MENTORS IN ORTHOPEDICS

SHORT PROXIMAL FEMORAL NAIL WITH CEMENT AUGMENTATION: CONCEPT, TECHNIQUE, AND LITERATURE REVIEW

https://doi.org/10.71165/set1-8bb1

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SUMMARY

Background: Trochanteric fractures in patients over 65 years of age frequently result from low-energy trauma and osteoporosis. While short intramedullary nailing is the standard treatment, poor bone-implant interface quality in osteoporotic bone can lead to mechanical failures such as cut-out or cut-through, necessitating revision surgery and increasing patient morbidity.

Objective: This article describes the technical application, biomechanical rationale, and clinical evidence for polymethylmethacrylate (PMMA) cement augmentation of cervico-cephalic screws in trochanteric nails.

Key Points: Cement augmentation involves injecting PMMA through cannulated, perforated implants to enhance the bone-implant interface. Technical success requires precise guide wire placement, ideally at least 1 cm from the joint, to prevent intra-articular leakage. The procedure utilizes specific injection kits with graduated cannulas and syringes to deliver 3 to 6 mL of cement. Biomechanical studies indicate that augmentation significantly increases rotational stability and pull-out strength compared to non-augmented constructs. Clinical data demonstrate a reduction in serious mechanical complications, with some series reporting 0% revision rates for augmented nails compared to 4.4%–13.8% in non-augmented cohorts. Furthermore, the technique serves as a potential salvage option for migrating implants.

Conclusion: Cemented augmentation of trochanteric nails is a reproducible technique that improves primary stability in osteoporotic bone. By reducing the incidence of mechanical failure, it facilitates early mobilization and helps preserve autonomy in the elderly population.

KEYWORDS

Hip Fractures; Fracture Fixation, Intramedullary; Bone Cements; Polymethyl Methacrylate; Bone-Implant Interface

Trochanteric fractures are among the most common [1]. The vast majority of patients with this type of fracture are over 65 years old. In this age group, they result from low-energy trauma. Due to the prevalence of osteoporosis, women are more affected than men [1],[2],[3].

Short trochanteric nailing is the recognised gold standard treatment for these fractures. The aim of this surgical treatment in these patients is to reverticalise and rehabilitate walking in order to combat the loss of autonomy and the slipping syndrome. However, serious mechanical complications, such as cut-out or cut-through, can occur, leading to revision surgery, functional problems, prolonged hospital stays, loss of autonomy and even death [4],[5],[6].

The manufacturers of short trochanter nails are trying to direct their innovations to banish these serious mechanical complications. Cemented augmentation is one of them.

Cemented augmentation" or "augmentation" of an implant consists of the injection of PMMA (polymethylmethacrylate acrylic) cement through one or more of the implant's components (cannulated, perforated, and provided for this purpose). The result is an injection of cement into a bone zone (generally metaphyseal or epiphyseal) via the implant. The injected cement is therefore integral to the implant in place, thanks to the cement "bridges" that diffuse through its perforations.

The primary stability of an implant such as the trochanteric nail depends on the stresses placed on the implant, but also on the quantity and quality of the bone-implant interface. Augmentation affects the latter factor. In osteoporotic bone, due to the poor trabecular bone, the bone-implant interface is poor in both quantity and quality. The injection of PMMA cement into osteoporotic bone through an implant will increase the quality and quantity of the contact surface between the bone and the implant: this is augmentation.

HISTORY

Cemented augmentation was introduced by spinal surgery with pedicle screw augmentation. For the trochanteric nail, Depuy-Synthes incorporated the augmentation option into their arsenal in 2009 on the PFNA® (Proximal Femoral Nail Antirotation), which was released five years earlier. This option did not exist on their two previous nails, the PFN® (Proximal Femoral Nail) and the TFN® (Titanium Fixation Nail). However, it was extended to the TFNA® (TFN-Advanced), ten years after the release of their last trochanteric nail (Table 1).

