INTRODUCTION

Displaced acetabular fractures frequently require open reduction and internal fixation (ORIF) to provide restoration of the congruent articular surface which is essential for optimal functional results. Acetabular fractures with quadrilateral plate involvement typically involve comminution of fracture fragments, medial displacement of the femoral head, and impaction of the superior articular surface of the acetabulum. In such fractures, the goals of anatomical reduction and stable fixation are difficult to achieve, mainly due to the intrapelvic location of fracture...
fragments, limited bone stock, juxta-articular nature, and comminution which is particularly challenging in the presence of osteoporosis8,9,10.

Reduction and stable fixation of acetabular fractures is a challenging procedure6. Detailed preoperative planning and selection of an appropriate surgical approach are necessary to avoid complications and achieve optimal results4,7. The use of a standard ilio-inguinal approach, popularized by Letournel8, offers limited exposure and access to manipulate fragments of the quadrilateral plate. The approach involves extensive dissection and manipulation of neurovascular structures, increasing the risk of complications8,10. In 1994, Cole and Bolhofner11 introduced the anterior intrapelvic approach which utilized a modified Stoppa technique and was a less invasive alternative to the ilioinguinal approach, providing the additional benefits of intra-pelvic access and direct exposure to the quadrilateral plate. An infraceptineal plate applied using a modified Stoppa approach is seated in the same plane as the fracture displacement, resulting in a biomechanically stronger construct that resists secondary protusio-type displacement. The plate is attached and secured posteriorly using screws placed superior to the sciatic notch and anterior to the superior pubic ramus along the infraceptineal line3,12).

The modified Stoppa technique has gained wide popularity with success rates ranging from 59% to 82% of cases13-15 compared to rates of 45% to 74%1,16 when performing anatomical reduction using the ilioinguinal approach. However, the number of retrospective studies that have specifically evaluated the utility and outcomes of using the modified Stoppa’s technique in acetabular fractures involving the quadrilateral plate are few and have limited patient numbers17. The goal of the current study was to investigate the quality of reduction, functional outcomes, and perioperative complications after ORIF with infraceptineal buttress plating of the quadrilateral surface via an anterior intrapelvic approach (the modified Stoppa technique).

MATERIALS AND METHODS

This current study is a retrospective review of 21 patients with acetabular fractures involving the quadrilateral plate who underwent ORIF with infraceptineal buttress plating using the modified Stoppa technique at Ghurki Trust Teaching Hospital in Lahore, Pakistan between January 2017 and December 2018. All patients had a minimum follow-up period of one year. Approval by the Institutional Review Board of Ghurki Trust Teaching Hospital was obtained prior to beginning the study. As our study was retrospective in nature and did not influence patient care, the need for ethical approval was waived by the institutional review board. Medical records were reviewed to collect demographic patient data including age, sex, co-morbidities, mechanism of injury, time elapsed since injury, and concomitant injuries other than acetabular fractures. All fractures were evaluated by both simple radiography (x-ray pelvis and Judet views) and computed tomography and classified according to the Letournel classification9. The appearance of a “Gull sign” (superomedial impaction), central dislocation, or comminution of the quadrilateral surface was specifically noted. The assessment of the quality of postoperative reduction was based on x-rays using the system proposed by Matta12. Postoperatively, anteroposterior and 45-degree oblique (Jude7) radiographs were taken, and residual displacement was measured in each. For all radiographs, the maximum displacement seen at any of the normal radiographic lines of the acetabulum or the innominate bone was recorded in millimeters, and the highest of the three values was used to grade the reduction according to one of four categories: anatomical (zero to one millimeter of displacement), imperfect (two to three millimeters), poor (more than three millimeters), or surgical secondary congruence (the acetabulum is reduced anatomically but displacements in the innominate bone alter the position of the joint). At final follow-up, x-rays were evaluated for loss of reduction and functional outcomes which were assessed using the Postel Merle d’Aubigné score10 to evaluate pain, gait, and mobility on a scale of 1 to 6, where 1 reflects the worst possible state of the patient and 6 the best. The total lowest possible score is 3, and the maximum is 18. A perfect score of 18 is categorized as excellent, 15-17 as good, 12-14 as fair, and less than 12 as poor.

