Journal of the Asociación Argentina de Ortopedia y Traumatología

AN ORGAN OF THE ASOCIACIÓN ARGENTINA DE ORTOPEDIA Y TRAUMATOLOGÍA

VOL. 89, N.° 4 / AUGUST 2024 / Pp. 331-441

www.aaot.org.ar • https://raaot.org.ar

Full English text available. Indexed in SciELO, LILACS, Latindex, Dialnet, Doaj, Redib, AmeliCA and JournalTOCs • Included in the Núcleo Básico de Revistas Científicas Argentinas del CONICET. ISSN 1852-7434 (ONLINE)

The Importance of Certification in Orthopedics and Traumatology Training

Federico D. Sartor
President of the Committee on Residency and Equivalent Systems in Orthopedics and Traumatology.

The Residency Committee of the Asociación Argentina de Ortopedia y Traumatología (AAOT) is responsible for overseeing every aspect of the specialty's residency program. This includes a variety of activities such as conferences, CIROT, soccer tournaments, and more. The Committee supervises resident training across both the specialty and its subspecialties. Residents are also involved through a subcommittee and participate in various Committee activities. These competitions and events not only strengthen the relationships within each residency but also enhance interactions among different residencies. In addition to these activities, the Committee has the essential duty of reviewing and accrediting residencies. This process is critical to ensuring the quality and competence of future traumatology professionals and involves a well-defined structure and regular evaluations.

Orthopedic and traumatology training typically lasts four years, while some programs extend up to five years. In addition, many physicians opt to further their specialization through advanced programs. Instead of using the term "fellowship," the Committee suggests "post-basic residency" or "post-residency training" for these programs. Combined with the initial residency, the total training time can range from six to seven years. Considering that a medical degree program lasts 6 or 7 years, a young professional might spend 12 to 14 years in training before entering the workforce. This is a significant commitment compared to other professions.

Several years ago, the Residency Committee collaborated with the Ministry of Health and other organizations to establish a framework for orthopedic and traumatology training programs. This framework, along with one for post-basic residencies developed with AAOT subsidiary societies, sets minimum standards and defines operational areas for these residencies. These frameworks provide some flexibility for program leaders while establishing essential requirements for residency accreditation.

The Residency Committee plays a crucial role in conducting periodic visits and evaluations of orthopedic and traumatology residencies. Despite logistical and economic challenges, this task has been carried out continuously for many years. During these visits, the Committee assesses whether the residencies meet minimum requirements and decides whether to grant or deny accreditation. This process is not merely administrative; it involves evaluating the center's capacity to train professionals based on its surgical and academic activities and physical conditions. The Committee has occasionally ceased accrediting centers for not meeting minimum standards or requested reductions in the number of available positions.

Despite these challenges, the evaluation and accreditation process by the AAOT and the Ministry of Health benefits all parties involved. Evaluators gain direct insights from residents across the country, helping identify previously unrecorded issues, guide new activities, and disseminate existing ones. The AAOT receives updated information on residents in training at each center, strengthening its national presence. Evaluated residencies gain valuable

Dr. FEDERICO D. SARTOR • fedes_3@yahoo.com https://orcid.org/0009-0005-6268-6524

How to cite this article: Sartor FD. The Importance of Certification in Orthopedics and Traumatology Training. *Rev Asoc Argent Ortop Traumatol* 2024;89(4):331-332. https://doi.org/10.15417/issn.1852-7434.2024.89.4.1990

external feedback, which highlights opportunities for improvement and change. Residents also have the chance to address difficulties, including allegations of physical and occupational abuse, that might otherwise go unreported.

With the information provided by the Committee, we were able to conduct the first census of 1st-year residency positions. We found that 346 positions were offered in 140 facilities in 2022. Personally, I have observed improvements in residencies following each evaluation, with the Committee's recommendations serving as a roadmap.

Training processes are dynamic and evolve over time, influenced by changes in management, institutional idiosyncrasies, new technologies, and shifts in established practices. The rise of remote and asynchronous training is one such change. It is essential to continuously evaluate, improve, and challenge these processes. Is it necessary to train for 15 years to provide high-quality medical care? Accrediting both basic and post-basic training processes is one way to ensure the delivery of high-quality medical education.

Return to Sports After Arthroscopic Rotator Cuff Repair in Recreational Athletes

Tomás Gorodischer, Luciano A. Rossi, Ignacio Tanoira, Maximiliano Ranalletta
Institute of Orthopedics and Traumatology "Prof. Dr. Carlos E. Ottolenghi", Hospital Italiano de Buenos Aires, Autonomous City of Buenos Aires, Argentina.

ABSTRACT

Objective: To assess return to sports in recreational athletes after arthroscopic rotator cuff repair (ARCR). **Materials and Methods:** Retrospective single-site study of recreational athletes who were operated on between August 2019 and December 2020 for ARCR, with a minimum follow-up of one year. Patients were divided into 2 groups based on their shoulder demand: high or low. The primary endpoint was return to sports. Secondary criteria included time to return, level achieved, pre and postoperative VAS for pain, and ASES and Constant scores. The minimal clinically important difference (MCID) and substantial clinical benefit (SCB) were calculated. Complications were recorded. **Results:** A total of 102 patients (mean age: 58.7 years) were included. Seventy patients practiced a sport with high shoulder involvement. The mean follow-up was 18 months. 82.3% of patients returned to recreational sports, with 63 participating at the same level. The median time to return was six months. Return to sports was 91% in the low-shoulder demand group versus 79% in the high-shoulder demand group. VAS, Constant and ASES scores improved after six and twelve months. For the ASES and Constant scores, 98 and 100% of patients met the MCID and SCB, respectively. A total of eight patients reported persistent pain. Five patients required revision surgery. **Conclusion:** Most recreational athletes who undergo ARCR are able to resume their previous level of activity. Most athletes achieved significant clinical improvement with a low rate of complications (7.8%).

Keywords: Shoulder; rotator cuff; return to sports; recreational sports.
Level of Evidence: IV

Retorno al deporte recreativo luego de la reparación artroscópica del manguito rotador

RESUMEN

Objetivo: Evaluar el retorno al deporte recreativo luego de una reparación artroscópica del manguito rotador. **Materiales y Métodos:** Se realizó un análisis retrospectivo de atletas recreativos sometidos a una reparación artroscópica del manguito rotador entre agosto de 2019 y diciembre de 2020 (seguimiento mínimo 1 año). Se los dividió en dos grupos: alta y baja demanda del hombro. El resultado principal evaluado fue el retorno al deporte y los resultados secundarios fueron: tiempo de retorno, nivel alcanzado, escala analógica visual pre y posoperatoria para dolor; escalas ASES y Constant. Se calcularon la diferencia mínima clínicamente importante y el beneficio clínico sustancial. Se registraron las complicaciones. **Resultados:** Se incluyó a 102 pacientes (media de edad 58.7 años). Setenta practicaban un deporte de alta demanda para el hombro. La media de seguimiento fue de 18 meses. El 82,3% volvió al deporte; 63, al mismo nivel. La mediana hasta el regreso fue de 6 meses. El 91% de los deportistas con baja demanda para el hombro y el 79% con alta demanda retornaron al deporte. Los puntajes de las escalas mejoraron a los 6 y 12 meses. El 98% y el 100% alcanzaron la diferencia mínima clínicamente importante y el beneficio clínico sustancial para las escalas ASES y Constant, respectivamente. Ocho tenían dolor persistente. Cinco fueron sometidos a una cirugía de revisión. **Conclusión:** La reparación artroscópica del manguito rotador en deportistas recreativos logró muy buenos resultados funcionales con una alta tasa de retorno deportivo al mismo nivel y un 7,8% de complicaciones.

Palabras clave: Hombro; manguito rotador; retorno al deporte; deporte recreativo.
Nivel de Evidencia: IV

Received on October 6th, 2023. Accepted after evaluation on May 23rd, 2024 • Dr. TOMÁS GORODISCHER • tomasgorodischer@gmail.com ID https://orcid.org/0000-0002-5044-5847

How to cite this article: Gorodischer T, Rossi LA, Tanoira I, Ranalletta M. Return to Sports After Arthroscopic Rotator Cuff Repair in Recreational Athletes. *Rev Asoc Argent Ortop Traumatol* 2024;89(4):333-340. https://doi.org/10.15417/issn.1852-7434.2024.89.4.1829

INTRODUCTION

Rotator cuff tears (RCT) are a common cause of shoulder pain and dysfunction. The reported prevalence of these injuries in the general population is 9.7% in patients under 20 years old and 62% in those over 80 years old.[1,2] Arthroscopic repair of these lesions is the treatment of choice, as recovery times are shorter than with open techniques, and long-term functional outcomes are identical.[3,4]

With the increase in life expectancy, the number of elderly people (over 55 years) who engage in physical activity for its health benefits and as a social activity is growing.[5] RCTs are common in this subgroup of patients and can limit or even prevent sports participation.[1]

Most published studies on return to sport after rotator cuff repair surgery focus on competitive athletes.[6-9] The main systematic reviews yield conflicting results when comparing the return to sport between this type of athlete and recreational athletes.[6,10] This controversy is due, in part, to the scarcity of publications on return to sport in the latter group of patients.[11,12]

The main objective of this study was to evaluate the proportion of patients who returned to recreational sports after undergoing surgery for RCT. The secondary objectives were to assess the proportion of patients who returned to the same level of sport as before the injury, both in general and according to the level of shoulder demand, as well as to evaluate the functional outcomes and the number of patients who reached the minimal clinically important difference (MCID) and substantial clinical benefit (SCB).[13,14] Finally, complications and reinterventions were recorded.

MATERIALS AND METHODS

Patients who underwent arthroscopic repair of a rotator cuff tear (RCT) between August 2019 and December 2020 were retrospectively identified.

Patients were included if they practiced a recreational sport at least once a week and had a complete unilateral RCT confirmed by preoperative MRI (involving the supraspinatus, infraspinatus, or subscapularis), with a tear size of <3 cm, no retraction (Patte classification grade I), mild to moderate atrophy (Goutallier classification grades 0-3), and a minimum follow-up of one year. Exclusion criteria included partial tears, revisions or massive/irreparable RCTs, not practicing sports, and being unreachable at the end of the follow-up period.

Preoperative and postoperative evaluations consisted of a physical examination by a shoulder surgeon or fellow, specific functional scales for the upper limb (*American Shoulder and Elbow Surgeons* [ASES] and Constant scales), and the visual analog scale (VAS) for pain, ranging from 0 to 10, where 0 represents no pain and 10 represents the maximum pain imaginable. Patients were monitored at 3, 6, and 12 months after surgery and then annually. They were asked if they practiced a sport before surgery, what type of sport, whether they were able to return to it after the procedure, how long it took, and at what level. If they had not been able to return to their sport, they were asked why.

Patients were divided into two groups based on the shoulder's involvement in their sport: a high-demand group and a low-demand group. After collecting the preoperative and postoperative functional scale scores, the number of patients who achieved the minimal clinically important difference (MCID) and substantial clinical benefit (SCB) according to the values established by Cvetanovich et al. was determined.[15] The ASES scale scores were 11.1 and 17.5, respectively, and the Constant scale scores were 5.5 in both cases.

During the study period, 206 patients underwent arthroscopic repair for RCT. Of these, 107 patients met the inclusion criteria, with five (4.7%) being unreachable. A total of 102 patients (95.3%) were analyzed (Figure 1).

The group consisted of 32 women and 70 men, with a mean age of 58.7 years (standard deviation [SD] 10.8) at the time of surgery. Demographic data are summarized in Table 1.

The average tear size was 2 cm (SD 1.2) in the coronal plane and 2.3 cm (SD 0.5) in the sagittal plane. Fat atrophy was grade 1 in 52 patients (48.6%), grade 2 in 39 (36.4%), and grade 3 in 16 (15%). The most common recreational sports were tennis (17.6%), gymnastics (13.7%), golf (11.7%), and gym activities (11.7%). A total of 68.6% (70 patients) participated in a sport with high demand on the shoulder (tennis, swimming, paddle tennis, paddleball, squash, gym activities, volleyball, taekwondo, crossfit, boxing, climbing, soccer), while 31.4% (32 patients) engaged in less demanding activities for the upper limb (hiking, gymnastics, running, cycling). The dominant side was affected in 82 patients (80.4%). The mean follow-up was 18 months (range 12-24 months).

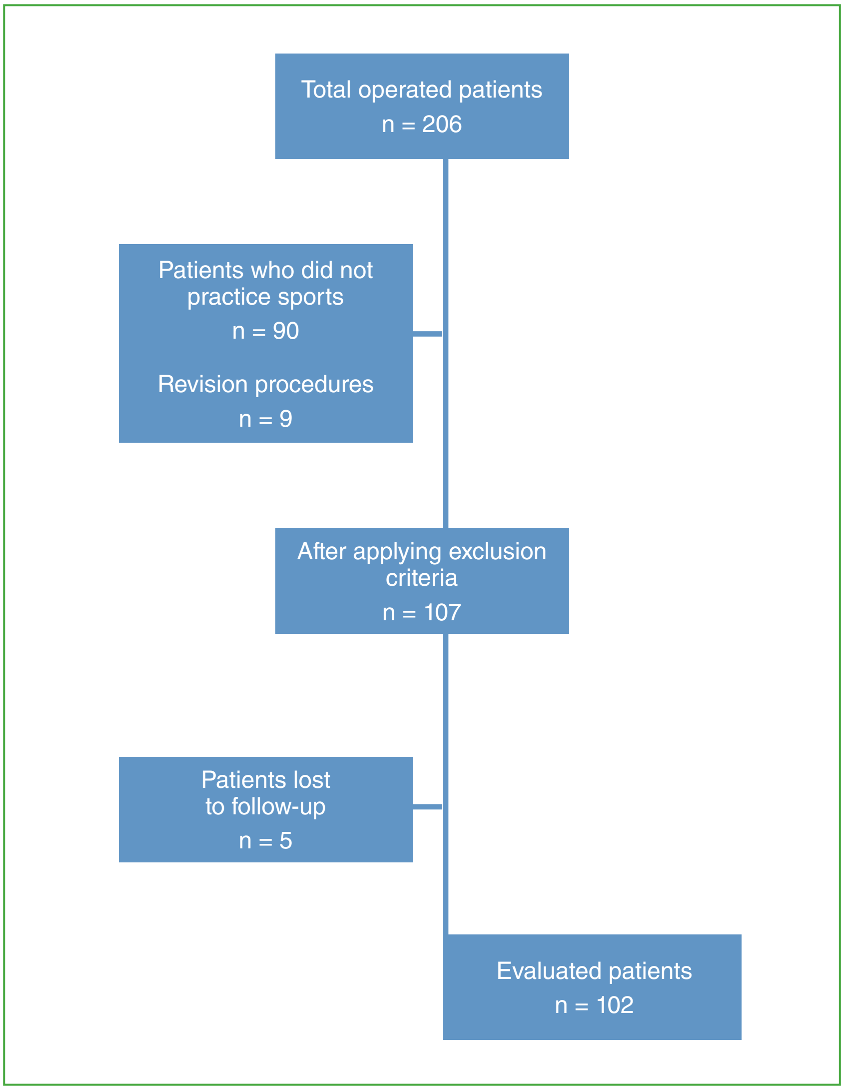


Figure 1. Flowchart of inclusion and exclusion of patients in the series.

Table 1. Demographic data of the series.

	Total (n = 102)	Did not return to sport (n = 18)	Returned to sport (n = 84)	p
Age (years), mean (SD)	58.7 (10.8)	58.3 (12.5)	58.8 (10.5)	0.884
Gender, n (%)	70 (68.6%)	13 (72.2%)	57 (67.9%)	0.934
Dominant shoulder, n (%)	82 (80.4%)	14 (77.8%)	68 (81.0%)	0.749
Time (months), mean (range)	18 (12-24)	-	18 (12-24)	.

SD = standard deviation.

Surgical technique

The patients were operated on in the beach chair position under general anesthesia with a regional interscalene block. All repairs were performed by three surgeons specializing in shoulder pathology, using the same transosseous-equivalent technique. A standard posterior visualization portal was used, through which a 30° arthroscope was introduced. Under direct vision and with the aid of a needle, an anterior portal was created through the rotator interval. Exploratory arthroscopy was then performed. Once the injury was identified, the arthroscope was moved to the subacromial space to perform a slight bursectomy with a shaver and radiofrequency until adequate visualization was achieved. An anterolateral accessory portal was used for anchor placement and suture management.

Before the repair, the tendon insertion area was prepared by reaming it until a bleeding bed was obtained. Depending on the size of the lesion, one or two 5-mm anchors with double-row sutures were placed at the level of the humeral articular cartilage margin. The sutures were passed through the tendon using pigtail needles, from anterior to posterior, approximately 1 cm proximal to the tear. When a single medial anchor was placed, the sutures were retrieved above the lesion and fixed laterally with a sutureless anchor. When two medial anchors were placed, one suture from each anchor was retrieved and fixed in a crisscross fashion with two lateral anchors separated by 1 cm from each other to complete the configuration. The sutures were tensioned under direct vision before inserting the lateral anchors. Finally, all sutures were trimmed, and the repair was examined with a probe. Figure 2 presents a case as an example.

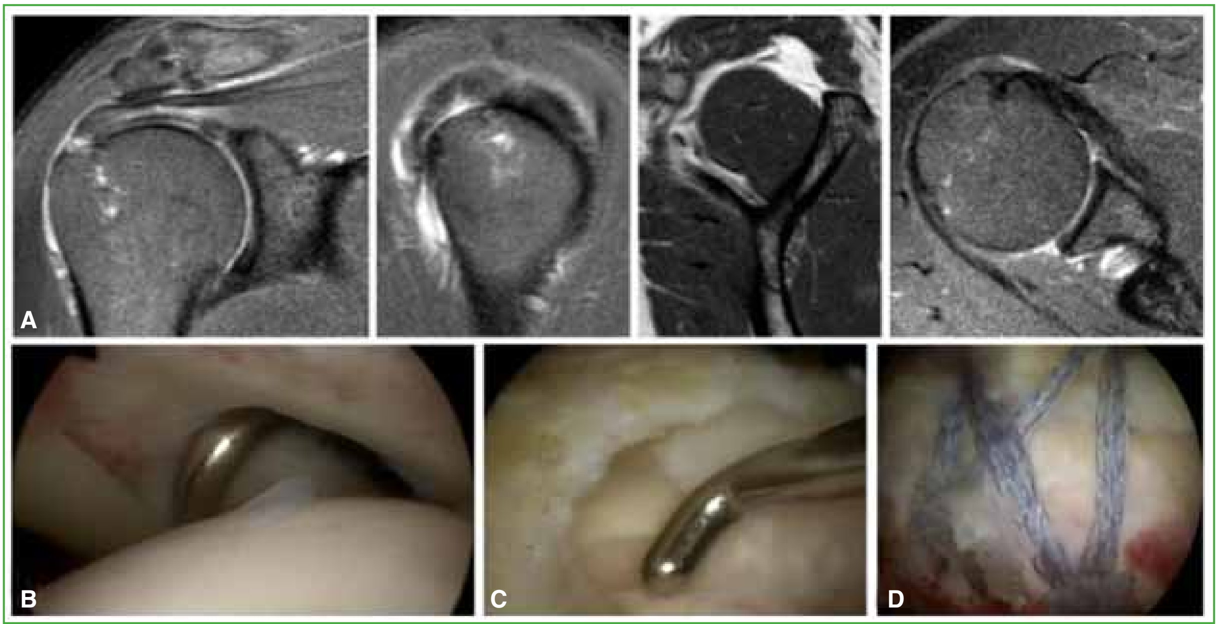


Figure 2. 60-year-old patient with right supraspinatus injury. **A.** Magnetic resonance images. A complete insertional injury of the supraspinatus is observed. **B.** Intrarticular view of the injury. **C.** Subacromial view of the injury. **D.** Final subacromial view of the repair. Two medial and two lateral anchors were used.

Postoperative protocol

All patients followed the same postoperative rehabilitation protocol. For the first four weeks, the arm was rested in a sling, with exercises for hand, wrist, and elbow mobilization. After one month, formal physical therapy began, starting with pendulum movements, progressive passive mobilization, and assisted active mobilization of the shoulder. Once anterior flexion greater than 90º was achieved, strengthening exercises were introduced, initially with elastic bands and then progressively with weights until a full active range of motion was restored. Patients were allowed to begin running eight weeks after surgery. Return to sport was permitted when the patient was pain-free, had regained full range of motion, and had strength close to pre-injury levels.

Statistical analysis

Demographic and outcome data were analyzed descriptively. Continuous variables are presented as mean and standard deviation (SD) or as median and interquartile range (IQR), depending on the distribution. Categorical variables are expressed as absolute and relative frequencies. Independent continuous variables were compared using either the t-test or the Mann-Whitney test, depending on their distribution. Categorical variables were compared using the chi-squared test or Fisher's exact test, as appropriate. All tests were two-tailed. Pre- and postoperative functional scales were compared using a paired t-test. STATA version 12 (StataCorp, College Station, TX, USA) was used for the analysis. A p-value of <0.05 was considered statistically significant.

RESULTS

Return to sport

Eighty-four patients (82.3%) were able to return to recreational sport by the end of the follow-up period (median 6 months [IQR 4-7]). Sixty-three of these patients returned to their pre-injury level of sport (76%, 95% confidence interval [95% CI] 65%-84%), while 18 returned at a lower level (22%, 95% CI 13%-32%), and two returned at a higher level (2%, 95% CI 0.3%-8%).

Eighteen patients (17.6%) were unable to resume their sport after the procedure: seven stopped due to persistent shoulder pain (6.9%), six due to fear or caution (5.9%), two due to work commitments (2%), and three due to other causes unrelated to the shoulder (2.9%).

Ninety-one percent of those who played low-demand sports for the shoulder and 79% of those in the high-demand group were able to return to sport ($p = 0.17$). In terms of time to return to sport, the low-demand group had a median of 3 months (IQR 3-6), while the high-demand group had a median of 6 months (IQR 5-9) ($p < 0.01$). Ninety-three percent of the low-demand patients returned to their previous level of sport compared to 70% of the high-demand group ($p = 0.015$).

Clinical results

The preoperative and postoperative scores on the VAS pain and functional scales are shown in Table 2. The improvement in scores on the VAS and functional scales was statistically significant at both 6 and 12 months postoperatively (Figure 3).

Table 2. Preoperative and postoperative scores on the clinical scales.

Functional scale	Before surgery	6 months after surgery	12 months after surgery	p
VAS	7.49 (1.73)	2.84 (2.22)	1.66 (2.04)	<0.001
Constant	31.2 (13.4)	75.7 (15.6)	89.0 (12.3)	<0.001
ASES	29.8 (14.1)	76.7 (15.8)	89.2 (12.7)	<0.001

VAS = visual analog scale; ASES = *American Shoulder and Elbow Surgeons Score*.

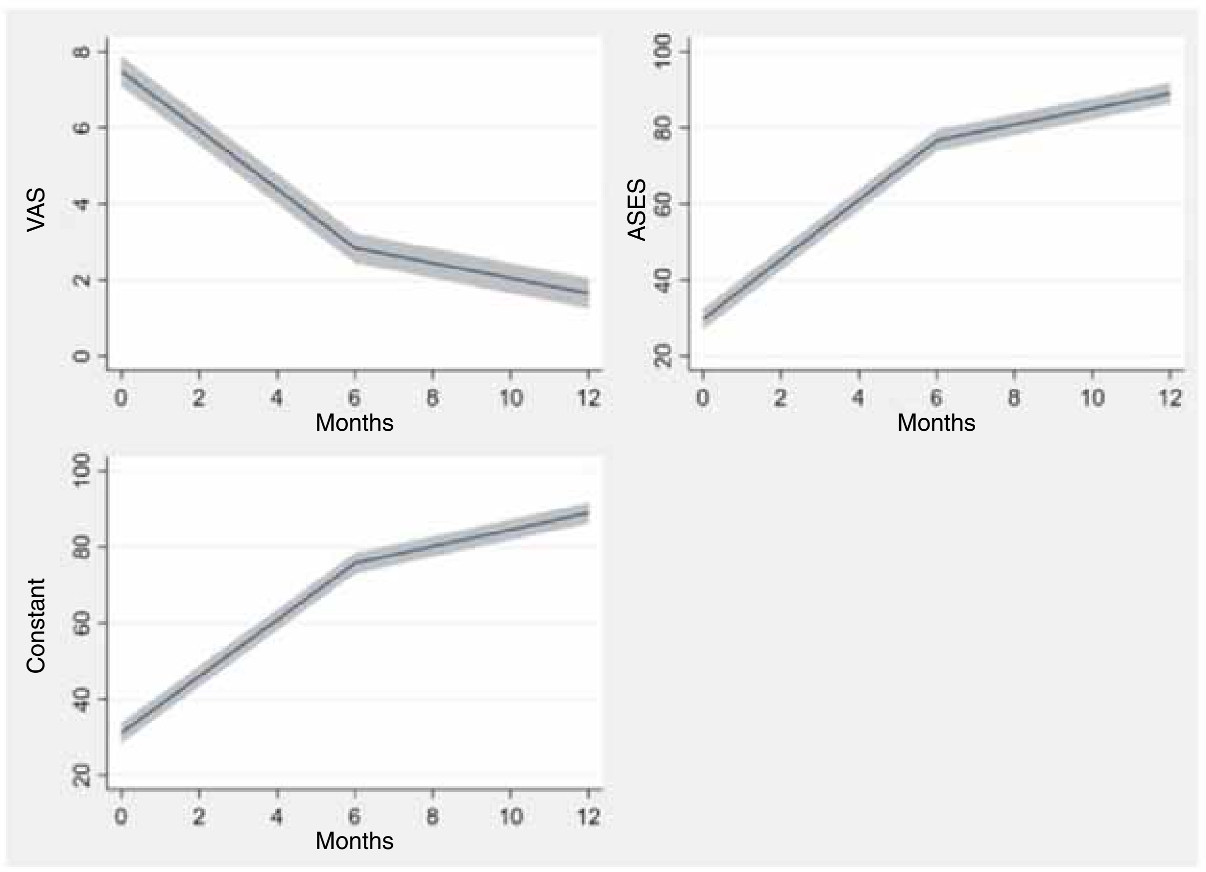


Figure 3. Progression of clinical scales before surgery and after 6 and 12 months. A marked decrease in the score on the visual analog scale (VAS) of pain is observed, as well as a progressive increase in the scores on the functional scales.
ASES = *American Shoulder and Elbow Surgeons Score*.

Regarding the ASES scale, 98% of patients achieved both the MCID and SCB. All patients achieved both the MCID and SCB on the Constant scale.

Complications

Eight patients (7.8%) experienced persistent pain at the end of follow-up, five of whom were unable to return to sport. Five patients (4.9%) suffered a re-tear and required reoperation. Four of these belonged to the high-demand shoulder group, and one to the low-demand group.

DISCUSSION

The most important finding of our study is that 82% of the patients were able to return to their recreational sport, with 76% of them reaching the same level as before the injury. Additionally, 98% of patients met the MCID and SCB criteria on the ASES scale. All patients experienced a statistically significant improvement in pain on the VAS and achieved both the MCID and SCB on the Constant scale.

To our knowledge, this study represents the largest series to evaluate return to exclusively recreational sport after rotator cuff tear (RCT) surgery, and the only one to report specific clinical measures such as MCID and SCB. In 2016, Antoni et al.[11] evaluated clinical outcomes and return to recreational sport in a series of 76 patients after arthroscopic rotator cuff repair. After a minimum follow-up of 2 years, 88.2% were able to resume a recreational sport, but only 68.4% returned to the same sport they played before surgery; the average return time was 6 ± 4.9 months. Our results were similar, with just over 80% of patients returning to their sport after a median of 6 months.

