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Review

Cement augmentation of sacroiliac screws in fragility fractures of the pelvic ring—A synopsis and systematic review of the current literature

Adriana König[a,*], Ludwig Oberkircher[b], Frank J.P. Beeres[c], Reto Babst[c], Steffen Ruchholtz[b], Björn-Christian Link[c]

[a] Resident at Cantonal Hospital Lucerne, Lucerne, Switzerland
[b] Center for Orthopaedics and Trauma Surgery, University Hospital Giessen and Marburg GmbH, Location Marburg, Germany
[c] Department of Orthopaedic and Trauma Surgery, Cantonal Hospital Lucerne, Lucerne, Switzerland

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ABSTRACT

Background: Fragility fractures of the pelvis (FFP) show a notable rise in prevalence. Minimally invasive surgical fixation of FFP is increasingly advocated for its obvious advantages with reference to early mobilization and weight bearing. Concerns regarding the holding power of osteosynthetic materials in osteoporotic bone led to the development of cementing techniques. However, the role of cement augmentation in the surgical treatment of FFP has yet to be defined. Therefore, the aim of this study was to conduct a systematic review of the current literature concerning studies that are comparing the performance of cement augmented versus non-augmented sacroiliac (SI) screws.
Methods: We conducted a systematic literature review from 01/01/2000 onwards. Inclusion criteria were randomized controlled studies, case series (n>3), biomechanical studies and reviews, comparing augmented and non-augmented SI screws. Only papers in German or English language were included.
Results: Out of 1247 initial hits, eleven studies met the inclusion criteria. Out of those, six were biomechanical studies and five were clinical case series. Most biomechanical studies showed cement augmented screws to have a greater mechanical stability, both regarding pull-out force and resistance to cyclic loading. The five case studies reported on a total of 98 patients with 122 screw fixations. Three cases of cement leakage into neuroforamina occurred, however, none of these patients showed clinical symptoms.
Conclusion: In clinical case series, cement augmentation of SI screws appears to be a safe surgical technique without relevant complications and biomechanical studies demonstrate greater pull-out forces of augmented SI screws but no advantage in regard of cyclic loading. Hence, applicability of the mechanical testing results on the clinical situation are debatable.
So far, there are neither retrospective nor randomized controlled studies comparing the performance of cemented and non-cemented SI screws in FFP. Therefore, the clinical benefit of SI screw cement augmentation is unclear and their use remains experimental.

Contents

* Corresponding author at: Cantonal Hospital Lucerne, 6000 Lucerne 16, Switzerland.
E-mail addresses: adriana.konig@hcuge.ch (A. König), oberkirc@med.uni-marburg.de (L. Oberkircher), frank.beeres@luks.ch (F.J.P. Beeres), reto.babst@luks.ch (R. Babst),

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Background

As life expectancy increases so does the incidence of osteoporotic pelvic ring fractures. Kannus et al showed an increase in incidence of 23% of osteoporotic pelvic ring fractures in people aged 60 years and older in Finland between 1970 and 1997 [1]. The incidence of those osteoporotic fractures (also fragility fractures of the pelvis FFP) is estimated to be 25–92 per 100 000 persons years [2,3], rising up to 450 per 100 000 persons years in patients older than 85 years [4]. These fractures are already commonly encountered in the clinical routine and will become even more frequent within the next decades, hereby representing a significant cause of morbidity and mortality [5].

Most fragility fractures of the pelvis are only minimally displaced [4,6] and few require prompt surgical treatment [7]. In 2013 Rommens et al [8] published a new classification system for FFP referring to the fracture pattern and taking under consideration the degree of resulting instability. According to the classification a treatment plan is recommended. FFP Type I lesions show a low degree of instability but are relatively rare in elderly patients. In FFP Type II lesions, there is an additional injury of the posterior pelvic ring making them more unstable mechanically. These injuries can occur uni- or bilaterally. An even higher degree of instability is characteristic in FFP Type III lesions, which show a dislocation of one of the fractures at least and may be bilateral as well [8]. FFP Type IV lesions have the highest instability with fractures at both sides in the posterior ring. They may even show a complete dissociation between the iliolumbar spine and the pelvic ring [8].