Model	Year of release	Blade	Screw	Augmentation otpion
PFN	1997	No	Yes	No
TFN	2002	Yes	Yes	No
PFNA	2004	Yes	No	Yes (in 2009)
TFNA	2014	Yes	Yes	Yes

Table 1: Availability of the augmentation option on the different Depuy-Synthes short trochanter nails.

TECHNIQUE

The following technique is illustrated using a TFN-Advanced nail (TFNA®, DePuy-Synthes). The time of augmentation comes after the locking of the cervico-cephalic screw by the locking screw, and before the distal locking.

There is one particular stage in the placement of a nail that will determine whether or not it can be augmented: the placement of the guide wire. Whatever the choice of positioning the guide wire in the femoral head (central or lower part), particular attention must be paid to avoid entering the joint. It is really important not to place this wire beyond 1 cm from the joint. Indeed, if it is positioned in the subchondral zone, it may happen that the wire pierces the femoral head when the auger is passed through, or when the cervico-cephalic screw is mounted. In this case, augmentation is contraindicated because of the risk of intra-articular cement leakage. In case of doubt, a contrast check can be performed using the injection cannula of the augmentation kit.

We strongly advise against starting the cement before removing the screwdriver from the locking screw, but also the screw holder and the guide pin. DePuy-Synthes claims a cement setting time of 27 minutes at 20°C and 15 minutes at body temperature (37°C). However, in our experience, we have realized that the cement sets very quickly and it becomes difficult to inject after only a few minutes of preparation. It is therefore necessary that everything be "ready" before preparing it. The augmentation "kit" (Figure 1) consists of three different, sterile, single-use boxes :

