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Review article

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Surgical approaches in the treatment of patients with acute acetabular fractures

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Abstract

Introduction According to the overwhelming majority of Russian and foreign authors, orthopedic traumatologists have been striving to improve the results of surgical treatment of acetabular (AC) fractures over the past decades. First of all, this is due to an increase in the number and severity of this injury, persisting complications and dissatisfaction of researchers with their own results of surgical treatment. **Purpose** Study of the rationale used by traumatologists for certain surgical approaches in the treatment of acute acetabular fractures. **Materials and methods** Literature sources were searched for information in the systems and databases Pubmed, Embase, Scopus, Medline, Cochran Library, eLibrary, Wiley Online Library using the keywords: acetabular fractures, surgical treatment, acetabular approach, open reduction and fixation of acetabular fractures, duration and blood loss, hip arthroplasty. Results The incidence of AC fractures, according to different authors, ranges from 2 to 23.4 %. The cause of this injury is road traffic accidents in up to 83 % of all cases. A significant increase in the number of AC fractures was noted. AC fractures in the vast majority of cases are classified according to AO/ASIF. Displaced AC fractures and multiplanar fractures are subject to surgical treatment. Open reduction and internal fixation still remain the standard treatment for AC fractures. The choice of the surgical approach is carried out more often taking into account the classification of AC fractures, and the type of fracture dictates the choice of approach to the acetabulum. It was found that the authors are forced to use surgical approaches taking into account the fractures of the AC columns. **Discussion** Adherence of traumatologists to the standards regarding indications for the choice of surgical approaches for complex AC fractures was noted. Surgical approaches for the treatment of two-column acetabular fractures are still often extended and traumatic, prolonged and accompanied by blood loss. **Conclusion** In the surgical treatment of pelvic and AC fractures, most authors adhere to standards in the choice of approach and fixation of columns and AC fragments. There is unanimity in the recognition of the trauma and "expansion" of the approaches used, accompanied by blood loss reaching up to 2000 ml and more, and the duration of the operation is on average 3 hours 50 minutes. For the surgical treatment of acute AC fractures, the researchers used both classical and modified anterior and posterior surgical approaches with the obligatory consideration of the classification of AC fractures. The rationale for choosing an operative approach, as a rule, was the determination of the type of AC fracture according to the AO/ASIF classification. The most effective approach in the surgical treatment of AC fractures is the combined anterior and posterior approach.

Keywords: fractures, acetabulum, surgical treatment, surgical approaches, open reduction, fixation, arthroplasty, hip joint

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INTRODUCTION

Management of acetabular (AC) fractures remains a relevant topic due to several factors such as an increase in road injuries, growth of the number and severity of this injury, problems of AC fracture treatment in elderly patients, a high traumatism of the approaches used, persistent complications and dissatisfaction with the results of surgical treatment [1–6]. D. Butterwick et al. note that geriatric patients are the fastest growing subgroup of patients with AC fractures. The incidence of AC fractures in patients over sixty years of age has increased 2.4 times over the past quarter of the century [5].

Purpose To study of the rationale used by traumatologists for certain surgical approaches in the treatment of acute acetabular fractures.

MATERIAL AND METHODS

Literature sources were searched for in the information systems and databases Pubmed, Embase, Scopus, Medline, Cochran Library, eLibrary, Wiley Online Library. Key words in the search were: acetabular fractures, surgical treatment, approaches to the acetabulum, open reduction and fixation of acetabular fractures, duration of intervention and blood loss, hip arthroplasty. No time limit of publications was specified. Fifty-nine sources were analyzed, 48 of which were published in journals indexed by Scopus.

RESULTS

The incidence of AC fractures, according to different authors, ranges from 2 to 23.4 % [1]. Many authors note that the main cause of this injury is road traffic accidents [1, 2, 6–9]. Some researchers attribute AC fractures to high-energy fractures [1, 6, 8, 9], others – to low-energy fractures [10, 11]. J. Jr. Borrelli and JO Anglen note that though the older patients may be involved in high-energy trauma mechanisms and with an increasing rate,

it is common for them to sustain acetabular fractures from low-energy mechanisms such as falling to the ground while playing golf [5, 12]. According to the study conducted by T.A. Ferguson et al. (2010), high-energy mechanisms accounted for 82 % in the adults younger than 60 years of age (884 cases out of the total of 1074 AC fractures) [13]. A regularity of the bimodal distribution of AC fractures by age was noted, with the first peak being fractures in young people, which are the result of high-energy trauma, while the second peak of fractures occurs in the elderly from low-energy mechanisms [4]. The publications provide data on a significant increase in the number of AC fractures, especially in the elderly [10, 12, 14].

The age of patients with AC fractures ranged from 19 to 90 years. E.I. Malt et al. (2009) presented surgical treatment of patients aged 19–49 years [15], R. D. Stibolt et al. (2018) indicated ages from 19 to 90 years, with the average age being 51.5 years [16]. Walley K. C et al. (2018) conducted a study comparing the results of surgical and non-surgical treatment of acetabular fractures in elderly patients (>75 years) and younger patients (> 65 years) patients with severe comorbidities [17]. In his research, D.O. Verbeek et al. (2018) indicate that the average age of patients who underwent open reduction and internal fixation was 51 years, while 72 % were men [18], and R. Firoozabadi et al. (2017) analyzed the results of treatment of 156 patients over 65 years old (mean, 78 years) [18]. T. Borg et al. (2019) in the analysis of short-term results of open reduction and internal fixation of AC fractures, the average age of patients was 72 years (range, 50 to 89) [20]. For the most complete characterization of the AC fractures, the researchers used different classifications, including the classification of R. Judet and E. Letournel [21–26], while others used the AO/ASIF classification [2, 15, 31]. To get a better understanding of the nature of the fracture, to assess the degree of displacement of fragments before and after surgical treatment, examination of patients with computed tomography (CT) with two- and three-dimensional reconstruction of the damaged acetabulum and the hip joint as a whole was performed. It was possible to comprehensively assess all injuries, their stability, the state of the osteochondral structures of the acetabulum and congruence in the hip joint (HJ) [3, 13, 18, 27–29].

Displaced and multiplanar AC fractures are subject to surgical treatment [3, 15, 29–31]. Open reduction and internal fixation (ORIF) remains the standard method of treating AC fractures until now [22, 30, 32, 33]. E. Letournel (1980) wrote that ideal open reduction is the method of choice for treating displaced AC fractures [22].

The terms of performing surgical interventions for AC fractures ranged from 4 to 35.9 days from the moment of injury [24, 28, 29, 31, 34, 35]. A.F. Lazarev et al. note that if the operation is performed in the first 3 weeks from the moment of injury (until the formation of a mature scar), good and excellent results may be achieved in about 80 % of cases while if the intervention is carried out more than 3 weeks later, the sucees is only 65 % [30].

