Risk Factors of Refracture and Morbidity During Removal of Titanium Pediatric Proximal Femoral Locking Plates in Children With Cerebral Palsy

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Background: Pediatric proximal femoral locking plates (PFLPs) are widely used when performing proximal femoral osteotomy in children with cerebral palsy (CP). The purpose of this study is to report the difficulties and risk factors of titanium PFLPs removal in CP.

Methods: PFLP removal was performed in 58 hips of 33 patients (17 males, 16 females). The mean age at the time of surgery (plate removal) was 10.9 (range, 5.7 to 19.2) years. The patients were divided into 2 groups as group 1 and 2, if any difficulty was observed during surgery or not.

Results: Difficulty was not detected in 42 (72.4%) hips (group 1). Difficulties were encountered in 16 (27.6%) hips (group 2). A total of 364 screws were used (259 in group 1, 105 in group 2). The mean plate screw density ratios were 0.88 in group 1 and 0.94 in group 2. The difference between group 1 and 2 was statistically significant. The mean duration between the insertion and removal of the PFLP was 14.9 months (11.9 mo in group 1, 22.7 mo in group 2). The difference between group 1 and 2 was statistically significant. The screw heads were cut and the shafts were left in the bone in 4 hips (4 screws); 3 of these 4 screws were calcar screws. Therefore, calcar screw application can be accepted as a handicap for screw removal.

Conclusions: As a conclusion, this study suggested that difficulty in titanium PFLP removal in CP is common and PFLP removal is not a harmless procedure. A longer time from internal fixation to removal, increased plate screw density ratio, and calcar screw application are risk factors for difficulties in titanium PFLP removal in CP.

Level of Evidence: Level III.

Key Words: cerebral palsy, plate removal, complication, risk factors, pediatric hip plate

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Pediatric proximal femoral locking plates (PFLPs) have become popular in recent years and are widely used when performing proximal femoral osteotomy in children with cerebral palsy (CP).[1,2] They provide an advantage of biomechanically higher stability in proximal femur.[3,4] Removal of plate is advised to avoid difficulties during possible further surgeries.[5] Although difficulty in removing titanium locking plates is an uncommon problem, it can cause significant morbidities, such as fracture, retained implant, or prolonged hospitalization time.[6,7] Furthermore, there is a lack of literature describing the detailed causes and risk factors for difficulties in the removal of PFLPs in CP. The purpose of this study is to report the difficulties and risk factors of titanium PFLPs removal in CP.

METHODS

This study included patients who had a diagnosis of CP, underwent proximal femoral osteotomy stabilized by using titanium PFLP (LC Pediatric Hip Plate and screws with a 3.5 mm diameter; TST Tibbi Aletler, Istanbul, Turkey), and then underwent plate removal between 2012 and 2014. The patient records were reviewed retrospectively following institutional review board approval.

PFLP removal was performed in 58 hips of 33 patients (17 males and 16 females). The mean age at the time of surgery was 10.9 ± 2.8 (range, 5.7 to 19.2) years. The reasons for plate removal were implant irritation after bone union (4 hips) and complete bone union (54 hips). Plate removal was performed in 22 patients bilaterally and in 14 patients unilaterally.

The patients were divided into 2 groups according to difficulties encountered. Difficulty was not detected in 42 (72.4%) hips (group 1). Difficulties were encountered in 16 (27.6%) hips (group 2) (group 1 included 26 patients and group 2, 10 patients). In 3 patients, who were operated bilaterally, difficulty was detected in 1 hip. These 3 patients belong to both group 1 and group 2.

Group 2 was divided into 2 subgroups: difficulty is classified as an obstacle (group 2A) or a complication (group 2B). An obstacle is defined as difficulty that arises during plate removal procedure that is completely resolved by the end of the operation. Need for additional instruments, stripping or breakage of a screw driver and/or a screw head, cutting the screw head or plate, and removing the bone were accepted as an obstacle. Complication is defined as intraoperative neurovascular injury, and residual problems that remain at the end of plate removal procedure and need additional treatment procedure (wound infection, femur fracture etc.).

Medical records were reviewed for demographics, the number of screws, position of calcar screws (the screws that were intentionally placed into the femoral neck at the time of plate insertion—bicortical or unicortical), plate screw density ratio as described by Gautier (number of screws/total number of plate holes),[8] union status, hospitalization time, reason for removal, and time between internal fixation and plate removal.

In bilateral cases, if a problem was encountered on 1 side, the patient was included in both group 1 and group 2. The correlations were evaluated statistically using SPSS 15 (SPSS Inc., Chicago, IL). For descriptive statistical analysis and to compare the differences between 2 groups, the χ^2 test and the Fisher exact test were used. The Mann-Whitney *U* test was used to compare the differences between the means of the groups. A *P*-value of <0.05 was accepted as statistically significant.

