석 사 학 위 논 문

Is it Necessary to Fix Directly the Displaced Quadrilateral Plate in Acetabular Fractures?

계 명 대 학 교 대 학 원

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이 논문을 석사학위 논문으로 제출함

2022년 8월

계 명 대 학 교 대 학 원

의학과 정형외과학 전공

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이인규의 석사학위 논문을 인준함

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가장 먼저 이 논문의 아이디어 및 디자인에 결정적인 과정마다 도움을 아끼지 않으셨던 민병우 교수님께 진심으로 감사드립니다. 교수님의 지지와 조언이 없었다면 이 논문은 결코 완성되지 못했을 것입니다. 항상 마음 깊이 감사드립니다.

또한, 논문 작성 진행 과정에 있어 항상 함께 고민해 주시고, 더 나은 방향으로 진행될 수 있도록 도와주신 이경재 교수님, 김범수 교수님께도 감사의 말씀 드립니다.

항상 부족한 점이 많은 저이지만 전공의 업무와 논문 작업을 병행할 수 있도록 배려해 주신 정형외과 의국 식구들께도 감사드립니다. 이런 과정들을 통하여 저도 수많은 의국 선배님들처럼 좀 더 나은 정형외과 의사로서 다시 한 번 발돋움할 수 있었고, 앞으로도 열심히 연구하여 훌륭한 정형외과 의사가 될 수 있도록 노력하겠습니다.

마지막으로, 바쁜 업무를 핑계로 소홀했지만 언제나 무조건적인 격려와 응원을 통해 힘을 주시는 사랑하는 부모님, 항상 표현이 서툰 아들이어서 죄송합니다. 주신 은혜 잊지 않고 훌륭한 사람이 되기 위해 노력하겠습니다.

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이 인 규

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1. Introduction

There are many challenges in management of acetabular fractures and associated injuries (1-3). As a result of complex surgical approaches and difficulty of achieving anatomical reduction of displaced fracture fragments, the surgical process is frustrating, with a steep learning curve, and demanding patient care (4-8).

Since the types of acetabular fractures were classified by Judet and Letournel (9,10) and several important factors in the surgical treatment of acetabular fractures were identified, a quadrilateral plate has not been specifically considered as a measure in systems for classification of acetabular fractures (11-15).

A quadrilateral plate fracture is indicated by displacement of the acetabular medial wall (16). Occurrence of these heterogeneous subtypes is increasing with the increasing number of patients with osteoporotic acetabular fractures (17-19).

Many methods for management of quadrilateral plate fractures have been reported (20-22). Some fractures can be fixed indirectly, however, use of indirect fixation could cause difficulty in achieving congruent, anatomical reduction of the hip joint in comminuted, multi-fragmentary fractures. Other studies described direct reduction of the quadrilateral plate and fixation using various types of plates or implants (23).

There is no consensus with regard to whether or not use of direct fixation of a quadrilateral plate results in a better outcome for an acetabular fracture with displaced quadrilateral plate. Therefore, the purpose of this study is to confirm the effect of direct fixation for quadrilateral plates in acetabular fractures, and to examine the strength of direct fixation compared to indirect fixation.

2. Materials and Methods

2.1. The Study Group:

Sixty patients visited this center and underwent surgery for open reduction and internal fixation of acetabular fractures with displaced quadrilateral plate from November 2005 to February 2021. Adult patients who underwent surgery for treatment of acetabular fractures with displaced quadrilateral plate were included. Patients with a follow-up period more than one year were selected, and patients who were lost to follow up during the follow-up period were excluded. This group of patients consisted of death during the period of follow up after discharge, and loss of contact address on record. Finally, 49 patients were enrolled in this study.

Patients were divided into two groups; the Indirect group, who underwent surgery using indirect fixation using a suprapectineal plate only, and the Direct group, who underwent surgery using direct reduction and fixation using an infrapectineal plate or a spring plate or a quadrilateral surface (QLS) plate (Pro - Pelvis and Acetabulum System®, Stryker, Kalamazoo, MI, USA). The Indirect group included 29 cases, and the Direct group included 20 cases, eight cases with contoured spring plate fixation, nine cases with an infrapectineal plate, and two cases with QLS plate fixation (Figure 1).

