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ORIGINAL ARTICLE

Technical complications during removal of locking screws from locking compression plates: a prospective multicenter study

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Abstract
Purpose To assess the risk for technical complications in patients undergoing removal of locking compression plates (LCP) with head locking screws.
Methods A total of 205 patients who were scheduled for implant removal surgery after a healed fracture of the femur, tibia, humerus, distal radius, or clavicle in nine Austrian clinics were prospectively included in the study, all of whom had previously undergone fracture fixation by plates, with titanium implants used in 98 % of the patients. Intraoperative technical complications and the methods used to solve them were documented by the surgeon.
Results During the course of this study, a total of 1,462 locking screws were removed from 204 LCPs. While 95 % of these screws could be removed without difficulties, technical complications were reported for 41 patients with 78 screws which could not be removed with standard screwdrivers and required the use of additional instruments. The estimated risk for the occurrence of at least one technical complication during implant removal surgery was 20.1 %. The most frequently observed complications were screws that could not be loosened because they were jammed in the LCP, screws with a damaged recess in which the screwdriver turned freely, as well as a combination of both events. The majority of these screws could be removed with the use of a conical extraction screw or by drilling off the screw head. In one patient, an intraoperative refracture of the humerus occurred during plate removal. Even though there is a rate of 20 % for technical complications when removing the implants, only a few patients experience a clinical impact.
Conclusions Titanium LCPs are prone to technical complications during implant removal, but the majority of the issues can be solved using special techniques.

Keywords Implant removal · Locking compression plate · Locking screw · Complications

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Introduction

Implant removal surgeries account for a relatively large number of elective orthopedic procedures in industrial countries [1, 2]. Nevertheless, the indications for the operation itself as well as its correct timing are cause for controversy [2, 3]. Retaining an implant may compromise the mechanical strength of the bone by stress shielding, or may cause fractures due to stress peaks at the end of a plate [4, 5]. Retained implants may cause pain, soft tissue irritations, or allergic reactions [4, 6]. Implant removal surgery, on the other hand, bears the costs and risks of an additional surgical intervention and may be followed by

complications such as neurovascular injury or refracture [7].

During the past decade, the materials and technologies used for osteosynthesis have evolved; titanium is increasingly chosen over stainless steel and locking compression plates (LCPs) have mostly outdated conventional plating systems. Titanium supports direct osseointegration and locked plating is thought to promote fracture healing under callus formation [4, 5]. Both factors may lead to bone overgrowth of the plate and screws, which raises concerns about implant removal [8]. The working mechanism of locking screws within the plates may also complicate the removal process. With the use of these new devices, implant removal has become a challenging procedure.

While there are many reports on the advantages of LCPs for fracture fixation, only a few studies have focused on the problems of implant removal. The aim of this study was, therefore, to systematically collect data on implant removal surgery in patients who had undergone fracture fixation with LCPs, with the focus on evaluating the occurrence of intraoperative technical complications and the techniques associated with resolving these events.

Methods

A prospective, multicenter case series was conducted in adult patients scheduled for implant removal surgery after a healed fracture of the femur, tibia, humerus, distal radius, or clavicle previously treated with internal fracture fixation using an LCP and locking screws. Patients who required implant removal due to acute infection and those having implants removed from more than one location were excluded.

A total of 205 patients scheduled for implant removal surgery in nine Austrian clinics were included between September 2009 and November 2010. The study protocol was approved by the local Ethics Committee of each site and all patients signed a written informed consent before participation.

Implant removal surgery was performed in 204 of the 205 patients and all surgeries were performed according to routine care at the individual clinics. In one patient who suffered from ischemia during anesthesia, the surgery had to be stopped prior to the removal of any hardware. Therefore, this patient was excluded from the analysis of technical complications.

