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ORIGINAL ARTICLE

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Minimally invasive intramedullary fixation with flexible nails in the treatment of metatarsal neck fractures

Fixação intramedular com hastes flexíveis no tratamento das fraturas do colo dos metatarsais, por técnica minimamente invasiva

Victor Chammas[1], Inácio Diogo Asaumi[1], Alfonso Apostólico Netto[1], Rafael da Rocha Macedo[1], Donato Lo Turco[1], Luciano Miller Reis Rodrigues[2]

1. Hospital IFOR, São Bernardo Do Campo, SP, Brazil.
2. Faculdade de Medicina do ABC, Santo André, SP, Brazil.

ABSTRACT

Objective: This study was designed to retrospectively assess patients with deviated central metatarsal neck fractures subjected to reduction and fixation with flexible intramedullary nails.

Methods: Thirty-six patients (36 feet) diagnosed with acute fractures of one or more metatarsals and whose therapeutic indication was exclusively surgical were evaluated between June 2010 and August 2011. Considering the metatarsophalangeal joint, such injuries should be located up to two centimeters in the proximal direction of this segment, with plantar deviation greater than 10 degrees and translation greater than three millimeters in any plane. Minimally invasive intramedullary fixation with two flexible titanium nails was used when adequate stability was not obtained with the use of one nail. The visual analog scale (VAS), American Orthopedic Foot & Ankle Society (AOFAS) forefoot score and specific statistical tests were used.

Results: There was a significant ($p<0.001$) improvement in the results until 6 months of follow-up. There was no significant difference ($p>0.05$) in the results between 6 and 12 months of follow-up. The average time of consolidation was 8 weeks, and there were no complications during the period evaluated.

Conclusion: This technique provided a significant ($p<0.001$) improvement in the VAS and AOFAS forefoot scores at 6 months of follow-up. Between 6 and 12 months of postoperative follow-up, we did not observe a significant ($p<0.05$) difference in the results of the analysis due to stabilization of the condition and fracture consolidation. Although the results were considered excellent, the level of evidence of studies should be increased to effectively demonstrate the efficacy of this technique.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Metatarsal Bones/surgery; Fractures, bone; Fracture fixation, internal.

RESUMO

Objetivo: Este estudo foi idealizado com o objetivo de avaliar retrospectivamente pacientes com fraturas, com desvio, do colo dos metatarsais centrais, que foram submetidas à redução e fixação com hastes intramedulares flexíveis.

Métodos: Foram avaliados 36 pacientes (36 pés), entre junho de 2010 e agosto de 2011, com diagnóstico de fraturas agudas de um ou mais metatarsais, cuja indicação terapêutica fosse exclusivamente cirúrgica. Considerando-se a articulação metatarso-falângica, tais lesões deveriam estar localizadas até dois centímetros no sentido proximal deste segmento, com desvio plantar maior que 10 graus e translação maior que três milímetros em qualquer plano. Foi utilizada a fixação intramedular com duas hastes flexíveis de titânio, quando não conseguida estabilidade adequada com a utilização de uma haste, com técnica minimamente invasiva. Foram utilizados a Escala Visual Analógica (EVA), escala da *American Orthopaedic Foot & Ankle Society* (AOFAS) para o antepé, e aplicados testes estatísticos específicos.

Work performed at the Hospital IFOR, São Bernardo do Campo, SP, Brazil.

Correspondence: Victor Chammas. Rua: Dom Pero Sardinha, 110, Vila Gumercindo, São Paulo, SP, Brazil. E-mail: vchammas@hotmail.com

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Resultados: Houve uma melhora estatisticamente significante dos resultados até o 6º mês de seguimento (p<0,001). Entre o 6º e o 12º mês de seguimento não houve diferença estatisticamente significativa (p<0,05). O tempo de consolidação foi, em média, de 8 semanas e não houve complicações no período avaliado.
Conclusão: Esta técnica proporcionou uma melhora estatisticamente significante considerando-se a EVA e AOFAS para o antepé até o 6º mês de seguimento (p<0,001). Entre o 6º e o 12º mês de seguimento pós-operatório não observamos diferença estatisticamente significante entre os resultados da análise (p<0,05), devido à estabilização do quadro e consolidação da fratura. Embora os resultados tenham sido considerados ótimos, devemos aumentar o nível de evidência desta pesquisa, para comprovar definitivamente a eficácia desta técnica.
Nível de Evidência IV; Estudos Terapêuticos; Séries de Casos.