2.2. Surgical Procedures:

In the chronological point of view, a conventional Ilioinguinal approach

for acetabular fractures with quadrilateral plate displacement was used before April 2014. That is the reason why there were only patients with indirectly fixed quadrilateral plate and relatively longer follow up periods before April 2014. Use of the ilioinguinal approach creates three anatomical windows for exposure of the fracture site. First, the lateral window is placed between ilium and iliopsoas. Second, the middle window is located between the iliopsoas muscle and the iliac neurovascular bundle. Last, the third window, or medial window is located between the neurovascular bundle and the inguinal spermatic cord or round ligament. The middle window allows an approach to the distal pelvic brim and the quadrilateral plate (24) (Figure 2).

After 2014, the modified Stoppa approach was brought in for treatment of acetabular fractures. Publication of descriptions of using an infrapectineal plate through use of a modified Stoppa approach began after 2006 (25,26), and this approach has been used for full-scale clinical use for the management of acetabular fractures with displaced quadrilateral plate since 2014 (Figure 3). Using this approach, the reduced quadrilateral plate could be fixed directly during surgery.

2.3. Radiologic Evaluation:

Acetabular fracture patterns were analyzed and sorted according to the Judet and Letournel (9,10,27); the displacement patterns of the quadrilateral plate were also analyzed. Using Matta's grading system for radiological outcome, assessment of the primary outcome was based on postoperative survivorship of the hip joint as post-traumatic osteoarthritis. Several radiologic findings, including osteophyte, joint space narrowing, subchondral sclerosis, and other factors including fem-

oral head collapse, were used in determination of grades. After measurement of the radiologic findings mentioned above, grades were given as excellent, good, fair, and poor. Excellent and Good grades were classified as the Success group, Fair and Poor grades as the Failure groups (11,28).

In addition, the postoperative fracture reduction status was compared using Matta's score (11,28). Up to 1 mm of displacement after reduction is graded as anatomical reduction, 2 to 3 mm of displacement as congruent, and above 3 mm of displacement as poor reduction. In addition, a comparison of medialization of femoral heads between two groups was performed after the surgery.

2.4. Postoperative Management:

Regular prophylactic intravenous antibiotics (1st cephalosporin) were administered to all patients for six days after surgery. Surgical site drainage tube insertions were maintained for one to three days and removed when the volume of the drain remained below 30 mL within 24 hours.

After awakening from anesthesia, rehabilitation for patients was started with non-weight bearing bedside exercise for approximately four weeks after surgery. Assisted weight bearing ambulation exercise using a walker or crutches was started at 4-8 weeks after surgery.

All patients underwent postoperative radiologic evaluation was done after the surgery, including pelvic X-rays and computed tomography (CT) with reconstruction of three-dimensional images. Follow up X-ray evaluations were performed 1, 3, 6 and 12 months after surgery, and CT follow up was performed 6, 12 months after surgery.

2.5. Statistical Analysis:

Statistical analysis was performed using SPSS statistics package program (ver. 25.0; IBM Co., Armonk, NY, USA). To analyze the differences in demographic parameters, chi-square tests and Mann-Whitney tests were used. Bivariate comparisons using Chi-square tests were done for categorical variables. Continuous variables of the 2 groups were analyzed by using Student-t test. The level of significance for all statistical comparisons was set at $p < 0.05$.

