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RADIOGRAPHIC EVALUATION OF IMMEDIATE LOADING SAFETY AFTER SURGICAL REDUCTION IN ACETABULAR FRACTURES: A COMPARATIVE-RETROSPECTIVE STUDY

AVALIAÇÃO RADIOGRÁFICA DA SEGURANÇA NA CARGA IMEDIATA APÓS REDUÇÃO CIRÚRGICA EM FRATURAS ACETABULARES: ESTUDO COMPARATIVO-RETROSPECTIVO

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ABSTRACT

Objective: Radiographically evaluate the quality of reduction over six weeks of follow-up in patients with surgically treated deviated acetabular fractures who underwent rehabilitation with immediate loading as tolerated and compare this with the results of the unloaded protocol. Methods: We retrospectively evaluated the records of 137 patients with deviated acetabular fractures treated with open reduction and internal fixation. Sixty-six (48.2%) patients underwent postoperative rehabilitation with immediate loading as tolerated, while 71 (51.8%) patients completed rehabilitation using a no-load protocol. The quality of the reduction was assessed radiographically by measuring the fracturing step and gap on radiographs taken immediately after surgery and three and six weeks after surgery. Results: Comparing the joint step, group 1 had an average of 0.44 ± 1.4 mm, 0.47 ± 1.5 mm, and 0.51 ± 1.6 mm immediately, three and six weeks after surgery, respectively. Group 2 had a mean step of 0.24 ± 0.8 mm, 0.27 ± 0.9 mm, and 0.37 ± 1.2 mm immediately, three, and six weeks after surgery. No statistically significant differences were observed between the groups. With a joint gap, group 1 had a mean of 1.89 ± 1.7 mm, 2.12 ± 1.8 mm, and 2.36 ± 2.1 mm; and group 2 had a mean of 2.16 ± 2.4 mm, 2.47 ± 2.6 mm, and 2.67 ± 2.8 mm in the immediate postoperative period, three, and six weeks, respectively. There was also no statistical difference between groups in these measurements. Conclusion: Immediate loading after surgical treatment of deviated acetabular fracture had no negative impact on radiographic reduction parameters and had similar results to the protocol without weight bearing. ***Level of evidence III; Therapeutic Retrospective Cohort Study.***

Keywords: Fractures, Bone. Acetabulum. Weight-Bearing. Rehabilitation. Fracture Fixation, Internal.

RESUMO

Objetivo: Avaliar radiograficamente a qualidade da redução ao longo de 6 semanas de acompanhamento em pacientes com fratura desviada do acetábulo tratados cirurgicamente e submetidos à reabilitação com carga imediata conforme tolerado e comparar com os resultados do protocolo sem carga. Métodos: Avaliamos retrospectivamente os prontuários de 137 pacientes com fraturas desviadas do acetábulo que foram tratadas com redução aberta e fixação interna. Sessenta e seis (48,2%) pacientes foram submetidos à reabilitação pós-operatória com carga imediata conforme tolerado, enquanto 71 (51,8%) pacientes completaram a reabilitação utilizando um protocolo sem carga. A qualidade da redução foi avaliada radiograficamente pela medição do degrau da fratura e do gap nas radiografias feitas imediatamente após a cirurgia e três e seis semanas após a cirurgia. Resultados: Comparando o degrau articular, o grupo 1 teve uma média de 0,44 ± 1,4 mm, 0,47 ± 1,5 mm e 0,51 ± 1,6 mm imediatamente, três e seis semanas após a cirurgia, respectivamente. O grupo 2 teve um degrau médio de 0,24 ± 0,8 mm, 0,27 ± 0,9 mm e 0,37 ± 1,2 mm imediatamente, três e seis semanas após a cirurgia. Não foram observadas diferenças estatísticas significantes entre os grupos. Com gap articular, o grupo 1 teve uma média de 1,89 ± 1,7 mm, 2,12 ± 1,8 mm e 2,36 ± 2,1 mm; e o grupo 2 de 2,16 ± 2,4 mm, 2,47 ± 2,6 mm e 2,67 ± 2,8 mm nos pós-operatório imediato, três e seis semanas, respectivamente. Também não houve diferença estatística entre os grupos nessas medidas. Conclusão: A carga imediata após o tratamento cirúrgico da fratura do acetábulo desviada não teve impacto negativo nos parâmetros de redução radiográfica e teve resultados semelhantes em comparação com o protocolo sem descarga de peso. ***Nível De Evidência III; Estudo Terapêutico de Coorte Retrospectivo.***

