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Effectiveness of distally slotted proximal femoral nails on prevention of femur fractures during and after intertrochanteric femur fracture surgery

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ABSTRACT

Introduction: Intra- and post-operative femoral shaft fractures related with nailing remain of concern. Although manufacturers have sought to solve the problem by providing distally slotted nails, it is not clear that these implants reduce fractures.
We compare two distally slotted proximal femoral nails [trochanteric nail (TRON) and proximal femur intramedullary nail (PROFIN)].
Patients and Methods: The medical records of 195 hips treated with TRONs (distally slotted in four places in the sagittal and coronal planes) and 583 hips treated with PROFINs (distally slotted in two places in the coronal plane) in two institutes were retrospectively evaluated. The inclusion criteria were follow-up for at least 6 months; pertrochanteric fractures and age over 55 years.
Results: In total, 161 hips in the TRON group and 512 hips in the PROFIN group were included. The mean follow-up time was 28.5 (range: 6–84) months in whole group. The demographic characteristics of the groups were similar. Only 2 intraoperative shaft and 3 proximal lateral cortex fracture was detected in PROFIN group, there wasn't any postoperative fracture. Four proximal lateral cortex and 2 femur shaft fractures were detected in TRON group (one during operation and one at postoperative 8th month after a fall at pedestrian way).
Conclusions: Distal cephalomedullary nail slotting prevented intra- and post-operative femoral fractures. A distal slot 50 mm in length may increase nail elasticity and reduce nail tip stress to a greater extent than a 30-mm slot. Distal slotting in both the sagittal and coronal planes afforded no advantage compared to coronal slotting only.
Level of evidence: Level III retrospective study

Introduction

Slotted devices are used to stabilize the intramedullary cavities of the proximal femora and reduce stress at nail tips, to mitigate later complications such as periprosthetic fractures and thigh pain [1]. In patients receiving either nails or endoprostheses, implant-related femoral fractures occurring after hip fracture surgery develop principally at implant tips [2]. Distally slotted femoral stems were initially introduced for use during hip arthroplasty. Musgrave et al. showed that use of such stems reduced the fracture risk during stem insertion [1]. However, placement of intramedullary nails (IMNs) during hip fracture surgery has been reported to increase the risk of iatrogenic femoral fractures [3]; several distally slotted or fluted nails have been developed to address this problem [4]. The proximal femoral nail (PFN) and proximal femoral nail antirotation (PFNA) (Synthes, Solothurn, Switzerland) are widely used; both have distally fluted tips facilitating insertion and bone stress reduction at the nail tips [5,6]. However, iatrogenic femoral fractures continue to be reported [5–9]. Although the severity of other complications decreased, there is no evidence that iatrogenic fracture severity was reduced after the introduction of fluted nails [10,11].

The InterTan (IT) nails (Smith & Nephew, London, UK), Endovis nails (Citieffe, Calderara di Reno, Italy), Endovis BA (EBA) nails (Citieffe, Calderara di Reno, Italy), proximal femur intramedullary

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nails (PROFINs) (TST, Istanbul, Turkey) and trochanteric nails (TRONs) (Tıpsan, Istanbul, Turkey) are all distally slotted but limited information is available as to whether they prevent femoral fractures during or after surgery. Smith & Nephew offer both short and long IT nails but only the short nails (length, 30–35 mm) are distally slotted in coronal plane. Endovis and EBA nails are of three subtypes. The standard nail (distally slotted in coronal and sagittal planes; distal slot length, 30 mm) and medium nail (distally slotted only in the coronal plane; distal slot length, 20 mm) have been used in many studies. PROFINs are distally slotted in the coronal plane (slot length, 50 mm); trochanteric nails (TRON) are similar to standard EBA nails, being distally slotted in the sagittal and coronal planes (slot length, 30 mm). Theoretically, distal coronal slots should reduce distal nail stiffness, particularly in the sagittal plane, allowing the nail to bend with the anterior bow of the femur and thus preventing iatrogenic shaft fractures [1]. The distal sagittal slots are designed to allow the nail to bend with the distal medial cortex, thus reducing stress on the proximal lateral cortex to prevent iatrogenic comminution. It remains unknown whether slotting the distal ends of cephalomedullary nails reduces iatrogenic femoral fractures. Here, we retrospectively compared the effectiveness of TRONs and PROFINs in terms of preventing intra- and post-operative fractures, and compare our results with literature data.

