Difficulty in locking head screw removal

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Title page

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Running title: Difficulty in LHS removal

Kenji Fujita[1, 2]

Hidetoshi Yasutake[1]

Takeshi Horii[1]

Noriyuki Hashimoto[1]

Tamon Kabata[2]

Hiroyuki Tsuchiya[2]

1. Department of Orthopaedic Surgery, Ishikawa Prefectural Central Hospital

2. Department of Orthopaedic Surgery, Graduate School of Medical Science, Kanazawa University

Please address all correspondence to:

Kenji Fujita, MD

Department of Orthopaedic Surgery, Graduate School of Medical Science, Kanazawa University,

13-1 Takaramachi, Kanazawa, Ishikawa, 920-8641, Japan

Phone: +81-76-265-2374

Fax: +81-76-234-4261

E-mail: kkkkkenji76@yahoo.co.jp

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Introduction

Locking plates are an internal fixation material useful in the treatment of bone fractures, which provides effective stabilization between the plate and locking head screws (LHSs) via the locking mechanism. However, difficulty in removing LHSs is relatively common, and such cases can require long surgical procedures or use of special removal equipment. Few studies have reported the causes and risk factors for difficulty in screw removal [1,2]. Therefore, the purpose of this study was to report the incidence and risk factors for difficult removal of LHSs.

Patients and Methods

During the 5-year 6-month period from April 2006 to September 2011, 83 locking plates containing a total of 482 LHSs were removed in 80 patients at our institution. All locking plates and LHSs were made of titanium. In all cases, after we confirmed bony union radiographically and clinically, the locking plates were removed only when patients requested implant removal. However, for the LCP Clavicle Hook Plate (Synthes, Paoli, PA), we recommended removal within 6 months to prevent loss of shoulder motion. Patients who required a second operation within 3 months of the first operation owing to infection, malalignment, nonunion, or another reasons were excluded from this study. “Removal difficulty” was defined as screw removal that was difficult using only a screwdriver, such that additional procedures were required. The following types of plate were removed: 18 clavicular, 2 humeral, 16 ulnar, 24 radial, 1 femoral, 15 tibial, and 7 fibular (Table 1). Plates that had more than 1 LHS with removal difficulty were as

follows: 1 clavicular, 1 humeral, 3 ulnar, 1 radial, 4 tibial, and 1 fibular (Table 2). In the 482 LHSs in 83 locking plates, the incidence of removal difficulty was examined on the basis of screw diameter. In addition, risk factors were assessed in only LHSs with a 3.5-mm diameter. For LHSs with a 3.5-mm diameter, the removed screws were divided into 2 groups: the difficult removal group (D group) and the easy removal group (E group), and the data were examined based on age, sex, time between insertion and removal, and screw position. In addition, the incidence of removal difficulty in 3.5 mm-diameter screws was examined every 6 months between insertion and removal.

Comparisons of age and time from internal fixation to removal were performed using Welch's *t* test. Comparisons of sex and screw location were performed using Fisher's exact test. A *P* value of $< .05$ was considered statistically significant. All patients were informed of the risk of difficult LHS removal, for which they provided written informed consent. This study was approved by the institutional review board.

Results

Difficulty in removal was encountered in none (0%) of 118 LHSs with a 2.4-2.7-mm diameter, 15 (4.9%) of 308 LHSs with a 3.5-mm diameter, and none (0%) of 56 LHSs with a 5.0-mm diameter (Table 3). When only LHSs with 3.5-mm diameters were considered, the mean ages of the patients in the D group and the E group were 32.1 and 45.6 years, respectively. There were 12 LHSs in men and 3 in women in the D group, whereas there were 207 LHSs in men and 86 in women in the E group. The average time between insertion and removal was 529.2 days in the D group and 389.2 days in the E group. In terms of location, 10 LHSs were

diaphyseal and 5 were metaphyseal in the D group, whereas 166 LHSs were diaphyseal and 127 were metaphyseal in the E group (Table 4). These findings indicate that removal difficulty occurred for only LHSs with a 3.5-mm diameter, and tended to occur with longer time from insertion to removal and in younger patients; these findings were statistically significant.

