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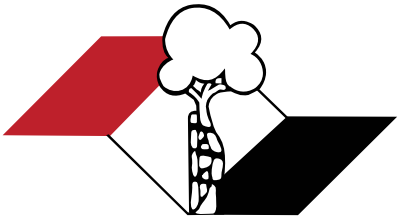

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ACTA ORTOPÉDICA BRASILEIRA

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(Reviewed January 2016)

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Original	Structured, up to 200 words	2.500 Excluding abstract, references, tables and figures	20	10	6	6
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CONCLUSION: The conclusion should be clear and concise, establishing a link between the conclusion and the study objectives. Avoiding conclusions not based on data from the study in question is recommended, as well as avoiding suggest that studies with larger samples are needed to confirm the results of the work in question.

ACKNOWLEDGEMENTS
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Levels of Evidence for Primary Research Question[a]

(This chart was adapted from material published by the Centre for Evidence-Based Medicine, Oxford, UK. For more information, please visit www.cebm.net.)

	Types of study			
Level	**Therapeutic Studies Investigating the Results of Treatment**	**Prognostic Studies – Investigating the Effect of a Patient Characteristic on the Outcome of Disease**	**Diagnostic Studies – Investigating a Diagnostic Test**	**Economic and Decision Analyses – Developing an Economic or Decision Model**
I	High quality randomized trial with statistically significant difference or no statistically significant difference but narrow confidence intervals	High quality prospective study[d] (all patients were enrolled at the same point in their disease with ≥80% of enrolled patients)	Testing of previously developed diagnostic criteria on consecutive patients (with universally applied reference ''gold'' standard)	Sensible costs and alternatives; values obtained from many studies; with multiway sensitivity analyses
	Systematic review[b] of Level RCTs (and study results were homogenous[c])	Systematic review[b] of Level I studies	Systematic review[b] of Level I studies	Systematic review[b] of Level I studies
II	Lesser quality RCT (eg, < 80% followup, no blinding, or improper randomization)	Retrospective[f] study	Development of diagnostic criteria on consecutive patients (with universally applied reference ''gold'' standard)	Sensible costs and alternatives; values obtained from limited studies; with multiway sensitivity analyses
	Prospective[d] comparative study[e]	Untreated controls from an RCT	Systematic review[b] of Level II studies	Systematic review[b] of Level II studies
	Systematic review[b] of Level II studies or Level I studies with inconsis tent results	Lesser quality prospective study (eg, patients enrolled at different points in their disease or <80% followup)		
		Systematic review[b] of Level II studies		
III	Case control study[g]	Case control study[g]	Study of non consecutive patients; without consistently applied reference ''gold'' standard	Analyses based on limited alternatives and costs; and poor estimates
	Retrospective[f] comparative study[e]		Systematic review[b] of Level III studies	Systematic review[b] of Level III studies
	Systematic review[b] of Level III studies		Case-control study	
			Poor reference standard	
IV	Case series[h]	Case series		Analyses with no sensitivity analyses
V	Expert opinion	Expert opinion	Expert opinion	Expert opinion

[a] A complete assessment of quality of individual studies requires critical appraisal of all aspects of the study design.

[b] A combination of results from two or more prior studies.

[c] Studies provided consistent results.

[d] Study was started before the first patient enrolled.

[e] Patients treated one way (eg, cemented hip arthroplasty) compared with a group of patients treated in another way (eg, uncemented hip arthroplasty) at the same institution.

[f] The study was started after the first patient enrolled.

[g] Patients identified for the study based on their outcome, called "cases" eg, failed total arthroplasty, are compared with patients who did not have outcome, called ''controls'' eg, successful total hip arthroplasty.

[h] Patients treated one way with no comparison group of patients treated in another way.

SUMMARY

VOLUME 27–Nº 6–2019

CLIQUE NO TÍTULO PARA LER O ARTIGO

Original Articles

DOI: http://dx.doi.org/10.1590/1413-785220192706223193

ORIGINAL ARTICLE

COMPARISON OF LCP AND INTRAMEDULLARY NAIL OSTEOSYNTHESIS IN CALCANEAL FRACTURES

COMPARAÇÃO ENTRE PLACA DE OSTEOSSÍNTESE E HASTE INTRAMEDULAR EM FRATURA DO CALCÂNEO

Jaroslav Zeman[1], Petr Zeman[1], Tomas Matejka[1], Jaroslav Belatka[1], Jiri Matejka[1]

1. Charles University, Faculty of Medicine in Pilsen, Department of Orthopaedics and Locomotive Apparatus Traumatology, Pilsen, Czech Republic.

ABSTRACT

Objective: This study compared groups of patients with calcaneal fractures of Sanders types II and III. One group was treated with ORIF using an LCP (plate), while the second was treated with a minimally invasive method using a C-Nail. Methods: The study included 217 patients in the ORIF group and 19 patients in the minimally invasive nail osteosynthesis group. Results: In the LCP group, the outcomes were excellent for 35.7% of the patients; good, 38.9%; satisfactory, 19.7%; and poor, 5.7%. In the C-Nail group, the outcomes were excellent for 36.9% of the patients; good; 31.6%; satisfactory, 21%; and poor, 10.2%. The mean values of the restoration of Böhler's angle from post-injury were 6.8° to 32.3° in the LCP group and 7.1° to 33.3° in the C-Nail group. After 12 months, there was only a minimal decrease in Böhler's angle to 29.2° in both the LCP and C-Nail groups. Conclusion: The outcomes obtained with C-Nail fixation are statistically identical to those obtained with LCP fixation. We conclude that osteosynthesis with a C-Nail is suitable as the first-choice treatment for Sanders types II and III fractures. ***Level of evidence IV, retrospective observational study.***

Keywords: Minimally Invasive Surgery. Heel Bone. Bone Nail. Bone Plate.

RESUMO

Objetivo: Comparar grupos de pacientes com fratura intra-articular do calcâneo tipos II e III de Sanders. Métodos: Estudo retrospectivo que incluiu 217 pacientes no grupo tratado por redução aberta e fixação interna com placa de compressão (Grupo PC) e 19 pacientes que seguiram um método minimamente invasivo com C-Nail. Resultados: No Grupo PC, os resultados foram excelentes em 35,7%, bons em 38,9%, satisfatórios em 19,17% e ruins em 5,7%. Os resultados registados no grupo que recebeu implante de unha foram excelentes em 36,9%, bons em 31,6%, satisfatórios em 21% e ruins em 10,2% Os valores médios do restauro do ângulo de Böhler desde o pós-ferimento variaram entre 6,8º e 32,3º, no Grupo PC, e entre 7,1º e 33,3º, no grupo tratado com C-Nail. Ao fim de 12 meses, apenas se observou redução mínima do ângulo de Böhler para 29,2º nos dois grupos. Conclusão: Os resultados do método recentemente introduzido de osteossíntese minimamente invasiva com C-Nail são estatisticamente idênticos aos obtidos pela redução aberta e fixação interna com placa de compressão. Assim, o novo tipo de osteossíntese com C-Nail é adequado como primeira escolha em fraturas do tipo Sanders II e III. ***Nível de evidência IV, Estudo retrospectivo de observação.***

Descritores: *Procedimentos cirúrgicos minimamente invasivos. Calcâneo. Pinos ortopédicos. Placas ósseas.*

Citation: Zeman J, Zeman P, Matejka T, Belatka J, Matejka J. Comparison of LCP and intramedullary nail osteosynthesis in calcaneal fractures. Acta Ortop Bras. [online]. 2019;27(6):288-93. Available from URL: http://www.scielo.br/aob.

INTRODUCTION

Calcaneal fractures are injuries resulting in long-term disqualification of patients from their usual way of life. The objective of surgical treatment is anatomical restoration of all articular surfaces, above all the posterior heel area, restoration of the height, length, width and axis of the calcaneus and primarily stable osteosynthesis.

Since 2005 has been using the method of open reduction and internal fixation with a Locking Calcaneal Plate (DePuy Synthes, 325 Paramount Drive, Raynham, MA 02767, USA) in our department. These pointed to good results and an adequate number of complications.[1,2] We added a minimally invasive osteosynthesis technique using the intramedullary C-Nail (Medin, a.s., Vlachovicka 619, 592 31 Nove Mesto na Morave, Czech Republic) to our surgical portfolio in 2014.

MATERIALS AND METHODS

The sample included only intra-articular fractures treated with plates of nails. Our surgical sample included 212 patients with 236 calcaneus fractures. These included 30 women (14.1%) and 182 men (85.9%), mean age 39.2 years (12 - 62 years).

All authors declare no potential conflict of interest related to this article.

The study was conducted at the Faculty of Medicine in Pilsen, Charles University, Pilsen, Czech Republic.
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The 236 fracture operations consisted in the use of the open reduction internal fixation (ORIF) method with plate in 217 and miniinvasive osteosynthesis using nail in 19 cases.
Of the 217 patients treated with LCP, the following patients were included in Sanders classification groups and types. (Table 1)
From August 2005 to June 2017 we treated types II and III intra-articular calcaneal fractures using the method of open reduction internal fixation (ORIF) Locking Calcaneal Plate (LCP).- Starting in early 2014 till June 2017 we also treated type II Sanders fractures with the calcaneal C-Nail method. The nail is made of steel, 65 mm long and 8 mm in diameter. Using an end cap it can be extended in 5 mm steps up to 85 mm. The nail comes in left and right modalities.
The fractures were classified based on the CT acc. to Sanders into type I – IV. Therapy with ORIF from an extended lateral approach was indicated in patients with intra-articular calcaneal fracture with dislocation of the articular surface of more than 1 mm, fractures with shortening of the axial deviation of the calcaneus (more than 10 degrees valgus / more than 5 degrees varus), i.e., types II and III fractures acc. to Sanders. So far, we indicate surgical treatment with minimally invasive access and C-Nail osteosynthesis only for Sanders type II fractures, but we know that other authors also indicate types III and IV here.[3,4]
Contraindications are age above 70 years, uncooperative individuals (alcoholics, drug addicts), heavy smokers, patients with peripheral vascular bed diseases.-
The group of patients undergoing surgery was evaluated using the Clinical Rating System AOFAS (American Orthopaedic Foot and Ankle Society), and the Ankle-Hindfoot Scale[4] for the heel region. The system evaluates foot function assigning 50 points, 40 points for pain, and 10 points for axial foot position. The result is considered excellent for 90 - 100 points, good for 80 - 89 points, acceptable for 70 - 79 points, and poor for lower than 69 points. The AOFAS functional evaluation score was recorded every six months and one year for both LCP osteosynthesis and C-Nail technique.
Our evaluation in the samples also included the influence of posterior articular area incongruence on the overall results, the impact of Böhler's angle and last but not least also the influence of patient age. All this was compared with the Sanders system used to classify the fractures. Articular area incongruence and disturbance of Böhler's angle were, without greater differences, in degrees II and III of the Sanders classification, so we presumed to evaluate the groups jointly for the ORIF and the minimally invasive methods. We finally evaluated the occurrence of infectious complications and surgical wound healing.

Surgery

The surgical procedure was performed after the restoration of "skin wrinkle", i.e., after reduction of the calcaneal oedema. (Figures 1-6) Patients were operated on in the lateral decubitus position with a tourniquet. Patients after surgery were mobilized in crutches as

Table 1. Distribution of fractures by Sanders classification.

Sanders	LCP 217	%	C-Nail 19	%	Fisher 2x2
I	29	13,4	4	21	0,486554
IIA	67	30,9	9	47,5	0,198468
IIB	33	15,2	4	21	0,510894
IIC	14	6,4	2	10,5	0,625011
III AB	31	14,3	0	0	0,146217
III AC	22	10,1	0	0	0,229755
III BC	13	6	0	0	0,401485
IV	8	3,7	0	0	1

Figure 1. Extended lateral approach – LCP.

Figure 2. Extended lateral approach – postoperatively.

Figure 3. Miniinvasive approach.

soon as possible after the procedure. Passive physiotherapy in the ankle joint was initiated in most cases on day 1 after surgery. All patients underwent follow-up X-ray or CT investigation, no later than within five days after surgery. Patients were allowed to walk with a light load starting in week 6 and with full load three months after surgery. The patients came for regular follow-ups after 6 weeks, in months 3, 6 and 12 after surgery, and then on an annual basis.

Figure 4. Miniinvasive approach – postoperatively.

Figure 5. Lateral X - ray postoperatively LCP.

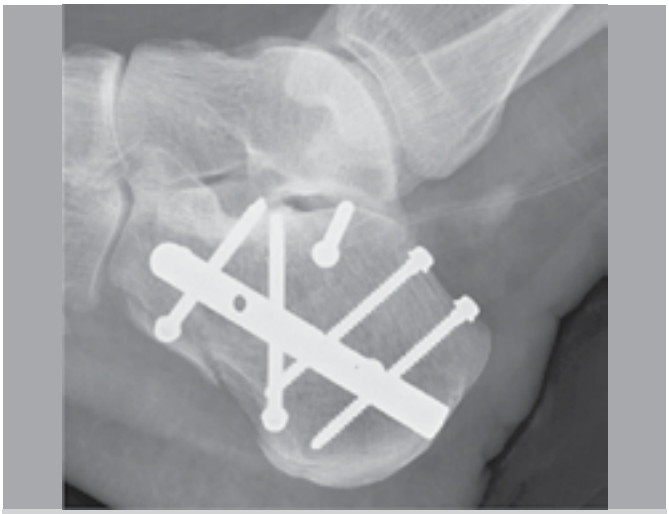

Figure 6. Lateral X - ray postoperatively C – nail.

Statistics

For statistical analyses we used Pearson's chi-squared test and Fisher's exact test.

Ethics

Each patient provided a detailed informed consent. The patients and their families were informed that data from the case would be submitted for publication, and gave their consent.

RESULTS

The surgery was performed after a mean interval of 11 days from injury in the ORIF group (3-26 days), and after 9 days (3-16) in the minimally invasive approach group. Mean duration of hospital stay was 18.2 days (6-38) in the LCP implant group and 14.3 days (7-21) in the group with C-Nail. The AOFAS functional evaluation score outcomes are described in Figure 7 and Table 2.

Mean values of the restoration of Böhler's angle was from post-injury 6.8° to 32.3° in the LCP group and from 7.1° to 33.3° in the C-Nail group. (Tables 3, 4) Only a minimal decrease of Böhler's angle to 29.2° was recorded after one year in both the LCP and nail groups. Values of articular area incongruence and the influence to the functional result are described in Figures 8, 9. Improvement of Böhler's angle on the functional result is seen in Figures 10, 11. Complication in skin healing and infection is described in Table 5.

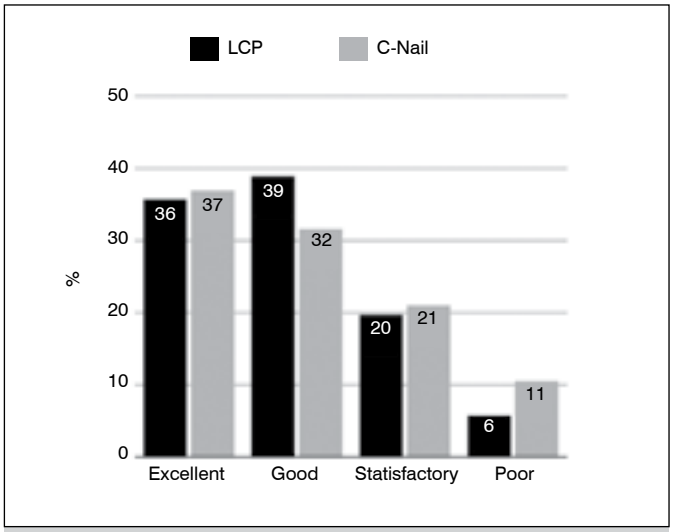

Figure 7. Results according to AOFAS.

Table 2. Results according to AOFAS.

Results	LCP		C-Nail	
	Number of patients	%	Number of patients	%
Excellent	69	35,7	7	36,9
Good	75	38,9	6	31,6
Satisfactory	38	19,7	4	21,0
Poor	11	5,7	2	10,5

Table 3. Preoperative Böhler's angle in individual groups.

	B angle < 15°		B angle 15-30°		B angle > 30°		p^2 3x2
	Number	%	Number	%	Number	%	
LCP	15	7,8	97	50,3	81	42,0	0,7978
C-Nail	1	5,3	11	57,9	7	36,9	
p Fisher 2x2	1,0000		0,6329		0,8086		Fisher 3x2 0,8669

Table 4. Postoperative Böhler's angle in individual groups.

	B angle < 10°		B angle 10-15°		B angle> 15°		p^2 3x2
	Number	%	Number	%	Number	%	
LCP	96	49,7	64	33,2	33	17,1	0,2142
C-Nail	6	31,6	10	52,6	3	15,8	
p Fisher 2x2	0,1536		0,1281		1,0000		Fisher 3x2 0,2307

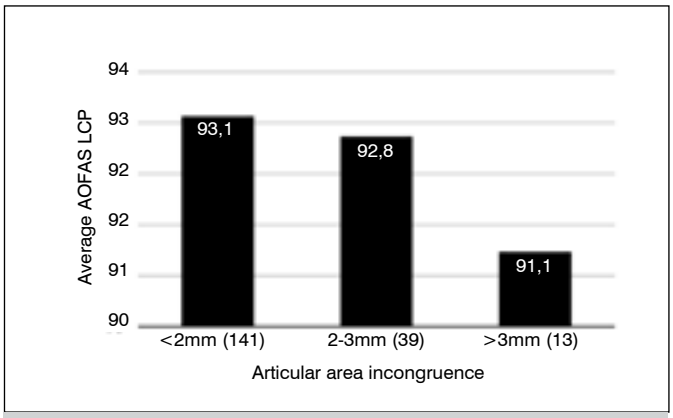

Figure 8. Influence of articular area incongruence on the functional result in fractures treated with LCP.

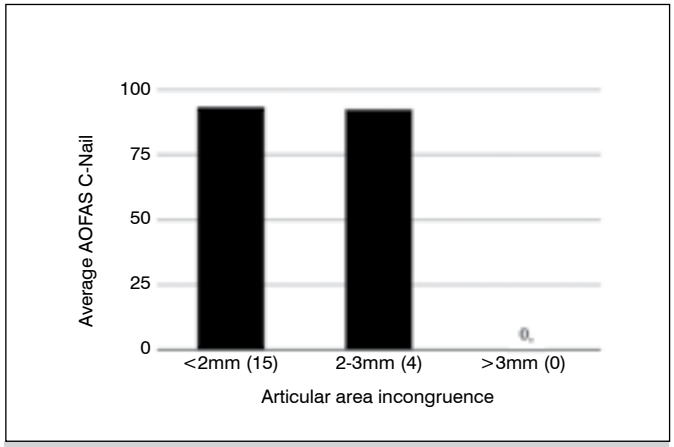

Figure 9. Influence of articular area incongruence on the functional result in fractures treated with C-Nail.

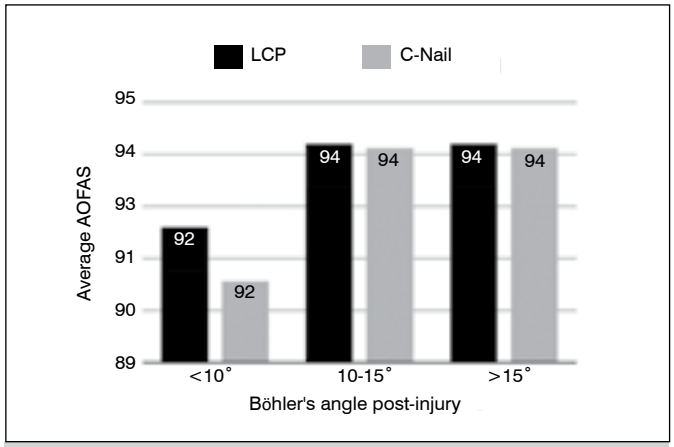

Figure 10. Influence of preoperative Böhler's angle on the functional result.

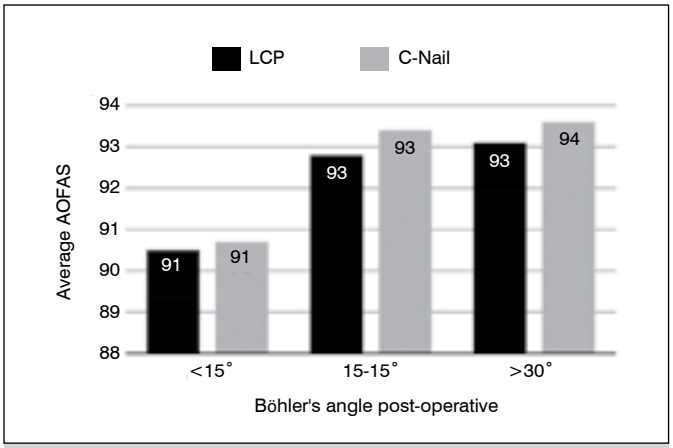

Figure 11. Influence of postoperative Böhler's angle on the functional result.

Table 5. Percentage rates of infectious complications.

	marginal skin necrosis		deep wound infection		marginal skin necrosis	deep wound infection
	Number	%	Number	%	p Fisher 2x2	p Fisher 2x2
LCP	13	6,1	4	1,9		
C-Nail	1	5,2	0	0	1,0000	1,0000

22 patients (9.3%) had to undergo arthrodesis as a result of pain in the subtalar joint and development of post-traumatic arthritis in the same joint. So far we have not recorded any development of post-traumatic arthritis in the group treated with C- Nail. It was also not necessary to remove the nail. These are, however, only short-term results and post-traumatic arthritis of the subtalar joint may still be expected.

A statistically significant difference was recorded only for the comparison of treatment results acc. to the AOFAS evaluation and the occurrence of marginal necrosis. In terms of complications or treatment results, the fractures treated with the C-Nail method statistically did not differ markedly from the group treated with the LCP method. The result could be due to the differing numbers of patient in the samples.

DISCUSSION

We approach fracture treatment either conservatively, with closed or combined reductions and K-wire transfixation[5,6] using various types of minimally invasive,[7] frequently arthroscopically-assisted[8] procedures, open procedures and internal fixation.[9,10] Our department uses the Sanders classification based on CT as indication schema.[11] Similar to other authors we indicate ORIF for fractures of Sanders types II, III, and exceptionally IV.[2,12,13] As an implant we use the LCP plate as part of the extended lateral approach. Sanders type I is treated conservatively. For fractures of type IV acc. to Sanders and for some patients who are contraindicated for ORIF with calcaneal LCP we prefer the method of combined reduction and internal stabilization with K-wires.[6] Since 2014 we have indicated type II Sanders fractures for minimally invasive osteosynthesis as well. In conformity with the literature we use the "sinus tarsi approach" and use the C-Nail implant for osteosynthesis.[3,4] As a rule we rely on CT scans conducted in the sagittal, coronal and transverse sections. CT 3D reconstructions are not absolutely necessary. We agree with the authors,[11] that native X-rays in the lateral and axial views are not sufficient for comminuted intra-articular fractures where depression of Böhler's angle is found.

Related to the risk of early complications and compartment syndrome, consistent preoperative evaluation of soft tissue condition, correct timing of surgery and thorough assessment of other indication criteria are necessary.[14,15] In recent years, our indications for surgical solution also include patients deemed in the past to be very risky. This is the age group above sixty years, smokers, patients with diabetes and sometimes even patients with signs of beginning peripheral arterial disease. For these patients we now use the minimally invasive sinus tarsi approach with nail osteosynthesis. This is due to both the literary results published by other authors and to our own accumulating experience from minimally invasive procedures in general.[3,4,6] So far, indication for C-Nail osteosynthesis includes only patients with type II Sanders fractures.

Zwipp presents one of the largest patient cohort with calcaneal fractures and includes a detailed description of healing complications as well.[2] The cohort includes 496 patients with 553 fractures of whom 90% were treated conservatively and 95% of these were treated from the lateral approach, 1.5% with the bilateral approach and only 1% with the medial approach. Percutaneous mini-osteosynthesis was used in 2.2% of cases and 0.3% of patients underwent primary fusion. Perioperatively he uses open arthroscopy to check articular area reduction. The use of LCP has resulted in a significant decrease in the use of bone grafting from 53% to 3.8%. Marginal necrosis occurred in 6.7% of the 453 fractures treated with ORIF, haematoma was observed in 4.7%, soft tissue infection in 4.3%, and bone infection in 2.2%. The authors did not have to conduct any amputations, but recorded compartment syndrome in 5.5% cases. They had excellent and good results in 72% of patients. This is comparable to our results with the LCP method reported above. In 2016, however, Zwipp et al. published a group of 106 patients with C-Nail implant osteosynthesis where the proportion of infectious complications was only 1.9%, with the other results being comparable.[3] In 2015 Pompach published a similar group where superficial skin necroses are reported in 1.9% and deep infection in 0.9% in C-Nail implant osteosynthesis,[3] similar to our group of patients. Goldzak does not report greater differences between intramedullary nail and angular stable plate stabilities in the biomechanical model.[7] Zwipp uses the medial approach in simple extra-articular fractures or in combination with the extended lateral approach in markedly displaced fractures. This approach consists in surgical incision on the medial side of the calcaneus halfway between the medial malleolus and medial edge of the foot. Burdeaux used this approach with very good results in 51 patients with 60 displaced fractures treated from the medial approach.[16]

Stehlík and Štulík obtain excellent results in the treatment of displaced calcaneal fractures using their own combined method, consisting in direct or indirect reduction and K-wire stabilisation.[6] We ourselves use this method only in very high risk patients and for Sanders IV.