Patient characteristics

The mean age of the study population was 46 years [standard deviation (SD): 15 years), with 55 % ($n = 113$) of the patients being female. Fifty-seven percent of the patients ($n = 116$) had healed fractures on the left body side and the most common fracture location was the distal radius (50 %), followed by the tibia/malleoli (23.4 %), the clavicle (11.2 %), the humerus (10.2 %), and the femur (4.9 %). On average, implants were removed 14.7 months after fracture fixation surgery (range 2.6–89.9 months) and the main medical indications for implant removal were skin and soft tissue irritations, pain, and feelings of discomfort (Fig. 1). Ninety-eight percent of the removed implants were made of titanium, and only 2 % were steel implants.

Outcomes

The primary outcome of this study assessed the risk of a technical complication during implant removal surgery. A technical complication was defined as any difficulty experienced by the surgeon while removing the locking screws from the plate. The type of complication and the actions taken to resolve it were documented by the operating surgeon for each screw separately.

Additional factors such as surgical time, fracture location, implant time in situ, and bone overgrowth of the implant were documented to analyze possible associations with the occurrence of technical complications.

Statistical analysis

Statistical analyses were performed using Intercooled Stata Version 11 (StataCorp LP, College Station, TX, USA). All baseline and follow-up parameters were described with the use of standard descriptive statistics.

The risk (incidence proportion) for a technical complication was estimated by the number of patients having experienced a complication during implant removal surgery divided by the total number of patients with a complete implant removal surgery ($N = 204$). The calculated risks were reported with their binomial exact 95 % confidence intervals (CIs).

Further influencing factors such as fracture location, implant time in situ, and status of bone overgrowth on the estimated complication risk were analyzed with use of the Fisher's exact test, logistic regression, and Chi-square test, respectively. p-values ≤ 0.05 were considered to be significant.

Results

Technical complications

During the course of this study, a total of 1,462 locking screws were removed from 204 LCPs (average: 7 screws

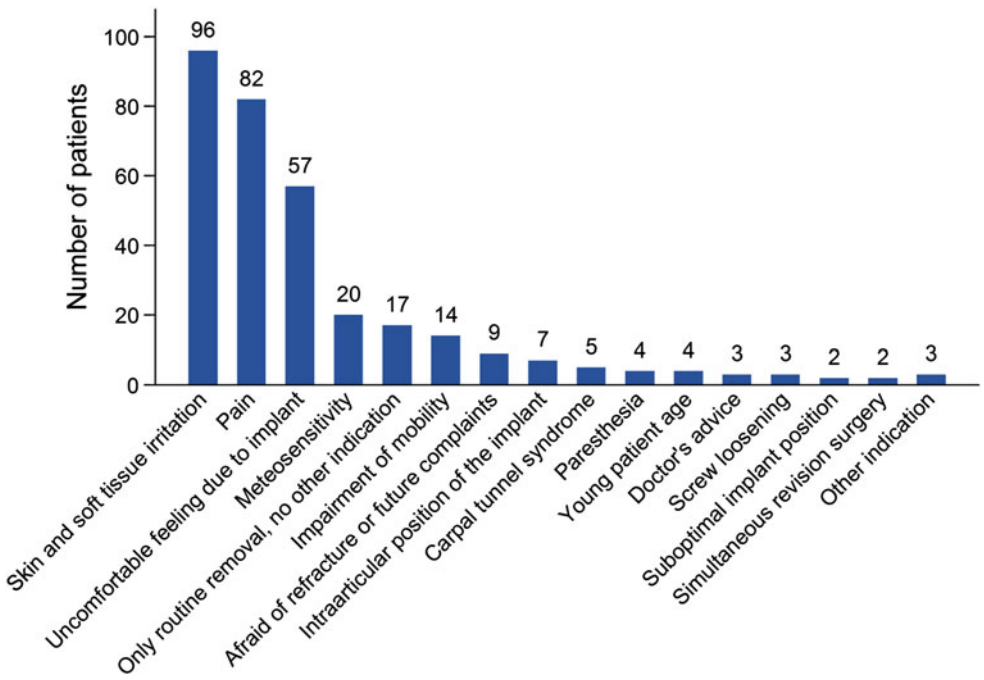

Fig. 1 Medical indication for implant removal ($N = 205$)