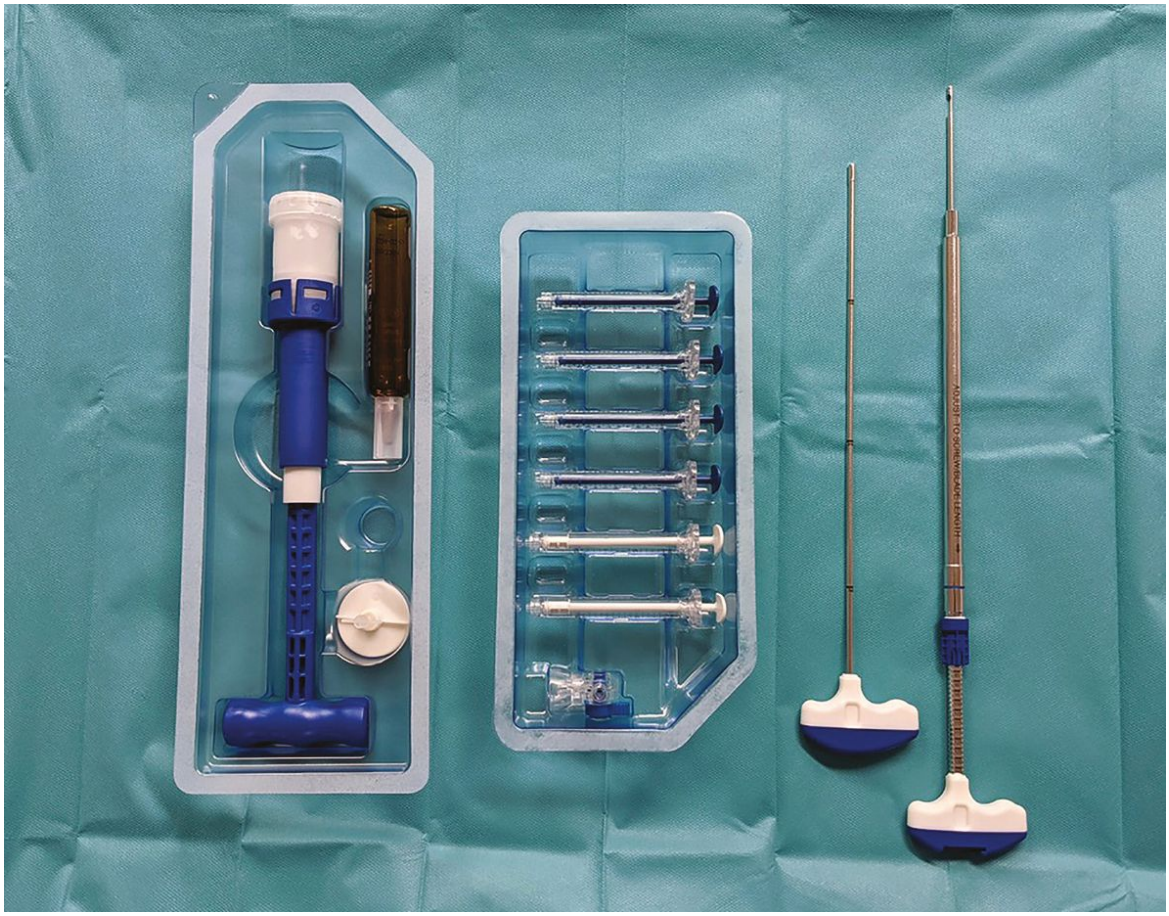


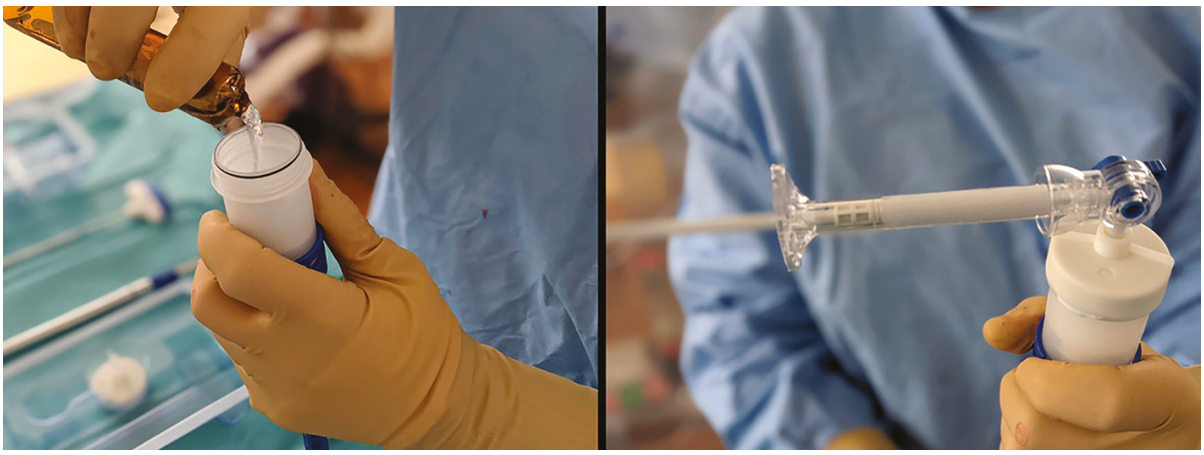
Figure 1: Components of the augmentation "kit", contained in three different sterile, single-use boxes.

- Traumacem V+ (PMMA) cement box, containing one ampoule of monomer (10 mL), a mixer already containing the cement powder, and a lid for transfers into syringes.

- Box of injection syringes, containing 2 x 2 mL syringes (white), 4 x 1 mL syringes (purple), and a stopcock.
- Injection box, containing the injection cannula and its piston.

All three boxes are required, and we do not recommend that TFNA be performed without all three boxes together (e.g. by using standard syringes, should the box of syringes be missing).

Cement preparation (Figure 2)



Preparation is done by keeping the mixer upright. The monomer is poured into the cement powder and the mixer is closed by screwing on the supplied lid.

The cement is mixed by moving the blue handle up and down between the stops (10 to 15 back and forth) and then with a rotary motion. The shut-off valve is connected to the mixer lid in the open position, and air is vented from the mixer by turning the blue handle clockwise.