1. Surgical Technique

The same surgical approach was used for all patients. The patient was placed in a supine position on a radiolucent table to allow for fluoroscopic imaging and the ability to obtain Judet views. After the patient was prepped and draped in a standard fashion, keeping the affected limb free for manipulation by an assistant, the main surgeon placed himself opposite to the injured hip with one assistant on each side. An anterior intrapelvic approach (the modified Stoppa technique13) in combination with the lateral window of the ilio-inguinal approach7 was utilized. Manual longitudinal
or trochanteric traction was used for preliminary reduction of centrally displaced femoral head. After proper exposure, fracture components were reduced and stabilized in a centripetal direction. The iliac wing, which was easier to access through the lateral window of the ilio-linguinal approach, was addressed first to stabilize high anterior column fractures and was fixed temporarily with screws or plates.

Fracture of the quadrilateral plate (and posterior column if present) was addressed through the medial window with direct visualization of the intra-pelvic region. The dissection was performed posterior to the sacro-iliac joint if needed. The hip joint was accessible through the fractured quadrilateral plate and allowed for the removal of osteochondral fragments. Depression in the weight-bearing area could be corrected by disimpacting the roof with an elevator through the joint line. Reduction was obtained with lateral traction combined with a ball spike impactor along the quadrilateral surface. Provisional reduction was maintained with a pelvic clamp, K-wires, 3.5 mm lag screws, or a short 3 to 4 holes pelvic recon plate. Although different plate configurations were possible, an under-contoured 3.5 mm locally manufactured recon plate (316 L stainless steel) was used to provide a spring effect when fitting the infra-pectineal region inside the true pelvis. Two 40 mm screws were routinely placed in the sciatic buttress area and 1 to 2 screws in superior pubic ramus. A suction drain was inserted, and layered closure was performed in the standard fashion.

The same postoperative rehabilitation protocol was implemented for all patients. Only toe-touch weight-bearing was allowed for the first 6 weeks followed by partial weight bearing until the 12th week and full weight-bearing thereafter. Physiotherapy included gait training and quadriceps/abductor strengthening exercises starting postoperatively. Range of motion exercises were added at six weeks postoperative. Mechanical and chemical (Enoxaparin 40 mg subcutaneously daily) thromboprophylaxis was prescribed for six weeks. Patients were reviewed clinically and radiologically at 3, 6, 12, and 24 weeks and bimannually thereafter.

**RESULTS**

The study cohort was comprised of 21 patients (15 male and 6 female) with a mean age of 40.67±12.17 years (range, 22-62 years). A road traffic accident was the predominant mode of injury in 15 patients. The most common fracture pattern was anterior column and posterior hemi-transverse in eight patients followed by true bicondyle fractures. Both transverse fractures were transtectal. The mean operative time was 178 minutes and the mean drop in hemoglobin was 1.8 g/dL. Patients remained in the hospital for an average of five days postoperatively. Table 1 summarizes data on demographics, type, and mechanism of injury, and radiological and functional outcomes.

All patients had a minimum of 1 year of follow-up (mean, 14.3±2.1 months). The quality of reduction was assessed according to Matta criteria and found to be anatomical in 14 patients, imperfect in five, and poor in two. Functional outcomes, assessed in terms of Postel Merle d’ Aubigné score, were excellent in 47.6% cases, good in 42.9%, and fair in 9.5% of cases with a mean overall score of 16.62±1.66. Both patients with fair outcomes had non-anatomical reduction, one of which required a total hip arthroplasty during the follow-up period. Superficial surgical site infection occurred in three patients, all of which were treated conservatively and did not require any additional surgical procedures. There were no cases of hernia, heterotopic ossification, vascular or genitourinary injury. Case studies are illustrated in Fig. 1 and 2.

**DISCUSSION**

The results of the current study indicate that in the majority of patients with acetabular fractures involving the quadrilateral plate, ORIF with an infrapectineal plate applied using an anterior intrapelvic approach yields excellent radiological and functional outcomes. Additionally, this approach lessens the operative time and intraoperative bleeding without any significant increase in perioperative complications. These findings are in line with the published literature. Notably, the mean age of patients in the current study was lower than patients included in prior reports.

Over the last 50 years, substantial progress has been made in the treatment of acetabular fractures. All treatment protocols share the same goal of providing pain relief, allowing early mobilization, and restoring normal hip joint anatomy; thereby limiting the risk of early post-traumatic arthritis. Various factors including age, functional status, fracture pattern, degree of displacement, associated injuries, pre-existing local and general conditions, and available surgical expertise influence the choice of treatment modality. Though the quadrilateral plate, which refers to the medial wall of the acetabulum, is not considered a separate parameter in acetabular fracture classifications, it is notorious for making ORIF challenging. Quadrilateral plate fractures are typically associated with bicondyle fractures,
anterior column and posterior hemitransverse fractures, posterior column fractures, and transverse or T-type fractures. Anatomical reduction and stable fixation are difficult to achieve, mainly due to the location in the true pelvis, limited bone stock, juxta-articular nature, and its comminution, particularly in the presence of osteoporosis. Failure to restore the buttressing function of the medial wall and reduce the central displacement results in incongruous hip and poor outcomes.

