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ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

Duration of intraoperative fluoroscopy as a determinant of operative time in supracondylar femoral fracture treatment

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SUMMARY

Introduction/Objective Supracondylar femoral fractures are relatively uncommon injuries which, owing to their specific characteristics, present a particular therapeutic challenge. Operative management is the gold standard for treatment. This study aims to analyse operative duration and intraoperative fluoroscopy time in patients treated with a condylar-type self-dynamizable internal fixator compared to a retrograde intramedullary nail for the femur, and to examine the association between these two parameters.

Methods The study included 66 patients, divided into two groups of 33 participants. Patients in the first group underwent treatment with a retrograde intramedullary nail, whereas those in the second group underwent fixation with a condylar-type self-dynamizable internal fixator. In both groups, operative time (in minutes) and fluoroscopy time (in seconds) were recorded.

Results The mean operative time in patients treated with a retrograde intramedullary nail was statistically significantly shorter than in those treated with the self-dynamizable internal fixator. Conversely, the mean fluoroscopy time was statistically significantly longer in the retrograde intramedullary nail group. Radiation exposure time was a significant predictor of operative duration.

Conclusion Operative duration is an important factor in planning the surgical schedule and the type of anaesthesia. As expected, operative time was shorter with a retrograde intramedullary nail than with a self-dynamizable internal fixator. Intraoperative fluoroscopy is standard practice in orthopaedic trauma surgery; therefore, continuous refinement of surgical technique is essential to minimise radiation exposure and protect the health of the surgical team. Intraoperative fluoroscopy time was shorter with the self-dynamizable internal fixator than with the retrograde intramedullary nail.

Keywords: self-dynamizable internal fixator; retrograde intramedullary nail; fluoroscopy; operative duration

INTRODUCTION

Supracondylar fractures of the femur are relatively uncommon injuries, accounting for approximately 1% of all fractures and 3–6% of femoral fractures. Due to their specific characteristics, they present a treatment challenge for both the patient and the surgeon. In younger patients, these fractures most commonly occur as a result of high-energy trauma. In contrast, in the elderly population, often in the context of osteoporosis, they typically result from low-energy trauma [1–5]. Operative treatment is the gold standard when managing this type of fracture. With the development of modern implants and advances in surgical techniques, nonoperative treatment is currently reserved only for patients who refuse surgical treatment or who are deemed unfit for surgery by an anesthesiologist [6, 7].

A wide range of implants can be used to treat supracondylar femoral fractures. External fixators are most commonly used as a temporary solution for early fracture stabilisation and the management of soft-tissue injuries [8–10]. As definitive treatment options, numerous extramedullary and intramedullary fixation systems are currently available. No significant advantages of one implant over another have been demonstrated in terms of final treatment outcomes. The choice of implant depends on the fracture pattern, specific characteristics of each implant, the implantation technique, the postoperative rehabilitation protocol, and is ultimately determined by the surgeon [11–14]. The difference between extramedullary and intramedullary fixation systems primarily reflects the surgical implantation technique and, subsequently, the biomechanics of fracture stabilisation, which play a crucial role in early patient rehabilitation [15].

In this study, we focus on differences between surgical implantation techniques, particularly on how extramedullary *vs.* intramedullary implants influence the operative course, with special emphasis on operative time and intraoperative fluoroscopy time. Operative time is essential for daily operating room scheduling and anaesthetic planning. At the same time, the duration of intraoperative fluoroscopy is relevant to the safety and protection of the surgical

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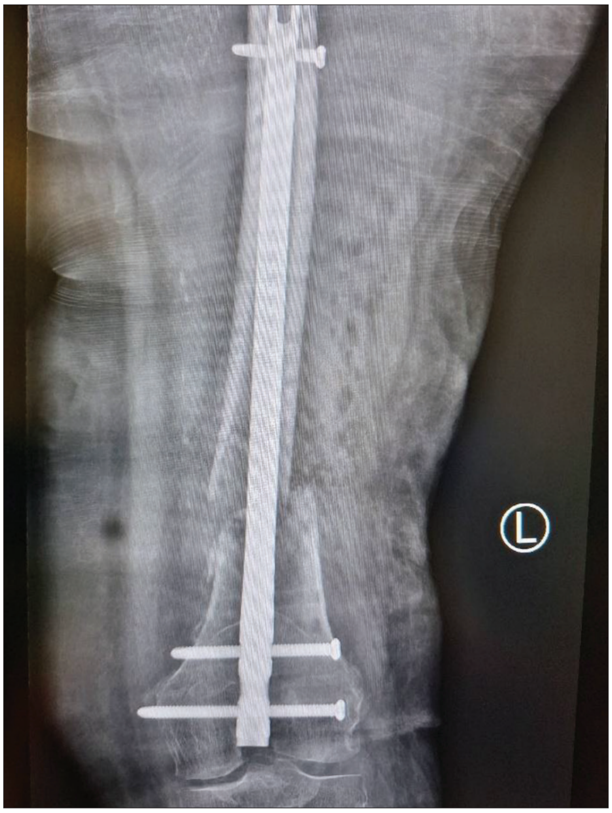