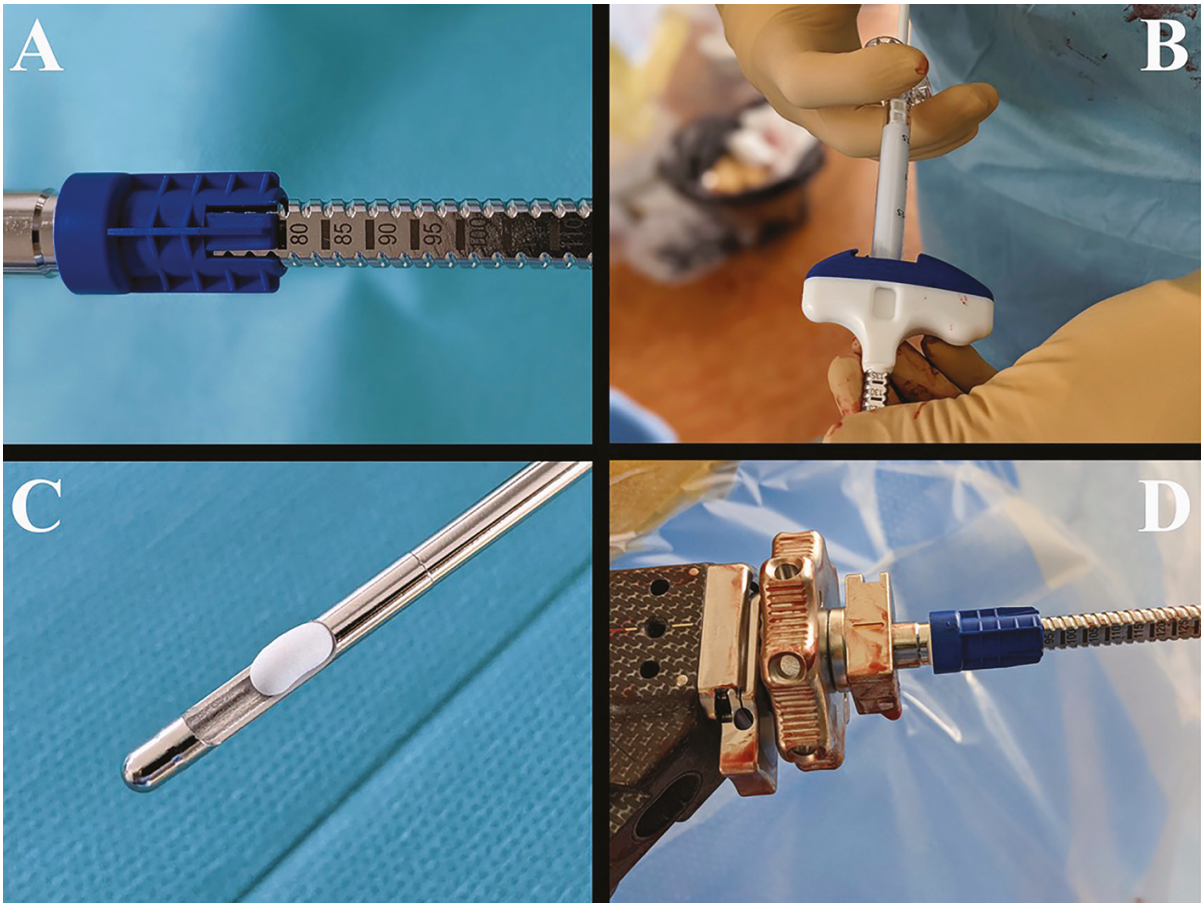
The syringes are connected (screwed in) to the stopcock and filled one after the other: first the two white 2mL, then the four purple 1 mL. Once the 6 syringes are filled, there is not enough cement in the mixer to refill the used syringes (see below).

NB: During these steps, the person preparing the cement will tend to place one hand around the transparent part of the mixer, for better ergonomics. However, the hands should remain on the blue part of the mixer so as not to heat the cement and accelerate its setting (Figure 3).

Filling the injection cannula (Figure 4)

The length of the cannula varies according to the length of the implanted neck screw. Before filling it with cement, this length must be adjusted using a sleeve that can be screwed or unscrewed. The cannula is graduated and the sleeve should be positioned on the number corresponding to the length of the neck screw (Figure 4A).