Patients and methods

After institutional review board approval was obtained, patients were enrolled from February 2012 to July 2017; follow-up continued to January 2018. We enrolled patients who underwent treatment of intertrochanteric fractures in two hospitals (a university hospital, and a public hospital). The treatment protocols were similar. All surgeries were performed by 18 surgeons (1 professor, 3 associate professors, 6 assistant professors, and 8 senior residents). Patients who had been treated only with TRON or PROFIN nails were included to the study. Intramedullary nailing has been performed in both institutes since 2005; all surgeons had mastered such treatment of intertrochanteric fractures. Residents performed operations under the supervision of experienced staff. All medical records were retrospectively evaluated. Data were acquired by the first two authors (MSS, EU) and cross-checked by the other authors to verify their reliability. Preoperative X-rays were evaluated and fractures classified using the AO Foundation/Orthopedic Trauma Association (AO/OTA) guidelines [12]. Patient age, gender, fracture side and pattern, American Society of Anesthesiologists (ASA) score, Singh index, and cause of fracture were recorded. Intraoperative notes were evaluated; iatrogenic shaft and proximal, lateral cortical fractures, implant breakages, distal and proximal locking problems, and implant sizes were recorded. All available postoperative X-rays and medical records were evaluated and shaft fractures, cut-outs, Z effects, nonunions, wound infections, fixation failures, and implant fatigue were recorded. The inclusion criteria were age above 55 years, an intertrochanteric fracture (including basicervical fractures and fractures with subtrochanteric extensions), placement of PROFINs or TRONs; follow-up more than 6 months, X-rays available from at least the 6-month follow-up, written informed consent from the patient (or a relative if the patient had dementia); and walking prior to fracture. The exclusion criteria were pathological fractures, lack of intra- and/or post-operative follow-up medical records and/or X-rays; and follow-up less than 6 months.

Implant characteristics

The PROFIN (TST) is made of titanium alloy and is distally slotted in the coronal plane to reduce stress at the nail tip. The slots are 50 mm in length, with 6° of proximal medio-lateral curvature and a neck-shaft angle of 135°. The PROFINs have a diameter of 10, 11, or 12 mm. The proximal diameter is 16 mm and nails of two different lengths (220 and 250 mm) are available. The nail is fixed proximally by two lag screws 8.5 mm in diameter and distally by two further screws 4.5 mm in diameter; one inserted into a dynamic hole and one into a static hole. The 250-mm nail has two static and one dynamic distal locking holes. The dynamic holes are connected by slots (Fig. 1). The TRON (Tipsan) is a titanium alloy nail available in lengths of 180, 200, and 220 mm; the proximal diameter is 16 mm in the trochanteric region and the distal diameter is 10, 11, or 12 mm. The neck shaft angle is 125° and the mediolateral curvature 5°. To reduce implant rigidity and compressive load at the nail tip, the distal end of the nail is slotted in the sagittal and coronal planes. The slots are 30 mm in length. The nail is locked proximally using two 6.5-mm-diameter lag screws, and distally with two 5.0-mm-diameter screws, using a dynamic and a static hole (Fig. 2).

Treatment

After admission, we recorded any history of comorbid disease and arranged a consultation if required. Low-molecular-weight heparin was started for all individuals and continued for 3 weeks postoperatively. Patients wore anti-embolic stockings from admission to 3 weeks postoperatively. Operation was delayed if a comorbidity required stabilization. Operative risk was scored using the ASA score and operations proceeded only after agreement from

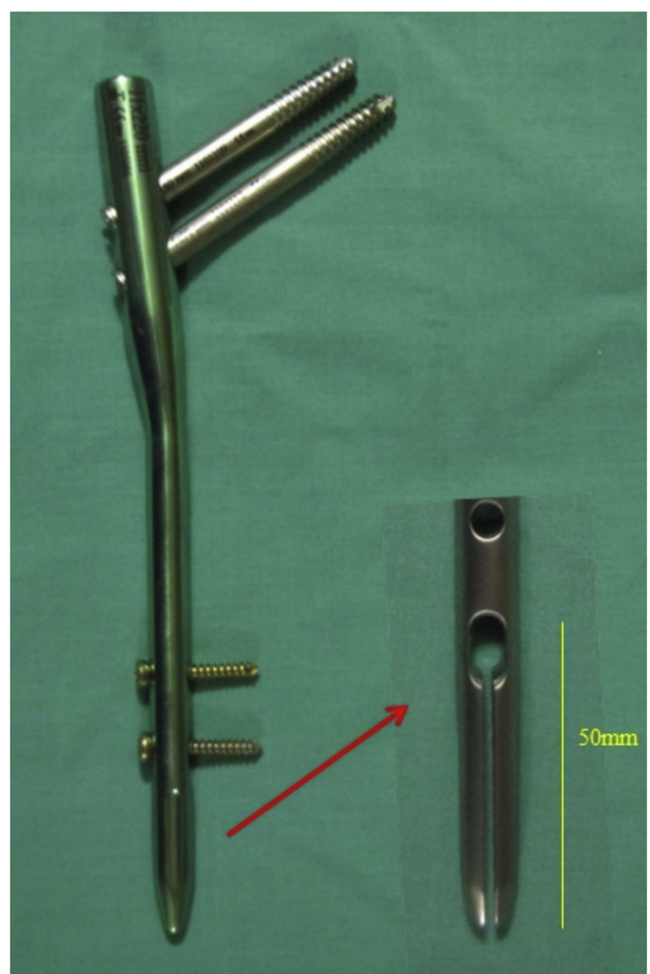

Fig. 1. The proximal femur intramedullary nail (PROFIN).