Figure 1. Retrograde intramedullar nail postoperative image – AP view

Figure 2. Retrograde intramedullar nail postoperative image – lateral view

team from radiation exposure [16, 17, 18]. The advantages of fluoroscopy have led to a significant increase in its use during surgical procedures, resulting in prolonged radiation exposure of the operating staff [19–22].

The literature most commonly compares operative time between retrograde intramedullary nailing (RIMN) and locking anatomical plates, whereas data on intraoperative fluoroscopy time are limited [23, 24, 25]. Two implants are compared in this study: the self-dynamizable internal fixator (SIF) with a condylar unit and the retrograde intramedullary nail (RIMN) for the femur. To the best of our knowledge, no comparative data between these two implants are currently available. The SIF with a condylar unit is an extramedullary fixation system that is anatomically contoured in its distal part to match the distal femur. A special feature of this implant is its ability to undergo a spontaneous, delayed transition from initially rigid to dynamic fixation along the bone's vertical axis, without the need for additional surgical intervention [26].

This study aims to analyse operative time and intraoperative fluoroscopy time during treatment of supracondylar femoral fractures using the condylar-type SIF and the retrograde intramedullary femoral nail, and to examine the relationship between these two parameters.

METHODS

The study included 66 patients, divided into two groups of 33 participants, who underwent surgical treatment between 2022 and 2024. The patients in the first group underwent surgical treatment at the Clinic for Orthopaedics and Traumatology of the University Clinical Centre of Vojvodina, where retrograde intramedullary nailing (RIMN; Expert R/AFN) was the predominant treatment method. The patients in the second group underwent surgical treatment at the Academician Prof. Dr Milorad Mitković Clinic for Orthopaedics and Traumatology of the Niš University Clinical Centre, where the condylar-type self-dynamizable internal fixator (SIF) was the predominant treatment method. Based on the Arbeitsgemeinschaft für Osteosynthesefragen (AO) and the Orthopaedic Trauma Association (OTA) classification, all patients had sustained fractures classified as types 33A2 or 33A3 (Table 1).

Table 1. Fracture type according to Arbeitsgemeinschaft für Osteosynthesefragen (AO) and the Orthopaedic Trauma Association (OTA) classification

Fixation	33A2	33A3			Σ
		33A3.1	33A3.2	33A3.3	
RIMN	6	3	10	14	33
SIF	9	4	11	9	33

RIMN – retrograde intramedullary nail; SIF – self-dynamizable internal fixator

In the first group, 19 patients (58%) were female, and 14 patients (42%) were male. In the second group, 20 patients (61%) were female, and 13 patients (39%) were male. The mean age of patients in the first group was 65.6 years, whereas in the second group it was 73.4 years.