A frequently discussed topic is the filling of calcaneus body defects. Brodt et al. report statistically higher calcaneal stability after osteosynthesis with augmentation, but do not use an angular stable plate.[13] There is no difference even in the complication rate in their patients when osteosynthesis with filling is used. At the same time, they do not report any advantages when tricalcium phosphate is used, and do not recommend full loading before 3 months after osteosynthesis. In his work Longino compares the results of calcaneal osteosynthesis with spongioplasty using a pelvic graft and without spongioplasty, without any pronounced differences in the final results in his sample.[10] Elsner evaluates the results of 18 patients in whom he used augmentation with calcium phosphate cement as part of osteosynthesis.[17] Over a three-year interval no increased percentage of complications occurred. Schildhauer evaluates early calcaneus loading with tricalcium phosphate cement augmentation. After three weeks of full loading he found no reduction loss.[18]

In our group of patients we have not recorded differences in results of patient on whom we either performed or did not perform defect augmentation in the neutral triangle region. There was no increase in the percentage of complications in patients with defect filling in the calcaneus. Coincidently with that there was no extension of bone healing or the need to delay full limb load in patients where the defect was left unaugmented. Neither did we record any more pronounced reduction loss, i.e., reduced calcaneal height, or shortening or redisplacement in the posterior articular heel area. This is certainly the result of the strict use of an angular stable implant (plate, nail) the rigidity of which ensures sufficient osteosynthesis stability and enables the use of relatively early loading without the need for defect augmentation.

Another slightly controversial point is indication of primary talocalcaneal arthrodesis when treating comminuted intra-articular calcaneal fractures of Sanders type IV. Clare and Sanders defend primary subtalar arthrodesis in these cases.[9] It is true, however, that one alternative is to perform standard ORIF from the extended lateral approach using an angular stable plate and postponing subtalar arthrodesis to second-stage surgery when the patient develops post-traumatic arthritis of the talocalcaneal joint and suffers progression of pain.[19]

We do not use arthroscopically-assisted minimally invasive procedures for calcaneal fractures. It is our view that arthroscopy is useful in controlling reduction and posterior articular heel area compression after osteosynthesis, as described by Zwipp and Rammelt.[2] Neither do we use the method of indirect reduction with Kirschner wire transfixation acc. to Stehlík and Štulík.[6] The reason is the necessity to exactly reduce the fragments in articular area regions, above all in the posterior articular heel area when its part becomes rotated and impacted into the neutral triangle region. Closed reduction is almost impossible in this case.

It has been found that the severity of damage to the posterior articular area as expressed in the Sanders classification is proportional to the AOFAS functional scoring system where there is a proportional decrease in the AOFAS result as related to fracture severity. This is connected with the AOFAS score being lower in larger postoperative posterior calcaneal articular area incongruence, that is, the lower the quality of the reduction, the worse the functional result.

AOFAS tends to be lower with lower Böhler's angle values after injury. The same holds in postoperative follow-up when it can be seen that the value of AOFAS improves after reduction and restoration of Böhler's angle. Again, the more Böhler's angle comes to its values prior to injury, the better the result.[20]

CONCLUSION

Calcaneal fractures continue to be some of the most complicated problems of post-traumatic surgery and an ideal treatment method is yet to be found. We succeeded in demonstrating in our sample that the rate of successful treatment (as evaluated with the AOFAS scale) declines with increasing fracture severity acc. to the Sanders classification, with both preoperative and postoperative Böhler's angle values, age, and less than perfect reduction of the posterior articular area of the calcaneus.

The results of the recently introduced method of minimally invasive C-Nail osteosynthesis are identical to those obtained with the ORIF LCP method; on the other hand, its use is associated with lower occurrence rates of superficial skin necroses and deep infections. Obtaining a significant difference will require a larger patient sample, but already now it is possible to state that the new method with C-Nail can be successfully used as the method of first choice in Sanders type II and III fractures.

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JZ (0000-0002-6944-860X)* contributed to the concept and design of the article, performed the surgeries, drafted the text, analyzed the data and wrote the article; PZ (0000-0002-8557-8236)* drafted the text, analyzed the data; TM (0000-0000-0000-0000)*, performed the surgeries, analyzed the data; JB (0000-0000-0000-0000)* performed the surgeries, analyzed the data; JM (0000-0003-4698-7640)* participated in drafting and reviewed the text, contributed to the intellectual concept of the study, head of the study. *ORCID (Open Researcher and Contributor ID).

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ORIGINAL ARTICLE

FUNCTIONAL OUTCOME OF OBERLIN PROCEDURE

RESULTADO FUNCIONAL DA CIRURGIA DE OBERLIN

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ABSTRACT

Objective: To evaluate the functional outcome of patients with traumatic brachial plexus injury undergoing the Oberlin procedure. Methods: Eighteen patients were assessed, comprising 17 men (94.4%) and 1 woman (5.6%), mean age 29.5 years (range 17-46 years), with upper traumatic brachial plexus injury (C5-C6 and C5-C7). We assessed active range of motion of the elbow, elbow flexion muscle strength and hand-grip strength, and applied the DASH (Disabilities of the Arm, Shoulder and Hand) questionnaire. Results: Four patients (22.2%) did not achieve effective elbow flexion strength (BMRC Grade 3). Mean active range of motion was 100.2º (±45.6º), and we observed a mean percentage of strength recovery relative to the contralateral limb of 35.5% (0-66.3%). Elbow flexion (p = 0.0001) and hand-grip (p = 0.0001) strength levels were lower on the affected side. Conclusion: The surgical technique described by Oberlin for brachial plexus injuries proved effective for restoring elbow flexion and produced no functional sequelae in the hand. Bicep strength outcomes were better when surgery was performed within 12 months of injury. ***Level of evidence II, retrospective study.***

Keywords: Brachial Plexus. Nerve Transfer. Muscle Contraction.

RESUMO

Objetivo: Avaliar o resultado funcional dos pacientes com lesão traumática do plexo braquial submetidos à cirurgia de Oberlin. Métodos: Foram analisados 18 pacientes, sendo 17 homens (94,4%), com idade média de 29,5 anos (17 a 46 anos), com lesão traumática alta do plexo braquial (C5-C6 e C5-C7). Avaliamos a amplitude de movimento ativa do cotovelo, a força muscular de flexão do cotovelo e a força de preensão palmar, e aplicamos o questionário Disabilities of the Arm, Shoulder and Hand (DASH). Resultados: Quatro pacientes (22,2%) não obtiveram força eficaz de flexão do cotovelo BRMC (Grau 3). A amplitude de movimentação ativa apresentou média de 100,2º (± 45,6º) e observamos média de 35,5% (0 a 66,3%) de percentual de recuperação da força em relação ao membro contralateral. Foi observada menor força de flexão de cotovelo (p = 0,0001) e de preensão manual (p = 0,0001) no lado acometido. Conclusão: A cirurgia descrita por Oberlin para lesões do plexo braquial mostrou-se eficiente para a restauração da flexão do cotovelo e não deixou sequelas funcionais para a mão. Os resultados para a força do bíceps são melhores nas cirurgias realizadas com menos de 12 meses de lesão. ***Nível de evidência II, estudo retrospectivo.***

Descritores: *Plexo Braquial. Transferência de Nervo. Contração Muscular.*

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INTRODUCTION

The incidence and severity of brachial plexus injuries has increased worldwide.[1] In the vast majority of cases, these injuries are caused by high-energy trauma. The increase in cases is directly associated with the growing number of motorcycle accidents involving young, economically active individuals, resulting in limitation both for activities of daily living and the occupational sphere.[1-5]

These injuries are usually classified according to the level of the injury into upper (injury of C5-C6 or C5-C6-C7 roots), lower (C8-T1) or total, affecting all roots of the brachial plexus.[4] Upper trunk (C5-C6) involvement results in significant disability, with loss of shoulder function (abduction and external rotation), elbow flexion and forearm supination.Involvement of theC7 root can lead to further deficits including wrist and elbow extension.Total injuries affect upper limb function completely.[1,6,7] The severity of these injuries range from neuropraxia (generally exhibiting spontaneous resolution) to complete injury due to avulsion, with no prospect of recovery.[6]

For patients with palsy of the upper roots of the brachial plexus (C5-C6 or C5-C7), the priority of first restoring elbow function, followed by shoulder abduction and external rotation, is well established in the literature.[2,4,8]

The strategies for brachial plexus repair consist of surgical exploration followed by reconstruction using nerve grafts.[6] This approach is reserved only for post-ganglionic injuries.In pre-ganglionic injuries involving root avulsion, the proximal root stumps are unavailable for grafting and surgical repair is based on nerve or tendon transfers.[2,6,9-12]

Evidence suggests that the outcomes of nerve transfers, also defined as neurotizations, are better than results attained for tendon transfers.[8,11-13] Neurotizations performed using nerves from the brachial

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plexus are called intraplexial, whereas situations in which the donor site is not part of the brachial plexus are referred to as extraplexial. Transfer of a nerve entails total or partial resectioning of a healthy nerve and suturing it to the end of a paralyzed nerve.In cases of total resectioning of the donor nerve, it is important to bear in mind that this involves potentially sacrificing the function that the nerve hitherto performed, resulting in permanent sequelae.Partial use of the donor nerve, in the form of single fascicles, spares most of the nerve, preserves motor and sensory function of the donor nerve, whilst also allows the reconstruction to attain acceptable functional levels.[14] The neurotization techniques significantly improve the outcomes of surgical management of upper brachial plexus injuries.[15] More specifically, for restoring elbow flexion (priority in reconstruction), the literature reports use of the intercostal nerve, spinal accessory nerve (cranial nerve pair XI), phrenic nerve or fibers in the ulnar nerve, as donor sites, which are transferred to the musculocutaneous nerve to reinnervate the brachial biceps muscle.[13] Recent studies have shown superior results for elbow flexion when fascicles of the ulnar nerve are employed as the donor nerve.[6,8] The technique described by Oberlin et al.[16] (1994) uses a predominantly motor fascicle of the ulnar nerve which is transferred and sutured at the motor branch to the biceps. Attaining satisfactory results using this technique hinges on several factors, such as nerve suturing occurring at a healthy, uninjured area with lower fibrosis compared to the injury site; use of a single suture, without the need for nerve grafting; a short distance for axonal regeneration to reach the target muscle; and use of a well-vascularized nerve for the transfer.[6,8,11,15] This is a procedure which causes no morbidity at the donor site.[13,16,17] The objective of the present study was to assess the functional outcome of traumatic brachial plexus injury patients submitted to surgery using Oberlin´s procedure.

MATERIALS AND METHODS

A cross-sectional study of patients of the Outpatient Clinic of the Hand Surgery and Microsurgery Group of the Santa Casa de Misericórdia de São Paulo Hospital was conducted to assess outcomes of the Oberlin surgical procedure for brachial plexus injury. The study included patients with upper brachial plexus traumatic injuries at levels C5-C6 and C5-C6-C7; aged > 15 years; submitted to the Oberlin procedure, in association or otherwise with other concomitant brachial plexus procedures (reconstructions with grafts, intraplexial or extraplexial neurotizations such as: accessory nerve transfer to the suprascapular nerve of the motor branch of the triceps muscles to the axillary nerve) and who were followed up post-operatively for at least six months.Patients diagnosed with obstetric palsy, pediatric patients, as well as those with lower and total brachial plexus injury, were excluded from this investigation. The following clinical aspects were assessed:age, gender, side affected, handedness, work activity prior to accident, type of accident, time elapsed (in months) between the trauma event and the surgery performed by the fast-track specialized team, presence of associated injuries and level of neural injury (trunks affected) as determined by physical examination and initial surgical findings. The active range of motion of the elbow, elbow flexion muscle strength, hand-grip strength and results on the DASH (Disabilities of the Arm, Shoulder and Hand) questionnaire were assessed.[18] Free active range of motion was measured using a goniometer, with the patient in a standing position. The goniometer was placed on the sagittal plane centered over the elbow joint and, starting from the point of maximum extension, the patients was instructed to perform maximum flexion, with the reading taken in degrees. Elbow flexion muscle strength was measured in two ways: using the British Medical Council scale and by dynamometer.

For the scale assessment, the patient was instructed to assume a sitting position, with trunk upright to prevent compensatory movements during the exam.The examiner stabilized the proximal region by providing the necessary support.Strength was graded as M0, no muscle contraction; M1, trace of contraction; M2, active movementwith gravity eliminated; M3, active movement against gravity; M4, active movement against resistance; M5, normal strength.A result below M3 was considered poor and these patientswere not subsequently submitted to the dynamometry tests.
The dynamometry assessment was done according to the recommendations of the American Society of Exercise Physiologists, as described by Brown.[19] Elbow flexion strength was measured in kilograms (Kgf) using a model 01163 Lafayette® Hand Held Dynamometer (Manual Muscle Test - MMT) consisting of two adjustable rigid straps, one end of which was affixed to the floor using a suction cup while the other end was attached to the patients hand.The patient remained in a sitting position holding the elbow at 90º alongside the body and with forearm in supination.The device was adjusted to patient height. Three consecutive measurements were made at 30-second intervals of 5-second contractions.An average of the three readings taken was calculated.The value obtained was compared with the force of the contralateral side, measured in the same manner as the affected limb. Hand-grip strength was quantified using a Jamar Plus® dynamometer. The test was performed in the sitting position with the elbow flexed at 90º.The examiner stabilized the patient´s wrist during the test, and patients were encouraged to exert the maximum grip-strength possible.Three measurements were made for each limb at 30-second intervals.The mean of these measurements in kilograms (Kgf) was used for the analysis, comparing the values obtained for each limb. The data gathered were stored on the Excel program for Windows and then compared and analyzed using the SPSS statistics program V20 for Windows.The elbow flexion and hand-grip strength data were first tested for normality and logarithmic transformations applied when appropriate.Mean values for normal and affected sides were then compared after neurotization using the paired *t*-test, with an alpha < %5 considered significant.All analyses were carried out using the Statistical Package for the Social Science for Windows (SPSSW) – version 15.0. The data were expressed as mean ± standard deviation. This study was approved by the Ethics Committee for Analysis of Research Projects (CAPPesq) (number 10179316.7.0000.5479). All patients signed an informed consent form after receiving a detailed explanation.

RESULTS

A total of 18 patients were analyzed.The patient group comprised 17 men (94.4%) and 1 woman (5.6%), with a mean age of 29.5 years (range 17-46 years).With regard to the trauma mechanism, most cases involved motorcycle accidents (17 individuals, 94.4%).The distribution of affected side, left or right, was similar in the sample studied, and 8 patients (44.4%) had other associated injuries.The analysis of injury level revealed predominantly C5-C6 injuries (13 cases) (72.2%) followed by C5-C7 injuries (5 cases)(27.8%).Time elapsed between trauma and performance of the surgical procedure ranged from 3 to 17 months, with a mean interval of 9.2 months. (Table 1)
Four patients (22.2%) did not attain effective elbow flexion strength (MRC Grade 3), mean active range of motion was 100.2º (±45.6) and mean percentage recovery of strength relative to the contralateral limb was 35.5% (0-66.3%).Mean score on the DASH was 37.87 (range 14.2-79.0). Three patients showed no improvement after the surgical procedure. (Table 2)
Elbow flexion (p= 0.0001) and hand-grip (p= 0.0001) strength was lower on the injured side submitted to neurotization, compared with the normal contralateral side.

Table 1. Clinical data.

Patient	Age	Sex	Handedness		Side affected	Trauma mechanism	Time elapsed to surgery (M)	Associated injuries	Level of injury
			Before	After					
1	17	M	R	L	Right	Motorcycle	15	None	C5-C7
2	27	M	R	R	Right	Motorcycle	12	None	C5-C6
3	46	M	R	R	Left	Motorcycle	8	None	C5-C6
4	38	F	R	R	Left	Fall from height	14	None	C5-C7
5	27	M	R	R	Left	Motorcycle	10	Humeral fracture	C5-C7
6	28	M	R	R	Left	Motorcycle	6	Fractures to foot, radius and femur	C5-C6
7	39	M	R	L	Right	Motorcycle	16	None	C5-C6
8	37	M	R	R	Left	Motorcycle	6	Fracture to radius	C5-C6
9	17	M	R	R	Left	Motorcycle	3	Fracture to scapula and rib	C5-C6
10	26	M	R	L	Right	Motorcycle	3	Tibia fracture	C5-C6
11	20	M	R	L	Right	Motorcycle	7	Clavicle fracture	C5-C6
12	37	M	R	R	Left	Motorcycle	16	Rib and cervical vertebrae fractures	C5-C7
13	35	M	R	R	Left	Motorcycle	17	None	C5-C6
14	24	M	R	R	Right	Motorcycle	6	None	C5-C6
15	27	M	R	L	Right	Motorcycle	6	None	C5-C6
16	25	M	R	L	Right	Motorcycle	5	None	C5-C6
17	37	M	R	R	Left	Motorcycle	9	Clavicle and wrist fracture	C5-C7
18	24	M	R	R	Right	Motorcycle	6	None	C5-C6

Table 2. Quantitative variables.

Patient	ROM (degrees)	Elbow				Grip		DASH
		MRC	Dynamometry(Kgf)		Strength (%)	Jamar (Kgf)		
			R	L		R	L	
1	130	3	11.3	29.3	38.6	21.3	38.0	51.6
2	100	3	13.0	36.5	35.6	42.7	54.7	27.3
3	132	4	26.7	17.7	66.3	50.0	14.0	22.3
4	14	2	12.7	0.0	0.0	34.0	6.7	79.0
5	100	3	31.7	7.9	24.9	49.3	22.0	39.1
6	130	4	33.2	20.0	60.2	48.6	21.3	35.1
7	0	2	0.0	31.7	0.0	21.0	41.3	30.8
8	130	4	30.9	14.3	46.3	34.0	11.3	30.0
9	110	4	29.0	13.0	44.8	38.6	18.3	22.5
10	150	4	4.2	11.1	37.8	37.0	46.0	30.0
11	130	3	3.6	11.3	31.9	26.3	38.6	34.1
12	10	2	12.0	0.0	0.0	39.3	2.0	58.3
13	80	2	20.3	0.0	0.0	34.0	12.0	60.0
14	100	4	10.3	27.6	37.3	38.0	42.0	34.1
15	128	4	12.0	20.7	58.0	34.0	51.3	28.0
16	130	4	23.0	37.3	61.7	22.6	40.3	33.3
17	120	3	32.5	10.7	32.9	36.6	11.3	52.0
18	110	4	21	33	63.63	38.0	47.0	14.2

DISCUSSION

Neurotizations or nerve transfers represent a favorable treatment option for brachial plexus injuries. In root avulsion injuries, the Oberlin procedure used alone has shown better outcomes than tendon transfers[11-13] or nerve grafting in reparable injuries.[6]

Factors determining improved outcomes include the proximity of the donor nerve to the motor end plate of the recipient muscle, and thus shorter reinnervation time; the need for only a single anastomosis as opposed to the two required for nerve grafting; and the more anatomic force vectors, contractile capacity and tension of the muscle previously determined for the primary motion compared to the reorientation and new characteristics of a muscle involved in a tendon transfer.[6,7,9,11,12]

Given the factors outlined above, allied with advances in dissection techniques, electrostimulation to select the best fascicle, magnification of the surgical field of view and improved neurorrhaphy techniques, nerve transfers are becoming the treatment of choice for nerve injuries.[11-13]

The results of the presentstudy are similar to those reported in the literature for recovery of elbow flexion strength after the Oberlin procedure (77.7% ≥ MRC grade 3 and 50% ≥ MRC grade 4),[2,7,14,20] yet worse than some studies reporting 90-100% successful outcomes.[1,13,21] This disparity appears to be related to the fact that delayed surgical treatment – longer than 12 months after injury – is associated with poorer outcomes[2,6,8,17,21] where 5 patients (27.8%) in the present sample had a time elapsed between injury and surgery of over 12 months.

Comparison of elbow flexion strength relative to the contralateral limb (35.5% of the unaffected limb), although statistically meaningful in terms of strength loss, showed similar results to those found in previous studies.[4,15]

Success of the Oberlin procedure hinges largely on the characteristics of the donor nerve.In theory, this should be specifically motor, close to the recipient motor end plate and the dysfunction caused by resection should be acceptable or compensated by other muscles.The use of an ulnar nerve fascicle potentially satisfies all these criteria.Previous studies have shown no loss of function in the affected hand submitted to surgery. Indeed, the operated hand sometimes shows improved grip strength scores after the surgery.[1,2,9,13,14,17] In the present study, mean grip strength was 22.2 kg (2-42.7) which, although demonstrating a statistically significant loss of strength, mirrors results of previous studies.[7,9] Despite the loss of grip strength seen in the present study, overall hand function was unaffected.This result is corroborated by the patients´ perceived functional deficit as assessed by the DASH score (37.87), which is in line with previously reported results.[15,21]

CONCLUSION

The surgical technique described by Oberlin for brachial plexus injuries proved effective for restoring elbow flexion and produced no functional sequelae in the hand.

Bicep strength outcomes were better when surgery was performed within 12 months of injury.

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ORIGINAL ARTICLE

TRANSFER OF THE RADIAL NERVE BRANCHES FOR THE TREATMENT OF THE ANTERIOR INTEROSSEOUS NERVE LESION: AN ANATOMICAL STUDY

TRANSFERÊNCIA DOS RAMOS DO NERVO RADIAL PARA TRATAMENTO DA LESÃO DO NERVO INTERÓSSEO ANTERIOR: ESTUDO ANATÔMICO

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ABSTRACT

Objective: This anatomical study aimed to analyze the possibility of transferring the radial nerve branches destined to the brachioradialis (BR), extensor carpi radialis longus (ECRL), extensor carpi radialis brevis (ECRB), and supinator (SM) muscles to innervate the AIN. Methods: Ten limbs from five male cadavers were prepared by intra-arterial injection of a solution of 10% glycerol and formalin. Results: The presence of only one branch to the BR muscle was noted in 7 limbs and two branches were noted in three limbs. In two members of a common trunk with branch to the ECRL. In eight cases, we identified one branch for the ERLC and two branches in two cases. We identified only one branch for the ECRB, while in six limbs, two branches were noted, penetrating the muscular body at two different points. We identified at least two branches innervating the supinator muscle. The AIN was detached from the median nerve distal to the intercondylar line of the humerus. In seven limbs, it originated from the nervous fascicles of the posterior region of the median nerve and from the posterolateral fascicles in three limbs. The flexor pollicis longus and flexor digitorum profundus muscles received more than one branch of the AIN in all limbs. Conclusion: The radial nerve branches for the ECRL, ECRB, and supinator muscles can be transferred directly to the AIN or to one of its branches after intraneural dissection, without tension even in elbow movements. ***Level of Evidence IV; Case series.***

Keywords: Radial nerve. Median nerve. Nerve transfer. Cadaver. Anatomy.

RESUMO

Objetivo: Analisar a possibilidade de transferir os ramos do nervo radial (NR) destinados aos músculos braquiorradial (BR), extensor radial longo do carpo (LREC), extensor radial curto do carpo (ERCC) e supinador (SM) para reinervar o nervo interósseo anterior (NIA). Métodos: Estudo anatômico, no qual foram dissecados dez membros de cinco cadáveres preparados com solução de glicerina e formol a 10%. Resultados: A presença de apenas um ramo para o músculo BR foi registrada em sete membros e de dois ramos em três membros. Em dois membros de um tronco comum com ramo para o ERLC. Em oito membros, identificamos um ramo para o ERLC e, em dois membros, dois ramos. Identificamos apenas um ramo para o ECRB, este em seis membros, se dividia em dois ramos. Ainda, identificamos pelo menos dois ramos para o SM. Em sete membros, originou-se dos fascículos nervosos da região posterior do MN e, em três membros, dos fascículos posterolaterais. Os músculos flexores longo do polegar (FLP) e profundo dos dedos (FPD) receberam mais que um ramo do NIA em todos os membros. Conclusão: Os ramos do NR destinados aos músculos BR, ERLC, ECRB e SM podem ser transferidos ao NIA ou a um de seus ramos, sem tensão mesmo durante a movimentação do cotovelo. ***Nível de Evidência IV, Série de casos.***

Descritores: *Nervo Radial. Nervo Mediano. Transferência de Nervo. Cadáver. Anatomia.*

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INTRODUCTION

The anterior interosseous nerve (AIN) is originated from the median nerve (MN) in variable place. In its origin it is initially located parallel to MN, lower it is located between the laterally long flexor of the thumb (LFT) and the deep medially flexor of the fingers, sending branches to both of these muscles. It has constant branches to the deep flexor of the index finger and provides partially the deep flexor of the medium finger. The deep flexor of the other fingers is provided

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The study was conducted at Faculdade de Ciências Médicas e da Saúde. Pontifícia Universidade Católica de São Paulo.
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by the ulnar finger. The AIN, after emitting the branches to FDP and LFT, follows along with the anterior interosseous artery, supporting itself on the anterior aspect of the interosseous membrane, distally innervating the square pronator muscle (SP), sending sensitive branches to the articulations of the carpus.[1] However, there are considerable variations about the proportion that the MN and NU provide to FDP.[1-3] High injuries of MN happen closely to the origin of AIN, resulting in an inability of the thumb flexion and forefinger with decrease of the muscular force of forceps and grip.

The primary reparation of a nervous injury provides the best function results. Autologous nerve grafts may be employed when the distance between the nerve stumps does not allow nerve suturing without tension. Nevertheless, there are injuries of nervous which are not able for primary repair and to which the grafts does not allow satisfactory results. These injuries include very proximal nerve injury; extensive injury zone, resulting in a long space between nerve stumps; and idiopathic nerve paralysis or neuritis in which there is no healthy proximal nerve segment.[4,5]

In case of high injuries of MN, with very long intervals between the extremities, it may not have enough time to generate the axon and so get the terminal motor places of the nervous muscles by AIN< before they become permanently resistant to the reinnervation. This long period of denervation let LFT and FDP muscles able to irreversible denegation of the fibrosis of the terminal motor plates.[4-6] In the distais, the time of reinnervation is minimized by the proximity with the motor plate. The donator nervous must be dispensable or redundant, must have pure motor fibers, diameter and number of compatible axons, and most preferably innervate synergistic muscles to the receptor.[7] The understading of brain plasticity and the potential of motor reeducation insentivated the developing of these techniques.[8,9]

Some authors have recommended that branches of the radial nerve (RN) for the muscles: brachioradialis (BR), radial extensor long of the carpi (ERLC), short radial carpal extensor (ECRB) and branches to supinator muscle (SM) were transferred to the nerve AIN.[10-14] Good functional results have been reported from clinical series of nerve transfer from RN branches to AIN in high MN lesions and in certain brachial plexus lesions. In spite of encouraging clinical reports, few anatomical studies have been conducted about this. The objective of this study was to evaluate in members of corpses the advantages and disadvantages of each one of the RN branches destined to the BR, ERLC, ECRB muscles, and branches to the SM to be transferred to the NIA. We considered the number of branches, fiber nature, muscle function, availability of the donor, synergistic relationships, diameter and number of myelinated fibers, and how close to the target muscles the transfer can be performed without tension even with elbow mobilization.