Descritores: Ossos do metatarso/cirurgia; Fraturas ósseas; Fixação interna de fraturas.

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INTRODUCTION

Metatarsal fractures have a higher prevalence among males in the third decade of life, with a ratio of 6.7:10,000 individuals[1].

Falls are the most common trauma mechanism (46.0%), followed by twisting (18.3%) and direct trauma (10.1%)[1]. However, the increasing number of motorcycle accidents has caused a rise in the prevalence of metatarsal fractures, corresponding to 4.3% of cases[2].

The indication for surgical treatment is related to failure of conservative treatment or when large deviations and/or instability are observed. This issue is critical when considering the metatarsal neck, whose deviations result from the action of the flexor tendons, which cause a plantar deviation[3].

Regarding possible surgical techniques, indirect or direct reductions with stabilization with Kirschner wires passed retrograde or antegrade, percutaneously or under direct axial or transverse view are described[4].

Some researchers advocate for the fixation of these injuries using flexible intramedullary nails based on studies where this technique was applied to traumatic metacarpal injuries[5]. The advantages of this fixation method include early return to activities of daily living, adequate stabilization control, low infection rates and low rates of loosening and migration of the synthesis material[5].

Therefore, the objective of this study was to evaluate the results of minimally invasive surgical treatment of central metatarsal neck fractures using flexible intramedullary nails for fixation after fracture reduction.

METHODS

This study was approved by the Ethics Committee and registered in the Brazil Platform (Plataforma Brazil).

A total of 36 feet from 36 patients were evaluated from June 2010 to August 2011. The ages of the patients ranged from 18 to 66 years (mean of 35.05 years, standard deviation of 14.38 years and median of 33.5 years). Among the evaluated patients, 19 (53%) were male, and 17 (47%) were female; there were 20 right feet (56%) and 16 left feet (44%).

Table 1 shows the distribution of the 36 patients in our study according to the fractured metatarsal bone.

We selected patients diagnosed with acute fractures of one or more central metatarsals whose therapeutic indication was strictly surgical. Considering the metatarsophalangeal joint and the deviations presented, the following fracture situations had surgical indications: location up to two centimeters in the proximal direction of this bone segment, plantar deviation greater than 10 degrees and translation greater than three millimeters in any plane.[6]

We adopted the following exclusion criteria: patients with fractures whose treatment of choice was conservative, individuals whose clinical conditions were not compatible with surgery, patients subjected to previous treatment and patients who refused to participate in the study after reading the informed consent form.

Table 1. Distribution of patients according to fractured metatarsals.

Metatarsal	N	%
II	2	6
II/III	5	14
II/III/IV	3	8
II/III	1	3
III/IV	7	19
IV	2	6
IV/V	2	6
V	14	39
Total	36	100

Source: Prepared by the authors based on the results of the study.

Surgical procedure

The procedure was performed by the same surgeon who was experienced with the technique. The patient was placed in the supine position on a radio-transparent operating table. After spinal anesthesia, discrete lateralization of the limb was achieved using a cushion placed on the ipsilateral gluteal region. A pneumatic tourniquet placed on the proximal third of the thigh was used to avoid intraoperative bleeding.

The base of the metatarsal was identified by palpation, and a single longitudinal 2-cm incision was then made proximally to this topography (Figure 1). After dissection of the tissues layer by layer, the periosteum was approached, and a hole was made on the metatarsal bone using a piercing instrument. Only the anterior cortical bone was incised with an inclination of approximately 45° to reach the medullary region of the metatarsal bone. A 1.4-mm nail was inserted with a fluoroscopy device (Figure 2A) until the fracture site was reached (Figure 2B). A reduction maneuver was performed by traction of the affected toe by ligamentotaxis. The fracture focus was not approached by direct incision to avoid compromising local nutrition and to preserve the capsular ligament complex. With the quality of the reduction observed by radioscopy, the nail was guided until adequate stability was obtained, which occurred when its tip reached the metatarsal head (Figure 3). Fixation quality was actively tested, and when it was considered unsatisfactory, as determined mainly by rotational instability, a second nail with a diameter of 1.2 mm was introduced through the same hole (Figure 4). Theoretically, three fixation points can be achieved in any direction when flexible titanium nails are used, although there are no biomechanical studies documenting this stability[7]. The nail was advanced into the metaphyseal bone at the end opposite to the metatarsal and firmly seated at the level of the metatarsal head[7]. After confirming clinical and fluoroscopic alignment, the nail was bent at the entry point with the aid of appropriate instruments[7] (Figure 4). We chose to keep the proximal cut end of the nail close to the bone, and both ends remained in the subcutaneous zone. Appropriate suturing was performed, followed by dressing and plaster casting.

