

# Prevention of Hip Lag Screw Cut-Out in Osteoporotic Patients

## Rationale and Review of the Literature

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**T**rochanteric hip fractures are the most common fractures in patients over the age of 65.<sup>1</sup> In elderly patients the prevention of complications and death is the primary goal and an early mobilization is a major concern. The treatment of choice for these fractures is a sliding compression screw telescoping through the barrel of a side plate or an intramedullary nail; this is a universally accepted and probably the most common method for treatment of trochanteric fractures.<sup>2</sup> In “unstable” fractures the evidence suggests this is the only suitable implant.<sup>3</sup> Those devices enable fracture compression with direct load transmission to the fracture site and are not prone to metal fracture as are the nail-plate and angled nails system.<sup>4</sup> This treatment allows early mobilization with weightbearing. Early mobilization is important because it helps to avoid complications linked to prolonged bed rest in elderly patients.

However, full weightbearing before healing of the fracture may provoke severe complications due to the displacement of fragments, migration of the lag screw, or both. Augmentation of the implant construct with cement has been one of the solutions described for this problem. The purpose of this paper is to review the rationale for the use of cement in the repair of trochanteric hip fractures.

### The Rationale for Lag Screw Augmentation

One of the most common complications associated with osteosynthesis by compression screw plate/nail of trochan-

teric fractures is screw migration and more specifically cut-out of the lag screw resulting in loss of fixation and varus collapse of the head and sometimes issue of the screw into the joint.<sup>5</sup> The reported frequency of cut-out varies from 5% to 20%.<sup>3,5-8</sup>

Failure is higher in so called unstable fractures, however the classification of stable versus unstable lesions maybe subject to questioning<sup>9,10</sup> and most of those fractures in osteoporotic patients should probably be considered as unstable.

An “optimal” placement of the screw in both antero-posterior and lateral views is supposed to decrease the failure rate. Unfortunately, there is a wide divergence as to what constitutes optimal placement, and trying to determine the “perfect” setting in both axes based on the available literature may be confusing.<sup>4,7,11-14</sup> Furthermore, optimal placement on both axis can be tricky to achieve and control accurately on the C-arm in some cases, especially when considering that this type of surgery is often performed by junior surgeons or trainees. Wolfgang and colleagues report technical errors in 23% of their cases with a 7% incidence of screw extrusion.<sup>15</sup> In a large series of 532 trochanteric fractures Larsson and associates<sup>16</sup> also demonstrated a very wide variability in screw placement. Moreover, it appears that even in “correctly” placed screws cut out may occur.<sup>6</sup>

The mechanical strength of the proximal femur (neck and trochanter) is correlated with bone mineral content.<sup>17</sup> Bone quality is of the utmost importance for the fixation strength and failure with screw migration is linked to the regional bone density since screw penetration loads are related to regional bone mineral content.<sup>18</sup> Those patients with marked osteoporosis are at increased risk for the loss of fixation.<sup>1,19,20</sup> With a bone mineral density of under 0.4 g/cm<sup>3</sup>, failure appears to be nearly inevitable under load.<sup>21</sup>

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If failure occurs, reoperation (with possible arthroplasty) or prolonged bed rest, in a medical or nursing home environment, is often required. Both options carry an high frequency of complications as well as very high costs.<sup>22,23</sup>

The majority of patients over 65 who have trochanteric fractures have osteoporotic bone and in the early postoperative period, and indeed until adequate union, the surgeon is divided between two conflicting options – should the patient be subjected to bed rest or weight-bearing. Trying to avoid loss of fixation with a protective postoperative management (bed or armchair rest and/or partial weightbearing which is often impossible to control in elderly and debilitated subjects) will lead to complications such as urinary and pulmonary infections, pressure sores, venous thrombosis, and further deconditioning, which are precisely the complications that early weightbearing will help avoid. However, weight-bearing in the early postoperative period has its obvious complications for these patients.

It appears that, in osteoporotic bone, sliding screw osteosynthesis often requires supplemental fixation. The primary fixation alone is not sufficient and it is therefore necessary to find some way to reinforce screw fixation to enable early weightbearing.

### Augmentation Techniques

Methylmethacrylate cement (PMMA) has been used to in comminuted intertrochanteric fracture as a means of fixation at the fracture site enabling immediate weight-bearing.<sup>24-26</sup> These reports<sup>24-26</sup> however describe immediate good results with minimal failure rate (1% to 3%), but do not report long-term outcome. Schatzker<sup>27</sup> reported good results in a follow-up at an average of 4 years, however only 10 patients out of 28 were reviewed.

In a cadaver study, Reigstad showed increase stability in femoral osteotomies fixed by a Thornton nail when augmented with PMMA. They used a large but unspecified amount of cement to fill the whole head, neck, and trochanteric region.<sup>28</sup>

Wu and coworkers<sup>29</sup> used a valgus osteotomy with a dynamic screw and plate. They added PMMA supplementation, of unspecified volume, in the neck-trochanter region and reported a favorable outcome at 1 year.