For FFP Type III and IV lesions, treatment is clearly surgically. They might be stabilized minimally invasive or, if required with open reduction and internal fixation to address the instability associated with these fracture patterns. In FFP Type I injuries, conservative management including initial bed rest, analgesia and weight bearing as tolerated is advocated. Although FFP Type II lesions are the most common fracture patterns in elderly patients with more than 50% of all fragility fractures of the pelvis [9,10] there is no clear evidence and no consensus on their treatment [7,11]. Often, the initial treatment is conservative and in case of persistent immobilizing pain surgical fixation is recommended [7,8,12]. However, since FFP can move from a category with lower instability to a category with higher instability, if not treated adequately, some authors suggest considering unprevaricating surgical treatment [8]. Consideration for surgical treatment is strongly influenced by the inability of elderly patients to perform partial weight bearing and the importance of early mobilization in geriatric trauma care.

Traditionally, percutaneous screw fixation is the most common surgical procedure to stabilize non- or minimally displaced fractures of the posterior pelvic ring. As an alternative, sacroplasty was first reported in 2002 [11]. Studies show significant postoperative pain relief [12]. Nonetheless, some authors doubt that sacroplasty can restore the biomechanical stability in a fractured pelvis. As cement is injected percutaneously directly into the fracture [13] it mainly enhances the stability of the pelvis regarding compression forces. Conversely, the leading forces acting on the pelvic ring are shear forces [11,14]. Another possible complication is the occurrence of cement leakage, either into the spinal canal or the neuroforamina, possibly resulting in a neurological impairment [15]. Biomechanically, shear forces are better addressed with percutaneous screws stabilizing the posterior pelvic ring. The recommendation is either to place two sacroiliac (SI) screws either through the body of S1 or one through S1 and the other one through S2 [16]. Possible complications especially in osteoporotic bone is backing or cutting out of the screws because of the diminished anchorage [12]. In other words, established ways of surgical fixation are more likely to fail because of reduced bone-implant-interface [17] (Fig. 1).

A combination of both methods, sacroplasty and percutaneous screw, is the cement augmentation of percutaneously placed SI-screws [14] (Fig. 2). Cement augmentation is an already established procedure in a number of fractures (e.g. femoral neck fractures or vertebral body fractures) providing higher pull-out force in osteoporotic cancellous bone [18,19], by increasing anchorage between bone and implant [20].

The aim of this study is to conduct a systematic review of the current literature concerning studies comparing augmented versus non-augmented SI-screws.

Methods

We conducted the literature research on 25/04/2019. To find eligible studies we performed a PubMed-research as well as Medline, Cochrane library and Web of Science using the keywords osteopor* and pelvi* working with PRISMA guidelines [21]. Only publications after 01/01/2000 and either in English or German language were included. All abstracts were reviewed. Duplicates or papers deemed not applicable based on the following criteria were removed. First, at least one of the studied groups had to be treated with augmented SI-screws. Secondly, the study had to be a randomized trial, a case series with more than three patients, a biomechanical study or a meta-analysis. Any ambiguity at this stage resulted in the paper being sourced rather than rejected. After applying these criteria, the remaining papers were all sourced in full and read. Data was extracted of the full texts by two investigators, inserted in a predesigned chart, and analysed. Differences were resolved by discussion between investigators.

Results

Applying the mentioned research criteria, a total of 1247 hits was acquired. Screening the headlines of the published articles, we extracted 58 abstracts for review. Out of these, three full-text publications were available only in Chinese (n = 2) or in Czech (n = 1), leading to their exclusion.

After reviewing the 57 remaining abstracts 25 articles were sourced in full and analysed. One of these studies listed in its references another case series also eligible for our review which was also included. Ultimately, eleven studies met the inclusion criteria for our systematic reviews (PRISMA Flow Diagram, Fig. 3).

Out of these eleven studies, five were case series and the other six were biomechanical cadaveric studies (Tables 1 and 2).

We also searched other databases such as Medline, Cochrane library and Web of Science. Results were scarce and mostly duplicates to the PubMed hits, so we decided to concentrate on these.