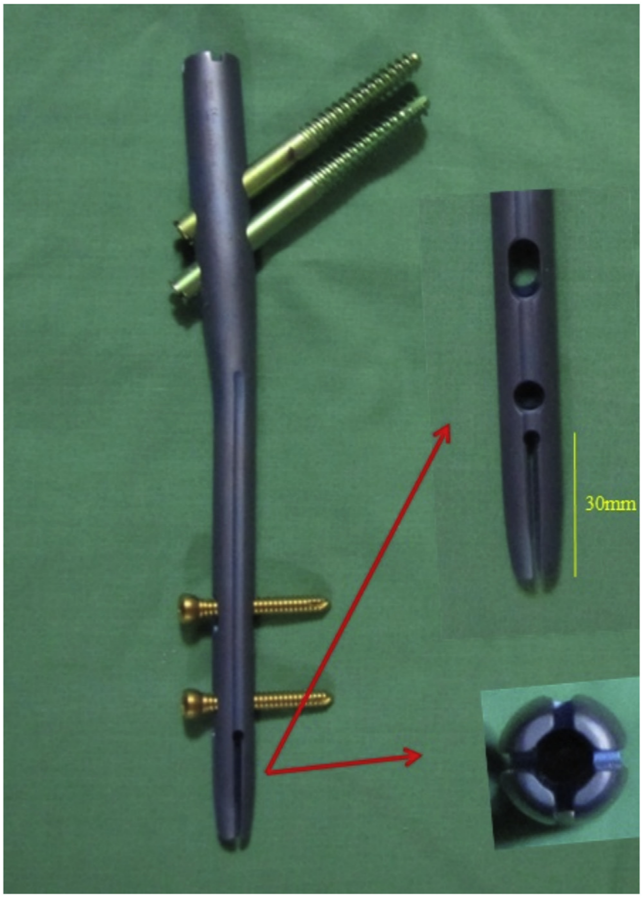

Fig. 2. The trochanteric nail (TRON).

the anesthetist. Thirty minutes prior to operation, 1 g Cefazolin (*xxxx company, country*) was given, with further doses administered 8 and 16 h later.

Operative technique

Operations were performed on a traction fracture table to ensure that a lateral position could be easily maintained. Closed reduction was achieved before surgery via manipulation and traction under fluoroscopy, and the patient was then draped. A small (5-cm) incision was created just proximal to the trochanter major, the tip of which was the nail entrance point. After insertion of a guidewire, the entrance point was verified fluoroscopically and the first 5 cm was reamed with a 16-mm reamer. No case underwent distal reaming. Fluoroscopy was used to choose a nail of appropriate size, which was then inserted. If the initial size was too small or too large, the nail was replaced. The nail was inserted gently and hammering was minimized. The optimal locations for the lag screws were assessed on anteroposterior (AP) and lateral X-rays after insertion of two guide wires through the femoral neck. After these locations were identified, we drilled, and inserted appropriately sized lag screws into the femoral head. In some cases with narrow femoral necks, only one lag screw was inserted. The choice of distal locking was at the surgeon's discretion. Sometimes, if the fracture was stable, the surgeon did not lock the distal hole. The most preferred distal locking option involved the dynamic hole only. After removal of the targeting device, both adequate reduction and appropriate nail placement were verified in both the AP and lateral views.

Weight-bearing was permitted immediately after surgery, i.e., on the first postoperative day, using a walker or crutches. Stitches were removed on postoperative day 15. Clinical follow-up was performed at 6-week intervals for the first 6 months, and then at 3-month intervals for the next 6 months. Patients were advised to visit annually for follow-up. AP and lateral X-rays were taken at all follow-up visits.

Statistical analyses

All statistical analyses were performed using SPSS software (ver. 22.0; IBM Corp., Armonk, NY, USA). The normality of the data was confirmed using the Shapiro–Wilk test, and the homogeneity of variance was assessed using the Levene test. The significance of between-group differences was evaluated using the independent-samples *t*-test with bootstrapping. Categorical variables were compared using the Pearson chi-squared test. Quantitative variables are expressed as means ± standard deviation (SD) or as medians ± interquartile range (IQR), and categorical variables as numbers with percentages; 95% confidence intervals (CIs) were derived. A p-value < 0.05 was taken to reflect statistical significance.