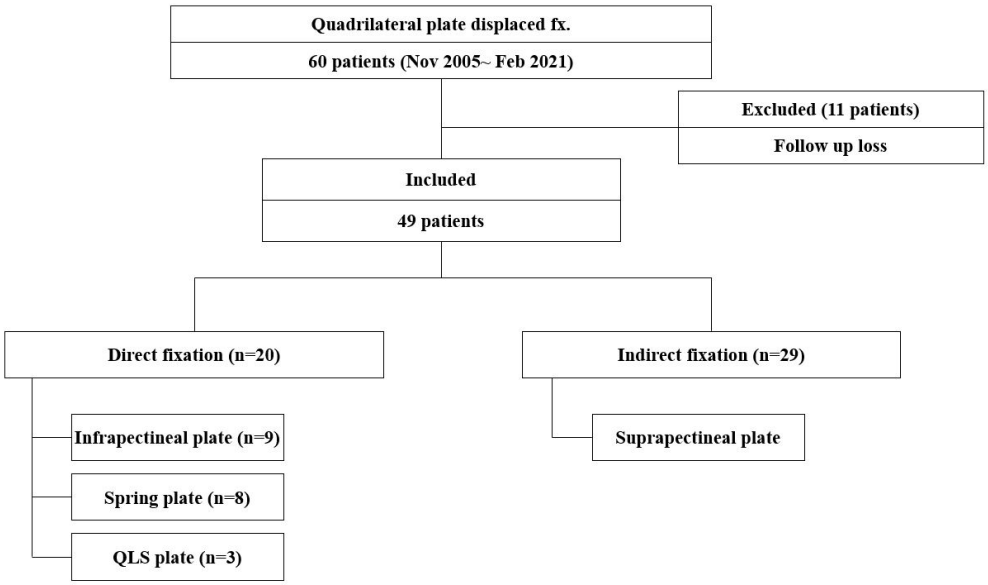

Figure 1. Patient's flow chart. Patient profiles and the groups included in the study. n: number; QLS: quadrilateral surface.

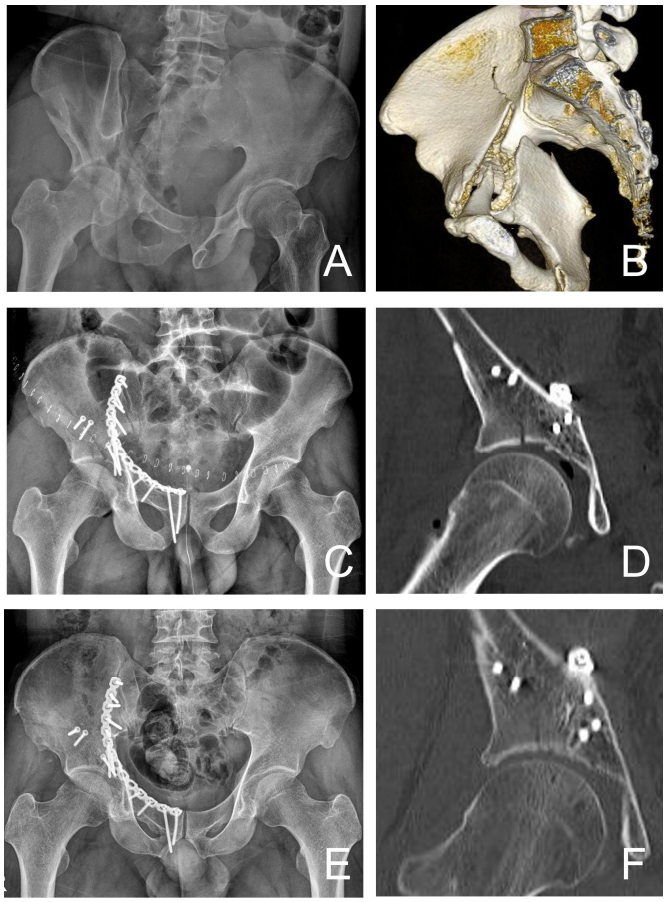

Figure 2. Case presentation I. A 41-year-old man underwent indirect fixation with suprapectineal plate. (A) Radiograph shows both column fracture with 30 mm displacement. (B) Three-Dimensional CT scan shows both column fracture with quadrilateral plate displacement. (C) Indirect fixation with suprapectineal plate is done. (D) CT scan shows congruent reduction. (E) Radiograph obtained 41 months after surgery shows union at the fracture site and good grade with Matta's outcome grading. (F) CT scan also shows mild joint space narrowing, but no sign of osteophyte, subchondral sclerosis and femoral head collapse. CT: computed tomography.