Descritores: *Fraturas Ósseas. Acetábulo. Suporte de Carga. Reabilitação. Fixação Interna de Fraturas.*

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INTRODUCTION

Acetabular fractures usually occur after high-energy trauma and are related to permanent motor impairment and high morbimortality rates.[1] Conservative treatment was the main method of management until Judet et al. published a study in 1964 that demonstrated superior outcomes after open reduction and internal fixation surgery, leading to the reduced incidence of post-traumatic osteoarthritis and higher rates of hip preservation.[2]

In other joints of the lower limb, stable internal fixation allows early weight-bearing, which improves functional rehabilitation, reduces time off work, and reduces the risk of the complications that relate to long periods of immobility.[3] In patients with acetabular fractures, even in those with stable internal fixation, there is no consensus on the weight-bearing protocol used during rehabilitation. Current protocols vary from non-weight-bearing, toe-touch, to partial weight-bearing.[4]

Until 2015, the postoperative protocol in our hospital for patients that underwent internal fixation of the acetabular fracture was 6 weeks of non-weight bearing rehabilitation. As of 2016, rehabilitation with immediate weight-bearing as tolerated was implemented. All other aspects of the treatment were similar.

The aim of this study was to evaluate the quality of reduction retrospectively radiographically over the 6 weeks of follow-up in patients that underwent rehabilitation with immediate weight-bearing as tolerated, and to compare these findings with the results of the non-weight bearing rehabilitation group. We hypothesized that immediate weight-bearing had no negative effect on the reduction and was comparable to that of the non-weight-bearing protocol.

PATIENTS AND METHODS

This therapeutic retrospective cohort study examined patients with displaced acetabular fractures that underwent open reduction and internal fixation surgery between January 2011 and December 2018. Two distinct weight-bearing protocols in the postoperative period were compared: non-weight-bearing and immediate weight-bearing as tolerated. This study was approved by the Research and Ethics Committee of the University (number: 3.212.380) and was carried out in accordance with the Declaration of Helsinki.

From the patients' records, we collected the baseline demographics (age, sex, fracture classification, associated injuries, time to surgery, and time to initiation of weight-bearing). All surgeries were performed by two of the authors (KEK and/or MCL).

The inclusion criteria were patients with a displaced acetabular fracture that underwent open reduction and internal fixation surgery, a mature skeleton, and six weeks of radiographic follow-up.

Patients were excluded if they underwent conservative treatment, has a follow-up shorter than six weeks, had inadequate radiographic exams, were treated with immediate total hip arthroplasty, had another fracture (bilateral, associated with pelvis injury), non-displaced, pathological, had an immature skeleton, fracture with more than 3 weeks, had a local infection, or were non-adherent to the weight-bearing protocol.

The non-weight-bearing group (group 1) consisted of patients who underwent the operation between 2011 and 2015; who were not allowed to bear weight for six weeks, while patients who underwent the operation between 2016 and 2018 formed the immediate weight-bearing group (group 2); who were allowed to bear weight as tolerated on the operated limb, with the support of two crutches, immediately after the surgical procedure.