RESULTS

The mean ages were 10.7 ± 2.8 years in group 1, 11.7 ± 2.6 years in group 2. No statistically significant difference was found between groups 1 and 2 in terms of age ($P = 0.146$).

In group 1, 23 cases were males and 19 females. In group 2, 8 cases were males and 8 females. No statistically significant difference was found between groups 1 and 2 in terms of sex ($P = 0.745$).

The mean hospitalization time was 1.1 days. The hospitalization time was not statistically significant, which was 1.07 days in group 1 and 1.21 days in group 2 ($P = 0.138$).

A total of 364 screws were used (259 in group 1, 105 in group 2). All screws in which we experienced difficulty were locking screws. The plate screw density ratios were 0.88 ± 0.07 in group 1 and 0.94 ± 0.07 in group 2. The difference between group 1 and 2 was statistically significant ($P = 0.004$).

A total of 7 calcar screws were applied and 3 of them were in group 2. The bone was removed and these 3 screw heads were cut with a screw head chisel while screws were stripped intraoperatively. The screw head was cut by placing the screw head chisel underneath the plate perpendicular to the long axis of the screw shaft and parallel to the long axis of the bone. Care was taken not to fracture the bone. After the screw heads were cut, the screw shaft was left in the bone. The difference between group 1 and 2 in terms of calcar screw application was not statistically significant ($P = 0.381$).

The mean duration between the insertion and removal of the PFLP was 14.9 ± 7.3 months (11.9 ± 5.6 mo in group 1, 22.7 ± 5.0 mo in group 2). The difference between group 1 and 2 was statistically significant ($P = 0.0001$). In group 1, there were 20 hips whose duration between the insertion and removal of the PFLPs was shorter than 1 year, and 22 hips whose duration was 1 year or longer. In group 2, all hips had the duration longer than 1 year between plate insertion and removal. The difference between groups 1 and 2 was statistically significant among the patients who had the duration of longer than 1 year ($P = 0.001$).

There were complications in 13 (22.4%) hips (group 2A). In 7 of them, plates could be removed with screws (2 plates were cut with a large bolt cutter: because of excessive bone-plate integration we were not able to reach under the plate to cut the screw head and we had to cut the plate); in 3 cases the screw head was cut and the screw shaft was left in the shaft of the femur after removing the plate (Fig. 1); and 3 cases required removal of bone gently with an osteotome through leverage but some near cortex was removed with this maneuver. The bone was not fractured; only the near cortex was destroyed.

There were 3 (5.1%) femur fractures intraoperatively, which were described as a complication (group 2B). The fatigue fracture occurred during removal of stripped screws. The oblique fracture lines were beyond the undermost head screw and close to the previous osteotomy area in all fractures (Fig. 2). In 3 cases, internal fixation by using another PFLP was performed (Fig. 3). There was no vascular injury, nerve injury, or wound infection.

DISCUSSION

PFLPs are widely used internal fixation implants for the treatment of hip subluxation and dislocation in CP.[1,2,3] Although implant removal may be a challenging procedure and can lead to complications, difficulties in removal of titanium PFLP and screws in CP remain unreported. Moreover, only a few reports have focused on the difficulties encountered in the removal of locking head screws.[7,9,10] A study by Raja et al[11] showed that the removal difficulty rate was 47% for locking plates. Likewise, Sanderson et al[12] reported a 21% complication rate.

Our obstacle and complication rates were 22.4% and 5.1%, respectively. The reasons could be explained as inadequate bone quality and shearing forces during plate or screw removal. Cold welding and overtightening of the screw heads can be predisposing factors for fracture of weak bone when performing PFLP removal. Children with CP have deficient bone growth and consequently an increased propensity for osteoporosis. In our study, we have no data about osteoporosis. However, surgeons should keep in mind that osteoporotic bone and/or cold welding of the screw lead to fracture of bone during plate removal in patients with CP. There is a high risk of fracture in osteoporotic bone (Fig. 4).

Overtightening and cross-threading of the screw heads may cause deformation of the screw heads. Thus, cold welding of the screw head to the plate can occur, and removal of the screw will not be possible.[6,10,13] Titanium provides beneficial mechanical properties similar to that of natural bone and its surface conditions play a critical

FIGURE 1. Postoperative radiograph; 1 screw shaft was left in the right and left femur.