METHODS

Ten members of 5 corpses were dissected, all adults and males, were prepared by intra-arterial injection of a 10% glycerol and formalin solution. The cadavers did not present evidence of deformities, previous surgical procedures or traumatic injuries in the studied area. We removed the skin and fascia from the third distal of the arm, forearm and wrist. MN was identified in the arm and dissected from proximal to distal. The bicipital aponeurosis was sectioned. The round pronator muscle (RP) was disinserted distally and put apart. Tendons of the flexor radial carpal (FRC) and long palmar muscles (LP) were sectioned in the third distal to make the identification of their nerve branches easier. The branches of MN destined for the muscles: RP, RFC, LP, FSD (superficial flexor of the fingers) and AIN with their branches destined to FPD, LFT and PQ were dissected after the longitudinal division of the FSD and its fibrous arch, following the AIN in the forearm from proximal to distal. RN was identified in the arm between the brachial (MB) and BR muscles and dissected from proximal to distal. The tendons of the BR, ERLC and ECRB muscles were sectioned in their third distal, separated from the fibrous connections that bonded them to facilitate identification of the nerve branches. The division of the RN into its branches: posterior interosseous nerve (PIN) and superficial branch of the radial nerve (SBRN) was identified and related to the humeral intercondylar line (HIL).

The destined branches for the BR, ERLC, ECRB, SM and NIP muscles were dissected. Vascular structures have not been preserved to make the dissection of the nerves easier. In certain phases of the dissection we used a 2.5 magnifying glass. The distance between the LIU was analyzed both with the radial nerve dividing point, as well as with the radial nerve emergence point in the arm, between MB and BR. The order of innervation and the number of branches were recorded with a digital caliper and a millimeter ruler, we measured the diameter and length of the branch for the muscles BR, ERLC, ECRB, NIP, branches for SM. The diameter of the nerves was measured at the midpoint of their length. We analyzed the advantages and disadvantages of each branch of the RN to be transferred to the AIN. We considered the number of branches, fiber nature, muscle function, donor availability, synergistic relationships, diameter, number of myelinated fibers and how close to the target muscles the transfer can be performed without tension. All measurements were performed during the procedures, directly on the anatomical pieces. This work was approved by the Ethics Committee with the number 2.207.258.

RESULTS

RN crossed the lateral intermuscular septum between the MB and BR muscles, on average 9.5 (8.5 to 10.5 cm) proximal to LIU. The first RN branch in the elbow region went to the BR muscle. The presence of only one branch to the BR muscle was recorded in 7 limbs, two branches in 3 limbs. In two limbs of a common trunk with branch to ERLC. The second branch went to ERLC. In 8 limbs we identified a branch for the ERLC, in two members, two branches. We identified only one branch for the ECRB, this one with 6 limbs, this one was divided in two branches, penetrating in the muscular body in two different points. We identified at least two branches for SM, which were originated from NIP. The length and diameter of RN branches are described in Table 1.

The AIN detached from the MN at a distance of 5.7 cm (2.0 to 7.8 cm), distal to the intercondylar line of the humerus. In 7 limbs it originated itself from the nervous fascicles of the posterior region of the MN and in 3 members of the posterolateral fascicles.

The interosseous nerve detached itself from the MN proximally to the RP muscle in 3 limbs, distally to it in 1 limb. In 6 limbs it detached itself from MN under the RP muscle mass.

In all the dissected limbs we recorded that the AIN detached from the MN proximally to the arcade formed between the insertions of

Table 1. Average length and diameters of donor nerves and receptor nerves.

	Libs	Lenght Average in mm	Lenght average in mm	Myelinated number and axons
BR	10	3,2 0,8	1,7 0,6	550 64
LREC	10	3,2 1,0	1,8 0,5	----------
DCRE	10	4,5 2,5	1,5 06	548 175
SM	10	2,0 1,2	1,6 0,7	545 101
AIN	10	5,2 2,7	2,0 0,9	2266 274

BM – brachioradiali muscle; LREC - extensor radial curto do carpo; ECRB- extensor radial curto do carpo; SM – supinator muscle; AIN – anterior interosseous nerve.

the FSD. We analyzed the number of branches destined for the LFT and FPD muscles that penetrated in different points of their muscle mass. The presence of two branches for the FPD and one for the LFT in 3 limbs, 2 branches for each muscle in 3 limbs, 3 for the FPD and 1 for the LFT in 2 members, 3 for the FPD and 2 for the FSD in 2 limbs. The longest branch was always destined to LFT (Table 2).

The advantages and disadvantages of each of the RN branches destined for the BR, ERLC, ECRB were analyzed and also branches for SM to be transferred to the AIN. The AIN nerve fibers were put apart from the MN to allow tension-free nerve co-optation. Thus, the nervous connections were possible in all the members.

Table 2. Average of the numbers of AIN braches to FLP and DFF.

Number of specimens	Branches to the lft	Branches to the DFF
3	1	2
3	2	2
2	1	3
2	2	3

AIN – anterior interosseous nerve; FLP – long flexor of thumb; DFF - deep flexor of fingers.

DISCUSSION

Traditionally, in the irreparable injuries of MN, the digital flexion has been repaired by tendon transferences. For example: Tendon transfer of the ERLC muscle to the FPD muscle and tendon BR to the LFT.

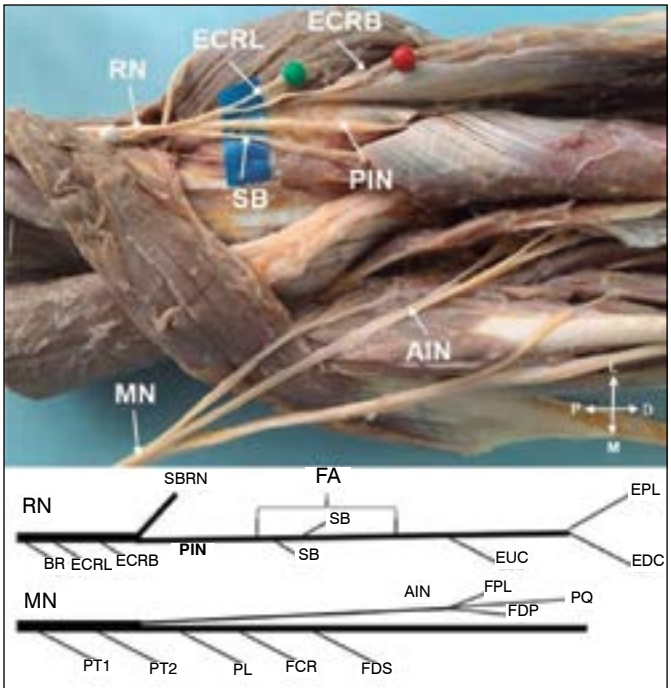
Nervous transference from RN branches for the reconstruction of the flexion of the fingers has been described in the literature. Garcia Lopes et al.[10] report advantages of nerve transfer over tendinous transfer: 1- the appropriate trajectory of the tendon is maintained; 2 - the transfer of nerves requires a less extensive surgical exposure; 3 - the good passive mobility of the wrist is not a prerequisite; 4 - the movement of flexion and extension of the fingers is much more independent and natural in the nerves transference than in the transfers of tendons. The disadvantage of nervous transferences is the waiting period for nerve growth.

Hsiao et al.[15] transferred SM branches to the AIN. Murphy et al.[12] transferred SM branches combined with the ECRB muscle branch for the NIA. García-López et al.[10] reported the transfer of the nerve branch of the BR muscle to the AIN. Bertelli [11] transferred the ECRB branch to the NIA. In another article they reported the distal branch transfer from the ECRB to the LFT.[13]

We evaluated the advantages and disadvantages of possible RN branch transfers to restore flexion of the fingers in MN lesions. (Figure 1) We considered the number of branches, fiber nature, muscle function, donor availability, synergistic relationships, diameter and number of myelinated fibers.

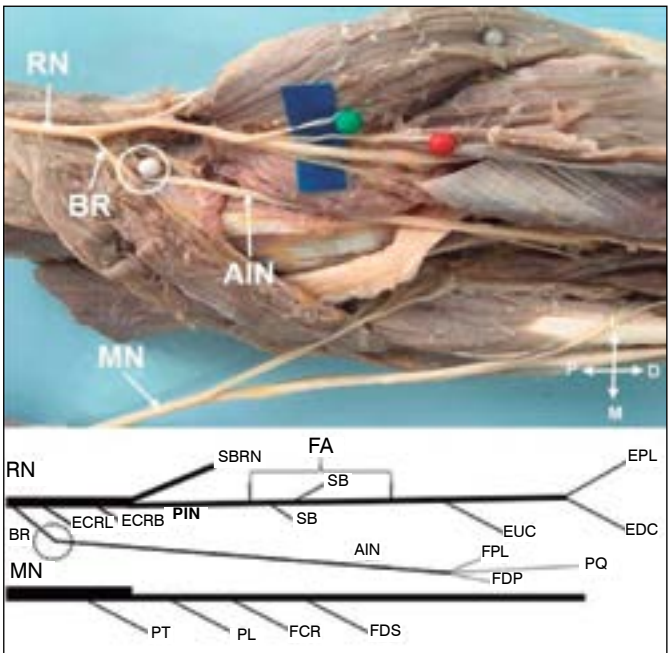
Transfer of the BR muscle motor branch to the AIN:

Advantages: 1- The branch to the BR muscle is made up of motor fibers only. It is an accessory flexor of the elbow, helps supination when the forearm is at maximum pronation, and has little importance for elbow flexion, its denervation does not significantly alter these functions.[10] - The presence of more than one branch of the radial nerve for BR has been found frequently,[16,17] thus one of the branches is preserved maintaining its innervation. The donor and receiver nerves are long enough for transfer. The average diameter of the AIN was 2.0 ± 0.9 mm and the branch diameter for the BR muscle 1.7 ± 0.6, which correspond to 85% allowing a compatible cooptation. We reproduced this neurotization in 10 limbs of 5 corpses and observed that the transfer of the motor branch of the BR muscle to the AIN was possible in all limbs. The AIN fibers were separated from MN to the cubital fossa, thus allowing direct co-optation of the nerves (Figura 2).



Radial nerve (NR); median nerve (MN); anterior interosseous nerve (AIN), branch to the brachioradialis (BR); branch to the long radial carpal extensor (LREC); branch to extensor carpi radialis brevis (ECRB), branch to the supinator (SB); Froshe arcade; branch to the ulnar carpal extensor (UCE); branch to the long extensor of the thumb (LET); branch to common finger extensor (CEF). Branches to the round pronator (RP); branch to long palmar (PL); branch to flexor of the carpus (RFC); branch to superficial flexor of the fingers (FSD); anterior interosseous nerve (AIN); branch to long flexor of the thumb (FLP); branch to deep flexor of the fingers (DFF).

Figure 1. Transfer of branches of the radial nerve (RN) to reinnervate the anterior interosseous nerve (AIN).



Radial nerve (RN); median nerve (MN); anterior interosseous nerve (AIN), branch to the brachioradialis (BR), branch to the radial extensor for carpus (LREC), branch to extensor carpi radialis brevis (ECRB), branch to supinator (SB), Froshe arcade; branch for the ulnar extensor of the carpus (UCE), branch to the long extensor of the thumb (LET), branch to common extensor of fingers (CEF). Branch to round pronator (RP); branch to long palmar (LP); branch to flexor of the carpus (RFC); branch to flexor of the fingers (FSD); anterior interosseous nerve (AIN); branch to flexor of the thumb (FLP); branch to deep flexor of the fingers (DFF).

Figure 2. Transfer of the branch of the brachioradialis (BR) to reinnervate the anterior interosseous nerve (AIN).

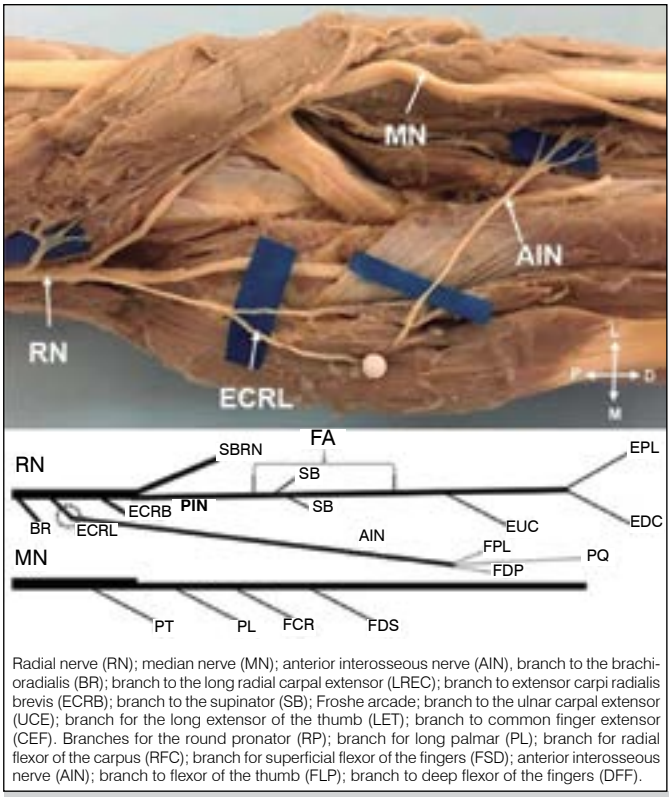
Disadvantages: The BR muscle has potential to be used in tendinous transfers, and its major indication is the transfer to the LFT tendon.[10] The average of myelinated BR axons was 550 and the AIN was 2266 myelinated axons,[10] therefore, the myelinated fibers for the BR muscle corresponded to only 24.3% of those of the AIN.[10] Schereiber et al.[18] consider that the number of myelinated fibers in the donor nerve should be at least 70% of the number of the receptor nerve. In contrast De Medinaceli[19] believed that reinnervation of 30% of muscle fibers is compatible with normal muscle function. Jiang et al.[20] report that axons in the proximal stump can multiply themselves by increasing their number by 3 to 4 times.

Transfer of the branch to the ERLC muscle for AIN

Advantages: 1- It is a pure motor nerve. 2 - It originates distally in relation to the BR and can be connected with greater proximity to the AIN. 3 - Being essentially a wrist extensor is more easily tested when compared to BR. 4- It frequently presents more than one branch, so one of the branches is preserved after the transfer.[16,17] 5- It has synergistic relationships with the flexors of the fingers; the extension of the wrist increases the passive tension of the flexors of the fingers and, as a result, causes the flexion of the fingers, increasing the flexion force. Donor nerves with synergistic functions to the receptor nerves facilitate cortical integration.[5,8] 6- The ECRB muscles and Ulnar extensor of carpi can extend the wrist without radial or ulnar deviation. 7- The average diameter of the AIN was 2.0 ± 0.9 mm and the branch diameter for the ERLC muscle 1.8 ± 0.5, in the 90% correspondence case, allowing a compatible co-optation. 8- We reproduced this neurotization in 10 limbs of 5 corpses. We observed that the transfer of the motor branch of the ERLC muscle to the AIN was possible in all limbs. The AIN fibers were separated from MN to the cubital fossa, therefore making it possible direct co-optation of the nerves (Figure 3).
Disadvantages: 1- It is potentially enough to be used in tendinous transfers, and its major indication is the transfer to the FPD muscle. 2- We did not identify in the literature any reference regarding myelinated fiber counts and the possibility of transferring the ERLC branch to MN branches.

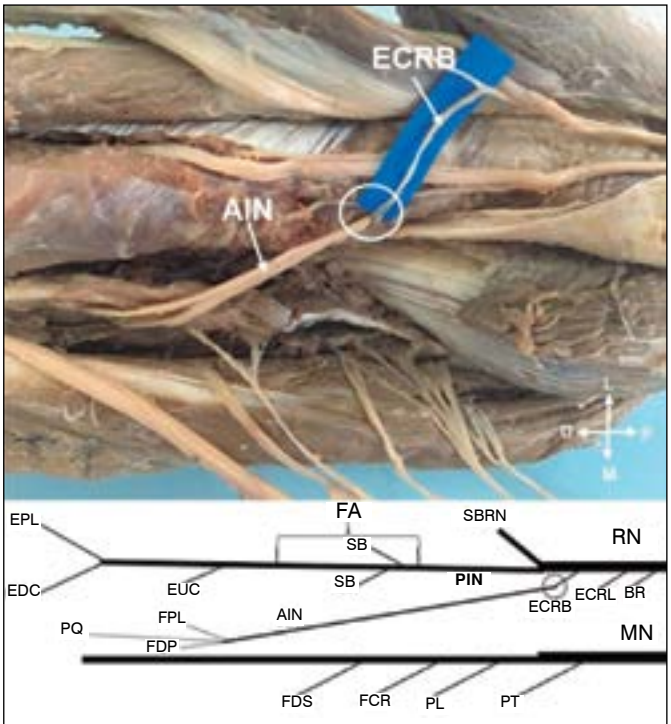
Transfer of the branch to the short radial carpal extensor muscle for AIN:

Advantages: 1- It is a pure motor branch. 2 - It originates distally in relation to BR and ERLC and can be connected with greater proximity to the AIN. 3 - It is the longest of the branches of the radial in the region of the elbow with length of 4,5 ± 2,5 cm. 4 - As long as it is essentially a wrist extensor, it is easily tested. 5- It has synergistic relationships with the flexors of the fingers. 6 - Its average diameter is 1.5 ± 06 and the AIN 2.0 ±, 09 corresponds, therefore, to 75% allowing a compatible cooptation; 7- In 50% of the limbs the distance between two motor points (penetration points in the muscle mass) was greater than 3 cm, allowing only its distal branch to be used as a donor, preserving its proximal motor branch, thus, the extension of the wrist can be maintained after transfer by hypertrophy of the remaining innervated portion of the muscle or even by reinnervation of the distal portion of the ECRB by sprouts from adjacent zones, that is, reinnervation by adoption.[21] We reproduced this neurotization in 10 limbs of 5 corpses. We observed that the transfer of the motor branch of the ERCC muscle to the AIN was possible in all limbs. The AIN fibers were separated from the MN, so allowing direct co-optation of the nerves. (Figure 4)
Disadvantages: 1- It has potential to be used in tendinous transfers and its major indication is the transfer to DFF or RP tendon.[15] 2- Contains an average of 545 myelinated axons, which correspond to 24% of the number of axons of the AIN. In the case of only one ERCC branch, this percentage would be even lower.



Radial nerve (RN); median nerve (MN); anterior interosseous nerve (AIN), branch to the brachioradialis (BR); branch to the long radial carpal extensor (LREC); branch to extensor carpi radialis brevis (ECRB); branch to the supinator (SB); Froshe arcade; branch to the ulnar carpal extensor (UCE); branch for the long extensor of the thumb (LET); branch to common finger extensor (CEF). Branches for the round pronator (RP); branch for long palmar (PL); branch for radial flexor of the carpus (RFC); branch for superficial flexor of the fingers (FSD); anterior interosseous nerve (AIN); branch to flexor of the thumb (FLP); branch to deep flexor of the fingers (DFF).

Figure 3. Transfer of the branch of the long radial extensor of the carpus (LREC) to reinnervate the anterior interosseous nerve (AIN).



Radial nerve (RN); median nerve (MN); anterior interosseous nerve (AIN), branch to the brachioradialis (BR); branch to the long radial extensor for carpus (LREC); branch to extensor carpi radialis brevis (ECRB), branch to the supinator (SB); Froshe arcade; branch to the ulnar carpal extensor (UCE); branch for the long extensor of the thumb (LET); branch to common finger extensor (CEF). Branches for the round pronator(RP); branch for long palmar (PL); branch to radial flexor of the carpus (RFC); branch to superficial flexor of the fingers (FSD); anterior interosseous nerve (AIN); branch to long flexor of the thumb (FLP; branch for deep flexor of the fingers (DFF).

Figure 4. Radial carpal extensor branch transfer of the carpus (ERCC) to reinnervate the anterior interosseous nerve (AIN).

Transfer of supinator muscle branches to AIN:

Advantages: 1- Pure motor branch. 2- In all limbs we have identified at least two branches for supinator. 3 - It originates from the NIP, distally in relation to the branches for BR, LREC and ERCC and may be connected with greater proximity to the AIN. Supination can be maintained by the action of the biceps brachial. 4- Due to its anatomical characteristics, it is not used for tendinous transfers. 5- The average diameter of the AIN was 2.0 ± 0.9 mm and the added diameter of the branches to the supinator muscle 1.6 ± 0.7, in the corresponding case of 80% allowing a compatible cooptation. We reproduced this neurotization in 10 limbs of 5 corpses. We observed that the transfer of the motor branch of the muscle ERCC to AIN was possible in all cases. The fibers of AIN were separated from MN, allowing direct co-optation of the nerves. (Figure 5)

Disadvantages: - 1 – There is not synergistic relationship with the flexors of the fingers. 2- Difficult to be tested clinically. 3- Greater difficulty in dissection, it is necessary to section the superficial head of the supinator muscle, to identify its branches. 4- The number of myelinated axons added to SM is 545, which corresponds to only 25%, of the number of myelinated axons of the AIN.

Combined BR branch transfer for AIN branches aimed to DFF and ECRB branch for LFT

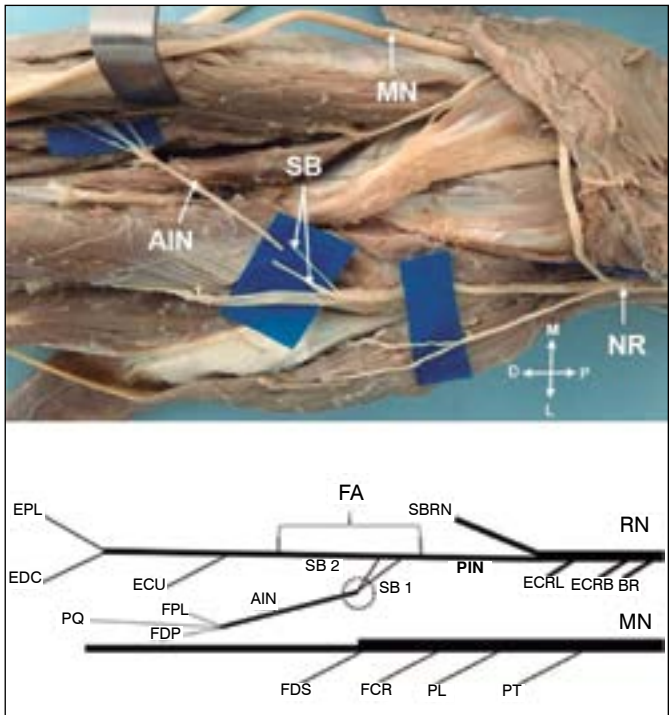
Advantages: 1- They are motor branches 2- The sum of the diameter of the donors is 3.2, surpassing the AIN diameter. 3- The sum of numbers of axons myelinated of the nerves for BR and ERCC is 1100, which corresponds to 48% of the number of axons the receptor nerve. 4- We reproduced this neurotization in 10 limbs of 5 corpses. We observed that the combined transfer of the BR branch to the branches of the AIN destined for the DFF and branch of the ERCC to the AIN was possible in all limbs. The AIN fibers were separated from MN to the cubital fossa, which allowed direct co-optation of the nerves. (Figure 6)

Disadvantages: 1- They are two muscles that have potential to be used in tendinous transfers. 2 - The intraneural dissection of the AIN separating branches into the FLP and DFF may cause damage to axons of the receptor nerve. 3- The synergism between donor and receiver is only partial.

Combined transfer of the ECRB branches to the AIN branches aimed to LFT and supinator branch for DFF

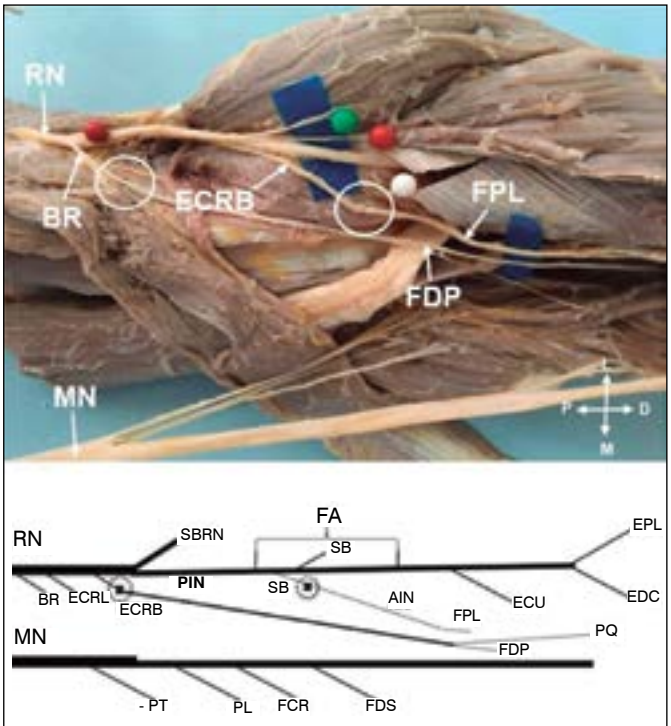
Advantages: 1- They are motor branches; 2- The sum of donor diameter is 3.1, exceeding the diameter of the receiver. 3- The sum of numbers of axons myelinated of the nerves for ERCC and supinator is 1090, which corresponds to 48% of the number of axons of the receptor nerve. 4- The supinator muscle has no potential for tendon transfer. We reproduced this neurotization in 10 limbs of 5 cadavers. We observed that the combined transfer from the ERCC branch to the AIN branches destined for the DFF and branches from the supinator to the AIN was possible in all members. The AIN fibers were separated from the MN, allowing direct co-optation of the nerves (Figure 7).