The two white 2 mL syringes are connected (screwed) and emptied into the injection cannula to purge it (Figure 4B). After filling with the two white syringes, the entire cannula is filled with cement, which begins to extrude from the distal part of the cannula (Figure 4C). The injection cannula can then be inserted into the proximal targeting system until it stops and augmentation can begin (Figure 4D).



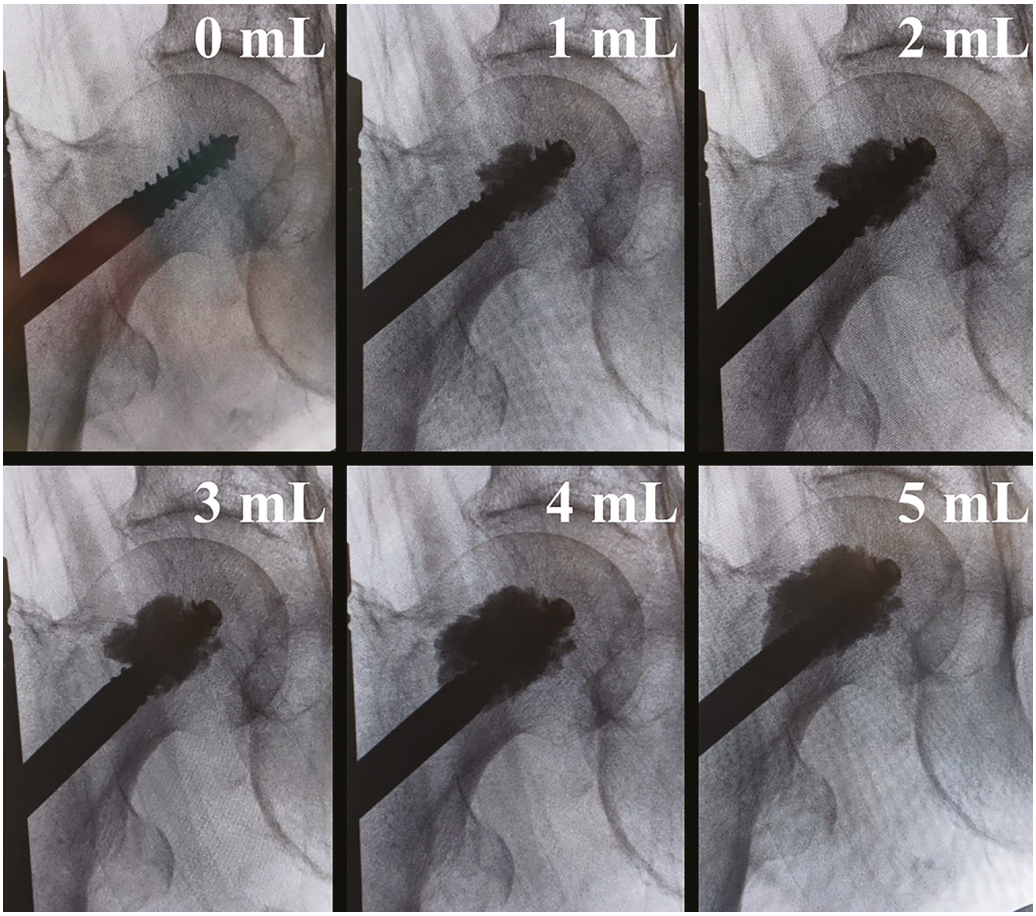
NB: The purple 1 mL syringes are used for augmentation but due to the injection pressures, the 2 mL syringes are not suitable for augmentation but only for cannula purging. It is therefore important not to reverse the syringe colours.

Augmentation

The 1 mL syringes are connected and emptied one by one into the injection cannula. The operator has 4 syringes of 1 mL each, with no possibility of refilling used syringes. To make an increase of more than 4 mL, the plunger of the cannula must be used to drain the remaining cement from the cannula. The plunger is graduated with three lines, each representing 1 mL of additional increase.