Results

PROFINs and TRONs were used in 583 and 195 patients, respectively, with peritrochanteric fractures. Seventy-one patients in the PROFIN group and thirty-four in the TRON group did not meet our inclusion criteria; all remaining patients were included. The mean patient age was 79.61 ± 13.41 and 78.52 ± 12.61 years in the PROFIN and TRON groups, respectively, and the respective mean follow-up duration was 31.2 months (range: 6–84 months) and 25.3 months (6–59 months). Gender, site, fracture pattern, ASA score and injury type were similar between the groups. The mean Singh index was slightly lower in the PROFIN group, while the follow-up period was significantly longer (Table 1). Intraoperative femoral fractures were noted in two (0.4%) patients in the PROFIN group, but no postoperative fracture occurred despite the longer follow-up period. In both of those patients, nails 250 × 12 mm in size were used (i.e., the longest available nails); spiral oblique fracture occurred at the distal nail tip in both patients. In one patient, distal fracture fixation using a plate carried out in the same session; the other patient required no additional stabilization and the fracture was stable. Early weight-bearing was prohibited for

Table 1
Patient demographics.

	TRON (n = 161)	PROFIN (n = 512)	P Value
Age(year) - (Mean ± SD.)	7852 ± 1261	7961 ± 1341	0254
Gender - n(%)			
Male	52 (323)	171 (334)	0848
Female	109 (687)	341(666)	
Side - n(%)			
Right	90 (559)	260(508)	0278
Left	71(441)	252(492)	
Fracture patterns AO type - n(%)			
AI	47 (292)	135 (264)	0039
AII	81 (503)	254 (496)	
AIII	30 (186)	81 (158)	
B2.1 (Basicervical)	3 (1,9)	42 (8,2)	
Stable (type A1)	47 (292)	135 (264)	0542
Unstable (type A2, A3 and B2)	114 (708)	377 (736)	
ASA Scores - (**Median ± IQR**)	2.78 ± 1	2.83 ± 1	0312
Singh İndex - (Median ± IQR)	324 ± 1	3 ± 1	0032
Energy of trauma n(%)			
Low	158 (981)	492 (961)	0232
High	3 (1,9)	20 (3,9)	
Follow-up(Months) - (Mean±SD.)	253 ± 12,3	312 ± 145	0.026

Independent *t*-test (Bootstrap) / Mann Whitney U Test (monte Carlo) / Pearson Chi-Square test(Monte Carlo) /SD.:Standard deviation - IQR:Interquartile range.

both patients, but good union was evident at 15 weeks postoperatively and both patients returned to normal daily life (Fig. 3). One intra- and one post-operative fracture developed in the TRON group. Patients had AO/OTA type A2,2 and type A2,3 fractures respectively. A 220 × 12-mm nail had been placed in the first patient; the fracture occurred at the nail tip and the nail was replaced by a longer femoral nail within the same session. The second patient sustained a nail-tip fracture after 8 months of follow-up during a low-energy fall while walking. The original nail (220 × 11 mm) that was distally locked through the dynamic hole was replaced with a long femoral nail.

Proximal, lateral cortical fractures during surgery were more common in the TRON group ($p = 0.035$) (four in the TRON and three in the PROFIN groups). Preoperatively, all were of similar AO/OTA type and were unstable. However, no revision surgery or additional intervention was required; all patients achieved union. In one PROFIN group patient, lateral migration of the distal lag screw was detected after union and the screw was removed. Cut-out, the Z effect, and the reverse Z effect were more common in the TRON group (n = 14 vs. 9 in the PROFIN group). Distal hole-locking problems were detected in 13 PROFIN and 1 TRON group patient. Distal bending of slotted end incarcerated to the cortex of distal fracture was detected in one patient in PROFIN group. No implant breakage was detected in the TRON group. Single distal locking was performed via the dynamic hole in most patients (n = 95 [58.2%] in the TRON group and n = 351 [69.6%] in the PROFIN group). PROFINs 220 and 250 mm in length were available; 220-mm nails were used more commonly (in 492 patients [96.1%]). However, shorter nails were placed in the TRON group (160- and 180-mm nails in 118 patients [73.4%]). Although 12-mm-diameter nails were preferred for the TRON group (78 [48.4%]), 11-mm- diameter nails were preferred for the PROFIN group (274 [53.5%]) (Table 2).

Discussion

Complications associated with intramedullary nailing of peritrochanteric fractures include cut-out, femoral neck or head rotation, diaphyseal fracture during nail insertion, and diaphyseal fracture beyond the nail attributable to stress shielding and difficulties encountered when seeking to distally lock the implant [2,13]. To the best of our knowledge (based on searches of PubMed, Medline, and the Cochrane Database performed on August 25, 2018), this is the first study exploring whether distally slotted nails prevent intra- and post-operative fractures in those with peritrochanteric fractures. Importantly, we discuss a large number of patients and present 30-month follow-up data.

