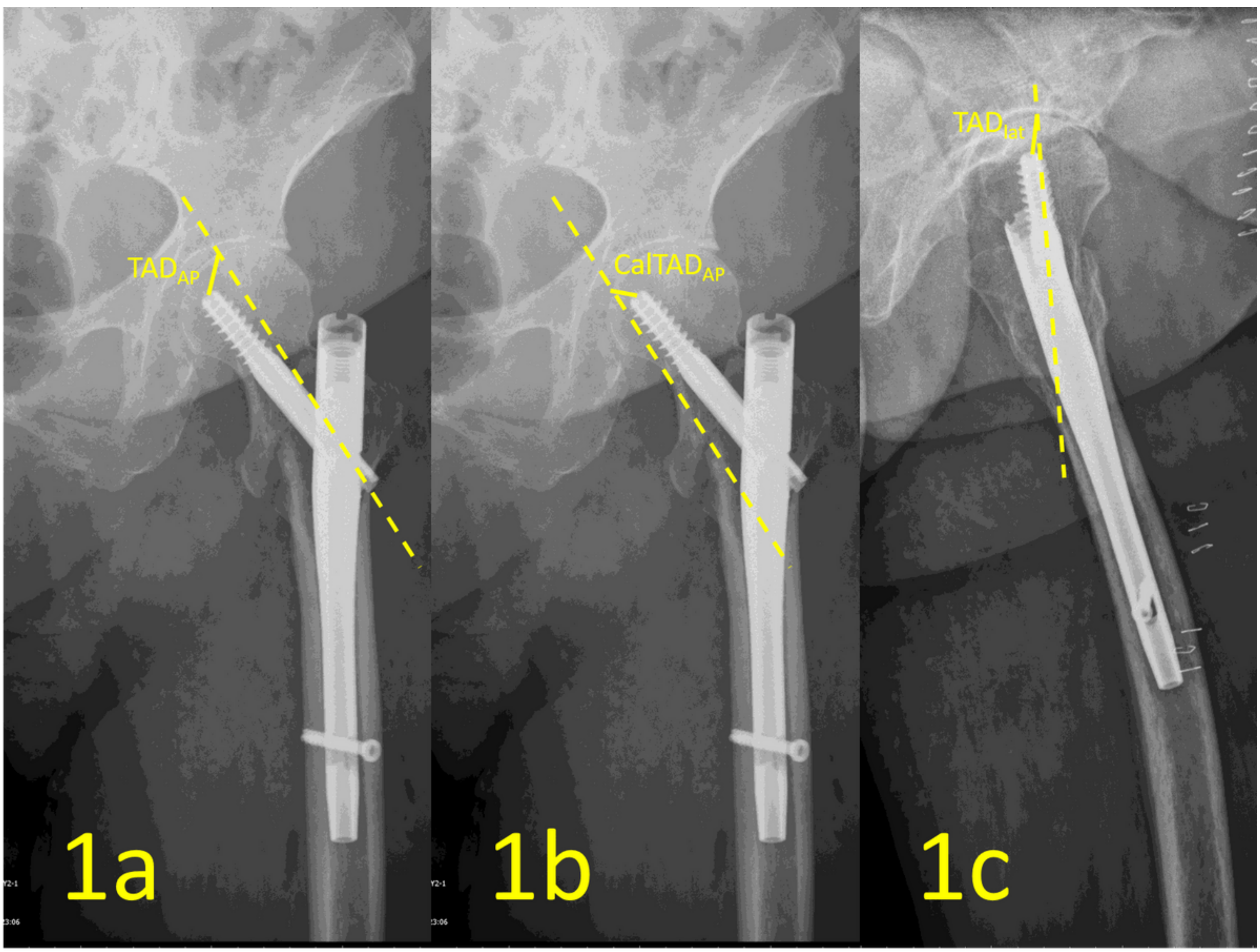

Figure 1

a: TADAP: Tip-apex distance (TAD) on the anteroposterior (AP) view. b: CalTADAP: Calcar-referenced TAD on the anteroposterior (AP) view. c: TADlat: Tip-apex distance on the lateral view.

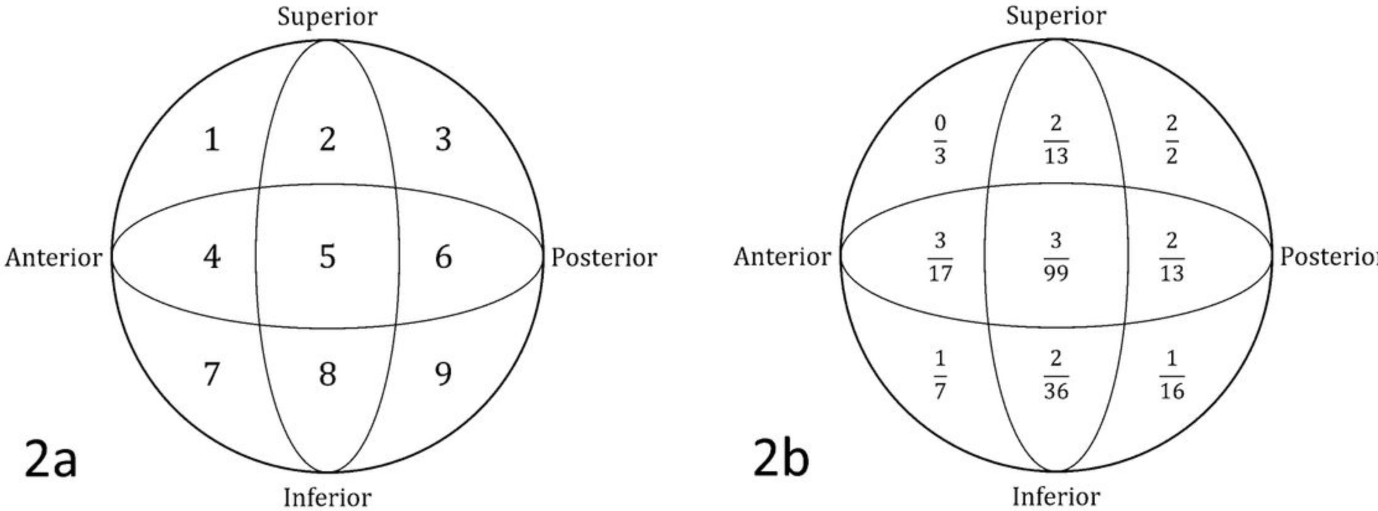

Figure 2

a: Screw positions classified by Cleveland index. b: Different incidences of fixation failure in various lag screw positions.