Indications for Implant Removal after Fracture Healing

a review of literature

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Abstract

Introduction The aim of this review was to collect and summarize published data on the indications for implant removal after fracture healing since these are not well defined and guidelines hardly exist.

Methods A literature search was performed.

Results Though there are several presumed benefits of implant removal, like functional improvement and pain relief, the surgical procedure can be very challenging and may lead to complications or even worsening of the complaints. Research has focused on the safety of metal implants (e.g. risk of corrosion, allergy and carcinogenesis). For these reasons implants have been removed routinely for decades. Along with the introduction of titanium alloy implants, the need for implant removal became subject of debate in view of potential (dis)advantages since in general, implants made of titanium alloys are more difficult to remove. Currently, the main indications for removal from both the upper and lower extremity are mostly 'relative' and patient driven like pain, prominent material or just the request for removal. True medical indications like infection or intra-articular material are minor reasons.

Conclusion This review illustrates the great variety of view points with large differences in opinions and practices about the indications for implant removal after fracture healing. Since some studies have described asymptomatic patients developing complaints after removal, the general advise nowadays is to remove implants after fracture healing only in symptomatic patients and after a proper informed consent. Well designed prospective studies on this subject are urgently needed to make guidelines based on scientific evidence.

Introduction

The different options for operative fracture treatment using metal implants have increased substantially the last decade. Worldwide metal implants (e.g. plates, screws and nails) are used which are generally made of stainless steel or titanium alloys. After fracture healing has taken place an implant no longer has any function and the question rises whether the implant should be removed and if so, why and when? Though there are several presumed benefits of implant removal, like functional improvement and pain relief, the surgical procedure can be very challenging and may lead to complications such as neurovascular injury and refractures, whereas the expected outcome is not well determined yet. The (medical) indications for surgical removal of these metal implants are not well defined and a variety of view points with large differences in opinions and practices between surgeons, countries, patients, anatomical locations and implant materials exist [1-6]. There is a lack of clear guidelines concerning implant removal, only in Germany a more or less consensus based guideline exists [7]. In this review of literature the indications for implant removal after fracture healing are discussed. Implant removal in children will be discussed elsewhere in this journal.

Methods

A Pubmed MEDLINE, Embase, Web of Science and Cochrane Library database search has been performed on all literature dealing with the indications for implant removal after healing of long bone fractures from the early sixties of the last century until january 2013 with at least an english abstract. The search strategy used was ((((((((((device) OR implant) OR hardware) OR metal) OR orthopaedic) OR orthopedic) OR osteosynthesis)) AND (fracture)) AND (((removal) OR remove) OR extraction)) NOT (((dent*) OR maxil*) OR mandib*)) NOT ((prosthe*) OR arthroplast*)) NOT ((thorac*) OR lumb*). This search strategy revealed 2164 hits. All titles and abstracts have been screened by the first author (DIV) for relevance. Literature on removal of prosthesis, implants from the maxillofacial and spine area and positioning screws of the ankle were excluded. Sixty-seven articles were considered eligible for use in this review. Full paper versions were obtained, read and subsequently searched for cross references. The majority of these articles were retrospective case series.

For a structured overview of various subjects concerning the indications for implant removal after fracture healing, the literature was used to answer the following questions: *'Do implants need to be removed because they damage health?',* **'***What are the current indications and pratices for implant removal after fracture healing?', 'What are the specific indications for implant removal from the upper extremity?'* and *'What are the specific indications for implant removal from the lower extremity?'*

Do implants need to be removed because they damage health?

Since World War II treatment of fractures has shifted from a nonoperative fashion towards an operative therapy using metal implants (e.g. plates, screws and nails). These implants used to be made of stainless steel, an alloy of chrome, nickel and molybdenum and much research focused on finding an optimal alloy for fracture treatment with the best biocompatibility. The alloy had to be strong enough, non-corrosive, non-carcinogenic, infection resistant and tolerated by the immune system.