The choice of the operative approach was based on the AO/ASIF classification of fractures [2, 8, 15, 31, 36] or the one by E. Letournel [24–26, 34, 35, 37]. The type of fracture dictates the choice of approach to acetabulum [22]. M. Erem et al. (2019) believe that the choice of one or two approaches should be determined based on the type and location of the fracture in order to improve functional results [25].

When reviewing the published works, it was found that the researchers, having accumulated experience in the treatment of AC fractures, used surgical approaches, first of all, taking into account the fractures of the AC columns, both isolated – anterior or posterior, and with simultaneous fractures of the anterior and posterior columns [38– 43]. We noted that for fractures of only the anterior AC column, in some studies the authors used the same approach as in cases of a combination of fractures of the anterior column and the anterior wall of the AC, and for fractures of the posterior column, they used the same approach as in cases of combined fractures of the posterior column and the posterior wall of the AC [39–44]. E. Letournel (1980) informed that until 1965 the Smith-Petersen incision or its modification, called iliofemoral approach, provided the only access to the upper part of the anterior column of the acetabulum [22]. However, T.V. Alton and A.O. Gee (2014) emphasized that to date, the optimal surgical approaches for each fracture model have not been determined and there is no convenient universal surgical access that would allow a simultaneous easy approach to both AC columns [38].

In fractures of the anterior column and the anterior wall of the AC, as a rule, the authors used the ilioinguinal approach or the Stoppa approach [10, 39, 43, 45–47]. P. Kloen et al. (2002) unequivocally argue that the classical ilioinguinal approach has proven itself well in the treatment of AC fractures [42]. Deng C. at al (2018) combined the ilioinguinal and Kocher-Langenbeck approaches in 31 cases of surgical treatment of AC fractures [24].

M. Rickman et al. (2012), in cases where ORIF of the anterior pelvis was needed, operated the patients in the supine position using a modified Stoppa approach through a transverse skin incision. For fractures of the anterior AC column that extended above the anterior superior iliac spine, the ilioinguinal but not extended, approach was used [10].

For fractures of the posterior column and posterior wall of the AC, some authors, as a rule, perform the

Kocher-Langenbeck approach, and for fractures of the anterior column, the ilioinguinal approach [38, 45–47]. SoThus, Lukas Negrin et al. (2017) consider the Kocher-Langenbeck approach to be the "gold" standard for posterior access to the hip joint and posterior AC column [8]. In the case of combined fractures of both columns, some authors first performed open reduction and internal osteosynthesis of the anterior column from the iliac-inguinal approach in the supine position of the patient, and then of the posterior column from the Kocher-Langenbeck approach with the patient position on his side, or vice versa, i.e. the sequence of approaches depended on the magnitude of main displacement [8, 10, 34]. Other authors preferred to perform first the Kocher-Langenbeck approach and then the ilioinguinal approach [47]. E.I. Malt et al. used the ilioinguinal approach for transverse fractures and fractures of the anterior column of the AC, and in cases of type C fractures, an extended femoral approach was used; for type C2 and C3 fractures, the Y-shaped approach was used [15]. Wang P. et al. (2016) used a modified ilioinguinal approach in combination with the Kocher – Langenbeck approach for fractures of both AC columns [34]. M. Rickman et al. (2012) successfully used the Kocher-Langenbeck approach in fractures of the posterior AC column for the simultaneous execution of ORIF and primary arthroplasty of the hip joint [10]. Erem M. at al (2019) used only one approach in 65.4 % (n = 26) of cases of combined AC fractures, and in other 34.4 % cases (n = 17) were reasonably forced to use two approaches [25].

DISCUSSION

It was decided that for a better acquaintance with the surgical approaches used for the treatment of AC fractures, the rationale for using the approaches, it was necessary to analyze the published works on this topic for the period starting from 1964, when the work of R. Judet, J. Judet, E. Letournel was published (1964), which marked the emergence of the anatomical classification of acetabular fractures (later improved by E. Letournel), in which the author identified 4 types of simple and 2 types of combined (associated) fractures, and a description of the operative access to the acetabulum [21], as evidenced by publications [9, 40, 43, 48, 49]. Moreover, to trace whether the attitude of specialists, even taking into account classified fractures, has changed to the choice of approaches to the acetabulum during this time, and to find out what justifications were used by the authors of publications for choosing indications for this or that approach. Considering the fact that it is impossible to include everything and the limitation of the list of references, we analyzed only some of the available studies on the issue covered. In Table 1 and in Figure 1, we tried to display the classical and modified approaches used by the researchers, while in no case do we pretend that the table is perfect. However, an objective analysis of these author's publications allowed us to draw several conclusions. We analyzed domestic and foreign articles published since 1964 [21], including 33 in the last 5 years. Table 1 includes 24 authors. The criteria for including authors in the Table were, first, the use of the most frequently used in practice [48] standard and modified approaches to the acetabulum. Second, we decided to highlight the features of the use of approaches to the acetabulum (which we noted in the conclusions) over several conditional periods: 1964 – 1980 – 1995 – 2000, 2001 – 2010 and 2011 – 2019, in order to understand whether there were changes over time periods. It is clear that the table could not be endless, so we could not include all the cited researchers. Third, we found to a greater extent the complete necessary information and received answers to our own questions in the text of the articles of the authors included in the table after comparison with other authors. Fourth, those authors were selected who gave a more detailed description to the approaches, their nuances, indications, complications associated with them, what was important for us. Five, the authors presented in their works the largest number of cases with the use of one or another approach to the acetabulum, which is also important. Sixth, the articles of the authors in the table were published in the time periods indicated by us.

Table 2 presents the types of AC fractures listed in scientific studies and classified according to E. Letournel [22]. The authors identified isolated and "associated" AC fractures (anterior column and anterior wall) [9, 40, 43, 46, 48 49], as well as in combination with fractures of the femoral head and neck (Table 2) [32, 46, 47, 50]. According to published studies, operative approaches were used according to the diagnosed and then classified AC fractures, which are reflected in Table 2 and Figure 2. Unfortunately, we could not include AC fractures accompanied by dislocation of the femoral head in Table 2 (so as not to overload it), and we consider it one of the disadvantages.