Figure 1. Skin incision.
Source: Author's personal archive.

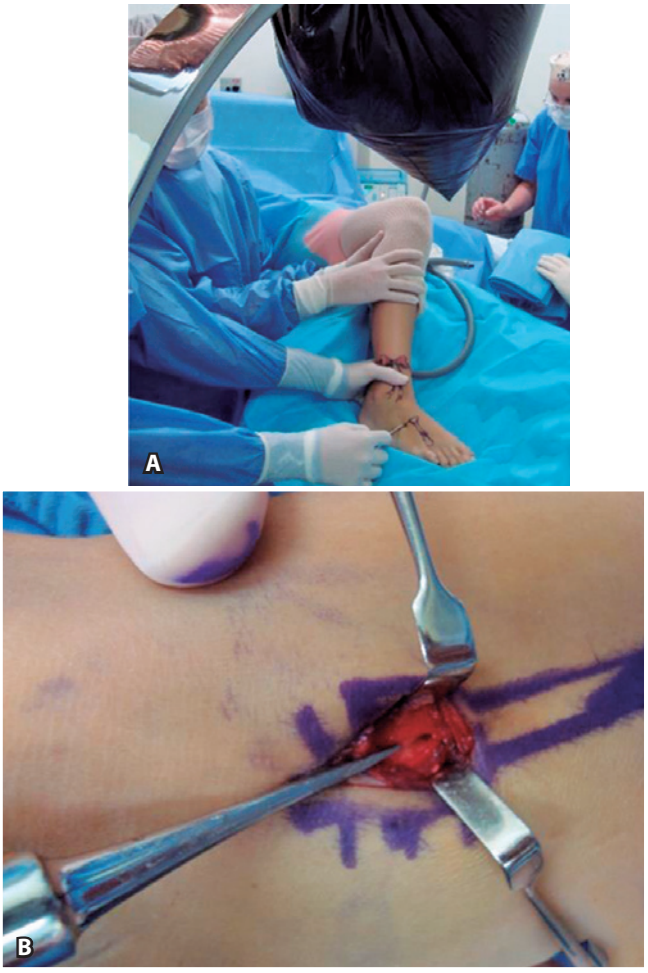

Figure 2. A) Intraoperative radioscopy guidance. B) Passage of the nail.
Source: Author's personal archive.

Outpatient follow-up was conducted weekly, and when the stitches were removed, the patients were allowed to walk with the aid of an orthowedge shoe. After the sixth postoperative week and adequate fracture consolidation as observed by radiography, full weight-bearing was allowed without the aid of the orthowedge shoe. Radiographic control in the anteroposterior, lateral and oblique views of the foot was performed at the first, third and sixth postoperative weeks to evaluate the alignment and signs of consolidation.

Figure 3. Position of the nail in the distal and proximal portion of the metatarsal.
Source: Author's personal archive.

Figure 4. Introduction of the second nail.
Source: Author's personal archive.

The following validated methodologies were used: pain assessment using the visual analog scale (VAS) and foot function using the American Orthopedic Foot and Ankle Society (AOFAS) forefoot score. All patients were evaluated and assessed using the questionnaires at 3, 6 and 12 months after surgery. We considered some specific aspects, such as the skin condition at the incision site; pain at the synthetic material implantation site; gait pattern; deviation of the axes; and the need for walking support devices after the sixth postoperative week.

Our results were analyzed by a professional specialized in applied statistics in the health field. First, all study variables were analyzed descriptively. For the quantitative variables, the minimum and maximum values, mean, standard deviation and median were calculated. For the qualitative variables, the absolute and relative frequencies were calculated.