For many years the potential risk of corrosion has been an indication for many surgeons to remove implants routinely after fracture healing. This process of oxidation of metal leads to loosening of small particles that can be biologically active. Such particles can lead to an inflammatory tissue reaction with the formation of necrosis, granulation and fibrous tissue. Most research on these aspects goes back to the seventies and eighties of the last century [8, 9]. Implants made of stainless steel produce corrosion in symptomatic and asymptomatic patients, but the clinical significance remained unclear [10]. Along with the problem of corrosion, metal implants were also considered to play a role in the genesis of cancer. However, several experimental studies could not reveal any association between metal implants and the development of any form of cancer [11]. Since the nineties corrosion and cancer were no longer considered to be an indication for standard removal anymore.

Allergic reactions to implants made of stainless steel, leading to skin changes, eczema, delayed wound healing, pain or even implant loosening (not to be mixed up with symptoms caused by a low grade infection), have been described and were another indication for routine removal. But in contrast to the high incidence of cutaneous metal contact allergy (e.g. nickel), allergies associated with internal devices are rare and epidemiological data on implant-related allergic reactions scarce [12, 13].

Also bone atrophy has been an argument for implant removal [14, 15]. Rosson *et al* published two detailed studies about the influence of plates to the underlying bone structure. Cortical bone atrophy was found in one patient in whom a plate of

the forearm was removed after 16 months. In 14 other patients, who had their forearm plates removed in a much later stage, the bone density had returned to its pre-fracture level. In young adults the bone mass at the site of residual holes after screw removal returned close to normal after 18 weeks [16, 17]. Therefore, in order to reduce the risk for a refracture, it was recommended to leave plates in for at least 21 months or not to remove them at all.

New generation metal implants are alloys of titanium, aluminum and niobium (TAN; Synthes®) or titanium, aluminum and vanadium (Stryker®). After the introduction of TAN in 1977 its composition has been improved continuously. The biocompatibility of TAN is excellent and so far no toxic reactions, signs of corrosion or allergic reactions have been described, which has made its use rather popular the last 15 years [18-20]. But since the widespread use of locked head TAN plates, technical difficulties during removal have become a new problem [21]. Removal of TAN implants can be extremely difficult due to screw-head locking into the plate or bone overgrowth at the implant surface. Richards *et al* described that not only the composition of the alloy, but also its surface structure matters in these cases [22-26].

Next to the lack of proof that implants damage health, the observed technical problems have made surgeons less enthusiastic to remove implants after fracture healing. But what to do with patients with complaints attributed to the implant?

What are the current indications for and pratices of implant removal after fracture healing?

The growing amount of arguments against routine implant removal, justify a re-evaluation of the existing ‘absolute’ and ‘relative’ indications for removal, since implant removal after fracture healing requires at least a new operation, the results are unpredictable and the procedure can be very frustrating; *“Attempts at hardware removal are often frustrating events, resulting in broken implants and retrieval equipment, prolonged surgical times and frustrated, humbled surgeons”* (citation James Kellam, Carolinas Medical Center, Charlotte, NC USA).

Minimal invasive plate osteosyntheses or intramedullary nailing can lead to ‘maximal invasive’ implant removal procedures with surgery related risks like bleeding, wound infection, nerve injury, refracture, a poor cosmetic result and the risk for anesthesiology related adverse events. All these drawbacks come with large costs and potential social consequences and are arguments against removal (Table 1).

In 1992 Sanderson *et al* described an overall complication rate of 20% in 188 patients who had their metal implants removed [27]. In forearm plate removal they even observed 42% complications. Instead in another prospective study, presenting the results of 86 adult patients who had their implant removed, 46 patients had been somehow symptomatic at the time of removal. A good clinical outcome was achieved in 91% of the symptomatic patients and no problems were seen in 95% of the asymptomatic cases. The overall complication rate was 3%, including a radial nerve injury and a refracture. It was concluded that in asymptomatic patients it might be appropriate to leave implants [28]. Minkowitz *et al* published a prospective study of 60 patients (57 with a complete follow up of one year) with pain in the region of their fixed and healed fracture in order to evaluate the outcome after implant removal [29]. Surgery related complications were not described. The overall improvement of function and pain one year after implant removal was significant (p= 0.00001). All patients were satisfied and if necessary would undergo the removal procedure again.