Anterior approaches were used for both simple / elementary AC fractures (anterior column, anterior wall) and associated fractures (anterior column and anterior wall) [9, 40, 43, 48, 49] in combination with fractures of the femoral head and neck [46, 47, 49, 50]. Of the anterior approaches, the authors more often used the ilioinguinal in the period from 1964 to 2019, including the modified iliac-inguinal [9, 19, 21, 24]. Ferguson T.A. (2010) and Clarke-Jenssen et al. (2017) in there large studies on the long-term

results of ORIF and hip arthroplasty, emphasize the detailed characterization of AC fractures classified by E. Letournel; however, we did not find the surgical approaches in these sources [13, 49].

According to Harris A.M. at al. (2008), some complex AC fractures can be effectively operated using a single approach, but some combined fractures require a broader approach. The simultaneous use of anterior and posterior approaches can be a safe and useful alternative to extended approaches. The authors point out the advantages of the combination of anterior and posterior approaches for transverse fractures of the posterior wall with wide anterior displacement, type T fractures with significant anteroposterior displacement, or fractures of both columns with involvement of the posterior wall [44]. Other authors also report the advantages of the simultaneous use of the anterior and posterior approaches [24, 25, 40, 51, 52]. Table 1 does not include approaches rarely cited in publications or a rare combination of approaches, and namely of Olier, Smith-Petersen, Watson-Jones, Harding, pararectal and a combination of approaches of Stoppa+Kocher – Langenbeck, used by one or two authors [24, 37 , 42, 50, 53].

Table 1

Approaches to the acetabulum and the number of operations with different approaches

Author, reference number	Number of operations with different approaches to the acetabulum according to the authors' data							
	Total of operations	1	2	3	4	5	6	7
Judet R. et al., 1964 [21]	173		n* / 129	n* / 129		n* / 129		
Letournel E., 1980 [22]	582	n*	n*	n*				
Letournel E., 1993 [7]	195	178			17			
Cole J. at al., 1994 [39]	55							55
Matta J.M., 1996 [41]	262	n* / 259	n* / 259	n* / 259	4			
Kloen P. et al., 2002 [42]	15	n*				n*		
Matta JM, 2006 [54]	373	211		159	3			
Harris AM et al., 2008 [44]	51		n*	n*				
Andersen RC et al., 2010 [45]	17							17
Rickman M. et al., 2012 [12]	12	n*		n*				n*
Yang Y. et al., 2015 [46]	46	26				20		
You-Shui Gao et al., 2015 [47]	61	49		12				
Boelch S. et al., 2016 [32]	23			3		20		
Wang P. et al., 2016 [34]	73	27		73	27	46		
Clarke-Jenssen J. et al., 2017 [49]	285	n*		n*	n*			
Reza Firoozabadi et al., 2017 [19]	409	282		119	8			
Deng C. et al., 2018 [24]	31		7		13			7
Salama W. et al., 2018 [55]	18			17	1			
Borg T. et al., 2019 [20]	27	8		5	1		2	
Erem M. et al., 2019 [25]	47	17		18	11			1
Frietman B. et al. , 2019 [26]	220	99	9	83				29
Lont, T. et al., 2019 [9]	59	25		34				
Boudissa M. et al., 2019 [51]	73	n*/38		n*/38	n*/38			
Kilinc CY et al., 2019 [48]	63							63

Legend: access to the acetabulum: 1 – ilio-inguinal; 2 – ilio-femoral; 3 – Kocher-Langenbeck; 4 – ilio-inguinal + Kocher-Langenbeck; 5 – modified iliac-inguinal; 6 – ilio-inguinal + Smith-Peterson; 7 – Stoppa modified.
Note: n* – not specified.

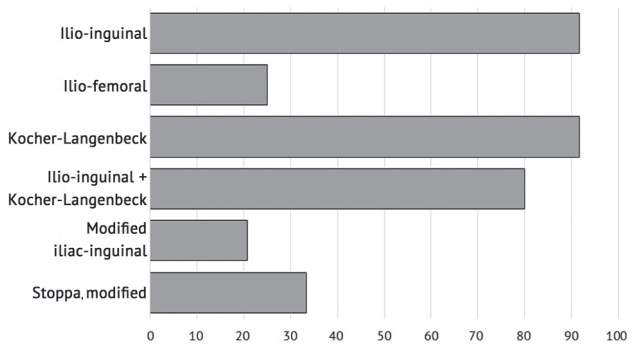

Fig. 1 Diagram of frequency of approaches to the acetabulum used

Table 2

Incidence of isolated and combined AC fractures (E. Letournel classification) in the publications of the authors

Author, reference number	Number of AC fractures according to the reported data of the authors											
	Total	1	2	3	4	5	6	7	8	9	10	11
Judet R. et al., 1964 [21]	173	9	57		17					74		16
Letournel E., 1980 [22]	195	n* / 39	n* / 39	n* / 98	n* / 39	n* / 39	n* / 98	39	n* / 98	n* / 39	n* / 98	98
Letournel E., 1993 [7]	582	27	157	18	27	15		37	43	56	134	131
Cole J. at al., 1994 [39]	55			n*	n*	n*		n*	n*	n*		n*
Matta J.M., 1996 [41]	92			n*			n*	n*			n*	35 %
Kloen P. et al., 2002 [42]	15				3	1		4				7
Matta J.M., 2006 [56]	373	15	20	7	22	2		22	71	20	67	127
Harris AM et al., 2008 [44]	51		13					2	10	3		23
Andersen RC et al., 2010 [45]	17	n*			n*							
Rickman M. et al., 2012 [12]	12	2		2				3	4	1		
Yang Y. et al., 2015 [46]	46				31							
You-Shui Gao et al., 2015 [47]	61	2	7	3		1	0	0	6	4	7	31
Boelch S. et al., 2016 [32]	32		3	1	3			1	n* / 7	n* / 7		15
Wang, P. et al., 2016 [34]	73								15	21	11	26
Clarke-Jenssen J. et al., 2017 [49]	99	n*	n*	n*	n*	n*	n*	n*	n*	n*	n*	
Reza Firoozabadi et al., 2017 [19]	409						9	283				107
Deng C. et al., 2018 [24]	31	0	0	0	0	0	0	8	5		6	12
Salama W. et al., 2018 [58]	18	1	12						2	3		1
Borg T. et al., 2019 [20]	27	0	5	1	0	0	0	12	0	0	2	7
Erem M. et al., 2019 [25]	47	n* / 21	n* / 21	n* / 26	n* / 21	n* / 21	n* / 26	n* / 26	n* / 26	n* / 21	n* / 26	n* / 26
Frietman B. et al. , 2019 [26]	220	3	38	17	27	21		33	14	7	23	37
Lont, T. et al., 2019 [9]	59	1	3	3	5	1	0	3	35	1	1	6
Boudissa M. et al., 2019 [51]	38	3	6	1	8	0	0	11	0	0	4	5
Kilinc CY. et al., 2019 [48]	63	0	0	0	5	2	0	7	12	10	0	27

Legend: 1 – Post. Column; 2 – Post. Wall; 3 – Post. column + Post. Wall; 4 – Anter. Column; 5 – Anter. Wal; 6 – Anter. column + anter. wall; 7 – Anter. column + anter. wall + semitransverse fracture of post. Wall; 8 – T-shaped fracture ; 9 – Transverse fracture; 10 – Transverse fracture of poster. Wal; 11 – Fracture of both columns.
Note: n* – not specified.