The five case series all were conducted prospectively. Fracture classification was not consistent neither was an additional fixation

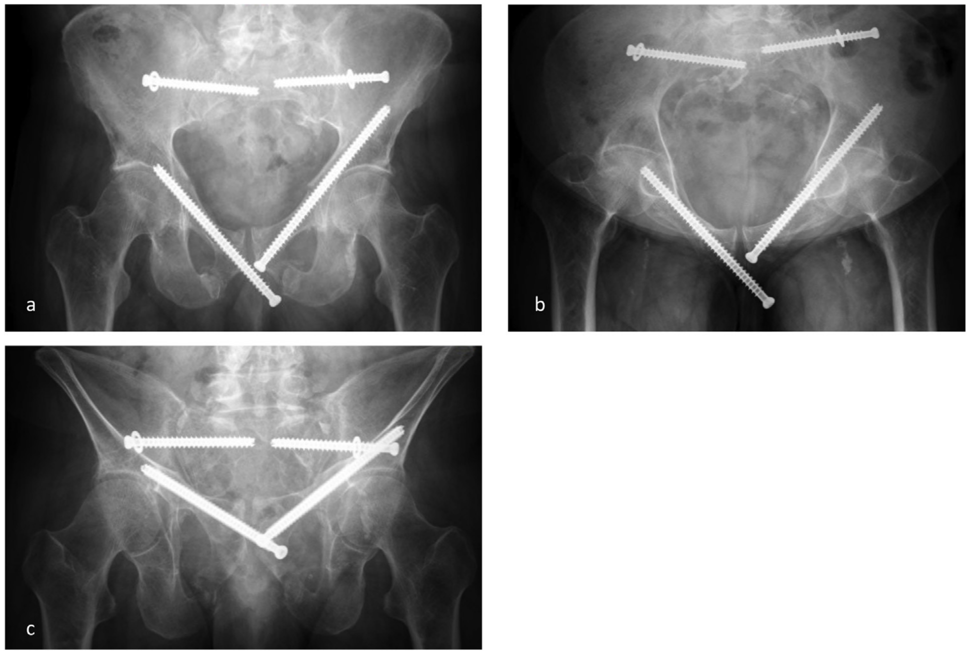

Fig. 1. AP pelvis (a), inlet (b) and out view (c) radiographs showing bilateral retrograde screw-fixation of the anterior pubic rami as well as bilateral non-augmented sacro-iliac screw-fixation six weeks after surgery. The patient was allowed immediate full weight bearing post-operativly.
Because of the poor bone-implant-interface due to the underlying osteoporosis, all screws migrated significantly causing relevant soft tissue irritation that needed revision.