Although various manufacturers have sought to solve the iatrogenic fracture problem by producing distally fluted or slotted nails, it is not clear that these nails actually reduce the incidence of fracture. Distally slotted nails have been evaluated less often than fluted nails; here, we focused on whether two distally slotted nails prevented iatrogenic femoral fractures. Use of IMNs became popular in the early 1990s after the introduction of Gamma nails (Howmedica Ltd., Newbury, UK). Theoretically, IMNs should be biomechanically superior to sliding hip screws (SHSs); both small- and large-scale studies found that the Gamma nail was associated with an increased risk of peri- and post-operative femoral fractures and an increased need for re-operation [3,4,14]. However, given the advantages of IMNs (minimal invasiveness, reduced exposure of soft tissue, shorter operation time, fewer peritrochanteric fracture-healing complications), new nails were soon introduced [15]. Later, a Cochrane study showed that the incidence of iatrogenic femoral fractures decreased when the distal stiffness of the new nails was reduced by fluting. However, the risk of intra- and post-operative femoral shaft fractures remained higher than that with use of SHSs[10]. In the present series, Z and reverse Z effects were more common in the TRON group, and comparable to the rates in the literature [16,17]. This may be because adjacent positioning of two 6.5-mm-long lag screws yielded poor anchorage (8.5-mm screws were placed in the PROFIN group), and the sliding mechanism thus failed [18,19]. Another explanation is that the nail was shorter than in the PROFIN group [20]. The intraoperative shaft fracture incidence remains at about 1.4% [6,8,9,16,17,21–26] (Table 3), and the incidence of postoperative fractures at about 2.13%, even using the new-generation PFN and PFNA (Table 3) [6,16,17,22–24]. However, slotted EBA nails have been reported to reduce the

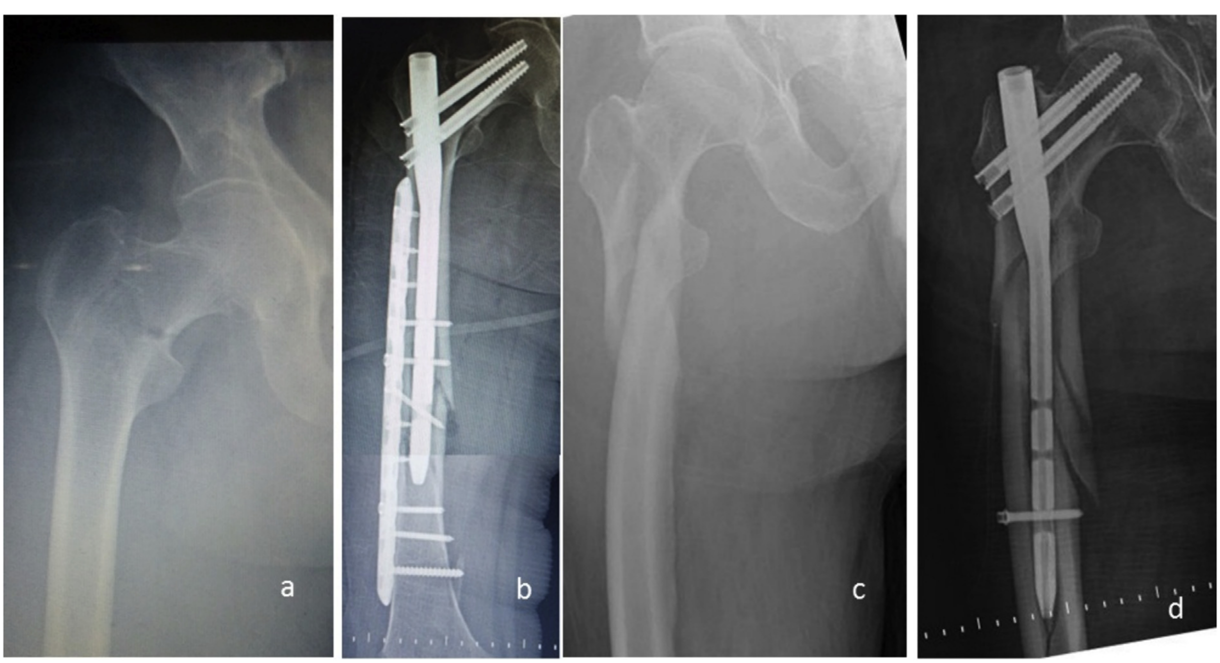

Fig. 3. a) Preoperative X-rays of a 72-year-old female who sustained an AO Foundation/Orthopedic Trauma Association (AO/OTA) B2.1 (basicervical) fracture. **b)** X-ray showing intraoperative fracture fixation with a plate. **c)** Preoperative X-rays of a 56-year-old male who sustained an AO/OTA 3.1 fracture. **d)** X-ray showing intraoperative fracture at the tip of the nail.

Table 2
İntraoperative and Postoperative Patient Data.