In professional athletes, despite satisfactory clinical outcomes, the rate of return to sport after RCT is often lower than in recreational athletes. In their 2015 systematic review and meta-analysis, Klouche et al.[6] reported an overall return-to-sport rate of close to 85%, with 66% of patients reaching their preinjury sport level between 4 and 7 months after surgery. The return rate was significantly higher in recreational athletes (82.4%) than in those who played competitively or professionally (49.9%). In our series, which focused solely on recreational athletes, the overall return rate was 82.3%, with 76% returning to the same level of sport.

In a more recent systematic review and meta-analysis, Altintas et al.[10] evaluated 15 studies involving 486 patients (499 shoulders) and reported an overall return-to-sport rate of 85.5%. Interestingly, and in contrast to Klouche et al.,[6] despite a difference in return rates between competitive and recreational athletes (84.8% vs. 86.4%), this difference was not statistically significant. The reported rate of return to the same level was 70.2%. Recreational sports were associated with a higher return-to-sport level rate (73.3%), while competitive sports (61.5%), especially those involving overhead maneuvers, were associated with a lower rate (38%). In the latter group, the rate of return to the same level dropped to 30% when the affected shoulder was the dominant one.[16-18] Our results are consistent with these findings, as 93% of patients participating in low-demand sports for the shoulder were able to return to their pre-injury sport level, while only 70% of those involved in high-demand activities for the shoulder were able to do so.

The differences in results obtained in the aforementioned meta-analyses may be due, in part, to the fact that Klouche et al.[6] evaluated open, mini-open, and arthroscopic procedures interchangeably, while Altintas et al.[10] focused only on arthroscopic rotator cuff repairs. Given the high physical demands on competitive athletes, the increased soft tissue trauma and adhesion formation associated with open procedures may have greater consequences on competitive athletes than on recreational athletes.[19-21] Arthroscopic techniques aim to minimize soft tissue impingement and scar tissue formation, offering a shorter recovery time compared to open procedures and potentially allowing for a higher and faster return to sport.[22,23] With these factors in mind, our series consisted exclusively of patients who underwent arthroscopic surgery with a transosseous-equivalent repair technique.

Our study has limitations. It is a retrospective series with inherent limitations. Furthermore, a group of patients treated with a different surgical method was not studied. Finally, all athletes were treated with the same institutional physical rehabilitation protocol.

CONCLUSION

Arthroscopic rotator cuff repair in recreational athletes achieved very good functional outcomes, with a high rate of return to sport at the pre-injury level and a 7.8% complication rate.

Conflict of interest: The authors declare no conflicts of interest.

L. A. Rossi ORCID ID: https://orcid.org/0000-0002-1397-2402
I. Tanoira ORCID ID: https://orcid.org/0000-0002-2869-2390
M. Ranalletta ORCID ID: https://orcid.org/0000-0002-9145-4010

REFERENCES

1. Teunis T, Lubberts B, Reilly BT, Ring D. A systematic review and pooled analysis of the prevalence of rotator cuff disease with increasing age. *J Shoulder Elbow Surg* 2014;23(12):1913-21. https://doi.org/10.1016/j.jse.2014.08.001
2. Yamamoto A, Takagishi K, Osawa T, Yanagawa T, Nakajima D, Shitara H, et al. Prevalence and risk factors of a rotator cuff tear in the general population. *J Shoulder Elbow Surg* 2010;19(1):116-20. https://doi.org/10.1016/j.jse.2009.04.006

3. Ji X, Bi C, Wang F, Wang Q. Arthroscopic versus mini-open rotator cuff repair: An up-to-date meta-analysis of randomized controlled trials. *Arthroscopy* 2015;31(1):118-24. https://doi.org/10.1016/j.arthro.2014.08.017
4. Baker CL, Liu SH. Comparison of open and arthroscopically assisted rotator cuff repairs. *Am J Sports Med* 1995;23(1):99-104. https://doi.org/10.1177/036354659502300117
5. Stenner BJ, Buckley JD, Mosewich AD. Reasons why older adults play sport: A systematic review. *J Sport Health Sci* 2020;9(6):530-41. https://doi.org/10.1016/j.jshs.2019.11.003
6. Klouche S, Lefevre N, Herman S, Gerometta A, Bohu Y. Return to sport after rotator cuff tear repair: A systematic review and meta-analysis. *Am J Sports Med* 2016;44(7):1877-87. https://doi.org/10.1177/0363546515598995
7. Namdari S, Baldwin K, Ahn A, Russell Huffman G, Sennett BJ. Performance after rotator cuff tear and operative treatment: A case-control study of major league baseball pitchers. *J Athl Train* 2011;46(3):296-302. https://doi.org/10.4085/1062-6050-46.3.296
8. Harris JD, Frank JM, Jordan MA, Bush-Joseph CA, Romeo AA, Gupta AK, et al. Return to sport following shoulder surgery in the elite pitcher: a systematic review. *Sports Health* 2013;5(4):367-76. https://doi.org/10.1177/1941738113482673
9. Mazoué CG, Andrews JR. Repair of full-thickness rotator cuff tears in professional baseball players. *Am J Sports Med* 2006;34(2):182-9. https://doi.org/10.1177/0363546505279916
10. Altintas B, Anderson N, Dornan GJ, Boykin RE, Logan C, Millett PJ. Return to sport after arthroscopic rotator cuff repair: Is there a difference between the recreational and the competitive athlete? *Am J Sports Med* 2020;48(1):252-61. https://doi.org/10.1177/0363546519825624
11. Antoni M, Klouche S, Mas V, Ferrand M, Bauer T, Hardy P. Return to recreational sport and clinical outcomes with at least 2years follow-up after arthroscopic repair of rotator cuff tears. *Orthop Traumatol Surg Res* 2016;102(5):563-7. https://doi.org/10.1016/j.otsr.2016.02.015
12. Bhatia S, Greenspoon JA, Horan MP, Warth RJ, Millett PJ. Two-year outcomes after arthroscopic rotator cuff repair in recreational athletes older than 70 years. *Am J Sports Med* 2015;43(7):1737-42. https://doi.org/10.1177/0363546515577623
13. Makhni EC, Steinhaus ME, Morrow ZS, Jobin CM, Verma NN, Cole BJ, et al. Outcomes assessment in rotator cuff pathology: what are we measuring? *J Shoulder Elbow Surg* 2015;24(12):2008-15. https://doi.org/10.1016/j.jse.2015.08.007
14. Katz NP, Paillard FC, Ekman E. Determining the clinical importance of treatment benefits for interventions for painful orthopedic conditions. *J Orthop Surg Res* 2015;10:24. https://doi.org/10.1186/s13018-014-0144-x
15. Cvetanovich GL, Gowd AK, Liu JN, Nwachukwu BU, Cabarcas BC, Cole BJ, et al. Establishing clinically significant outcome after arthroscopic rotator cuff repair. *J Shoulder Elbow Surg* 2019;28(5):939-48. https://doi.org/10.1016/j.jse.2018.10.013
16. Azzam MG, Dugas JR, Andrews JR, Goldstein SR, Emblom BA, Cain EL Jr. Rotator cuff repair in adolescent athletes. *Am J Sports Med* 2018;46(5):1084-90. https://doi.org/10.1177/0363546517752919
17. Dines JS, Jones K, Maher P, Altchek D. Arthroscopic management of full-thickness rotator cuff tears in major league baseball pitchers: The lateralized footprint repair technique. *Am J Orthop (Belle Mead NJ)* 2016;45(3):128-33. PMID: 26991564
18. Plate JF, Haubruck P, Walters J, Mannava S, Smith BP, Smith TL, et al. Rotator cuff injuries in professional and recreational athletes. *J Surg Orthop Adv* 2013;22(2):134-42. https://doi.org/10.3113/jsoa.2013.0134
19. Kelly BC, Constantinescu DS, Pavlis W, Rap AR. Arthroscopic versus open rotator cuff repair: Fellowship-trained orthopaedic surgeons prefer arthroscopy and self-report a lower complication rate. *Sports Med Arthrosc Rehabil Ther Technol* 2021;3(6):e1865-e1871. https://doi.org/10.1016/j.asmr.2021.09.001
20. Wang KY, Agarwal AR, Xu AL, Best MJ, Kreulen RT, Jami M, et al. Increased risk of surgical-site infection and need for manipulation under anesthesia for those who undergo open versus arthroscopic rotator cuff repair. *Sports Med Arthrosc Rehabil Ther Technol* 2022;4(2):e527-e533. https://doi.org/10.1016/j.asmr.2021.11.012
21. Kelly BC, Constantinescu DS, Vap AR. Arthroscopic and open or mini-open rotator cuff repair trends and complication rates among American Board of Orthopaedic Surgeons Part II Examinees (2007-2017). *Arthroscopy* 2019;35(11):3019-24. https://doi.org/10.1016/j.arthro.2019.06.022
22. Yamaguchi K, Levine WN, Marra G, Galatz LM, Klepps S, Flatow EL. Transitioning to arthroscopic rotator cuff repair: the pros and cons. *Instr Course Lect* 2003;52:81-92. PMID: 12690842
23. Dey Hazra R-O, Ernat JJ, Rakowski DR, Boykin RE, Millett PJ. The evolution of arthroscopic rotator cuff repair. *Orthop J Sports Med* 2021;9(12):23259671211050899. https://doi.org/10.1177/23259671211050899

Proximal Row Carpectomy in Degenerative Wrist Conditions. Our Medium-term Experience

Clara Matellanes Palacios, Isabel Cabanes Ferrer, Miguel Alfonso Porcar, Gemma Gázquez Gázquez, Ana Losar Sogues Colom, Laura Castillo Ruipérez, José Garrido Ferrer, Lorenzo Hernández Ferrando
Upper Limb Unit, Hospital General Universitario de Valencia, Spain.

ABSTRACT

Objective: Examining the medium-term clinical and radiological outcomes of proximal carpectomy for treating degenerative wrist conditions. **Materials and Methods:** Retrospective study of 33 patients who underwent proximal carpectomy between 2009 and 2019. Outcomes were assessed through range of motion measurements, pain evaluation using the Visual Analog Scale (VAS), and functional capacity using the Quick-DASH questionnaire. Biomechanical tests were performed and the rate of complications and reoperations was analyzed. Radiological progression of osteoarthritis and its impact on clinical outcomes were examined. **Results:** The mean range of motion was 77.11º (range 51–80º) in flexion-extension and 36.7º (range 29–42º) in radioulnar deviation. VAS scores improved significantly from 7.9 (range 7–9) to 2.7 (range 0–7) post-surgery ($p<0.003$). The Quick-DASH score at the final follow-up was 24.3 (range 11–45). We observed an inverse relationship between preoperative radiocarpal osteoarthritis severity and clinical outcomes ($p<0.03$), but no link between postoperative osteoarthritis progression and poor outcomes ($p<0.04$). Four patients (12.12%) required reoperation with total wrist arthrodesis. **Conclusions:** Proximal carpectomy demonstrates satisfactory medium-term outcomes for degenerative wrist conditions, offering good range of motion and a low complication rate. However, patients with more severe preoperative joint degeneration may lead to poorer clinical outcomes.

Keywords: Carpectomy; row; resection.
Level of Evidence: IV

Carpectomía de la fila proximal en procesos degenerativos de la muñeca. Nuestra experiencia a mediano plazo

RESUMEN

Objetivo: Evaluar los resultados clínico-radiográficos a mediano plazo del tratamiento de los procesos degenerativos de la muñeca mediante carpectomía proximal. **Materiales y Métodos:** Estudio descriptivo retrospectivo de 33 pacientes operados entre 2009 y 2019 en nuestro Centro. Se evaluaron el rango de movilidad, el dolor con la escala analógica visual y la capacidad funcional con el cuestionario QuickDASH. Se realizaron pruebas de valoración biomecánica. Se estudió la incidencia de complicaciones y de una segunda intervención. Se evaluó la progresión radiográfica de la artrosis y su asociación con los malos resultados clínicos. **Resultados:** El seguimiento medio fue de 10 años. El rango de movilidad medio fue de 77,11º en el arco de flexo-extensión y 36,7º en el radiocubital. El puntaje medio de dolor evolucionó de 7,9 a 2,7 tras la cirugía ($p <0,003$). El puntaje QuickDASH en el último control fue de 24,3. Se halló una asociación inversa entre el grado de artrosis radiocarpiana preoperatoria y el resultado clínico ($p <0,03$); sin embargo, no hubo una relación entre la evolución artrósica radiográfica posoperatoria con la mala evolución ($p <0,04$). Cuatro pacientes necesitaron una segunda intervención mediante artrodesis total de muñeca. **Conclusiones**: La carpectomía proximal es una opción terapéutica que ofrece resultados satisfactorios a mediano plazo en pacientes con procesos degenerativos de la muñeca, proporciona un adecuado rango de movilidad con una baja tasa de complicaciones. El uso de esta técnica en pacientes con degeneración articular de mayor grado antes de la cirugía puede llevar a un peor resultado clínico.

Palabras clave: Carpectomía; hilera; resección.
Nivel de Evidencia: IV

Received on November 2nd, 2023. Accepted after evaluation on May 9th, 2024 • Dr. CLARA MATELLANES PALACIOS • claramatellanes@hotmail.com ID https://orcid.org/0000-0002-8478-2577

How to cite this article: Matellanes Palacios C, Cabanes Ferrer I, Alfonso Porcar M, Gázquez Gázques G, Losar Sogues Colom A, Castillo Ruipérez L, Garrido Ferrer J, Hernández Ferrando L. Proximal Row Carpectomy in Degenerative Wrist Conditions. Our Medium-term Experience. *Rev Asoc Argent Ortop Traumatol* 2024;89(4):341-352. https://doi.org/10.15417/issn.1852-7434.2024.89.4.1843

INTRODUCTION

Radiocarpal osteoarthritis is a leading cause of wrist pain and functional disability. The most common causes of wrist osteoarthritis are the sequelae of fractures and fracture-dislocations of the distal radius and carpus.[1] Other frequent causes include nonunion and flexion instability of the scaphoid, known by the acronyms SNAC (Scaphoid Nonunion Advanced Collapse) and SLAC (ScaphoLunate Advanced Collapse), respectively, as well as necrosis of the lunate, or Kienböck's disease. Symptoms accompanying these degenerative processes include weakness, stiffness, pain, and restricted functional range of the wrist joint. Surgical treatments range from procedures that sacrifice motion, such as wrist arthrodesis, to those that aim to preserve it, such as partial arthrodesis, wrist denervation, and proximal row carpectomy.[2]

The goal of PRC is to achieve symptomatic relief while preserving wrist mobility.[3] It was originally described by Stamm[4] in 1944 for the palliative treatment of wrist osteoarthritis and involves creating a neoarticulation between the radius and the capitate bone that reproduces and preserves range of motion and grip strength while relieving pain.[2]

Good medium and long-term outcomes of proximal row carpectomy have been reported.[2,3] Numerous studies compare these outcomes with those of four-corner arthrodesis, with no clear superiority of one technique over the other.[5-8]

The primary objective of this study was to evaluate the medium-term clinical-functional outcomes of surgical treatment for degenerative wrist conditions using proximal carpectomy. Secondary objectives included analyzing the rate of complications and the need for subsequent total wrist arthrodesis. The study also evaluated the correlation between clinical scales and biomechanical tests that establish functional impairment and assessed whether there is an association between the degree of preoperative radiocarpal arthrosis and functional outcomes, with the aim of improving surgical indications for this procedure.

MATERIALS AND METHODS

A descriptive, retrospective, single-center, hospital-only study was conducted. The study population consisted of 33 consecutive patients who underwent proximal row carpectomy between January 2009 and January 2019 at the Hospital General Universitario de Valencia. All were registered in the surgery database of the Upper Limb Unit. Two patients were excluded from the study: one due to loss to follow-up and the other due to death from causes unrelated to the surgery under study. There is no evidence that the patient excluded due to loss to follow-up experienced complications related to the proximal row carpectomy.

The data were obtained by reviewing clinical records in accordance with the ethical principles of the Declaration of Helsinki and current regulations (Good Clinical Practice Guidelines).

Twenty-seven patients (82%) were men and six (18%) were women. The mean age was 51 years (range 26-71). In 22 patients (67%), the dominant hand was operated on, while in 11 patients (33%), the non-dominant hand was operated on. The etiologies included SNAC grade II (48%), Kienböck stage IIIB disease (24%), SLAC grade II (18%), and conditions such as psoriatic arthritis, rheumatoid arthritis, or chronic perilunate dislocation without degenerative involvement of the lunate fossa of the radius or capitate bone (9%) (Table 1). SLAC/SNAC grades were determined using Watson's classification,9 and Kienböck's disease stage was assigned based on Lichtman's classification, as recommended by De Carli and Zaidenberg, 2020.[10]

Surgical procedure

Preoperative planning was performed using MRI without contrast in most cases (97%) to study the articular cartilage and rule out associated injuries. In one patient, MRI was not possible due to the presence of metallic material, so computed tomography was used to assess the condition of the articular cartilage.

The mean time from surgical indication in outpatient clinics to surgery was 24 months. No new imaging studies were requested during this waiting period.

Table 1. Demographic data of the patients in the series.

Age	Sex	Dominant hand	Occupation	Diagnosis	Follow-up (months)
49	M	Yes	Unemployed	Kienböck* IIIB	55
44	M	No	Manager	Kienböck IIIB	58
61	F	Yes	Pre-retiree	SLAC II	58
51	F	Yes	Stay-at-home wife	SNAC II	79
26	M	Yes	IT specialist	Kienböck IIIB	87
45	M	Yes	Manager	Chronic perilunate dislocation	90
49	M	Yes	IT specialist	SNAC II	90
60	M	No	Painter	SNAC II	93
65	M	Yes	Retiree	SLAC II	94
57	M	No	Cook	Kienböck IIIB	95
48	M	No	Formworker	SNAC II	102
57	M	Yes	Printer	SLAC II	111
41	M	No	Farmer	SNAC II	112
52	M	No	Unemployed	SNAC II	114
53	M	Yes	Sanitary	Kienböck IIIB	115
44	M	No	Forklift	SNAC II	120
54	M	Yes	Warehouse handler	SNAC II	121
58	M	Yes	Banker	SLAC II	121
35	M	Yes	Waiter	Kienböck IIIB	126
53	M	Yes	Cartographer	SLAC II	128
59	M	Yes	Pastry chef	Rheumatism	130
58	M	Yes	Unemployed	SNAC II	138
60	M	Yes	Painter	SNAC II	140
40	M	No	Administrative	SNAC II	143
71	F	No	Retiree	SLAC II	150
44	F	Yes	Administrative	SNAC II	151
34	M	Yes	Engineer	Kienböck IIIB	156
57	M	Yes	Worker	Kienböck IIIB	159
50	M	No	Cook	Psoriatic arthritis	159
49	M	No	Mason	SNAC II	161
55	F	Yes	Nurse	SNAC II	162
52	F	Yes	Cake maker	SNAC II	163
48	M	Yes	Painter	SNAC II	171

*Lichtman classification.
M = male; F = female; SNAC = Scaphoid Nonunion Advanced Collapse; SLAC = ScaphoLunate Advanced Collapse.

Surgical technique

All operations were performed by the same surgical team. A dorsal approach was used, following the surgical and postoperative techniques described by Escribano Rey et al.[11]

Antibiotic prophylaxis was administered with 2 g of cefazolin intravenously, or clindamycin in cases of beta-lactam allergy.

With the use of a pneumatic tourniquet and prior exsanguination of the arm, the surgery began with a dorsal zigzag incision over the wrist, with the proximal end of the incision 1 cm proximal to Lister's tubercle and the distal end at the level of the base of the third metacarpal. An inverted "T" capsulotomy was performed, leaving a 2-3 mm capsular segment for subsequent closure. Total excision of the triquetrum, lunate, and scaphoid bones was performed (Figure 1). If radial styloid impingement was present, a partial styloidectomy was performed in 15% of cases. When a chondral injury was observed on the capitate bone (12% of cases), a capsule interposition was performed, and the joint was closed (Figure 2).

In all surgeries, the posterior interosseous nerve was also resected as an adjunctive measure for postoperative pain management, as we consider it a simple procedure that does not add morbidity to the patient.

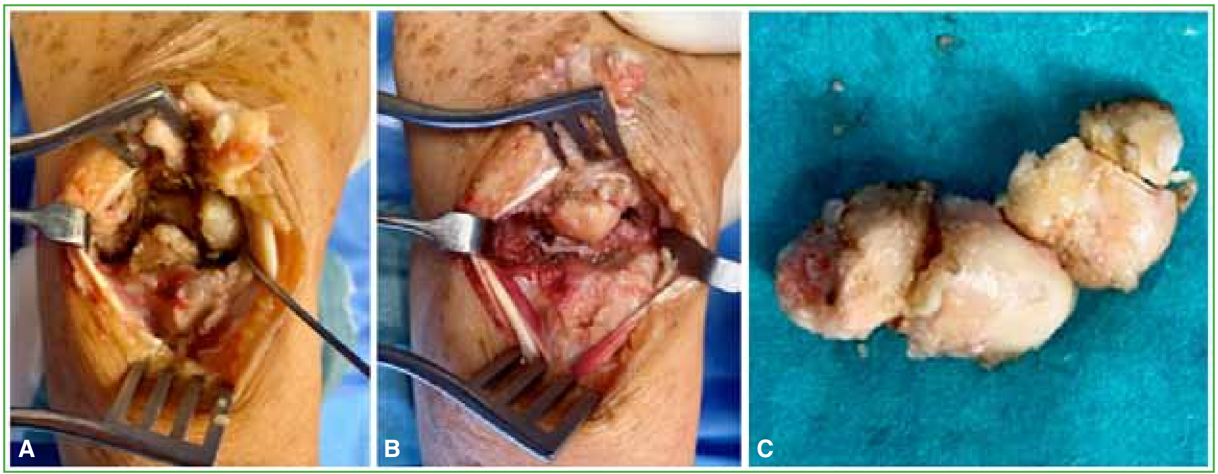


Figure 1. Intraoperative images. Proximal row carpectomy. **A.** Before resection. **B.** After carpectomy. **C.** Carpal bones after resection.

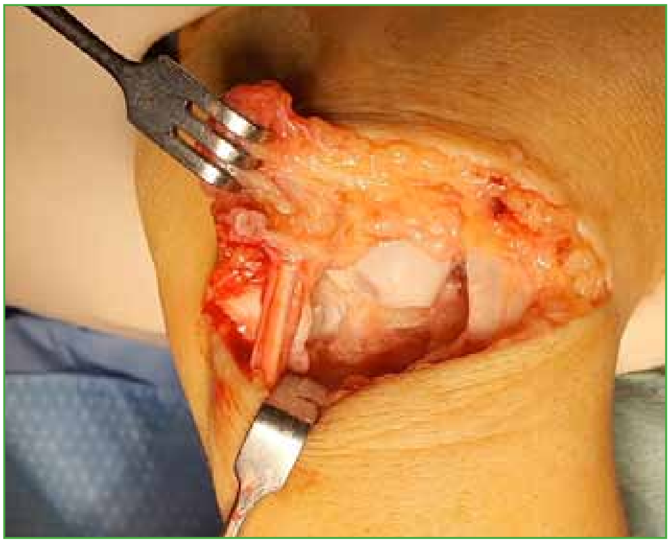


Figure 2. Patient with a small erosion in the cartilage of the capitate bone. A proximal row carpectomy was performed associating an interposition of the joint capsule.

Postoperative evaluation

Patients were evaluated clinically and radiographically at 3, 6, and 12 weeks, at 6 months, and then annually. To determine the degree of postsurgical osteoarthritis in the new joint between the radius and the capitate bone, the Culp-Jebson classification[12] was used based on radiographs. Postoperatively, patients were immobilized with a posterior splint for 3 weeks to ensure proper soft tissue healing and pain control. After this period, they began passive and active joint mobilization progressively and were referred to the Rehabilitation Service.

Pain was assessed using the visual analog scale (VAS), active joint range of motion was measured with a goniometer, and functional capacity was evaluated with the QuickDASH questionnaire.[13] Biomechanical assessment tests were conducted using a system developed by the Biomechanics Institute of Valencia, called NedMano/IBV and NedRangos/IBV,[14] thanks to collaboration with our hospital's Rehabilitation Service. NedMano/IBV is a computer program that assesses maximum strength in grip, distal pinch, and lateral pinch movements (Figure 3), records the data, and compares the results with the contralateral hand, as well as with a database of the Spanish population segmented by age, sex, and dominance. This allows for a comprehensive functional assessment of the hand. NedRangos/IBV assists specialists in assessing joint movement amplitudes, using data obtained from goniometers. The maximum amplitudes of the joints in all planes of anatomical movement are recorded with electronic instrumentation that aids in this process.

The complication rate and the need for a second operation were also studied. Radiographically, the degree of osteoarthritis progression in the new joint between the radius and the capitate bone was evaluated.

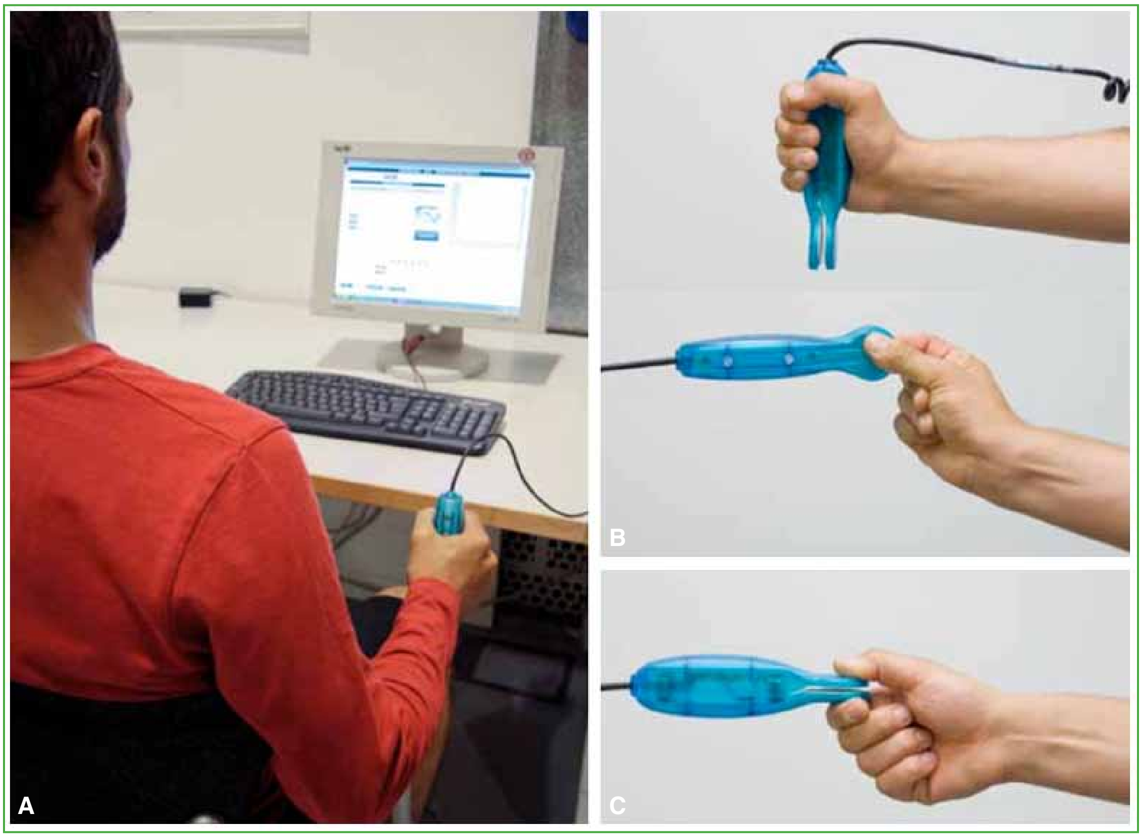


Figure 3. Biomechanical assessment using the NedMano/IBV system during different gestures. **A.** Gripping. **B.** Tip pinch. **C.** Lateral pinch.