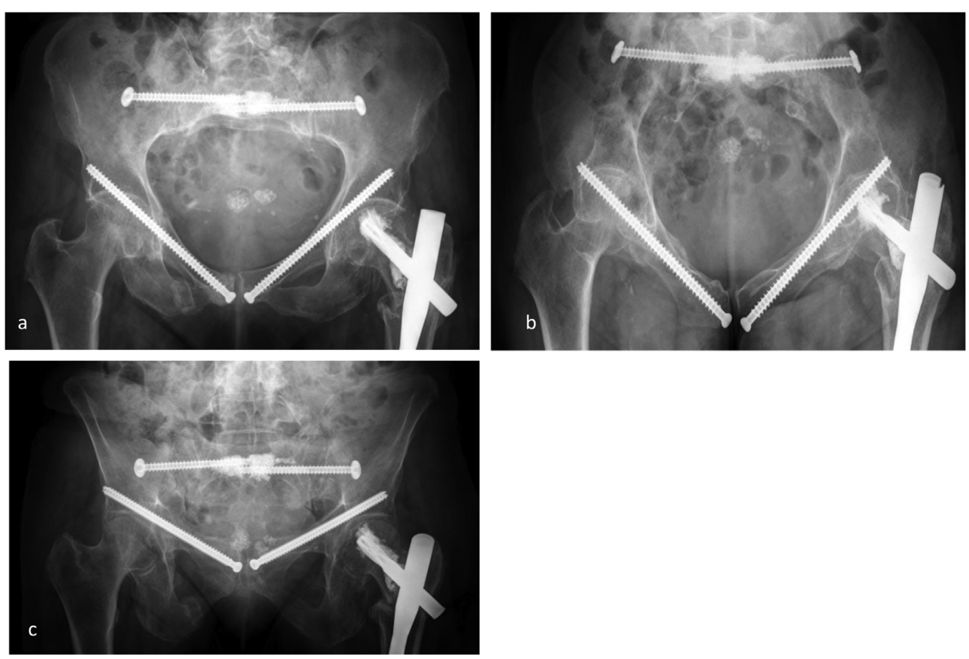

Fig. 2. AP pelvis (a), inlet (b) and out view (c) radiographs showing bilateral retrograde screw-fixation of the anterior pubic rami as well as bilateral cement-augmented sacro-iliac screw-fixation twelve weeks after surgery. The patient was allowed immediate full weight bearing post-operatively.
The cement-augmented proximal femoral nail was implanted just eight weeks prior to the fall that resulted in the fragility fractures of the pelvis.

of a possibly concurring anterior pelvic ring fracture. Surgery was conducted both as primary stabilization and as secondary treatment after failure of conservative management.

Mode of fixation

Collinge et al used a cannulated screw and inserted resorbable calcium phosphate material through the screw [22]. Höch et al implanted a fully threaded screw with additional perforations ad the distal end through which the polymethylmethacrylate (PMMA) could spread at the tip of the screw [23]. König et al introduced a cannulated, fully threaded screw and injected the cement after turning back the screw 3 cm [24]. Wähnert et al worked with fully threaded, cannulated and perforated screws. Cement was applied through the screw [25]. Sandmann et al implemented in their technique the advantages of balloon-assisted kyphoplasty by first

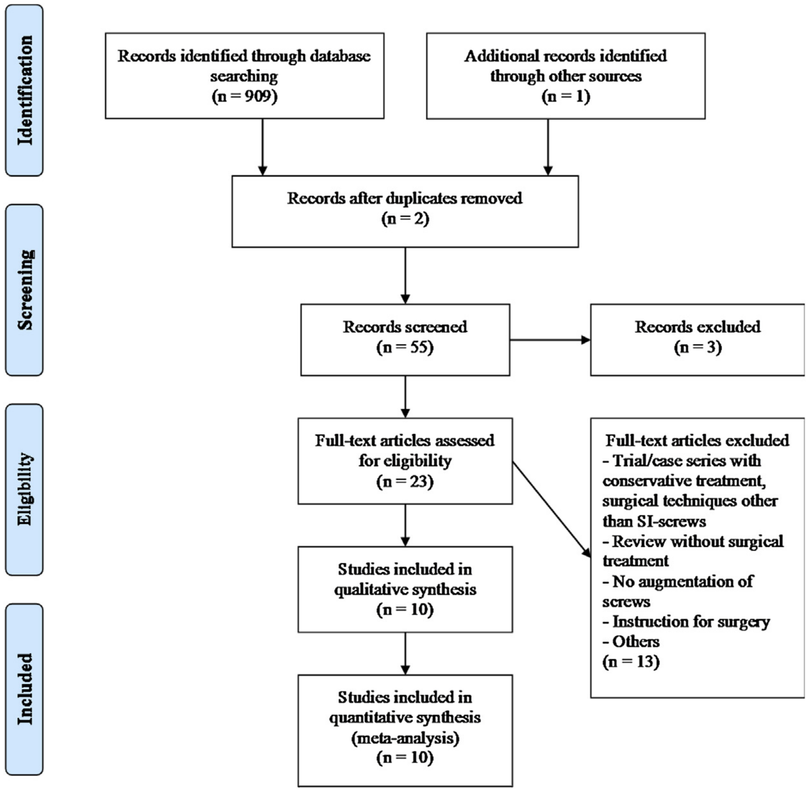

Fig. 3. PRISMA Flow Diagram.

Table 1
Case series included.