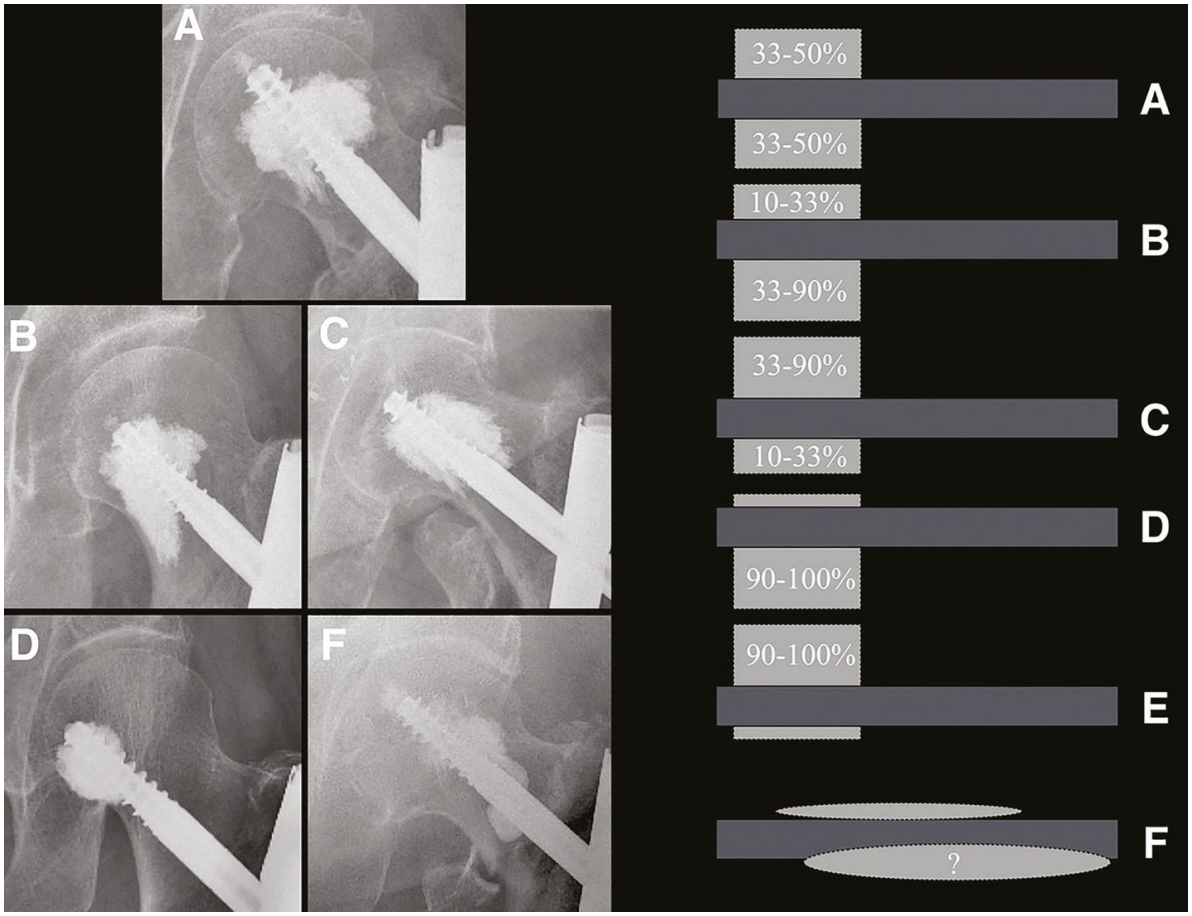
DePuy Synthes recommends an augmentation of between 3 and 6 mL of cement. The theoretical maximum volume of augmentation with one kit (3 boxes) is 7 mL.

Very regular fluoroscopic checks should be made during augmentation to monitor the diffusion of cement into the femoral head (Figure 5).



NB: To improve the diffusion possibilities of the cement, it is advisable to vary the orientation of the injection cannula so that the cement passes through all the perforations of the screw.

We found that the homogeneity of the cementing on the AP hip radiograph varied, and that the distribution of cement above and below the screw could be classified into 6 different types (Figure 6):



- type A: symmetrical distribution of cement (33-50%) above and below the screw.
- types B and C: moderate asymmetric cement distribution (10-33% on one side and 33-90% on the other), with the majority of cement below (type B) or above (type C) the screw.
- types D and E: major asymmetric distribution of cement (0-10% on one side and 90-100% on the other), with a majority of cement below (type D) or above (type E) the screw.
- type F: random distribution of cement that does not meet the criteria of types A-E.