Statistical analysis

The data were analyzed using SPSS 22 and XLSTAT statistical software for MAC OS. A descriptive analysis was performed, with quantitative variables expressed as mean and range (e.g., age, results from various classifications such as VAS, QuickDASH questionnaire, follow-up), and qualitative variables as absolute and relative frequencies (e.g., sex, laterality, diagnosis). The normality of quantitative variables was tested using the Kolmogorov-Smirnov test. The cumulative survival function was evaluated with the Kaplan-Meier method. In all statistical analyses, the significance level was set at 5%.

RESULTS

Clinical-functional outcomes

The mean follow-up time was 10 years (range 4.6-14.6 years). The mean preoperative VAS score was 7.9 (range 7-9), which decreased to 2.7 (range 0-7) at the last follow-up ($p<0.003$). In terms of functional outcomes, the mean joint range of motion was 77.11° (range 51°-80°) in the flexion-extension arc and 36.7° (range 29°-42°) in the radioulnar arc. The mean score on the QuickDASH questionnaire was 24.3 (range 11-45) (Table 2).

The complications recorded during surgery included one case of extensor tendon traction injury, which was repaired during the surgery. This required an extended period of immobilization, but the clinical and functional recovery was good by the last follow-up. Postoperative complications included one case of complex regional pain syndrome, which was completely resolved after 10 months of oral medication and intensive rehabilitation, and one case of acute intra-articular infection that required surgical debridement with synovectomy and antibiotic therapy, which also had a good outcome.

Seventy-eight percent of patients reported being satisfied or very satisfied with the surgery (Figure 4).

The need for further intervention with total wrist arthrodesis due to poor clinical outcomes was also assessed. A total of 12.12% (4 cases) required a second operation; these were patients with SNAC/SLAC II and a chondral injury in the capitate bone detected during surgery (Figure 5). The mean time to arthrodesis was 16.5 months (range 10-22 months).

Biomechanical outcomes

Biomechanical assessment tests were conducted using the NedMano/IBV and NedRangos/IBV systems,[14] developed by the Biomechanics Institute of Valencia, in collaboration with our hospital's Rehabilitation Service.

Statistical analysis revealed a statistically significant decrease in grip strength ($p <0.05$) in the operated dominant hands, but not in the non-dominant hands. For both lateral and distal pinch grips, there was a decrease in strength in both dominant and non-dominant hands, although the data were not statistically significant ($p >0.05$). An increase in fatigue was observed in all patients who completed the test, with statistically significant values in the non-dominant hand ($p <0.01$) but not in the dominant hand ($p >0.05$).

Radiographic outcomes

According to the Culp-Jebson classification,[12] 39.4% of the sample remained at stage 0 (no osteoarthritis); 24.24% at stage I (joint space narrowing <50%); 27.27% developed stage II (joint space narrowing >50% plus subchondral bone condensation), and three patients (9.1%) reached stage III (complete loss of joint space). Thus, postoperative degenerative changes between the radius and the capitate bone were detected in the medium term in 60.6% of the sample. However, no poor clinical or functional outcomes were observed in these patients according to the VAS and QuickDASH questionnaire ($p <0.04$), indicating no clinical-radiographic correlation in the medium term.

There was an inverse correlation between the degree of preoperative radiocarpal osteoarthritis and the clinical outcome as measured by the VAS ($p<0.03$). The worst clinical outcomes occurred in patients with a chondral injury in the capitate bone detected during surgery, who later required reoperation with total wrist arthrodesis.

Table 2. Proximal carpectomy outcomes.

n	Postoperative VAS*.	Average joint balance: flexion-extension arc (°)	Average joint balance: radioulnar arc (°)	QuickDASH score	Degree of postoperative osteoarthritis*.
1	2	79	41	27	II
2	3	78	38	25	II
3	4	80	42	11	I
4	3	79	39	16	I
5	2	78	36	16	0
6	2	79	37	20.5	I
7	2	78	38	16	0
8	2	78	35	27	0
9	0	80	40	11	I
10	2	79	39	16	0
11	3	79	38	34	II
12	6	66	30	43	III
13	7	74	31	20.5	I
14	0	80	38	16	0
15	3	78	39	16	0
16	7	75	32	27	I
17	2	78	35	34	0
18	2	80	39	16	0
19	1	79	37	25	0
20	2	78	36	16	I
21	3	76	33	43	II
22	2	78	38	25	0
23	2	80	39	20.5	0
24	3	75	30	43	II
25	1	80	42	34	III
26	4	74	31	43	II
27	2	79	35	16	0
28	2	80	41	16	0
29	2	79	42	27	II
30	2	80	39	11	III
31	0	79	34	29.5	II
32	7	51	29	45	II
33	3	79	38	16	I

*According to the Culp-Jebson classification. VAS = visual analog scale.

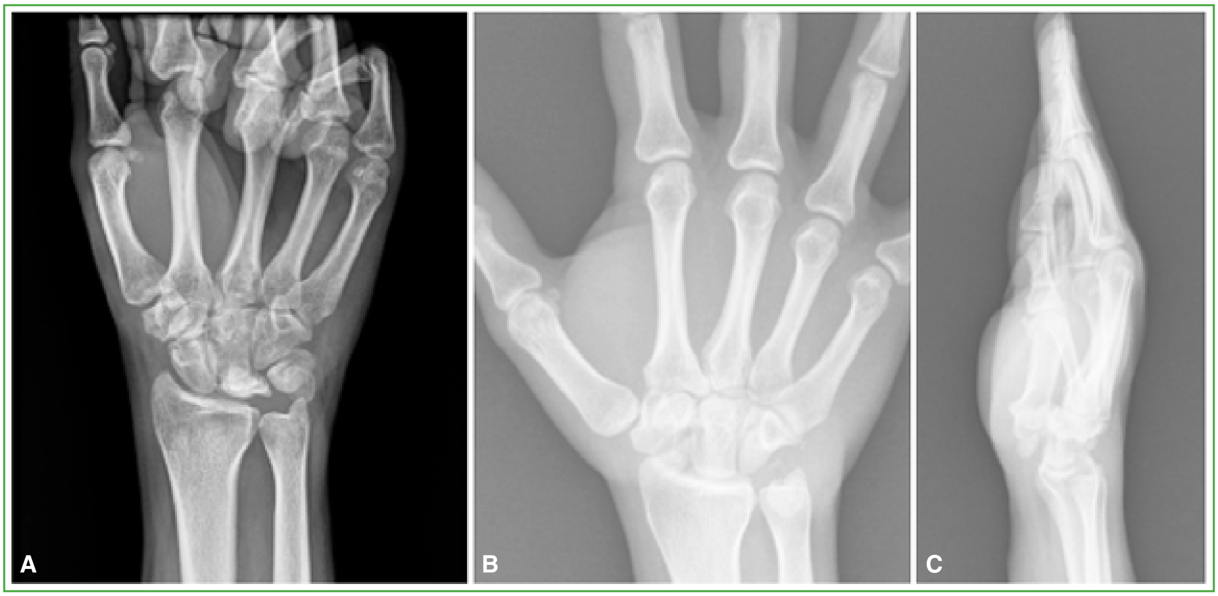


Figure 4. A. 26-year-old patient, manual worker, diagnosed with Kienböck's disease in the right hand. **B.** Anteroposterior radiograph of the right wrist, 7 years after proximal carpectomy. **C.** Lateral radiograph of the right wrist at 7 years of follow-up. Good clinical and radiographic evolution.

Figure 5. A. 57-year-old patient diagnosed with a SLAC wrist in the dominant hand. **B.** Poor clinical and radiographic evolution after proximal row carpectomy, with progression of osteoarthritis between the capitate bone and the radius. **C.** New intervention with total wrist arthrodesis, with good outcomes.

Survival

The Kaplan-Meier curve analysis for reoperation with total wrist arthrodesis due to poor clinical evolution showed a cumulative survival rate of 87.9% at 5 years. All second interventions were performed within the first 2 years of follow-up (Figure 6).

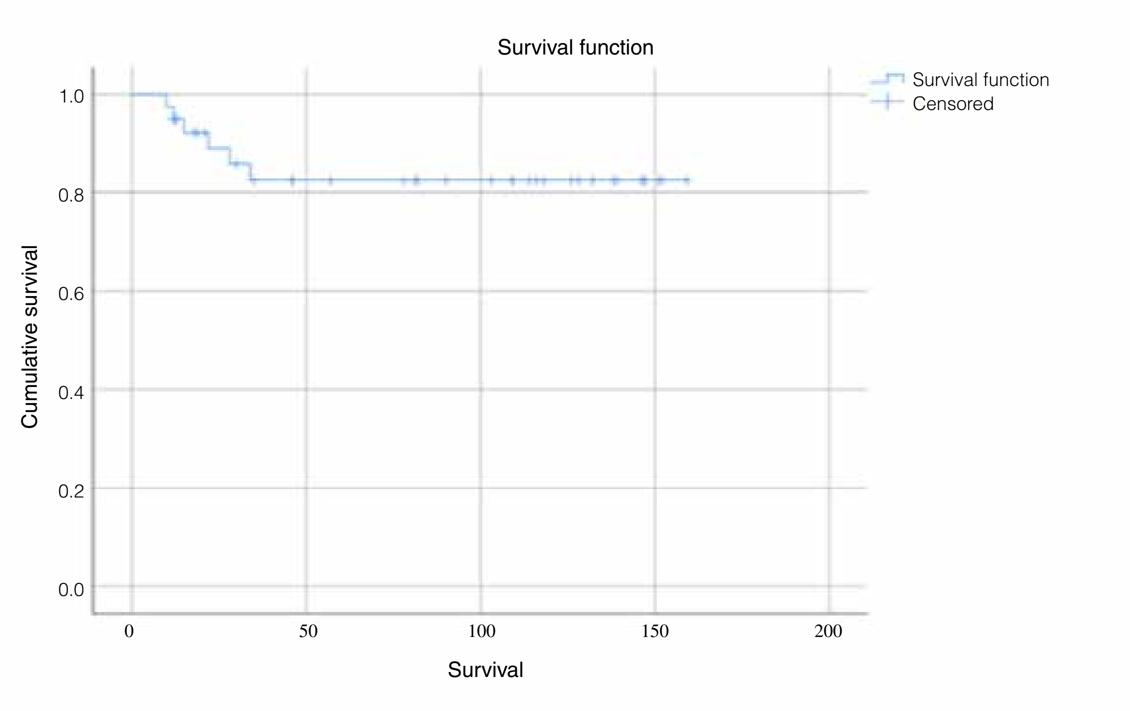


Figure 6. Kaplan-Meier curve for the second operation with total wrist arthrodesis due to progression of osteoarthritis, with poor clinical evolution (Survival expressed in months).

DISCUSSION

Our medium-term clinical-radiographic outcomes of treating degenerative wrist processes with proximal row carpectomy (PRC) show a significant improvement in the VAS pain score, without greatly sacrificing joint range of motion. This procedure also resulted in high patient satisfaction and a reoperation rate of 12.12% for total wrist arthrodesis.

The medium- and long-term results published on PRC confirm that it is a procedure capable of maintaining an adequate range of motion in the radiocarpal joint, with good functional outcomes and high levels of patient satisfaction.[3,12,15] Despite these positive results, a conversion rate to radiocarpal arthrodesis ranging from 4.9% to 15% has been reported.[3,16] Some authors have found that patient satisfaction with PRC is comparable to that of other procedures, such as four-corner fusion with a circular plate or midcarpal arthrodesis.[2,17]

PRC provides significant pain relief. El-Mowafi et al. reported an 80% reduction in pain,[18] which aligns with our findings, where the mean preoperative VAS score of 7.9 decreased to 2.7 at the final postoperative follow-up.

As shown in Table 3, the functional outcomes in our study are consistent with those of other published series involving similar patient samples. [3,12,15,19-22]

A significant number of patients exhibited radiographic signs of progressive degeneration in the space between the radius and the capitate. However, these radiographic changes did not correlate with wrist pain or function. Numerous studies have shown that the osteoarthritic changes in the capitate-radius that develop after PRC do not necessarily cause pain.[3,12,15] Hogan et al.[23] evaluated these radiographic changes and found that, post-surgery, load transmission in the lunate fossa of the radius increased by 37% compared to pre-carpectomy levels. The increased pressure on the radius makes it relatively common for medium-term radiographic osteoarthritis to develop. In our study, 60.6% of patients developed some degree of osteoarthritis in this new joint; however, no association was found between these findings and poor clinical or functional outcomes according to the VAS and QuickDASH questionnaire ($p < 0.04$).

Table 3. Comparison of functional outcomes with those of other published series.

	n	Flexion-extension arc (°)	Radio-ulnar arch (°)
This study	33	77.11	36.7
DiDonna et al. [15]	15	72	40
Renart et al.[19]	12	56.7	32.9
Richou et al.[20]	24	72	45
Ali et al.[21]	61	69.4	30.08
Jebson et al.[12]	20	76	34
Montiel et al.[3]	14	90.08	35
Bijon et al.[22]	24	93	28

A proper indication for PRC requires minimal or no involvement of the articular surfaces that come into contact. Stern et al. state that if the affected cartilage surface is less than 3 mm, the technique can be applied.[24] Several modifications have been proposed to minimize wear and preserve the capitate-radius joint. Rabinovich and Lee describe the use of decellularized dermal allograft to expand the indications for PRC to include selected patients with capitate degeneration.[25] In our series, we performed joint capsule interposition between the new radius joint and the capitate to prevent or slow osteoarthritic degeneration in four patients who had a chondral injury in the capitate bone detected during surgery.

In our sample, 12.12% of patients required another intervention—a total wrist arthrodesis due to poor clinical evolution—consistent with figures published in other studies, which report a conversion rate to radiocarpal arthrodesis between 4.9% and 15%.[3,7,16] These cases involved injuries diagnosed as SNAC/SLAC II, where a chondral injury in the capitate bone was detected during surgery. This suggests that using PRC in patients with more advanced joint degeneration before surgery may lead to poorer outcomes. We also believe that the long delay from diagnosis and patient inclusion on the surgical waiting list to the day of surgery (a mean of 2 years) may have contributed to the intraoperative finding of chondral injuries in the capitate boneAs described in numerous studies, posterior interosseous nerve denervation is used as an adjunctive procedure for postoperative pain management and does not alter outcomes, as it is a partial denervation that can spontaneously reinnervate. Moreover, denervation as an isolated technique has a failure rate of 25% within the first year after surgery.[26] In our cases, the posterior interosseous nerve was denervated in all operations as an adjunct to postoperative pain management, without any related complications.

A 2020 systematic review and meta-analysis by Amer et al. demonstrated that, in comparative studies, PRC was statistically superior to four-corner fusion for treating SLAC, with increased range of motion, grip strength, and decreased pain, although the differences were minimal.[6] Rahgozar et al. found that conversion rates to total wrist arthrodesis were significantly higher with partial arthrodesis (19.2%) than with PRC (4.9%), and that partial arthrodesis had higher associated direct costs.[7] However, other authors argue that patients undergoing PRC present more osteoarthritic changes in the long term compared to those with four-corner fusion, which has a 10% higher complication rate due to non-consolidation of the arthrodesis, dorsal impingement, and issues related to the osteosynthesis material.[5]

A 2022 meta-analysis was the first to include medium- and long-term studies comparing PRC and four-corner fusion.[8] In an analysis of 1,059 wrists, the main finding was that PRC is generally superior, achieving better range of motion and a lower complication rate. The authors reported no difference in grip strength or conversion rates to total wrist arthrodesis.

Perhaps future studies that evaluate patients with longer follow-up may affirm the superiority of one of these techniques over the other.

Future studies with longer follow-up periods may eventually affirm the superiority of one of these techniques over the other. We believe that further research, including the application of new and promising biological therapies for articular cartilage regeneration, may help improve the treatment of these conditions.

This study has several limitations, including those inherent in retrospective analyses, a heterogeneous cohort with a wide range of ages and mechanisms of injury, and the challenge of accurately assessing the progression of degenerative changes between the radius and capitate bone after surgery. Postoperative CT scans, while informative, would involve additional radiation exposure and economic costs, and are therefore not routinely performed at our hospital.

CONCLUSIONS

We consider proximal row carpectomy to be a therapeutic option that provides satisfactory medium-term results in treating degenerative wrist processes, as it achieves adequate radiocarpal joint range of motion with a low complication rate. However, using this technique in patients with a higher degree of joint degeneration before surgery may result in worse outcomes.

Conflict of interest: The authors declare no conflicts of interest.

I. Cabanes Ferrer ORCID ID: https://orcid.org/0000-0003-0479-8024
M. Alfonso Porcar ORCID ID: https://orcid.org/0009-0001-5527-4629
G. Gázquez Gázquez ORCID ID: https://orcid.org/0000-0003-1038-1356
A. Losar Sogues Colom ORCID ID: https://orcid.org/0000-0002-8527-6043
L. Castillo Ruipérez ORCID ID: https://orcid.org/0000-0002-5091-3014
J. Garrido Ferrer ORCID ID: https://orcid.org/0000-0002-7581-2404
L. Hernández Ferrando ORCID ID: https://orcid.org/0000-0003-0276-9369

REFERENCES

1. Sociedad Española de Cirugía Ortopédica y Traumatología (SECOT). *Manual de cirugía ortopédica y traumatología.* 2nd ed. Madrid: Panamericana; 2010, pp. 978-85.
2. Uceda Carrascosa P, Izquierdo Fernández A, Múñoz Reyes F, Carpintero R, Peces Gonjar D, Serrano Lázaro P, et al. Carpectomía proximal en osteoartritis de muñeca. *Rev Soc Andal Traumatol Ortop* 2011;28(2):100-9. Available at: https://www.portalsato.es/documentos/revista/Revista11-2/Rev.%202011-2-03.pdf
3. Montiel V, Payo-Ollero J, Amillo S. Resección de la primera fila del carpo en pacientes mayores de 50 años: 3 a 16 años de seguimiento. *Rev Esp Cir Ortop Traumatol* 2019;63(4):295-9. https://doi.org/10.1016/j.recot.2019.02.001
4. Stamm TT. Excision of the proximal row of the carpus. *Proc R Soc Med* 1944;38(2):74-5. PMID: 19992990
5. Berkhout MJL, Bachour Y, Zheng KH, Mullender MG, Strackee SD, Ritt MJPF. Four-corner arthrodesis versus proximal row carpectomy: A retrospective study with a mean follow-up of 17 years. *J Hand Surg Am* 2015;40(7):1349-54. https://doi.org/10.1016/j.jhsa.2014.12.035
6. Amer KM, Thomson JE, Vosbikian MM, Ahmed I. Four-corner arthrodesis versus proximal row carpectomy for scapholunate advanced collapse: A systematic literature review and meta-analysis. *Ann Plast Surg* 2020;85(6):699-703. https://doi.org/10.1097/SAP.0000000000002398
7. Rahgozar P, Zhong L, Chung KC. A comparative analysis of resource utilization between proximal row carpectomy and partial wrist fusion: A population study. *J Hand Surg Am* 2017;42(10):773-80. https://doi.org/10.1016/j.jhsa.2017.07.032
8. Chammas PE, Hadouiri N, Chammas M, Ramos-Pascual S, Stirling P, Nover L, et al. Proximal row carpectomy generates better mid- to long-term outcomes than four-corner arthrodesis for post-traumatic wrist arthritis: A meta-analysis. *Orthop Traumatol Surg Res* 2022;108(7):103373. https://doi.org/10.1016/j.otsr.2022.103373
9. Watson HK, Ballet FL. The SLAC wrist: scapholunate advanced collapse pattern of degenerative arthritis. *J Hand Surg Am* 1984;9(3):358-65. https://doi.org/10.1016/s0363-5023(84)80223-3
10. De Carli P, Zaidenberg E. Enfermedad de Kienböck: conceptos actuales. *Rev Asoc Argent Ortop Traumatol* 2020;85(Supl.):S26-S35. https://doi.org/10.15417/issn.1852-7434.2020.85.4S.1170

11. Escribano Rey R, Flórez Alvarez F, Duart J, Amillo S. Resección de la primera fila del carpo: indicaciones y resultados. *Rev Esp Cir Osteoartic* 2008;43(234):60-4. Available at: http://www.cirugia-osteoarticular.org/adaptingsystem/intercambio/revistas/articulos/35_05_reseccion%20primera%20fila.pdf
12. Jebson PJL, Hayes EP, Engber WD. Proximal row carpectomy: a minimum 10-year follow-up study. *J Hand Surg Am* 2003;28(4):561-9. https://doi.org/10.1016/s0363-5023(03)00248-x
13. Hudak PL, Amadio PC, Bombardier C, Beaton D, Cole D, Davis A, et al. Development of an upper extremity outcome measure: The DASH (disabilities of the arm, shoulder, and head). *Am J Ind Med* 1996;29(6):602-8. https://doi.org/10.1002/(SICI)1097-0274(199606)29:6<602::AID-AJIM4>3.0.CO;2-L.
14. Montero Vilela J, Baydal Bertomeu JM, Garrido Jaen JD, Bermejo Bosch I, Page Del Pozo AF, Porcar Seder RM, et al. Objetivamos los gestos característicos de la mano. *Revista de Biomecánica* 2012;(58):47-0. Available at: https://m.riunet.upv.es/bitstream/handle/10251/38483/MONTERO%3BBaydal%3BGarrido%20-%20Objetivamos%20los%20gestos%20caracter%C3%ADsticos%20de%20la%20mano.pdf?sequence=1&isAllowed=y
15. DiDonna ML, Kiefhaber TR, Stern PJ. Proximal row carpectomy: study with a minimum of ten years of follow-up. *J Bone Joint Surg Am* 2004;86(11):2359-65. PMID: 15523004
16. Green DP, Perreira AC, Longhofer LK. Proximal row carpectomy. *J Hand Surg Am* 2015;40(8):1672-6. https://doi.org/10.1016/j.jhsa.2015.04.033
17. França Bisneto EN, Freitas MC, Paula EJL de, Mattar Jr R, Zumiotti AV. Comparison between proximal row carpectomy and four-corner fusion for treating osteoarthrosis following carpal trauma: a prospective randomized study. *Clinics (Sao Paulo)* 2011;66(1):51-5. https://doi.org/10.1590/s1807-59322011000100010.13
18. El-Mowafi H, El-Hadidi M, El-Karef E. Proximal row carpectomy: a motion-preserving procedure in the treatment of advanced Kienbock's disease. *Acta Orthop Belg* 2006;72(5):530-4. PMID: 17152414
19. Renart IP, Gómez CL, Pujals JI, Rodríguez JDC. Resección de la primera fila del carpo (Carpectomía proximal). *Revista Iberoamericana de Cirugía de la Mano* 2005;33(67):22-30. https://doi.org/10.1055/s-0037-1606674
20. Richou J, Chuinard C, Moineau G, Hanouz N, Hu W, Le Nen D. Proximal row carpectomy: Long-term results. *Chir Main* 2010;29(1):10-5. https://doi.org/10.1016/j.main.2009.10.003
21. Ali MH, Rizzo M, Shin AY, Moran SL. Long-term outcomes of proximal row carpectomy: a minimum of 15-year follow-up. *Hand (N Y)* 2012;7(1):72-8. https://doi.org/10.1007/s11552-011-9368-y
22. Bijon C, Saab M, Amouyel T, Sturbois-Nachef N, Guerre E, Chantelot C. Long-term radiological changes and functional outcomes after proximal row carpectomy: Retrospective study with 3 years' minimum follow-up. *Orthop Traumatol Surg Res* 2020;106(8):1589-95. https://doi.org/10.1016/j.otsr.2020.03.038
23. Hogan CJ, McKay PL, Degnan GG. Changes in radiocarpal loading characteristics after proximal row carpectomy. *J Hand Surg Am* 2004;29(6):1109-13. https://doi.org/10.1016/j.jhsa.2004.07.006
24. Stern PJ, Agabegi SS, Kiefhaber TR, DiDonna ML. Proximal row carpectomy. *J Bone Joint Surg Am* 2005;87 Suppl 1(Pt 2):166-74. https://doi.org/10.2106/JBJS.E.00261
25. Rabinovich RV, Lee SJ. Proximal row carpectomy using decellularized dermal allograft. *J Hand Surg Am* 2018;43(4):392.e1-392.e9. https://doi.org/10.1016/j.jhsa.2018.01.012
26. Ishida O, Tsai TM, Atasoy E. Long-term results of denervation of the wrist joint for chronic wrist pain. *J Hand Surg Br* 1993;18(1):76-80. https://doi.org/10.1016/0266-7681(93)90202-q

Complications in Total Hip Arthroplasties After Acetabulum Fractures: A Comparative Study of Conventional Cups Versus Dual Mobility Cups

Franco Tantera
Traumatology Service, Hospital Municipal de Urgencias, Córdoba, Argentina.

ABSTRACT

Introduction: Degenerative hip disease can develop after an acetabulum fracture. Total Hip Arthroplasty (THA) is a common salvage procedure that generally yields good outcomes but is not without technical difficulties and complications. **Objective:** To analyze the clinical and radiological outcomes and short- and medium-term complications of THA by comparing uncemented, dual-mobility acetabular cups with conventional uncemented cups. **Materials and Methods:** We retrospectively evaluated 37 patients who underwent THA between 2003 and 2022. Clinical and functional outcomes were assessed using the Merle d'Aubigné and Postel scale, while radiographic outcomes were evaluated according to the modified Stauffer criteria and the stability of cementless components based on Engh parameters. **Results:** The final sample included 37 patients (11 women and 26 men) with an average age of 43.78 years. The average follow-up time was 6.6 years. Outcomes were excellent in 54% of cases, good in 32.4%, fair in 8.1%, and poor in 5.5%. Fisher's exact test showed no significant correlation between the type of cup used and the risk of complications. **Conclusions:** Total hip arthroplasty using dual-mobility cups is a highly effective treatment option for the sequelae of acetabular fractures, offering excellent outcomes and a very low complication rate.

Keywords: Acetabulum fractures; dual mobility; total hip replacement; dislocation; revision of total hip arthroplasty; instability.
Level of Evidence: IV

Complicaciones en las artroplastias totales de cadera después de fracturas de acetábulo. Estudio comparativo entre cotilos convencionales y de doble movilidad

RESUMEN

Introducción: La enfermedad degenerativa de la cadera puede desarrollarse después de una fractura de acetábulo. La artroplastia total de cadera es un procedimiento de salvataje muy utilizado que logra buenos resultados, pero que no está libre de dificultades técnicas y complicaciones. **Objetivos:** Analizar los resultados clínicos y radiográficos de la artroplastia total de cadera y sus complicaciones a corto y mediano plazo, comparando componentes acetabulares de doble movilidad no cementados y cotilos convencionales no cementados. **Materiales y Métodos:** Se evaluó retrospectivamente a 37 pacientes sometidos a una artroplastia total de cadera entre 2003 y 2022. Se analizaron los resultados clínicos y funcionales según la escala de Merle D´Aubigné; los resultados radiográficos, según los criterios modificados de Stauffer; y la estabilidad de los componentes no cementados mediante los parámetros de Engh. **Resultados:** La muestra estaba compuesta por 37 pacientes (11 mujeres y 26 hombres), con una media de edad de 43.78 años. El tiempo promedio de seguimiento fue de 6.6 años. Los resultados fueron excelentes (54%), buenos (32,4%), regulares (8,1%) y malos (5,5%). Mediante la prueba exacta de Fisher, se comparó entre el tipo de cotilo empleado y el riesgo de complicaciones, y no se encontró una correlación significativa. **Conclusiones:** La artroplastia total de cadera con cotilos de doble movilidad es una opción muy válida para tratar las secuelas de fracturas acetabulares, logra excelentes resultados y la tasa de complicaciones es muy baja.