Disadvantages: 1 - the ERCC muscle has potential to be used in tendinous transfers. 2 - The intraneural dissection of the AIN separating branches to the FLP and DFF, may cause damage to axons of the receptor nerve. 3- The synergism between donor and receiver is only partial.



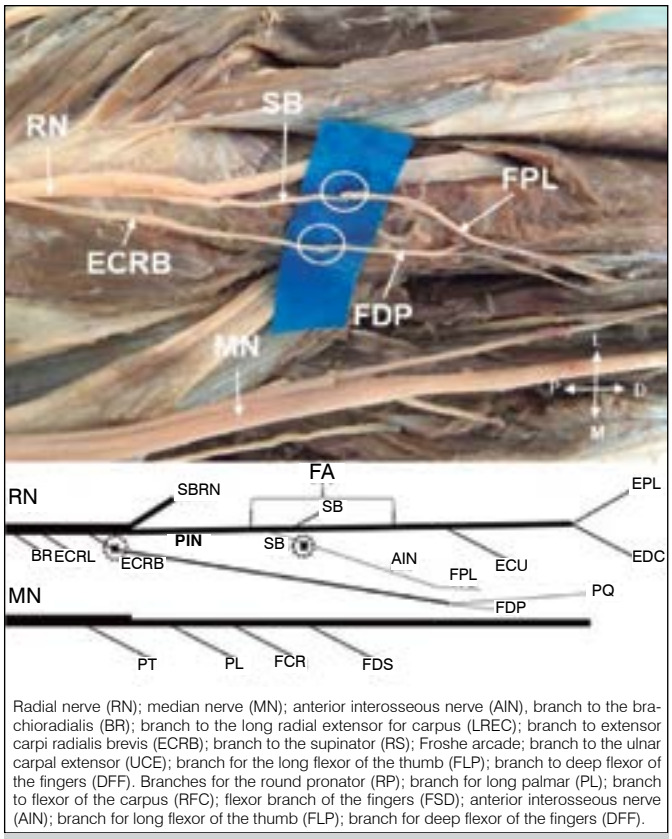
Radial nerve (RN); median nerve (MN); anterior interosseous nerve (AIN), branch to the brachioradialis (BR); branch to the long radial extensor for carpus (LREC), branch to extensor carpi radialis brevis (ECRB), branch to the supinator (RS), Froshe arcade, branch to the ulnar carpal extensor (UCE), branch to the long extensor of the thumb (LET); branch to common extensor of the fingers (CEF). Branches to round pronator (RP); long palmar branch (PL); branch to radial flexor of the carpus (RFC), branch to flexor of the fingers (FSD); anterior interosseous nerve (AIN branch to long flexor of the thumb (FLP); branch to deep flexor of the fingers (DFF).

Figure 5. Transfer of the branches of the supinator (SB), to reinerve the anterior interosseous nerve (AIN).



Radial nerve (RN); median nerve (MN); anterior interosseous nerve (AIN), branch to the brachioradialis (BR); branch to the long radial extensor for carpus (LREC), branch to extensor carpi radialis brevis (ECRB), branch to the supinator (RS), Froshe arcade, branch to the ulnar carpal extensor (UCE), branch to the long extensor of the thumb (LET); branch to common extensor of the fingers (CEF); branches to round pronator (RP); long palmar branch (PL), branch to radial flexor of the carpus (RFC), branch to superficial flexor of the fingers (FSD); anterior interosseous nerve (AIN); branch to long flexor of the thumb (FLP); branch to deep flexor of the fingers (DFF).

Figure 6. Transfer of the branch of the brachioradialis to reinerve the deep flexor of the fingers and branch of the short radial extensor of the carpus to reinerve the long flexor of the thumb.



Radial nerve (RN); median nerve (MN); anterior interosseous nerve (AIN), branch to the brachioradialis (BR); branch to the long radial extensor for carpus (LREC); branch to extensor carpi radialis brevis (ECRB); branch to the supinator (RS); Froshe arcade; branch to the ulnar carpal extensor (UCE); branch for the long flexor of the thumb (FLP); branch to deep flexor of the fingers (DFF). Branches for the round pronator (RP); branch for long palmar (PL); branch to flexor of the carpus (RFC); flexor branch of the fingers (FSD); anterior interosseous nerve (AIN); branch for long flexor of the thumb (FLP); branch for deep flexor of the fingers (DFF).

Figure 7. Transfer of the ERCC branch to reinerve the deep flexor of the fingers and branch of the supinator to reinerve the long flexor of the thumb.

We suggest that surgical approach of the branches of the radial nerve in the elbow region can be done with the forearm in pronation. Incision approximately 13 cm of length, starting from a point three centimeters proximal to the lateral epicondyle following the axis of the radius. The fascia is incised in the distal region of the arm and forearm and the space between the MB and BR is identified. Deepening the dissection in this space allows NR identification with the branches for the MB, BR, LREC and ERCC. More distally, the space between the short radial extensor carpi (ERCC) and the common extensor of the fingers (CEF) is identified. The dissection is deepened in this space, identifying the SM and the Frohse arcade.

The NIP, proximally the Froshe arcade, can be identified by palpation against the radial diaphysis. The superficial head of the SM must be sectioned, following the path of the NIP, thus exposing the intramuscular portion of the NIP and the branches destined to the SM. Limitations of this study include a limited number of corpses limbs, therefore, statistical analyzes could not be performed.

CONCLUSION

We analyzed the advantages and disadvantages of each of the RN branches to be transferred to the AIN. We considered the number of branches, fiber nature, muscle function, donor availability, synergistic relationships, diameter, number of myelinated fibers and how close to the target muscles the transfer can be performed without tension. The RN branches destined to the BR, LREC, ERCC, and SM muscles can be transferred directly to the AIN or to one of its branches after the intraneural dissection of these without tension even during the movement of the elbow.

AUTHORS' CONTRIBUTIONS: Each author has significantly contributed to this article. EBC (0000-0003-4572-3854)* e LAV (0000-0003-4406-2492)*: writing of the manuscript, statistical analysis of the data, and intellectual concept of the manuscript and development of the research project. FCMJ (0000-0002-0425-5700)* LG (0000-0001-9111-0544)* e MPSS (0000-0001-7085-5715)*: data collection, data analysis, manuscript writing and revision. LAV: data collection and analysis. RAA (0000-0002-7062-2177)*: revision of the manuscript and intellectual concept. EBC: critical analysis of the intellectual concept and final approval of the manuscript version to be published. *ORCID (Open Researcher and Contributor ID).

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ORIGINAL ARTICLE

ORTHOPEDIC ASSESSMENT OF THE HIPS IN NEWBORNS AFTER INITIAL PEDIATRIC SURVEY

AVALIAÇÃO ORTOPÉDICA DOS QUADRIS DE RECÉM-NASCIDOS APÓS EXAME PEDIÁTRICO INICIAL ALTERADO

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ABSTRACT

Objective: To analyze and follow-up patients previously selected by pediatricians at the time of birth who presented altered initial physical examination results to identify the pathological changes in their hips. Methods: A prospective cohort study was conducted involving 34 newborns (68 hips) out of a total of 1273 live births; these infants were assessed within the first days of life as altered findings were noted in the initial examination by the pediatrician. The results of clinical and ultrasonographic examination performed using the GRAF method and of specific treatments were analyzed. Results: Of the 68 hips in 34 patients, 2 hips in 2 patients required intervention using the Pavlik harness for 8 weeks; a satisfactory treatment outcome was obtained in both cases. Conclusions: Despite the low orthopedic workload in medical courses, it was possible to identify data consistent with the literature, both in the presentation of clinical findings and in those that required treatment, indicating that an initial evaluation of all newborns is mandatory, especially those with risk factors. ***Level of evidence IV, case series.***

Keywords: Hip Dislocation Congenital. Hip Dislocation. Infant newborns.

RESUMO

Objetivo: Analisar e acompanhar os pacientes previamente selecionados por pediatras desde o nascimento, em busca de alterações patológicas nos quadris, naqueles considerados com exame físico inicial alterado. Métodos: Estudo de coorte prospectivo, iniciado nos primeiros dias de vida, em 68 quadris de 34 recém-nascidos, de um total de 1.273 nascidos vivos no ano da pesquisa, devido a alguma alteração no exame inicial do pediatra. Primeiramente, foram utilizados exame clínico e ultrassonográfico, com o método de Graf, tendo sido instituído tratamento específico naqueles que se fizeram necessários. Resultados: Dos 68 quadris em 34 pacientes, dois quadris em dois pacientes distintos necessitaram de intervenção com uso do suspensório de Pavlik por 8 semanas, obtendo resultado satisfatório em ambos após o término do tratamento. Conclusão: Apesar da baixa carga horária da Ortopedia nos cursos de medicina, podem-se observar dados condizentes com a literatura, tanto na apresentação de achados clínicos, quanto nos que se fez necessário o tratamento, de forma que se mostra necessária a realização de avaliação inicial adequada de todos os recém-nascidos, em especial naqueles que possuem fatores de risco. ***Nível de evidência IV, Série de casos.***

Descritores: *Luxação Congênita de Quadril. Luxação do Quadril. Recém-nascidos.*

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INTRODUCTION

Developmental Dysplasia of the Hip (DDH) is a condition that is expressed in different ways and at different ages, idiopathic, but associated with risk factors such as joint capsule laxity, family history, female sex, pelvic presentation during pregnancy or some ethnicities where they are most prevalent.[1]

In the newborn can be identified in the form of partial or complete displacement of the femoral head relative to the acetabulum.[2] When diagnosed and treated early, there is a satisfactory progression in 95% of the cases with non-invasive treatments such as the Pavlik harness (developed by Arnold Pavlik [1902-1965], an orthopedist born in the former Czechoslovakia due to unsatisfactory treatment results at the time). Pavlik harness are the gold standard treatment up to six months of age,[1] being a dynamic orthosis that allows the child to mobilize the lower limbs within certain limits, containing an anterior band that keeps the hips flexed, avoiding its extension and posterior bands limiting adduction. They should be initially used for twenty-four hours per day for about twelve weeks if stable hips, with weekly assessments for possible readjustments. After this period, progressive withdrawal is performed, taking four hours a day in the first two weeks, followed by eight hours daily between weeks two and four, and finally twelve hours a day until the eighth week, and is reevaluated after this period.[3]

All authors declare no potential conflict of interest related to this article.

The study was conducted at the Orthopedics and Traumatology Medical Residency of Santa Casa de Misericórdia de Ribeirão Preto, SP, Brazil.
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With late diagnosis and treatment there is worsening of prognosis and disastrous consequences as permanent functional limitations due to loss of joint congruity.[2,4]

The incidence of DDH varies from 1:1000 to 3.4:100, more common in Native Americans, and also with higher rates in people who have a habit of wearing Swaddling bands (a kind of cloth used to wrap the buttocks and legs of newborn children with their hips in extension and adduction) or cradleboards,[1] it is possible to get a greater number of findings when using the combination of clinical examination and ultrasonography. Depending on the used method, different incidences can be found; 1.4:1000 are reported for dislocation; 2.3:100 for isolated clinical findings; and abnormalities in USG of up to 8:100.

Etiology is not well defined, but the predisposing factors are: ligament laxity (related to hormone, most important in females), intrauterine pelvic position, postnatal position with extended hips, racial preference (higher incidence in whites and Native Americans) , and primary acetabular dysplasia (unlikely).[2] The most common pathological change in DDQ is the hypertrophy of the cartilaginous rim of the acetabulum in its upper, lower, and posterior portions.[1]

The examination of the hip in the newborn should be performed routinely in the nurseries. The diagnosis is basically clinical at first, through clinical tests such as those of Ortolani and Barlow, which are performed with the patient in the supine position and flexion of the hips and knees, the first is a reduction maneuver, in which the examiner will feel replacement of the dislocated hip after abduction and a pressure in the region of the great trochanter; the second one is a provocative maneuver in which a force will be performed in the inner region of the thigh and in the posterior direction, positive if the hip is dislocated.[5] Conventional radiography has limited value and ultrasound is the ideal exam.[6]

In view of the amount of orthopedic assessments requested by the pediatrician for initial changes in the examination of the hip of the newborns, whether by clicks, subluxations or dislocations, this article was done with the intention of quantitatively ascertaining those in which these anomalies will evolve pathologically or if they are only cases of joint immaturity.

Treatment is challenging for both the pediatric and generalist orthopedist. The aim is early diagnosis associated with reduction of joint incongruity and stabilization of the hip in a safe position, which will be obtained according to the age of initiation of treatment, Pavlik harness up to six months of age is considered the gold standard, after this age other forms of treatment should be considered such as traction, closed or open reduction, or even femoral or pelvic osteotomies, depending on the age and severity of the condition.[6]

Justification

Newborns are usually evaluated only by Pediatricians, however, due to the incidence of clinical findings in approximately 2.3:100 live births[2] and to the good prognosis of the DDH, when treated early, it is necessary to clarify the need for evaluation by the Orthopedist, in those who had changes in the initial physical examination.

Since there is little published scientific material on the subject to date, this may serve as an aid in the formation of a protocol, adapted to the local reality. This simple measure, associated with adequate screening, may reduce the number of serious sequelae due to diagnostic failure in initial care, also reducing the cost involved.[2]

OBJECTIVES

The objective of this study was to analyze and monitor patients previously selected by pediatricians from birth, with anamnesis in search of risk factors, initial clinical examination by using specific maneuvers, and complementary exams such as ultrasonography and radiography, to verify the incidence of hip pathologies that will develop in the first months of life.

MATERIALS AND METHODS

Made as a prospective cohort study started in the first days of life of the newborn, with analysis of patients with suspected DDH under evaluation by the pediatrician due to some alteration in their initial physical examination.

Data was collected from the patients, after authorization from the parents, with the standard informed consent term.

Next, the specific orientation of each case was given, with a three-week clinical and ultrasonographic reassessment, evaluating both hips by the Graf method,[1,2,4] and then choosing the appropriate treatment.

In cases in which there was no need for intervention, a final pelvic x-ray was performed at 6 months old for documentation, analysis of ossification nuclei, and closure of the case.

After collecting the data, we analyzed the number of evaluations requested by the pediatricians, in which they considered the initial examination abnormal, and how many of them were shown to have dysplastic changes of the hips, which required any kind of surgical or conservative intervention.

During the study, 34 patients with 68 hips were selected, from birth, when asked for evaluation in the maternity ward, until the outpatient discharge or follow-up to the appropriate treatment.

This work was approved by the Ethics Committee of the Centro Universitário Barão de Mauá (CAAE: 92682418.4.0000.5378 / Parecer 2.808.501).

RESULTS

With an average of approximately 1300 live births annually at the institution, 1273 of which in the year of patient selection, 34 were selected with suspected dysplasia. The 34 patients were submitted to outpatient follow-up, separated by sex, 10 males, 24 females, with a female numerical superiority, consistent with the incidence of dysplastic pathologies.[2] (Table 1)

During follow-up, patients who needed some type of intervention according to the GRAF method were selected by the ultrasonographic evaluation, according to the protocol already established in the literature[1] and treated those classified as IIB or higher.

Of the 34 patients, only 02 were classified as needing treatment. We instituted the conservative treatment with the Pavlik harness for 8 weeks and observed a satisfactory result in both at the end of the treatment.

The remaining patients were discharged from the outpatient clinic or are under observation until the age of 6 months, when they should be discharged if there was no radiographic or clinical change to the examination.

Table 1. Selected patients.

Feminine			Masculine			Total		
24			10			34		
	I	IIA	IIB	IIC	IID	III	IV	Total
Fem	14	8	1	1	0	0	0	24
Mas	6	4	0	0	0	0	0	10
Total	20	12	1	1	0	0	0	34

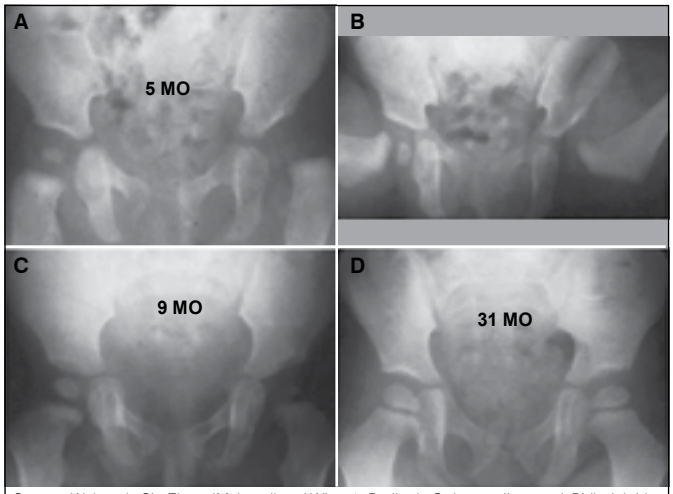
DISCUSSION

DDH can be defined as a spectrum of disorders that presents in different forms, variable according to age, with idiopathic cause, characterized by the inability to maintain the femoral head in the acetabulum, being related to predisposing factors such as: female sex; ligament laxity; prenatal pelvic presentation; postnatal positioning with hips in extension and adduction; and racial predilection, more common among Native Americans.[1,2,7]

It is a pathology that evolves over time. During embryogenesis, the development of the hip occurs from the seventh week of gestation, by forming the acetabulum from the contact with the femoral head and medial rotation of 90 degrees by the ninth week of gestation. In DDH, normal structures gradually deteriorate for several reasons, especially poor fetal position (pelvic presentation) associated with ligament laxity.[8] DDH is a progressive pathology associated with anatomical changes, which are usually reversible initially,[1] (Figure 1) since the hips at birth are formed by cartilage and a fibrocartilaginous labrum, in addition to a flattened posterior-superior rhyme of acetabulum. In some cases, the unstable hip at birth reduces spontaneously and progresses satisfactorily with complete resolution of the changes. Others, however, will remain permanently displaced and other anatomical alterations will appear, consequently there will be abnormal radiological parameters.[1] (Figure 2)

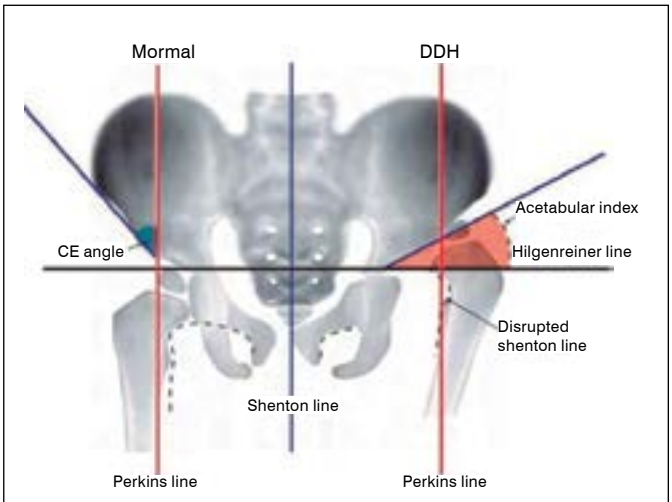
Early diagnosis and treatment is imperative for the good prognosis of patients.[1] As the hip remains displaced, secondary barriers to reduction appear, as the thickening of the acetabular pulvinar and the round ligament lengthens and thickens; the anatomical deformity of the lower capsule, which contracts and narrows its diameter in relation to the femoral head (hourglass deformity). In addition to these described changes, the shortening of the pelvis-femoral muscles in chronic cases caused by femoral ascension should be remembered.[2] Classically, instability was defined by the positivity of the Ortolani and Barlow tests, but this definition is currently challenged because of some clinically stable patients who have sonographic changes. Due to inconsistent data, the rate of those who will have spontaneous resolution is unknown.

The "click" that was considered for the selection of study patients, although most of the time it has no clinical significance, has an important correlation with some ultrasonographic changes. It is also worth mentioning that the reassessment of all patients is important due to some instabilities occurring only after the neonatal period. Patients' treatments were guided with Ultrasonographic aid, taking into account the angle between the bony roof and the cartilaginous roof of the acetabulum, (Figure 3) using the GRAF method, in which treatment was instituted in those classified with IIb or higher, since already are considered as having abnormal hip. (Table 2)



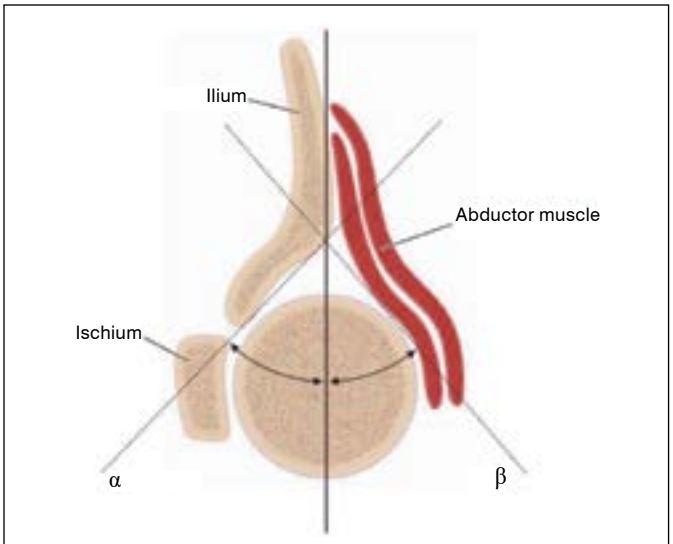
Source: Weinstein SL, Flynn JM. Lovell and Winter's Pediatric Orthopaedics. 7 ed. Philadelphia: Lippincott Williams & Wilkins; 2014.

Figure 1. Follow-up of patients with left dysplastic hip, from the 5th to the 31st month of life. In which there is a progressive improvement of the Acetabular Index.



Source: Weinstein SL, Flynn JM. Lovell and Winter's Pediatric Orthopaedics. 7 ed. Wolters Kluwer; 2014.

Figure 2. Radiologic Parameters: Wiberg CE Angle; Perkins Line; Shenton Line; Hilgenreiner Line; Acetabular Index.



Source: Herring JA. Tachdjian's Pediatric Orthopaedics: From the Texas Scottish Rite Hospital for Children. 5 ed. Philadelphia: Elsevier Saunders; 2013.

Figure 3. Alpha and Beta angle measurement.

Table 2. Graf Classifcation System of Developmental Dysplasia of the Hip on the Basis of the Sonographic Angles of the Hip.

Class	Alpha Angle	Beta Angle	Description	Treatment
Standard Classification				
I	>60°	<55°	Normal	None
II a	50°-60°	55°-77°	Immature (<3 months)	Observation
II b	>50°-60°	>77°	>3 months	Pavlik harness
II c	43°-49°	>77°	Acetabular deficiency	Pavlik harness
II d	43°-49°	>77°	Everted labrum	Pavlik harness
III	<43°	>77°	Everted labrum	Pavlik harness
IV	Unmeasurable	Unmeasurable	Dislocated	Pavlik harness/closed vs. open reduction
Simplified Classification				
I	>60°	<55°	Normal	None
II	43°-60°	55°-77°	Delayed ossification	Variable
III	<43°	>77°	Lateralization	Pavlik harness
IV	Unmeasurable	Unmeasurable	Dislocated	Pavlik harness/closed vs. open reduction

Source: Herring JA. Tachdjian's Pediatric Orthopaedics: From the Texas Scottish Rite Hospital for Children. 5 ed. Philadelphia: Elsevier Saunders; 2013.

An average of 2.67:100 of live births that showed abnormal clinical findings was observed and, thus, compatible with the data described in the specialized literature.

It is also worth noting that in none of the patients evaluated, the Ortolani and Barlow tests were positive, as described in the literature, since they are considered as low sensitivity tests, despite good specificity.

As the study was made with newborns, all treatments were performed using the Pavlik harness, a high-efficiency and low-cost method.[9] Satisfactory results were obtained in the patients until the conclusion of the study. The remaining cases remain in outpatient follow-up, progressing satisfactorily until then.

If started after 6 months of age, the treatment will consist of more complex methods, from traction to the open reduction of dislocation. Performing pelvic osteotomy is a possibility, especially if performed after 18 months of life. Thus, the importance of an evaluation as early as possible, which will generate the diagnosis and early treatment, improving the quality of life and reducing costs for the patient.[2,10]

CONCLUSION

It could be observed that despite the low workload and the low importance usually presented in medical courses related to orthopedic specialty, the data obtained is consistent with the literature, considering the clinical findings that generated the request for evaluation, and those who should receive specific treatment.

In the literature it is described that the Pavlik suspensory has good results in approximately 97% of those with Graf lower than III, who receive early treatment. In the 2 cases presented, satisfactory results were observed at the end of the treatment, then the efficacy of the method was verified, despite the low sampling.

Thus, the importance of performing early evaluation of the newborns, both in the clinical and ultrasonographic areas, was observed, despite the negative Ortolani and Barlow tests, 2 cases were diagnosed, received the early treatment and thus severe sequelae were avoided in the future. Noninvasive, low-cost treatment plays an important role in avoiding considerable expense with hospitalizations and corrective procedures.

AUTHORS' CONTRIBUTIONS: Each author contributed individually and significantly to the study. FF (0000-0001-9545-685X)*: manuscript writing, data collection, and manuscript review; GASM (0000-0002-9043-0340)* manuscript writing and comprehensive analysis of the intellectual concept; FCG (0000-0002-9324-2409)* analysis of intellectual concept; DML (0000-0001-5355-1832): manuscript writing, comprehensive analysis of the intellectual concept, and manuscript review; DLF (0000-0002-1847-4621)*: comprehensive analysis of the intellectual concept; JASF (0000-0002-3391-1754)*: comprehensive analysis of the intellectual concept, data collection, and manuscript review. *ORCID (Open Researcher and Contributor ID).