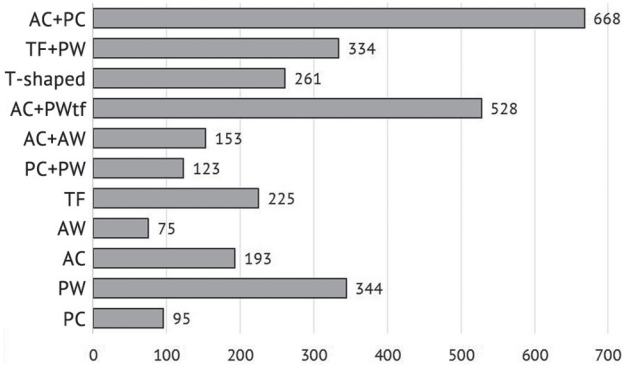

Fig. 2 Diagram of the incidence of isolated and combined AC fractures

The combined use of anterior and posterior approaches is primarily due to the complexity of AC fractures, significant displacement of columns and fragments, and difficulties in visualizing all injuries during reduction and osteosynthesis [21, 40, 52]. The simultaneous use of anterior and posterior approaches created conditions for a good view of the damaged parts of the AC, allowed surgeons to perform adequate reduction of both columns and fragments and perform their osteosynthesis, and, if necessary, primary arthroplasty of the hip joint [42, 50, 54–56]. Noteworthy is the study by P. Kloen et al. (2019), in which the authors describe the technique of "opening" the hip joint with subluxation or dislocation of the femoral head by adduction and external rotation of the leg with "gentle" traction of the femur. This technology allowed the authors to assess the articular surfaces of the femoral head and AC, examine the cartilaginous labrum of the AC, and perform reduction and fixation of fragments under intra-articular visual control [42]. It should be noted that many studies contain data on the results of using modified approaches to AC [12, 35, 37, 39, 45, 46]. Wang P. et al. (2019), while studying the modified ilioinguinal access, noted that conventional approaches have serious complications associated with the duration of surgery, trauma, including the inguinal neurovascular bundle and lymphatic structures, large blood loss, and the development of surgical infections, hernias and heterotopic ossification.

The authors also point out that the modified ilioinguinal approach in combination with the Kocher – Langenbeck approach suggests a shorter operation time, less blood loss, and fewer complications [34]. It is appropriate to say here that many authors note significant blood loss in ORIF for AC fractures, which reaches from 600 to 2000 ml and more, and the duration of the operation, as a rule, exceeds 2 hours, and on average is 3 hours 50 minutes [8, 12, 14 , 34, 35].

P. Kloen et al. (2002) stated three main, in their opinion, reasons for the modification of the ilioinguinal approach. First, there is no possibility of good visualization in cases of fragmentated fractures of the anterior wall or lower parts of the anterior column to ensure accurate anatomical reduction and internal fixation. In the classical ilioinguinal approach, this limitation is conditioned by the iliopsoas muscle. Second, there is no possibility for intra-articular visualization by the ilioinguinal approach, which assumes the congruence of the joint to be assessed by the state of the visible extra-articular surface of the joint. Third, mobilization of the iliopsoas muscle in the classical ilioinguinal approach requires separation of the iliocapsular muscle ("iliocapsular", author's term) from the iliac muscle. And, finally, a frequent postoperative complication is trauma to the external cutaneous femoral nerve, which can be an unpleasant problem both for the patient and the surgeon. At the same time, the authors note that the modification of the ilioinguinal approach is a useful addition to the arsenal of surgery of the acetabulum and hip joint for certain types of fractures and clearly does not propose to replace the classical ilioinguinal approach, but rather to expand its versatility in specific cases [42]. A number of authors used the Stoppa modified approach technique and studied the results of treatment of AC fractures [12, 25, 39, 43, 45, 48]. S. McDowell et al. (2012), in a retrospective clinical study, described the results of Olier's modified trans-trochanter approach in 95 cases of treatment of AC fractures. Among the advantages of the technology, the author pointed to a good overview of the proximal ilium and a complete view of the acetabulum [37]. J. Chen et al. (2019) believe that the lateral direct approach to the acetabulum is an alternative to the ilioinguinal approach in elderly patients [53]. In terms of highlighting separate cases is a rare case so far of using arthroscopy for open reduction of anterior AC fractures described by Y. Kazushige et al. (2016). The simultaneous use of arthroscopy allowed the authors to reduce trauma and increase the efficiency of the main anterior approach [57].

The authors paid special attention to surgical approaches in elderly patients with AC fractures. J. Chen et al. (2019) obtained good functional and radiological results and a low rate of complications using the pararectal (lateral rectal, author term) approach in elderly patients with AC fractures [53]. A number of authors have successfully used a combination of the anterior ilioinguinal approach with the Kocher-Langenbeck approach in the treatment of AC fractures in elderly patients for simultaneous ORIF and primary hip arthroplasty [6, 49, 51, 53, 58].

Figure 3 shows a diagram of the rates of surgical approaches used over 4 time periods. Figure 4 shows a diagram of the number of surgical interventions performed with access to the AC.