In addition, the incidence of removal difficulty in LHSs with a 3.5-mm diameter was examined every 6 months between insertion and removal. Removal was difficult in 0 of 31 LHSs in <6 months from insertion to removal, 0 of 112 LHSs in 6 months to 1 year, 10 (8.7%) of 115 LHSs in 1 year to 1 year 6 months, 2 (8.3%) of 24 LHSs in 1 year 6 months to 2 years, and 3 (11.5%) of 26 LHSs in >2 years (Table 5). Therefore, removal difficulty occurred in 15 (9.1%) of 165 LHSs in >1 year from insertion to removal. One of the 15 LHSs had been inserted in an inappropriate direction. Of the 15 LHSs, 8 were removed with conical removal screws and 3 were removed by bending the plates and then rotating the screws with the plates. The screw heads of the remaining 4 LHSs were destroyed with a carbide drill, and the screw shafts left in the bone were removed using removal bolts and emergency reamer tubes.

Discussion

LHSs are an internal fixation material used in the treatment of bone fractures. However, cases of screw removal difficulty are occasionally reported. According to the AO Manual of Fracture Management, the following commonly cause difficulty in LHS removal: damaged screw head recess, LHSs that are locked too tightly, jamming the screw head into the plate hole, excessive self-drilling, self-tapping LHSs, and bone growth into the LHS [3]. The use of LHSs has

become widespread over the last 10 years; however, few reports have focused on the difficulties encountered in their removal. A study by Bae et al. showed that of 159 LHSs with a 5.0-mm diameter and 279 LHSs with a 3.5-mm diameter, 24 were difficult to remove, all of which were 3.5-mm–diameter screws [1]. Suzuki et al. reported screw removal difficulty in 37 (10.6%) of 349 LHSs, and investigated the predictors of screw removal difficulty, but found no significant differences among the cases [2].

In this study, the incidence of removal difficulty in 3.5-mm-diameter LHSs with >1 year elapsed between insertion and removal was 9.1%; this rate seems considerably high. Since a locking plate is inserted by multiple LHSs, the possibility of removal difficulty reaches 24.9% in a plate with 3 LHSs, 43.6% with 6 LHSs, and 57.6% with 9 LHSs, theoretically. Actually, our study had 25 locking plates inserted by 3.5-mm–diameter LHSs with >1 year elapsed between insertion and removal. Eleven (44%) of these 25 plates, with a mean number of 6.6 LHSs inserted, had at least 1 LHS removal difficulty. This rate of removal difficulty was much higher than we expected.

When a surgeon plans to remove a locking plate with 3.5-mm–diameter LHSs with >1 year elapsed between insertion and removal, he should explain the high risk of removal difficulty, which reaches approximately 50%, to his patient.

This study suggests that (1) the use of LHSs with a 3.5-mm diameter is necessary condition for difficulty in screw removal, and that (2) longer time from internal fixation to removal, and (3) younger age are risk factors for it. The risk associated with screw diameter appears to be related to the depth of screwdriver insertion into the screw head, bone quality, and length of the screw (Table 5). Typically, 2.3 to 2.7 mm–diameter screws are used in the distal radius, and the

depth of screwdriver insertion into the screw head is shallow. However, removal difficulty is considered unlikely because of poor underlying bone quality due to osteoporosis, and the short screw length. In some locking plates used in the distal radius, LHSs with difficult-to-strip, star-shaped heads were used in this study. However, even with standard hexagonal-head screws, which were used in the majority of cases, there was no occurrence of screw removal difficulty. In contrast, 5.0 mm–diameter screws are long and used in sites with good bone quality, such as the femur and tibia. However, the screw head is unlikely to be stripped because the depth of screwdriver insertion into the screw head is deep. Longer 3.5-mm–diameter screws are used in regions with good bone quality; for example, the diaphyseal screws that are used with the LCP Distal Tibia Plate in younger patients are likely to be stripped and should be removed very carefully. In such regions, star-shaped screw heads, 5.0 mm–diameter screws, or stainless steel screws may be appropriate. The risk associated with longer time between insertion and removal suggests that the biocompatibility of the screws allows them to bind firmly with bone due to the long time period, whereas the risk associated with younger age suggests that high-quality underlying bone leads to screw removal difficulty. In addition, insertion in an inappropriate direction and excessive tightening are factors that contribute to screw removal difficulty, and that care should be taken during the initial surgery.