Author	Title	Year	Journal	Study design	Number of Patients/ Specimens (study group)	Number of Patients/ Specimens (control group)
Collinge C. et al.	Combined percutaneous iliosacral screw fixation with sacroplasty using resorbable calcium phosphate cement for osteoporotic pelvic fractures requiring surgery	2016	Journal of Orthopaedic Trauma	Case series	24 patients, 33 osteoporotic pelvic fractures, prospective	None
Höch A. et al.	In-screw polymethylmethacrylate-augmented sacroiliac screw for the treatment of fragility fractures of the pelvis: a prospective, observational study with 1-year follow-up	2017	BMC Surgery	Case series	34 patients, 43 PMMA-augmented sacroiliac screws, prospective	None
König M. et al.	In-screw cement augmentation for sacroiliac screw fixation in posterior ring pathologies with insufficient bone stock	2016	European Journal of Trauma and Emergency	Case series	20 patients, 26 augmented sacroiliac screws, prospective	None
Wähnert D. et al.	Cement augmentation of the navigated iliosacral screw in the treatment of insufficiency fractures of the sacrum. A new method using modified implants	2013	International Orthopaedics	Case series	12 patients, prospective	None
Sandmann G. et al.	Balloon guided cement augmentation of iliosacral screws in the treatment of insufficiency fractures of the sacrum – description of a new method and preliminary results	2018	Acta chirurgiae orthopaedicae et traumatologiae Cechoslovaca	Case series	8 patients, prospective	None

insufflating the balloon, checking for leakage with a contrast medium and putting the cement (Traumacem V+, PMMA) through the working sleeve. Afterwards, a fully threaded 7.3 mm screw was inserted [26].

Stability/follow-up

All patients were mobilized on the first operative day with weight bearing as tolerated. Combining all five case series, a total of 98 patients was treated and 122 augmented screws were used. After one year, Höch et al found no failures of screw fixation in 23 of 34 patients, that completed their follow-up [23].

Complications

Collinge et al reported one patient with a minor amount of cement extravasation into the SI joint that did not require an intervention [22]. König et al had to remove SI screws in three

Table 2
Biomechanical cadaveric studies included.

Author	Title	Year	Journal	Study design	Number of Patients/ Specimens (study group)	Number of Patients/ Specimens (control group)
Grechening S. et al.	PMMA-augmented SI screw: a biomechanical analysis of stiffness and pull-out force in a matched paired human cadaveric model	2015	Injury	Biomechanical cadaveric study	6 hemi-pelvises	6 hemi-pelvises
Grüneweller N. et al.	Biomechanical comparison of augmented versus non-augmented sacroiliac screws in a new hemi-pelvis test model	2016	Journal of Orthopaedic Research	Biomechanical cadaveric study	5	5
Hack J. et al.	Cement-augmented sacroiliac screw fixation with cannulated versus perforated screws – A biomechanical study in an osteoporotic hemipelvis model	2018	Injury	Biomechanical cadaveric study	8 hemi-pelvises: cannulated screw 8 hemi-pelvises: perforated screw	
Höch A. et al.	Biomechanical analysis of stiffness and fracture displacement after using PMMA-augmented sacroiliac screw fixation for sacrum fractures	2017	Biomedical Engineering/ Biomedizinische Technik	Biomechanical cadaveric study	8	8
Oberkircher L. et al.	Primary stability of three different iliosacral screw fixation techniques in osteoporotic cadaver specimens – a biomechanical investigation	2015	The Spine Journal	Biomechanical cadaveric study	Group B – 10 (SI screw, augmented via cannulation) Group C – 10 (SI screw, augmented, additional perforations)	10 (SI screw, non-augmented)
Osterhoff G. et al.	Cement augmentation in sacroiliac screw fixation offers modest biomechanical advantages in a cadaveric model	2016	Clinical Orthopaedics and Related Research	Biomechanical cadaveric study	5	Group A – 5 (SI screw, non-augmented) Group C – 5 (transsacral screw)

patients within one year because of screw migration and screw-disturbance [24].

Within the six biomechanical studies, Grechening et al [27] and Oberkircher et al [28] replicated no fracture; Hack et al reproduced in their pelvises FFP Type IIb [29]; Höch et al [30], Osterhoff et al [31] and Grüneweller et al [32] generated FFP Type IIIc.