In an overview published in 2003 about the indications for and risks of implant removal after osteosynthesis, implants clearly interfering with surrounding tissues and function and implants in growing individuals were defined as absolute indications for removal [30]. Mild implant related tissue reactions were considered to be debatable indications.

Currently the indications in favour of implant removal are mostly 'relative' [31]. The absolute indications for implant removal nowadays only include perforating material (e.g. K-wires or external fixators). Even implant removal in the growing skeleton has become controversial and is no longer considered an absolute indication anymore. No evidence that supports routine implant removal in children can be found [3, 32-34]. Also infection after operative fracture treatment is not always an absolute indication for removal. On the contrary, maintenance of fracture stabilization is mandatory to treat the infection. In most cases the hardware can be left in situ until the fracture has healed. Operative wound débridement, local and systemic antibiotic therapy and retention of the hardware has proven to be a succesfull concept [35-38].

However, after internal osteosynthesis many patients experience complaints and symptoms like pain, discomfort, soft tissue compression, swelling and stifness of the previously fractured limb. Whether these problems are really due to the implant or exist anyway because of the injury, subsequent surgery and the healed fracture with resulting scar tissue is often unclear. Also the reason '*the implant doesn't belong in my body'* and *'I simply want to get it out'* can be a relative indication for removal. Possible future problems like metal implants behaving as a stress riser resulting in peri-implant fractures or the future need for a joint replacement because of osteoartrosis can be a 'relative' indication for implant removal after fracture healing. No literature exists that supports these potential indications.

Four 'large' surveys on current practices and different aspects of implant removal have been published so far. In 2008 a survey on implant removal was performed by Jamil *et al* in the United Kingdom [6]. Goal of this survey was to determine the current practice of orthopaedic surgeons regarding implant removal after healed

limb fractures. Routine removal in patients under the age of 16 years was advocated by 60%, in the age of 16-35 years by 12% and in patients older than 35 years by only 3% of the surgeons. Indications for implant removal in symptomatic patients were pain, implant loosening, infection, broken implants, skin irritation, peri-prosthetic fractures and functional limitation. Only 7% of the respondents had some kind of guideline on implant removal available in their hospital. Hanson *et al* published a survey under 730 participants of the 2007 AO courses on operative fracture treatment in Davos [1]. It contained questions about general beliefs and reasons for implant removal. With a response rate of almost 90%, 58% of the participants did not advocate routine removal and 48% believed that in general it is more risky to take the implant out than leaving it in. In symptomatic patients implant removal was rated more effective, though orthopaedic surgeons were less enthusiastic than trauma surgeons in doing so. Loder and Feinberg presented the opinion of 273 pediatric and 99 non-pediatric orthopaedic surgeons in the United States about routine removal of orthopaedic implants in children [3]. Forty-one percent of the surgeons were in favour of implant removal in general even if the child had no related complaints, 36% removed “sometimes” and 22% (almost) never removed implants in children. The more experienced and elderly surgeons, regardless of their background, were in favour of routine implant removal in children in general because of their experience with potential future problems.

Though implant removal is not routinely performed in the Netherlands, in our own survey under 250 Dutch surgeons, 89% agreed that implant removal is a good option in case of pain or functional deficits. Also infection of the implant or bone was one of the main reasons for removal (> 90%). In younger patients (< 40 years of age) only 34% of the surgeons agreed that metal implants should always be removed [39].

What are the specific indications for implant removal from the upper extremity?

Complaints of the patient (e.g. pain, prominent material, cosmetically disturbing material, functional impairment) are the main reasons for implant removal from the upper extremity, but evidence based literature about the expected improvement of these complaints hardly exists. Ten studies about implant removal from the upper extremity could be found. All were retrospective, didn't deal specifically about the indications and - except for two studies - were mostly published 20-30 years ago (Table 2). These older studies mainly focussed on complications like refractures after removal of ulna and radius plates. Complication rates between 19 and 26% were described. Protective splints and prevention of torsional stress and/or contact sports up to one year after the removal were advised [40, 41]. In studies published in the nineties 4-6% refractures were reported [42, 43]. All studies have contributed to the recommendation that due to the high numbers of complications forearm plates should be left *in situ* in asymptomatic patients [44, 45]. Moreover it was advised that only experienced surgeons should perform implant removal surgery [46].