per plate; range 1–16). While the majority of these screws (1,384 [95 %]) could be removed without difficulties, technical complications were reported for 41 patients with 78 screws which could not be removed with standard screwdrivers and required the use of additional instruments. The estimated risk for the occurrence of at least one technical complication during implant removal surgery was 20.1 % (95 % CI 14.8–26.3) (Table 1). The most frequently observed complications were screws that could not be loosened because they were jammed in the LCP, screws with a damaged recess in which the screwdriver turned freely, as well as a combination of both events. Other than that, a few cases of damaged screw threads and broken screw heads or screw shafts were reported.

Table 1 Risk of intraoperative technical complications

Complication type	*n*	Risk (%)	(95 % CI)
Any intraoperative technical complication ($N = 204$)	41	20.1	(14.8–26.3)
Type of intraoperative technical complication ($N = 204$)			
Damaged screw recess	24	11.8	(7.7–17.0)
Jammed locking screws	24	11.8	(7.7–17.0)
Screw head breakage during implant removal	3	1.5	(0.3–4.2)
Screw shaft breakage during implant removal	1	0.5	(0.0–2.7)
Damaged screw thread	3	1.5	(0.3–4.2)

N number of patients that were available for intraoperative evaluation; *n* number of patients with at least one of the listed complications; *95 % CI*, 95 % binomial exact confidence interval

The two most commonly applied methods for screws that could not be removed from the LCP with a standard screwdriver were the use of an extraction screw or drilling off the screw head (Table 2).

The extraction screw has a conical tip with a left-handed thread which is pressed into the recess of the locking screw. A T-handle is attached to the extraction screw and the locking screw can be loosened from the LCP by turning the handle in a counterclockwise direction. The extraction screw was successfully used for the removal of 34 screws that were jammed in the LCP and/or had a damaged screw recess. Pre-drilling of the locking screw recess was required in some cases in order to attach the extraction screw.

Drilling off the screw head disconnects the LCP from the screw by separating the screw head from the shaft. As soon as the head is drilled off, the plate can be removed while the screw shaft remains inside the bone. This technique was applied to 29 screws that were jammed and/or had a damaged recess and to three screws with a damaged thread. In order to remove the remaining screw shafts, additional techniques, such as drilling of the screw shaft, the use of a gouge, the use of forceps, or the use of a hollow reamer, were applied.

Some complications could be resolved by simply exchanging the standard worn out screwdriver or by applying an additional lever arm to the standard screwdriver. In one case where the locking screw could not be removed, the plate was cut from the side to access the screw hole. In another patient, the screw was pulled out by bending the plate; however, this caused an iatrogenic

Table 2 Actions taken to resolve the reported technical complications

Type of action	Number of screws[a,b]	Number of patients[a]
Conical extraction screw	27	13
Conical extraction screw with pre-drilling of the screw recess	7	5
Drilling off screw head	32	18
Drilling of screw shaft	3	2
Hollow reamer	4	4
Gouge to expose the screw shaft	3	3
Forceps to remove screw shaft	1	1
Exchange of worn out screwdriver	3	3
Application of additional lever arm	1	1
Cutting the plate	1	1
Bending the plate	1	1

[a] The number for which an action was taken to resolve the associated technical complication

[b] More than one action could be taken to resolve the technical complication for each individual screw

fracture to the bone which required internal fixation with a new plate.

Altogether, 204 LCPs were removed completely, whereas 21 screw shafts had to be partially left in the patient.

Other complications

Apart from the technical complications described above, nine non-technical complications occurred in eight patients during or after implant removal surgery. In one patient, the implant removal surgery had to be interrupted for signs of cardiac ischemia and another patient experienced an iatrogenic fracture of the humerus during implant removal. Moreover, there were two wound infections and one postoperative hemorrhage. One patient experienced compartment syndrome with paresis of the peroneal nerve, requiring fasciotomy. One patient had persistent paresthesia in the upper extremity and two patients had pain in the forearm which was not present before surgery and which did not recover within the 3-month observation period.