Radiographs of the affected hip were taken immediately after the surgery and on postoperative weeks three and six of all patients. The quality of reduction was quantified by analysis of the radiographic images in the alar and obturator oblique views. The reduction was evaluated based on the measurement of the articular step and gap, in accordance with the method described by Borrelli et al.[5] The intact weight-bearing dome (WBD) was identified using the 45° method described by Matta,[6] and a digital circular template matching the arc of curvature of the intact WBD was drawn. The subchondral fracture margin of the intact portion of the acetabulum was marked as A, and the subchondral fracture margin of the displaced fragment was marked as C. A straight line between the center of the circle and point C was drawn, and the point of intersection with the circle was labeled point B. The distance between points A and B represented the gap deformity, while the distance between points B and C was the articular step. (Figure 1) The articular step and gap were measured in both views, taking into consideration the necessary adjustments that needed to be made to correct for the radiographic amplification.

To decrease bias, the measurements were performed by three authors who were not involved in the surgeries (BMM, BSK, DSP), and the median value of the three different measurements was used for the analysis.

The reduction was considered satisfactory if the articular step and gap was $\leq$ 1 mm and $\leq$ 5 mm, respectively, which allows for maximized sensitivity and specificity when considering conversion to total hip arthroplasty as reported by Verbeek et al.[7] An increase of $>$ 2 mm in either of the measurements at the three- or six-week follow-up was noted as a loss of reduction.

Statistical analyses were performed using SigmaPlot 11.0 software (SPSS, Richmond, CA, USA). Fracture patterns and associated fracture prevalence were compared using the Z-test to establish if there was any selection bias. Quantitative results were compared between equivalent time points after surgery between the two groups, and between time points within each group. Non-parametric distribution was determined using a normality test. Ergo, quantitative comparison was performed with the Mann-Whitney U test and Wilcoxon signed rank test in non-paired and paired evaluations, respectively. For qualitative comparison, we utilized Fischer's exact test and McNemar's test for non-paired and paired analyses, respectively. A p-value that was less than 0.05 was considered as statically significant.

RESULTS

Between 2011 and 2018, there were a total of 187 patients who underwent treatment for acetabular fracture, and 137 met the criteria for inclusion in our study. Of these patients (Table 1), 115 (83.9%)

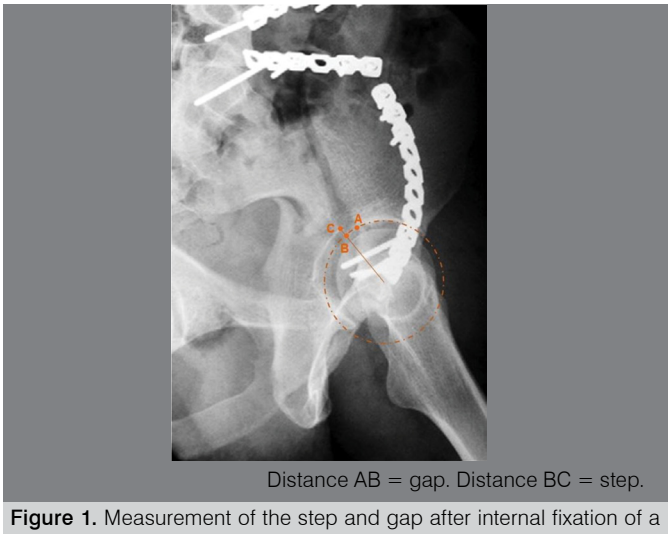

Figure 1. Measurement of the step and gap after internal fixation of a left acetabular fracture.