	TRON (n = 161)	PROFIN (n = 512)	P Value
Fracture fixation Complications - n(%)			
İntraoperative femur fracture	1(0,6)	2(0,4)	1000
Postoperative femur fracture	1(0,6)	0(0)	0239
Proximal lateral cortex fracture	4(2,4)	3(0,6)	0035
Cut-Out,	6(3,7)	5(1,0)	0027
Z Effect, Reverse Z effect	8(5,0)	4(0,8)	0002
Superficial Wound İnfection	1(0,6)	3(0,6)	1000
Failure of fixation	2(1,2)	2(0,4)	0243
Nonunion	0(0)	1(0,2)	1000
Fixation with one lag screw because of narrow neck	1(0,6)	9(1,8)	0465
Distal hole locking failure	1(0,6)	13(2,5)	0206
İmplant breakage(diaposan incarceration)	0(0)	1(0,2)	1000
Reoperation because one of above mentioned complications	12(7,5)	12(2,3)	0005
Fixation and implant choice characteristics - n(%)			
Locked distally with one screw through static hole	28 (175)	53 (105)	0005
Locked distally with one screw through dynamic hole	93 (581)	351 (696)	
Locked distally with two screws through static and dynamic holes	2 (1,3)	18 (3,6)	
Distally not locked as a surgical choice	37 (231)	82 (163)	
Nail Diameter n(%)			
10 mm	13 (8,1)	68 (133)	0002
11 mm	70 (435)	274 (535)	
12 mm	78 (484)	170 (332)	
Nail Lengths n(%)			
160 mm	5 (3,1)	*	<0001
180mm	113 (702)	*	
220mm	43 (267)	492 (961)	
250mm	*	20 (3,9)	

Pearson Chi-Square test(Monte Carlo).
* İs not a choice for this group.

incidence of intra-operative fractures to only 0.34% [27–30], 0.69% for IT nails [6,16,17,24,26,31], and 0% for PROFINs [32–35]. We recorded two (0.4%) intraoperative femoral fractures in the PROFIN group and one (0.6%) in the TRON group, in agreement with published studies on EBA nails, IT nails, and PROFINs (Table 3). Large-dimension nails are known to cause intra-operative shaft fractures, especially of excessively curved femurs (common in the elderly) [28]. This was first observed by Boriani et al. in 1996; fewer complications were noted with use of narrower than recommended Gamma nails (11 mm in diameter) [36]. In agreement with Boriani et al., we found that iatrogenic shaft fractures in both PROFIN and TRON patients were associated with the use of nails of the largest available dimensions (250 × 12 and 220 × 12 mm, respectively) (Fig. 3). Both patients exhibited narrow medullary cavities at the level of the isthmus and one patient showed excessive femoral bowing. In such cases, careful preoperative planning of an appropriate implant (nail or a dynamic hip screw) is important. If the nail will be the ultimate choice for the treatment, the entire intramedullary area (not only the entrance) should be reamed. The evidence suggests that although iatrogenic fractures are significantly reduced when slotted nails are used, the problem persists even when the level of surgical experience is high and the surgical technique is well-defined. Femoral-fractures persist when surgical planning was inappropriate or not accordant to the surgical technique [7,19]. Distally slotted nails also seem to effectively prevent postoperative fractures. The use of IT nails [6,16,17,24,22,22,23,24,25,2631] and PROFINs [32–35] was associated with no such fractures; the EBA nail was associated with a postoperative fracture incidence of 0.45% [27–30]. We recorded no postoperative fracture in our PROFIN group despite relatively long follow-up of patients of advanced age, and only one (0.6%) in the TRON group. Postoperative shaft fractures tend to occur after low-energy falls, and are typically spiral-oblique in nature [24]. Nails with a long, slotted distal end may show reduced modulus of elasticity at the nail tip; the nail may bend with the bone at the moment of trauma, rather than retaining the shape of the anterior cortex [28]. A recent meta-analysis comparing the PFNA, IT nail, and Gamma 3 nail found that use of the IT nail reduced the risk of peri-implant fracture [37]. However, four distal slots seemed to be no better than two. Moreover, although evidence is lacking, the 50-mm distal slot of the PROFIN in 220-mm length nails is probably associated with maximal bending of all slotted nails; we recorded no intra- or post-operative fracture despite the fact that 220-mm nails were placed in 492 patients (96.1%).

Inappropriate placement of the distal locking screws and/or mis-drilling may also cause iatrogenic fractures [24]]. However, excessive bending tends to create distal locking problems; we encountered 13 such cases (2.5%) in the PROFIN group and 1 (0.6%) in the TRON group, in line with the literature [16,17,25,26,30,33]. Makridis et al. reported that the incidence of distal screw misplacement using EBA nails was 3.8%, because these nails are of small diameter (10 mm) [29]. In femurs with excessive anterior curvature, the distal nail tip may be more bent than expected, changing the position of the distal dynamic hole and creating mechanical difficulties with respect to distal locking (Fig. 4) [29,33]. We routinely use the distal dynamic hole, rather than the static hole, to prevent cortical hypertrophy and decrease stress shielding by the nail tip [35]. However, we did lock through the static hole in five patients, where use of a targeting device greatly simplified this procedure, and did not lock at all in eight patients with stable fractures because further attempts to lock might have weakened the distal cortex. Slotted nails can cause opening of the distal slot, as first reported by Caiaffa et al. in two patients receiving EBA nails [28]. We detected a single distal slot opening in a PROFIN group patient, and changed the nail within the operation.