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ORIGINAL ARTICLE

SHOULDER ISOKINETIC PERFORMANCE IN HEALTHY PROFESSIONA JUDO ATHLETES: NORMATIVE DATAS

DESEMPENHO ISOCINÉTICO DO OMBRO DE ATLETAS PROFISSIONAIS DE JUDÔ SAUDÁVEIS: DADOS NORMATIVOS

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ABSTRACT

Objective: To evaluate normative data of shoulder isokinetic strength in healthy professional judo athletes. Methods: Cross-sectional study with 20 professional male and female athletes (10 female), evaluated with an isokinetic dynamometer. The strength assessment was carried out in external and internal rotation, flexion, extension, adduction and abduction. All data collected on muscle torque were normalized with body mass index. Results: Athletes demonstrated higher peak torque and joint work in shoulder adduction, abduction, flexion, and extension for the dominant limb compared to the non-dominant limb ($p < 0.05$), with most of these deficits below 10%. Shoulder internal/external rotation ratios for male and female athletes had no significant differences between dominant and non-dominant sides, demonstrating values at 60°/s of 49.4 ± 7.2 on the dominant side of males and 49.1 ± 4.9 for females. Conclusion: The normative data are described to assist during treatment, return to sport and injury prevention. ***Level of evidence IV, cross-sectional study.***

Keywords: Shoulder. Muscle Strength Dynamometer. Judo. Martial Arts.

RESUMO

Objetivo: Avaliar dados normativos da força isocinética do ombro de judocas profissionais, saudáveis. Métodos: Estudo transversal com 20 atletas profissionais de ambos os sexos (dez mulheres) avaliados com dinamômetro isocinético. A avaliação da força foi realizada em rotação externa e interna, flexão, extensão, adução e abdução. Todos os dados coletados do torque muscular foram normalizados com o índice de massa corporal. Resultados: Os atletas demonstraram maior pico de torque e trabalho articular em adução, abdução, flexão e extensão do ombro para o membro dominante, comparado ao contralateral ($p < 0,05$), com a maioria desses défices abaixo de 10%. As razões de rotação interna/externa do ombro para atletas de ambos os sexos não apresentaram diferenças significativas entre o lados dominante e não dominante, demonstrando valores a 60°/s de 49,4 ± 7,2 no lado dominante dos homens e 49,1 ± 4,9 no das mulheres. Conclusão: Os dados normativos são descritos para auxiliar durante o tratamento, o retorno ao esporte e a prevenção de lesões. ***Nível de evidência IV, estudo transversal.***

Descritores: *Ombro. Dinamômetro de Força Muscular. Judô. Artes Marciais.*

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INTRODUCTION

Judo is a combat sport that demands high intensity from almost all of the joints in the body. The athlete attempts to throw the opponent onto his/her back or to control the opponent on the ground by pinning techniques. It is a common sport, entering the Olympic Games for men in 1964 as a demonstration sport, and officially in 1972 for men and in 1992 for women.[1] According to the International Judo Federation, there are 20 million judo practitioners worldwide,[2] with relatively high risk of injury.[3]

The technical of combat depends on many aspects during the fight, but in all situations, there is a great demand on the shoulders. According to the data published by Pocecco et al[3] shoulder injuries are common in judo practice, and the second most common injury in this sport. Similarly, Cierna et al[4] found that shoulder injuries are the second most common injuries in elite European judo competitions. Acromioclavicular joint dislocation, rotator cuff tendinopathy and shoulder dislocation are the most common injuries of the shoulder.[3] The judoka frequently transfers energy from the trunk to the upper limbs during a continuous closed chain that overloads the shoulder joint. This is one of the reasons why judo movement is very demanding on shoulders; in throwing movements, to control the falls to the ground and to apply pin or armlock techniques. Not surprisingly, most of the injuries at the shoulder joint come from a throwing movement or from being thrown,[5] with no difference in the localization of injuries between male and female judokas.[5]

All authors declare no potential conflict of interest related to this article.

Work conducted at the Universidade Estadual de Campinas (UNICAMP) and at Instituto Vita, São Paulo, SP, Brazil.
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There are several studies that describe the normative data of isokinetic shoulder tests in different populations, like tennis players,[6] baseball players[7] and swimmers.[8] This data helps to determine the safest time for an athlete's return to sport, preventing new injuries. However, there is a lack of normative data on isokinetic strength of judoka's shoulders and this is important information during the athlete's treatment and a criterion to return to the sport.

Thus, the purpose of this study was to evaluate the performance of the shoulders of 20 asymptomatic, elite judo athletes (10 females), who are members of the national judo team in international competitions.

MATERIALS AND METHODS

Brazilian national judo team athletes were screened as possible study participants during a pre-season period. All athletes are competitors at the international level, with at least 10 years of practice. All the athletes were volunteers in the study and signed the informed consent form approved by the Institutional Review Board, under number 1.241.261. Inclusion criteria: high level athlete, asymptomatic for at least six months; no history of surgical treatment of the upper limbs or cervical spine. Exclusion criteria: previous shoulder and/or cervical spine surgery; previous humerus, scapula and/or clavicle fracture. Twenty asymptomatic high-performance competitive judo athletes were enrolled in the study. The sample size was defined by convenience. A single physiotherapist with 10 years of practice in isokinetic assessment conducted the tests in the athletes, using the same machine. An isokinetic dynamometer was used for the tests, (Figure 1) Cybex/ HUMAC NORM Extremity System (Henley Healthcare, serial no. A8814). The machine had been calibrated according to the manufacturer's instructions.

Prior to the assessment, the athletes performed a warm-up consisting of riding for 10 minutes on a stationary bicycle. Before each test, the judokas went through a familiarization process, so that the evaluation method was better understood. The familiarization was done initially in 3 repetitions at 60°/s, followed by the official test performed in 5 repetitions at 60°/s. The athlete then passed the familiarization process at 180°/s speed, performing 4 repetitions at this speed, followed by the official test consisting of 15 repetitions at 180°/s. There was a 60-second rest between the familiarization series and the official tests. There was also a rest of approximately 5 minutes between flexion/extension, abduction/adduction and internal/external rotation tests, to make the necessary modifications to the machine for the correct performance of the tests. All evaluations were performed concentrically. The evaluation methods and the exact sequence are described as follows.

The flexion/extension tests were performed according to the manufacturer's protocol, with the athlete in supine position and the axis of rotation of the shoulder joint aligned with the axis of rotation of the dynamometer arm. The handgrip and lever arm of the dynamometer were adjusted to allow the elbow to remain in full extension.[9] Total range of motion used in the test was between 0° and 120° of flexion. Belts were used to stabilize the athlete›s scapular and pelvic girdle. The hips and knees were kept in a neutral position, that is, at 0 degree. The gravity correction was performed with the athlete's arms relaxed at 80° of flexion.

The abduction/adduction movements were evaluated in the sitting position, and the trunk and pelvis were stabilized with the belts. The arm was positioned in the coronal plane, in neutral rotation and with the elbow in full extension. The axis of rotation of the humeral head was aligned with the axis of rotation of the dynamometer lever arm. The total range of motion allowed was 0° to 90°.[10] Gravity correction was performed with the athlete's arms relaxed at 80° of abduction.

The test of the external/internal rotation movements was performed with the athlete standing on the monorail deck, feet shoulder-width apart and with knees slightly flexed. The height of the dynamometer was adjusted to allow a position of 45° of abduction and 30° in horizontal adduction (scapular plane). The rotation axis of the dynamometer was aligned to the rotation axis of the glenohumeral joint. The elbow was supported on a stabilizer pad and secured with an adhesive strap in 90° of flexion. The lever arm was adjusted to the length of the athlete's forearm, in neutral position allowing an appropriated handgrip.[11,12] Gravity correction was performed with the athlete's arms relaxed at 60° of external rotation. The total range of motion allowed in the test was 60° of external rotation and 45° of internal rotation. The athlete was informed that trunk rotation movements would not be allowed, and the evaluator was aware of possible compensatory movements. All data from muscle torque were normalized with body mass using the formula: (Muscle torque/body mass) x 100.[11] After verifying the normality of the data distribution, a sample t-test was used to compare limbs: dominant and non-dominant. For the clinical analyses findings, the effect size was calculated (d of Cohen), where the amplitudes of < 0.31, 0.31-0.70 and >0.70 were defined as small-size effect, moderate and broad, respectively (Cohen, 1988).

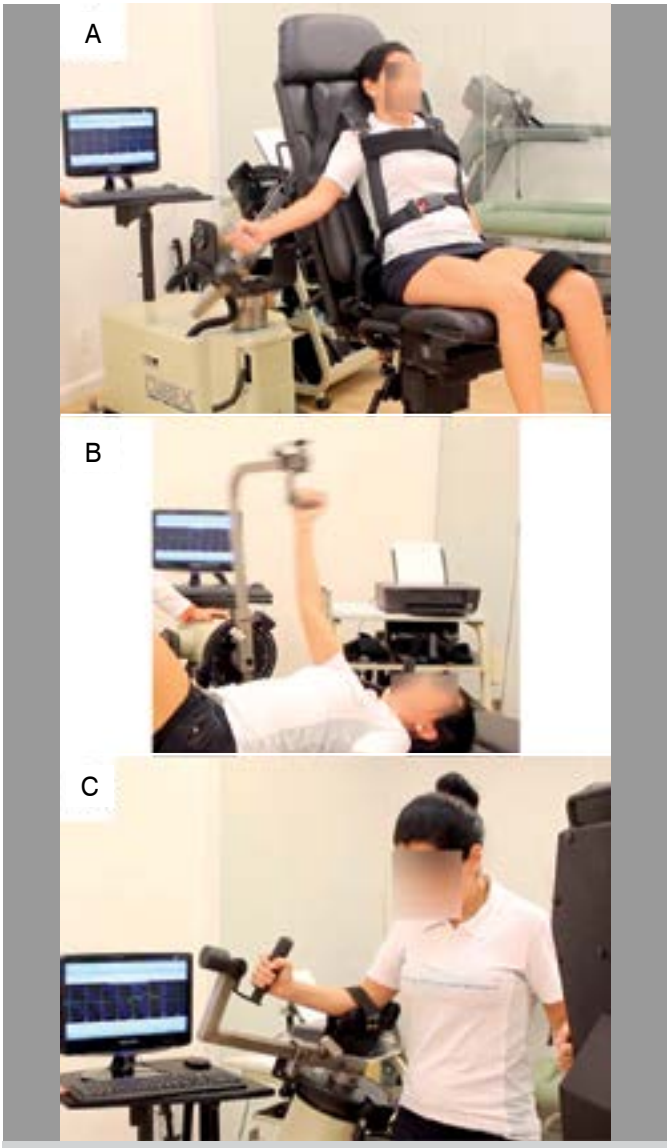

Figure 1. Illustrative figures of the shoulder isokinetic testing in 60°/s and 180°/s: (A) abduction/ adduction; (B) flexion/ extension; (C) Internal/ external rotation.

The data is shown as average ± standard deviation and has a 95% reliability interval for the average differences. The level of significance adopted in the entire analyses was 5% ($P < 0.05$). The analyses were conducted using PASW statistic 18.0 software, SPSS Inc., Chicago, USA.[13]

RESULTS

The demographic data of the sample is demonstrated in Table 1. Men and women demonstrated higher peak torque and joint work for all the movements analyzed (shoulder adduction, abduction, flexion, and extension) for the dominant limb in comparison to the contralateral side ($P < 0.05$). The exception was for the adductor peak torque at 180°/s and joint work abductor at 60°/s ($P = 0.098$ and $P = 0.092$) for men, and extensor peak torque at 180°/s for women ($P = 0.018$). (Table 2; Table 3)

Table 4 shows the differences between male and female shoulder performance on isokinetic tests. Table 5 shows the external and internal rotation ratios for males and females, for both shoulders.

Table 1. Demographic data from the enrolled athletes.

Parameter	Men (n = 10)	Women (n = 10)	Total (n = 20)
Age (years old)	26 ± 4	21 ± 2	23 ± 4
Weight (kg)	82.7 ± 12.5	70.2 ± 15.1	76.5 ± 14.9
Dominant limb	50% Right	50% Right	50% Right

Data is shown as mean values ± standard deviation.

DISCUSSION

The objective of the current study was to analyze the normative parameters of shoulder strength and performance in international level, high performance judo athletes. The isokinetic testing at speeds of 60°/s and 180°/s were chosen because are better to detect deficits that may represent risk factors for lesions, especially in agonist/antagonist ratio analysis.[12] According to Codine, speeds above 180°/s may be difficult to achieve, even for professional athletes.[14] One of the few study published about the theme, Ghrairi et al,[15] evaluated 10 male professional judo athletes from the Tunisian

Table 2. Peak Torque (% Body Mass) and Total Joint Work (J) for Male Judo Athletes (n = 10).

Parameter	Dominant limb	Non-dominant limb	Deficit (%)	Difference	IC 95%	Effect (d)	P Value
Peak torque							
Abduction 60°/s	86.1 ± 2.5	81.8 ± 3.9	5.4	4.4	2.6 - 6.1	1.36	0.001
Abduction 180°/s	163.5 ± 25.4	154.5 ± 25.1	5.9	9.1	5.3 - 12.8	0.36	0.001
Adduction 60°/s	111.3 ± 10.9	105.7 ± 11.2	5.3	5.6	3.4 - 7.7	0.50	0.001
Adduction 180°/s	183.3 ± 36.4	177.5 ± 28.3	3.3	5.8	-0.4 - 11.9	0.18	0.098
Flexion 60°/s	102.3 ± 7.4	96.7 ± 7.7	5.8	5.6	4.0 - 7.1	0.74	< 0.001
Flexion 180°/s	172.1 ± 17.9	164.1 ± 16.5	4.8	7.9	4.1 - 11.8	0.46	0.003
Extension 60°/s	126.8 ± 11.6	119.1 ± 13.3	6.5	7.7	4.8 - 10.6	0.62	0.001
Extension 180°/s	215.9 ± 19.2	208.5 ± 19.8	3.5	7.3	4.0 - 10.6	0.37	0.002
External rotation 60°/s	40.1 ± 6.5	35.7 ± 5.3	12.3	4.4	1.9 - 6.9	0.75	0.007
External rotation 180°/s	69.2 ± 7.8	64.7 ± 8.3	7.0	4.5	2.1 - 7.0	0.56	0.006
Internal rotation 60°/s	81.4 ± 8.6	76.7 ± 6.5	6.1	4.7	2.4 - 7.0	0.62	0.003
Internal rotation 180°/s	161.5 ± 12.5	156.4 ± 13.5	3.3	5.1	3.2 - 7.1	0.39	0.001
Total Joint work							
Abduction 60°/s	93.4 ± 13.8	89.9 ± 13.5	3.9	3.5	-0.1 - 7.1	0.26	0.092
Adduction 60°/s	115.4 ± 22.1	112.1 ± 22.2	2.9	3.3	0.8 - 5.8	0.15	0.031
Flexion 60°/s	100.7 ± 23.2	97.0 ± 22.9	3.8	3.7	0.8 - 6.6	0.16	0.033
Extension 60°/s	121.4 ± 24.6	116.6 ± 25.4	4.1	4.8	1.4 - 8.2	0.19	0.021
External rotation 60°/s	45.6 ± 1.5	40.7 ± 10.7	12.0	4.9	3.0 - 6.8	0.44	0.001
Internal rotation 60°/s	84.6 ± 28.4	78.2 ± 28.1	8.2	6.4	3.3 - 9.5	0.23	0.003

IC 95%: Limits with 95% confidence for the difference between dominant and non-dominant limbs.

Table 3. Peak Torque (% Body Mass) and Total Joint Work (J) for Female Judo Athletes (n = 10).

Parameter	Dominant limb	Non-dominant limb	Deficit (%)	Difference	IC 95%	Effect (d)	P Value
Peak Torque							
Abduction 60°/s	71.0 ± 11.9	64.5 ± 8.4	10.1	6.5	2.8 - 10.2	0.64	0.008
Abduction 180°/s	110.1 ± 18.0	102.2 ± 22.4	7.8	7.9	4.7 - 11.1	0.39	0.001
Adduction 60°/s	76.2 ± 5.8	69.7 ± 5.4	9.4	6.5	3.5 - 9.6	1.17	0.002
Adduction 180°/s	114.5 ± 12.4	106.6 ± 15.8	7.4	7.9	4.0 - 11.8	0.56	0.003
Flexion 60°/s	72.4 ± 8.2	67.7 ± 8.0	6.9	4.7	1.8 - 7.6	0.58	0.012
Flexion 180°/s	112.9 ± 20.2	106.8 ± 20.4	5.7	6.1	1.9 - 10.3	0.30	0.020
Extension 60°/s	93.1 ± 9.9	87.7 ± 9.3	6.1	5.4	0.7 - 10.0	0.56	0.050
Extension 180°/s	145.1 ± 14.1	139.5 ± 16.9	4.0	5.6	-2.0 - 13.2	0.36	0.180
External rotation 60°/s	33.3 ± 3.3	29.6 ± 5.0	12.6	3.7	0.9 - 6.5	0.90	0.029
External rotation 180°/s	55.5 ± 5.3	50.2 ± 6.1	10.5	5.3	3.9 - 6.6	0.93	< 0.001
Internal rotation 60°/s	67.5 ± 4.7	63.0 ± 5.5	7.1	4.5	2.6 - 6.3	0.88	0.001
Internal rotation 180°/s	124.3 ± 12.1	117.1 ± 12.2	6.1	7.2	4.7 - 9.7	0.59	< 0.001
Total Joint work							
Abduction 60°/s	65.2 ± 21.4	61.6 ± 21.6	5.8	3.6	1.9 - 5.3	0.17	0.002
Adduction 60°/s	83.0 ± 25.7	78.0 ± 23.7	6.4	5.0	1.4 - 8.6	0.20	0.025
Flexion 60°/s	63.5 ± 14.2	59.7 ± 14.8	6.4	3.8	2.4 - 5.2	0.26	< 0.001
Extension 60°/s	78.7 ± 15.3	72.4 ± 18.0	8.7	6.3	2.4 - 10.2	0.38	0.012
External rotation 60°/s	32.4 ± 7.1	28.0 ± 6.9	15.7	4.4	3.1 - 5.7	0.63	< 0.001
Internal rotation 60°/s	62.4 ± 13.9	57.7 ± 13.1	8.1	4.7	3.2 - 6.2	0.35	< 0.001

IC 95%: Limits with 95% confidence for the difference between dominant and non-dominant limbs

Table 4. Peak Torque (% Body Mass) and Total Joint Work (J) comparison between male and female judo athletes.

Parameter	Male peak torque (mean)	Female peak torque (mean)	Difference (%)	Difference	IC 95%	P Value
Peak torque						
Abduction 60°/s	83.9	67.8	19.3	16.2	9.3 – 23.0	< 0.001
Abduction 180°/s	159.0	106.2	33.2	52.8	31.5 – 74.2	< 0.001
Adduction 60°/s	108.5	73.0	32.8	35.6	27.6 – 43.5	< 0.001
Adduction 180°/s	180.4	110.6	38.7	69.8	46.4 – 93.1	< 0.001
Flexion 60°/s	99.5	70.1	29.5	29.4	22.2 – 36.5	< 0.001
Flexion 180°/s	168.1	109.9	34.6	58.2	40.8 – 75.6	< 0.001
Extension 60°/s	123.0	90.4	26.5	32.6	22.6 – 42.6	< 0.001
Extension 180°/s	212.2	142.3	32.9	69.9	53.9 – 85.8	< 0.001
External rotation 60°/s	37.9	31.5	16.9	6.4	2.0 – 10.8	0.007
External rotation 180°/s	67.0	52.8	21.0	14.1	7.7 – 20.5	< 0.001
Internal rotation 60°/s	79.0	65.3	17.5	13.8	7.9 – 19.7	< 0.001
Internal rotation 180°/s	158.9	120.7	24.1	38.3	26.6 – 50.0	< 0.001
Total Joint work						
Abduction 60°/s	113.9	89.6	21.3	24.3	0.5 – 48.1	0.046
Adduction 60°/s	137.7	113.7	17.4	24.0	6.8 – 41.2	0.009
Flexion 60°/s	119.5	88.2	26.2	31.3	15.9 – 46.7	< 0.001
Extension 60°/s	143.9	107.9	25.1	36.1	22.1 – 50.1	< 0.001
External rotation 60°/s	52.0	43.1	17.1	8.9	1.8 – 15.9	0.017
Internal rotation 60°/s	96.8	85.6	11.6	11.2	-4.6 – 27.0	0.153

IC 95%: Limits with 95% confidence for the difference between male and female

Table 5. External Rotation/Internal Rotation Ratio (in %) for Male and Female Judo Athletes on Dominant and Non-dominant Limbs (n = 20).

	Ratio ER / IR Dominant	Ratio ER / IR Non-dominant	P Value
Male 60°/s	49.4 ± 7.2	46.6 ± 6.4	0.524
Male 180°/s	42.9 ± 3.7	41.6 ± 5.1	0.533
Female 60°/s	49.1 ± 4.9	47.3 ± 8.3	0.554
Female 180°/s	44.8 ± 3.2	42.8 ± 4.7	0.299

IC 95%: Limits with 95% confidence for the difference between dominant and non-dominant limbs.

national team. They demonstrated that the peaks of internal and external rotation muscles torque (60°/s and 120°/s) were higher on the dominant shoulder (84N/m versus 71N/m for internal rotation and 34.7N/m versus 29N/m for external rotation). The current study showed that both men and women athletes presented a higher peak muscle torque on their dominant side on nearly all of the movements. The exceptions were for adductor peak torque at 180°/s and adductor joint work at 60°/s (P = 0.098 and P = 0.092) for men, and extensor peak torque 180°/s for women (P=0.180). In the present study, athletes were evaluated on speeds of 60°/s and 180°/s, differing from Ghrairi et al,[15] which evaluated at 60°/s and 120°/s. Moreover, Ghrairi et al[15] did not normalize muscle force production with athlete's body weight.

Furthermore, when concentric internal and external muscle torque rotation ratios are analyzed, Ghrairi et al[15] measured these values at 90°/s and 180°/s, and observed ratios of 36.3 ± 5.2 and 35.4 ± 4.1 on the dominant side of male athletes, respectively. On the non-dominant side, the values observed were 46.8 ± 4.9 and 44.1 ± 4.3, respectively, showing that on the dominant side the external rotation torque is lower. Differently, in our study we found that male judo athletes demonstrated higher ratios (measured at 60°/s and 180°/s) of 49.4 ± 7.2 and 42.9 ± 3.7 on the dominant side, respectively. This different could happened because the athletes performed the tests in seated position in Ghrairi study, and we performed the internal and external rotation tests in standing position. Maybe in standing position the athletes performed more external rotation torque, raising the ratio value.

Considering external and internal rotation ratios, in our study the female judo athletes demonstrated external rotation/internal rotation ratios of 49.1 ± 4.9 and 44.8 ± 3.2 on the dominant side when evaluated at 60°/s and 180°/s, respectively. (Table 5) On the non-dominant side, the female athletes obtained ratios of 47.3 ± 83 and 42.8 ± 4.7 when evaluated at 60°/s and 180°/s, respectively. Following the same pattern as the male evaluations, there were no significant differences on the external rotation/internal rotation ratios comparing the dominant side to the non-dominant side at 60°/s and 180°/s, as shown in Table 5 (P = 0.0554 and P = 0.299, respectively). These ratio values between 42% and 49% represents that in healthy shoulders of judo athletes the external rotation torque is almost the half of internal rotation. It can be a normal adaptation of the judo practice in high level athletes and probably a normative data for this shoulder performance measure.

When we compared the dominant side with the non-dominant side, we observed that the deficits did not surpass a difference of 10% in most cases, except for external rotation peak torque value and joint work at 60°/s for men. (Table 2) Female judo,kas showed differences between sides below 10%, except in abduction and external rotation peak torque at 60°/s, external rotation peak torque at 180°/s and external rotation total joint work at 60°/s. (Table 3) On the other hand, Drid et al[16] compared external and internal rotation peak torque values between the dominant side and non-dominant side and they did not observe any differences in European judo athletes that compete at an international level.

When we evaluated the ratio between abductors and adductors, we observed that male athletes obtained results close to 77% and 89% at 60°/s and 180°/s, respectively. For female athletes, the values of the ratio between abductors and adductors were approximately 93% and 96% at 60°/s and 180°/s, respectively. In the studies of McMaster et al,[17, 18] the ratio founded were close to 50% when evaluated at 30°/s and 180°/s in water polo athletes and swimmers, showing that the adduction strength may be twice as large as abduction. Different from judokas, polo athletes use more adduction movement to keep their upper bodies out of the water, like swimmers that needs more adduction strength to move their bodies forward.

When the flexion and extension torque are compared, Alderink & Kuck[19] evaluated baseball players (pitchers) and found values close to 50% when evaluated at 90°/s in flexion and extension movements, while in judokas we observed values close to 80% at 60°/s in both genders. These results showed that healthy judokas produce approximately 20% more torque in extension than flexion.

When the values of external and internal rotation ratios are analyzed, McMaster et al[17] found ratio values close to 57% and 52% at 30°/s and 180°/s, respectively, in water polo athletes. Edouard et al.[20] studied the values of external rotation/internal rotation ratios in professional female handball athletes, and found values close to 71% on the dominant side. In our study, we observed values close to 49% and 42% at 60°/s and 180°/s, respectively, for male judokas. For the female athletes we found values close to 49% and 44% at 60°/s and 180°/s, respectively. In our studies we found values of agonist/antagonist ratios different from other high-performance sports, showing that the practice of high-performance judo generates specific adaptations of the shoulders. However, it is not possible to say whether these characteristics may predispose to injury in judoka's shoulders in the long term. Once the external rotation torque in judokas is almost the half of internal rotation, maybe the external rotation strengthening can be used to avoid symptoms.
Male judokas produce more muscular torque in all the movements analyzed, when compared with females. (Table 4) However, when the external/internal rotation ratio is compared, there's no significant difference between males and females. (Table 5) There is no difference in external/internal rotation between dominant and non-dominant sides. (Table 5)

This study demonstrates limitations, like the sample size (20 asymptomatic international level athletes were studied). However, judo is a physical contact sport in which a high demand on the shoulder is required. That's why is difficult to find high-level competitors that do not refer pain in the shoulder for at least 6 months. Moreover, this study has the biggest sample of normative data analyzed for judo athletes in both genders, publish at this time. The internal and external rotations were evaluated with the athletes in orthostatic position, thus allowing trunk compensation, making it difficult to compare with other tests in the sitting position. However, other studies evaluated athletes and non-athletes in the standing position[11,12] and observed that the method is reproducible and reliable. Another limitation was the absence of height and body mass index of all the athletes, but these data were not included since the category divisions are based in the body weight.