In other areas of the arm, literature is scarce. Very recently Gyuricza *et al* described the effects of removal of locked volar plates in a retrospective series of 28 patients after a distal radius fracture [47]. Reasons for removal included tenosynovitis, tendon rupture, prominent or intra-articular material and pain. Apart from two implant related complications all plates were succesfully removed and preoperative complaints improved. Lovald published the results of a nationwide study about hardware removal after internal fixation of humeral fractures [48]. Hardware removal is not part of standard care in the United States and implant removal from the humerus only was performed in case of complications like nonunion, mechanical problems and infection (10%). Older patients were more likely to undergo the procedure than younger ones, whereas self-pay patients were less likely to have their humerus implant removed.

What are the specific indications for implant removal from the lower extremity?

A limited number of publications (*n*=13) on removal of intramedullary femur and tibia nails exist, all adressing different issues (Table 3a&b). Retrospective studies analysing patients who had their femur nail removed, describe indications as soft tissue irritation, patient's request, pain in hip and knee region, infection or no specific indication. No differences between titanium and stainless steel nails could be found with regard to complications of removal. Though pain seemed to decrease in all symptomatic patients, the advise was only to remove femur nails in symptomatic patients [49-53]. Gösling *et al* showed, in a retrospective study analysing the removal of 164 femoral nails after fracture healing, that 78% of the patients with existing local complaints improved postoperatively [54]. However, 10 out of 51 patients who were asymptomatic preoperatively reported long-term complaints after removal. Therefore they advised to remove femur nails only in symptomatic patients. Apart from these clinical complaints and symptoms it has been described that femoral nails are more often removed in patients with litigations [55].

Indications for removal of various proximal femur implants (e.g. sliding hip screw and cephalocondylic intramedullary nail systems) have been described by Kukla *et al* [56]. Absolute indications for removal were considered avascular necrosis of the femur head, deep infection, a fracture just below the implant and a cephalic cut out of the implant. Removal of cephalocondylic nails in patients younger than 60 years, was also seen as a more or less absolute indication, because of the risk for ipsilateral shaft fractures distal to the implant. But in all other cases they advised to inform the patient about the disbalance between potential advantages and complications prior to removal. Krettek and Mommsen described a similar advise in their review [57].

Out of these 13 articles six articles analysed the effect of removal of tibia nails. Anterior knee pain is among the most frequent complaints after tibia nailing and a main indication for removal. Keating *et al*, Karladani *et al* and Boerger *et al* found

that approximately half of the patients with anterior knee pain benefit from nail removal (22/49, 40/75 and 9/16 respectively) [49, 58, 59]. However, in the latter study 4/16 asymptomatic patients developed anterior knee pain after nail removal. Recent studies suggest that anterior knee pain might result from other causes, such as iatrogenic infrapatellar nerve injury and this problem will not be solved by extraction of the nail, but can even induce such complaints [60]. Improvement of other symptoms was described in 72% of the patients, but up to 17% of the preoperatively asymptomatic patients reported (new) long-term complaints at follow up [61, 62]. Complications during tibia nail removal merely exist from failures to extract the implant and iatrogenic fractures [63, 64]. All authors stated that routine removal is not indicated and should be appraised critically in asymptomatic patients.

Publications on the outcome of removal of proximal, midshaft or distal femur or tibia plates hardly exist. A retrospective study, published in 2001, evaluated pain improvement in the distal tibia and fibula area after implant removal of unstable ankle fractures. Although in the group of 29 patients pain in general decreased, nearly half of them persisted having pain and functional outcome scores (Short Form-36 Health Survey and Short Form Musculoskeletal Functional Assessment) seemed to be independent of implant removal [65]. Benefits of implant removal from the foot and ankle were described in a prospective study of 69 patients who underwent elective removal of symptomatic implants. Pain relief and a high rate of patient satisfaction 91% were described [66].