Lateral comminution of the proximal femur is infrequently reported and does not seem to compromise the clinical outcome. In a comparison between PFN and dynamic hip screws, proximal lateral fractures occurred in 3 of 25 patients but caused no problems [21]. Papasimos et al. reported a 25% rate of proximal lateral cortical fractures using PFN [9]. The extent of proximal, lateral cortical comminution may be affected by the number and

Table 3
Reported femur fractures and other complications releated with use of distally fluted or slotted cephalomedullary nails.

Author(Year)	Nail Design (n)	Femur shaft fracture (n)	Proximal lateral cortex Fracture (n)	Distal locking failure (n)	Cut-out(n)	Lateral or medial screw migration(n)	Implant breakage(n)	Reoperation (n)
Papasimos et.al (2005) [9]	PFN(40)	0	10	2	1	5	0	5
Kumar et al(2012) [13]	PFN(25)	0	3	0	0	1	0	1
Schipper et al. (2004) [14]	PFN(211)	4 (all postop)	*	3	11	12	0	29
Banan et al(2002) [15]	PFN(60)	2 (all postop)	*	*	4	*	1	7
Zhang et al(2013) [16]	PFNAII(56)	2 intraop 1 postop	1	1	2	4	0	3
	InterTan(57)	1	6	1	0	1	0	2
Zhang et al/(2018) [17]	PFNA II(88)	1	7	1	2	1	0	*
	InterTan(86	0	0	0	1	0	0	*
Müller et al(2016) [18]	PFN(705)	23	*	*	*	*	*	*
	DHS(597)	3	*	*	*	*	*	*
Simmermacher et al.(2008) [6]	PFNA(313)	7(all postop)	*	2	4	4	1	28
Vaquero et al. (2012) [8]	PFNA(24)	0	*	*	3	1	0	*
	Gamma3(27)	1	*	*	0	0	1	*
Yu et al(2016) [19]	Intertan(75)	1	8	2	0	4	*	0
	PFNA II(72)	8	1	2	6	4	*	0
Seyhan et al(2015) [20]	Intertan(32)	0	0	*	0	0	0	0
	PFNA(43)	1	1	*	0	0	0	0
Hopp et all(2016) [21]	Intertan(39)	0	*	*	2	*	*	2
	Gamma 3(39)	1	*	*	1	*	*	3
Oda et al(2002) [22]	Endovis(25)	0	*	*	0	*	*	0
Caiaffa et al(2007) [23]	Endovis BA std (1091)	4 all postop	*	3	10	6	4 diaposan opening, 2 nail breakage	*
Makridis et al (2011) [24]	Endovis BA std (105)	0	*	4	3	10	1	5
	IMHS(110)	1 postop 1 intraop	*	1	1	0	1	2
Geraci et al(2011) [25]	Endovis BA (87)	1 postop	1	*	4	*	*	5
Koyuncu et al (2015) [26]	PROFIN(152)	0	*	*	4	5	0	14
Ertürer et al(2012) [27]	PROFIN(36)	0	3	*	0	0	0	3
Akan et al(2011) [28]	PROFIN(80)	0	*	8	4	4	0	2
Ozkan et al(2009) [29]	PROFIN(24)	0	*	**	0	1	0	1
Present sudy	PROFIN(512)	2 intraop	3	13	5	4	1	12
	TRON(161)	1 postop 1 intraop	4	1	6	8	0	12

n; number of hips included in the study.
std: standart.
IMHS: Intramedullary hip screw(Smith and Nephew).
* Have not been mentioned.
** Distal locking had not were carried out as a routine.

diameter of inserted screws, the type of fracture (stable or unstable), and the entrance point (excessively lateral or postero-lateral) [16,17,25]. We encountered fewer lateral proximal cortical fractures (four in the TRON group and three in the PROFIN group [p = 0.035]) than reported in the literature [9,16,17,21]. We believe that: i) appropriate positioning of the entrance point; ii) reaming of the entrance point; and, iii) use of a nail with a flexible tip can prevent such fractures. However, in severely bowed femora, nails create stress at three points: 1) the anterolateral proximal cortex; 2) the posterior cortex at subtrochanteric region; and, 3) the anteromedial cortical region at the tip of the nail (Fig. 3a). During nail insertion, the tip bends toward the anterior and medial cortex; the subtrochanteric region serves as a hinge and further insertion targets the nail tip in a more posterior direction, in turn causing anterior and lateral movements of the proximal part of the nail (Fig. 4a,b). We used nails with distal slots and carefully reamed the entrance points to a depth of 16 mm in both groups; this may explain why we encountered fewer proximal lateral fractures than might be expected. We believe that the significantly lower incidence of proximal lateral cortical fractures in our PROFIN group was attributable to the nail having a longer slotted end than other nails, enhancing overall flexibility despite longer overall length. However further studies are needed to confirm this theory. Although the IT nail is distally slotted, two studies comparing PFNA and IT nails [16,17] reported different incidences of proximal lateral fractures (10 and 0% respectively) associated with IT use. Yu et al. reported that the incidence of proximal lateral fractures was 10%, attributed to the trapezoidal shape of the proximal end of the nail (which rendered it difficult to insert that end) and more rigid fracture fixation than afforded by PFNA[25]. Conversely, Seyhan et al. used IT and PFNA to treat 75 patients; a single proximal lateral fracture was found in the PFNA group [26]. One study reported only a single proximal lateral fracture in 87 patients receiving EBA nails [30]. Another study noted three proximal lateral fractures in 36