were men and 22 (16.1%) were women, and the mean age was 34.1 years (range, 16 - 74 years).
Of the 137 patients, 71 (51.8%) were treated between 2011 and 2015 and underwent rehabilitation with the non-weight-bearing protocol. The remaining 66 (48.2%) patients were treated between 2016 and 2018 and underwent rehabilitation with immediate weight-bearing as tolerated. (Table 1)
Associated fractures were more common in the lower extremity (34.3%) and were not different between the two groups. (Table 2)
The most common acetabular fractures were posterior wall fractures (22.6%), followed by associated both column fractures (15.3%). Overall, associated fractures were more frequent than elementary fractures. There was no difference in the incidence of fracture patterns between the two groups (Table 3).
The average articular step in the non-weight-bearing group on the day immediately after surgery was 0.40 ± 1.4 mm and increased to 0.47 ± 1.5 mm and 0.51 ± 1.6 mm in the third- and sixth-week post-surgery, respectively. In the immediate weight-bearing group, the articular step immediately post-surgery was 0.24 ± 0.8 mm. At the three- and six-week evaluations, the measurements were 0.27 ± 0.9 mm and 0.37 ± 1.2 mm, respectively. Both groups showed a statistically significant difference between the immediate and six-week postoperative time points (p = 0.001; Graph 1). Comparison of the articular step measurements between groups 1 and 2 using Mann-Whitney U test revealed no statistical difference immediately after surgery (p = 0.300), after 3 weeks (p = 0.310), or after 6 weeks (p = 0.453).
In the non-weight-bearing group, the mean articular gap measurement immediately after the surgery was 1.89 ± 1.7 mm. At the three- and six-weeks post-surgery, the gap were 2.12 ± 1.8 mm and 2.36 ± 2.1 mm, respectively. In the immediate weight-bearing group, the articular gap in the day immediately after the surgery was 2.26 ± 2.4 mm; and 2.47 ± 2.6 mm and 2.67 ± 2.8 mm in the third- and six-week examinations, respectively. Similar to the results obtained from the analysis of the articular step, a significant difference was observed between the immediate and six-week postoperative time points in both groups (p = 0.001; Graph 2). Analysis of the articular gap measurements using the Mann-Whitney U test revealed no statistical differences between both groups an any time point (immediate post-surgery, p = 0.933; three weeks post-surgery, p = 0.902; six weeks post-surgery, p = 0.995).
Based on the analysis of the changes in the articular step, satisfactory reduction was observed in 63 (88.8%) and 61 (92.4%) patients in the non-weight-bearing and immediate weight-bearing groups, respectively (p = 0.487). In the final evaluation at six weeks, the number of patients with satisfactory reduction in group 1 was 61 (86.0%), and 59 (89.4%) in group 2 (p = 1.000) (Table 2). From the analysis of the changes in the articular gap measurements, 67 (94.4%) and 57 (86.3%) of the patients in group 1 and group 2, respectively, had a satisfactory reduction (p = 1.000). In the sixth week, the number of patients with a satisfactory gap reduction in group 1 and group 2 was 61 (86.0%) and 51 (77.2%) patients, respectively (p = 0.671;). (Table 3)
As we classified that an increase of > 2 mm in either the articular step or gap as loss of reduction, a total of 5 (7.0%) cases in group 1 and 7 (10.6%) cases in group 2 were considered to fall into this category. Loss of reduction due to early weight-bearing presented a relative risk of 1.506 (CI: 0.503-4.514), although there was no significant difference in the number of cases between groups (p = 0.664) when compared using Fischer's exact test.

Table 1. Mean age, time to surgery and gender.

	Age Mean (SD)	Time to surgery Mean (SD)	Gender n (%)
Non-weight bearing (n=71)	32.9 (12.0)	13.4 (8.5)	Women = 9 (12.7) Men = 62 (87.3)
Immediate weight-bearing (n=66)	35.5 (14.1)	18.5 (21.0)	Women = 13 (19.7) Men = 53 (80.3)

n = number; SD = standard deviation.

Table 2. Associated injuries.

	Immediate weight-bearing n (%)	Non-weight bearing n (%)	Total n	p*
Lower limbs	19 (28,8%)	28 (39,4%)	47	0,260
Vertebral column	4 (6,0%)	6 (8,4%)	10	0,832
Upper limbs	3 (4,5%)	2 (2,8%)	5	0,941

*Z test "p" value.

Table 3. Fracture pattern.