CONCLUSIONS

From the normative data of this study it was possible to report the normal performance of all shoulder movements of high-level healthy judo athletes. Such data can be used as criteria for discharge following treatment and as reference values in pre-season evaluation of judo athletes.

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ORIGINAL ARTICLE

ANTEGRADE X RETROGRADE NAILING IN FEMORAL FRACTURES: A STUDY ON CONSOLIDATION AND INFECTION

HASTE ANTERÓGRADA X RETRÓGRADA EM FRATURAS FEMORAIS: UM ESTUDO SOBRE CONSOLIDAÇÃO E INFECÇÃO

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ABSTRACT

Objective: Osteosynthesis with intramedullary nailing is considered the method of choice to treat diaphyseal femur fractures in adults. The objective of this retrospective study was to evaluate the bone healing time and incidence of infection in patients with diaphyseal femur fractures treated surgically with retrograde and antegrade intramedullary nailing. Methods: The medical records of 123 patients from two university hospitals dated 2011-2013 were evaluated, with 126 diaphyseal femur fractures having been found. The most frequent treatment was antegrade intramedullary nailing (51%), of which 38% involved reaming (n=25). Results: We found evidence of 92% healed fractures at 12 months postoperatively. Complications included chronic osteomyelitis in one patient and femoral neck fracture in another patient, both after reamed antegrade nailing. Pyoarthritis of the knee associated with osteomyelitis affected two patients after reamed retrograde nailing and one patient after unreamed retrograde nailing. Conclusion: We did not observe a significant difference in bone healing rates with the use of reamed or unreamed antegrade or retrograde nailing. Complications included the presence of infection with an incidence similar to that reported in the literature, and of particular significance, unrelated to the type of approach. ***Level of evidence III, Retrospective comparative study.***

Keywords: Femoral Fracture. Fracture Fixation. Femur. Fracture Healing. Pseudoarthrosis. Fracture Fization, Intramedullary.

RESUMO

Objetivo: A osteossíntese com haste intramedular é considerada o método de escolha para tratamento das fraturas diafisárias do fêmur em adultos. O objetivo deste estudo retrospectivo foi avaliar o tempo até a consolidação e a incidência de infecção em pacientes com fratura diafisária do fêmur, operados com haste intramedular retrógrada e anterógrada. Métodos: Foram avaliados os prontuários de 123 pacientes de dois hospitais universitários entre os anos de 2011 e 2013, tendo sido encontradas 126 fraturas diafisárias do fêmur. O tratamento mais frequente foi com haste intramedular anterógrada (51%), das quais 38% (n=25) eram fresadas. Resultados: Com 12 meses de pós-operatório, evidenciamos 92% de consolidação. Entre as complicações, observamos um paciente com osteomielite crônica e um com fratura do colo do fêmur, ambos submetidos à haste intramedular anterógrada fresada e pioartrite do joelho, associada à osteomielite em dois pacientes submetidos à haste intramedular retrógrada fresada e em um paciente após a utilização de haste intramedular retrógrada não fresada. Conclusão: Não observamos diferença significativa entre a taxa de consolidação com o emprego das hastes retrógradas e anterógradas, fresadas ou não fresadas. Dentre as complicações, observamos a presença de infecção em incidência similar à da literatura e particularmente sem relação com a via de acesso escolhida. ***Nível de evidência III, estudo retrospectivo comparativo.***

Descritores: *Fraturas do Fêmur. Fixação de Fratura. Fêmur. Consolidação da Fratura. Pseudoartrose. Fixação Intramedular de Fraturas.*

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INTRODUCTION

Intramedullary nailing has been the osteosynthesis method of choice to treat diaphyseal femoral fractures in adults.[1,2] Compared to other treatments, intramedullary nailing is less aggressive to tissues, may reduce fragments without approaching the fractured area, and is associated with less bleeding, high consolidation rates, and fewer complications.[2,3]

Intramedullary nails can be inserted by a proximal (antegrade) or distal (retrograde) approach.[4,5] Disadvantages of the proximal approach include difficult insertion of the stem in obese patients and risks of femoral head necrosis or fracture, implant-related pain, gluteus medius insufficiency, and heterotopic ossification around the hip.[6,7] Disadvantages of the distal approach include the need to open the joint to introduce the nail, knee pain, mobility restriction,

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iatrogenic injury to the anterior cruciate ligament, and risk of septic arthritis.[8] Advantages with the antegrade approach include greater availability of nail types, familiar technique, and absence of joint violation associated with the fracture treatment.[6,9] Indications for the retrograde use of the implant include possible simultaneous fixation in the same operative field in cases of bilateral femoral fractures or simultaneous proximal/diaphyseal fractures using two implants, in addition to stabilization of floating knee using the same access path, shorter surgical time due to less manipulation required to position the patient, and the possibility of performing the procedure on a radiotransparent table, in case of polytraumatized patients.[5,7] In terms of consolidation rates and complications, both techniques present similar clinical outcomes according to the literature.[1,2,9]
Based on these considerations, the aim of this study was to perform a radiographic evaluation of the consolidation and clinical evaluation of the relative infection rates of diaphyseal femoral fractures operated on with either retrograde or antegrade, reamed or unreamed intramedullary nailing.

MATERIAL AND METHODS

Between January 2011 and December 2013, a total of 157 diaphyseal femoral fractures were treated with intramedullary nailing at two teaching hospitals in Brazil (Hospital Central da Santa Casa de São Paulo and Hospital Estadual Dr. Albano da Franca Rocha Sobrinho). The protocol of the study was approved by the Ethics Committee for Research Involving Human Beings of the Santa Casa de São Paulo (CAAE: 41444915.2.0000.5479, approval 02/11/2015). The study was conducted according to the criteria set by the Declaration of Helsinki (1995). Hospital Estadual Dr. Albano da Franca Rocha Sobrinho was a co-participating center in this study.
The radiographic images of the participants were obtained from digital image storage systems maintained by both centers (Impax and Synapse). The inclusion criteria comprised a minimum age of 18 years (considered a proxy for mature bone), diaphyseal femoral fracture treated definitively with antegrade or retrograde intramedullary nailing, and a follow-up ≥1 year. The exclusion criteria were fractures in pathological bone or extending proximally or distally to the joint, and cases with consolidations that could not be evaluated in the radiographs obtained. In all, 31 cases were excluded from the analysis.
The radiographs were obtained at 4, 6, 8, and 12 months of follow-up and were evaluated by three independent readers, who were orthopedic surgeons and Full Members of the Brazilian Society of Orthopedic Trauma.
Fractures were considered consolidated when observed to have bone continuity in three of the "four cortical" areas by at least two of the three readers. The minimum follow-up was 12 months, which is also the minimum time to establish a diagnosis of pseudoarthrosis.[10] The requirement of subsequent surgery to treat post-traumatic osteomyelitis or remove the implant was considered diagnostic of infection.
The data collected included the patients' age and sex, AO fracture classification, and time to fracture consolidation. We also collected information on whether reaming was carried out or not and whether the implant was performed with a proximal (antegrade intramedullary nail, AIMN) or distal (retrograde intramedullary nail, RIMN) approach. The type of approach used in the procedures depended on the surgeons' preferences and the patients' characteristics. All AIMNs were inserted through the trochanteric fossa, while the RIMNs were inserted using a medial parapatellar and intercondylar approach. Static interlocking fixation was performed in all cases, regardless of the type of approach, and included fastening with two proximal and two distal screws relative to the location of the fracture.

Statistical Analysis

The data were analyzed with SPSS v.17 (IBM Corp., Armonk, NY, USA), Minitab 16 (Minitab, Inc., State College PA, USA), and Excel Office 2010 (Microsoft Corp., Washington, USA). Analysis of variance (ANOVA), chi-square test and the equality of two proportions test were applied, considering a significance level of 0.05.

RESULTS

Of the 157 diaphyseal femoral fractures retrieved in the search, 126 (123 patients) met the inclusion criteria and were included in the analysis. The mean age of this cohort was 29 years (median 27 years, range 18–67 years) and most patients (85%) were men. The AIMN was the most used osteosynthesis technique (n=65, 51.6%) and reamed nailing was used in 25 of these cases (38.5%). The RIMN technique was used in the remaining 61 cases (48.4%), of which 35 involved reaming (57.4%). (Table 1)
The fractures were all classified as AO-32[11] and included the three classification types according to the complexity of the fracture line. The most frequent types were A3 (n=37), A2 (n=22), and B3 (n=17). The remaining 50 fractures were distributed as shown in Figure 1. Type 32B fractures were more frequently associated with pseudoarthrosis (n=7) when compared with types 32A and 32C, regardless of the approach used in the procedure.
On the postoperative evaluation, 55 fractures showed consolidation at 4 months and 91 at 6 months. A total of 104 fractures showed consolidation at 8 months, corresponding to a consolidation rate of 82.5%, regardless of the type of approach or use of reamed or unreamed nailing. At 12 months, 92% of the fractures (n=116) had consolidated and 8% had pseudoarthrosis (n=10). (Table 2)
Patients without radiographic consolidation were divided into three groups: reamed AIMN (n=3), unreamed AIMN (n=4), and unreamed RIMN (n=3). No cases of nonunion were observed among fractures treated with reamed RIMN. (Table 3) The p values of the analysis of the time to consolidation according to the approach and reamed versus unreamed nailing are shown in Table 4.
The complications observed in our cohort included osteomyelitis in one patient and ipsilateral femoral neck fracture in another patient (both treated with reamed AIMN) and knee pyoarthritis associated

Table 1. Distribution of diaphyseal femoral fractures according to the surgical approach and use of reamed versus unreamed nailing.

	Reamed nailing (n)	Unreamed nailing (n)	Total (n)
Proximal approach	25	40	65
Distal approach	35	26	61

Abbreviation: n – number of fractures.

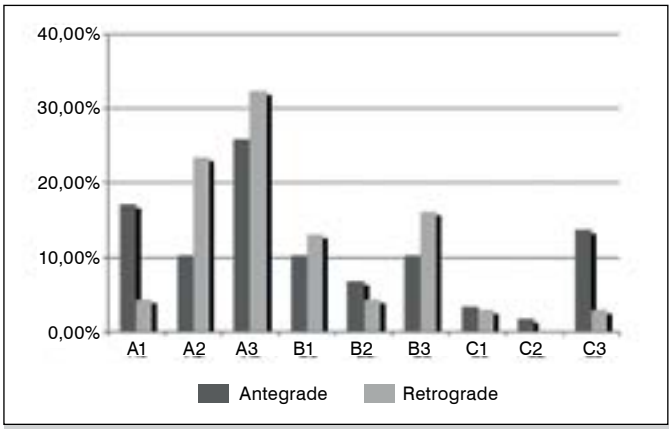

Figure 1. Distribution of diaphyseal femoral fractures according to AO classification and type of osteosynthesis used in the procedure.

Table 2. Distribution of consolidation rates of diaphyseal femoral fractures according to the surgical approach and use of reamed versus unreamed nailing.

Consolidation	4 months		6 months		8 months		12 months	
	n	%	n	%	n	%	n	%
Retrograde, reamed	14	56%	21	84%	24	96%	25	100%
Retrograde, unreamed	11	43%	17	68%	21	81%	22	88%
Antegrade, reamed	10	40%	18	72%	21	84%	22	88%
Antegrade, unreamed	17	44%	31	79%	33	84%	35	89%

Abbreviation: n – number of fractures.

Table 3. Distribution of cases with nonunion of diaphyseal femoral fractures according to the surgical approach and use of reamed versus unreamed nailing.

Nonunion	4 months		6 months		8 months		12 months	
	n	%	n	%	n	%	n	%
Retrograde, reamed	15	44%	5	16%	1	4%	0	0%
Retrograde, unreamed	14	56%	8	31%	4	18%	3	12%
Antegrade, reamed	15	60%	7	28%	4	16%	3	12%
Antegrade, unreamed	22	55%	8	21%	6	15%	4	10%

Abbreviation: n – number of fractures.

Table 4. P values of the analysis of the time to consolidation according to the approach and reamed versus unreamed nailing (Tables 1 and 2).

		3-4 months	4-6 months	6-8 months	8-12 months
Reamed, retrograde	4-6 months	0.031			
	6-8 months	<0.001	0.157		
	8-12 months	<0.001	0.037	0.312	
	> 12 months	<0.001	0.034	0.303	- x -
Unreamed, retrograde	4-6 months	0.044			
	6-8 months	0.001	0.221		
	8-12 months	<0.001	0.053	0.461	
	> 12 months	<0.001	0.053	0.461	1.000
Reamed, antegrade	4-6 months	0.023			
	6-8 months	0.001	0.306		
	8-12 months	<0.001	0.157	0.684	
	> 12 months	<0.001	0.157	0.684	1.000
Unreamed, antegrade	4-6 months	0.002			
	6-8 months	<0.001	0.554		
	8-12 months	<0.001	0.192	0.470	

with osteomyelitis in two cases (reamed RIMN) and in one case (unreamed RIMN). All these patients required further surgical procedures for additional treatment and removal of the implant, along with prolonged antibiotic therapy.

DISCUSSION

After intramedullary nails were initially described by Küntscher in 1939,[12] they emerged as an excellent method to treat diaphyseal femoral fractures, yielding high consolidation rates (85 to 99%) and few complications.[1,9,13] However, when associated with the development of pseudoarthrosis, multiple procedures may be required to manage this complication, increasing costs and compromising the patient's rehabilitation.

Causes of nonunion in diaphyseal femoral fractures include factors associated with the trauma itself or with the patient and the surgical procedure. Smoking, obesity (body mass index >30 kg/m^2), use of nonsteroidal anti-inflammatory drugs, and late weight-bearing gait are patient-related factors described in the literature.[10] Factors associated with the surgery include the use of reamed or unreamed nailing, the diameter of the nail, the quality of the fracture reduction, and the approach used to insert the nail, while factors associated with the trauma include the mechanism and energy of the trauma itself, the AO classification of the fracture, and the involvement of soft tissues.

Tornetta & Tiburzi analyzed 83 fractures treated with reamed intramedullary nailing and 89 managed with unreamed nailing and found a significantly shorter consolidation time among patients undergoing reamed compared with unreamed nailing.[1] This finding differed from ours. (Figure 2) However, the group receiving unreamed AIMN in our study had the lowest consolidation rate at 4 months (44.7%), which was significantly different when compared with other moments of the study (p=0.002).

Selvakumar et al.[14] randomized 102 closed diaphyseal femoral fractures to reamed (n=52) and unreamed (n=50) nailing and found nonunion rates of 0% and 8%, respectively. A multicenter study by the Canadian Orthopaedic Association also compared the nonunion rates of 224 patients with fractures treated with intramedullary reamed and unreamed nailing. The study found 7.5% of nonunion in 107 fractures in the unreamed group and 1.7% in 121 fractures in the reamed group.[15]

Aligned with other studies,[11,16,17] we observed a rate of pseudoarthrosis of 9.8% in the reamed group and 12% in the unreamed group, divided as follows: 5 patients after reamed AIMN, 4 patients after unreamed AIMN, and 5 patients after unreamed RIMN (p = nonsignificant for the comparison among the groups). Patients undergoing reamed RIMN had a 100% consolidation rate.[18,19]

Our results corroborate the findings of a study by Metsemakers et al.[17] evaluating 248 diaphyseal femoral fractures undergoing definitive treatment with intramedullary nailing. The rate of pseudoarthrosis in that study was 11.3% (n=28). Pseudoarthrosis was associated with the type of fracture according to the AO classification, in which type 32C was a protective factor for consolidation when compared with types 32A and 32B. Reaming, polytrauma, exposed fracture, and prior use of an external fixator did not contribute to the consolidation.

In our cases, type 32B fractures presented a higher incidence of pseudoarthrosis (n=7) when compared with types 32A and 32C, regardless of the approach. No cases of nonunion were observed among type 32C fractures, which may be attributed to the small number of cases in this subgroup (n=15). Taistman et al.[7] found no association between the AO classification of the fractures and nonunion, indicating that the classification alone is not predictive of nonunion.

Zhang et al.[2] carried out a meta-analysis of randomized trials including the use of intramedullary nailing in the treatment of

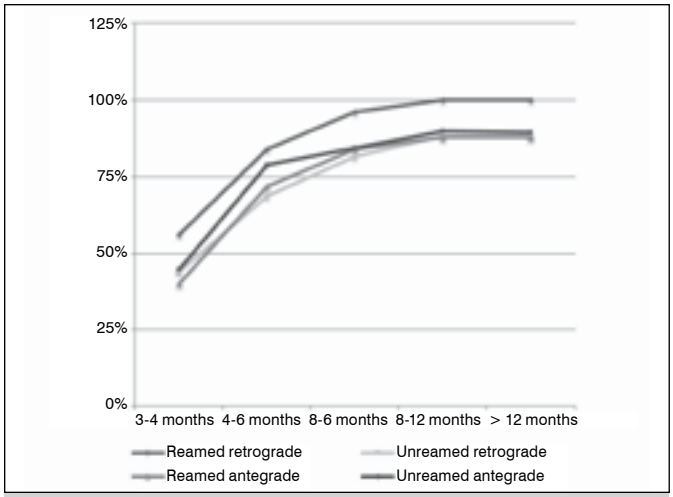

Figure 2. Time to consolidation according to the approach and reamed versus unreamed nailing in patients with diaphyseal femoral fractures.

diaphyseal femoral fractures. Only three studies (with a total of 240 diaphyseal femoral fractures) fulfilled the criteria to enter the study. The authors observed no difference in consolidation and rehabilitation rates between patients treated with the antegrade and retrograde approaches, although they noted that more studies are still needed to identify the best approach.

Theoretically, there is an increased risk of septic knee arthritis after RIMN due to the intra-articular entry point, which is not required in the AIMN approach. O'Toole et al.[8] evaluated the risk of septic knee arthritis in 93 open fractures or fractures with a direct communication with the knee joint and observed one case of septic arthritis (1.1%) in a polytraumatized patient and two cases of osteomyelitis, yielding an incidence of 4.3%.[9] Becher & Ziran[20] observed an infection rate of 5.7% related to Gustilo type 3 open diaphyseal fractures treated with RIMN and no cases of knee joint infection.[20]

We observed in our cohort four cases of infection (3.1%), three of which were cases of septic knee arthritis related to RIMN and one was a case of chronic osteomyelitis related to AIMN. These findings are aligned with those in the literature.[9]

A potential limitation of our study is its retrospective design. Better insights would have been possible if the analysis had accounted for factors potentially contributing to the pseudoarthrosis, such as smoking, use of nonsteroidal anti-inflammatory drugs, and soft tissue injury.

CONCLUSIONS

In our cohort of patients with diaphyseal femoral fractures treated with intramedullary nailing, the consolidation rates were high and independent of the use of a reamed or undreamed approach, or antegrade or retrograde nailing. Infection occurred at a low rate (close to the rates found in the literature) and was not associated with the type of implant.

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DEMOGRAPHIC ANALYSIS OF ACETABULAR FRACTURES TREATED IN A QUATERNARY CARE HOSPITAL FROM 2005 TO 2016

ANÁLISE DEMOGRÁFICA DAS FRATURAS DO ACETÁBULO TRATADAS EM UM HOSPITAL QUATERNÁRIO DE 2005 A 2016

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ABSTRACT

Objective: Analyze the clinical and sociodemographic data on acetabular fractures in a Brazilian quaternary care hospital and compare with data reported in the literature. Methods: A descriptive, analytical cross-sectional epidemiological study analyzing 87 patients with acetabular fractures at Hospital São Paulo (UNIFESP/EPM) between 2005 and 2016. Demographic variables such as age, sex, occupation, educational level and color were investigated. Acetabular fractures were classified according to the AO/OTA group and Judet and Letournel classification. Therapeutic approach, hospital length of stay and waiting time for surgery as well as complications were analyzed. Associations were established among the various variables obtained. Results: The mean age of patients with acetabulum fractures was 39.8 years (SD 13.1 years). There was a predominance of posterior wall (34.5%) and dual-column (14.9%) fractures. The average hospital length of stay was 14.4 days. More than 90% of patients underwent a surgical procedure. One-fourth of patients had complications, the main one being infection (12.6%). Conclusions: Unimodal age distribution was obtained with a predominance of white male economically active patients. There was a predominance of posterior wall fractures. More than 90% of patients underwent surgery before they had been in hospital for 14 days. A statistically significant association was found between complications and exceeded length of hospital stay. ***Level of evidence II, Retrospective study.***

Keywords: Analysis. Acetabulum. Fractures, Bone. Wounds/complications.

RESUMO

Objetivo: Analisar os dados clínicos e sociodemográficos das fraturas acetabulares em um hospital quaternário brasileiro e comparar com dados relatados na literatura. Métodos: Estudo epidemiológico, descritivo, analítico transversal, em que foram analisados 87 pacientes com fraturas acetabulares no Hospital São Paulo (UNIFESP/EPM) entre 2005 e 2016. Variáveis demográficas como idade, sexo, profissão, escolaridade e cor foram pesquisadas. As fraturas acetabulares foram classificadas conforme o grupo AO/OTA e conforme Judet e Letournel. A terapêutica, o tempo de internação e de espera para cirurgia bem como as complicações foram analisadas. Foram feitas associações entre as diversas variáveis obtidas. Resultados: A média de idade dos pacientes vítimas de fraturas do acetábulo foi de 39,8 anos (DP 13,1 anos). Houve predomínio das fraturas da parede posterior (34,5%) e dupla coluna (14,9%). Os pacientes ficaram, em média, 14,4 dias internados. Mais de 90% dos pacientes foram submetidos à abordagem cirúrgica. Um quarto dos pacientes tiveram complicações, sendo a principal, infecção (12,6%). Conclusões: Foi obtida uma amostra etária unimodal com predomínio de pacientes do sexo masculino, brancos e economicamente ativos. Houve um predomínio das fraturas da parede posterior. Mais de 90% dos pacientes foram operados antes dos 14 dias de internação. Constatou-se uma associação estatisticamente significante entre complicações e tempo excedido de permanência hospitalar. ***Nível de evidência II, Estudo retrospectivo.***

Descritores: *Análise. Acetábulo. Fraturas ósseas. Lesões/complicações.*

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INTRODUCTION

Acetabular fractures are uncommon and are usually the result of high-energy trauma.[1,2,3] Road accidents constitute the main cause of these injuries, which represent a major orthopedic challenge.[4] In this scenario, there is considerable associated morbidity, dictating prolonged periods of absence from work and a heavy burden on the health system and the community.

Over the past few decades, there has been an important shift from non-surgical to surgical treatment, as evidenced by the work of Judet & Letournel, who have achieved good results through the surgical

All authors declare no potential conflict of interest related to this article.

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treatment of these fractures and defined open reduction and internal fixation as the gold standard treatment for displaced fractures.[3] Encouraged by these results, other authors (Matta, Tile)[5] started case series in an attempt to reproduce the reduction quality and outcome, which despite representing a technical challenge to the surgeon and presenting a long learning curve, confirmed superiority when compared to the outcome of conservatively treated cases. The aim of this study is to describe the clinical and sociodemographic characteristics of patients with acetabular fractures treated at a quaternary care university hospital.

MATERIALS AND METHODS

This is a descriptive, retrospective, analytical cross-sectional study. The participants are patients treated by the Trauma Group of the Department of Orthopedics and Traumatology of the Universidade Federal de São Paulo (DOT-UNIFESP/EPM), who presented with acetabulum fracture and were admitted to Hospital São Paulo between 2005 and 2016. The study was designed according to the Brazilian Standards for Human Subject Research, and its design was submitted and approved by the Institutional Review Board of Hospital São Paulo - Unifesp (CAAE [Certificate of Application for Ethical Review]: 62369616.0.0000.5505).

We included 89 patients admitted to Hospital São Paulo, men and women aged over 16 years with acetabulum fractures. Exclusion criteria were: ineligible medical records, unclear diagnosis, patients without clinical data and the patient's own refusal to participate in the study, by not signing the ICF (Informed Consent Form).

The physical and electronic medical records of the patients were analyzed during the screening period. Demographic variables such as age, sex, occupation, level of education and color were investigated. Acetabular fractures were classified according to the AO/OTA and Judet & Letournel classifications by two independent observers. Hospital length of stay and waiting time for surgery were also analyzed. Therapy was instituted as per protocol and the patient management guidelines established by the Trauma Division of UNIFESP/EPM and reviewed by the teaching staff. Complications arising from the injuries or inherent to the treatment were analyzed. Finally, associations were established among the various variables obtained in order to find any causal relationship of the analyzed variables. Excel 2016 and the statistical software SPSS 2016 were used for the descriptive data analysis, applying the Chi-Square Test and Fischer's Exact Test when necessary. We considered $p < 0.05$ for statistical significance.

RESULTS

Eighty-nine patients with acetabular fracture were admitted, but 2 patients were excluded from the analysis due to insufficient data in their medical records, and only 87 patients were used.