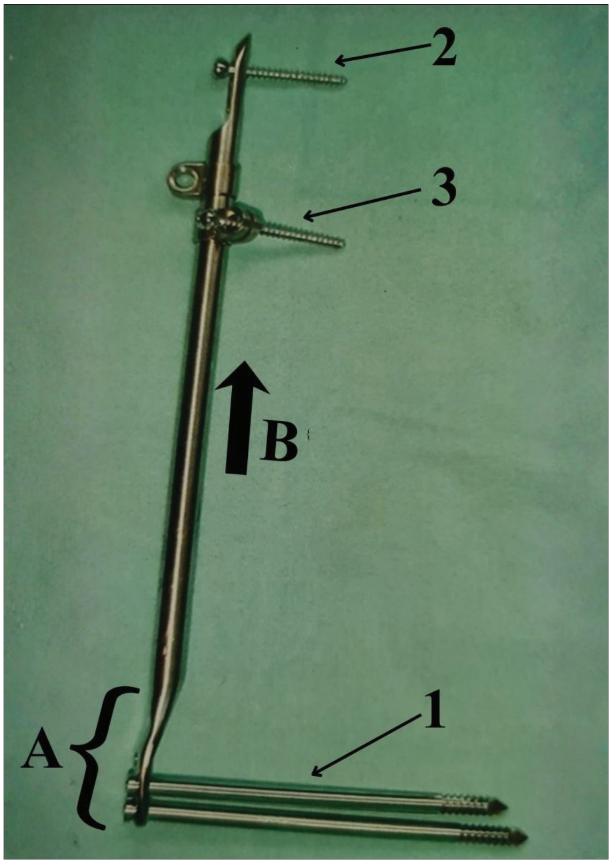

Figure 3. Self-dynamizable internal fixator condylar-type: A – condylar unit; B – dynamisation in the long femoral axis; 1 – locking screw; 2 – cortical anti-rotational screw; 3 – screw with the clamp

Figure 4. Self-dynamizable internal fixator condylar-type – postoperative image

Surgical Technique for Retrograde Intramedullary Nail (RIMN, Expert R/AFN) – All patients were operated on in the supine position on a radiolucent table, with the knee of the injured limb free and flexed up to 90 degrees. Using a standard approach with a longitudinal skin incision and transection of the patellar ligament, the surgeon accessed the intercondylar space. The entry point of the nail was determined by digital palpation and under fluoroscopic control, immediately anterior and lateral to the femoral attachment of the posterior cruciate ligament. Fracture reduction, guidewire insertion, canal reaming, determination of nail dimensions, and nail insertion were all performed and verified under fluoroscopic guidance. The nail was locked distally using a targeting guide and proximally by hand under fluoroscopic control (Figures 1 and 2).

Surgical Technique for Condylar-Type Self-Dynamizable Internal Fixator (SIF) – a standard lateral approach was used to expose the fracture. Fracture reduction was performed under visual control with fluoroscopic assistance. The internal fixator was inserted and temporarily fixed with a Kirschner wire in the condylar region under fluoroscopic guidance. Subsequently, one locking screw was inserted into the condylar region, followed by placement of a cortical anti-rotational screw through the dynamic slot, which allowed for final fracture reduction and stabilisation using bone-holding forceps. After achieving a satisfactory fracture position, a second locking screw was inserted, followed by screw placement through the clamps (Figures 3 and 4). In addition to the open technique, some surgeons employed a mini-incision technique for placement of the self-dynamizable internal fixator, using two incisions – one distal at the level of the condylar region and one proximal to the fracture site. This technique enabled closed indirect fracture reduction but required longer fluoroscopy to confirm adequate fracture reduction and correct implant positioning.

In both groups, operative time (in minutes) and fluoroscopy time (in seconds) were recorded. Operative time was measured from the initial surgical incision to placement of the final suture in the operative wound. Fluoroscopy time was recorded from the C-arm display upon completion of the surgical procedure.

Data were analysed using descriptive and analytical statistical methods. A Student's t-test was used to compare mean values, while Pearson's correlation coefficient (r) was used to assess correlations, along with the coefficient of determination (r^2). Differences between correlation coefficients were tested using Fisher's r-to-z transformation. Linear regression with operative time as the outcome variable was used in the combined data analysis. A p-value < 0.05 was considered to be statistically significant, and a p-value < 0.01 was considered to be highly statistically significant. Data analysis was performed using SPSS Statistics version 26.

Ethics: The study was performed in line with the Declaration of Helsinki and approved by the Ethics Board of the University Clinical Centre Niš (Decision No. 12–6647–2/9).

RESULTS

Comparison of the two surgical techniques in terms of operative time and fluoroscopy duration

During the retrograde intramedullary nailing (RIMN) procedure, the mean operative time was 65.8 ± 19.3 minutes (range: 40–120 minutes), whereas in the self-dynamizable internal fixator (SIF) technique, the mean operative time was 88.3 ± 23.5 minutes (range: 50–150 minutes). This difference was statistically significant, indicating that the RIMN technique was associated with a significantly shorter operative time.

Regarding fluoroscopy duration, the mean exposure time for the RIMN technique was 44.1 ± 10.7 seconds (range: 25–69 seconds), whereas that for the SIF technique was 31 ± 12.2 seconds (range: 11–54 seconds). This difference was highly statistically significant, indicating that the RIMN technique was associated with longer fluoroscopy time.