Discussion

Indications for implant removal after fracture healing are diverse and hardly supported by literature since most publications are retrospective studies, case reports and expert opinion (evidence level III, IV or V). It remains clear that there is no worldwide consensus. Opinions and habits not only vary between surgeon related factors (e.g. differences between countries), but also patient related factors (e.g. differences between children and adults, anatomical locations) and implant related factors (e.g. stainless steel versus titanium alloys). Even the ability of the patient to pay for implant removal surgery or accident related litigations seem to be of influence in the decision making.

Each operation has its costs, implies a recovery period and temporary unability to work with possible social consequences. In Scandinavia implant removal accounts for 15% of all operations in the orthopaedic and trauma unit, in comparison to less than 5% in the United States. Two Scandinavian studies investigating the workload related to implant removal, concluded that without a strict removal policy a considerable portion of the resources allocated for elective orthopaedic operations was spent on routine and possibly unnecessary implant removal. Therefore more evidence based research will be necessary to support the indications for implant removal.

Currently most indications for removal are ‘relative’ meaning they are not really necessary and often are driven by patients complaints and symptoms. Pain, functional impairment, prominent material, possible future problems and the patients’ request are the main examples of ‘relative’ indications for removal. ‘Absolute’ indications for removal are avascular necrosis of the femur head, deep infection and the cut out of an implant. Corrosion and the possible role of metal implants in the genesis of cancer are no longer accepted reasons for removal. Surgeons and patients are more aware of the appropriate indications for and expectations of the risks and benefits of implant removal. Improvement of complaints after removal is debatable and disadvantages, like surgery related complications or even worsening of the complaints can appear and are important reasons for the antagonists of removal to leave the implant in [27, 28, 30, 67]. In

general the complication rate differs significantly between studies and estimated risks for adverse events vary from 0 to 1% for postoperative hematoma, up to 14% for wound infection, 1 to 29% for nerve injury, 1 to 30% for a refracture and up to 9% for obtaining a cosmetically disturbing scar [27, 28, 40-42, 44-46, 68]. However, in symptomatic patients the disadvantages are accepted to give these patients the benefit of the doubt, as one of the potential advantages of implant removal might be improvement of complaints. On the other hand in asymptomatic patients it is accepted to leave the implant in.

Operative fracture treatment and subsequent implant removal from the upper extremity differs from the lower extremity because bones are smaller and do not bear body weight, more plates than nails are used, the risk of disabilitating nerve injury is higher (e.g. radial nerve at humerus shaft) and scars are more exposed. Instead most of the indications for removal (e.g. pain, functional impairment) are not very different between extremities. The fear for refractures after implant removal used to play an important role in the upper extremity, since refractures after proper healing are hardly seen in the lower extremity. But along with the shift from routine removal to removal in symptomatic patients only, the number of refractures seems to have decreased during the past years.

Though a removal procedure can be very challenging and make surgeons humble, symptomatic patients do seem to benefit. Since some authors described significant complaints at long-term follow up due to removal in previously asymptomatic patients, the general advise nowadays is to remove implants after fracture healing only in symptomatic patients after a proper informed consent.

Conclusion

The overall magnitude of the problem of the indications for implant removal after fracture healing is illustrated by the great variety of reported view points with large differences in opinions and practices between surgeons, countries, patients, extremities and implants. Robust evidence hardly exists in the literature and only a few clear guidelines are formulated so far. With the increasing popularity of operative fracture treatment using metal implants, initially routine implant removal was advised because of the supposed implant related risk of corrosion and carcinogenesis. However, it became clear that these risks were minimal or even nonexistent. Since the introduction of titanium alloys the potential disadvantages of removal plays an important role in the decision making. Currently, indications for removal are mainly ‘relative’ and patient driven, like in case of complaints of the patient (e.g. pain, prominent material). Although some studies support implant removal in symptomatic patients, well designed prospective studies are urgently needed to make proper guidelines.