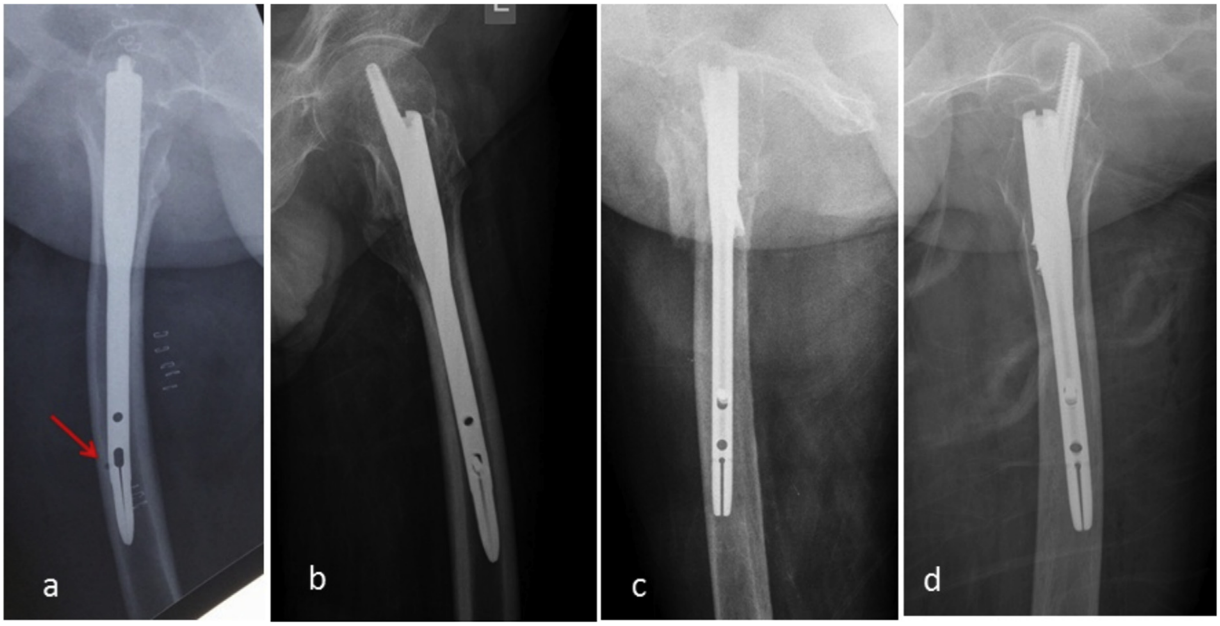

Fig. 4. a,b) Lateral X-rays of two different patients who received 220 × 11-mm PROFINs. Excessive bending of the distally slotted nail ends is apparent. Note that locking was unsuccessful because of the excessive bending evident in image **a** (red arrow). **b,c)** Lateral X-rays of two different patients receiving 180 × 11-mm TRONs. Although the nails are bent distally toward the anterior cortex, their shorter length seems to limit bending compared to that of PROFINs.

patients receiving PROFINs [33]. However, all studies included very small numbers of patients and all authors were unfamiliar with the implants. Most reports did not assess the extent of proximal lateral fractures, rendering it impossible to attribute the high incidence of such fractures to either the nail design or the skill of the operating surgeon.

The limitations of this study included its retrospective design. Moreover, we evaluated only TRONs and PROFINs among nails with distal slots (c.f. PFN, PFNA, and IT nails). Although the reasonable follow-up duration allows us to draw certain conclusions, most patients remain alive and may thus sustain later peri-implant fractures. A prospective multicenter study is required including more cases over a longer period of time, using the implants described above. However, it must be emphasized that the absence of detailed clinical and radiological follow-up in the present study reflects that it would be unethical to recall demented patients to the hospital for additional radiological follow-up[24].

Conclusions

All distally slotted nails reduce iatrogenic and postoperative fractures. However, four distal slots are no better than two slots. The 50-mm slot length of PROFINs render these nails optimal in terms of preventing postoperative fractures. Iatrogenic fractures supposedly associated with the use of slotted nails are attributable to inappropriate preoperative planning rather than low surgical skill or poor implant design.

Declaration of Competing Interest

The authors declare that they have no conflict of interest. No funding has been received for this study.

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