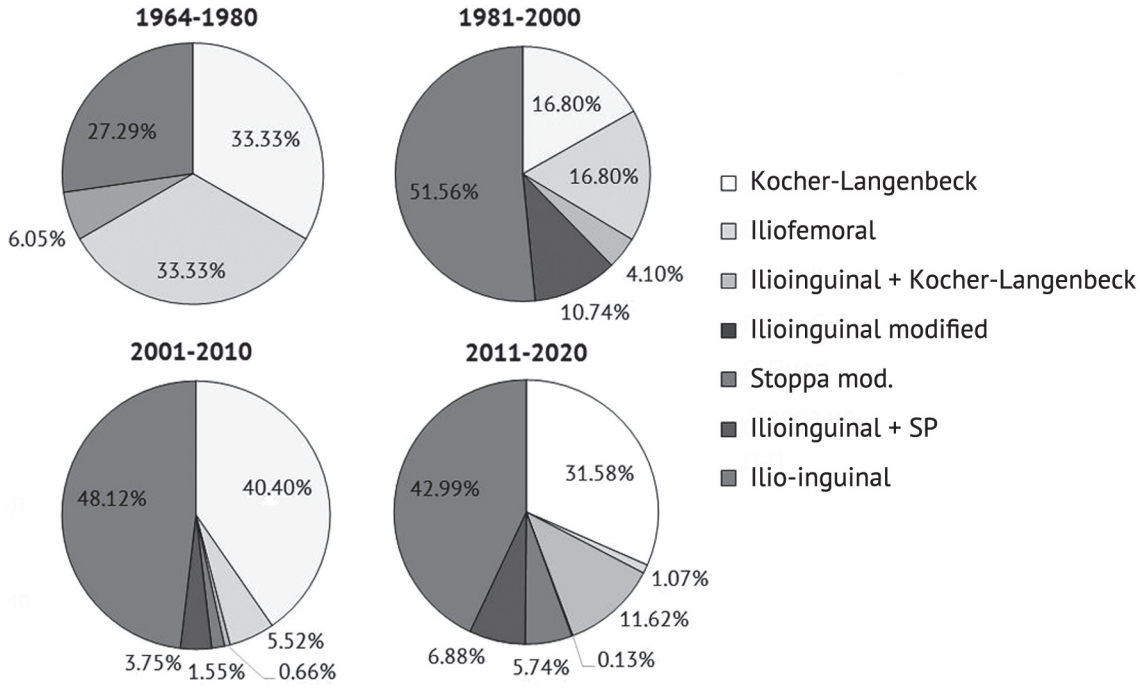

Fig. 3 Diagram of the rates of applied surgical approaches in four periods of time

It must be admitted that the indicated in Figure 3 data, unfortunately, do not fully reflect the actual reality of the use of approaches to AC for reasons understandable to all of us, since not all authors publish their materials. We have no real opportunity to find all published and reliable material on this topic. However, it can be clearly seen that the ilioinguinal approach (27–51 %), the Kocher-Langenbeck approach (16–40 %), the modified iliac-inguinal approach (5–33 %) and the combination of ilioinguinal and Kocher-Langenbeck approaches in 11 % of cases are most common.

It is seen that the ilioinguinal approach was used with almost equal frequency with small fluctuations in the 4 periods studied. In our opinion, it depended on the number of injuries and the nature of the fractures. The Kocher-Langenbeck approach was also used evenly during these periods, but with less frequency.

Of particular interest is Figure 4, where the number of surgical interventions performed using different approaches and its association with periods. In the last two decades, the dominance of the number of operations performed using the ilio-inguinal, Kocher-Langenbeck approaches and a combination of the latter has been clearly traced. Also, there has been an increase in surgical interventions using modified ilioinguinal and Stoppa approaches and a sharp decrease in the number of operations performed using the ilio-femoral approach.

There has been a clear trend towards primary hip arthroplasty for displaced AC fractures in recent years, which is the best treatment option due to the possibility of early mobilization of patients and prevention of complications associated with bed rest [9, 19, 50, 51, 55, 59]. M. Rickman et al. (2012) and Mehdi Boudissa et al. (2019) performed hip joint arthroplasty from the posterior Kocher-Langenbeck approach, and ORIF was performed from the anterior ilioinguinal approach [10, 51]. This tactic is justified by many authors, especially when treating elderly patients [11, 12, 13, 20, 32, 33]. Wael Salama et al. (2018) simultaneously performed ORIF and hip arthroplasty using the Kocher-Langenbeck approach in 18 patients. It should be noted that the first step in cases of arthroplasty was resection of the femoral neck to visualize fragments of the acetabulum, which had been adjusted and fixed with Kirschner wires [58].

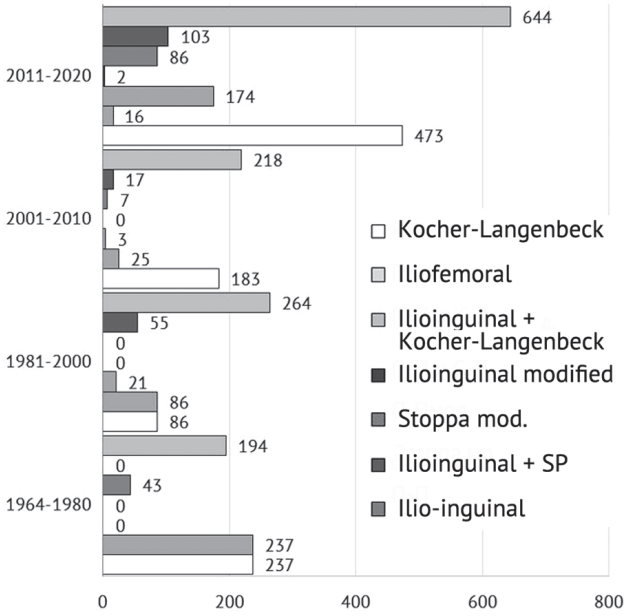

Fig. 4 Diagram of the number of surgical interventions performed and approaches to the acetabulum

CONCLUSION

The incidence of AC fractures ranges from 2 to 23.4 %; according to a number of authors. They are high-energy injuries, and in 83 % of all cases the cause of the injury is road traffic accidents. Displaced AC fractures and multiplanar fractures are subject to surgical treatment. Open reduction and internal fixation (ORIF) remains the standard method of treating acetabular fractures to this day. The choice of the operative approach is based on the classification of fractures according to AO / ASIF. To improve functional results, the choice of one or two approaches should be determined based on the type and location of the fracture. All authors used classical surgical approaches to the acetabulum, taking into account the classification of fractures. In the opinion of the majority of the cited authors, the most effective in the surgical treatment of AC fractures is the combined anterior and posterior approach. The combined use of the anterior and posterior approaches is primarily due to the complexity of AC fractures, significant displacement of columns and fragments, and creats conditions for good visualization of almost all damaged AC parts, which allows surgeons to perform adequate open reduction and osteosynthesis of both columns and fragments, and primary hip arthroplasty, if necessary.

According to the cited authors, the ilioinguinal approach was used by 17 of them (70.8 %). Modified options were practiced by 5 (20.8 %) authors, and, in general, along with simultaneous use of the Kocher-Langenbeck access by 12 authors (50 %), this approach was used by 22 (91.7 %) authors. The Kocher-Langenbeck approach was also practiced, which was used by 17 (70.8 %) authors in an isolated version and in combination with the ilioinguinal approach by 12 (50 %). In general, the access was used by 22 (91.7 %) authors. Stoppa's approach, both in “pure” form and in combination was applied by 8 authors (33 %). The use of the modified classical ilioinguinal and Kocher-Langenbeck approaches is determined by the emerging serious intra- and postoperative complications associated primarily with the duration of surgery,

tissue trauma, including the inguinal neurovascular bundle and lymphatic structures, large blood loss, the development of surgical infection, the formation of hernias and heterotopic ossification, and is aimed at improving the visualization of the acetabulum, especially in fragmented fractures, ensuring accurate anatomical reduction and internal fixation, accurate anatomical reduction and internal fixation, reducing the operation time, blood loss and complications.