FIGURE 3. Postoperative radiograph after treatment of intraoperative fracture on the left hip.

role in excessive bone formation associated with superior osteoblast adhesion.[14] However, cold welding is a major problem in titanium implants compared with stainless implants and results in the screw head adhering firmly to the plate.[15] We have no data comparing titanium and stainless steel. However, we believe that stainless steel plate has advantage of less stripping. Furthermore, our screws were made of titanium but the screw drivers were made of stainless steel. Because titanium is a more deformable metal than stainless steel, screw head stripping will occur more likely when the extraction torque is high. To prevent this complication, stainless steel implants and external targeting guides, torque-limiting drill attachment, and checking that the insertion handle is tightly locked should be used to ensure the appropriate screw insertion axis.[14] However, we observed that although appropriate screw insertion axis is obtained, deformation of screw head would be detected. An instrument for screw removal should be prepared for possible problem during implant removal. In addition, the screw heads that we used were hexagonal. We have another patient group, whose screw heads were AO octagonal. We also observed that it was easy to remove the screw in which screw heads were octagonal. However, this was only an observation because we do not have any objective data to compare the hexagon and octagon screw heads and prove it.

FIGURE 2. Radiograph of intraoperative femur fracture.

Placement of screw limits micromotions and reduces stress, but every drill hole represents a point of potential fracture. However, leaving screw holes empty can cause plate failure. The stability of a locking plate is related to the length of the plate and the plate screw density.[16] When using longer plates, not all screw holes need to be filled. Plate screw density is the quotient formed by the number of screws inserted and the total number of plate holes.[8] Güven et al[17] reported that high plate screw density increases the stiffness and stability of fracture fixation and therefore reduces the rates of delayed nonunion in simple-type fractures. However, Suzuki et al[6] evaluated the frequency of intraoperative problems and complications involved with Less Invasive Stabilization System plate removal. They found that plate screw density was higher in cases in which difficulty was encountered. In current study, the plate screw density ratios were 0.88 ± 0.07 in group 1 and 0.94 ± 0.07 in group 2. The plate screw density ratio was higher for patients who experienced an obstacle or a complication in the plate removal surgery. We also believe that, the plate screw density should be higher at the metaphyseal and epiphyseal areas of the CP patients with osteoporosis.

FIGURE 4. Intraoperative photograph shows cold welding and good bone-screw integration. Screw stripping occurred and the screw was removed with the plate. The bone was separated from its surroundings by forcibly dislodging the plate with an attached stripped screw. The detached part of femur was marked with red circle.

Furthermore, we assume that a higher plate screw density ratio is a predisposing factor for difficulty during removal surgery but necessary sometimes for stable fixation in the osteoporotic bones. We also believe that fixation technic of the screws is a factor too. To avoid difficulties, care should be taken during insertion. The use of a torque-limiting drill attachment, checking that the insertion handle is tightly locked, and use of external targeting guides can minimize these problems. Consequently, high plate screw ratio, which is necessary for stable fixation, can be a problem during plate removal in patients with CP.

Loder and Feinberg[5] recommended the removal of all pediatric implants used for the fixation of long bone fractures to avoid complete osseous integration. Fujita et al[9] pointed out that removal difficulty reaches approximately 50% when the locking plate removal procedure is planned 1 year or longer after insertion. They believed that the biocompatibility of the titanium screws allows them to bind accurately with the bone of the growing child. Similarly, we observed good bone-screw integration in some cases in which we experienced difficulties (Fig. 3). We also observed that the duration between titanium PFLP insertion and removal was longer than 1 year in patients who had difficulties during surgery and it is harder to remove titanium PFLPs 1 year after insertion. We suggest plate removal at 1 year to decrease complication rates.

Calcar screw application has advantages in cases of osteoporosis, but can lead to difficulty in screw removal.[6,18,19] As cortical bone ingrowth occurs in the flute at the far cortex, screw removal may be problematic. A total of 7 calcar screws were applied, and 3 of them were in group 2. We had to cut the screw heads and leave the shafts in the bone in 4 hips (4 screws); 3 of these 4 screws were calcar screws. Although the difference in terms of calcar screw application was not statistically significant, we believed that calcar screw application can be accepted as a handicap for screw removal.

We did not find any statistically significant correlations between difficulty in titanium PFLP removal and age at plate removal. However, some authors have suggested that younger age is a risk factor, but there are not yet any published data about pediatric populations.[9] We suggest that for all age groups surgeons should be aware when performing titanium PFLP removal.

In conclusion, this study suggested that difficulty in titanium PFLP removal in CP is common and PFLP removal is not a harmless procedure. We believe that surgeons should be aware of the appropriate indications. Likewise, patients and parents should be informed in detail by surgeon and have realistic expectations of the risks. A longer time from internal fixation to removal, increased plate screw density ratio, and calcar screw application are risk factors for difficulties in titanium PFLP removal in CP.

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