Fracture pattern	Immediate weight-bearing n (%)	Non-weight bearing n (%)	Total n	p*
Posterior wall	19 (28,7%)	12 (16,9%)	31	0,148
Both column	8 (12,1%)	13 (18,3%)	21	0,422
Transverse posterior wall	6 (9,1%)	12 (16,9%)	18	0,273
T-shaped	8 (12,1%)	8 (11,2%)	16	0,918
Transverse	5 (7,5%)	10 (14,0%)	15	0,344
Posterior wall posterior column	11 (16,6%)	4 (5,63%)	15	0,073
Anterior column posterior hemitransverse	4 (6,06%)	5 (7,0%)	9	0,913
Anterior column	5 (7,5%)	1 (1,4%)	6	0,183
Anterior wall	0	2 (2,8%)	2	0,513
Posterior column	0	1 (1,4%)	1	0,966
Non classifiable	0	3 (4,2%)	3	0,272

*Z test "p" value.

DISCUSSION

Following lower limb fracture fixation surgery, early weight-bearing is advantageous as it rapidly improves functional outcome, allowing a faster return to work and minimizing the economic impact of the injury. However, allowing the patients to bear weight may lead to loss of reduction or fixation failure, thereby compromising patient outcomes.[9]
In diaphyseal fractures, the likelihood of complications with early weight-bearing is very low.[10-12] In articular fractures, such as those in the tibial plateau and the ankle, there is evidence that early weight-bearing is safe because it does not cause fracture displacement, and there is no loss of fixation, leading to positive functional outcomes.[13]
In postoperative rehabilitation after operative fixation of an acetabular fracture, the weight-bearing protocol varies from non-weight-bearing for 4 to 10 weeks, toe-touch weight-bearing within the first 6 to 12 weeks, or partial weight-bearing for 6 to 12 weeks.[4] The potential consequences of weight-bearing leading to fixation failure and subsequent loss of reduction may explain the restriction of weight-bearing after acetabular surgery.
With respect to a posterior wall fracture, a systematic review by Heare et al. compared the outcomes following early (unrestricted weight-bearing before 12 weeks) and late weight-bearing (restricted weight-bearing for 12 weeks). They found no significant difference in the Merle dÁubigné functional score and no difference in heterotopic ossification, avascular necrosis, infection, or osteoarthritis.[14]
For associated fracture patterns, existing studies only examined percutaneous fixation of non-displaced or minimally displaced fractures

(< 2 mm). Mouhsine et al.[15] studied the impact of weight-bearing as tolerated after fixation of non-displaced and minimally displaced transverse, T-type, or associated both column fractures subjected to percutaneous fixation, and found that fixation failure did not occur and that the functional results were satisfactory. Kazemi and Archdeacon[16] showed that in anterior column and anterior column posterior-hemitransverse fractures that were fixed percutaneously, rehabilitation with immediate full weight-bearing resulted in radiographic union in all cases and good functional outcomes in 87% of cases.

The literature on the comparison of weight-bearing protocols after fixation of displaced fractures of the acetabulum is limited. To our knowledge, this is the first study to compare immediate weight-bearing as tolerated and non-weight-bearing after surgical fixation of displaced acetabular fractures, while also taking into consideration both elementary and associated fractures.

The mean age of our patients was lower than the mean age reported by Kelly et al. in their literature review (34.1 vs. 43.8).[4] However, we believe that this difference is not significant because the population of patients in both studies are young and have good bone quality. Regarding gender, the majority of our participants were men (83.9%). In our patients, the elementary fracture pattern accounted for 40.1% of the cases, with associated fracture patterns making up 59.9%, with no statistically significant difference between the two groups ($p > 0.05$; Table 3).

The time interval between the fracture and the surgical treatment was 13.4 days, which could have been an issue, as the delay may affect the ability to achieve a successful reduction. Indeed, the average interval in the study completed by Kelly et al.[4] was 6.6 days. However, even with a delay in the surgery, a satisfactory reduction of articular step and gap was achieved in most patients (88.8% for step and 94.4% for gap), similar to the results to the reported by Kelly et al.[4] (87.3%).