Most authors who adhere to the standard classical approaches and fixation of fragments in the surgical treatment of AC fractures point their significant trauma, accompanied by blood loss reaching up to 2000 ml or more and the average duration of the operation of 3 hours 50 minutes, which becomes a restricting factor in widespread use in the acute the period of injury. However, open reduction and internal fixation are currently the standard treatment for pelvic and AC fractures. In our opinion, the search for an alternative approach to the surgical treatment of some, although not all types of AC fractures, will be justified.

REFERENCES

1. Grin A.A., Runkov A.V., Shlykov I.L. Vybor operatsionnogo dostupa pri lechenii dvukhkolonnykh perelomov vertluzhnoi vpadiny [Selection of the surgical approach for the treatment of two-column acetabular fractures]. *Travmatologiia i Ortopediia Rossii*, 2014, no. 1 (71), pp. 92-97. (in Russian)
2. Bondarenko A.V., Kruglykhin I.V., Plotnikov I.A., Voitenko A.N., Zhmurkov O.A. Osobennosti lecheniia povrezhdenii taza pri politravme [Particular characteristics of the treatment of pelvic injuries in polytrauma]. *Politravma*, 2014, no. 3, pp. 46-57. (in Russian)
3. Beletskii A.V., Voronovich A.I., Murzich A.E. Opredelenie pokazanii k operativnomu lecheniiu i vybor khirurgicheskikh dostupov pri slozhnykh kompleksnykh perelomakh vertluzhnoi vpadiny [Determination of indications for surgical treatment and selection of surgical approaches for difficult complex acetabular fractures]. *Vestnik Travmatologii i Ortopedii im. N.N. Priorova*, 2010, vol. 17, no. 4, pp. 30-37. (in Russian)
4. Sardesai N.R., Miller M.A., Jauregui J.J., Griffith C.K., Henn R.F., Nascone J.W. Operative management of acetabulum fractures in the obese patient: challenges and solutions. *Orthop. Res. Rev.*, 2017, vol. 9, pp. 75-81. DOI: 10.2147/ORR.S113424.
5. Butterwick D., Papp S., Gofton W., Liew A., Beaulé P.E. Acetabular fractures in the elderly: evaluation and management. *J. Bone Joint Surg. Am.*, 2015, vol. 97, no. 9, pp. 758-768. DOI: 10.2106/JBJS.N.01037.
6. Erden A. Acetabular Fractures – A Review of their Management. *J. Trauma & Treatment*, 2015, vol. 4, no. 4. DOI: 10.4172/2167-1222.1000278.
7. Laird A., Keating J.F. Acetabular fractures: a 16-year prospective epidemiological study. *J. Bone Joint Surg. Br.*, 2005, vol. 87, no. 7, pp. 969-973. DOI:10.1302/0301-620X.87B7.16017.
8. Negrin L.L., Seligson D. Results of 167 consecutive cases of acetabular fractures using the Kocher-Langenbeck approach: a case series. *J. Orthop. Surg. Res.*, 2017, vol. 12, no. 1, pp. 66. DOI: 10.1186/s13018-017-0563-6.
9. Kubota M., Uchida K., Kokubo Y., Shimada S., Matsuo H., Yayama T., Miyazaki T., Takeura N., Yoshida A., Baba H. Changes in gait pattern and hip muscle strength after open reduction and internal fixation of acetabular fracture. *Arch. Phys. Med. Rehabil.*, 2012, vol. 93, no. 11, pp. 2015-2021. DOI: 10.1016/j.apmr.2012.01.016.
10. Rickman M., Young J., Bircher M., Pearce R., Hamilton M. The management of complex acetabular fractures in the elderly with fracture fixation and primary total hip replacement. *Eur. J. Trauma Emerg. Surg.*, 2012, vol. 38, no. 5, pp. 511-516. DOI: 10.1007/s00068-012-0231-9.
11. Lont T., Nieminen J., Reito A., Pakarinen T.K., Pajamäki I., Eskelinen A., Laitinen M.K. Total hip arthroplasty, combined with a reinforcement ring and posterior column plating for acetabular fractures in elderly patients: good outcome in 34 patients. *Acta Orthop.*, 2019, vol. 90, no. 3, pp. 275-280. DOI: 10.1080/17453674.2019.1597325.
12. Borrelli J. Jr., Anglen J.O., editors. *Arthroplasty for the Treatment of Fractures in the Older Patient. Indications and current techniques*. Springer International Publishing, 2018, pp. 280. DOI: 10.1007/978-3-319-94202-5.
13. Ferguson T.A., Patel R., Bhandari M., Matta J.M. Fractures of the acetabulum in patients aged 60 years and older: an epidemiological and radiological study. *J. Bone Joint Surg. Br.*, 2010, vol. 92, no. 2, pp. 250-257. DOI: 10.1302/0301-620X.92B2.22488.
14. Chegurov O.K., Menshchikov I.N. Lechenie povrezhdenii vertluzhnoi vpadiny i ikh posledstvii (obzor literatury) [Treatment of acetabular injuries and the consequences (review of literature)]. *Genij Ortopedii*, 2018, vol. 24, no. 1, pp. 95-101. DOI 10.18019/1028-4427-2018-24-1-95-101.
15. Solod E.I., Lazarev A.F., Lazarev A.A., Gudushauri Ia.G., Kakabadze M.G., Roskidailo A.S., Dan I.M. Vozmozhnosti operativnogo lecheniia perelomov vertluzhnoi vpadiny s ispolzovaniem maloinvazivnykh tekhnologii [Possibilities of surgical treatment of acetabular fractures using minimally invasive technologies]. *Vestnik Travmatologii i Ortopedii im. N.N. Priorova*, 2009, vol. 16, no. 2, pp. 3-9. (in Russian)
16. Stibolt R.D. Jr., Patel H.A., Huntley S.R., Lehtonen E.J., Shah A.B., Naranje S.M. Total hip arthroplasty for posttraumatic osteoarthritis following acetabular fracture: A systematic review of characteristics, outcomes, and complications. *Chin. J. Traumatol.*, 2018, vol. 21, no. 3, pp. 176-181. DOI: 10.1016/j.cjtee.2018.02.004.
17. Walley K.C., Appleton P.T., Rodriguez E.K. Comparison of outcomes of operative versus non-operative treatment of acetabular fractures in the elderly and severely comorbid patient. *Eur. J. Orthop. Surg. Traumatol.*, 2017, vol. 27, no. 5, pp. 689-694. DOI: 10.1007/s00590-017-1949-1.
18. Verbeek D.O., van der List J.P., Tissue C.M., Helfet D.L. Long-term patient reported outcomes following acetabular fracture fixation. *Injury*, 2018, vol. 49, no. 6, pp. 1131-1136. DOI: 10.1016/j.injury.2018.04.031.
19. Firoozabadi R., Cross W.W., Krieg J.C., Routt M.L.C. Acetabular Fractures in the Senior Population – Epidemiology, Mortality and Treatments. *Arch. Bone Jt. Surg.*, 2017, vol. 5, no. 2, pp. 96-102.
20. Borg T., Hernefalk B., Hailer N.P. Acute total hip arthroplasty combined with internal fixation for displaced acetabular fractures in the elderly: a short-term comparison with internal fixation alone after a minimum of two years. *Bone Joint J.*, 2019, vol. 101-B, no. 4, pp. 478-483. DOI: 10.1302/0301-620X.101B4.BJJ-2018-1027.R2.
21. Judet R., Judet J., Letournel E. Fractures of the acetabulum: classification and surgical approaches for open reduction. Preliminary report. *J. Bone Joint Surg. Am.*, 1964, vol. 46, pp. 1615-1646.
22. Letournel E. Acetabulum fractures: classification and management. *Clin. Orthop. Relat. Res.*, 1980, no. 151, pp. 81-106.
23. Butler B.A., Lawton C.D., Hashmi S.Z., Stover M.D. The Relevance of the Judet and Letournel Acetabular Fracture Classification