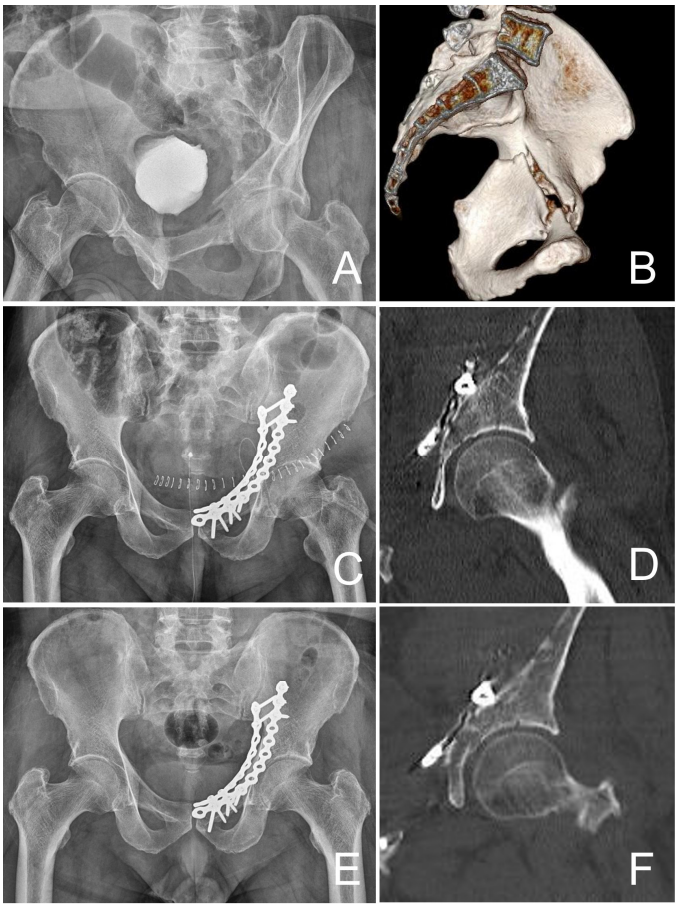

Figure 3. Case presentation II. A 66-year-old man underwent direct fixation with infrapectineal plate. (A) Radiograph shows both column fracture with 13 mm displacement. (B) Three-Dimensional CT scan shows both column fracture with quadrilateral plate displacement. (C) Direct reduction and fixation with infrapectineal plate is done. (D) CT scan shows anatomical reduction. (E) Radiograph obtained 24 months after surgery shows union at the fracture site and excellent grade with Matta's outcome grading. (F) CT scan also shows no sign of osteophyte, joint space narrowing, subchondral sclerosis and femoral head collapse. CT: computed tomography.

3. Results

Forty-nine patients were included in the study; the average age was 49.4 years old; there were 40 males and nine females. In the Direct group, the mean interval to surgery from initial trauma was seven days, and the average follow-up period was 20.0 months. In the Indirect group, the mean interval to surgery from initial trauma was 8.9 days, and the average follow-up period was 63.3 months (Table 1).

Associated both column fracture was the most common type of fracture in both groups. In the Direct group, 13 out of 20 patients were diagnosed as associated both column fracture; the other cases included five anterior columns, one anterior column with posterior hemitransverse, and one T-shaped fracture. In the Indirect group, 24 out of 29 patients were diagnosed as associated both column fractures. And the Indirect group included four patients with anterior column fractures and one anterior column with posterior hemitransverse. Six cases had an acetabular dome impacted fracture pattern. One case was in the Direct group, which consisted of 5% of the group. The other five cases were in the Indirect group, which consisted of 17.2% of the group. In the Direct group, the fracture pattern of quadrilateral plate (QLP) had 15 cases of comminuted QLP. The other three patients showed a simple QLP fracture pattern. In the Indirect group, 22 patients (75.9%) had a comminuted QLP fracture, and the other seven patients (24.1%) had simple QLP fractures (Table 2).

Significantly better survivorship of the hip joint, which was regarded as the primary outcome after the fracture, was observed in the Direct group. In the Direct group, 19 (95%) patients were included in the success group while in the Indirect group 19 (65.5%) patients were included

in the success group ($p < 0.05$) (Table 3).

An evaluation of postoperative reduction status with the degree of displacement of the fracture site was performed after the surgery. Reduction status was graded as anatomical, which was less than 1 mm of displacement, congruent (satisfactory) for 2-3 mm of displacement, and poor (unsatisfactory) for more than 3 mm of displacement. In the Direct group, 12 (60%) cases were measured as anatomical reduction, and seven (35%) cases as congruent cases. In the Indirect group, 13 (44.8%) cases were measured as anatomical reduction, nine (31%) cases as congruent, and seven (24.1%) cases as poor. A higher level of medialization of the femoral head after surgery was observed in the Indirect group. The mean degree of medialization was 0.3 mm in Direct group (Range : 0-3 mm), but 3.9 mm in the Indirect group (Range : 0-6 mm) ($p < 0.001$) (Table 4).