Only one of these complications, the iatrogenic fracture, was directly associated with a technical complication. None of the study patients experienced a refracture within the 3-month follow-up period after removal of the LCP.

Association between technical complications and other factors

The occurrence of a technical complication was associated with an average prolongation of the surgical time of 40 min compared to the surgical time for patients without a technical complication (75 vs. 35 min; $p < 0.001$).

The risk for a technical complication varied with different fracture locations ($p < 0.001$). Patients with implant removal from the distal radius had the lowest risk for a technical complication (5.9 %), followed by those with an implant removed from the tibia/malleoli (27.1 %), the clavicle (30.4 %), the humerus (47.6 %), and the femur (50 %) (Table 3).

A longer time in situ (time elapsed between fracture fixation and implant removal surgery) was associated with a higher risk for a technical complication during implant removal (Table 4).

In 51 patients, the plate and/or the screws were overgrown by bone before the implant removal surgery. These patients were 2.6 times (95 % CI 1.5–4.4) more prone to technical complications than those without bone overgrowth (37 vs. 14 %; $p < 0.001$).

Discussion

The present study assessed the risk for technical complications in patients undergoing removal surgery of mostly titanium LCPs with locking screws. Soft tissue irritation, pain, or general discomfort were the most frequent indications for surgery. One technical complication occurred in every fifth surgery, with the most commonly observed complications being jammed locking screws and screws with a damaged recess. The majority of these complications could be resolved with the use of a conical extraction screw or by drilling off the screw head. Longer surgery times were associated with the occurrence of a technical complication, and the risk for a technical complication specifically increased with longer implant in situ time, bone overgrowth, and humerus and femur fractures.

Our study showed a remarkable difference in complication rates among the different fracture locations, with the lowest observed for the distal radius (5.9 %) and much higher rates reported for the clavicle (30.4 %), tibia (27.1 %), humerus (47.6 %), and femur (50 %). No other study has directly compared complication rates for the various fracture sites, except for two retrospective studies which focused on one or two specific fracture locations and found similar complication rates to the present study. A retrospective case series including 28 distal radius fracture patients who underwent LCP removal reported a low complication rate of 7.1 % [9]. The second retrospective study assessed the technical complications associated with implant removal from the tibia and femur and showed a much higher complication rate (38.9 %), which corresponds to our findings [10].

Table 3 Relationship between implant location and the risk of technical complications associated with implant removal

Implant location ($n = 204$)	n	Risk for a technical complication (%)	(95 % CI)
Humerus ($n = 21$)	10	47.6	(25.7–70.2)
Clavicle ($n = 23$)	7	30.4	(13.2–52.9)
Distal radius ($n = 102$)	6	5.9	(2.2–12.4)
Femur ($n = 10$)	5	50	(18.7–81.3)
Tibia/malleoli ($n = 48$)	13	27.1	(15.3–41.8)

n number of patients reported with any technical complication according to the defined implant locations, where the total number of patients reported with any technical complication is 41

Table 4 Relationship between implant time in situ and the risk of technical complications associated with implant removal

Time in situ	Risk (%)	Odds ratio	(95 % CI)	p-Value[a]
≤9 months	5.7	–	–	
>9–15 months	16.5	3.28	(0.89–12.14)	0.075
>15 months	34.7	9.06	(2.56–32.02)	0.001