Mode of fixation

All authors used polymethylmethacrylate bone cement (PMMA).

Grechening et al applied short-threaded, self-drilling, cannulated screw, screw removed four full turns for application of cement [27]. Grüneweller et al added cement through the screws which showed four custom made perforations at the screw tip [32].

Osterhoff et al matched sacroiliac screws with and without cement augmentation with transsacral screws. They were the only group to stabilize the concomitant disruption of the anterior pelvic ring with a retrograde screw [31].

Oberkircher et al built comparison groups without cement augmentation, augmentation before screw placement and augmentation through perforated screws [28].

Höch et al compared the stability of augmentation in cannulated versus perforated screws. In both groups they placed the screw first and inserted the cement through the cannulation [30]. Hack et al used a similar set-up [29].

Stability/follow-up

Grechening et al tested the pull-out forces and construct stiffness. They found the stiffness in augmented screw fixations to be significantly higher as well as the pull-out force [27]. Oberkircher et al also conducted a pull-out test and confirmed the augmented screw constructs to be significantly stronger than non-augmented screws. Nevertheless, timing and modality of cement application was of no significance [28].

Grüneweller et al examined screw-out, pull-out, cut-out and fracture displacement. Though the required number of cycles to failing did not significantly differ, the augmented construct survived 424% more load-cycles until loss of fixation on the sacrum [32].

Osterhoff et al simulated cyclic single-leg stand to look at the amount of screw loosening, construct survival and the amount of sacral fracture site motion. They showed no significant differences, however, the augmented screws displayed less screw subsidence [31].

Höch et al replicated one leg-standing as well but noticed no difference in stability or total interfragmentary displacement [30].

Hack et al tested construct failure through axial loading. Maximal load, plastic deformation and stiffness did not differ significantly. In their investigated specimens, they saw no screw-out and no screw breakage [29].

Complications

Grüneweller et al [32] and Osterhoff et al [31] both experienced cement leakage into the neuroforamen. Grüneweller et al had one (1 in 5) retrograde cement leakage. Osterhoff et al reported cement leakage in the S1 foramen in 3 of 5 specimen (n = 2 S2 screw, n = 1 S1 screw) and in one case cement leakage into the fracture site.

Discussion

The aim of this systematic review was to evaluate the current literature regarding cement augmentation of SI screws. Even though literature search produced over 1000 hits, only eleven publications met our inclusion criteria. Cement augmented techniques show better biomechanical properties in biomechanical studies regarding pull-out forces and construct stiffness [27,28], however, studies examining more life-like set-ups remained unable to prove an advantage of augmented screw fixation [29–32]. There is only limited clinical data available as reflected by this review.