Regarding postoperative complications, the major concerns were arthritis and hip joint survival. Patients who showed development of arthritic change received either conservative management or conversion to total hip arthroplasty. Among the patients in this study, one out of 20 patients in the Direct group and 10 out of 29 patients in the Indirect group were considered as the failure group according to Matta's grading system for radiologic outcome. Some of the patients are under conservative management, considering tolerable clinical symptoms, however, five of the patients were managed by converting to total hip arthroplasty (Figure 4).

Table 1. Demographic Data

	Direct group (n = 20)	Indirect group (n = 29)	Total (n = 49)	p-value
Index age	52.1	47.63	49.4	> 0.05
Gender (male : female)	18 : 2	22 : 7	40 : 9	> 0.05
Laterality (right : left)	10 : 10	15 : 14	25 : 24	> 0.05
Interval from initial trauma to surgery (days)	7	8.9	8.1	> 0.05
Follow-up period (months)	20.0	63.3	45.6	< 0.05 *

*: Statistically significant.

Table 2. Fracture Morphology, Pattern, and Classification in Both Groups

	Direct group (n = 20)	Indirect group (n = 29)	p-value
Fracture classification			
ABC	13	24	> 0.05
Anterior column	5	4	> 0.05
ACPHT	1	1	> 0.05
T-shaped	1	0	> 0.05
Transverse	0	0	> 0.05
QLP fracture pattern			
Simple	5	7	> 0.05
Comminuted	15	22	> 0.05
Medial displacement (mm)	18.8	20.3	> 0.05
Number of case with dome impaction	1	5	> 0.05

ABC: associated both column; QLP: quadrilateral plate; ACPHT: anterior column with posterior hemitransverse.

Table 3. Primary Outcome According to Matta's Grading System for Radiological Outcome

	Direct group (n = 20)	Indirect group (n = 29)	p-value
Success			< 0.05 *
Excellent	12	16	
Good	7	3	
Failure			< 0.05 *
Fair	0	4	
Poor	1	6	

N: number. *: Statistically significant.

Table 4. Postoperative Evaluations

	Direct group	Indirect group	p-value
Postoperative reduction status			
Anatomical (< 1 mm)	12	13	> 0.05
Congruent (2-3 mm)	7	9	> 0.05
Poor (> 3 mm)	1	7	> 0.05
Medialization of femoral head (mm)	0.3	3.9	< 0.05 *

*: Statistically significant.