Analysis of the correlation between operative time and fluoroscopy duration for each surgical technique

Correlation analysis revealed a strong positive association between operative time and fluoroscopy duration for both surgical techniques:

a) In the RIMN group, the correlation coefficient was $r = 0.602$, and the correlation was highly statistically significant. The coefficient of determination (r^2) was 36%.

b) In the SIF group, the correlation coefficient was $r = 0.673$, and the correlation was also highly statistically significant. The coefficient of determination (r^2) was 45%.

Comparison of these two correlation coefficients did not demonstrate a statistically significant difference between the correlations ($z = -0.47$, $p = 0.64$).

Table 2. Effect analysis of fluoroscopy duration, type of surgical procedure, and their combined effect as independent variables on operative time as the dependent variable

Model	Unstandardised coefficients		95% confidence interval	
	Coefficient ß	p-value	Lower bound	Upper bound
1 (Constant)	43.393	< 0.001	27.385	59.402
Intraop fluorosc sec	1.288	< 0.001	0.807	1.770
Type of surgery	-25.430	0.091	-55.081	4.221
Rad_Tech_Int*	-0.211	0.565	-0.940	0.518

*Interaction between fluoroscopy duration and type of surgical procedure

Effect analysis of fluoroscopy duration, type of surgical procedure, and their combined effect as independent variables on operative time as the dependent variable (Table 2):

Using linear regression analysis that included fluoroscopy duration, surgical technique, and their interaction, fluoroscopy duration was a statistically significant predictor of operative time, with each additional second prolonging operative time by 1.29 minutes ($p < 0.001$). The interaction between fluoroscopy duration and surgical technique was not statistically significant ($p = 0.565$), indicating a similar relationship between radiation exposure and operative time across surgical techniques.

DISCUSSION

The longer operative time associated with the SIF technique can be explained by the need for a larger surgical incision through the skin and subcutaneous tissue, then mobilisation of the muscle tissue (primarily the vastus lateralis, which is often associated with significant bleeding), and the need for manual fracture reduction and manual maintenance of the reduction until definitive fixation and stabilisation are achieved. After fracture stabilisation with the fixator, a considerable portion of operative time is devoted to attaining hemostasis, wound irrigation, and wound closure. Due to the deforming effect of muscle forces, particularly those of the gastrocnemius, closed fracture reduction is often challenging to achieve and maintain until final fixation is completed.

In contrast, RIMN is performed through a significantly smaller incision, approximately 4–5 cm in length, and does not require muscle mobilisation. A substantial portion of operative time is devoted to determining the entry point, inserting the guidewire into the proximal fragment, and reaming the intramedullary canal. Fracture reduction is typically indirect and closed, and is achieved through insertion of the intramedullary nail itself. This manoeuvre significantly shortens operative time, as nail insertion neutralises the gastrocnemius muscle's deforming forces and facilitates adequate fracture reduction. Nail locking is performed as with the SIF, with two screws placed distally and then proximally. Proximal locking, however, is performed with a freehand technique under fluoroscopic guidance, which requires more exposure time than the SIF technique, which is performed under direct visual control.

Currently, there is no available literature analysing operative time associated with the use of the SIF. In contrast, data are available for the RIMN and other extramedullary fixation devices, including anatomical locking plates, dynamic condylar screws (DCS), and condylar plates. The mean operative times observed in our study for RIMN are consistent with those reported in the literature. Similarly, operative time with anatomical locking plates is reported to be comparable to or longer than those observed with the SIF [27–30]. The longer operative time associated with anatomical locking plates can be explained by the need to insert more screws, while the implantation technique itself is otherwise similar.

If the time required for wound closure were excluded from the analysis, the difference in the duration of the fixation technique between the RIMN and the SIF could be expected to be smaller.

Fluoroscopy time is significantly longer in the RIMN group. This can primarily be explained by the more complex technique of RIMN placement compared with the SIF. During RIMN insertion, additional steps must be performed under fluoroscopic guidance, including determining the entry point, inserting the guidewire, selecting nail dimensions, reaming the canal, inserting the nail, and placing proximal locking screws. In contrast, during SIF placement, fluoroscopy is mainly used to position the Kirschner wire and free screws in the condylar region. Subsequent positioning and stabilisation of the fixator can be performed without fluoroscopic assistance.