Considering the risk of removal difficulty, indications for the use of locking plates for fractures should be determined carefully, including whether sufficient stabilization will be achievable with conventional plates, and whether plate removal is possible due to soft tissue irritation or other reasons. As a reference, during the same time period as this survey, at our institution, the incidence of

removal difficulty with conventional screws was found to be only 5 (0.6%) of 890 screws, indicating that conventional screws are much easier to remove than LHSs. Regarding the methods for removal of broken hardware, Hak et al. stated that screw extractors, trephines, and extraction bolts are useful for removing stripped or broken screws, and that carbide drills and high-speed metal cutting tools are necessary to remove cold-welded screws [4]. At our institution, the methods used for dealing with difficult-to-remove screws are as follows (in the order of ease of removing): (1) inserting a foil from a suture into the stripped screw head [5], (2) using a conical removal screw, (3) bending a flexible plate and then rotating the last screw together with the plate, and (4) destroying the screw head with a carbide drill and then removing the plate. In practice, the methods using a foil are difficult for LHSs with a 3.5-mm diameter, but are possible for those with a 5.0-mm diameter. Although there was no case of removal difficulty of LHSs with a 5.0-mm diameter in our study, difficulty in removal may occur rarely [2]. When using a conical removal screw, it is important to use a screwdriver with a thick handle, which allows for the application of sufficient force. However, our experience has shown that this method often fails, and in this case, it is important to avoid trying this again, and an alternative method should be used instead. Bending a plate is feasible only with flexible plates such as the LCP Reconstruction Plate 3.5 (Synthes) or the LCP Metaphyseal Plate 3.5 (Synthes), with only 1 screw remaining. If available, a metal cutting bar or thread wire saw are helpful to cut the plate around the screw head. Destroying the screw head will certainly remove the plate, but after removal of the plate, the screw shafts left in the bone must be removed using removal bolts and emergency reamer tubes. Destroying the screw head also will cause metal powder to scatter over the surrounding tissue; therefore,

it must be covered with a sterile adhesive film.

Conclusions

We investigated cases with difficulty in LHS removal at our institution. This study suggests that (1) the use of LHSs with a 3.5-mm diameter is necessary for difficulty in screw removal, and that (2) longer time from internal fixation to removal and (3) younger age are risk factors for difficulty in removal. When removing LHSs with a 3.5-mm diameter, proper instruments and sufficient training are necessary.

Conflicts of interest

None of the authors of this manuscript received any type of support, benefits or funding from a commercial party related directly or indirectly to the subject of this article.

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Table 1 Characteristics of the plates and locking head screws that were removed in this study

Site	Plate	Screw diameter (mm)	Plate number	Screw number
clavicle	LCP Clavicle Hook Plate[1]	3.5	14	58
	LCP Reconstruction Plate 3.5[1]	3.5	4	19
humerus	PHILOS[1]	3.5	1	11
	LC-LCP 4.5/5.0 narrow[1]	5.0	1	6
ulnar	LCP Olecranon Plate[1]	3.5	7	60
	LC-LCP 3.5[1]	3.5	7	21
	LCP Metaphyseal Plate 3.5[1]	3.5	2	12
radius	VariAx Distal Radius Locking Plate[2]	2.7	7	33
	Acu-Loc Distal Radius Plate[3]	2.3 and 3.5[4]	6	53
	Locking Distal Radius Plate[1]	2.4	4	26
	Matrix SmartLock Plate[2]	2.7	3	21
	LC-LCP 3.5[1]	3.5	4	17
femur	LCP Distal Femur[1]	5.0	1	9
tibia	LCP Distal Tibia Plate[1]	3.5	8	64
	LC-LCP 4.5/5.0 broad[1]	5.0	4	18
	LCP Proximal Lateral Tibia[1]	5.0	1	8
	LCP Proximal Tibia Plate 3.5[1]	3.5	1	9
	LC-LCP 3.5[1]	3.5	1	4
fibula	LCP Metaphyseal Plate 3.5[1]	3.5	7	33

LCP: locking compression plate

LC-LCP: limited contact-LCP

1; (Synthes, Paoli, PA, USA)

2; (Stryker Osteosynthesis, Freiburg, Germany)

3; (Acumed, Hillsboro, OR, USA)