A multitude of direct and indirect reduction techniques, surgical approaches, and implants have been described in the literature in an effort to address the challenges of this specific anatomic area. A standard ilio-inguinal approach, popularized by Letournel, does not allow ample exposure to adequately reduce and fix fractures of the quadrilateral plate. Additionally, this approach poses an increased risk to neurovascular structures due to direct manipulation. By contrast, it is possible to expose 80% of quadrilateral plate as well as the greater part of both columns and the anterior wall of the acetabulum by utilizing a modified Stoppa approach.

In addition to excellent exposure, the modified Stoppa approach permits fixation of the fracture with multiple implant configurations including supraperiosteal or infraperiosteal plates or a combination of buttress plates and peri-articular screws. In their biomechanical study, Ryan et al. compared the stability of three fixation strategies for transverse acetabular fractures: a reconstruction plate with anterior and posterior column screws; an infraperiosteal precontoured quadrilateral surface buttress (iPQSB) plate alone; and an anterior column lag-screw and iPQSB plate. It was concluded that under anatomical loading, iPQSB plates with anterior column lag-screw fixation demonstrated increased stability. By using finite element modeling, Yücenş et al. sought to compare the stability and implant stress of a supraperiosteal plate with an infraperiosteal plate in three subconfigurations of screw types for anterior column fractures. Infraperiosteal plate fixation with unlocked screws was found to be the most stable fixation method. The superiority of the infraperiosteal plates in terms of stability could be attributed to three factors. First, the infraperiosteal plate supports the pelvic ring from the inner side, in which both ends of the plate form a sealed and more stable structure. Second, mechanically it is easier to band a plate on the frontal aspect (2-3 mm) than on the side aspect (10 mm) due to differences in the inertia.

Table 1. Patient Demographics, Fracture Characteristics, and Outcomes

| Age (yr) | Sex | MOI | AO classification | Fracture pattern | Pelvic fracture | Gull sign | Quadrilateral plate cominution | Matta radiological classification | Postel Merle d’Aubigné score |
|---------|-----|-----|-------------------|-----------------|----------------|----------|-------------------------------|-------------------------------|-------------------------------|
| 28      | M   | RTA | 62C1              | True bicolumn   | -              | -        | Yes                           | Anatomical                    | Excellent                     |
| 62      | M   | Fall| 62B3.1            | ACPHT           | -              | Yes       | Yes                           | Anatomical                    | Good                          |
| 38      | F   | RTA | 62B3.3            | ACPHT           | -              | -        | -                            | Anatomical                    | Excellent                     |
| 51      | M   | RTA | 62B3.3            | ACPHT           | -              | Yes       | Yes                           | Anatomical                    | Excellent                     |
| 33      | F   | RTA | 62B2.2            | T-type          | LC II          | -        | -                            | Anatomical                    | Good                          |
| 22      | M   | RTA | 62B3.3            | ACPHT           | -              | -        | Yes                           | Anatomical                    | Good                          |
| 33      | F   | RTA | 62B1.3            | Transverse      | -              | -        | -                            | Anatomical                    | Excellent                     |
| 28      | M   | RTA | 62C1              | True bicolumn   | -              | -        | -                            | Imperfect                     | Good                          |
| 44      | M   | Fall| 62B2.1            | T-type          | VS             | -        | Yes                           | Imperfect                     | Good                          |
| 57      | F   | RTA | 62B3.1            | ACPHT           | -              | Yes       | -                            | Anatomical                    | Excellent                     |
| 40      | M   | RTA | 62C2              | True bicolumn   | -              | -        | -                            | Anatomical                    | Good                          |
| 42      | M   | Fall| 62B1.3            | Transverse      | APC II         | -        | -                            | Anatomical                    | Good                          |
| 50      | M   | Fall| 62C2              | True bicolumn   | -              | Yes       | Yes                           | Poor                          | Fair                          |
| 33      | M   | RTA | 62C1              | True bicolumn   | -              | -        | -                            | Anatomical                    | Good                          |
| 59      | F   | RTA | 62B3.2            | ACPHT           | -              | -        | -                            | Anatomical                    | Excellent                     |
| 27      | M   | RTA | 62B3.3            | ACPHT           | LC II          | -        | -                            | Imperfect                     | Good                          |
| 36      | F   | RTA | 62B2.3            | T-type          | -              | -        | -                            | Anatomical                    | Excellent                     |
| 47      | M   | Fall| 62C2              | True bicolumn   | -              | -        | Yes                           | Poor                          | Fair                          |
| 60      | M   | Fall| 62B3.2            | ACPHT           | -              | Yes       | -                            | Anatomical                    | Good                          |
| 38      | M   | RTA | 62B2.2            | T-type          | -              | -        | -                            | Imperfect                     | Excellent                     |
| 26      | M   | RTA | 62C2              | True bicolumn   | -              | -        | -                            | Anatomical                    | Excellent                     |