System in the Modern Era: A Review. *J. Orthop. Trauma*, 2019, vol. 33, no. Suppl 2, pp. S3-S7. DOI: 10.1097/BOT.0000000000001401.
24. Deng C., Ni W.D., Guo S.Q., Luo G., Shui W., Qiao B. [Operative treatment of delayed acetabular fractures through combined anterior and Kocher-Langenbeck approaches]. *Zhonghua Wai Ke Za Zhi*, 2018, vol. 56, no. 3, pp. 196-200. DOI: 10.3760/cma.j.issn.0529-5815.2018.03.006. (in Chinese)
25. Erem M., Copuroglu C., Copuroglu E., Ciftdemir M., Ozcan M., Saridogan K. Effects of the incısıon preference ın acetabular surgery on the postoperatıve functıonal outcomes. *Niger. J. Clin. Pract*., 2019, vol. 22, no. 6, pp. 862-868. DOI: 10.4103/njcp.njcp_455_18.
26. Frietman B., Biert J., Edwards M.J.R. Patient-reported outcome measures after surgery for an acetabular fracture. Bone Joint J., 2018, vol. 100-B, no. 5, pp. 640-645. DOI:10.1302/0301-620X.100B5.BJJ-2017-0871.R3.
27. Meesters A.M.L., Kraeima J., Banierink H., Slump C.H., de Vries J.P.P.M., Ten Duis K., Witjes M.J.H., IJpma F.F.A. Introduction of a three-dimensional computed tomography measurement method for acetabular fractures. *PLoS One*, 2019, vol. 14, no. 6, pp. e0218612. DOI: 10.1371/journal.pone.0218612.
28. Cai L., Lou Y., Guo X., Wang J. Surgical treatment of unstable pelvic fractures with concomitant acetabular fractures. *Int. Orthop*., 2017, vol. 41, no. 9, pp. 1803-1811. DOI: 10.1007/s00264-017-3532-0.
29. Magu N.K., Gogna P., Singh A., Singla R., Rohilla R., Batra A., Mukhopadhyay R. Long term results after surgical management of posterior wall acetabular fractures. *J. Orthop. Traumatol*., 2014, vol. 15, no. 3, pp. 173-179. DOI: 10.1007/s10195-014-0297-8.
30. Lazarev A.F., Solod E.I., Gudushauri Ia.G., Kakabadze M.G., Stoiukhin S.S., Sakharnykh I.N. Problemy lecheniia perelomov vertluzhnoi vpadiny [Problems of treating acetabular fractures]. *Vestnik Travmatologii i Ortopedii im. N.N. Priorova*, 2013, vol. 20, no. 4, pp. 81-85. (in Russian)
31. Solod E.I., Lazarev A.F., Gudushauri Ia.G., Kakabadze M.G., Sakharnykh I.N., Stoiukhin S.S. Sovremennye vozmozhnosti osteosinteza vertluzhnoi vpadiny [Modern possibilities of acetabular osteosynthesis]. *Vestnik Travmatologii i Ortopedii im. N.N. Priorova*, 2014, vol. 1, no. 2, pp. 25-32. (in Russian)
32. Boelch S.P., Jordan M.C., Meffert R.H., Jansen H. Comparison of open reduction and internal fixation and primary total hip replacement for osteoporotic acetabular fractures: a retrospective clinical study. *Int. Orthop*., 2017, vol. 41, no. 9, pp. 1831-1837. DOI: 10.1007/s00264-016-3260-x.
33. Hanschen M., Pesch S., Huber-Wagner S., Biberthaler P. Management of acetabular fractures in the geriatric patient. *SICOT J*., 2017, vol. 3, pp. 37. DOI: 10.1051/sicotj/2017026.
34. Wang P., Zhu X., Xu P., Zhang Y., Wang L., Liu X., Mu W. Modified ilioinguinal approach in combined surgical exposures for displaced acetabular fractures involving two columns. *Springerplus*, 2016, vol. 5, no. 1, pp. 1602. DOI: 10.1186/s40064-016-3316-9.
35. Liu Z.J., Jia J., Zhang Y.G., Tian W., Jin X., Hu Y.C. Internal Fixation of Complicated Acetabular Fractures Directed by Preoperative Surgery with 3D Printing Models. *Orthop. Surg*., 2017, vol. 9, no. 2, pp. 257-260. DOI: 10.1111/os.12324.
36. Tornetta P. 3rd. Non-operative management of acetabular fractures. The use of dynamic stress views. *J. Bone Joint Surg. Br*., 1999, vol. 81, no. 1, pp. 67-70. DOI: 10.1302/0301-620x.81b1.8805.
37. McDowell S., Mullis B., Knight B.S., Dahners L.E. Modified Ollier transtrochanteric approach for the treatment of acetabular fractures. *Orthopedics*, 2012, vol. 35, no. 2, pp. e132-e136. DOI: 10.3928/01477447-20120123-03.
38. Alton T.B., Gee A.O. Classifications in brief: Letournel Classification for acetabular fractures. *Clin. Orthop. Relat. Res*., 2014, vol. 472, no. 1, pp. 35-38. DOI: 10.1007/s11999-013-3375-y.
39. Cole J.D., Bolhofner B.R. Acetabular fracture fixation via a modified Stoppa limited intrapelvic approach. Description of operative technique and preliminary treatment results. *Clin. Orthop. Relat. Res*., 1994, no. 305, pp. 112-123.
40. Matta J.M. Operative treatment of acetabular fractures through the ilioinguinal approach. A 10-year perspective. *Clin. Orthop. Relat. Res*., 1994, no. 305, pp. 10-19.
41. Matta J.M. Fractures of the acetabulum: accuracy of reduction and clinical results in patients managed operatively within three weeks after the injury. *J. Bone Joint Surg. Am*., 1996, vol. 78, no. 11, pp. 1632-1645.
42. Kloen P., Siebenrock K.A., Ganz R. Modification of the ilioinguinal approach. *J. Orthop. Trauma*, 2002, vol. 16, no. 8, pp. 586-593. DOI: 10.1097/00005131-200209000-00008.
43. Jakob M., Droeser R., Zobrist R., Messmer P., Regazzoni P. A less invasive anterior intrapelvic approach for the treatment of acetabular fractures and pelvic ring injuries. *J. Trauma*, 2006, vol. 60, no. 6, pp. 1364-1370. DOI: 10.1097/01.ta.0000208139.97474.f7.
44. Harris A.M., Althausen P., Kellam J.F., Bosse M.J. Simultaneous anterior and posterior approaches for complex acetabular fractures. *J. Orthop. Trauma*, 2008, vol. 22, no. 7, pp. 494-497. DOI: 10.1097/BOT.0b013e3181830d2a.
45. Andersen R.C., O'Toole R.V., Nascone J.W., Sciadini M.F., Frisch H.M., Turen C.W. Modified Stoppa approach for acetabular fractures with anterior and posterior column displacement: quantification of radiographic reduction and analysis of interobserver variability. *J. Orthop. Trauma*, 2010, vol. 24, no. 5, pp. 271-278. DOI:10.1097/BOT.0b013e3181b2b4ca.
46. Yang Y., Li Q., Cui H., Hao Z., Wang Y., Liu J., Li L., Zhou D. Modified ilioinguinal approach to treat pelvic or acetabular fractures: a retrospective study. *Medicine* (Baltimore), 2015, vol. 94, no. 37, pp. e1491. doi: 10.1097/MD.0000000000001491.
47. Gao Y.S., Zhou Z.B., Tang M.J., Yu X.W., Chen S., Zhang C.Q., Sun Y.Q. Late surgery for acetabular fractures in a Chinese level I trauma centre: surgical experience and outcomes. *Int. Orthop*., 2015, vol. 39, no. 9, pp. 1865-1871. DOI: 10.1007/s00264-015-2932-2.
48. Kilinc C.Y., Acan A.E., Gultac E., Kilinc R.M., Hapa O., Aydogan N.H. Treatment results for acetabulum fractures using the modified Stoppa approach. *Acta Orthop. Traumatol. Turc*., 2019, vol. 53, no. 1, pp. 6-14. DOI: 10.1016/j.aott.2018.11.003.
49. Clarke-Jenssen J., Røise O., Storeggen S.A.Ø., Madsen J.E. Long-term survival and risk factors for failure of the native hip joint after operatively treated displaced acetabular fractures. *Bone Joint J*., 2017, vol. 99-B, no. 6, pp. 834-840. DOI: 10.1302/0301-620X.99B6.BJJ-2016-1013.R1.
50. Resch H., Krappinger D., Moroder P., Auffarth A., Blauth M., Becker J. Treatment of acetabular fractures in older patients-introduction of a new implant for primary total hip arthroplasty. *Arch. Orthop. Trauma Surg*., 2017, vol. 137, no. 4, pp. 549-556. DOI: 10.1007/s00402-017-2649-3.
51. Boudissa M., Francony F., Drevet S., Kerschbaumer G., Ruatti S., Milaire M., Merloz P., Tonetti J. Operative versus non-operative treatment of displaced acetabular fractures in elderly patients. *Aging Clin. Exp. Res*., 2020, vol. 32, no. 4, pp. 571-577. DOI: 10.1007/s40520-019-01231-5.
52. Letournel E., Judet R. *Fractures of the Acetabulum*. 2nd Ed. Berlin, Heidelberg, Springer-Verlag, 1993, pp. 375-385, 521-540, 591-633. DOI: 10.1007/ 978-3-642-75435-7.
53. Chen J., Liu H., Wang C., Lin X., Gu C., Fan S. Internal fixation of acetabular fractures in an older population using the lateral-rectus approach: short-term outcomes of a retrospective study. *J. Orthop. Surg. Res*., 2019, vol. 14, no. 1, pp. 4. DOI: 10.1186/s13018-018-1039-z.
54. Matta J.M. Operative treatment of acetabular fractures through the ilioinguinal approach: a 10-year perspective. *J. Orthop. Trauma*,