Importantly, in group 2, there was no loss of reduction in articular step (Table 4) or gap (Table 5) when patients underwent rehabilitation with immediate weight-bearing protocol at the third- and six-week evaluation, demonstrated by the stable level of reduction that was comparable to the non-weight-bearing group. Both sets of data show that there is no negative radiographic impact of the immediate weight-bearing protocol on the degree of reduction after 6 weeks, indicating that the fixation was sufficient to withstand the physiological load of the weight-bearing as tolerated.

Reduction loss due to early weight bearing presented a relative risk of 1.506 (CI: 0.503 to 4.514), but no significant difference in the total number of cases was apparent when comparing between the groups ($p = 0.664$), indicating that immediate weight-bearing rehabilitation protocol implemented after surgical reduction and fixation of displaced acetabular fractures have no negative repercussions when compared to non-weight-bearing protocol.

While articular step and gap distances were significantly increased in the weight-bearing group after 6 weeks compared to the measurements on the day immediately after surgery ($p = 0.001$), such a difference was also found in the non-weight-bearing group ($p = 0.001$). Although statistically significant, Graphs 1 and 2 reveal a small quantitative variation in both groups. For instance, the mean step and gap increase in the former group was 0.30 mm and 0.12 mm, respectively. The question remains whether such values would have any impact on functional outcomes. We are currently conducting another study to evaluate the functional results in group 2 to further clarify the answer to this question.

As the goal of the study was to analyze de quality of reduction, no functional evaluation was performed. However, it has been shown that there is a correlation between the quality of the reduction, the patient outcomes, and the development of arthritis.[8-17] Therefore, we can infer that as the immediate weight-bearing group achieved and maintained a satisfactory reduction over the 6 weeks, the patients are likely to have a positive functional outcome.

Our study may have been limited by small number of patients, which in turn limited the power of the study. Therefor we may have not detected differences that would otherwise be statistically relevant. The intrinsic limitations to the methodology of retrospective cohort studies should also be considered. Furthermore, we inferred the outcome based on radiographic findings alone, and did not directly assess the functional scores of the patients. Finally, intrinsic difficulties exist when making radiographic measurements, as subjective errors can be introduced by surgeons, or by the malposition of the patient during the X-ray.

CONCLUSION

In conclusion, we found that rehabilitation with immediate weight-bearing after displaced acetabular fracture surgical treatment did not negatively impact the radiographic reduction parameters, and the outcomes were like that of the non-weight-bearing rehabilitation protocol.

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Table 4. Articular step qualitative analyzes.

	Postoperative		3 weeks		6 weeks	
	Satisfactory n (%)	Unsatisfactory n (%)	Satisfactory n (%)	Unsatisfactory n (%)	Satisfactory n (%)	Unsatisfactory n (%)
Group 1 (n=71)	63 (88.8%)	8 (11.2%)	63 (88.8%)	8 (11.2%)	61 (86.0%)	10 (14.0%)
Group 2 (n=66)	61 (92.4%)	5 (7.6%)	60 (90.0%)	6 (10.0%)	59 (89.4%)	7 (10.6%)
	*p = 0.487		*p = 0.555		*p = 1.000	

*Fisher Exact test "p" value.

Table 5. Gap qualitative analyzes.

	Postoperative		3 weeks		6 weeks	
	Satisfactory n (%)	Unsatisfactory n (%)	Satisfactory n (%)	Unsatisfactory n (%)	Satisfactory n (%)	Unsatisfactory n (%)
Group 1 (n=71)	67 (94.4%)	4 (5.6%)	64 (90.2%)	7 (9.8%)	61 (86.0%)	10 (14.0%)
Group 2 (n=66)	57 (86.3%)	9 (13.7%)	54 (81.8%)	12 (18.2%)	51 (77.2%)	15 (22.8%)
	*p = 1.000		*p = 0.582		*p = 0.671	

*Fisher Exact test "p" value.

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