However, cement at the fracture site has potential drawbacks as it can keep fragments apart and lead to nonunion.<sup>24,25,30</sup> Bartucci tried to apply cement only in the proximal fragment in an attempt to minimize that drawback.<sup>31</sup> He found fewer complication of fixation but lower functional scores for patients having had cement fixation. He was using 15 to 20 cc of cement injected in the proximal fragment in which the screw was then introduced. With such quantity it seems unavoidable that cement would leak along the barrel of the screw and at the fracture site.

Cheng and colleagues<sup>32</sup> reported the long-term follow-up of a group of patients with PMMA fracture site augmentation. They describe 16% complications including screw migration, subcapital fractures around the tip of the screw, and cases of avascular necrosis. Avascular necrosis is considered exceptional in peritrochanteric fractures<sup>33</sup> and the cases reported are probably due to the impairment of the blood supply to the femoral head by the cement.

It appears that PMMA used as a means of fixation at the fracture site does, indeed, provide immediate stability but at the cost of potential late complications. The large amount of material necessary and the high temperature generated by curing of large masses of PMMA cement may cause thermal necrosis of the blood vessels and bone.

To prevent cutout of the lag screw without interfering with the healing process at the fracture site, the use of cement around only the screw head has been reported in a number of recent studies. Cement around the screw head enhances congruence between the fixation construct and bone and increases the purchase of the screw. It also distributes forces generated by weightbearing over a larger area of the fixation/bone interface<sup>23,31</sup> thus minimizing pressure, and covering the cutting edges of the threads. Cement around screw threads in the femoral head has also been showed to increase femoral stiffness.<sup>34</sup>

Different techniques and injectable materials have been described. Laros<sup>35</sup> enlarged the drill channel around the screw head with a curette and injected approximately 15 cc of PPMA before inserting the screw (however he did not include any results in his report). A specific device allowing controlled cement delivery restricted to the femoral head (Alta Dome Plunger, Howmedica, Rutherford NJ) was used by Choueka and associates in cadaver studies.<sup>36,37</sup> The device enables the extrusion of “a small bolus” of PMMA cement in the head after insertion of the device. The authors compared this setup with a classic lag screw, around the head of which 1 cc of PMMA was placed by injection with a cement gun in the pre-tapped canal prior to screw insertion. They demonstrated better results with the specific device. They also reported that post-failure examination showed a high variability in cement delivery in the group where the classic screw was augmented.

Kramer and coworkers,<sup>38</sup> in a cadaver study, showed improved screw holding strength using a modified Synthes DHS screw (Synthes AG, Chur, Switzerland). Three longitudinal slots were machined at the level of the threads at 120° intervals. The slots were communicating with the screw central hole through which an unspecified amount of low viscosity PMMA was injected.

Moore and colleagues, in a cadaver study, compared a resorbable calcium phosphate cement (Norian SRS) with PMMA.<sup>39</sup> After drilling and tapping the screw chan-

nel the screw was removed and the track was filled with 6 cc of cement in a retrograde fashion before reinsertion of the screw. After mechanical testing they found that both cements are efficient in decreasing the risk of screw cutout.

The same calcium phosphate cement was used by Goodman and associates<sup>40</sup> in 39 patients with intertrochanteric fractures. An unspecified volume of cement was injected, with needles of various curvatures and lengths, at the fracture site and initially in the lag screw tract. They abandoned the lag screw tunnel delivery after the occurrence of cement hardening preventing full insertion of the screw. They report that all fractures united at 6 month, but did not report results beyond that.

In femoral neck fractures, calcium phosphate cement (Norion SRS, Norian Corporation, Cupertino, CA) around cannulated screw threads was also shown to improve stiffness and fixation strength.<sup>41</sup>

An experimental, biodegradable, composite cement (polypropylene fumarate, PPF) was used by Witschger and coworkers<sup>42</sup> in a cadaver study where hip screws were reinforced by either PPF or PMMA. Six grams of cement were injected in the proximal end of the drilled and reamed screw channel before screw reinsertion. They reported that both composites enhanced congruence between implant and bone and thus increased the projected load bearing area of the implant resulting in increased yield force. This increased was, however, higher with PMMA than with PPF.

Glass ionomer cement was also used to reinforce dynamic hip screws by Claes and associates in a cadaver study.<sup>43</sup> They injected 6 gm of cement, with a cement gun, in the screw channel after drilling and tapping and before inserting the screw. They reported good biomechanical stability.

One study described the use of hydroxyapatite granules to enhance screw fixation in one case with a good result.<sup>44</sup>

A new dimethacrylate polymer composite, Cortoss (Orthovita Inc., Malvern, PA), was used in a preliminary clinical trial.<sup>45</sup> A limited quantity (2.5 cc) was injected by means of a catheter inserted through the lag screw. After full insertion the screw was backed up by the length of the threaded extremity, the cement then injected and device fully re-screwed. Preliminary results showed good results enabling very early full weightbearing in severely osteoporotic patients. The technique allows a precise and reproducible delivery of cement.