[a] Wald test

Bae et al. [11] assessed the occurrence of technical complications in a prospective study including 58 patients undergoing LCP removal from various fracture locations. While the removal of all 159 large (5.0-mm) locking screws was unproblematic, 8.6 % (24/279) of the smaller screws (3.5-mm) had a damaged recess and required the use of additional techniques, such as cutting the plate or bending and rotating the plate around the screw. Screw diameters were not specifically assessed in our study, but our data revealed less frequent problems with smaller screws, such as those associated with distal radius plates, in comparison with the larger screws used in the fixation of the humerus or femur. We believe that this outcome is mainly the result of the fracture location and associated implant time in situ, and less likely due to the general screw size. While distal radius implants were removed, on average, 11 months after surgery, the time interval between fracture fixation and implant removal ranged from 16 to 31 months for other fracture locations. A longer time in situ allows for better bony integration of the implant, which, in turn, causes more difficulties during removal. There might also be a correlation between the length of a screw and removal difficulties, especially with thin long screws, but this aspect has not been evaluated by our study. Overall, the proportion of screws (5.3 %) affected by a technical complication in the present study is within the range observed by Bae et al. [11].

In our study, almost half of the screws with a technical complication were successfully removed with a conical extraction screw, whereas other authors have reported more difficulties with this technique. Bae et al. [11] applied the conical extraction screw to 24 screws but could only successfully remove six; the reasons for the difficulties experienced were not clearly outlined. In our study, the conical extraction screw was used without difficulties at all study sites, and we recommend using this instrument. Nevertheless, the extraction of a jammed screw with a conical screw is a delicate technique requiring adequate training in order to be successfully applied; a lack of skill may be a reason for failure.

Other methods used in our study to explant jammed screws and plates such as drilling off the screw head, cutting the plate around the screw, bending the plate, and applying a leverage force to remove the plate with the screws attached have also been reported in a number of case reports and technical notes [8–10, 12–14]. Although described in the literature [10], removing the plate with screws still in place and applying a leverage force was only used for one of our study patients; this patient experienced an iatrogenic fracture. We have also observed further similar complications outside of this reported study group; therefore, we cannot recommend this technique. A jammed screw must be removed from the plate by drilling off the screw head or by cutting the plate before any attempts at separating the plate from the bone can be initiated.

Although the type of removal technique used was left to the discretion of all surgeons who participated, the techniques among the nine study sites were quite similar and there was an overall agreement on the use of the conical extraction screw and drilling off the screw head.

Inappropriate insertion of locking screws has been mentioned as a possible cause for technical complications at implant removal [15]. Application of too much torque (i.e., using a screwdriver without torque limiting capacity) and cross-threading of the screw may damage the screw recesses and jam the screws within the plate, respectively [15]. For all participating clinics, LCPs and locking screws have been routinely used for the last decade and the correct implantation technique is widely instilled. We, therefore, believe that the issue of an inadequate implantation technique is a negligible factor associated with the technical difficulties in screw removal observed in our study.

Our study has shown that the removal of LCPs is still a relatively difficult surgical procedure that can be complicated by a longer implant time in situ. With the combination of titanium and locking plate technology, these factors seem to be the main contributors that cause difficulties associated with implant removal by favoring implant ingrowth. Changing the implant material or altering the

metal surface may help to reduce these problems [16, 17]. In cases where routine implant removal is planned to occur after the primary surgery, we recommend using stainless steel rather than titanium implants.

In conjunction with the technical complications, patients undergoing implant removal surgery are at a risk of experiencing other complications, such as wound healing complications or neurological problems. The risks and benefits of removal surgery should certainly be carefully considered. Clear guidelines on the indications and correct timing of implant removal should be evaluated and include references to different age groups, implant locations, and implant materials.

The main limitations of the present study are the heterogeneity of fracture locations and implants. Future studies should focus on one specific fracture location and limit the number of implants used. Nevertheless, our study is the largest prospective study so far allowing for a good general overview on technical complications during implant removal surgery and the solution to these problems.

In conclusion, technical complications are a major concern for the surgeon during the removal of titanium LCPs, but the majority of the complications can be solved using special techniques. It is obvious that removal problems have become a major issue since the introduction of titanium head locking screws. Therefore, further research must also focus on implant metallurgy.

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Conflict of interest The authors declare that they have no conflict of interest.

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