It is imperative to note that during SIF implantation, the surgeon does not need to remain in proximity to the operative field during fluoroscopy, as the steps requiring fluoroscopy do not require direct hand positioning within the operative field. Conversely, during RIMN placement, numerous steps – including determining the entry point, guidewire insertion, nail insertion, and placement of locking screws – require the surgeon's direct presence within the operative field during fluoroscopy. As a result, during RIMN procedures, the surgeon is directly exposed to radiation and must wear protective equipment. In contrast, during SIF procedures, the surgeon can maintain a safe distance of approximately 2 meters from the radiation source, making protective equipment unnecessary [16–22].

Correlation analysis demonstrates a strong positive association between operative time and fluoroscopy duration for both surgical techniques. The correlation is stronger in the SIF group, which can be explained by fewer fluoroscopy steps, for which repeated use has a more pronounced effect on overall operative time. In the RIMN group, more steps require fluoroscopy. However, these steps typically take less time when repeated and have a less significant impact on total operative time. Nevertheless, operative time is clearly strongly influenced by fluoroscopy duration, with each additional second of radiation exposure prolonging the operation by 1.29 minutes.

When considering cases in which delayed initiation of dynamisation is required to achieve proper fracture healing, the SIF may be regarded as advantageous. In such cases, in addition to shorter fluoroscopy duration, the SIF also reduces the overall operative burden, as its capacity for spontaneous activation of dynamisation eliminates the need for an additional surgical intervention. In contrast, initiation of dynamisation in intramedullary nailing requires a further surgical procedure to remove the static locking screw [26].

CONCLUSION

The duration of the operative procedure is a significant factor when planning the daily surgical schedule and deciding on the type of anaesthesia. As expected, a shorter operative time was observed when using the retrograde intramedullary nail compared with the self-dynamizable internal fixator. Intraoperative fluoroscopy is a standard component of orthopaedic trauma surgery, which is why continuous improvement of surgical techniques is necessary to protect the health of the surgical team. As anticipated, intraoperative fluoroscopy time was shorter with the use of the self-dynamizable internal fixator compared with the retrograde intramedullary nail. The absence of the need for an additional surgical intervention to initiate delayed dynamisation with the SIF may have contributed to a shorter overall cumulative operative time compared with intramedullary nailing in patients who required delayed dynamisation.

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Conflict of interest: None declared.

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Утицај трајања интраоперативне флуороскопије на трајање оперативног захвата код лечења супракондиларних прелома фемура

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САЖЕТАК
Увод/Циљ Супракондиларни преломи фемура су ретке повреде које због својих специфичности представљају посебан изазов за лечење. Оперативно лечење представља златни стандард лечења. Циљ рада је анализа трајања оперативног захвата и интраоперативне флуороскопије код пацијената лечених применом самодинамизирајућег унутрашњег фиксатора кондиларног типа и ретроградног интрамедуларног клина за фемур и испитивање њихове повезаности.
Методе Истраживање је обухватило 66 пацијената, подељених у две групе од по 33 испитаника. Испитаници у првој групи оперисани су применом ретроградног интрамедуларног клина за фемур, док су испитаници друге групе оперисани применом самодинамизирајућег унутрашњег фиксатора кондиларног типа. У обе групе мерено је оперативно време у минутима и време флуороскопије у секундама.
Резултати Просечно трајање операције код пацијената оперисаних ретроградним интрамедуларним клином било је статистички значајно краће него код пацијената оперисаних самодинамизирајућим унутрашњим фиксатором. Насупрот томе, просечно време примене флуороскопије било је статистички значајно дуже код пацијената оперисаних ретроградним интрамедуларним клином. Време изложености зрачењу било је значајан предиктор трајања операције.
Закључак Дужина трајања оперативног захвата је значајан фактор у планирању оперативног програма и врсте анестезије. Као што се и очекивало, време оперативног захвата било је краће код примене ретроградног интрамедуларног клина у односу на самодинамизирајући унутрашњи фиксатор. Интраоперативна флуороскопија је стандард у ортопедској траума хирургији, због чега је неопходно додатно усавршавати хируршке технике, како би се заштитило здравље хируршке екипе. Време интраоперативне флуороскопије било је краће код примене самодинамизирајућег унутрашњег фиксатора у односу на ретроградни интрамедуларни клин.
Кључне речи: самодинамизирајући унутрашњи фиксатор; ретроградни интрамедуларни клин; флуороскопија; трајање операције