Palabras clave: Fracturas de acetábulo; doble movilidad; reemplazo total de cadera; luxación; revisión de artroplastia total de cadera; inestabilidad.
Nivel de Evidencia: IV

Received on September 9th, 2023. Accepted after evaluation on May 30th, 2024 • Dr. FRANCO TANTERA • ftantera@gmail.com https://orcid.org/0000-0002-5995-7611

How to cite this article: Tantera F. Complications in Total Hip Arthroplasties After Acetabulum Fractures: A Comparative Study of Conventional Cups Versus Dual Mobility Cups. *Rev Asoc Argent Ortop Traumatol* 2024;89(4):353-364. https://doi.org/10.15417/issn.1852-7434.2024.89.4.1820

INTRODUCTION

Degenerative hip disease, also known as secondary hip osteoarthritis, may develop after a fracture of the acetabulum due to joint incongruity or the severity of the initial injury. Its incidence ranges from 12% to 57%.[1]

Osteonecrosis of the femoral head is another possible complication of fractures and fracture-dislocations of the acetabulum, occurring with a frequency of 2% to 40%. [2]

When post-traumatic osteoarthritis develops, total hip arthroplasty (THA) is a common and effective salvage procedure, although it is not without challenges and complications. Patients who present with post-traumatic osteoarthritis tend to do so at an earlier age compared to those with primary hip osteoarthritis, yet they exhibit similar symptoms: limited joint range of motion, pain, and functional limitations.

Open reduction and internal fixation of a displaced acetabular fracture may reduce the risk of post-traumatic osteoarthritis. This approach can also optimize acetabular bone stock and minimize pelvic deformity, which could be advantageous if a THA is needed later. However, a history of acetabular osteosynthesis may present technical challenges during joint replacement surgery, as the patient may present with scar tissue, heterotopic ossifications, osteosynthesis material, pseudarthrosis of acetabular fracture lines, cavitary or segmental bone defects, and even hidden infection. Therefore, preoperative planning is crucial to prevent major complications, reduce surgical time, and optimize outcomes.

In selected cases where a displaced acetabular fracture has a low likelihood of a favorable long-term outcome after osteosynthesis, THA during the acute stage may provide an alternative means of achieving a painless, mobile hip.[4,5] Indications for THA within 30 days of fracture (acute stage) include patients over 60 years old, posterior wall comminution or impaction, dome impaction (gull sign),[6] severe osteopenia, severe osteochondral injury to the femoral head, and associated femoral neck fracture. This approach is based on evidence that the short-term conversion rate to THA for acetabular fractures in older adults treated with open reduction and internal fixation is 22% to 54%.[7,8]

Unfortunately, most published studies are short or medium-term and report significant failure rates and many technical problems related to surgery and previous trauma.[9-11] One of the persistent challenges of THA after acetabular fracture is prosthetic dislocation, which is one of the most frequent complications after mechanical aseptic loosening and infection.[12-15] Moreover, patients in this group tend to be younger and more physically active, often seeking to return to the same sports and work activities as before the accident.

OBJECTIVES

The purpose of this study was to analyze the clinical and radiographic outcomes of total hip arthroplasty (THA) performed after the development of post-traumatic osteoarthritis following an acetabular fracture, as well as its short- and medium-term complications. The study compared the outcomes between uncemented dual-mobility acetabular components and conventional uncemented cups.

MATERIALS AND METHODS

We retrospectively evaluated 49 patients, including their medical records and radiographic files, who had undergone THA as treatment for post-traumatic osteoarthritis following an acetabular fracture, as well as acute-stage THA in selected cases, between 2003 and 2022 (Figures 1 and 2).

The inclusion criteria were as follows: 1) patients admitted to the Hospital Municipal de Urgencias or Clínica Privada Vélez Sarsfield in Córdoba, with an initial diagnosis of acetabular fracture, who underwent THA as definitive treatment with a follow-up of no less than six months; 2) age >15 years; 3) regular attendance at follow-up appointments; and 4) availability of clinical records and complementary studies for clinical and radiographic evaluation.

The exclusion criteria were: 1) pathological fractures; 2) previous rheumatic diseases affecting the joint; and 3) loss to follow-up or death due to other causes.

After applying these criteria, 37 patients were selected.

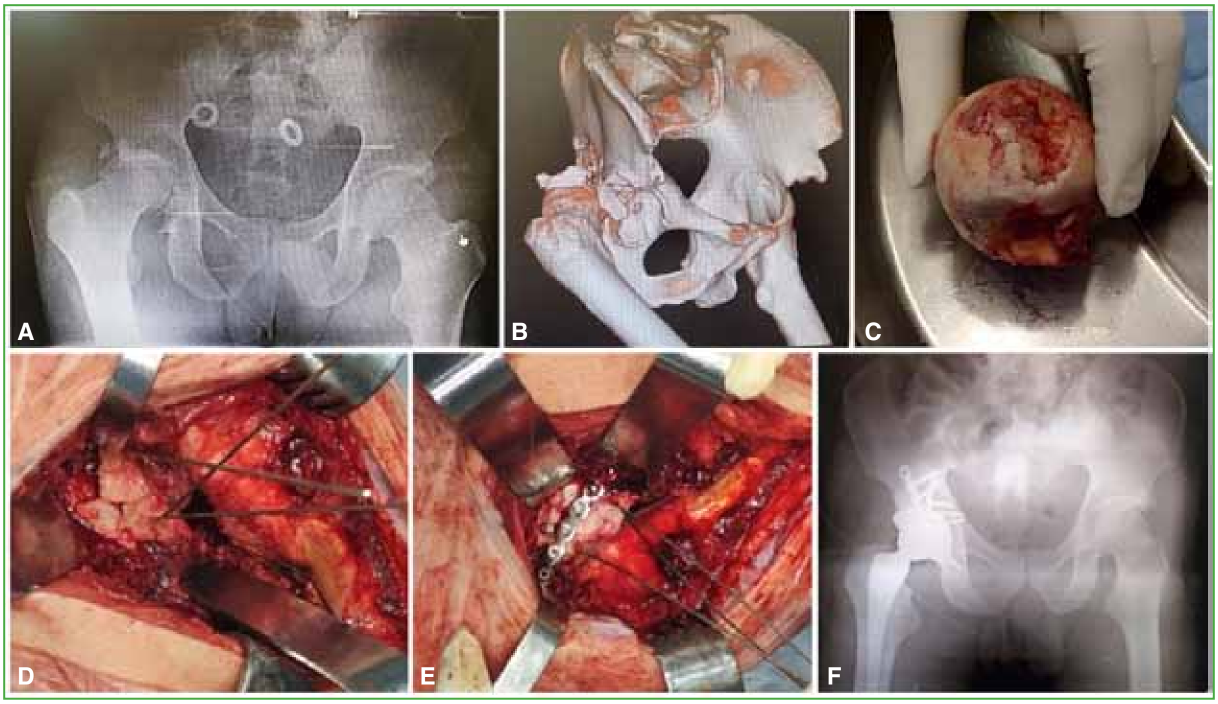


Figure 1. 59-year-old man with acetabular fracture-dislocation due to a traffic accident, with more than 30 days of evolution. **A.** Anteroposterior radiograph of the pelvis. **B.** Tomography with 3D reconstruction showing a fracture-dislocation of the posterior wall and column. **C.** Image showing a severe osteochondral lesion of the femoral head. Osteosynthesis plus total hip arthroplasty is indicated in one stage. **D and E.** Intraoperative images: wall reduction and provisional posterior column fixation with a 3.5 mm reconstruction plate. F. Postoperative anteroposterior pelvis radiograph showing cementless total hip arthroplasty. Excellent outcomes were achieved by the end of the study.

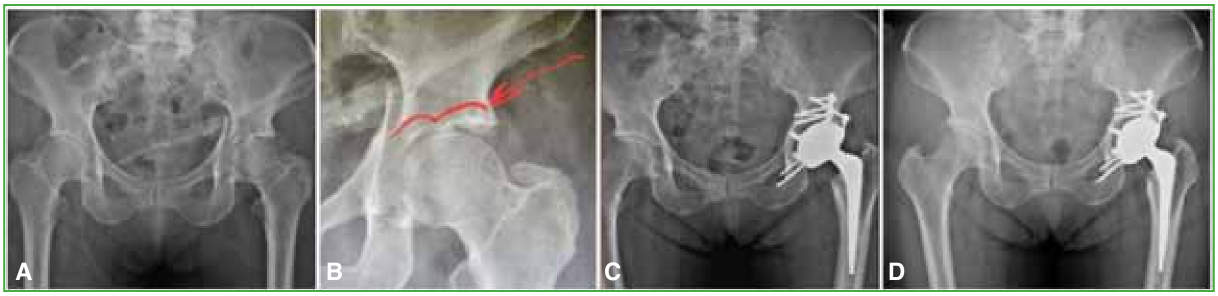


Figure 2. 75-year-old woman with a transverse and posterior wall fracture of the left acetabulum. **A.** Anteroposterior radiograph of the pelvis. **B.** Magnified radiograph showing the "gull sign" due to impaction of the acetabulum bearing zone. **C.** Anteroposterior radiograph of the pelvis in the immediate postoperative period, with osteosynthesis of the posterior wall and column and hybrid total hip arthroplasty with a dual-mobility cup. **D.** Anteroposterior radiograph of the pelvis 3 years after surgery, showing very good clinical and radiographic evolution.

The outcomes were classified as excellent, good, fair, or poor according to the Merle D'Aubigné functional evaluation scale, which is based on three parameters: pain, range of motion, and gait (Table 1). The final score was the sum of the values obtained for each parameter (Table 2).

Table 1. Merle D'Aubigné functional assessment scale.

Score	Pain	Range of motion	Gait
6	None	90° flexion	Normal
5	Mild	70°-90° flexion	Slight limp after long distances
4	After 30 minutes of walking	50°-70° flexion	Limp after long distances, may require cane or crutches
3	Moderate	30°-50° flexion	Significant limp, requires cane
2	Severe	<30° flexion	Very limited
1	Very severe	Very restricted	Bedridden

Table 2. Merle D'Aubigné total score scale.

Total sum	Scoring
17-18	Excellent
15-16	Good
13-14	Fair
<13	Poor

The collected data were evaluated by comparing conventional uncemented cups with uncemented dual-mobility cups.

As a working hypothesis, we aimed to determine whether the use of dual-mobility cups was statistically significant in reducing the risk of complications such as loosening or prosthetic dislocation. To assess this, we used the chi-squared method with Yates correction, and the results were further compared using Fisher's test.

Preoperative planning

Preoperative evaluation and planning was conducted on anteroposterior radiographs of the pelvis in the Judet views (inlet and outlet) and CT scans. Acetabular fractures were classified according to the Judet and Letournel classification, while residual acetabular defects were categorized using the *American Academy of Orthopaedic Surgeons* (AAOS) scale, which divides them into five types: type I, segmental defects; type II, cavitary defects; type III, combined defects; type IV, pelvic discontinuity; and type V, hip arthrodesis.

The surgical approach most commonly used for THA was the posterolateral approach over the previous scar (Kocher-Langenbeck). In cases without a previous wound, the Gibson posterolateral approach was performed. Trochanteric osteotomy was not performed in any case. Femoral stems were selected based on bone quality or density and the type of femoral canal according to the Dorr classification. The selection of acetabular components depended on the presence of previous defects or a history of acetabular fracture-dislocations, with dual-mobility cups indicated in such cases. Osteosynthesis material was removed, partially or totally, only if it interfered with acetabular reaming (Figure 3). For the treatment of acetabular bone defects, iliac crest bone graft or autologous bone graft from the femoral head was used (Figure 4). Neither cadaveric nor lyophilized donor grafts were used in any case. To restore the anatomy of the acetabular labrum, structural grafts were used for segmental defects, while 4 x 4 mm cancellous bone chips (impregnated with 1 g of vancomycin) were used for cavitary defects. Autologous structural grafts were provisionally fixed with 1.8 mm diameter pins, and once the optimal position was achieved, definitive osteosynthesis was performed with AO reconstruction plates and 3.5 mm cortical screws. No acrylic bone cement (polymethylmethacrylate) or bone substitute was used as a filler for bone defects.

Figure 3. 24-year-old male, referred from another province, with failed osteosynthesis and hip dislocation. Removal of the osteosynthesis and an uncemented total hip arthroplasty with a dual-mobility cup (due to severe osteochondral joint injury) are planned. **A.** Anteroposterior radiograph of the pelvis. **B.** Anteroposterior radiograph of the pelvis after hip reduction, awaiting arthroplasty. **C.** Postoperative anteroposterior radiograph of the pelvis showing very good clinical evolution.

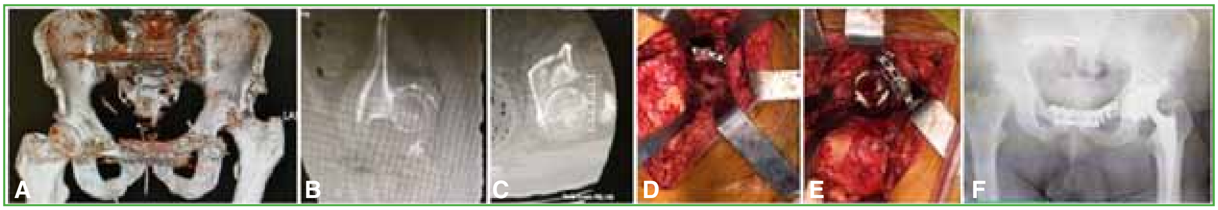


Figure 4. 54-year-old man with a chronic fracture-dislocation of more than 12 months' duration, due to cardiovascular contraindications and a history of pelvis osteosynthesis with a dislocated left hip. **A.** 3D tomography of the pelvis. **B and C.** Computed tomography scans, selected slices, showing chronic left hip dislocation. **D.** Femoral head autograft plus osteosynthesis with a 3.5 mm plate. **E.** Dual-mobility cementless acetabular component implant with ischial, ilial, and pubic anchors. **F.** Postoperative anteroposterior pelvis radiograph of hybrid total hip arthroplasty, showing excellent clinical and radiographic evolution.

In selected cases, THA was indicated within 30 days of the accident (acute stage) based on criteria predicting poor prognosis for acetabular fractures: patients >60 years old, comminution or impaction of the posterior wall, dome impaction, advanced age, severe osteopenia, femoral head impaction, and fractures of the femoral neck and head.

Treatment and postoperative evaluation

Twenty-four hours after surgery, all patients began a plan of passive and active assisted hip movements. Antibiotic prophylaxis was continued with 1 g of cephalothin for 48 hours. Patients who did not require bone grafting were permitted immediate full weight-bearing, while those with structural grafting were instructed to begin partial weight-bearing at 30 days and full weight-bearing at 45 to 60 days. No indomethacin prophylaxis or radiotherapy was administered to reduce the incidence of heterotopic ossifications. Anteroposterior and axial radiographs of the hip were taken at 1, 3, and 6 months after THA, and then annually. Probable or definitive loosening of cemented femoral stems was assessed on radiographs using the modified Stauffer criteria. The stability of uncemented components was evaluated according to Engh criteria. Femoral stems were assessed based on Gruen zones.[18]

Statistical analysis

Categorical variables are expressed as percentages and the number of patients observed. Continuous variables are presented as mean and standard deviation, providing measures of central tendency and data dispersion. Table 3 summarizes the different statistical tests and values of the comparisons performed. Fisher's exact test was used to evaluate whether there was an association between the type of cup used and the risk of complications.

Table 3. Results of statistical tests.

Variable	Comparison	Statistical test	p	Significant (p <0.05)
Age	Study patients' gender	Mann-Whitney U	0.64	No
Merle D'Aubigné's score	Types of cups used	Mann-Whitney U	0.38	No
Complications	Risks and complications with the prosthesis type	Fisher's Exact	0.25	No

RESULTS

Out of the 49 patients evaluated, 12 were excluded due to loss to follow-up, including three who died of causes unrelated to the condition under study. Therefore, the final sample included 37 patients (11 women and 26 men). All cases were unilateral. The mean age was 43.78 years (range 23-75) (Figure 5).

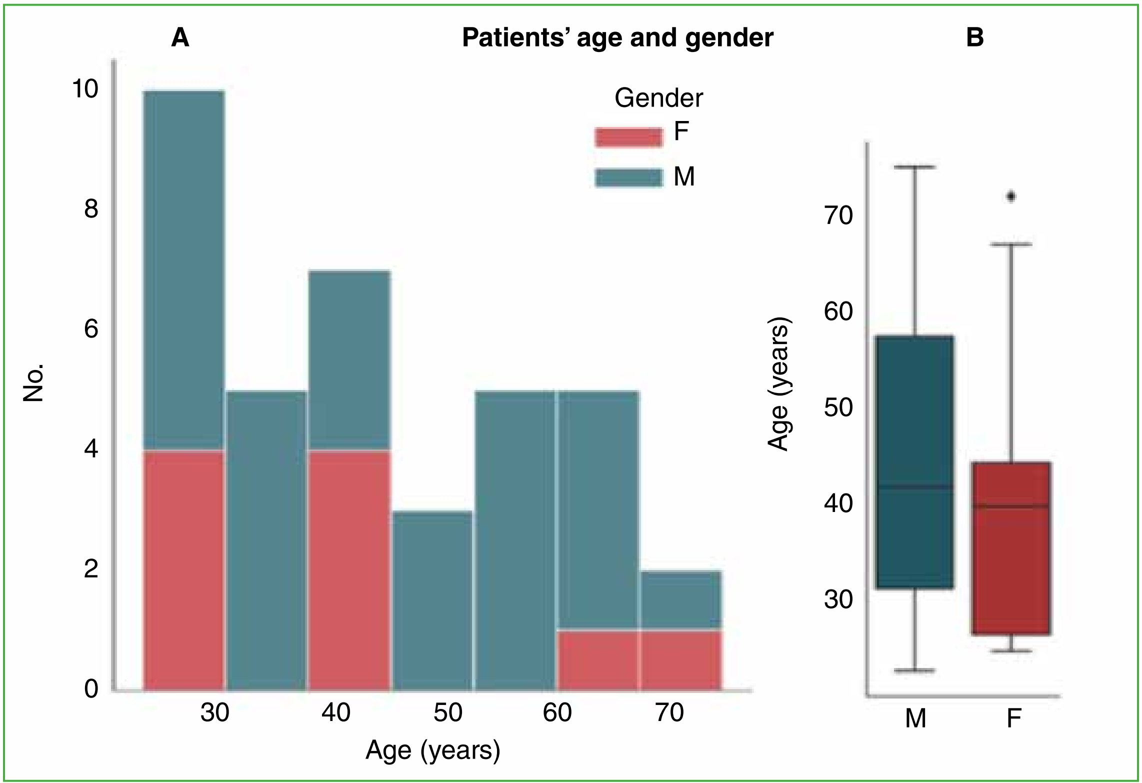


Figure 5. Age and gender of the patients included in the study. **A.** Age distribution. **B.** Percentage according to gender.

The mean follow-up time after THA was 6.6 years (min. 6 months; max. 16 years).

Cemented stems were used in 32.4% of the patients, primarily in those with Dorr C femur, generally due to osteopenia resulting from post-fracture dysfunction of the acetabulum. Cementless stems were used in 67.6% of the cases, with excellent outcomes and no loosening observed by the end of the study (Figure 6).

As for the acetabular component, the fixation system was always cementless. Jumbo cups were not used. In 14 patients, cementless dual-mobility cups were implanted, which were coated in hydroxyapatite of French origin, with additional anchorages to ilium, ischium and pubis with corresponding liners and a captive cobalt-chromium head of 28 mm diameter. One patient (case 48) received a custom-made, porous, uncemented cup of national origin, into which a dual-mobility cup was cemented, with good clinical outcomes to date. In the rest of the sample (23 cases), conventional uncemented cups were used (from the Mercosur and imported) with porous titanium coating and additional fixation with 1 to 3 screws of 6.5 mm diameter, as needed (Figure 6). Of these, 18 hips were fitted with 28 mm diameter heads, and five with 32 mm diameter heads. This variation depended on the provision by the Ministry of Health, as most patients were public hospital patients without insurance.

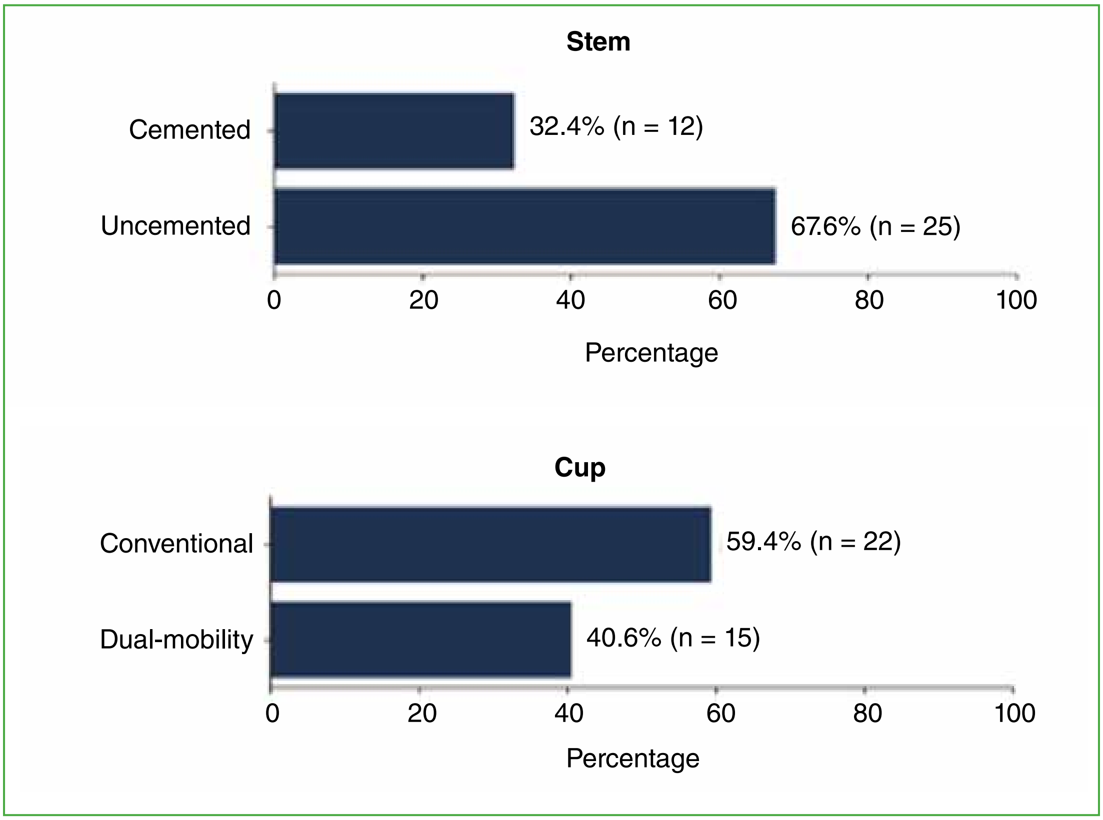


Figure 6. Proportion of stem and cup types used in hip arthroplasty surgeries.

During THA, some technical difficulties arose related to the approach for acetabular fracture fixation in hips that had been previously operated on, due to the existing scar, some asymptomatic heterotopic calcifications (Brooker grade I), and the presence of osteosynthesis materials. In only four cases was it necessary to remove the osteosynthesis material; in two of these, only the screws that interfered with acetabular reaming were removed. After dislocation of the hip and osteotomy of the femoral neck, acetabular defects were re-evaluated and classified under direct vision. The resulting acetabular defects, according to the AAOS scale, are shown in Figure 7. In three cases, the initial treatment of the fracture was conservative due to economic problems, and the condition progressed to early post-traumatic osteoarthritis. In five cases, THA was the initial treatment. Two of these patients were lost to follow-up and excluded from the study. The remaining three patients (cases 7, 40, and 49) had good outcomes until the end of the study. In four other cases (with AAOS type III defects), acetabular reconstruction with structural and ground bone autograft, osteosynthesis with a 3.5 mm plate and screws, and THA was performed, all with excellent outcomes by the end of the study. The mean time between the accident causing the acetabular fracture and THA was 26.9 months (range 1-144). The most frequent types of fractures that progressed to post-traumatic osteoarthritis were: posterior wall with posterior hip dislocation (43%), spine and posterior wall (16.2%), transverse plus posterior wall (16.2%), and isolated transverse (8.1%). In the latter, rapid erosion of the femoral head occurred due to joint incongruity (Figure 8).

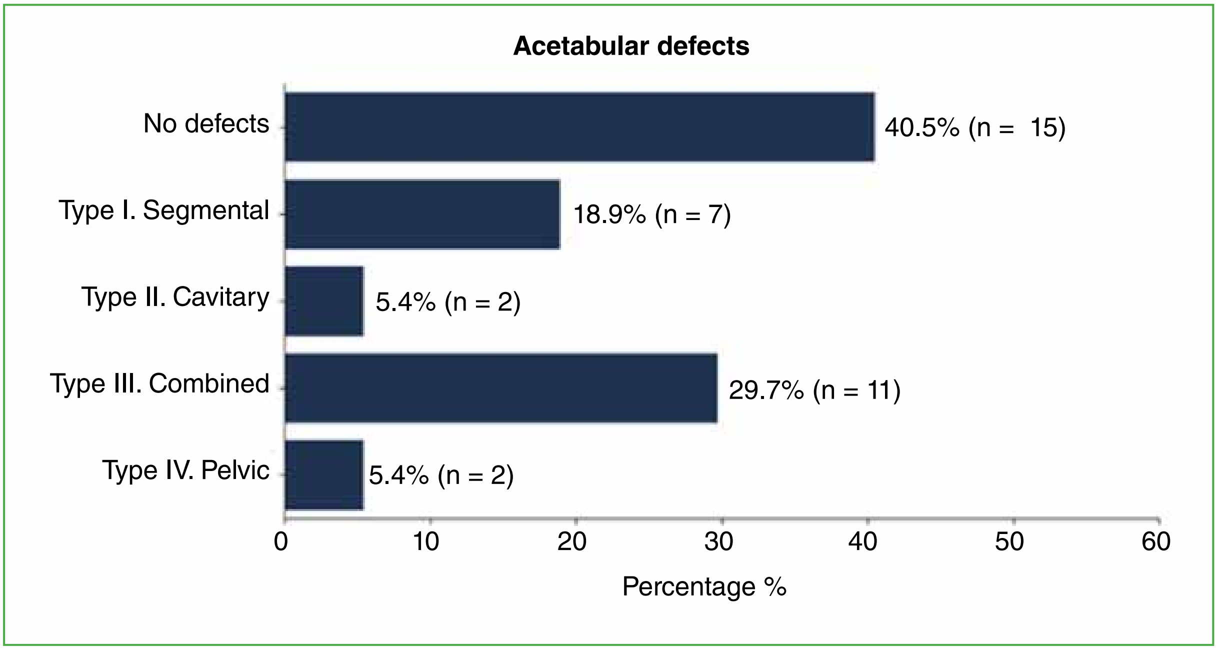


Figure 7. Percentage and number of patients according to the different types of acetabular defects according to the AAOS scale.