Many different techniques have been presented, often with very little technical details. The amount of cement used is usually quite important. In the majority of techniques described the cement is inserted in the empty screw tunnel after drilling, reaming, and sometimes enlarging. In those conditions if cement is only deposited at the apex of the tunnel, where the screw threads will

purchase, it is inevitable that it will leak backward in the tunnel before insertion of the screw and the amount remaining for screw fixation will be uncontrolled, hence the large quantities usually used to fill the whole tunnel. In order to be sure that enough cement remains at the right place, excessive amount are used. Choueka and colleagues showed that trying to deliver small amounts of cement in such a way results in variability of delivery leading to unpredictable failure patterns.<sup>37</sup>

Many authors do not specify the exact amount of cement used or do so very vaguely using terms like "adequate amount"<sup>27</sup> or "appropriate amount."<sup>32</sup>

The use of large amounts of cement has important drawbacks: thermal injuries through the high temperature curing of the large mass of cement may cause vascular and bone tissue damage and the reflux of composite in the fracture site may impair the contact between fragment and thus impede healing. The reflux of cement around the unthreaded screw barrel may block the screw from sliding within the barrel and prevent the compressive effect or, sometimes, even preserves fragment distraction at the fracture site.

The cement is usually injected with the tip of a cement gun inserted "as far as possible" adding to the lack of precision and the potentially poorly controlled reproducibility of efficient application.

Only three studies<sup>37,38,45</sup> present a controlled and reproducible technique for the delivery of a limited quantity of cement at the screw head level. Only one description<sup>45</sup> can be used with almost any cannulated lag screw, the other two require a specific<sup>37</sup> or experimental devices.<sup>38</sup>

### **Which Material for Augmentation?**

The choice of which cement to use is a major consideration. PMMA is the most widely used composite. It has the advantage of adequate mechanical properties combined with a wide availability and moderate price. However its high polymerization temperature and slow temperature decrease have the potential to cause thermal damage in already compromised bone structures.<sup>46</sup> Some PMMA cements on the market are not radiopaque, thus requiring a cumbersome mix of a radiopaque supplement in order to be able to monitor application.

Calcium phosphate cements have the advantage of hardening in a non-exothermic reaction. They are osteoconductive, resorbable, and are eventually replaced by ingrowth of bone. These properties are of great interest for when those cements are applied at the fracture site to fill voids, but they do not appear that important when it is used in the augmentation of the screw head. In the latter application, resistance to compressive loads at the screw/cement interface and resistance to the shear and tensile loads generated by the screw threads during weightbearing are essential properties. The compressive

strength of calcium phosphate cements is about two<sup>47</sup> to three<sup>48</sup> times lower than that of PMMA. Furthermore their chalk-like texture makes them difficult to use in small dose injections. Some problems were reported with set time (which may be unpredictable) and this led some investigators away from using it in the screw channel because it could prevent insertion of the screw.<sup>40</sup> Additionally, calcium phosphate cements usually have a long set time to full hardening (after 12 hours the hardening reaction is only 85% complete).<sup>49</sup>

Glass ionomer cement is reported to be biocompatible and bioactive. However, markedly increased aluminum serum levels and aluminum deposit in adjacent connective tissues and bone leading to toxic bone damage seems to severely limit its use in orthopaedic surgery.<sup>50</sup>

Cortoss, a dimethacrylate polymer composite, is a bioactive substance, thanks to combeite glass ceramic particles, enabling direct bonding with bone tissue without fibrous interposition. The curing temperature (58°C) is markedly lower than that of PMMA and the temperature decreases faster therefore minimizing potential thermal damage due to important thermal energy dissipation.<sup>51,52</sup> The compression strength is over twice that of PMMA and tensile and shear strengths are also much higher.<sup>52</sup> The coupled syringe bi-component nature of the composite makes it easy to mix on demand.

## Conclusion

In severely osteoporotic patients, who account for the majority of trochanteric fractures in the elderly, early full weightbearing is highly desirable. However, in those subjects, low regional bone mineral content will favor lag screw migration and cut-out. This secondary displacement will induce severe complications and high costs.

It appears that screw augmentation reduces that risk by decreasing pressure and the cutting effect at the screw-bone interface. A delivery of composite cement limited to the screw head seems efficient and limits complications due to exothermic reaction and cement interposition at the fracture site.

Different cements are available, PMMA has good mechanical properties, is widely available, and inexpensive, but cures at very high temperatures. Calcium phosphate cements set at low temperature and are osteoconductive, but have poor mechanical properties, are difficult to use, and are expensive. Dimethacrylate-active glass component composite is bioactive, has very good mechanical properties, sets at a moderate temperature, and mixes on demand. It appears to be an interesting choice for this application.

Augmentation of lag screw heads in trochanteric fractures in osteoporotic patients appears to enable earlier and more secure functional rehabilitation and potentially decreases complications and costs linked to this highly frequent traumatic pathology.

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