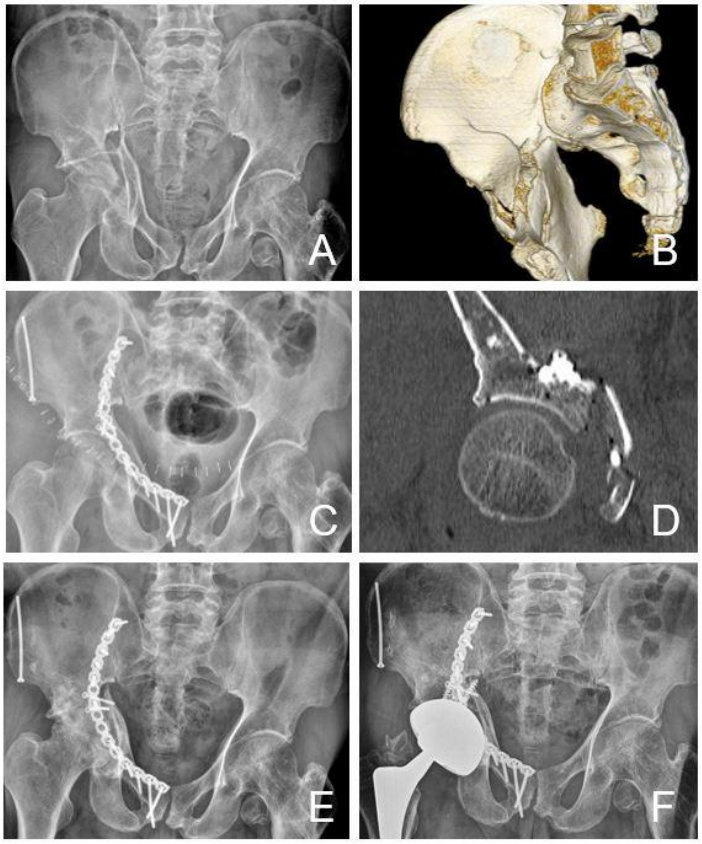

Figure 4. Case presentation III. A 57-year-old man underwent indirect fixation with suprapectineal plate. (A) Radiograph shows both column fracture with 20 mm displacement. (B) Three-Dimensional CT scan shows both column fracture with quadrilateral plate displacement. (C) Indirect fixation with suprapectineal plate is done. (D) CT scan shows congruent reduction. (E) Radiograph obtained 15 months after surgery shows poor grade with Matta's outcome grading with joint space narrowing above 50% and severe subchondral sclerosis (F) Radiograph obtained after conversion total hip arthroplasty 15 months after initial surgery. CT: computed tomography

4. Discussion

In this study, superior results were obtained from use of direct fixation group for quadrilateral plate of acetabular fractures, not only for postoperative reduction status, but also for primary outcome regarding hip joint survival from arthritis based on radiologic evaluation. Therefore, the findings of this study might provide proof of the assumption that direct fixation of a quadrilateral plate fracture can result in better outcomes than with indirect fixation of displaced quadrilateral plates.

The primary limitation of this study is the retrospective design of the research. Second, the number of patients in the groups are relatively small, particularly for the direct reduction group. In addition, conduct of future studies with a longer follow-up period and larger patient groups might be required in order to demonstrate the efficacy of direct reduction of quadrilateral plate fractures compared to indirect reduction.

According to White et al. (20), there was previously a predominant trend toward conservative treatment; they emphasized the importance of operative treatment in order to achieve better outcomes for the patients. In their study, they compared the outcomes between patients who underwent surgical treatment after quadrilateral plate fractures with screws, pins, plates and cerclage wiring or cables. They suggested that plating could currently be the most frequently employed method. However, although they compared the fixation method itself, they did not determine the exact effective value of whether the fractures are directly or indirectly reduced.

Karim et al. (21), who introduced the fixation method using a buttress screw, demonstrated some of the effect of anatomical reduction of ace-

tabular fractures with quadrilateral plates with fewer complications. They suggested the use of a plate with buttressing screw, which provides the advantage of avoiding the risk of hardware penetration to the joint and dissection of the quadrilateral plate is not required. Obviously, they suggested one method for reducing and fixing displaced quadrilateral plate fractures, however, when using this method to emphasize the efficacy of the buttressing screw, there is not much of a direct reduction.

Several factors can affect the prognosis after operative treatment of acetabular fractures. An associated fracture or injury type, reduction status, presence of joint dislocation, and delay of surgery are known predictors of the outcome of surgically treated acetabular fractures (12, 13,15). Because of quadrilateral plate fracture is considered a heterogeneous subtype of acetabular fractures (20), failure to reconstruct the buttressing function of the medial wall can cause an incongruous hip and poor reduction status, resulting in worse outcome (29,30).

The conventional ilioinguinal approach for acetabular fractures has been widely used because of its advantage of allowing a wide view of some types of fracture patterns such as anterior and transverse fractures, with a low risk of vascular injury (31,32). Use of quadrilateral plate has also been manageable with use of an ilioinguinal approach using implants such as a suprapectineal plate, buttressing screw (4,21). However, when using this approach, because of complicated anatomic structures in this surgical field and steep learning curve, there is difficulty in identifying the exact fracture pattern and in obtaining an adequate operation view.

In an explanation of the modified Stoppa approach through the rectus abdominis muscle to reach the pelvic ring reported by Cole and Bolhofner (32), the main advantage was infrapectineal plating and man-

agement of quadrilateral plate fractures because use of this approach can allow direct assessment not only to the posterior surface of the pubic ramus, pubic eminence, and infrapectineal surface, but also to the medial surface of acetabulum, in other words, the quadrilateral plate.