Conflict of interest

The authors declare that they have no conflict of interest

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Table 1 Arguments in favour and against Implant Removal

In favour of removal	Against removal
Perforating material (absolute indication)	
Risk for corrosion, allergic reactions, bone atrophy, cancer (hardly a reason anymore)	
Growing skeleton, children (debatable)	
	New operation
Surgeon derived arguments: -broken material -infection -avasculair necrosis -cut out of material -intra-articular material -tenosynovitis -tendon rupture	Surgeon derived arguments (depending on location, type and material of the implant): -implant is difficult to remove -implant is difficult to find -bone overgrowth -removal failures -stripping of screw head -implant breakage -minimal invasive in, maximal invasive out -implant removal is very frustrating -obtaining a cosmetically disturbing scar
	Postoperative complications: -bleeding -refracture -nerve injury -wound infection -other comorbidities
	Social and economical consequences: -costs -new recovery period -inability to work
Patients' request: -it doesn't belong in my body -litigations -possible future problems -advice from any doctor -advice from family or relatives	
Patients' complaints: -pain -functional impairment -prominent material -swelling -paresthesia -problems in daily living -cosmetically disturbing	Symptoms and complaints: -don't improve -worsen -new complaints appear

Table 2 Literature on implant removal from the upper extremity

Author & Journal	Study type	Number of patients & plates	Location implant	Indication for removal	Time of implant removal	Complications	Advice
Hidaka J Bone Joint Surg Am 1984	Retrospective	23 patients 32 plates	Ulna & radius	Routinely or complaints	8-62 months	Refracture 26%	Splint or brace for few weeks after removal No athletics/ torsional stress 1 year
Deluca J Bone Joint Surg Am 1988	Retrospective	37 patients 62 plates	Ulna & radius	Not described	Not described	Refracture 19% Nerve injury 8%	Radiographic check for consolidation Watch out in multi trauma patients and a failure to achieve initial good compression
Rumball J Orthop Trauma 1990	Retrospective	63 patients 88 plates	Ulna & radius	Routinely	Average 15 months	Refracture 6% Neurovasculair 6%	Removal planned after 15 months Use 3.5 small dynamic compression plate and thoughtful planning
Labosky J Hand Surg 1990	Retrospective	51 patients 80 plates	Ulna & radius	Routinely or complaints	4-36 months	Refracture 4%	Removal should be done because of risk of metal corrosion and refracture due to plates. No specific cast post-operatively Experienced surgeon
Langkamer J Bone Joint Surg Br 1990	Retrospective	55 patients 81 plates	Ulna & radius	Routinely or complaints	5-84 months	Overall 40% Wound sepsis 7% Poor scar 9% Nerve injury 29% Refracture 4%	Removal of forearm plates only in significant symptomatic patients and not by a junior surgeon
Rosson J Bone Joint Surg Br 1991	Retrospective	80 patients 115 plates	Ulna & radius	No strict protocol	3-39 months	Refracture 5%	Removal of plates in the forearm only in symptomatic patients and at least after 18 months
Chia Singapore Med J 1996	Retrospective	82 patients 128 plates	Ulna & radius	On indication, symptoms and complaints	5-84 months	Overall 27% Wound sepsis 5% Poor scar 6% Nerve injury 7% Refracture 3%	Plates should be left in situ and not removed before 18 months Removal by experienced surgeon After removal restricted physical activity for 3 months, especially after open fractures
Gyuricza J Hand Surg Am 2011	Retrospective	28 patients	Distal radius	Tenosynovitis, tendon rupture, pain, prominent material	1-52 months	Stripping screw head 7%	The overall result of removal is successful in symptomatic patients
Lovald J Trauma 2011	Retrospective	751 patients	Humerus	Nonunion, mechanical complications, infection	Not mentioned	Failure removal 10%	Older people are more likely to undergo implant removal, self-pay patients are less likely to have implant removal

Table 3a Literature on implant removal from the lower extremity (femur)