The nonparametric Friedman test[8] was used to compare the assessment times, as the assumption of normality was rejected. The level of significance used in the tests was 5%. Statistically significant values are marked with an asterisk.

RESULTS

Significant differences ($p<0.001$) were observed in the AOFAS score among the evaluation times. In the third postoperative month, the mean score was 94.25, with a standard deviation of 5.20, median of 95.00, minimum of 80.00 and maximum of 100.00. At the sixth month, the mean score was 97.50, with a standard deviation of 4.13, with a median of 100.00, minimum of 85.00 and maximum of 100.00. At 12 months of follow-up, the mean score was 98.00, with a standard deviation of 4.10, median of 100.00, minimum of 85.00 and maximum of 100.00. The results at 3 months were significantly lower than those obtained at 6 months ($p<0.05$) and 12 months ($p<0.05$). The AOFAS scores at 6 and 12 months did not differ significantly. The study also revealed significant differences in VAS scores among the evaluation times ($p<0.001$) (Figure 5A). After 3 months of postoperative follow-up, the mean VAS score was 2.10, with a standard deviation of 1.36, median of 2.00, minimum of 0.00 and maximum of 5.00. At 6 months, the mean score was 0.82, with a standard deviation of 0.84, median of 0.75, minimum of 0.00 and maximum of 2.50. At 12 months, the mean score was 0.35, with a standard deviation of 0.54, median

of 0.00, minimum of 0.00 and maximum of 2.00. The VAS score at 3 months was significantly lower than those at 6 ($p<0.05$) and 12 ($p<0.05$) months. There was no significant difference in the VAS scores at 6 and 12 months (Table 2 and Figures 5A and 5B).

In our study, there were no complications during outpatient follow-up. In no case was there a need to remove the nails, and we observed a mean consolidation time of 8 weeks.

DISCUSSION

Although several studies have reported different fixation methods for metatarsal and metacarpal fractures[9-10], none is considered the gold standard for treatment. However, the therapeutic principles include restoration of the anatomy, stable fracture fixation, elimination of angular and rotational deformities and rapid recovery of function[5].

For the neck region of the metacarpal bones in particular, the main stabilization techniques are percutaneous fixation, cerclage, plates, screws, wires with tension bands and external fixators[9-10]. Of these, fixation with Kirschner wires is the most used because of the adequate stability achieved and the simplicity of applying this device, which causes minimal damage to soft tissues; the technique is typically indicated for transverse or oblique fractures and cases with involvement of more than one metacarpal[5].

Percutaneous fixation has the following advantages: a small surgical incision, which reduces the occurrence of adhesions and maintains the function of the toes without appreciable changes; adequate fracture stabilization; early mobility; high levels of good functional results; and a simple and easy technique with low complication rates[5]. There are additional benefits associated with this technique, such as requiring low radiation doses and short hospital stays, which reduce treatment costs[11].

The complications of internal fixation with intramedullary devices are similar to those of other surgical treatment methods using internal fixation, such as nonconsolidation, vicious consolidation, superficial and deep infections, stiffness, implant migration, bone shortening, need for implant removal, articular stiffness with adhesions and tendon rupture[5,7,12,13].

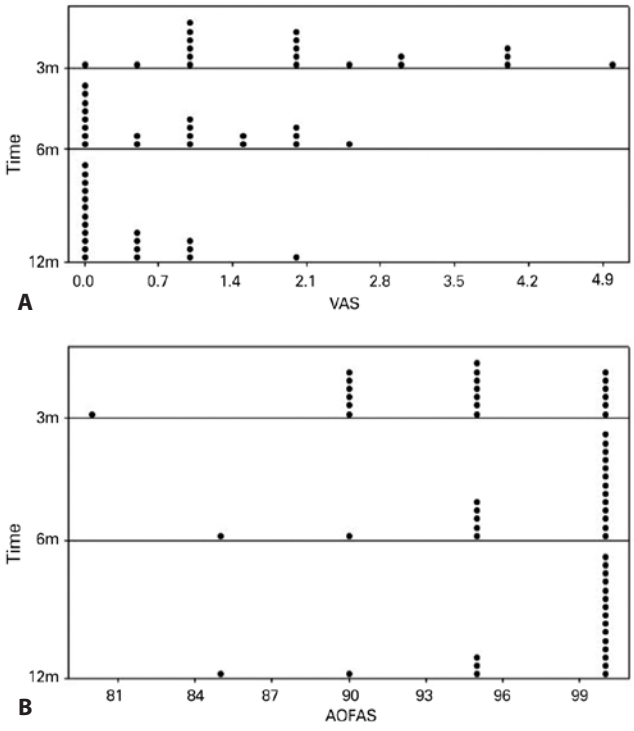

Figure 5. A) Plot of VAS scores at 3, 6 and 12 months. B) Plot of AOFAS scores at 3, 6 and 12 months.
Source: Prepared by the authors based on the results of the study.