Some surgeons prefer to position the cervicocephalic screw of the nail in the lower third of the femoral head to position itself under the dense centre of the femoral head. This leaves the screw head in medium quality bone, but with a better quality bone "ceiling" on which to rest under load. If an augmentation is undertaken with such a screw placement, the cement will diffuse into the lower part of the femoral head (less dense), but will not diffuse, or not well, into the middle third of the femoral head (more dense). This will result in a type D augmentation.

On the other hand, if the cervicocephalic screw is positioned in the dense centre of the femoral head (which some surgeons do not prefer since the "ceiling" is then of average quality), and an augmentation is performed, the cement will easily diffuse into the less dense areas, i.e. the upper and lower thirds, giving a more homogeneous, i.e. symmetrical (type A), or slightly asymmetrical (types B and C), cementation.

In the mind of the surgeon, augmentation therefore really begins at the moment of placing the guide pin of the neck screw, on the one hand in its positioning, but also in the precaution and safety of its insertion.

Mechanical studies

Biomechanical data on cemented augmentation of trochanteric nails are very scarce. In 2011, Erhart compared the behaviour of augmented and non-augmented PFNA blades in 18 cadaveric femoral heads subjected to rotational and pull-out [7] stresses. In the rotation tests, the mean peak torque before mechanical failure in the

augmented group was significantly higher (p = 0.017) than in the non-augmented group (17.2 vs. 11.7 Nm). The pull-out tests also showed a significant difference (p = 0.047) in the maximum pull-out force before mechanical failure between the augmented and non-augmented blades (2315.2 vs 1180.4 N).

Windolf simply reported in 2015 that even small amounts of cement (3 ml) resulted in an increase of more than 50% in the number of test cycles before mechanical failure for the same type of stress [8].

Clinical studies

The clinical studies on augmentation are summarised in Table 2. The most represented nail in the literature is the NFP.

Author	Year	Type of study	No. of patients	Nail type	Mechanical complication rate
Kammerlander	2011	prospective descriptive multicentric	59	PFNA	0%
Kammerlander	2013	prospective descriptive multicentric	62	PFNA	0%
Neuerburg	2016	prospective descriptive	72	PFNA	0%
Kammerlander	2018	prospective controlled randomized multicentric	68 vs 57	PFNA	4,4% vs 0%
Yee	2020	retrospective comparative multicentric	47 vs 29	TFNA	2,1% vs 13,8%

Table 2: Details of clinical studies on short trochanteric nail augmentation

In 2011, Kammerlander described the technique of PFNA augmentation and reported the results of a first multicentre prospective series of 59 patients with a mean follow-up of 4 months. [9] In 2013, he reported in another paper the results of 62 patients who had undergone PFNA augmentation [10]. In these two series, in addition to very good clinical results, the author describes no cases of serious mechanical complications or revision surgery. Finally, in 2018, he published the results of a prospective randomised controlled trial of PFNA (n=68) versus augmented PFNA (n=57). He found 4.4% of repeat surgeries for serious mechanical complications in the PFNA group versus none in the augmented 6 PFNA group.

Kammerlander's findings were confirmed by Neuerburg in 2016 [11]. In his series of 72 patients, he described no cases of mechanical complications.

To date, only one study of TFNA blade augmentation has been published [12], and Yee reports 2.2% serious mechanical complications in the augmented TFNA group versus 13.8% in the TFNA group (p = 0.047).

In addition to these series, augmentation has also been described as a salvage solution after the onset of migration of the cervical-head component of the PFNA [13],[14].

Cemented augmentation of trochanteric nails is a simple technique, and when well performed, carries few risks, particularly of intra-articular leakage. Augmentation is part of the fight against serious mechanical complications and therefore against repeat surgery, which is very harmful for elderly patients.

All the literature on this subject tends to place augmentation as a major asset in the management of trochanteric fractures in this population.

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