Although implantation of SI screws was first described in 1973 by Vidal et al [33] it remains a challenging technique which should be performed by experienced surgeons. Implant malposition occurs in up to 18–25%, exposure to X-ray radiation can be high and complications are severe, such as damage of lumbosacral nerve roots, the superior gluteal artery or iliac vessels [34,35]. Regarding the correct placement of the screws, additional safety may be achieved by intraoperative 3D-imaging [14,36,37] or intraoperative navigation [37,38]. Nevertheless, percutaneous SI screw fixation is most commonly used minimally invasive fixation technique for posterior pelvic ring injuries with shorter operation time, less blood loss and less damage to soft tissue than an open reduction procedure [34,35]. Key argument to augment SI screws is to optimize implant-bone interface and thereby reducing the risk of screw loosening or pull-out [32]. In clinical practice, this should allow patients to mobilize with full weight bearing immediately following surgery [22,24,25]. Thus, prolonged immobilization with concomitant risk of infections, cardiovascular events, high rate of dependency and institutionalization can be avoided [6,9]. Höch et al observed 128 patients with an FFP over two years. Both in the operatively and in the non-operatively treated group mortality rates were high. Nevertheless, the survival rate for operatively treated patients was significantly higher (2-year survival: operatively treated 82% vs conservative 61%) [39]. In biomechanical studies, cement augmentation improved the stability in sacral screw fixation [28,32]. Regarding the resulting stability, it does not seem to make any difference, whether the screw is placed first and the cement applied through the screw or if the cement is applied first and the screw is inserted into the cement [28]. Likewise, biomechanical testing showed no difference in stability by applying cement through cannulated or cannulated and perforated screws [29]. Inserting cement through the screws is meant to improve safety by preventing cement leakage, especially into the neuroforamina. However, neither testing of axial pull-out force nor cyclic loading represents exactly the actual mechanical forces working in an osteoporotic pelvis after surgical fixation [27,29,30]. The superior performance of augmented screws for axial pull-out force but not consistently for cyclic loading might actually reflect the arguable applicability of results. Additionally, biomechanical testing on a hemipelvis cleaned off most soft tissue might not actually reflect the physiological situation in an osteoporotic pelvis. Therefore, clinical studies are needed to prove an advantage of augmented versus non-augmented SI screws. So far, very few and small case series are published concerning augmented SI screws and none of them provided a control group. In general, these case series could show a significant decrease in pain after placement of the SI screws. They allowed early mobilization with full weight bearing. No failure of the fixation occurred [22–25]. With a mean follow-up of 10 months, Collinge et al [22] reported their experiences with augmented SI screws over 13 years. They treated 33 osteoporotic pelvic fractures with augmented SI screws. All of those healed without fracture displacement or failure of fixation. Their patients experienced a significant decrease in pain immediately after fixation. In one patient, a cement leakage occurred within the SI joint at the far side of the fracture, which showed no symptoms and did not require further interventions. König et al [24] demonstrated similar results but had a mean follow-up of only 1.5months limiting the significance of the study. The most recent results published Höch et al [23] in 2017 with their case series of 34 patients of which they could conduct a follow-up of one year in 23 patients. They reported comparable findings with all their patients being able to walk postoperatively. After one year the patients expressed no increase in pain and showed no failures of screw fixation radiologically.

None of the studies clearly expressed indications for cement augmentation. Most commonly, the authors stated that they would use cement augmentation whenever the patient showed osteoporosis on the CT scan or radiograph [22,25]. Finally, there seems to be no consensus on when to treat patients with an osteoporotic pelvic ring fracture conservatively and when to perform surgery. Most authors don`t specify their indications for a surgical treatment. For the most part, a surgical procedure is performed when the conservative treatment with bedrest and analgesia failed to provide sufficient pain relief that would allow for adequate mobilization [7]. The duration of this trial period differs. Some authors wait up to one week, other prefer to intervene earlier [8,23,40,41]. Unfortunately, many authors fail to define a time or a pain, or a pain medication threshold which triggers the indication for an operative treatment [4,11].

Regarding concomitant fractures of the anterior pelvic ring, which are frequent in FFP Type II, there is no consistent recommendation whether to treat those fractures surgically (retrograde screw) or not. In our review, Collinge, Höch and Osterhoff et al where the only ones to treat coexisting anterior pelvic ring fractures [22,23,31]. So far, we don`t know if it is necessary to stabilize those fractures as well or if it might be sufficient to solely treat the fractures of the dorsal pelvic ring, when using augmented screws.

Conclusion

Most biomechanical studies show that cement augmentation of percutaneously placed SI screws is improving stiffness and fixation of the osteosynthesis. The minimally invasive surgical technique is technically well-described in literature. Few clinical case series with relatively low numbers of patients confirm the method to be safe and effective. Unfortunately, to date, larger case series, prospective data or randomized trials are missing. Even though fragility fractures of the pelvic ring gain prevalence, cement augmentation of SI screws still is not common practice. Considering the importance for elderly patients to safely apply full weight bearing and regain mobility as soon as possible, this is surprising.

In conclusion, prospective randomized controlled trials need to demonstrate the superiority and safety of cement augmented SI screws over uncemented osteosynthesis. Additionally, clinical studies should clarify whether early fixation of fragility fractures of the pelvis will result in better outcome compared to successful conservative therapy or attempted conservative treatment that, where required, is followed by operative management, respectively. In this regard, it is of utmost importance to define clinical and radiological thresholds to allow for allocation of patients to the appropriate therapy regime.

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