Figure 6. Divergence between nails.
Source: Author's personal archive.

Table 2. Descriptive statistics of the AOFAS and VAS scores of the 36 patients at 3, 6 and 12 months after surgery.

Variable	Time	n	Mean	SD	Median	Minimum	Maximum	p*
AOFAS	3	36	94.25	5.20	95.00	80.00	100.00	
	6	36	97.50	4.13	100.00	85.00	100.00	<0.001
	12	36	98.00	4.10	100.00	85.00	100.00	
VAS	3	36	2.10	1.36	2.00	0.00	5.00	
	6	36	0.82	0.84	0.75	0.00	2.50	<0.001
	12	36	0.35	0.35	0.00	0.00	2.00	

(*) descriptive level of probability of the nonparametric Friedman test.
Source: Prepared by the authors based on the results of the study.

Another problem of this technique is the possibility of occurrence of the phenomenon known as cutout. To avoid cutting the metatarsal head with the nails, careful fluoroscopic monitoring should be performed during surgery while advancing the nail in the bone. To increase the stability of the osteosynthesis, divergence between the nails in the distal fragment should be achieved (Figure 6).

Generally, most complications were related to fractures at the distal third, where we do not recommend the use of this implant; this is also true for cases where there is a large shortening between the bones[7].

The technique we used was associated with a low complication rate and spared the metatarsophalangeal joint surface, thus avoiding extension and stiffness of this joint.

Regarding the level at which the intramedullary nail will be sectioned, there is no consensus on whether it should be near the metatarsal bone base or whether the tip should be left in the subcutaneous layer or external to the skin.

In this regard, Faraj and Davis[13] suggested that the intramedullary nail should be buried in the metacarpal rather than sectioned, leaving a small salient portion to prevent retraction, migration, loosening and soft tissue injury.

However, Blazar and Leven[7] reported that the buried nail can be left for later percutaneous removal if needed. However, local manipulation would be more extensive, resulting in greater tissue damage if left inside the bone. When the implant is left percutaneously, its removal requires a simpler manipulation; therefore, the preference is to remove these implants with the aid of sedation[7].

Due to local skin complications such as infection in the nail path, we decided to section the nails close to the base of the bone without premeditated removal.

The patients in our sample were active individuals who required an early return to work, and the surgical technique that we used thus provided early rehabilitation and return to activities.

We obtained a significant improvement in parameters based on VAS and AOFAS forefoot scores at 6 months of follow-up.

CONCLUSION

From the analysis of the results, we can conclude the following:

1. The minimally invasive technique was effective and enabled an early return to work;
2. It provided significant ($p<0.001$) improvements in VAS and AOFAS forefoot scores at 6 months of follow-up;
3. There was no significant difference ($p<0.05$) between the evaluations performed at the sixth and 12th postoperative months.

Authors' contributions: Each author contributed individually and significantly to the development of this article: VC *(https://orcid.org/0000-0001-7736-0483) conceived and planned the activities that led to the study, wrote the article, bibliographic review, interpreted the results of the study and approved the final version; IDA *(https://orcid.org/0000-0002-4074-0412) data collection and approved the final version; AAN *(https://orcid.org/0000-0001-9237-869X) statistical analysis, interpreted the results of the study, performed the surgeries; RRM *(https://orcid.org/0000-0002-2563-2085) conceived and planned the activities that led to the study, performed the surgeries, data collection, wrote the article, statistical analysis and approved the final version; DLT*(https://orcid.org/0000-0001-9024-2553) Participated in the review process, bibliographic review; RMRR *(https://orcid.org/0000-0001-6891-5395) conceived and planned the activities that led to the study, data collection, statistical analysis and approved the final version. *ORCID (Open Researcher and Contributor ID).

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