M: male, F: female, MOI: mechanism of injury, RTA: road traffic accident, ACPHT: anterior column and posterior hemitransverse, LC: lateral compression injury, VS: vertical shear jury, APC: anterior posterior compression.
bending moment. In standing positions, the loads act vertically and the suprapectineal plate faces the loads frontally, whereas the infrapectineal plate faces loads on its side aspect. Third, the infrapectineal plate supports four critical corners of the fractured acetabulum in a balanced manner, converting the standing loads to compression forces with-
out evident shear. The current clinical study substantiates biomechanical analyses finding that an infrapectineal plate applied in the same plane as the fracture displacement rather than perpendicular to it provides better fixation and prevents secondary protrusion\(^{25}\). This mechanical advantage, in conjunction with the biological advantage of the modified Stoppa approach, may explain our low rate of complications. The Stoppa approach is associated with faster hip abductor rehabilitation and lower rates of heterotopic ossification around the hip. Future reconstruction including total hip arthroplasty may similarly be performed unhampered\(^{12}\).

Unfortunately, not all fracture components can be managed using a modified Stoppa approach including fractures of the iliac fossa, fractures running high in the anterior column, or fractures of the posterior wall. In such situations, it becomes essential to either create the first window of the classical ilioinguinal approach or to combine with a posterior approach\(^6\). In recent studies, the lateral window combination has been reported in up to 40% of surgeries\(^{15,29,30}\), but was reported in only 28.6% of procedures in the current study.

Direct comparisons between studies reporting outcomes of infrapectineal plating via the Stoppa approach are hampered by the great variance in the way fractures of the quadrilateral plate have been described in published literature. Therefore, the summation of results from case series and correlation of outcomes to different treatment modalities is not possible\(^{25}\). Hirvensalo et al.\(^{14}\) reported that by using the anterior intrapelvic approach in 164 cases of pelvic and acetabular surgery, anatomic reduction was obtained in 138 (84.1%) cases. Sagi et al.\(^{15}\) and Andersen et al.\(^{31}\) reported anatomic reduction rates of 92% and 82% respectively; however, inclusion criteria differed between these studies. In a retrospective series of 16 acetabular fractures with quadrilateral plate involvement treated using the modified Stoppa approach, Andrés-Peiró et al.\(^{6}\) reported that the quality of reduction was anatomical in nine cases, imperfect in three and poor in four. However, seven patients had complications related to the procedure, four required additional surgical procedures and despite good radiological results, a high infection rate was reported. Laflamme et al.\(^{12}\) investigated the appropriateness of ORIF using an infra-pectineal buttress plate via a modified Stoppa approach in 21 cases of osteopenic acetabular fractures involving the quadrilateral plate. Anatomic reduction was obtained in 66.7% (14/21) of cases, imperfect reduction in 23.8% (5/21) of cases, and poor reduction in 9.5% (2/21) of cases. Significant loss of reduction was seen in two patients. Functional assessments were obtained in 19 patients and 71% of patients required no walking aid. According to the Postel Merle d’Aubigné score, results were excellent in 47.6% of patients, good in 42.9%, and fair in 9.5%.

The findings of the current study are limited by the small sample size and retrospective nature of the study. Additionally, follow-up in the current study was too short to evaluate the subsequent development of post-traumatic arthritis.

**CONCLUSION**

Quadrilateral plate reconstruction with an infrapectineal buttress plate applied through an anterior intrapelvic approach provides a high rate of anatomical reduction and yields positive functional results.

**CONFLICT OF INTEREST**

The authors declare that there is no potential conflict of interest relevant to this article.

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