The purpose of this study is not to focus on the advantages of a certain surgical approach itself. In some way or another, the findings of this study demonstrated that direct fixation of the displaced quadrilateral plate is superior to indirect fixation. Three methods were applied for directly fixing the quadrilateral plate; infrapectineal plate, spring plate, and QLS plate. Treatment with an infrapectineal plate was administered in eight patients. The reconstruction plates were over-bent and then attached to the infrapetineal surface, directly buttressing the quadrilateral plate and preventing secondary medialization of the femoral head. Treatment with a spring plate, which is a reconstruction plate bent over the pelvic brim buttressing the medial wall, was administered to the other eight patients. Treatment with a QLS plate was administered in the two remaining patients who underwent direct fixation. No significant difference in outcomes was observed among these fixation methods, which means that meaningful results can be obtained using direct fixation, no matter what method is used.

This study has several strengths that could support its results. First, treatment of all patients included in this study was administered by a single surgeon at a single medical institution, which rules out other varieties of factors which could alter not only the consistency of treatment protocols and evaluations, but also the result of the treatment. Second, The two patient treatment method groups (direct fixation, indirect fixation) with the same fracture patterns could be compared. No significant difference preoperatively evaluated fracture morphology and classification of fracture types was observed between the two groups of patients.

5. Summary

This study was designed to demonstrate the strength of direct fixation of a displaced quadrilateral plate in acetabular fractures. This study included 49 patients who underwent treatment for acetabular fractures with a displaced quadrilateral plate between November 2005 and February 2021. Analysis of several radiologic findings to compare the result between direct fixation and indirect fixation of quadrilateral plates. Findings of this study demonstrates that surgical treatment of acetabular fractures with displaced quadrilateral plates using direct fixation with buttress plates can improve the reduction quality of articular displacement and thus offer better survivorship of the affected hip joint.

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Is it Necessary to Fix Directly the Displaced Quadrilateral Plate in Acetabular Fractures?

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(Abstract)

Quadrilateral plate fractures represent a heterogeneous group of acetabular fractures. Accurate reduction is required to prevent post-traumatic arthritis. The purpose of this study is to confirm the effect of direct fixation for displaced quadrilateral plate in acetabular fracture. Between 2005 and 2021, 49 patients underwent surgery for open reduction and internal fixation in acetabular fractures with severely displaced quadrilateral plate. Twenty-nine patients were indirect fixation group and twenty patients were direct fixation group. In a comparison of primary outcome between two groups, 10 out of 29 indirect group patients and 1 out of 20 direct group patients developed posttraumatic osteoarthritis which difference between two groups is statistically significant. In the assessment of postoperative Matta's radiological reduction status,

19 out of 20 patients in the direct group had achieved anatomical and congruent reduction. The treatment using a direct reduction and internal fixation improved reduction quality of articular displacement and offered better survivorship of affected hip joint.

비구 골절에서 전위된 장사방면 판의 고정이 필요한가?

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(초록)

장사방면 판 골절 및 전위는 비구 골절의 한 종류로서, 고관절의 외상 후 관절염 방지를 위해서는 전위된 장사방면 판의 정확한 정복이 요구된다. 이 연구의 목적은 비구 골절에서 전위된 장사방면 판의 직접 고정의 효과와 필요성을 제시하는 것이다. 전위된 장사방면 판을 동반한 비구 골절로 관혈적 정복술 및 내고정술을 받은 49명의 환자가 연구에 포함되었다. 장사방면 판을 간접적으로 고정한 군과 직접적으로 고정한 군 사이에 주요 치료결과로서, 간접 고정 군 29명 중에 10명이, 직접 고정 군 20명 중 1명이 방사선학적으로 술 후에 외상 후 관절염 소견을 보였으며 통계적으로 유의하게 간접 고정 군에서 더 많은 비율을 보였다. 술 후 전위의 정복 정도를 방사선학적으로 평가하였을 때도 직접 고정 군에서 높은 비율로 보다 더 우수한 결과를 나타내었다. 결론적으로 비구 골절에서 전위된 장사방면 판을 직접 고정하는 것이 정복 상태뿐 아니라 이환된 고관절의 생존에도 더 나은 결과를 얻을 수 있을 것으로 사료된다.