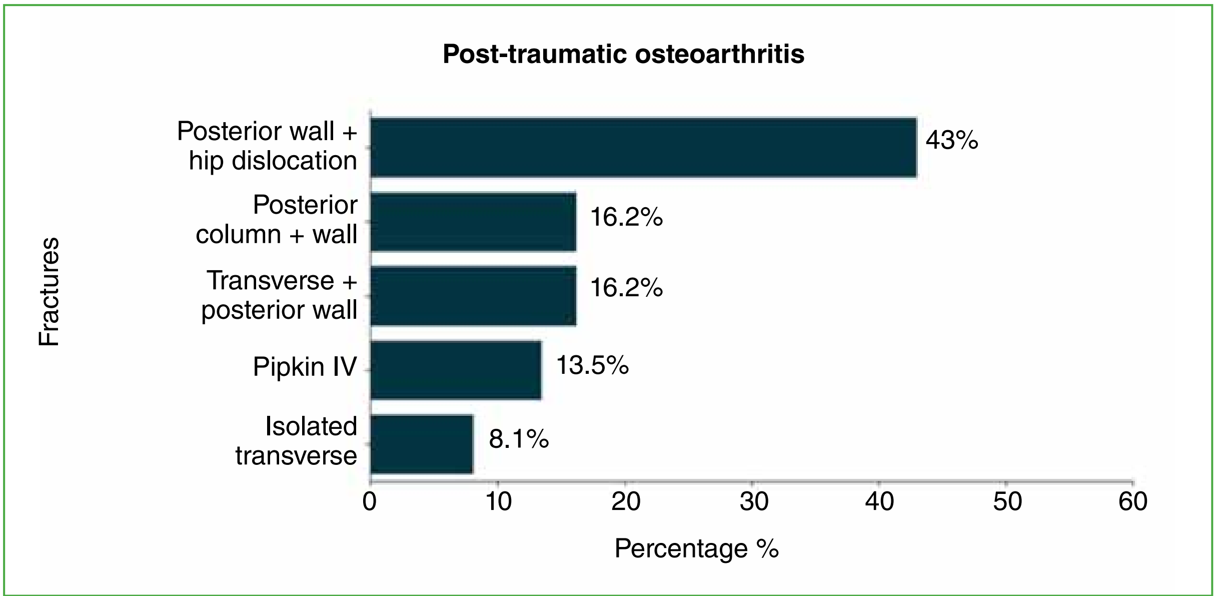


Figure 8. Percentage of the different types of fractures in patients who developed post-traumatic osteoarthritis.

In addition, there were five cases of femoral head and acetabulum fractures classified as Pipkin type IV (13.5%), one of which was excluded due to loss to follow-up. The remaining four cases rapidly progressed to necrosis and post-traumatic osteoarthritis due to the severity of the initial osteochondral lesion. Three patients received conventional cementless prostheses, and one received a cementless dual-mobility cup. All had good to excellent functional and radiographic outcomes by the end of the evaluation.

Clinical and radiographic findings

According to the Merle D'Aubigné scale, the outcomes were classified as excellent (54%), good (32.4%), and fair (8.1%). Of these, Case 3 underwent revision at 6 years due to septic loosening, and Case 10 (with cementless THA) experienced two episodes of posterior prosthetic dislocation, which were resolved with closed reduction, and has not had any new episodes. In 5.5% of the cases, the results were fair or poor. One of these patients is awaiting revision due to acetabular loosening (conventional cementless) and resorption of the structural bone graft. By the end of the study, there had been no septic or aseptic loosening of any of the implanted dual-mobility components, nor were there significant signs of acetabular radiolucency. In Case 45, a possible proximal debonding of an uncemented hydroxyapatite-coated stem was noted in Gruen zones 1 and 7. In one of the mirror-polished Charnley cemented stems (Case 3), femoral hypertrophy was detected around the tip of the stem (Gruen zones 3, 4, and 5), indicating load concentration.

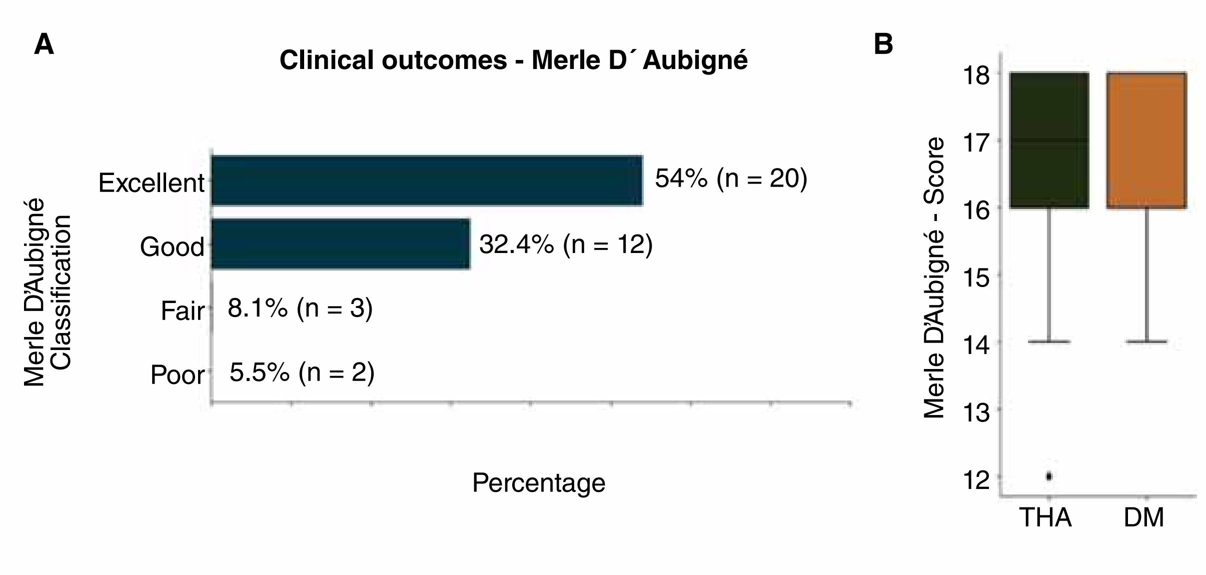


Figure 9. A. Percentage and number of patients classified according to the Merle D'Aubigné scale. **B.** Box plot of the scores obtained according to this same scale, for conventional cups (total hip arthroplasty, THA) and dual-mobility (DM) cups.

The dislocation rate in THAs with conventional cups was 8.1% (Cases 2, 10, and 13), all of which involved a previous Kocher-Langenbeck posterior approach and 28 mm diameter heads. In contrast, there were no prosthetic or intraprosthetic dislocations with dual-mobility cups.

No significant correlation was found between the type of cup used (conventional vs. dual-mobility) and the risk of complications (p = 0.25).

DISCUSSION

The main complication of THA following acetabular fractures is prosthetic dislocation, which prompted this study. Matta and Ferguson[1] reported a dislocation rate of 8% with conventional cups in 57 patients. In this series, the rate was the same, but it was possible to reduce it to zero with the use of dual-mobility cups.

Like other authors,[19,20] it was confirmed that THA after acetabular fracture is more difficult than routine primary arthroplasty due to previous scarring, heterotopic ossifications, remaining osteosynthesis material, and residual acetabular defects. Additionally, acetabular reconstruction was more challenging and technically laborious in patients who had not undergone prior surgery (open reduction and acetabular internal fixation). Some of these conservatively treated cases had severe medial defects with intrapelvic protrusion, complicating the procedure.

Several authors have reported that aseptic loosening is more frequent in patients with type III acetabular deficiencies (AAOS classification).[21] According to several studies, better outcomes are obtained with uncemented acetabular components compared to cemented cups if acetabular deficiencies are present. In this series, the short- and medium-term results with biologically fixed acetabular components were very good. This was likely because the acetabular components were implanted with a bone remnant of at least 60% of the patient's own bone. Additionally, structural grafts demonstrated excellent osseointegration, mainly due to the initial stability provided by the corresponding osteosynthesis.Patients who progressed more rapidly to post-traumatic osteoarthritis or avascular necrosis and required immediate THA were those who sustained fractures of the posterior wall or column with joint impaction, associated with chondral lesions from dislocation at the time of the initial trauma. The average time elapsed between the accident causing the acetabular fracture and THA was 26.9 months. Several publications[22,23] note that patients over 60 years old with acetabular fractures treated with reduction and internal fixation have a conversion rate to THA exceeding 30%. In Kreder et al.'s study,[24] 54% of 128 patients with a history of posterior acetabular wall fracture underwent THA within less than two years. In another study of 46 cases, O'Toole et al. reported a 34% conversion rate. These data suggest a favorable balance toward THA in the acute stage when making decisions for older patients. According to various French authors, after 15 years of follow-up with new technologies applied to dual-mobility cups, the survival rate improved from 81.4% to 96.3%, and the dislocation rate improved from 0% to 1%. The intraprosthetic dislocation rate ranged from 0% to 5.2%. Causes of cup failure included aseptic loosening (1.8-3.4%), excessive wear of the polyethylene insert (1-2%), and screw fracture (1%). Guyen et al.,[25] Leclercq et al.,[26] and Vielpeau et al.,[27] in published series of 167, 200 and 231 patients with primary THAs using current dual-mobility designs, with a follow-up time of 3-6 years, reported a dislocation rate of 0%.

CONCLUSIONS

Based on the above, THA with dual-mobility cups is a highly effective option for treating acetabular fracture sequelae, yielding excellent clinical and radiographic outcomes with a very low complication rate. However, conventional cementless cups with 32 or 36 mm diameter prosthetic femoral heads remain the gold standard. In selected cases with combined acetabular defects, porous titanium 3D custom cups should be considered, as they are cost-effective and have thus far shown promising results. Although no statistically significant correlation was found between the type of cup used (conventional vs. dual-mobility) and the risk of complications, and no prosthetic dislocations were observed with dual-mobility cups, it is important to continue with long-term follow-up, include more cases, and obtain more reliable results.

Conflict of interest: The author declares no conflicts of interest.

REFERENCES

1. Matta JM, Ferguson T. Total hip replacement after acetabular fracture. *Orthopaedics* 2005;28:959-62. https://doi.org/10.3928/0147-7447-20050901-23
2. Lugones MA, Díaz Gallardo P, Bidolegui F, Vindver G, Allende BL. Artroplastia total de cadera con copa no cementada en secuela de fractura de acetábulo. *Rev Asoc Argent Ortop Traumatol* 2012;77(3):185-91. https://doi.org/10.15417/128
3. Brooker AF, Bowerman JW, Robinson RA, Riley LH. Ectopic ossification following total hip replacement. Incidence and method of classification. *J Bone Joint Surg* 1973;55:1629. PMID: 4217797
4. Larson C. Fracture dislocation of the hip. *Clin Orthop Relat Res* 1973;92:147-54. https://doi.org/10.1097/00003086-197305000-00013
5. Mears DC, Velyvis JH. Acute total hip arthroplasty for selected displaced acetabular fractures. Two to twelve-year results. *J Bone Joint Surg Am* 2002;84:1-9. https://doi.org/10.2106/00004623-200201000-00001
6. Anglen JO, Burd TA, Hendricks KJ, Harrison P. The "gull sign". A harbinger of failure for internal fixation of geriatric acetabular fractures. *J Orthop Trauma* 2003;17(9):625-34. https://doi.org/10.1097/00005131-200310000-00005
7. O'Toole RV, Hui E, Chandra A, Nascone JW. How often does open reduction and internal fixation of geriatric acetabular fractures lead to hip arthroplasty? *J Orthop Trauma* 2014;28(3):148-53. https://doi.org/10.1097/bot.0b013e31829c739a
8. Daurka JS, Pastides PS, Lewis A, Rickman M, Bircher MD. Acetabular fractures in patients aged >55 years: a systematic review of the literature. *Bone Joint J* 2014;96-B(2):157-63. https://doi.org/10.1302/0301-620x.96b2.32979
9. Sermon A, Broos P, Vanderschot P. Total hip replacement for acetabular fractures. Results in 121 patients operated between 1983 and 2003. *Injury* 2008;39(8):91421. https://doi.org/10.1016/j.injury.2007.12.004
10. Ranawat A, Zelken J, Helfet D, Buly R. Total hip arthroplasty for posttraumatic arthritis after acetabular fracture. *J Arthroplasty* 2009;24(5):759-67. https://doi.org/10.1016/j.arth.2008.04.004
11. Romness DW, Lewallen DG. Total hip arthroplasty after fracture of the acetabulum. Long-term results. *J Bone Joint Surg Br* 1990;72(5):761-4. https://doi.org/10.1302/0301-620x.72b5.2211750
12. Lachiewicz PF, Watters TS. The use of dual-mobility components in total hip arthroplasty. *J Am Acad Orthop Surg* 2012;20:481-6. https://doi.org/10.5435/jaaos-20-08-481
13. Schairer WW, Sing DC, Vail TP, Bozic KJ. Causes and frequency of unplanned hospital readmission after total hip arthroplasty. *Clin Orthop Relat Res* 2014;472:464-70. https://doi.org/10.1007/s11999-013-3121-5
14. Combes A, Migaud H, Girard J, Duhamel A, Fessy MH. Low rate of dislocation of dual-mobility cups in primary total hip arthroplasty. *Clin Orthop Relat Res* 2013;471:3891-900. https://doi.org/10.1007/s11999-013-2929-3
15. Philippot R, Farizon F, Camilleri JP, Boyer B, Derhi G, Bonnan J, et al. Survival of cementless dual mobility socket with a mean 17 years follow-up. *Rev Chir Orthop Reparatrice Appar Mot* 2008;94:e23-e27. https://doi.org/10.1016/j.rco.2007.10.013
16. Stauffer RN. Ten-year follow-up study of total hip replacement. With particular reference to roentgenographic loosening of the components. *J Bone Joint Surg Am* 1982;64:983-90. PMID: 7118986
17. Engh CA, Bobyn JD, Glassman AH. Porous-coated hip replacement. The factors governing bone ingrowth, stress shielding, and clinical results. *J Bone Joint Surg Br* 1987;69(1):45-55. https://doi.org/10.1302/0301-620x.69b1.3818732
18. Gruen TA, McNeice GM, Amstutz HC. "Modes of failure" of cemented stem-type femoral components: a radiographic analysis of loosening. *Clin Orthop Relat Res* 1979;141:17. PMID: 477100
19. Giannoudis PV, Grotz MRW, Papakostidis C, Dinopoulos H. Operative treatment of displaced fractures of the acetabulum. A meta-analysis. *J Bone Joint Surg Br* 2005;87(1):2-9. PMID: 15686228
20. Judet R, Judet J, Letournel E. Fractures of the acetabulum: classification and surgical approaches for open reduction. Preliminary report. *J Bone Joint Surg Am* 1964;46:1615-46. PMID: 14239854
21. Pritchett JW, Bortel DT. Total hip replacement after central fracture dislocation of the acetabulum. *Orthop Rev* 1991;20:607-10. PMID: 1945506
22. Waddell JP, Morton J. Total hip arthroplasty following acetabular fracture. Annual Meeting of the Orthopaedic Trauma Association, Los Angeles, California, Sept. 23, 1994.
23. Weber M, Berry DJ, Harmsen SH. Total hip arthroplasty after operative treatment of an acetabular fracture. *J Bone Joint Surg* 1998;80(9):1295-305. https://doi.org/10.2106/00004623-199809000-00008

24. Kreder HJ, Rozen N, Borkhoff CM, Laflamme YG, McKee MD, Schemitsch EH, et al. Determinants of functional outcome after simple and complex acetabular fractures involving the posterior wall. *J Bone Joint Surg Br* 2006;88(6):776-82. https://doi.org/10.1302/0301-620x.88b6.17342
25. Guyen O, Chen QS, Bejui-Hugues J, Berry DJ, An KN. Unconstrained tripolar hip implants: effect on hip stability. *Clin Orthop Relat Res* 2007;455:202-8. https://doi.org/10.1097/01.blo.0000238796.59596.1f
26. Leclercq S, Benoit JY, de Rosa JP, Euvrard P, Leteurtre C, Girardin P. Results of the Evora dual-mobility socket after a minimum follow-up of five years. *Rev Chir Orthop Reparatrice Appar Mot* 2008;94(8):e17-e22. https://doi.org/10.1016/j.rco.2007.10.015
27. Vielpeau C, Lebel B, Ardouin L, Burdin G, Lautridou C. The dual mobility socket concept: experience with 668 cases. *Int Orthop* 2011;35(2):225-30. https://doi.org/10.1007/s00264-010-1156-8

Description of Proximal Femoral Growth in Pediatric Patients Without Hip Disorders Using Tomography

Rodrigo Huertas Tafur,* Antonio J. Solano Noguera, María Fernanda García Rueda,# Helmuth R. Rashid Forero,** Martha L. Caicedo Gutiérrez#**

*School of Medicine, Universidad Nacional de Colombia, Bogota, Colombia.
**School of Medicine, Universidad del Rosario, Bogota D.C., Colombia.
#Department of Orthopedics and Traumatology, Roosevelt Institute, Bogota, Colombia.

ABSTRACT

Introduction: This study aims to perform a descriptive analysis of proximal femoral growth in a Latin-American population through femoral offset, neck-shaft angle, femoral neck length, and femoral head diameter evaluated through computed tomography in pediatric patients without hip pathology. **Materials and Methods:** Retrospective study evaluating CT images of the hips of healthy patients under 18 years. The following measurements were taken by a trained orthopedist: femoral offset, femoral neck length, femoral head diameter, and neck-shaft angle. **Results:** Femoral offset increases by 1.96 mm until age 12.5. From 12.5 to 16 years of age, it increases by 1.2 mm. A constant rise in the growth of the femoral neck length was found. The neck-shaft angle presented a progressive decrease until age 12. After that point, the curve flattened. An increase in femoral head diameter of 1.56 mm per year was observed until age 13 and then 0.62 mm per year. **Conclusions:** The measurements evaluated in this study are essential for the diagnosis, follow-up, and treatment approach in hip pathologies during growth. More extensive research is needed to define normal ranges that will serve as a baseline for anatomy restoration in hip joint preservation surgery.

Keywords: Femoral head; femoral neck; human development.
Level of Evidence: IV

Descripción del crecimiento del fémur proximal mediante tomografía en pacientes pediátricos sin enfermedad de cadera

RESUMEN

Objetivo: Describir el crecimiento femoral proximal en una población latinoamericana a través del desplazamiento femoral, el ángulo cervico-diafisario, la longitud del cuello femoral y el diámetro de la cabeza femoral evaluados con tomografía computarizada en pacientes pediátricos sin enfermedad de cadera. **Materiales y Métodos:** Estudio retrospectivo que evaluó imágenes de tomografía computarizada de caderas de pacientes sanos <18 años. Se tomaron las siguientes medidas: desplazamiento femoral, longitud del cuello femoral, diámetro de la cabeza femoral y ángulo cervico-diafisario. **Resultados:** El desplazamiento femoral aumenta 1,96 mm hasta los 12.5 años, y desde los 12.5 hasta los 16 años, aumenta 1,2 mm. Se constató un aumento lineal del crecimiento de la longitud del cuello femoral. El ángulo cervico-diafisario disminuyó progresivamente hasta los 12 años. A partir de ese momento, la curva se aplanó. Se observó un aumento anual del diámetro de la cabeza femoral de 1,56 mm hasta los 13 años y de 0,62 mm anuales, en adelante. **Conclusiones:** Las medidas descritas en este estudio son esenciales para el seguimiento, el diagnóstico o el abordaje conductual en múltiples cuadros articulares de cadera durante el crecimiento. Se expone la necesidad de realizar estudios más amplios para establecer rangos de normalidad en la población local con las herramientas tecnológicas disponibles, que fundamenten una referencia para la restauración de la anatomía en la cirugía de preservación.

Palabras clave: Cabeza femoral; cuello femoral; desarrollo humano.
Nivel de Evidencia: IV

Received on August 28th, 2023. Accepted after evaluation on July 4th, 2024 • Dr. RODRIGO HUERTAS TAFUR • rhuertast@unal.edu.co https://orcid.org/0000-0003-3056-3296

How to cite this article: Huertas Tafur R, Solano Noguera AJ, García Rueda MF, Rashid Forero HR, Caicedo Gutiérrez ML. Description of Proximal Femoral Growth in Pediatric Patients Without Hip Disorders Using Tomography. *Rev Asoc Argent Ortop Traumatol* 2024;89(4):365-373. https://doi.org/10.15417/issn.1852-7434.2024.89.4.1816

INTRODUCTION

The biomechanics of the hip are sensitive to the relationship between the elements of the Pauwels scale. During growth, maintaining the correct proportions of femoral neck length, femoral neck angulation, and the pelvic-trochanteric index is essential for achieving a limp-free gait in patients with stable, reduced hips. In skeletally mature individuals, the normal values for femoral offset, cervico-diaphyseal angle, and pelvic-trochanteric index are well-defined.[1] Although these relationships are valuable for planning proximal femoral osteotomies in the pediatric population, they have often been neglected due to the emphasis on improving femoral-acetabular congruence, ensuring sufficient femoral head coverage, and maintaining mobility through osteotomies that restore anatomy and joint relationships.[2]

As part of the development of femoral joint preservation surgery, which aims to maintain functionality and delay the onset of osteoarthritis in adulthood, several metrics have been described for the acetabulum and proximal femur. However, most of these metrics do not consider the restitution of the lever arms and soft tissue tension that ensure the stability of the hip joint, sometimes leading to changes in the length of the lower extremities. [2,3,5,6]

The averages and dispersion in joint relationship values during skeletal maturation, based on measurements obtained using the biplanar radiography method developed by EOS imaging™[7], have been published in a European population, where the median height and weight are higher than those in Latin America. In the absence of EOS imaging™[7] in Colombia, it is necessary to study age-adjusted normal values in the local population using available diagnostic imaging techniques.

This study describes the progression of proximal femur growth in a healthy pediatric population using computed tomography (CT) from 6 months to 17 years of age at Roosevelt Children's Orthopedic Institute in Bogota, Colombia.

MATERIALS AND METHODS

A retrospective study was conducted using hip CT scans obtained between 2014 and 2021 from Latin American patients under 18 years of age, with no history of surgery or neuromuscular, metabolic, or genetic disease. Images of healthy hips were obtained from patients with suspected infectious disease or avascular necrosis in the hip contralateral to the one used in this study. All images that met the inclusion criteria were included.

Demographic and clinical variables, such as sex, age, femoral offset, cervico-diaphyseal angle, femoral neck length, and femoral head diameter, were collected from the clinical records and the institution's image archive. All information was stored in REDCap®. Since CT does not allow direct evaluation of the cartilaginous component, measurements were taken using the technique described by Amador et al.,[9] which predicts the location of the femoral head center and its diameter without the use of MRI or ultrasound, ensuring accuracy and reproducibility.

In patients over 4 years old, femoral offset was measured as the orthogonal distance between the geometric center of the femoral head and the axis of the proximal femoral diaphysis (Figure 1).

In patients aged 4 years or younger, the method described by Amador et al. was used to locate the center of the femoral head. A secant line was drawn connecting the most distal points of the medial and lateral metaphyseal curvatures, and a perpendicular line was drawn from the center of this secant. The center of the femoral head is the point on this perpendicular line located at the distance from the metaphysis described by Amador et al., according to age.[9] The cervico-diaphyseal angle is the angle between the femoral neck axis and the femoral diaphyseal axis in all cases (Figure 2).[10]

The length of the neck corresponds to the distance from the center of the proximal femoral physis along the axis of the femoral neck to the axis of the diaphysis (Figure 3).

To calculate the diameter of the femoral head in children over 4 years old, the longest line within the circumference of the head that passes through the center was measured (Figure 4). In patients aged 4 years or younger, the diameter of the complete circumference was measured using the reference points described by Amador et al.[9]

Measurements were taken by an orthopedist trained in these techniques, following the specifications mentioned above. All measurements were conducted on the coronal slice of the CT scan, where the sphericity of the femoral head and the fovea capitis could be best appreciated.

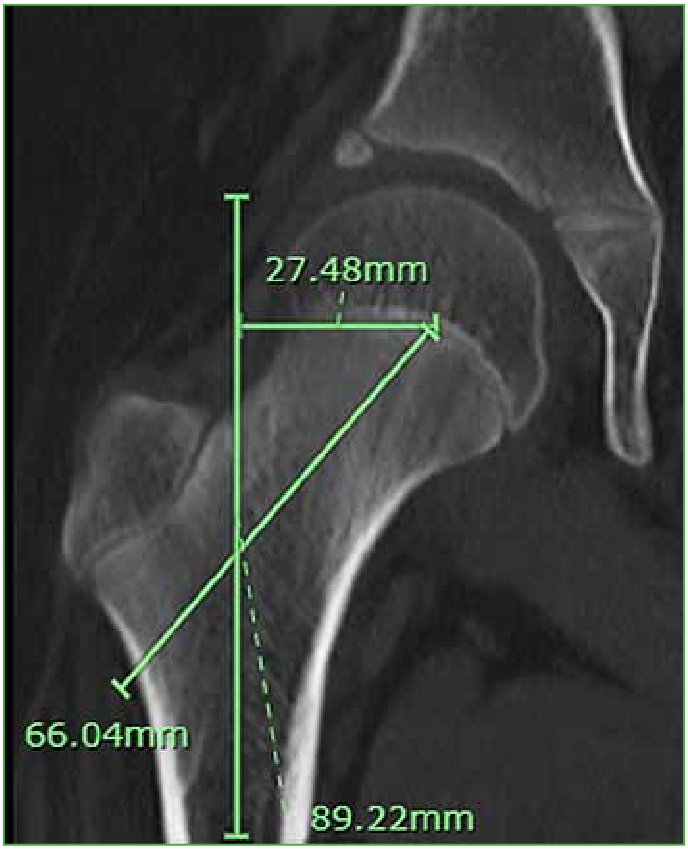


Figure 1. Lateral femoral offset. Distance from the center of rotation of the femoral head to the diaphyseal anatomical axis of the femur. In this case, it is 27.48 mm.

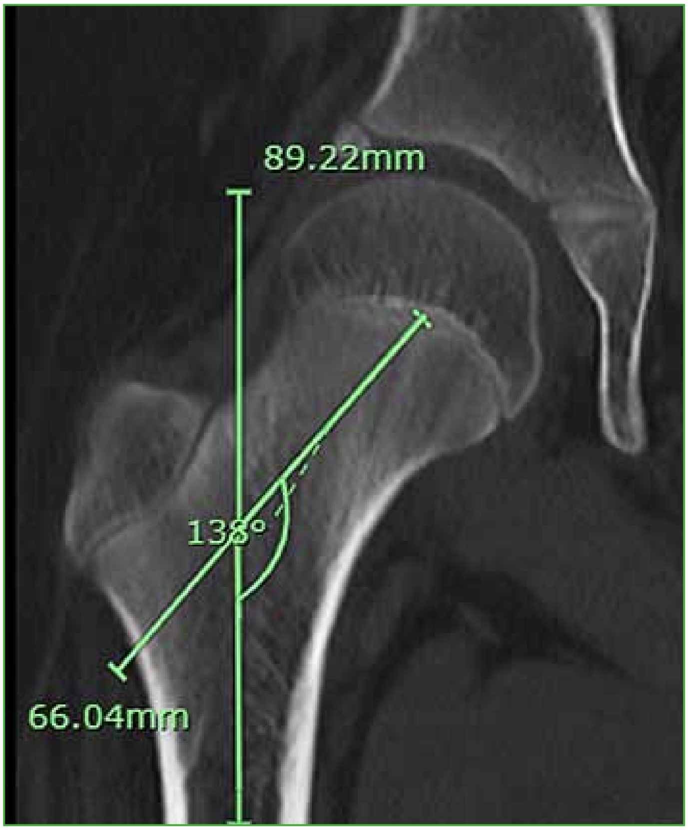


Figure 2. Cervico-diaphyseal angle. Angle formed between the anatomical axis of the femoral neck and the diaphyseal anatomical axis of the femur. In this case, it is 138°.