The mean age of patients with acetabulum fractures was 39.8 years (SD 13.1 years). The youngest patient was 20 years old and the oldest was 82. Of the total sample of 87 patients, 75 were male, resulting in 86.2%. Approximately half of the patients declared themselves white (54%), followed by mixed-race (41.4%) and black (4.6%). Eighty-one percent of patients declared themselves economically active. With regard to level of education, 25.3% had completed high school and only 3.4% were illiterate. (Figure 1)

There was a slight predominance of right-sided fractures (51.7%). In terms of fracture classification, 56.3% had associated fractures and 43.7% had fractures with an elementary pattern, according to the Judet and Letournel classification. Moreover, there was a predominance of posterior wall (34.5%) and double column (14.9%) fractures. The fractures were also classified by AO/OTA. (Table 1 and 2)

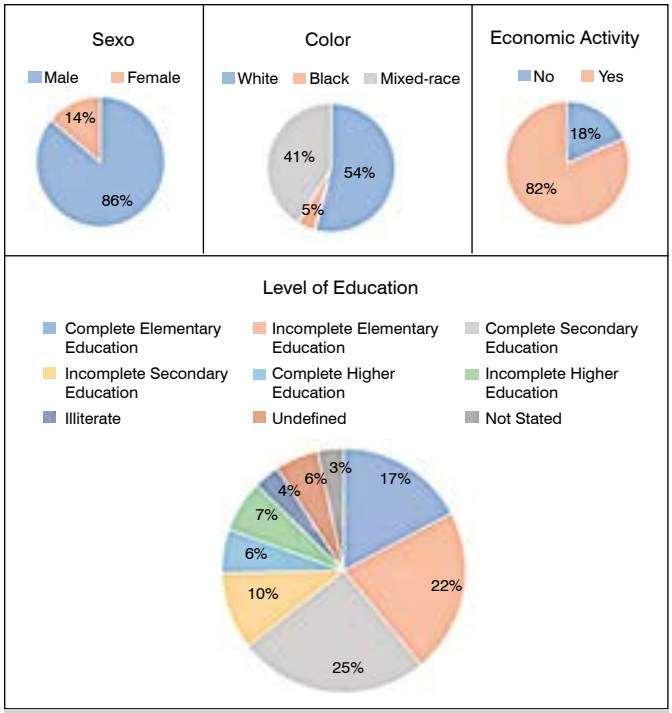

Figure 1. Description of the sociodemographic data of the 87 patients.

Table 1. Description of the acetabular fractures according to the Judet & Letournel classification.

	Frequency	Percentage (%)
Anterior column	2	2.3
Posterior column	3	3.4
Posterior wall	30	34.5
Transverse	4	4.6
Anterior column + posterior hemitransverse	7	8.0
Posterior column +posterior wall, t-shaped	6	6.9
T-shaped	8	9.2
Posterior wall	1	1.1
Anterior wall + posterior hemitransverse	2	2.3
Transverse + posterior wall	11	12.6
Dual column	13	14.9

Table 2. Description of the acetabular fractures according to the AO/OTA classification.

	Frequency	Percentage (%)
A1	30	34.5
A2	3	3.4
A3	2	2.3
B1	19	21.8
B2	8	9.2
B3	12	13.8
C1	11	12.6
C2	1	1.1
C3	1	1.1

Patients had a length of hospital stay averaging 14.4 days (SD 13.9), with a minimum period of 1 day and a maximum of 85 days. Of these, 50.6% stayed for more than 10 days at Hospital São Paulo. Of the total patients, 93.5% underwent surgery before they had been in hospital for 14 days, while 6.5% only had surgery later.

Seventy-nine patients (90.8%) underwent surgical treatment and 8 (9.2%) received conservative treatment. Of the total, 4 patients underwent percutaneous surgery, representing 4.6% of the sample. Most patients were operated on using a posterior approach (62.02%), followed by the anterior (26.51%) and combined (6.2%) approaches. (Table 3)

Forty-six percent (46%) of patients presented with complications. More than 30 associated injuries were documented, mainly consisting of pelvic ring injuries (9.2%), tibia fractures (6.8%), proximal femoral fractures (6.8%) and traumatic brain injuries (5.74%). Twenty-two patients (25.3%) had complications resulting from their injuries or inherent to the treatment, the main ones being infection (12.64%), peripheral nerve injury (4.59%), and heterotopic ossification (3.44%). Associations were also established between several variables. Of all 22 patients with complications, 40.9% were found to have no associated fractures while 59.1% had them ($p = 0.069$). (Table 4) Seventeen of these patients (77.3%) had a length of hospital stay greater than 10 days while for 5 (22.7%) their hospital stay did not exceed this period ($p = 0.004$). Therefore, there was statistical significance between the association of complications with exceeded length of hospital stay. (Table 5)

Table 3. Surgical approaches.

	Frequency	Percentage (%)
Ilioinguinal + Kocher Langenbeck	1	1.2
Ilioinguinal	17	21.51
Kocher Langenbeck	49	62.02
Kocher Langenbeck + Pfannenstiel	2	2.5
Kocher Langenbeck + Stoppa	2	2.5
Stoppa	2	2.5
Stoppa + 1st Ilioinguinal window	2	2.5
percutaneous	4	5.0

Table 4. Association between associated fractures X complications.

		Complications		Total
		No	Yes	
Associated Fractures	No	41	9	50
		63.1%	40.9%	57.5%
	Yes	24	13	37
		36.9%	59.1%	42.4%
Total		65	22	87
		100.0%	100.02%	100.0%

Table 5. Association between length of hospital stay greater than 10 days X complications.

		Complications		Total
		No	Yes	
Length of Hospital Stay > 10 days	No	38	5	43
		58.5%	22.7%	49.4%
	Yes	27	17	44
		41.5%	77.3%	50.6%
Total		65	22	87
		100.0%	100.0%	100.0%

DISCUSSION

Epidemiological studies that represent the profile of certain fractures are still rare in Brazil, especially those that represent uncommon fractures, such as acetabular fractures. This study seeks to overcome this deficiency by providing an overview of a quaternary care hospital in the most densely populated city in the country.

The average age of the sample group of 39.85 years is similar to that reported by Ahmed et al.,[6] Dias et al.[7] and Mauffrey et al.[8] Acetabular fractures have a bimodal distribution, affecting at one extreme young and active patients who have sustained high-energy trauma. At the other extreme we find elderly patients who have sustained low-energy trauma.[9] This pattern is more prevalent in developed countries than in developing countries, which tend to have a unimodal age distribution. A study conducted by Mauffrey et al.[8] in 2014 draws this parallel between the US and China. The data obtained in our sample indicate a distribution with characteristics that more closely resemble those of the Chinese population.

The proportion of men was within the average range of the national and international literature, around 3 men to every woman.[8] In our sample, 81% of patients declared themselves economically active. This data is extremely important because the requisite study, management and treatment of this fracture reduces the economic burden, allowing the subject to resume their professional duties as soon as possible.

Mauffrey et al.,[8] in their epidemiological comparative study of 661 Chinese and 212 North American subjects, discovered that 30-32% had posterior wall fractures and 17-21% dual-column fractures, according to the Judet and Letournel classification. These data closely resemble those found in our study with 34.5% and 14.9%, respectively.

The average length of hospital stay of the 87 patients was 14.4 days, which closely resembles that reported in the study by Boudissa et al.,[10] in which 414 patients were studied in France. Conversely, in the work conducted by Laird[2] with 351 patients in Scotland, the hospital stay was 24 days on average. Matta et al.[10] reported that fractures older than 14 days entailed impaired reduction quality due to surgical difficulty. Based on this assumption, we found that 93.5% of the HSP patients underwent surgery before this critical period.

Of the 87 patients studied, 46% had associated injuries, with more than 30 lesions characterized in this case. This denotes the importance of treating these patients and the difficulty involved. A quarter of the studied sample had some kind of complication, of which the most relevant was infection (12.6%). In the study by Laird et al.,[2] 6.5% of the operated patients developed this complication, almost half of the value obtained in our study.

We observed statistical significance in the association between longer hospital stay and higher incidence of complications. However, there was no significance between higher number of associated fractures and complications.

As limitations of this study we can emphasize that it is a retrospective study with a small sample group in comparison to international studies, and that it was not possible to analyze important late complications, such as osteoarthritis, present in 26.6% of patients in the study by Giannoudis et al.[11] However, even with these limitations, important data from our university hospital were imparted and compared with different populations, allowing a reflexive analysis of acetabular fractures.

CONCLUSION

A unimodal age distribution sample was obtained with economically active white male patients with a mean age of 39.85 years predominating. There was a predominance of posterior wall fractures followed by

dual-column fractures, which is consistent with data from national and international literature. More than 90% of patients underwent surgery less than 14 days after admission, and the posterior surgical approach predominated.

A quarter of the patients had complications, the most prevalent of which was infection.

A statistically significant association was found between complications and exceeded length of hospital stay.

AUTHORS' CONTRIBUTIONS: Each author made significant individual contributions to this manuscript: MCC (0000-0003-1207-9185)*: data collection, data tabulation, writing of the article; FAAA (0000-0002-7647-3344)*: data collection, data tabulation, writing of the article; GB (0000-0002-4846-9188)*: statistical analysis, data review, article review; GTS (0000-0001-9732-8763)*: statistical analysis, data review, article review; DB (0000-0003-4955-5317)*: data collection, data tabulation, data review, article review; FBR (0000-0003-2431-2634)*: data review, article review, intellectual concept of the article and creation of the entire research project. *ORCID (Open Researcher and Contributor ID).

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CHRONIC CONSUMPTION OF ALCOHOL ADVERSELY AFFECTS THE BONE OF YOUNG RATS

CONSUMO CRÔNICO DE ÁLCOOL AFETA NEGATIVAMENTE O OSSO DE RATOS JOVENS

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ABSTRACT

Objective: To assess the effect of chronic alcohol consumption on the longitudinal growth of the tibia and bone quality parameters in young rats under an experimental setup. METHODS: The control (n=10) rats received only water. The ethanol (n=10) rats received ethyl alcohol at concentrations established in the protocol for the induction of chronic alcohol consumption. The blood samples were immediately collected via cardiac puncture and processed to evaluate the levels of alkaline phosphatase by automated spectrophotometry. Following blood sample collection, both tibias were dissected, and weighed; the tibial length was measured., and the samples were stored in a freezer for future analysis of the bone mineral content and mechanical resistance, known as maximal load and stiffness. RESULTS: Compromised bone health, with a 35.3% decrease in the serum alkaline phosphatase levels ($p < 0.01$), a 10% decrease in the tibial mass ($p < 0.05$), and a 5.3% decrease in the tibial length ($p < 0.0001$) were noted. Furthermore, a 10% decrease in the bone mineral density was observed ($p < 0.01$), which led to a 17.2% decrease in the maximum strength ($p < 0.01$) and 22.6% decrease in stiffness ($p < 0.001$). CONCLUSION: Chronic consumption of alcohol affected the bones of young rats, making them weaker and osteopenic. In addition, the long bones were shorter, suggesting interference with growth. ***Level of Evidence III, Case Control Study.***

Keywords: Ethanol. Bone development. Bone density. Tibia. Rats.

RESUMO

Objetivo: Verificar a influência do consumo experimental crônico de álcool no crescimento longitudinal da tíbia e em parâmetros de qualidade óssea de ratos jovens. Métodos: Dez ratos controle receberam água, outros dez receberam álcool etílico nas concentrações estabelecidas no protocolo para indução. Após eutanásia, as amostras de sangue foram coletadas por punção cardíaca e processadas para avaliar os níveis de fosfatase alcalina por espectrofotometria automatizada. Após a coleta de sangue, ambas as tíbias foram dissecadas, pesadas e medidas em comprimento. Foram realizadas análises do conteúdo mineral ósseo e resistência mecânica, por meio da análise da força máxima e rigidez. Resultados: Houve comprometimento da saúde óssea, com redução de 35,3% no nível de fosfatase alcalina no plasma ($p<0,01$), redução de 10% na massa da tíbia ($p<0,05$) e queda de 5,3% no comprimento das tíbias ($p<0,0001$). Também foi observada redução de 10% na densidade mineral óssea ($p<0,01$), que levou à redução de 17,2% na força máxima ($p<0,01$) e 22,6% na rigidez ($p<0,001$). Conclusão: O consumo crônico de álcool afetou os ossos de ratos jovens, tornando-os mais fracos e osteopênicos. Ainda, os ossos longos eram mais curtos, sugerindo interferência no crescimento. ***Nível de evidência III, Estudo caso-controle.***

Descritores: *Etanol. Desenvolvimento Ósseo. Densidade Óssea. Tíbia. Ratos.*

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INTRODUCTION

Alcohol consumption is common throughout the world in different social and cultural contexts. Types of alcohol consumption differ between: only occasional consumption; heavy chronic alcohol consumption and binge drinking, being, at the moment, common among young people and adolescents.[1] The abusive consumption of alcohol can be harmful to different tissues and organs, including for example bones.[2]

To bone health, the excessive use of alcohol is concerned between young people, as it usually occurs when peak bone mass is reached.[3] Even in the case of this evidence, there is little information regarding the damage in the skeletal system of adolescents who make excessive use of alcohol[4], mostly the attainment of growth and peak bone mass.

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The study was conducted at the Laboratory of Human, Universidade Federal do Triângulo Mineiro, Uberaba, MG, Brazil.
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Some research indicates that chronic alcohol use may interfere with bone metabolism and cause osteoporosis[2,5] by inhibiting osteoblastic cells.[6,7] Other authors believe that alcohol has a negative impact on mineral content, but does not interfere with bone growth.[8] Thus, the aim of the study was to evaluate the effect of experimental chronic alcohol consumption in growing rats on longitudinal growth of the tibia and parameters of bone quality.

MATERIAL AND METHODS

Experimental Design

According to well established methods, male Wistar rats (Rattus norvegicus albinus var. Wistar) were housed under standard laboratory conditions (room temperature 22 ± 2°C, humidity 55 ± 5%, 12 h light-dark cycles) with free access to tap water and chow (Nuvilab CR-1, Colombo, PR, Brazil).[9]

This study was carried out in strict accordance with international guidelines, as recommended in the Guide for the Care and Use of Laboratory Animals of the National Institutes of Health. The experimental protocol was approved by Ethical Animal Committee from the Federal University of Triângulo Mineiro - Brazil (CEUA/UFTM – Nº 323/2014). All euthanasia occurred with overdose of thiopental sodium injected intraperitoneally, and all efforts were made to minimize suffering.

The rats weighed 300 to 350 g (80–100 days old) and were kept in the laboratory environment during 1 week for acclimatization and were randomly distributed into two groups: Control (n=10) - rats received tap water ad libitum and Ethanol (n=10) – rats received 20% (v/v) ethanol in their drinking water.[10] To avoid loss of animals, the ethanol-treated group was submitted to a brief and gradual adaptation period. The animals received 5% ethanol in their drinking water in the 1st week, 10% in the 2nd week, and 20% on the 3rd and 4th week. The animals received 5% ethanol in their drinking water in the 1st week, 10% in the 2nd week, and 20% on the 3rd and 4th week. After this period, the experimental period started, with a concentration of 20% for eight weeks (2 months) until the end of the 12th week. All animals were housed in standard laboratory cages, with the same number of animals per box, allowing similar gait activity.

The animals were inspected daily and weighed weekly. After euthanasia, followed by Cardiac Puncture Blood Collection. Subsequently, both tibias were dissected, weighed, length measured and were stored in a freezer for future analysis of the bone mineral content and mechanical resistance: maximal load and stiffness. A planned euthanasia was performed

Analysis of alkaline phosphatase activity in blood plasma

After obtaining whole blood, the material was centrifuged at 1831g for 10 minutes and the serum was obtained. The determination of alkaline phosphatase was performed using an automated spectrophotometer (COBAS INTEGRA 400; Roche Diagnostics, São Paulo, SP, Brazil), following the manufacturer's instructions for commercial kits (Roche Diagnostics, São Paulo, SP), and all quality control recommendations for experimental analytical evaluation were performed.11 The results were expressed in UI/L that corresponds to 0.01667 μkat/L.

Bone length

The length of tibias was obtained with a digital caliper (Series 530, Mitutoyo, Suzano, SP, Brazil) by three consecutive measurements and average calculation.

Bone Mineral Density

The bone mineral density was determined by dual-energy X-ray absorptiometry (DXA) using a Lunar DPX-IQ densitometer (Lunar; software version 4.7e, GE Healthcare, Chalfont St. Giles, United Kingdom) with software for small samples. The tibias were immersed in ethanol in a small container and scanning of the entire bone was performed. Then, the region of interest was delimitated by a square measuring 0.90 cm^2 using the tibial tuberosity as an anatomical landmark.[12]

Mechanical Testing

The entire bone was tested in 3-point flexion. The bone extremities rested on two metallic supports that were 25 mm apart, and a progressive load was vertically applied at the center of the posterior surface of the bone at a constant displacement rate of 1 mm/min, until failure.[12] The testing device (EMIC, São José dos Pinhais, PR, Brazil) was equipped with a 500 N load cell, and the load-deflection curve was obtained in real time. The maximal load and stiffness were calculated by a specific software (TESC software, version 13.4, São José dos Pinhais, PR, Brazil).

Statistical Analysis

SPSS (SPSS for Windows - Version 11.0 - SPSS inc.,) was used for statistical analysis, and GraphPad Prism 5.0 was used for graphical presentation of the data. Data were initially submitted to descriptive analysis, with a calculation of means and standard deviations. Variables were tested by the Shapiro-Wilk test for normality and analysis of variance. For normal distributed variables, Student´s t parametric test was applied to compare the two groups. Differences were statistically significant at 5% reliability ($p < 0.05$).

RESULTS

The activity of alkaline phosphatase in blood plasma after 60 days of exposure to alcohol consumption was 35.3% lower in relation to the control group ($p < 0.01$). The mean values obtained in the control animals were 82.8 ± 20.7 IU/L and 53.6 ± 15.3 IU/L in the ethanol group (Figure 1A). The tibia mass of the ethanol group (0.78 ± 0.08 g) showed a significant reduction of 10% ($p < 0.05$), compared with the control group (0.70 ± 0.07 g) (Figure 1B). The mean tibia length from ethanol group was 5.3% shorter than in the control group ($p < 0.0001$). The tibias of control animals averaged 47.2 ± 1.0 mm, while the mean in the ethanol group was 44.7 ± 1.3 mm (Figure 1C). The bone mineral density of the tibias from the ethanol group was reduced by 30% ($p < 0.01$) compared with the control group. The average bone mineral density in the control group was 0.010 ± 0.002 g/cm^3 and in the ethanol group was 0.007 ± 0.002 g/cm^3 (Figure 1D). The maximal load of the tibias from ethanol group (82.5 ± 13.5 N) was reduced by 17.2% ($p < 0.01$), compared with the control group (99.7 ± 21.3 N) (Figure 2A). The mean stiffness of the tibias from ethanol groups was significantly decreased by 22.6% in comparison with the control animals ($p < 0.001$). The mean stiffness of the tibias of the control animals was 146.95 ± 31.20 N/mm and that of those in the ethanol group was 113.78 ± 25.18 N/mm (Figure. 2B).

DISCUSSION

Long-term alcohol consumption, besides being related to several behavioral pathologies, causes a multiplicity of biochemical, physiological and clinical abnormalities.[13,14] Heavy alcohol use has been associated with structural alterations in several tissues.[2,15]

Regarding bone health and osteoporosis, alcohol consumption is associated with reduced bone mass and increased risk of fracture.5,6 (5,6). In the literature, it is reported that young people between the ages of 18 and 30 (approximately 20% of women and 25% of men) participate in at least one episode of drinking every month, comprising 6 or more doses per occasion.[16] These data are in agreement with those of another study on young adult drinking behavior, which suggests that problem drinking behaviors that begin during adolescence

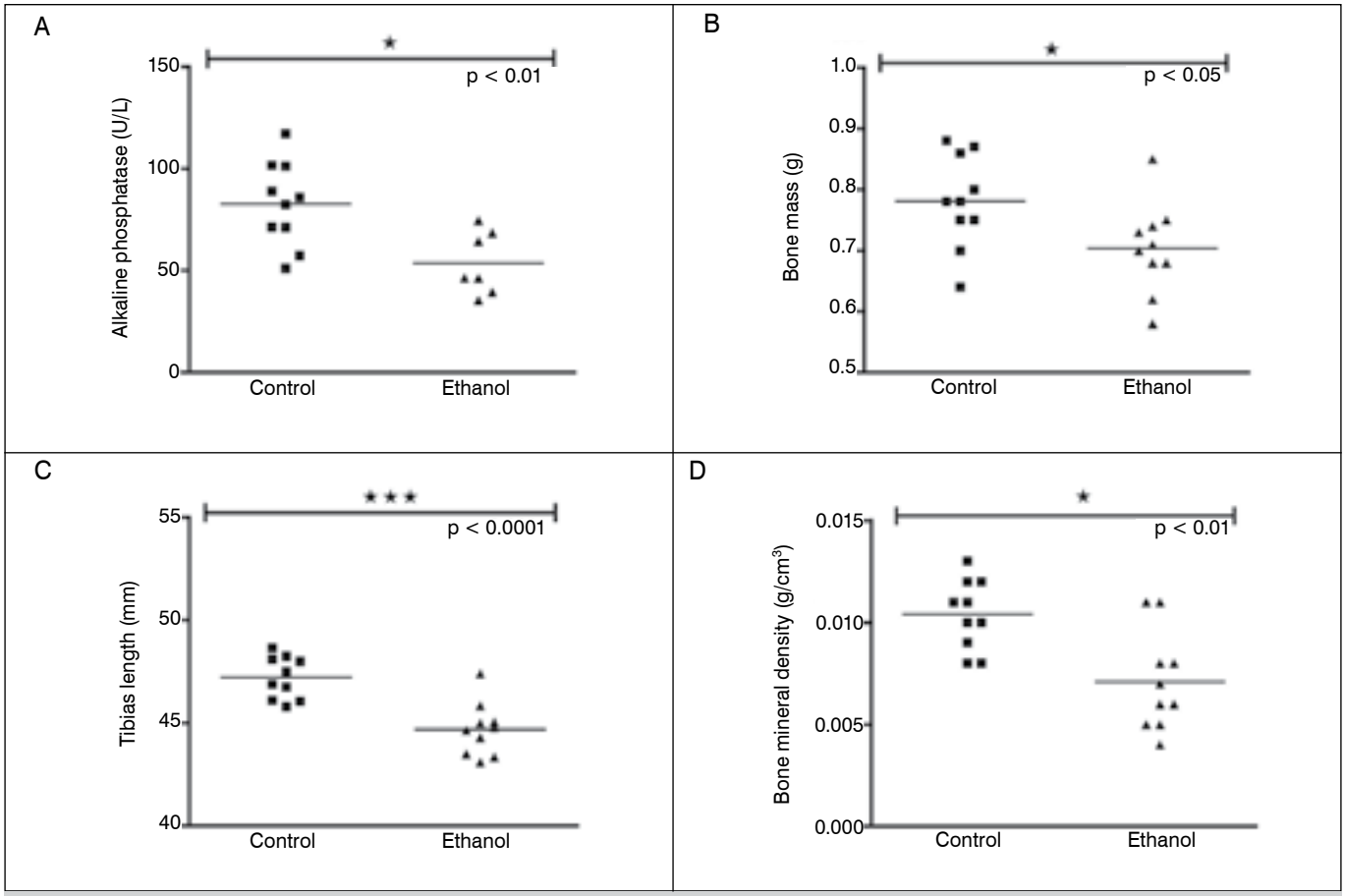

Figure 1. Biochemical analysis, skeletal development, and bone mineral content. A. alkaline phosphatase; B. bone mass; C. tibial length; D. bone mineral density. Statistical tests: Student´s t. $p < 0.05$. The asterisks indicate the comparison with significant difference.

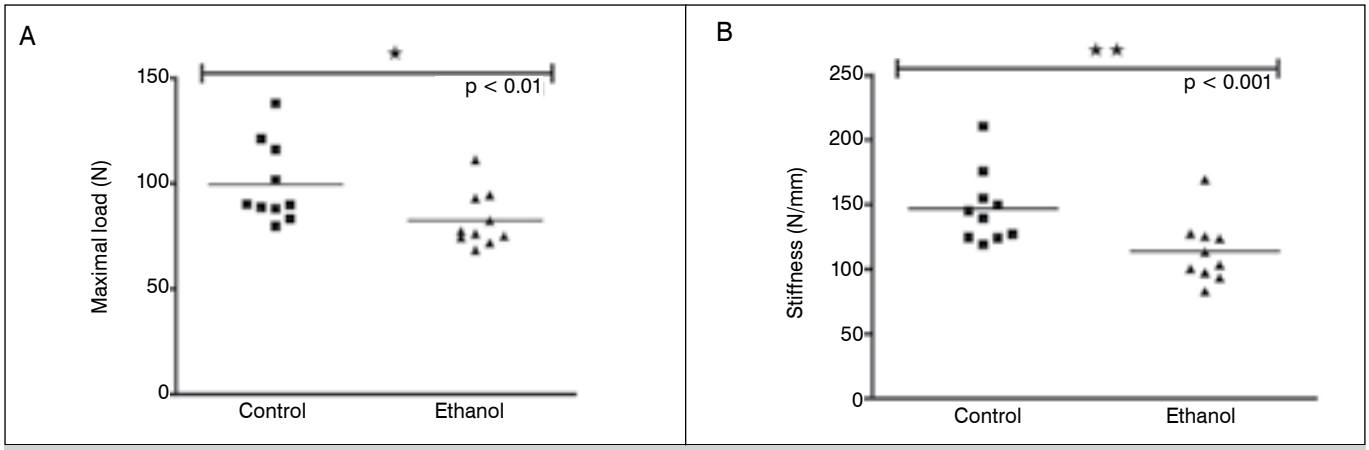

Figure 2. Analysis of mechanical resistance. A. maximal load; B. stiffness. Statistical tests: Student´s t. $p < 0.05$. The asterisks indicate the comparison with significant difference.

(ages 16–19) tend to continue into the early adult years (ages 30–31),[17] encompassing the most critical periods related to peak bone growth and accruement of bone mass.[3]

In the literature it has been described that alcohol can lead to compromises in the architecture of spongy bone, decrease bone mineral mass and inhibit bone growth in immature rats.[18] Evidence describes that a considerable proportion of adolescents and young adults use alcohol compulsively.[4] Our results demonstrate that exposure to experimental chronic consumption of alcohol significantly compromises bone health as demonstrated by the negative repercussions in bone mineral content and mechanical resistance. Additionally, the long bones were shorter, suggesting interference with growth.