2006, vol. 20, no. 1 Suppl., pp. S20-S29. DOI: 10.1097/01.bot.0000202389.40246.c0.
55. Salama W., Mousa S., Khalefa A., Sleem A., Kenawey M., Ravera L., Masse A. Simultaneous open reduction and internal fixation and total hip arthroplasty for the treatment of osteoporotic acetabular fractures. *Int. Orthop*., 2017, vol. 41, no. 1, pp. 181-189. DOI: 10.1007/s00264-016-3175-6.
56. Capone A., Peri M., Mastio M. Surgical treatment of acetabular fractures in the elderly: a systematic review of the results. *EFORT Open Rev*., 2017, vol. 2, no. 4, pp. 97-103. DOI: 10.1302/2058-5241.2.160036.
57. Tempelaere C., Divine P., Bégué T. Early simultaneous bilateral total hip arthroplasty for the management of bilateral acetabular fracture in an elderly patient. *Arthroplast. Today*, 2019, vol. 5, no. 2, pp. 139-144. DOI:10.1016/j.artd.2019.03.008.
58. Yoshida K., Maruyama M., Kasama K., Hashidate H., Kitagawa K. Open Reduction by Fenestration to the Ilium for Central Acetabular Depression Fractures: A Case Report and Operative Technique. *Open J. Orthop*., 2016, vol. 6, no. 8. DOI: 10.4236/ojo.2016.68029.
59. De Bellis U.G., Legnani C., Calori G.M. Acute total hip replacement for acetabular fractures: a systematic review of the literature. *Injury*, 2014, vol. 45, no. 2, pp. 356-361. DOI: 10.1016/j.injury.2013.09.018.

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