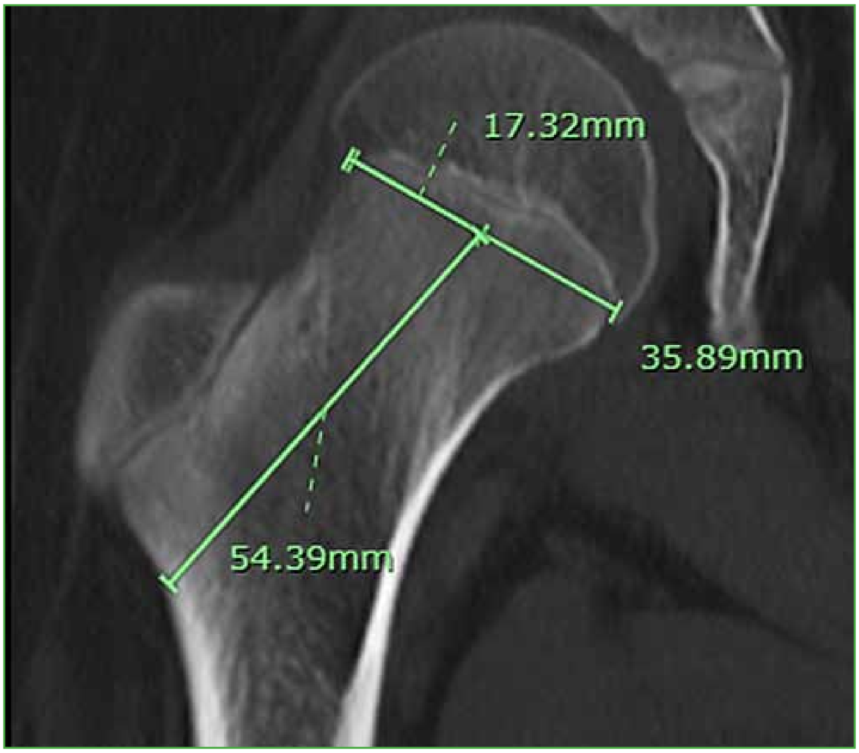


Figure 3. Femoral neck length. Distance from the center of the fissure line of the proximal femur to the lateral cortex of the intertrochanteric region, passing through the axis of the femoral neck. In this case, it is 54.39 mm.

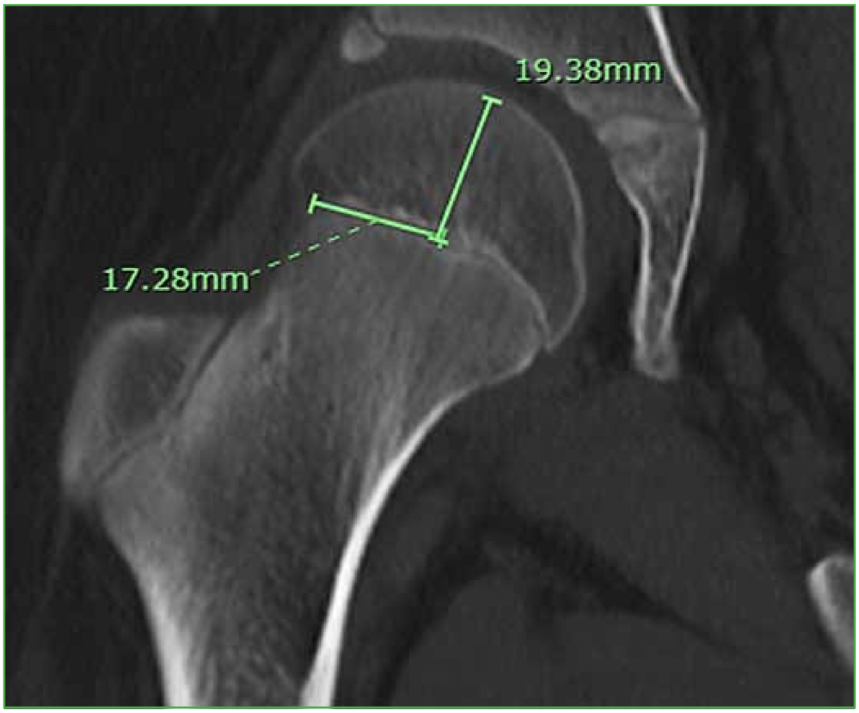


Figure 4. Femoral head radius. Its measurement is adjusted for age. In children aged >4, the longest line contained in the circumference of the femoral head passing through the center of rotation was measured. In children aged <4, the circumference was completed using the technique described by Amador et al. In this case, it is 19.38 mm.

Statistical analysis

Absolute and relative frequencies were calculated for qualitative variables, and scatter plots were created for each variable of interest according to age. The trend was established in these graphs, with smoothing added as necessary to regularize the curve in the cervico-diaphyseal angle graph. The growth rate for each parameter was determined by calculating the change in slope.

RESULTS

Forty patients were included (mean age: 9 years; range: 6 months to 18 years). Femoral offset shows linear growth over time, with a trend of increasing approximately 1.96 mm per year until 12.5 years of age, followed by a flattening of the curve and an increase in offset of 1.2 mm between 12.5 and 16 years of age (Figure 5). Regarding femoral neck length, the growth trend remains constant at a rate of 1.95 mm per year (Figure 6).

For the measurement of the cervico-diaphyseal angle, a smoothing factor of 0.6 was applied. A progressive decrease of 1.16° per year was observed from birth to 10 years of age. This rate continues to decrease by 0.88° per year between 10 and 12 years of age, followed by a flattening of the curve between 12 and 16 years of age, with a decrease of 0.09° per year (Figure 7). The femoral head diameter increases 1.56 mm per year during the first 13 years of life, with a slower growth of 0.62 mm per year thereafter (Figure 8).

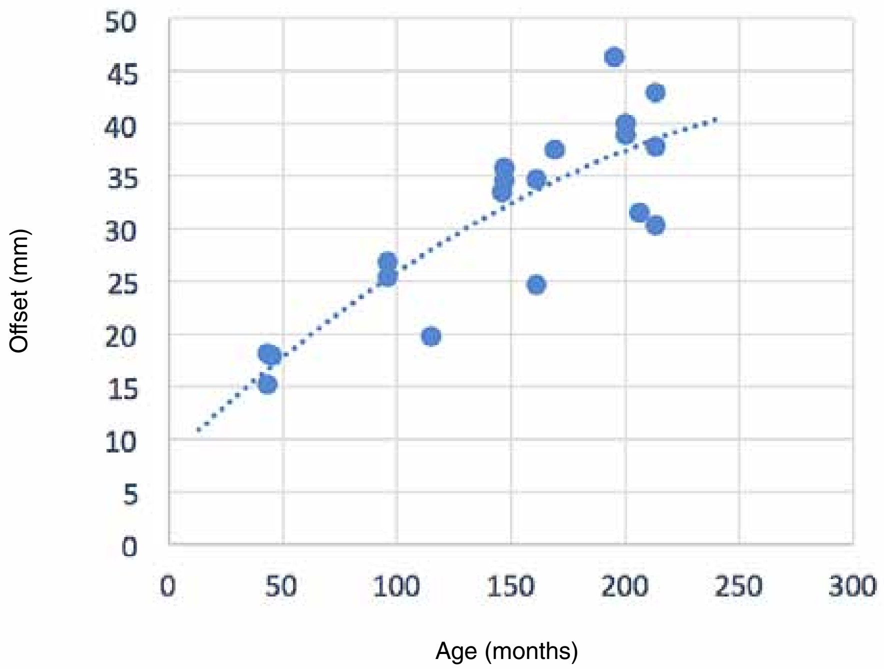


Figure 5. Femoral offset (mm) vs. age in months.

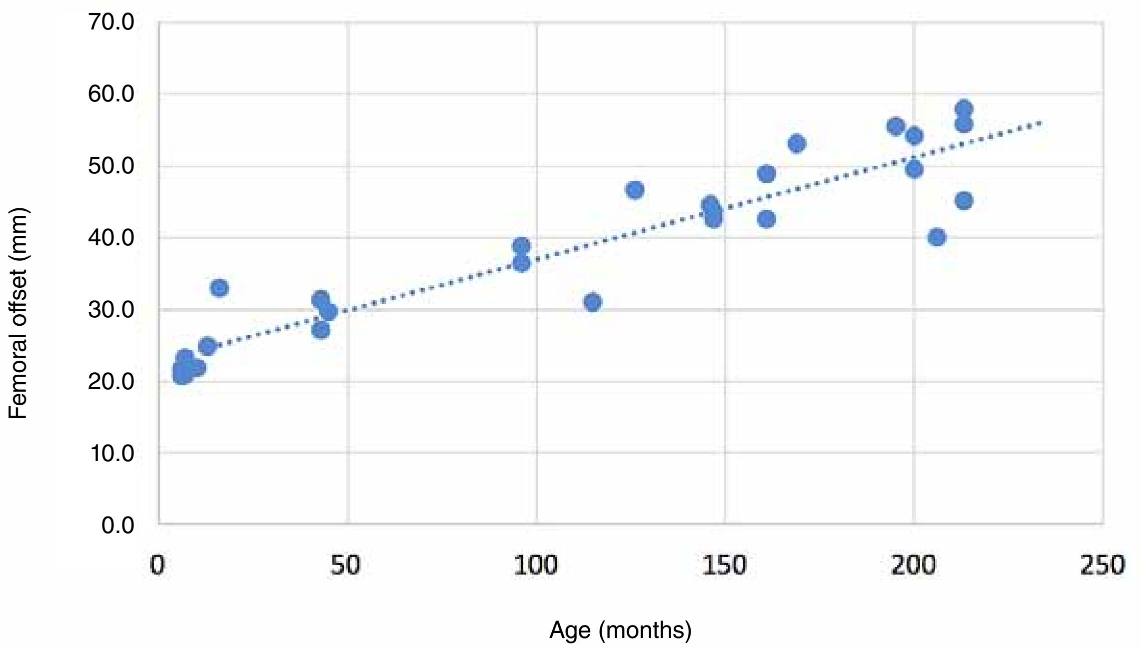


Figure 6. Femoral neck length (mm) vs. age in months.

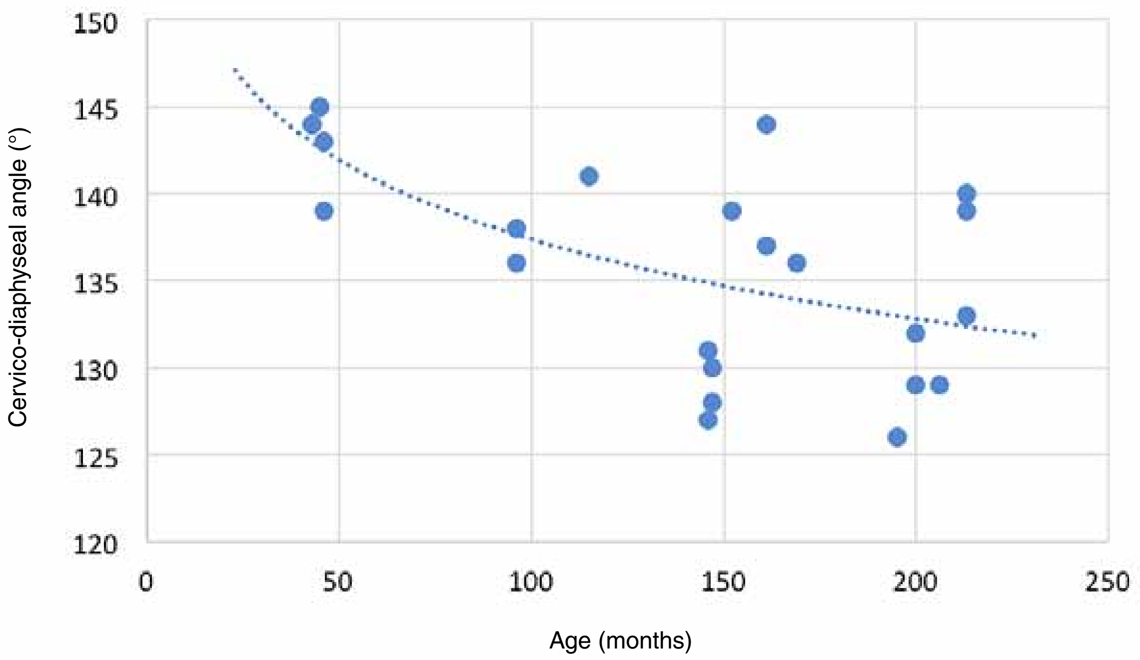


Figure 7. Cervico-diaphyseal angle (°) vs. age in months.

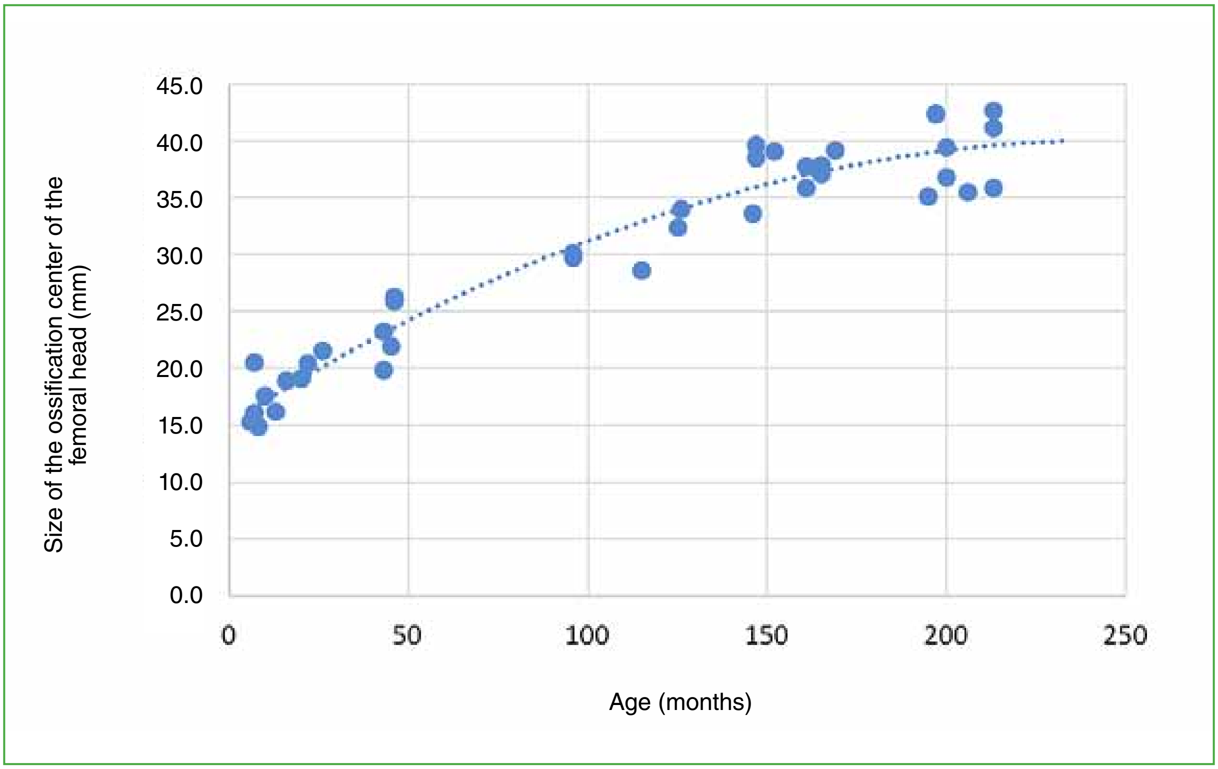


Figure 8. Size of the ossification center of the femoral head (mm) vs. age in months.

DISCUSSION

The aim of this study was to characterize the growth of the proximal femur in terms of anatomical parameters evaluated in CT scans of healthy hips from 40 Latin American pediatric patients. Previous studies have focused on describing the femoroacetabular relationship and establishing cut-off points for certain ages to facilitate decision-making, using reference points such as the center-edge angle (Wiberg) and the acetabular index, among others.[11,12] This approach does not allow for an exact or dynamic evaluation over time of the effect that femoral anatomy has on the lever arm of the hip, but it does indirectly infer alterations in the femoroacetabular relations, which are the basis for surgical interventions. An exception to this is the study published by Novais et al.,[13] which reports the median and dispersion of the acetabular index and the acetabular depth ratio from birth to 17 years of age. In the case of the femur, the analysis of femoral growth using the EOS system[7] in the Hungarian population has been described.

As described by Pauwels,[2,14] hip biomechanics are strongly influenced by the length of the lever arms of its components. This influence is evident in pediatric patients with conditions that modify these relationships, such as Perthes disease, hip dysplasia, or the sequelae of septic arthritis.

It is challenging to obtain femoral growth measurements in the population under 4 years of age. To address this, Amador et al.[9] described a reproducible method based on cadaveric dissections and radiographs, which allows for locating the center of the femoral head and its circumference when ossification is incomplete. In 1981, Wientroub et al.[10] described the normal hip development of the infant population using plain radiographs, but they did not refer to the calculation of the femoral head center in patients without femoral head ossification. As a complement to this review, in 2012, Monazzam et al.[15] demonstrated the possibility of extrapolating results from radiographic measurements to CT.

As shown in Figures 5-8, there is a relationship between the parameters evaluated and the age of the patients. The averages of the measurements at 5 and 15 years were calculated and compared with the results of Szuper et al.,[7] which is the only published study that establishes reference values for the anatomical parameters of normality of the proximal femur in the pediatric population.

In our population, the offset increased with age, from an average of 20 mm at 5 years to 37 mm at 15 years (6 mm and 3 mm less, respectively, than in the Szuper et al. population). Femoral neck length averaged 33 mm at age 5 years and 49 mm at age 15 years (1 mm and 1.5 mm less, respectively, than in the Szuper et al. population). Femoral head size was also smaller than in the comparison population, with averages of 24.6 mm at 5 years and 38.2 mm at 15 years (4 mm and 5.5 mm smaller, respectively). These differences may be related to a lower average height in our population from birth to adulthood compared to the Hungarian population. The gap found decreases progressively due to a higher rate of increase in femoral head offset and size.

In addition, the cervico-diaphyseal angle decreased with age, averaging 141.5° at 5 years and 133.8° at 15 years (differences of 11.1° and 5.8°, respectively). Although genetic differences in our population prevent direct extrapolation to other populations, the trends of increase or decrease in measurements in this study were similar to those published by other authors.[5,7]

The main limitation of this study is the size of the population sample, which allows us to show trends but is insufficient to determine the medians and percentiles required for a growth and development curve. The selection of a convenience sample limits the extrapolation of the findings to the general population.

When comparing our population with that of Szuper et al.,[7] a difference in the values of each variable for the same age groups is evident, highlighting the need to establish reference values for each population, as they cannot be universally extrapolated.

CONCLUSIONS

The measurements of the proximal femur described in this study provide valuable information and growth trends in Hispanic minors using imaging available in Colombia. These findings should be considered for the diagnosis, follow-up, and surgical planning of proximal femur alterations, aiming to restore anatomy to the normal values specific to the Latin American pediatric population. Expanding the studied sample is necessary to develop growth charts and guide treatment with appropriate instrumentation for this population.

Conflict of interest: The authors declare no conflicts of interest.

A. J. Solano Noguera ORCID ID: https://orcid.org/0000-0002-9749-2624
M. F. García Rueda ORCID ID: https://orcid.org/0000-0001-9173-1121
H. R. Rashid Forero ORCID ID: https://orcid.org/0000-0002-7869-2583
M. L. Caicedo Gutiérrez ORCID ID: https://orcid.org/0000-0002-0802-765X

REFERENCES

1. Kumar A, Passey J, Kumar M, Dushyant C, Saini M, Das S. Reliability of relation between greater trochanter and center of rotation of femoral head in Indian population. *J Clin Orthop Trauma* 2020;11(Suppl 4):S522-S525. https://doi.org/10.1016/j.jcot.2020.04.017
2. Pauwels F. *Biomechanics of the normal and diseased hip*. Berlin: Springer; 1976, p. 8-21.
3. Johnston JD, Noble PC, Hurwitz DE, Andriacchi TP. Biomechanics of the hip. En: Callaghan J, Rosenberg AG, Rubas HE (eds). *The adult hip*. Philadelphia: LWW; 1988, p. 81-90.
4. Muñoz Gutiérrez J. *Atlas de mediciones radiográficas en ortopedia y traumatología*. [Internet] 2ª ed. México: McGraw-Hill; 2011.

5. Birkenmaier C, Jorysz G, Jansson V, Heimkes B. Normal development of the hip: a geometrical analysis based on planimetric radiography. *J Pediatr Orthop B* 2010;19(1):1-8. https://doi.org/10.1097/BPB.0b013e32832f5aeb
6. Lecerf G, Fessy MH, Philippot P, Massin P, Giraud F, Flecher X, et al. Femoral offset: Anatomical concept, definition, assessment, implications for preoperative templating and hip arthroplasty. *Orthop Traumatol Surg Res* 2009;95(3):210-9. https://doi.org/10.1016/j.otsr.2009.03.010
7. Szuper K, Tibor Schlégl Á, Leidecker E, Vermes C, Somoskeöy S, Than P. Three-dimensional quantitative analysis of the proximal femur and the pelvis in children and adolescents using an upright biplanar slot-scanning X-ray system. *Pediatr Radiol* 2015;45(3):411-21. https://doi.org/10.1007/s00247-014-3146-2
8. López-Laiseca JD, Massuça LM. Valores de referencia para estatura, peso e índice de masa corporal en niños, niñas y adolescentes de 2 a 18 años. Una revisión sistemática con énfasis en la población colombiana. *Rev Fac Med* [Internet] 2021;69(1):e300. https://doi.org/10.15446/revfacmed.v69n1.88774
9. Amador A, Gil C, Gutiérrez J, Duque C. Center of the femoral head in children: Anatomic-radiologic correlation. *J Pediatr Orthop* 2003;23(6):703-7. PMID: 14581770
10. Wientroub S, Tardiman R, Green I, Salama R, Weissman SL. The development of the normal infantile hip as expressed by radiological measurements. *Int Orthop* 1981;4(4):239-41. https://doi.org/10.1007/BF00266063
11. Kleinberg S, Lieberman HS. The acetabular index in infants in relation to congenital dislocation of the hip. *Arch Surg* 1936;32(6):1049-54. https://doi.org/10.1001/archsurg.1936.01180240137007
12. Than P, Sillinger T, Kránicz J, Bellyei A. Radiographic parameters of the hip joint from birth to adolescence. *Pediatr Radiol* 2004;34(3):237-44. https://doi.org/10.1007/s00247-003-1119-y
13. Novais EN, Pan Z, Autruong PT, Meyers ML, Chang FM. Normal percentile reference curves and correlation of acetabular index and acetabular depth ratio in children. *J Pediatr Orthop* 2018;38(3):163-9. https://doi.org/10.1097/BPO.0000000000000791
14. Byrne DP, Mulhall KJ, Baker JF. Anatomy & biomechanics of the hip. *The Open Sports Medicine Journal* 2010;4:51-7. https://doi.org/10.2174/1874387001004010051
15. Monazzam S, Bomar JD, Cidambi K, Kruk P, Hosalkar H. Lateral center-edge angle on conventional radiography and computed tomography. *Clin Orthop Relat Res* 2012;471(7):2233-7. https://doi.org/10.1007/s11999-012-2651-6

Regenerative Medicine: Effect of Treatment with Biphasic Cross-Linked Hyaluronic Acid in Osteochondral Lesions

José Luis Álvarez,* Nicolás Francioni,* Clara Operti,* Marcelo F. Orellana,* Octavio Santiago,* Leandro Sarrio, Mariel Stur,* Joao P. Mardegan Issa,# Santiago Fonseca,* Sara Feldman***

**LABOATEM Laboratory of Osteoarticular Biology, Tissue Engineering and Emerging Therapies, School of Medical Sciences, Universidad Nacional de Rosario, Santa Fe, Argentina.*

***Anatomical Pathology Department, Hospital Central de Mendoza, Mendoza, Argentina.*

#Ribeirao Preto School of Dentistry, Universidad de Sao Paulo, Brazil

ABSTRACT

Objective: To demonstrate whether treatment with biphasic cross-linked hyaluronic acid in osteochondral lesions promotes the regeneration of cartilage tissue. **Materials and Methods:** Fifteen adult female rabbits were randomly assigned to three groups. G1 was the control group, whereas G2 and G3 underwent surgery to treat an osteochondral injury in the right knee (4mm diameter, 5mm depth). G3 received treatment with 0.2 ml of hyaluronic acid intrarticularly after surgery. Clinical, biochemical, histopathological controls and imaging studies were performed. **Results:** Clinically, G3 exhibited less pain on palpation than G2 after 45 days. In G3, almost all samples showed evidence of cartilage tissue regeneration at the injury site, with neither bone edema or considerable joint effusion detected on MRI. The histological tests of G3 samples revealed an increase in the extracellular matrix of cartilaginous tissue when compared to G2, with hypercellularity caused by chondrocytes that formed axial and coronal isogenic groups. **Conclusions:** This study provides evidence that treatment with biphasic cross-linked hyaluronic acid in experimental units of rabbits with osteochondral injuries did not cause pain in the early stages of the injury. In turn, imaging and histopathological studies revealed that the injured tissue had been repaired.

Keywords: Hyaluronic acid; cartilage regeneration; osteochondral injury.

Medicina regenerativa de cartílago: efecto del tratamiento con ácido hialurónico reticulado bifásico en lesiones osteocondrales

RESUMEN

Objetivo: Evaluar si el tratamiento con ácido hialurónico reticulado bifásico de lesiones osteocondrales promovería la regeneración del tejido cartilaginoso, favoreciendo así la reparación de la lesión. **Materiales y Métodos:** Quince conejos hembra adultos fueron divididos aleatoriamente en tres grupos: grupo 1, de control; grupo 2 y grupo 3, sometidos a una estrategia quirúrgica de lesión osteocondral en la rodilla derecha (4 mm de diámetro, 5 mm de profundidad), el grupo 3 recibió tratamiento con 0,2 ml de ácido hialurónico por vía intrarticular después de la cirugía. Se realizaron controles clínicos, bioquímicos, histopatológicos y estudios por imágenes. **Resultados:** Se detectaron menos casos de dolor a la palpación en el grupo 3 que en el grupo 2 a partir de los 45 días. En la resonancia magnética, casi todas las muestras del grupo 3 tenían signos de regeneración del tejido cartilaginoso en el sitio de la lesión, sin edema óseo, ni derrame articular significativo. Los estudios histopatológicos de las muestras del grupo 3 indicaron un aumento de la matriz extracelular propia de tejido cartilaginoso, comparada con la del grupo 2, con hipercelularidad, dada por condrocitos, los que formaban grupos isogénicos axiales y coronales. **Conclusiones:** Este estudio brinda evidencias de que el tratamiento con ácido hialurónico reticulado bifásico en unidades experimentales de conejos con lesión osteocondral no tuvieron dolor en etapas tempranas después de la lesión, a diferencia de las unidades intervenidas y sin dicho tratamiento. A su vez, los estudios por imágenes e histopatológicos mostraron la reparación del tejido dañado.

Palabras clave: Ácido hialurónico; regeneración de cartílago; lesión osteocondral.