In the current study, we used immature animals, making it possible to detect the detrimental effects on bone growth. These effects caused a reduction of 5.3% in tibia length, which may be related to the fact that chronic alcohol consumption seems to promote changes in bone metabolism due to nutritional deficiencies, liver damage, and hypogonadism. Thus, the etiology of alcohol-associated bone disease is multifactorial.

Excess alcohol increases urinary calcium, magnesium and zinc excretion. Zinc deficiency has been associated with osteoporosis caused by hypogonadism, which decreases the secretion of sex hormones. Moderate and prolonged alcohol consumption raises serum parathyroid hormone levels and may stimulate cortisol secretion. Chronic consumption of alcohol interferes in metabolism of vitamin D. These changes caused by alcohol consumption contribute to a reduction in bone formation, which results in osteopenia and increases the risk of fractures.[18]

As expected, the aforementioned characteristics are confirmed by the results of mechanical tests; tibias from exposed animals were weaker and less rigid. Stiffness is a parameter that represents how the bone deforms, and the maximal load refers to the bone mineral content and mechanical resistance. These results are consistent with some studies showing that alcohol ingested by immature rats provides inhibition of bone growth, decreased BMD which negatively impacts bone architecture.19 (19). These studies too teem that may not major loss of the cortical doma esponjoso has been associated to pesces adult after the status of the adult stereo, in the adult subordined status in the development study.[19]

Our current results show a significantly reduction of 30% in BMD and 22.6% in stiffness. The metabolic changes were expressed by a reduction of 35.3% in plasma concentrations of alkaline phosphatase for the animals from the ethanol group. Because the majority of serum alkaline phosphatase during the growing period is of skeletal origin,[18,19] these findings may also reflect a depression in bone metabolism. Thus, chronic alcohol consumption affected the bones of young rats, making them weaker and osteopenic. In addition, the long bones were shorter, suggesting interference in the growth.

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AUTHORS' CONTRIBUTIONS: Each author contributed individually and significantly to this study. RCR (0000-0003-3157-0826)*: Substantial contribution to the conception of the work, data interpretation, and critical review of the intellectual content. WFR (0000-0002-3426-2186)*: Analysis of microscope slides, writing of the manuscript, and statistical analysis of the data. CBM (0000-0002-1834-1394)*: Biochemical analysis, manuscript writing and manuscript revision. FAGC (0000-0001-7520-2879)*: Manuscript review and final approval of the version of the manuscript to be published. APE (0000-0002-9282-4482)*: Manuscript review and data interpretation. CJFO (0000-0003-2211-7333)*: Review of the manuscript and intellectual concept. JBV (0000-0002-2120-0138)*: Manuscript review, statistical analysis of the data, review of the intellectual concept, and development of the research project. *ORCID (Open Researcher and Contributor ID).

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REVIEW ARTICLE

BIOLOGICAL ENHANCEMENTS FOR ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

ESTRATÉGIAS DE TRATAMENTO BIOLÓGICO PARA CIRURGIA DE RECONSTRUÇÃO DO LIGAMENTO CRUZADO ANTERIOR

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ABSTRACT

The anterior cruciate ligament (ACL) is mostly responsible for providing knee stability. ACL injury has a marked effect on daily activities, causing pain, dysfunction, and elevated healthcare costs. ACL reconstruction (ACLR) is the standard treatment for this injury. However, despite good results, ACLR is associated with a significant rate of failure. In this context, the mechanical and biological causes must be considered. From a biological perspective, the ACLR depends on the osseointegration of the graft in the adjacent bone and the process of intra-articular ligamentization for good results. Here, we discuss the mechanisms underlying the normal graft healing process after ACLR and its biological modulation, thus, presenting novel strategies for biological enhancements of the ACL graft. ***Level of evidence III, Systematic review of level III studies.***

Keywords: Anterior Cruciate Ligament. Anterior Cruciate Ligament Reconstruction. Osseointegration. Orthopedics.

RESUMO

O ligamento cruzado anterior (LCA) é um dos principais responsáveis pela estabilidade do joelho. Sua lesão gera importante prejuízo nas atividades diárias, causando dor e disfunção, com elevado custo socioeconômico. A reconstrução ligamentar é o tratamento padrão atual e, embora com bons resultados, ainda apresenta significativo índice de falhas. Nesse contexto, causas mecânicas e biológicas são consideradas. Do ponto de vista biológico, a reconstrução do LCA depende da osteointegração do enxerto no osso adjacente e do processo de ligamentização intra-articular para um bom resultado. Neste artigo, são discutidos o processo de cicatrização normal do enxerto após a reconstrução ligamentar e os mecanismos biológicos de modulação dessa cicatrização, apresentando as atuais estratégias biológicas já estudadas para otimizar esse processo. ***Nível de evidência III, Revisão sistemática de estudos nível III.***

Descritores: *Ligamento Cruzado Anterior. Reconstrução do Ligamento Cruzado Anterior. Osseointegração. Ortopedia.*

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INTRODUCTION

The anterior cruciate ligament (ACL) is important for knee stability being a primary passive restrictor of anterior tibial translation and contributes to the rotational stability in different plane.[1] Movements such as jumping or sidecutting manouvers are particularly controlled by this ligament[2] In this regard, articular instability caused by ACL injury leads to significant impairment in daily activities, especially in athletes or young active individuals.

Classically, ACL injury occurs after trauma in valgus and internal/external rotation, during landing movement or abrupt changes of direction, usually in non-contact conditions (without direct knee contact)[2] In addition to instability caused by ACL injury, the evolution to early osteoarthrosis represents an important concern in long-term prognosis.[1,3] Currently, more than 200,000 cases of ACL tears are estimated annually in the United States leading to high socioeconomic losses.[4,5] Despite the different proposed treatment options given to the patient, ACL reconstruction has remained the gold standard to treat ACL injury.[6,7] In fact, ACL reconstruction is recommended in 60-90% cases of injury.[5] Among the different materials used as the *neoligament*, autografts often lead to better results when compared to artificial ligaments or allografts.[5,6]

The sports return is an important indicator to evaluate the success of ACL reconstruction.[8] According to a meta-analysis study, one in three patients did not returned to their pre-injury activity level and 45% did not successful return to sport in a competitive level.[8] Despite the performance in sports, satisfactory results range from 75 to 97% of the patients. However, less favorable outcomes may occur in up to 25% of cases, depending on the assessment methods.[9] Failures in ACL reconstruction are characterized by patient inability to return to routine activities or absence of knee stability.[7] The main clinical signs and symptoms observed in cases of failure are joint instability, persistent edema and chronic pain.[7] Therefore, mechanical and biological factors are evaluated to better understand the failure reason and obtain better functional results.

The mechanical factors include choice of graft, inaccuracies in graft harvest, inappropriate methods of fixation and errors in the

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The study was conducted at the Instituto de Ortopedia e Traumatologia do Hospital das Clínicas, da Faculdade de Medicina - Universidade de São Paulo.
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bone tunnels positioning. The femoral tunnel malpositioning is the major cause of failure in ACL reconstruction.[9,10] Inadequate graft position may lead to loss of knee motion, graft impingment and higher rate of re-rupture.[10] In addition, other anatomical alterations such as tibial slope increase,[11] malignment of lower limb and other associated lesions (not diagnosed or not adequately treated) can also increase graft mechanical stress.[12] In fact, LaPrade *et a*l (1999) showed a higher force exerted on the ACL graft when there is concomitant posterolateral corner lesions,[13] leading to procedure impairment. In addition to mechanical factors an adequate biological response should also occur.[14] Biological factors related to failure include the intrusion of the synovial fluid after ACL injury and necrosis during graft hasvesting and bone drilling.[9] Moreover, unfavorable mechanical and biological factors can induce the release of inflammatory cytokines by macrophages, sinoviocytes or fibroblasts - activating osteoclasts - and stimulate the production of metalloproteinases (MMPs) causing degradation of extracellular matrix (ECM) components.[9]

The native ACL attaches in the bone through both direct and indirect insertions being a complex highly specialized structure capable of transmitting mechanical loads from a soft tissue to the bone.[15] The direct insertion of ACL consists in 4 morphological zones gradually transitioning the ligament to the cartilage and the bone.[6,15,16] The composition of the ECM of direct ligament insertion relates directly to the mechanical demand in the ligament-bone interface.[17] The compressive strength that occurs especially in the insertion sites of the ligament leads to the production of molecules that compose the cartilage.[17] Proteoglycans (inluding glycosaminoglycans - GAGs), agrecans and binding proteins are examples of ECM molecules of entheses that are increased during compression.[18] Moreover, an enrichment of chondroitin 6 sulfate, instead of chondroitin 4 sulfate, is observed in the fibrocartilage during increased compression.[16] Other components of the direct ACL insertion include cartilage-specific collagens, such as type II, IX, X and XI. Collagen X is especially important to maintain the interface between the non-mineralized and mineralized portion of the fibrocartilage. The indirect insertion of ACL occurs through the Sharpey fibers, which anchor the ligament to the adjacent bone, providing additional mechanical resistance.[15]

After ACL reconstruction, the native ligament structure cannot be restored due to the absence of fibrocartilage remodeling at the graft-bone interface.[15,19] In this case, instead of forming the 4 gradual zones, tissue incorporation occurs through a fibrovascular scar tissue layer,[15,20] in which the osteointegration process of the graft is initiated.[20] Progressive mineralization of the interface occurs, with subsequent bone ingrowth and graft incorporation. Finally, the continuum of collagen fibers is restored leading to the reformation of the ligament-bone junction.[15]

In order to improve the results after ACL reconstruction a growing number of evidences suggest that the enhancement of biological process is beneficial in graft healing. The different histological origins of ACL makes the graft incorporation in the bone a complex and slow healing process divided in osteointegration and intra-articular ligamentization.[6,21] Different strategies to improve ACL healing have been studied in basic orthopedic science such as the use of mesenchymas cells, platelet-rich plasma (PRP), gene therapies, biophysical and pharmacological actions.[6]

Here, we are going to review the mechanisms of ACL healing process after ligament reconstruction describing some of biological modulation mechanisms and the alternatives existing to improve it results. The scientific understanding of the mechanisms involved in ligament reconstruction favors the development and implementation of new technologies focusing on the improvement of clinical outcomes.

ACL healing process

The graft healing process after ACL reconstruction involves three phases: early healing phase, proliferative phase and ligamentization phase.[21] The early healing phase comprises the period up to the 4th postoperative week and it is initially marked by hypocellularity and increased necrosis, mainly in the center of the graft.[7] Here, the inflammatory responses triggered in the site of injury is characterized by the release of cytokines and chemokines that leads to the production of growth factors culminating to the migration and proliferation of cells, revascularization and synthesis of ECM components.[22] In addition to pro-inflammatory cytokines, reactive oxygen species (ROS) are also modulators of cell recruitment.[23] The tissue remodeling also starts during the early phase between the 1st and 2nd week with the influx of neutrophils and macrophages in the periphery of the graft.[22]

Approximately 4 weeks after graft implantation, the proliferative phase starts with the infiltration of cells derived from the synovial fluid, the native ACL remnant or from bone marrow elements released during bone tunnels drilling.[21,24] The mechanical properties of the graft decreases until the 6th postoperative week and is potentially associated to breakage of collagen fibers of the graft.[21] The proliferative phase is characterized by maximum cellular activity and alterations of ECM.[21] This phase is defined as the period between 4 and 12 weeks after surgery.[25] The cellularity increases progressively with cell clusters observed mainly in the periphery of the graft and acellular areas in the middle. These hypercellular areas are formed by mesenchymal cells and fibroblasts, which secrete different growth factors,[7] as bFGF, TGF-beta, PDGF.[21] At the end of this phase, cellularity decreases progressively, but still remains high in comparison to the native ACL.[21] During this period, a large number of myofibroblasts are observed, which are capable of exerting isometric tension in the cellular and extracellular environment. In intact ACL, these cells are responsible for the crimping structure of the collagen fibers.[26] The number of myofibroblasts progressively increases during the first 3 months postoperatively and are responsible for restoring the tension required for the next process of ligamentization.[21] Interestingly, although the number of myofibroblasts is considerable during recovery, the cell invasion is lower than in the normal tendon.[27]

In response to hypoxia during avascular necrosis in the early healing phase, there is an increase in VEGF expression, with consequent intense revascularization.[7] This process, as in cellular infiltration, runs from the periphery to the entire graft.[26] The increase in vascularization and extracellular infiltrate reduces the mechanical capacity of the tissue. Thus, it is considered that the graft has the lower mechanical properties in 6 to 8 weeks after reconstruction. In addition, there is a reduction in the density of large diameter collagen fibrils which are predominant in the native ACL, which are progressively replaced by small diameter fibrils,[21] whose mechanical strength is lower.[28] The lack of the mechanical strength in the neoligament is also justified by the increase in type III collagen concentration.[26]

Most of the knowledge gathered regarding ACL healing is based on animal models. In humans, the remodeling process is likely to be more discreet and prolonged. In this regard, the complete replacement of intrinsic graft cells is not observed, and the central necrosis and denervation are smaller, not exceeding 30% of the graft's thickness. In addition, the neovascularization process in humans is not so prominent when compared to experimental models.[21,26]

Lastly, the maturation or ligamentization phase starts 3 months after the graft implantation.[26] This phase involves the progressive transformation of the graft in order to restore the native characteristics of the ligament. However, the complete restoration of ACL characteristics is controversial. Here, the progressive return to normal tissue cellularity takes place until the 6th postoperative

month.[21] Similarly, ECM proteins and collagen crosslink values also tend to normalize in this period.[26] The graft vascularization decreases, and the normal distribution of vessels occurs up to 12 months after the surgery. However, some changes remain. The diameter of the collagen fibrils remains heterogeneous and the regular crimp of the collagen does not return completely.[25] The increased synthesis of collagen type III decreases during the ligamentization phase in comparison to the proliferative phase, but still remains in higher concentration than in native ACL.[26] An experimental study in goats showed that the concentration of type III collagen returns to baseline values only 3 years after graft implantation, suggesting that the ligamentization phase might be active throughout this long period.[29]

While the proliferation phase has differences between animals and humans, the ligamentization phase seems to be very similar. Distinction exists only in the period of time which the changes occur.[26] Bone maturation occurs simultaneously with remodeling of the intra-articular portion. Several studies have shown that after 12 weeks the transition zone between the graft and the bone tunnel becomes more organized with an increase in the density of Sharpey fibers.[21,26]

Biological mechanisms for modulation of healing

As mentioned before, modulation of healing mechanisms favors a better outcome after ACL reconstruction. Although the weakest portion of graft rupture is in the intrasubstance (intra-articular) portion, the major investigation is directed towards the healing of the tendon-bone interface.[14] Strategies to modulate this response have been pointed out as promising and involves: osteointegration in the tendon-bone interface, cell supplementation, osteogenesis, angiogenesis and modulation the inflammatory process.[6,14,22,26]

The ligamentous healing process should be balanced in order to ensure an efficient integration of the graft without compromising the intra-articular mechanical strength. In this sense, the induction of angiogenesis is essential to favor the survival and integration of graft into the bone, but when in excess can lead to weakness, decreasing the mechanical properties.[14] In addition, the inflammatory response and production of matrix degradative enzymes are essential for the healing process, but when exacerbated may increase ligament deterioration in the intra-articular environment.[14] Of note, the impact of non-steroidal anti-inflammatory drugs (NSAIDs) in tendon/ligament repair is still poorly known.[30] The use of NSAIDs is efficient in control the pain specially in the initial postoperative period, however it is difficult to assume the routine use by surgeons, since local inflammation should be regulated but not inhibited.[14]

The use of biological therapies to modulate the healing process in the ACL reconstruction has been increasingly explored due to its promising potential to favor a better outcome in the postoperative period. In the next sections we are going to explore the recent findings on biological enhancement strategies for ACL reconstruction.

Growth factors

Growth factors are molecules biologically involved in cell proliferation, differentiation, migration and adhesion. They are produced and secreted by different types of tissues, and are crucial orchestrators of tissue repair processes, acting in all phases of healing.[31]

Several studies have evidenced a positive association between the administration of exogenous growth factors with the improvement of ligamentous healing, acting both in the process of osteointegration and ligamentization.[6]

Among the different factors, BMP, bFGF,[32] EGF, TGF-beta and VEGF are the most studied. The platelet concentrate, that are formed by different growth factors, such as PDGF, TGF-BETA and VEGF is also well described in literature being a potential approach for enhancement of the healing process.[24]

In clinical studies, the most commonly used strategy is the treatment with platelet-rich plasma (PRP), derived from autologous blood. PRP is a source of several growth factors and other bioactive molecules, which can active transcription factors after binding to specific receptors increasing expression of growth-related and immunomodulatory genes. During ACL reconstruction, PRP favors the ligamentization process while has a lower impact in bone-graft integration.[33]

Gene Therapy

Gene therapy is designed to introduce genetic modifications into joint cells to induce the production of beneficial molecules for specific treatment proposals.[34]

The transfection of BMP-2 gene into different cells in the graft, and the consequent increase in BMP-2 expression, significantly increases the integration of the semitendinosus graft into the bone tunnel.[35] Along with this study, others have shown the beneficial impact of transfection of growth factors'genes during healing. In this context, gene therapy can optimize the supply of growth factors in the integration site. Modulating stem cells with growth factors, such as BMP, TGF-beta and PDGF-B, a continuous concentration of these factors is released at the graft-tunnel interface.[6] Therefore, there would be a continuous, larger and more controlled supply of these substances. Importantly, the use of these factors is limited due to its low half-life, typically varying from minutes to hours. In addition, gene therapy still finds some resistance due to the potential risk for malignancy and exaggerated release of cytokines.[36]

Biomaterials

Biomaterials are composed by inert molecules that interact with the patient biological system without causing immunological rejection.[37] Examples of biomaterials include chitin fabrics,[38] bioglass,[39] hyaluronic acid[14] and collagen matrix[6].

Biomaterials are implanted in the human body functioning as biological fixation and coating methods, biosynthetic bone substitutes or osteoconductive materials. The biodegradable orthopedic devices favors modulation of the inflammatory response, regulation of the ECM formation, angiogenesis stimulation, osteoblastic proliferation and differentiation and accelerates the mineralization process improving the bone formation.[38-40]

In particular, biosynthetic bone substitutes, such as the demineralized bone matrix, are promising materials for ACL reconstruction due to its osteoinductive and osteoconductive properties.[6] Osteoinduction is the process by which osteogenesis is induced, implying the recruitment and stimulation of immature cells to become osteoblasts precursors. Osteoconduction is the capability to allow bone growth over its surface.[41] Osteoconductive materials, such as calcium phosphate, showed good results related to improvement the osteointegration process.[42]

Multi and pluripotent cells

Stem cells, multi or pluripotent, are defined as cells capable of long-term proliferation, self-renewal and differentiation into many cell lineages and types.[34] Examples are: induced pluripotent cells (iPSCs), umbilical cord-derived mesenchymal stem cell,[6] stem cells derived from fat (ADSCS), bone marrow (BMSCs)[43] or from tendons and ligaments (derived from ACL CD34 +).[44] Usually, these cells are placed on scaffolds for their stocking and release.

The use of multipotent cells stimulates the formation of a native-like fibrocartilage in the graft-bone interface[45] due to its osteogenic, chondrogenic and/or adipogenic potential.[44] Stem cells can removed through aspiration of blood from the bone marrow during the ACL reconstruction or be cultivated and expanded prior to the surgical procedure.[6] The advantage of autologous cells is to avoid the risk of rejection, infection or malignization.[46] The so-called

mesenchymal stem cells are multipotent cells with the ability to differentiate into mesoderm adult cells,[34] such as the periosteum.[15] In this context, the use of periosteum-derived stem cells can recreate the fibrocartilage present in the normal ACL insertion through the promotion of osteogenesis and chondrogenesis.[43] In fact, good results were found when synthetic grafts covered by periosteum were used in ligament reconstruction.[40] Interestingly, the presence of the ACL-remained mesenchymal cells was beneficial in favoring the proprioception and vascularization of the graft enhancing the healing process.[47]

Pharmacological strategies

Pharmacological strategies to enhance ACL healing include the use of agonists or antagonists that modulate the different phases of the repair process, namely: bone growth or bone resorption, inflammatory response and degradative enzymes present after ACL injury, and during the postsurgical healing period. Metalloproteinases (MMPs) inhibitors, which reduce the MMPs in the synovial fluid, improving the maturity of the graft-bone interface[48] are one example of pharmacological treatment.

In addition, agonists of the parathyroid hormone (PTH) receptor 1 have been suggested to improve reconstruction outcome. PTH is an anabolic regulator of calcium and phosphorus homeostasis, acting on the osteocytes and chondrocytes via PTH receptor (PTH1R). This is the only PTH receptor present in the bone tissue, being expressed in the stem cells derived from the bone marrow (BMSCs), osteoblasts and osteocytes. In the early phase of the ligament osteointegration process, PTH binds to the receptor present in these cells, balancing the bone turnover process, preventing osteoblastic apoptotic and stimulating bone formation. Thus, accelerates the heal during osteointegration.[49]

Drugs primarily described for different purposes, may also be beneficial. Simvastatin, a drug commonly used to treat dyslipidemia, has both anti-inflammatory and antioxidant effects decreasing inflammatory mediators (such as TNF-alpha and INF-gamma) and oxygen free radicals.[50] Moreover, Simvastatin showed an anabolic effect on the bone formation inducing BMP-2 culminating with angiogenesis and osteogenesis in the early stages after ACL reconstruction. However, without improves the long-term biomechanical properties.[15]

Bisphosphonates are drugs used in the treatment of diseases affecting bone metabolism. It has high affinity for hydroxyapatite, the main component of inorganic bone matrix, and act directly or indirectly by osteoclasts inhibition, interfering in bone remodeling with increased bone mass and improvement of mineralization. Bisphosphonates also act through inhibition of inflammatory mediators.[51] The use of alendronate, one type of bisphosphonates, reduces the tunnel bone resorption and promotes osteointegration of the graft during the early phases of the healing process.[52]

Biophysical measures

Other strategies were also studied and proved to be effective in enhancing the healing process after ACL reconstruction. Hyperbaric Oxygen Therapy promotes a better organization of collagen fibers. Moreover, it optimizes neovascularization,[53] inducing the expression of angiopoetin, bFGF and VEGF and accelerates the osteoinduction *via* BMP-2,[54] leading to a higher maximal pullout strength.[53]

The use of low intensity pulsed ultrasound (LIPUS)[48,55] and extracorporeal shockwave therapy (ESWT) proved to be effective in improving the healing process acting in both molecular and biomechanical aspects.[6] LIPUS can stimulate osteoblasts and fibrocytes and align collagen fibers. In addition, it increases the expression of angiogenic factors, such as VEGF.[55] ESWT proved to be effective in bone formation *via* BMP and neovascularization.[56] It is suggested that the shock waves may influence the mechanotransduction in the tissue, which is the ability of biological modulation through physical stimuli, converting acoustic mechanical energy into biological signals.[57] Thus, it induces the production of angiogenic factors such as VEGF and endothelial nitric oxide synthase (eNOS), leading to cell proliferation and formation of neovessels.[57] Indeed, a clinical study showed reduction in tibial tunnel bone loss in the group that received the ESWT treatment compared to the control group, two years after ACL reconstruction.[56]

Bioactive molecules

Lastly, the use of bioactive molecules has also been studied in ACL reconstruction. The addition of vitamin C (ascorbic acid) in the intraoperative irrigation prevented graft deterioration, restoring the anteroposterior stability of the knee in the 6th week after surgery.[23] Ascorbic acid acts as an antioxidant, neutralizing ROS and antagonizing the oxidative stress caused by the inflammatory process.[23] By modulating the cell recruitment, it reduces graft degeneration improving bone, tendon and graft healing process.[58]

Vitamin D is essential for mineralization and consequently for the maintenance of bone quality, with an important role in skeletal homeostasis. During the consolidation process it acts on the inflammatory cells, cytokines, growth factors, osteoblasts and osteoclasts.[59] Although no study has evaluated the direct effect of vitamin D during the healing process after ACL reconstruction, it is expected that by improving mineralization, vitamin D may optimize graft osteointegration.

Another bioactive molecule that is potentially beneficial during ACL healing is omega-3 fatty acid family. Omega-3 lipids act as an antioxidant and anti-inflammatory, leading to good results during the healing of the medial collateral ligament. In this regard, studies that address the direct effect of omega-3 derived molecules are needed to better understand the mechanisms of repair induction.[60]

CONCLUSION

Anterior cruciate ligament injury is one of the major causes of knee surgery and, despite the satisfactory results, ACL reconstruction can lead to joint instability and early osteoarthritis. In recent years, the increasing number of surgeries and the on-demand need for good results explain the growing amount of technological investment in the field. Among the different aspects of ACL reconstruction that may be modulated, the graft healing process is an interesting therapeutic target. Given that the biological mechanisms involved in ACL healing are being appreciated in literature, new focused therapies are beginning to emerge. In the present study, we discussed the natural pathway of graft integration and healing in order to explore the major biological regulatory mechanisms that enhance graft repair. Despite the several studies and controversies regarding ACL healing, the mechanisms that explain different outcomes are not completely described hindering the development of new opportunities for treatment. The restoration of the native condition of osteotendinous insertion is still challenging and more research is needed to clarify the pathophysiology of ACL injury and healing leading to a more guided and intelligent design of new therapies.

Here we presented different biological strategies to enhance *neoligament* repair. Each type of management has specific advantages and disadvantages; therefore, the treatment choice must be based on patient needs and medical history. Timing, treatment schedule and the dose of different treatments are still controversial and further studies will shed light on the impact of biological enhancements for ACL reconstruction. In this regard, surgical management of ACL injury may be followed by adjunctive biological therapies that will decrease failure rates, leading to a better/faster functional recovery and patient return to usual activities.

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