4; The Acu-Loc Distal Radius Plate was inserted using 2.3-mm screws in the metaphysis and 3.5-mm screws in the diaphysis

Table 2 Characteristics of the plates and locking head screws with removal difficulty

Site	Plate	Plate number	Screw number
clavicle	LCP Reconstruction Plate 3.5	1	1
humerus	PHILOS	1	1
ulnar	LCP Metaphyseal Plate 3.5	2	2
	LCP Olecranon Plate	1	1
radius	LC-LCP 3.5	1	4
tibia	LCP Dital Tibia Plate	4	5
fibula	LCP Metaphyseal Plate 3.5	1	1

Table 3 Removal difficulty and screw diameter

Screw diameter (mm)	2.3-2.7	3.5	5.0
Number of screw with removal difficulty / Number of all screws	0/118 (0%)	15/308 (4.9%)	0/56 (0%)

Table 4　Characteristics of the difficult removal group (D group) and the easy removal group (E group) in 3.5mm-diameter locking head screw

		D group	E group	P value
Number of screws		15	293	
Age		32.1±17.2	45.6±17.8	0.010*
Sex (male/female)		12/3	207/86	0.567
Days from insertion to removal		529.2±143.2	389.2±190.5	0.002*
Screw location	diaphysis	10	166	0.595
	metaphysis	5	127	

*P< 0.05

table 5　Remaval difficulty and the time elapsed between insertion and removal in 3.5mm-diameter locking head screw

The time elapsed between insertion and removal (year)	< 0.5	0.5 to 1	1 to 1.5	1.5 to 2.0	> 2
Number of screw with removal difficulty / Number of all screws	0/31 (0%)	0/112 (0%)	10/115 (8.7%)	2/24 (8.3%)	3/26 (11.5%)

Locking head screw の抜去困難例の検討　　要旨　1200 文字

【背景】

ロッキングプレートは、プレートと locking head screw (LHS)のロッキング機構により強固な固定性が得られ、骨折治療に有用な内固定材料である。一方、LHS の抜去困難が生じることは稀ではなく、その場合長時間の手術や特殊な抜去器具が必要とされることがある。本研究の目的は、LHS の抜去困難例の頻度、その危険因子について検討することである。

【対象と方法】

2006 年 4 月～2011 年 9 月の 5 年 6 か月間に、当院でロッキングプレートを抜去した症例は 80 例 83 枚、LHS は 482 本であった。抜去した 482 本の LHS は、2.4～2.7mm 径 118 本、3.5mm 径 308 本、5.0mm 径 56 本であった。抜去困難例の頻度についてスクリュー径ごとに調査した。また、3.5mm 径 LHS に限定し、抜去困難の危険因子の検討を行った。3.5mm 径 LHS を抜去困難群（D 群）と抜去容易群（E 群）にわけ、スクリュー抜去時の年齢、性別、抜去までの期間、スクリュー位置について検討を行った。また、抜去までの期間を半年ごとにわけ、3.5mm 径 LHS の抜去困難の頻度を調査した。

【結果】

抜去した LHS 482 本のうち、抜去困難例は 15 本であった。抜去困難例の頻度は、2.4～2.7mm 径 LHS では 0%（0/118 本）、3.5mm 径 LHS では 4.9%（15/308 本）、5.0mm 径 LHS では 0%（0/56 本）であった。3.5mm 径 LHS を D 群 15 本、E 群 293 本にわけ、2 群間を比較した。スクリュー抜去時の平均年齢は D 群 32.1 歳、E 群 45.6 歳であり、抜去までの平均期間は D 群 529.2 日、E 群 389.2 日であり、2 群間に有意差を認めた。性別、スクリュー位置に関しては、2 群間に有意差を認めなかった。また、3.5mm 径 LHS の抜去困難例の頻度は、抜去までの期間が 1 年未満では 0% (0/143 本) であり、1 年以上では 9.1%（15/165 本）であった。

【結論】

本研究において、 (1) 3.5mm 径 LHS の使用、が抜去困難の必要条件であり、(2) 抜去までの期間が長いこと、(3) 若年者への使用、が抜去困難の危険因子であると考えられた。3.5mm 径 LHS の抜去の際は、抜去用の器械を必ず準備し使用方法を熟知しておく必要がある。