Received on December 30th, 2023. Accepted after evaluation on July 19th, 2024 • Dr. JOSÉ LUIS ÁLVAREZ • joseluisalvarezfcm@gmail.com ID https://orcid.org/0009-0008-4641-2621

How to cite this article: Álvarez JL, Francioni N, Operti C, Orellana M, Santiago O, Sarrio L, Stur M, Mardegan Issa JP, Fonseca S, Feldman S. Regenerative Medicine: Effect of Treatment with Biphasic Cross-Linked Hyaluronic Acid in Osteochondral Lesions. *Rev Asoc Asoc Argent Ortop Traumatol* 2024;89(4):374-384. https://doi.org/10.15417/issn.1852-7434.2024.89.4.1871

INTRODUCTION

Osteochondral tissue is composed of articular cartilage and subchondral bone, and it has a low regenerative capacity. Its chemical nature and histoarchitecture allow it to support the high loads it endures. Osteochondral lesions involve the hyaline cartilage and subchondral bone of the joints, with effects ranging from minor discomfort to disabling conditions.[3] These lesions are acquired pathological entities of the subchondral bone that also involve the associated articular cartilage.[4] Regarding etiology, they are linked to mechanical factors, recurrent trauma, overload, infections, and vascular compromise, among others. These injuries commonly occur in the knee, but the articular surfaces of the elbow, ankle, hip, and shoulder can also be affected. The injury can result in delamination and potential sequestration of the affected bone, compromising joint function. Such injuries can lead to progressive joint destruction and cause moderate to severe pain, resulting in disabling conditions.[5-7] Their management and treatment remain a challenge in Traumatology and Orthopedics, as these entities behave differently depending on the joint affected. Despite promising clinical outcomes in the short and medium term, bone marrow stimulation often results in fibrocartilaginous tissue with mechanical and biological properties that differ from those of normal cartilage.[8]

Among the strategies that have shown improvement for patients with joint injuries, treatments with hyaluronic acid (HA) stand out. HA is a biologically active molecule, naturally secreted by chondrocytes, the cells of joint tissue.[9] It was first isolated in 1934.[10] HA is a natural, non-sulfated glycosaminoglycan, consisting of repeating units of D-glucuronic acid and N-acetylglucosamine, forming a central part of the proteoglycans in the extracellular matrix of the tissue. These complex macromolecules are responsible for the compressive strength of cartilage, playing a fundamental structural role in the tissue. HA can also interact with cells through receptors on the plasma membrane, such as the CD44 receptor, which activates several biological effects, including increased motility and amplified cell proliferation. [11-13]

The initial proposal to treat patients with osteochondral lesions using HA was based on promoting viscosupplementation, reducing pain, and improving the viscoelasticity of joint tissue. [14-17]

Numerous studies on HA treatment for joint injuries have been published, with encouraging clinical results.[15-18] In our country, a biphasic cross-linked HA (XLHA) with a longer half-life has been developed. However, there are no studies specifically considering the potential action of XLHA in osteochondral lesions in an in vivo model, examining clinical, biochemical, imaging, and histological aspects, and characterizing the potential changes in the injured tissue area after treatment.

Our working hypothesis is that in situ treatment with this product for osteochondral lesions would promote cartilage tissue repair and de novo cartilage tissue regeneration, thereby favoring the repair of the lesion with tissue that properly fulfills its functions.

MATERIALS AND METHODS

The *in vivo* studies were conducted on female New Zealand line rabbits (3-4 months old) in accordance with the Bone and/or Cartilage Tissue Engineering III project of the Faculty of Medical Sciences at the Universidad Nacional de Rosario. This project was approved by the Ethics Committee and CICUAL (Institutional Commission for the Care and Use of Animals in Laboratories), Code 80020220700113UR, Resolution No. 4888/2022. The rabbits were housed in individual cages with food and water provided *ad libitum* until the day before surgery and from the day after.

Fifteen experimental units were randomly divided into three groups (5 in each): group 1 (without osteochondral lesion: 1a, 1b, 1c, 1d, 1e) was used for control clinical and biochemical studies; group 2 (with osteochondral lesion, without receiving treatment: 2a, 2b, 2c, 2d, 2e); and group 3 (with osteochondral lesion treated with XLHA [Cientific Sinovial 60 A.F., Lab. Futerman International Products - Allanmar International Company S.R.L.]: 3a, 3b, 3c, 3d, 3e). Preliminary studies confirmed that this treatment did not clinically or biochemically affect healthy rabbits.

Preparation for the surgical procedure

A sterile surgical environment was established using ultraviolet irradiation. The right knee was shaved, and skin asepsis was performed with an iodine solution. Cefazolin (50 mg/kg/day) was administered intramuscularly. Anesthesia-sedation was achieved by administering a combination of ketamine hydrochloride (35 mg/kg), xylazine hydrochloride (2.0%, 18 mg/kg), and acepromazine maleate (1.0%, 1 mg/kg) intramuscularly.

Surgical procedure

Each experimental unit was placed in a supine position on the operating table, on sterile fields. A fenestrated sterile drape was placed centered on the knee, covering the torso while leaving the head uncovered. A 5 cm long midline skin incision was made on the right knee, with dissection through the skin layers. The medial approach was followed by arthrotomy via a subvastus approach, followed by lateral dislocation of the patella. An osteochondral lesion 4 mm in diameter and 5 mm deep was created in the trochlear groove at the level of the epicondyles using a motorized drill as an anatomical reference. The patella was reduced, and the joint capsule and medial retinaculum were sutured with Vicryl #2.0. A continuous subdermal suture was placed with Vicryl #4.0, and the skin was closed with Nylon 3.0. XLHA was then infiltrated into the knee.

Treatment with XLHA

After surgery, each experimental unit in group 3 received a single intra-articular injection of 0.2 ml of XLHA into the right knee.

Treatment of postoperative pain

Tramadol (100 mg/ml, 0.12 ml every 12 hours, 6 mg/kg/day) was administered intramuscularly for three days to manage postoperative pain.

Clinical monitoring

Clinical monitoring included assessments of body temperature, general condition, and response to light stimuli (using a flashlight with an intensity of 2-4 lux, each eye of each experimental unit was shined at a distance of 30 cm, and it was observed whether the rabbits squinted, as all healthy control units typically do). The presence or absence of associated inflammatory states in the operated area was also noted macroscopically. These evaluations were performed daily during the first week, and then every 15 days until the end of the experiment. From day 15 onwards, knee palpation was conducted every 15 days to detect pain (when experiencing pain, the experimental units would retract the leg and emit complaining sounds). This process involved lightly compressing the knee with the palm of the hand, first thing in the morning, on each knee of all experimental units. This procedure was carried out by a single operator in the presence of two other observers to verify the results.

Sampling for biochemical studies

Blood samples were taken before the procedure and at 1, 7, and 120 days after implantation. After homogenization, the samples were placed in EDTA tubes for hemograms. Red blood cell and white blood cell counts, hemoglobin levels, and platelet counts were determined to assess post-surgical status.

Statistical analysis

Non-parametric tests were conducted to determine if there were intergroup differences in the biochemical variables tested (Kruskal-Wallis test at 1, 7, and 120 days after implantation).

Imaging studies

At 120 days post-procedure, the anesthetized animals underwent magnetic resonance imaging (1.5 TESLA, General Electric, Signa HDxt with microcoil). MRI images were obtained in 1 mm slices in axial, sagittal, and coronal planes. The sequence used was proton density with fat suppression, which is suitable for assessing the articular cartilage. At the lesion site, the following were evaluated based on previous research:

a) the presence of cartilage,[19-21]

b) the possible presence of bone edema,[22,23].

c) joint effusion. [24,25]

Animal euthanasia protocol

The animals were euthanized immediately after the MRI scans. While still sedated, they were placed in a CO2 chamber, following international standards approved by CICUAL.

Protocol for sample collection, preservation and procedures for histopathological studies.

A longitudinal incision was made on the medial aspect of the thigh, following the direction of the femur. Two transverse incisions were made, one proximal to the coxofemoral junction and the other distal to the end of the knee joint. Dissection was performed in layers. The knee was disarticulated by incising the articular ligaments, separating the thigh from the leg. The femur was then disarticulated from the hip by incising the capsule and coxofemoral ligaments, and each piece was obtained for study.

Histopathological studies

The samples were preserved in 10% formaldehyde (48 hours), followed by decalcification processes. Each sample was immersed in stabilized decalcifying Biopur solution (EDTA 0.5M), with gentle periodic shaking, and the solutions were exchanged weekly until the absence of minerals in the samples was verified. The samples were then processed using conventional histological methods until paraffin-embedded plugs were obtained. These plugs were sectioned with a microtome (Leica SM2010 R) into 3 µm longitudinal sections, placed on slides, and stained with hematoxylin-eosin (Biopack). All samples were processed simultaneously during this final stage. The samples were observed under an optical microscope at 100x and 400x magnifications and evaluated using a double-blind strategy. For cell counting, 10 fields were observed at higher magnification for each sample.

RESULTS

Clinical studies

All animals in groups 2 and 3 responded adequately to the anesthetic and surgical processes. None of the animals experienced a temperature increase above normal values (compared to group 1), indicating a successful surgical process and effective antibiotic prophylaxis (normal temperature for New Zealand rabbits: 38.5°-39.5°C).

After the anesthesia wore off, the animals received normal hydration, and food consumption was enabled four hours later, matching that of group 1 animals from the second post-surgical day (300 ± 20 g/experimental unit/day).

There were no significant intergroup differences in response to light stimuli from day 4 post-procedure. On days 1, 2, and 3, all experimental units that underwent surgery were less responsive to light, which is typical of animals treated with tramadol, causing mild lethargy.

None of the units subjected to the procedure exhibited macroscopically visible inflammatory phenomena during the experiment. Beginning on day 15, knee palpation was performed every 15 days to assess pain. All animals in group 2 showed retraction to palpation with audible signs of pain up to and including day 120. From day 45 until the end of the study, none of the experimental units in group 3 retracted the knee or showed signs of pain upon palpation.

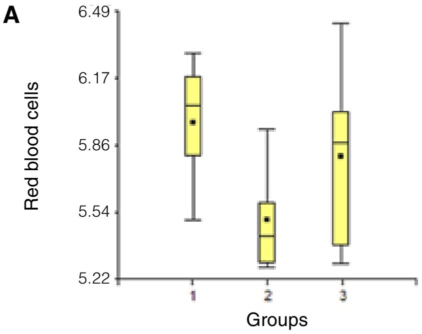
Biochemical results

No significant intergroup differences were found in the levels of red blood cells, white blood cells, hemoglobin, and platelets at any of the times studied (Figure 1).

Results obtained by MRI

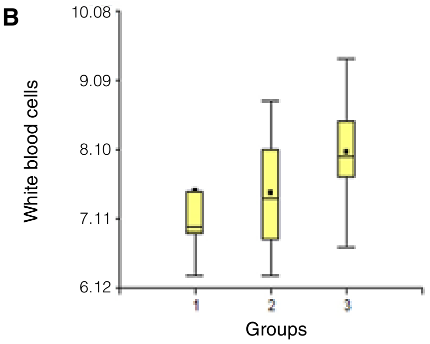
In group 2, no features indicative of cartilage regeneration were observed. A large amount of bone edema, increased joint effusion, and the absence of chondral tissue in the lesion area were noted (Table).

In contrast, group 3 showed the presence of cartilage, with no bone edema or significant joint effusion in the T1 sequence, as reported by other authors[19-21] (Table, Figure 2).



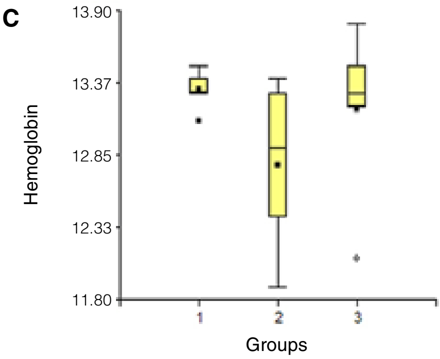
Kruskal–Wallis test

Variable	Groups N	Mean	S.D.	Median	H	p
Red blood cells 1	5	5.96	0.32	6.04	3.82	0.1479
Red blood cells 2	5	5.50	0.27	5.43		
Red blood cells 3	5	5.80	0.47	5.87		



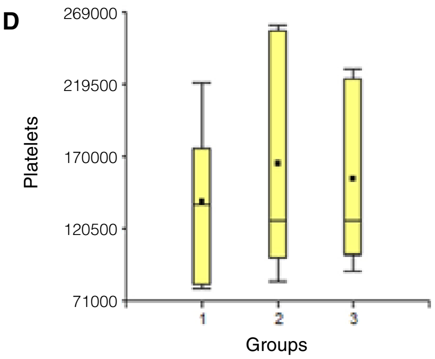
Kruskal–Wallis test

Variable	Groups N	Mean	S.D.	Median	H	p
White blood cells 1	5	7.52	1.40	7.00	-5.22	>0.9999
White blood cells 2	5	7.48	1.00	7.40		
White blood cells 3	5	8.06	1.00	8.00		



Kruskal–Wallis test

Variable	Groups N	Mean	S.D.	Median	H	p
Hemoglobin 1	5	13.32	0.15	13.30	2.18	0.3283
Hemoglobin 2	5	12.78	0.63	12.90		
Hemoglobin 3	5	13.18	0.65	13.30		



Kruskal–Wallis test

Variable	Groups N	Mean	S.D.	Median	H	p
Platelets 1	5	139000.00	60547.50	137000.00	0.76	0.6851
Platelets 2	5	165400.00	85806.76	126000.00		
Platelets 3	5	154400.00	67069.37	126000.00		

Figure 1. Box-and-whisker plots showing the distribution and central tendency of numerical values through their quartiles for different variables in groups 1, 2, and 3. **B.** Values for the variable white blood cell levels. **C.** Values for the variable hemoglobin levels. **D.** Values for the variable platelet levels. The results of the Kruskal-Wallis statistical analysis performed with the Infostat program are displayed alongside each graph.

Table. Results obtained by magnetic resonance imaging.

Sample	Group	Presence of cartilage	Presence of bone edema	Hydrarthrosis
2a	2	No	No	Moderate
2b	2	Data lost due to technical problems		
2c	2	No	No	Moderate
2d	2	No	Yes	Moderate
2e	2	No	Yes	Scarce
3a	3	Slight	No	Scarce
3b	3	Yes	No	Moderate
3c	3	Yes	No	Scarce
3d	3	Yes	No	Moderate
3e	3	Yes	No	Scarce

Figure 2. Representative images from each group obtained by magnetic resonance imaging using a General Electric 1.5 TESLA equipment with microcoil, four months after treatment. **A.** Representative image of group 2. **B.** Representative image of group 3.

Results of histopathological studies

Representative images from each experimental unit of each group are shown in Figure 3.

Group 1: Chondrocytes with axial or coronal arrangements were observed in all fields of each unit, within a basophilic extracellular matrix typical of normal cartilaginous tissue.

Group 2: At the injury site, tissue with eosinophilic matrix staining, characteristic of scar connective tissue, was observed. Chondrocytes were few and arranged in a scattered, disorganized manner, as expected in an osteochondral lesion.

Group 3: Generally, the extracellular matrix showed more basophilic staining than in group 2, and more closely resembled that of group 1. Additionally, hypercellularity due to chondrocytes arranged in axial and coronal isogenic groups was observed in many areas.

The chondrocyte cell count was: group 1 > group 2 ($p < 0.0002$; Wilcoxon test), group 2 < group 3 ($p < 0.0002$; Wilcoxon test), with no significant differences between groups 1 and 3. The Kruskal-Wallis test for the three groups showed highly significant differences between groups 1 and 2, but not between groups 1 and 3. Although group 3 exhibited some variation, with one sample showing low cellularity, the rest displayed high cellularity consistent with healthy cartilage tissue. In all samples treated with XLHA, the chondrocyte arrangement was similar to that of healthy cartilage tissue, which is strongly associated with proper tissue functionality (Figure 4).[1,2]

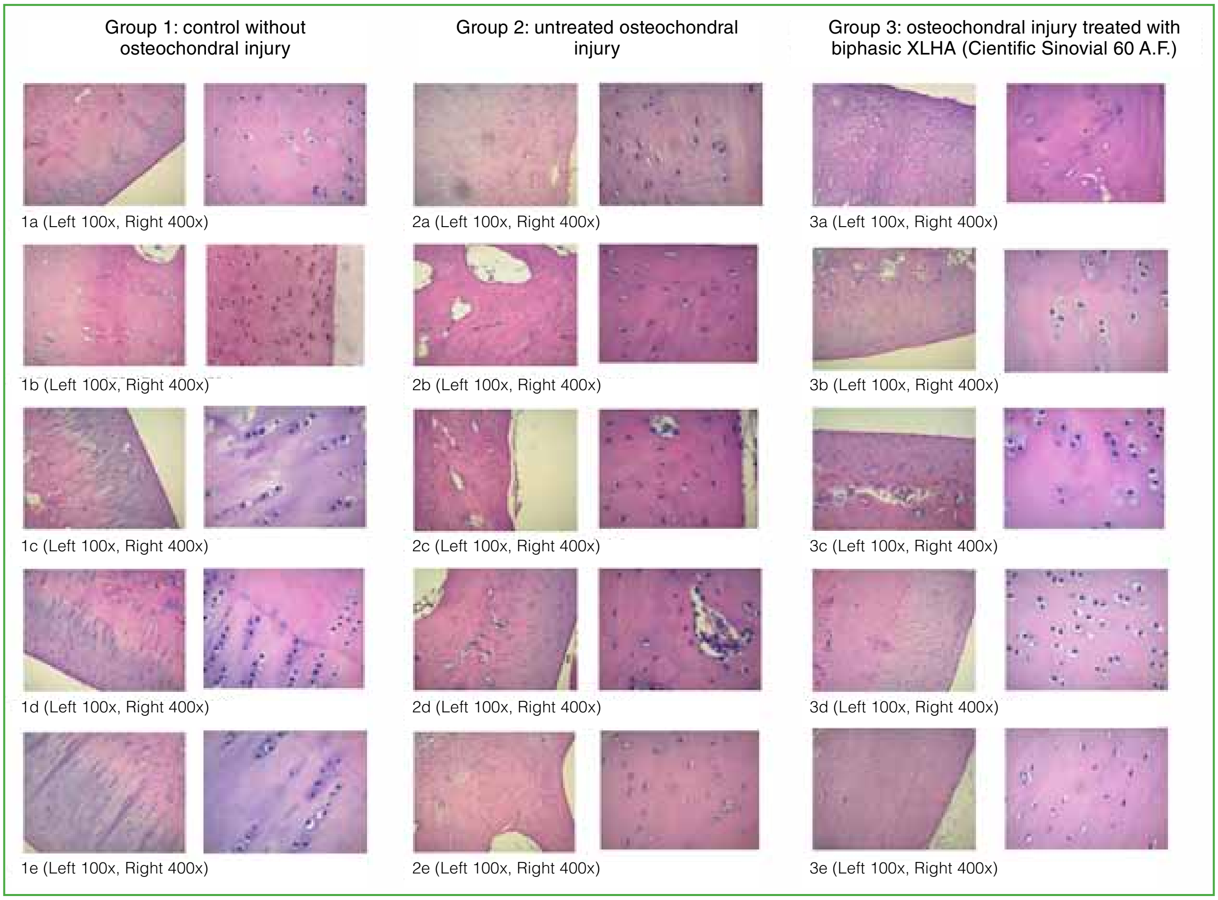


Figure 3. Images obtained through a camera connected to an optical microscope, displaying histological samples from the three groups.

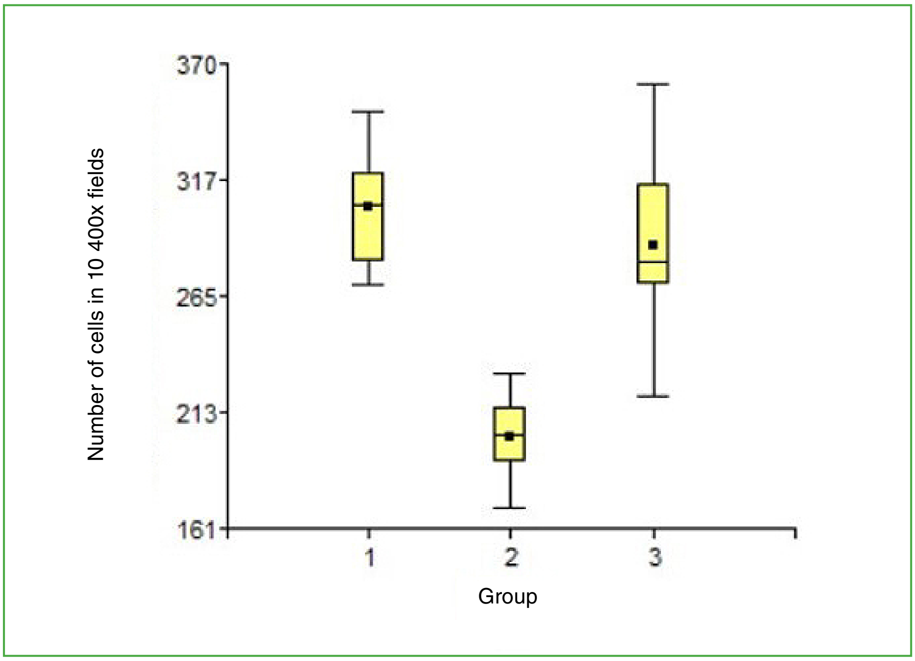


Figure 4. Chondrocyte count.

DISCUSSION

It has been demonstrated that cartilage tissue, when faced with an osteochondral lesion, lacks the capacity to regenerate on its own, meaning it does not form new tissue identical to the original that can fulfill the same functions.[26] When a cartilage defect is left untreated, the joint deteriorates progressively and irreversibly, leading to osteoarthritis and eventually disability.[27]

HA is commonly used via intra-articular injections to increase viscosupplementation as a treatment for osteoarthritis, due to its ease of use and good tolerability.[28] However, there are very few studies that explore the potential regenerative effect of HA, and in those published, HA is usually applied in combination with other molecules. [29-33]

Although some evidence of rabbit ear cartilage regeneration through HA application has been reported,[34] as well as research in rats,[35] these are preventive studies in which HA is injected before inducing an osteoarthritis phenomenon. There is no evidence, based on imaging and histological studies, that exclusive treatment with XLHA promotes cartilage repair in an established osteochondral lesion in the knee. In this study, the cartilage regenerated with an appropriate histological structure to perform its functions as in healthy tissue, which may explain the 100% absence of pain in treated experimental units, compared to untreated animals. While determining the presence of pain may introduce subjective bias, it provided an additional contribution to other investigations, since pain is a common issue in living beings with osteochondral lesions.

This research builds on other studies conducted in our laboratory in the field of tissue engineering,[36-41] which suggest that using certain biomolecules or matrices derived from them can promote the *de novo* repair of damaged tissue with characteristics similar to those of healthy tissue. This approach offers a simple, less invasive treatment compared to conventional methods, with fewer undesirable side effects[42-44] and more cost-effective.[45,46] Future studies on the functional profiles of chondrocytes will further enhance our understanding of joint biology, imaging, and treatment options.[47]

CONCLUSIONS

This study provides preliminary evidence that the experimental units with osteochondral lesions treated with XLHA experienced no pain in the early stages after the lesion, unlike the intervened units that did not receive such treatment. This suggests that cartilaginous tissue repair occurred at the injured site, as confirmed by magnetic resonance and histological studies, without any undesirable side effects. Future studies utilizing cell markers and immunohistochemical techniques will further enhance this regenerative medicine proposal.

Acknowledgments

Paola Luciana Salvatierra from the Instituto de Ciencias Básicas y Aplicadas, Villa María, Córdoba, Argentina, for reviewing the statistical analysis.

Conflict of interest: The authors declare no conflicts of interest.

N. Francioni ORCID ID: https://orcid.org/0009-0005-6352-5351
C. Operti ORCID ID: https://orcid.org/0009-0009-9065-4991
M. F. Orellana ORCID ID: https://orcid.org/0009-0002-4313-8301
O. Santiago ORCID ID: https://orcid.org/0009-0004-0163-1303
L. Sarrio ORCID ID: https://orcid.org/0009-0007-1450-8517
M. Stur ORCID ID: https://orcid.org/0000-0003-1662-5913
J. P. Mardegan Issa ORCID ID: https://orcid.org/0000-0002-1056-0795
S. Feldman ORCID ID: https://orcid.org/0000-0001-9804-8421
S. Fonseca ORCID ID: https://orcid.org/0009-0008-6660-3118

REFERENCES

1. Mills SE. *Histología para patólogos*. 4th ed. Medellin: Editorial Amolca; 2015.
2. Ham HW, Cormack DH. *Tratado de histología*. 8th ed. Buenos Aires: Editorial Médica Panamericana; 1996.
3. Sanders RK, Crim JR. Osteochondral injuries. *Semin Ultrasound CT MR* 2001;22(4):352-70. https://doi.org/10.1016/s0887-2171(01)90026-5
4. Lories RJ, Luyten FP. The bone-cartilage unit in osteoarthritis. *Nat Rev Rheumatol* 2011;7(1):43-9. https://doi.org/10.1038/nrrheum.2010.197
5. Wiewiorski M, Pagenstert G, Rasch H, Jacob AL, Valderrabano V. Pain in osteochondral lesions. *Foot Ankle Spec* 2011;4(2):92-9. https://doi.org/10.1177/1938640010395749
6. Cross M, Smith E, Hoy D, Nolte SM, Ackerman I, Frnsen M, et al. The global burden of hip and knee osteoarthritis: estimates from the Global Burden of Disease 2010 study. *Ann Rheum Dis* 2014;73(7):1323-30. https://doi.org/10.1136/annrheumdis-2013-204763
7. Pape D, Filardo G, Kon E, van Dijk CN, Madry H. Disease-specific clinical problems associated with the subchondral bone. *Knee Surg Sports Traumatol Arthrosc* 2010;18(4):448-62. https://doi.org/10.1007/s00167-010-1052-1
8. Bravo Molina B, Forriol F, Álvarez Lozano E. Regenerar el cartílago articular: perspectivas y futuro. *Rev Esp Artrosc Cir Articul* 2021;28(1):51-62. Available at: https://fondoscience.com/sites/default/files/articles/pdf/reaca.28171.fs1911064-regenerar-cartilago-articular-perspectivas-futuro.pdf
9. Savage-Elliott I, Ross KA, Smyth NA, Murawski CD, Kennedy JG. Osteochondral lesions of the talus: a current concepts review and evidence-based treatment paradigm. *Foot Ankle Spec* 2014;7(5):414-22. https://doi.org/10.1177/1938640014543362
10. Meyer K, Palmer J. The polysaccharide of the vitreous humor. *J Biol Chem* 1934;107(3):629-34. https://doi.org/10.1016/S0021-9258(18)75338-6
11. García-Fuentes M, Meinel AJ, Hilbe M, Meinel L, Merkle HP. Silk fibroin/hyaluronan scaffolds for human mesenchymal stem cell culture in tissue engineering. *Biomaterials* 2009;30(28):5068-76. https://doi.org/10.1016/j.biomaterials.2009.06.008
12. Salter DM, Godolphin JL, Gourlay MS, Lawson MF, Hughes DE, Dunne E. Analysis of human articular chondrocyte CD44 isoform expression and function in health and disease. *J Pathol* 1996;179(4):396-402. https://doi.org/10.1002/ (SICI) 1096-9896(199608)179:4<396: AID-PATH606>3.0.CO; 2-G