Author & Journal	Study type	Number of patients	Location & type of implant	Indication for removal	Time of implant removal	Complications	Outcome	Advice
Brumback J Bone Joint Surg 1992	Retrospective	103	Femur nail SS*	Soft tissue irritation, patient's request	14 months (10-31)	1 refracture at the site of original fracture	Improvement of pain in all symptomatic patients	Circumferential healing of the femoral cortex before removing Minimal of 12 months before nail removal
Boerger Injury 1999	Retrospective	50 50	Femur nail Tibia nail	Pain hip region (femur nail), anterior knee pain (tibia nail), infection of the implant, no indication found	29 months	Prolonged operation time (femur 2x, tibia 6x) Wound infection (femur 4x, tibia 1x) Intra-operative complication (tibia 3x)	56% improvement of anterior knee pain 4 asymptomatic patients developed anterior knee pain after tibia nail removal	Crutches for an average of two weeks after removal
Husain J Orthop Trauma 1996	Retrospective	45	Femur nail 23 titanium 22 SS	Persistent pain, discomfort, patients request, immature skeleton	17 months for titanium 36 months for SS	1 suture abscess 1 wound infection	The use of titanium material is not per se a risk for difficulty in late removal of nails	Removal only in symptomatic patients
Dodenhoff J Bone Joint Surg 1997	Retrospective	27	Femur nail	Pain, heterotopic ossification	18 months	Not described	35% no pain relief after removal	Implant removal does not always cures pain in case of heterotopic bone formation
Kukla Acta Chir Austriaca 2000	Retrospective	81	DHS** or gamma nail	Patients request, deep infection, avasculair necrosis, pain, ipsilateral shaft fracture	13 months	Not described	Not described	Removal of DHS or gamma nail in patients < 60 years to avoid associated complications like shaft fracture distal to the implant
Toms Injury 2002	Retrospective	34	Femur nail	Persistent pain, Prominent material, prior to hip replacement, No specific reason	Not described	Not described	Improvement of physical and mental components	Nail removal in symptomatic patients
Gösling Clin Orthop 2004	Retrospective	164	Femur nail	Routine removal, advice surgeon, patient request, pain, restriction of motion	27 months (8-82)	Breakage of the nail or screws, post-operative hematoma, seroma,	78% improvement in symptomatic patients, 16 % no change, 20% of the previously asymptomatic patients became symptomatic, 46% no benefit	Only nail removal in symptomatic patients Inform patients about soft tissue problems, prolonged hospitalization, reoperation or worsening of symptoms
Hui Can J Surg 2007	Retrospective	15	Femur nail	Pain or irritation	Not described	Not described	Litigants more often require removal	Routine removal in asymptomatic patients is not recommended

Table 3b Literature on implant removal from the lower extremity (tibia)

Author & Journal	Study type	Number of patients	Location & type of implant	Indication for removal	Time of implant removal	Complications	Outcome	Advice
Sidky Can J Surg 2008	Retrospective	29	Tibia nail	Pain, prominent material	25 months (5-77)	Not described	72% improvement	Gender and litigation status influence the rate of nail removal
Gösling Chirurg 2005	Retrospective	69	Tibia nail	Pain & symptoms 59%, Asymptomatic 41%	21 months (13-43)	7% knee punction because of fluid 1% left screw in ankle joint	73% improvement 8% aggravation of complaints in the symptomatic group, 17% long term complaints in the asymptomatic group	Routine removal of tibial nails should be discussed critically in asymptomatic patients
Keating J Orthop Trauma 1997	Retrospective	49	Tibia nail	Knee pain	Not described	Not described	44% complete pain relief	Nail removal for patients with a painful knee
Karladani Acta Orthop 2007	Retrospective	71	Tibia nail	Anterior knee pain, pain elsewhere, infection, prominent material, patient request	17 months (4-50)	Not described	55% reduced pain, 20% unaltered pain, 25% elevated pain	The outcome after tibia nail removal to alleviate pain is generally poor
Im Int Orthop 2003	Retrospective	35	Tibia nail	Expected difficulties in treating possible new fractures < 50 years	26 months (13-61)	3 iatrogenic fracture because of considerable force needed to remove the nail 2 removal failures	Not described	Anticipate on the type of nail when removal is being considered

*SS = stainless steel, **DHS = dynamic hip screw