13. Knudson CB, Knudson W. Hyaluronan and CD44: modulators of chondrocyte metabolism. *Clin Orthop Relat Res* 2004;(427 Suppl):S152-62. PMID: 15480059
14. Arnold W, Fullerton DS, Holder S, May CS. Viscosupplementation: managed care issue for osteoarthritis of the knee. *J Manag Care Pharm* 2007;13(4):S3-19. https://doi.org/10.18553/jmcp.2007.13.s4.3
15. Volpi N, Schiller J, Stern R, Soltés L. Role, metabolism, chemical modifications and applications of hyaluronan. *Curr Med Chem* 2009;16(14):1718-45. https://doi.org/10.2174/092986709788186138
16. Peck J, Slovek A, Miro P, Vij N, Traube B, Lee C, et al. A comprehensive review of viscosupplementation in osteoarthritis of the knee. *Orthop Rev (Pavia)* 2021;13(2):25549. https://doi.org/10.52965/001c.25549
17. Marshall KW. Intra-articular hyaluronan therapy. *Curr Opin Rheumatol* 2000;12(5):468-74. https://doi.org/10.1097/00002281-200009000-00022
18. Pereira H, Sousa DA, Cunha A, Andrade R, Espregueira-Mendes J, Oliveira JM, et al. Hyaluronic acid. *Adv Exp Med Biol* 2018;1059:137-53. https://doi.org/10.1007/978-3-319-76735-2_6
19. Roemer FW, Guermazi A, Demehri S, Wirth W, Kijowski R. Imaging in osteoarthritis. *Osteoarthritis Cartilage* 2022;30(7):913-934. https://doi.org/10.1016/j.joca.2021.04.018
20. Figueroa D, Calvo R, Vaisman A, Carrasco MA, Moraga C, Delgado I. Knee chondral lesions: incidence and correlation between arthroscopic and magnetic resonance findings. *Arthroscopy* 2007;23(3):312-5. https://doi.org/10.1016/j.arthro.2006.11.015
21. Sifre V, Ten-Esteve A, Serra CI, Soler C, Alberich-Bayarri Á, Segarra S, et al. Knee cartilage and subchondral bone evaluations by magnetic resonance imaging correlate with histological biomarkers in an osteoarthritis rabbit model. *Cartilage* 2022;13(3):19476035221118166. https://doi.org/10.1177/19476035221118166
22. D'Ambrosi R, Maccario C, Ursino C, Serra N, Usuelli FG. The role of bone marrow edema on osteochondral lesions of the talus. *Foot Ankle Surg* 2018;24(3):229-35. https://doi.org/10.1016/j.fas.2017.02.010
23. Ahn J, Choi JG, Jeong BO. Clinical outcomes after arthroscopic microfracture for osteochondral lesions of the talus are better in patients with decreased postoperative subchondral bone marrow edema. *Knee Surg Sports Traumatol Arthrosc* 2021;29(5):1570-6. https://doi.org/10.1007/s00167-020-06303-y
24. Roemer FW, Guermazi A, Felson DT, Niu J, Nevitt MC, Crema MD, et al. Presence of MRI-detected joint effusion and synovitis increases the risk of cartilage loss in knees without osteoarthritis at 30-month follow-up: the MOST study. *Ann Rheum Dis* 2011;70(10):1804-9. https://doi.org/10.1136/ard.2011.150243.
25. Wang X, Blizzard L, Jin X, Chen Z, Zhu Z, Han W, et al. Quantitative assessment of knee effusion-synovitis in older adults: Association with knee structural abnormalities. *Arthritis Rheumatol* 2016;68(4):837-44. https://doi.org/10.1002/art.39526
26. Kleemann RU, Krocker D, Cedraro A, Tuischer J, Duda GN. Altered cartilage mechanics and histology in knee osteoarthritis: relation to clinical assessment (ICRS Grade). *Osteoarthritis Cartilage* 2005;13(11):958-63. https://doi.org/10.1016/j.joca.2005.06.008
27. Huey DJ, Hu JC, Athanasiou KA. Unlike bone, cartilage regeneration remains elusive. *Science* 2012;338(6109):917-21. https://doi.org/10.1126/science.1222454
28. Legré-Boyer V. Viscosupplementation: techniques, indications, results. *Orthop Traumatol Surg Res* 2015;101(1 Suppl):S101-8. https://doi.org/10.1016/j.otsr.2014.07.027
29. Montarele LF, Pitol DL, Fiorelini Pereira B, Feldman S, Sassoli Fazan VP, Mardegan Issa JP. Histological and immunohistochemical analysis of the effects of topical melatonin treatment associated with collagen sponge and rhBMP-2 protein on bone remodeling. *Biomolecules* 2022;12(12):1738. https://doi.org/10.3390/biom12121738
30. Salamanna F, Giavaresi G, Parrilli A, Martini L, Nicoli Aldini N, Abatangelo G, et al. Effects of intra-articular hyaluronic acid associated to Chitlac (arty-duo®) in a rat knee osteoarthritis model. *J Orthop Res* 2019;37(4):867-876. https://doi.org/10.1002/jor.24259
31. Cardoneanu A, Macovei LA, Burlui AM, Mihai IR, Bratoiu I, Rezus II, et al. Temporomandibular joint osteoarthritis: Pathogenic mechanisms involving the cartilage and subchondral bone, and potential therapeutic strategies for joint regeneration. *Int J Mol Sci* 2022;24(1):171. https://doi.org/10.3390/ijms24010171
32. Park YB, Ha CW, Lee CH, Yoon YC, Park YG. Cartilage regeneration in osteoarthritic patients by a composite of allogeneic umbilical cord blood-derived mesenchymal stem cells and hyaluronate hydrogel: Results from a clinical trial for safety and proof-of-concept with 7 years of extended follow-up. *Stem Cells Transl Med* 2017;6(2):613-21. https://doi.org/10.5966/sctm.2016-0157
33. KhaliliJafarabad N, Behnamghader A, Khorasani MT, Mozafari M. Platelet-rich plasma-hyaluronic acid/chondrotin sulfate/carboxymethyl chitosan hydrogel for cartilage regeneration. *Biotechnol Appl Biochem* 2022;69(2):534-47. https://doi.org/10.1002/bab.2130

34. Gümüş N, Acaban MB, Demirbağ HO. Hyaluronic acid dermal filler promotes cartilage reshaping in rabbit ears. *Aesthetic Plast Surg* 2022;46(4):1932-41. https://doi.org/10.1007/s00266-022-02873-z
35. Ozkan FU, Uzer G, Türkmen I, Yildiz Y, Senol S, Ozkan K, et al. Intra-articular hyaluronate, tenoxicam and vitamin E in a rat model of osteoarthritis: evaluation and comparison of chondroprotective efficacy. *Int J Clin Exp Med* 2015;8(1):1018-26. PMID: 25785088
36. Vitello Xavier M, Farez N, Salvatierra PL, Jardini AL, Kharmandayan P, Feldman S. Biological performance of a bioabsorbable Poly (L-Lactic Acid) produced in polymerization unit: *in vivo* studies. *F1000Res* 2021;10:1275. https://doi.org/10.12688/f1000research.73754.1
37. Paulini M, Camal Ruggieri IN, Ramallo M, Alonso M, Rodriguez-Cabello JC, Esbrit P, et al. Recombinant proteins-based strategies in bone tissue engineering. *Biomolecules* 2021;12(1):3. https://doi.org/10.3390/biom12010003
38. Mardegan Issa JP, dos Santos Neto OM, Macedo AP, Gonçalves Gonzaga M, Lara Pereira YC, Feldman S. Evaluation of tissue in repair with natural latex and/or hyaluronic acid in surgical bone defects. *Braz Dent J* 2021;32(4):83-95. https://doi.org/10.1590/0103-6440202104302
39. Ramallo M, Carreras-Sánchez I, López-Fernández A, Vélez R, Aguirre M, Feldman S, et al. Advances in translational orthopedic research with species-specific multipotent mesenchymal stromal cells derived from the umbilical cord. Preclinical research with MSCs from the umbilical cord. *Histol Histopathol* 2021;36(1):19-30. https://doi.org/10.14670/HH-18-249
40. Coletta DJ, Missana LR, Martins T, Jammal MV, García LA, Farez N, et al. Synthetic three-dimensional scaffold for application in the regeneration of bone tissue. *Journal of Biomaterials and Nanobiotechnology* 2018;9:277-89. https://doi.org/10.4236/jbnb.2018.94016
41. Cícero AM, Issa JPM, Feldman S. Matrices de tercera generación en la ingeniería de tejidos óseos. t al.: Matrices: ingeniería tisular ósea. Actualizaciones en Osteología. 2017;13(2):157. https://ri.conicet.gov.ar/handle/11336/78781
42. Chuckpaiwong B, Berkson EM, Theodore GH. Microfracture for osteochondral lesions of the ankle: outcome analysis and outcome predictors of 105 cases. *Arthroscopy* 2008;24(1):106-12. https://doi.org/10.1016/j.arthro.2007.07.022
43. Ferkel RD, Zanotti RM, Komenda GA, Sgaglione NA, Cheng MS, Applegate GR, et al. Arthroscopic treatment of chronic osteochondral lesions of the talus: long-term results. *Am J Sports Med* 2008;36(9):1750-62. https://doi.org/10.1177/0363546508316773
44. Polat G, Ersen A, Erdil ME, Kizilkurt T, Kilicoglu O, Asik M. Long-term results of microfracture in the treatment of talus osteochondral lesions. *Knee Surg Sports Traumatol Arthrosc* 2016;24(4):1299-303. https://doi.org/10.1007/s00167-016-3990-8
45. Geurts J, Jurić D, Müller M, Schären S, Netzer C. Novel ex vivo human osteochondral explant model of knee and spine osteoarthritis enables assessment of inflammatory and drug treatment responses. *Int J Mol Sci* 2018;19(5):1314. https://doi.org/10.3390/ijms19051314
46. Yousefi A, Hoque ME, Rangabhatala GSV Prasad, Uth N. Current strategies in multiphasic scaffold design for osteochondral tissue engineering: A review *J Biomed Mater Res* A2015;103(7):2460-81. https://doi.org/10.1002/jbm.a.35356
47. Sebastian A, McCool JL, Hum NR, Murugesh DK, Wilson SP, Christiansen BA, et al. Single-cell RNA-Seq reveals transcriptomic heterogeneity and post-traumatic osteoarthritis-associated early molecular changes in mouse articular chondrocytes. *Cells* 2021;10(6):1462. https://doi.org/10.3390/cells10061462

Efficacy of Telerehabilitation Programs for Patients Undergoing Hip Fracture Surgery. Systematic Review

Jesús Sánchez-Lozano,[*] Sandra Martínez-Pizarro[**]
[*]*Physiotherapy Center, Policlínica Baza, Baza, Spain*
[**]*Granada Health District, Granada, Spain*

ABSTRACT
Introduction: Hip fracture is the leading cause of hospitalization in frail geriatric patients, due to osteoporosis and frequent falls. They affect 18% of women and 6% of men. The global number of hip fractures is expected to increase to 4.5 million by 2050. Surgery remains the predominant treatment of choice, and clinical practice guidelines recommend starting rehabilitation early. However, patients often have difficulty attending physical therapy clinics. **Objective:** To evaluate the effectiveness of telerehabilitation programs for patients undergoing hip fracture surgery. **Materials and Methods:** A review was carried out following the PRISMA guidelines. The databases of PubMed, Cinahl, PsycINFO, SPORTDiscus, Academic Search Complete, Lilacs, IBECS, CENTRAL, SciELO, and WOS were consulted. The Cochrane tool was used to assess the risk of bias. **Results:** 59 articles were retrieved from all databases. After applying the inclusion criteria, 5 clinical studies remained. The total sample was 282 patients operated on for hip fractures. The total duration of telerehabilitation ranged from 3 to 12 weeks. All studies showed safety and good tolerability. **Conclusions:** Telerehabilitation is effective in patients undergoing hip fracture surgery. This method improves mobility, quality of life, effectiveness of falls, anxiety, depression, and supports physical recovery to pre-fracture levels.
Keywords: Telerehabilitation; hip fracture; review.
Level of Evidence: IV

Eficacia de los programas de telerrehabilitación para pacientes operados de fractura de cadera. Revisión sistemática

RESUMEN
Introducción: La fractura de cadera es la causa más común de hospitalización en personas de edad avanzada, frágiles, debido a la osteoporosis y las caídas recurrentes. El 18% de las mujeres y el 6% de los hombres sufren este tipo de fractura. Se espera que el número global de estas fracturas aumente a 4,5 millones en el 2050. La cirugía sigue siendo el tratamiento de elección predominante, y las guías de práctica clínica recomiendan iniciar la rehabilitación de forma precoz. Sin embargo, en muchas ocasiones, los pacientes tienen problemas para asistir a las clínicas de fisioterapia. **Objetivo:** Evaluar la eficacia de los programas de telerrehabilitación para pacientes operados de fractura de cadera. **Materiales y Métodos:** Se realizó una revisión siguiendo la normativa PRISMA. Se consultaron las bases de datos de PubMed, CINAHL, PsycINFO, SPORTDiscus, Academic Search Complete, LILACS, IBECS, CENTRAL, SciELO y WOS. Se utilizó la herramienta Cochrane para valorar el riesgo de sesgo. **Resultados:** Se obtuvieron 59 artículos. Tras aplicar los criterios de inclusión, quedaron 5 ensayos clínicos. La muestra total estaba formada por 282 pacientes operados de fractura de cadera. La duración total de la telerrehabilitación osciló entre 3 y 12 semanas. En todos los estudios, se comunicó la seguridad y la buena tolerabilidad. **Conclusiones:** La telerrehabilitación es eficaz en pacientes operados de fractura de cadera. Este método mejora la movilidad, la calidad de vida, el nivel de miedo a caerse, la ansiedad, la depresión, y favorece la recuperación del nivel de estado físico anterior a la fractura.
Palabras clave: Telerrehabilitación; fractura de cadera; revisión.
Nivel de Evidencia: IV

Received on April 5th, 2024. Accepted after evaluation on May 28th, 2024 • Dr. JESÚS SÁNCHEZ LOZANO • jesus-dbz@hotmail.com ID https://orcid.org/0009-0003-7595-5733

How to cite this article: Sánchez-Lozano J, Martínez-Pizarro S. Efficacy of Telerehabilitation Programs for Patients Undergoing Hip Fracture Surgery. Systematic Review. *Rev Asoc Argent Ortop Traumatol* 2024;89(4):385-392. https://doi.org/10.15417/issn.1852-7434.2024.89.4.1942

INTRODUCTION

Hip fracture is a serious injury affecting the upper part of the femur, which can occur either in the neck of the femur or in the intertrochanteric region. It causes severe pain, immobility, bruising, and swelling. Visually, one lower limb may appear shorter than the other, often accompanied by an outward twisting of the lower limb on the side of the injured hip.[1,2]

Hip fracture is the most common cause of hospitalization among frail elderly individuals, primarily due to osteoporosis and recurrent falls. It is a significant and debilitating condition in the elderly, particularly in women.[3]

Epidemiological data vary between countries, but it is estimated that globally, about 18% of women and 6% of men will suffer a hip fracture. Although the age-standardized incidence is gradually decreasing in many countries, this trend is more than offset by the aging population. As a result, the global number of hip fractures is expected to increase from 1.26 million in 1990 to 4.5 million in 2050.[4,5]

Patients with hip fractures are typically elderly and often have various comorbidities. Upon hospital admission, they frequently present with acute pain, electrolyte disturbances, anemia, coagulopathy, and delirium. As hip fracture rates increase with age, so do morbidity, mortality, and functional impairment, making the management of these patients a significant challenge for orthogeriatric and rehabilitation healthcare professionals. [6,7]

The economic cost associated with hip fractures is substantial, as they require prolonged hospitalization and subsequent rehabilitation. Additionally, hip fractures are linked to other negative outcomes, such as disability, depression, and cardiovascular disease, all of which add to the cost.[8] Despite the poor prognosis, surgery remains the predominant treatment of choice today.[9]

Clinical practice guidelines for rehabilitation after hip fracture surgery recommend early initiation of treatment. However, many patients face difficulties in attending physiotherapy sessions due to mobility issues, transportation challenges, family availability, or economic constraints. For this reason, telerehabilitation has recently been proposed as a viable alternative.[10]

Telerehabilitation refers to the use of technology to deliver rehabilitation services to patients in their homes. Given the need for long-term care for individuals with hip fractures, home-based telerehabilitation could enhance independence, reduce hospital stays, and lessen the burden on caregivers.[11]

The aim of this study was to review the available scientific literature on the efficacy of telerehabilitation programs for patients with hip fractures.

MATERIALS AND METHODS

A literature review was conducted following the recommendations of the PRISMA (*Preferred Reporting Items for Systematic Review and Meta-Analysis*) Statement. Specifically, the PRISMA 2020 Statement and its accompanying 27-item checklist were used.[12]

Electronic searches were performed across multiple databases. The primary database utilized was PubMed, accessed via the *National Library of Medicine* platform. In addition, LILACS and IBECS were consulted through the *Virtual Health Library* platform; CENTRAL via the *Cochrane Library* platform; and Academic Search Complete, PsycINFO, CINAHL, and SPORTDiscus through the EBSCO Host platform. WOS Core and SciELO were accessed through the *Web of Science.*

The search strategy was based on the following PICOS (*Patient, Intervention, Comparison, Outcome, Study*) framework:[13]

- P (Patient): Patients who underwent surgery for hip fracture.
- I (Intervention): Telerehabilitation.
- C (Comparison): Not applicable.
- O (Outcome): Efficacy.
- S (Study Design): Randomized controlled clinical trials.

The search strategy in the various databases involved using a combination of terms from the English thesaurus, MeSH (*Medical Subject Headings*) terms, and free terms (TW terms). Additionally, the truncated term "Random*" was used to capture studies classified as randomized clinical trials. All terms were combined using the Boolean operators "AND" and "OR."

Only randomized clinical trials published in national and international peer-reviewed journals within the last 10 years were included. These studies specifically evaluated the efficacy of telerehabilitation programs for hip fracture patients. The risk of bias was analyzed individually using the tool proposed by the Cochrane Handbook for Systematic Reviews of Interventions. This tool comprises six specific domains that are assessed as having a high, medium, or low risk of bias. The domains evaluated include selection bias, performance bias, detection bias, attrition bias, reporting bias, and other biases.[14]

The quality of evidence was assessed using the *Grading of Recommendations, Assessment, Development and Evaluation* (GRADE) system. This system evaluates the quality of evidence based on the confidence users can have that the reported effect accurately reflects the item being assessed. The quality of evidence assessment considers factors such as risk of study bias, inconsistency, imprecision, publication bias, indirect outcomes, and other elements that may influence the overall quality of evidence. To summarize this information, summary of findings tables were developed.[15]

RESULTS

A total of 59 studies were retrieved from all the databases consulted. After removing duplicates using the Rayyan QCRI program,[16] the titles and abstracts of 27 studies were reviewed, with 16 meeting the inclusion criteria. Upon reading the full text of these studies, 11 were excluded for not meeting the specific selection criteria. Ultimately, five trials were included in this systematic review (Figure).

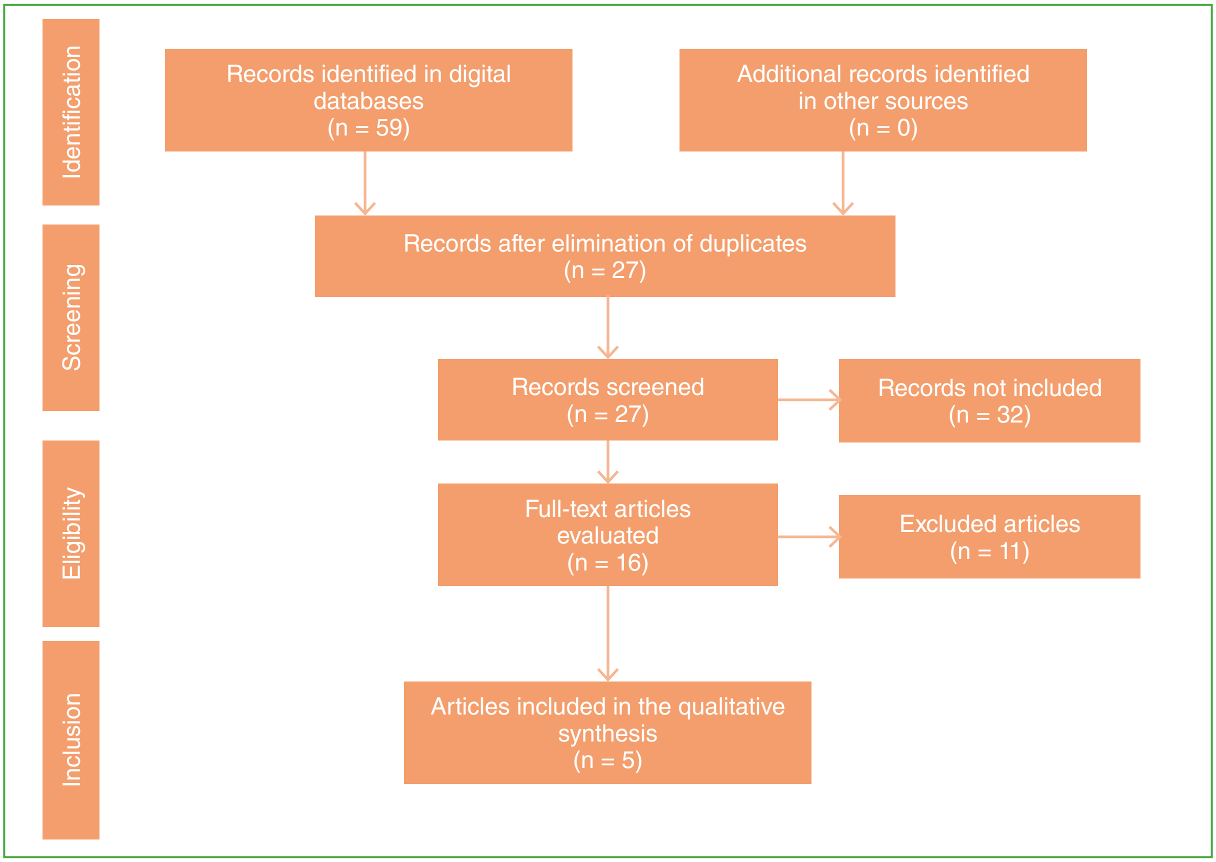


Figure. Flowchart.

All studies included in this review were randomized controlled clinical trials, published between 2015 and 2024.

Regarding the countries where these studies were conducted, 40% were from Spain, 20% from the United States, 20% from Israel, and the remaining 20% from China. The studies were published in journals such as: *Stud Health Technol Inform, BMC Geriatr, Int J Environ Res Public Health*, and *J Telemed Telecare* (Table 1).

Table 1. Included studies

Author	Year	Journal	Country	Design
Bedra and Finkelstein[17]	2015	Stud Health Technol Inform	United States	RCT
Gilboa et al.[18]	2019	BMC Geriatr	Israel	RCT
Ortiz-Piña et al.[19]	2021	Int J Environ Res Public Health	Spain	RCT
Li et al.[20]	2022	J Telemed Telecare	China	RCT
Mora-Traverso et al.[21]	2024	J Telemed Telecare	Spain	RCT

RCT = randomized controlled trial.

In all these studies, telerehabilitation was implemented for hip fracture patients in the experimental group. In the trials by Bedra and Finkelstein, Ortiz-Piña et al., and Mora-Traverso et al., the control group received face-to-face rehabilitation, whereas the control groups in the studies by Gilboa et al. and Li et al. were provided with an exercise booklet for self-directed practice.

The sample consisted of 282 patients who underwent hip fracture surgery. The clinical trial by Ortiz-Piña et al. had the largest sample size (133 patients), while the trial by Bedra and Finkelstein had the smallest (14 patients).

Telerehabilitation duration ranged from 3 to 12 weeks. Across all studies, telerehabilitation was found to be safe, tolerable, and free of significant side effects.

A variety of measurement instruments were used to evaluate the patients. The *Timed Up and Go* test was used in the trials by Gilboa et al. and Ortiz-Piña et al. Motor performance was assessed in the studies by Gilboa et al., Ortiz-Piña et al., and Li et al. Bedra and Finkelstein, along with Mora-Traverso et al., used anxiety and depression scales. The *Yale Physical Activity Survey* and Barthel Index were utilized only in the study by Bedra and Finkelstein. The *2-minute walk* test, *10-meter walk* test, *sit-to-stand* test, gait speed, and mean stride length were used exclusively in the study by Gilboa et al. The *Functional Independence Measure* and the *Short Physical Performance Battery* were only employed in the study by Ortiz-Piña et al. The level of fear of falling was assessed only in the study by Li et al., while the EuroQol scale and the level of physical fitness, evaluated with the *International Fitness Scale*, were used only in the study by Mora-Traverso et al (Table 2).

The main results are summarized below in chronological order:

The study by Bedra and Finkelstein, conducted in 2015 in the United States, examined the efficacy of home-based telerehabilitation in older adults following hip fracture. The study aimed to assess the impact of home-based telerehabilitation on range of motion, psycho-behavioral factors, quality of life, and satisfaction with care in community-dwelling older adults during the post-acute phase of recovery after hip fracture. It also sought to estimate the acceptance of the telerehabilitation system and compliance with the exercise program. Fourteen patients were randomly assigned to either the telerehabilitation or face-to-face rehabilitation group. The instruments used included the *Center for Epidemiologic Studies Depression Scale*, the *Yale Physical Activity Survey*, and the Barthel Index. Results showed statistically significant improvements in exercise self-efficacy, range of motion, quality of life, and patient satisfaction after 30 days of telerehabilitation.[17]

Table 2. Intervention characteristics.

Author	Intervention	Sample	Safe	Duration	Instruments	Results
Bedra and Finkelstein[17]	Telerehabilitation vs. on-site rehabilitation	14	Yes	4 weeks	*Center for Epidemiologic Studies Depression Scale*, *Yale Physical Activity Survey*, Barthel Index	Telerehabilitation improves exercise self-efficacy, range of motion, quality of life and patient satisfaction.
Gilboa et al.[18]	Telerehabilitation vs. workbooks	40	Yes	6 weeks	*Timed Up and Go*, *2 min walk* test, *10 m walk* test, *sit-and-stand* tests, gait speed and mean stride length	Telerehabilitation generates a positive effect on the mobility of people after hip fracture surgery
Ortiz-Piña et al.[19]	Telerehabilitation vs. on-site rehabilitation	133	Yes	12 weeks	*Functional Independence Measure*, *Timed Up and Go* and *Short Physical Performance Battery.*	Telerehabilitation improves *Functional Independence Measure* scores and functional recovery.
Li et al.[20]	Telerehabilitation vs. workbooks	31	Yes	3 weeks	Motor performance, function in activities of daily living and fear of falling.	Telerehabilitation improves the level of fear of falling and the performance of instrumental activities of daily living
Mora-Traverso et al.[21]	Telerehabilitation vs. on-site rehabilitation	64	Yes	12 weeks	EuroQol questionnaire, *Hospital Anxiety and Depression Scale* and fitness level, according to the *International Fitness Scale.*	Telerehabilitation improves quality of life, anxiety, and depression, and favors the recovery of the level of previous physical condition

In the 2019 clinical trial by Gilboa et al. in Israel, the effects of telerehabilitation on range of motion after hip fracture surgery were evaluated. This randomized controlled trial included 40 participants who were randomly assigned to either a control group or a telerehabilitation intervention group (6 weeks, 3 sessions/week). Telerehabilitation was based on video clips of common rehabilitation exercises focused on the lower extremities. The control group received an exercise booklet. Both groups participated in twice-weekly physical therapy sessions. Outcome measures included the *Timed Up and Go* test, *2-minute walk* test, *10-meter walk* test, *sit-to-stand* tests, gait speed, and mean stride length. The telerehabilitation group showed greater improvements in five out of six tests compared to the control group. The most significant improvements in the telerehabilitation group were observed in the 2-minute walk (86.1%) and gait speed (65.6%) tests. At follow-up, the telerehabilitation group continued to improve in all outcome measures, whereas the control group showed no change in five of the six measures. Telerehabilitation, as a complementary treatment to standard physical therapy, had a positive effect on mobility in patients following hip fracture surgery.[18]

The study by Ortiz-Piña et al. (2021) in Spain examined the effect of a telerehabilitation program on the functional recovery of older adults who underwent surgery for hip fracture, comparing it to face-to-face rehabilitation. The telerehabilitation group participated in a 12-week program supervised by their family caregivers, while the control group received the usual postoperative rehabilitation. The primary endpoint was patient-reported functional status, assessed using the *Functional Independence Measure*. Performance-based functional recovery was also evaluated using the *Timed Up and Go* test and the *Short Physical Performance Battery*. The study included 133 participants. Those in the telerehabilitation group scored higher on the *Functional Independence Measure* and performed better on the *Timed Up and Go* test compared to the control group. However, differences between the groups on the *Short Physical Performance Battery* were not statistically significant after the intervention. The telerehabilitation intervention proposed in this study is a valuable treatment option in the recovery process of older adults with hip fractures.[19]

The study by Li et al. (2022) in China examined the efficacy of home telerehabilitation using a smartphone to improve motor performance, function in activities of daily living, and the level of fear of falling in outpatients receiving rehabilitation after hip fracture surgery. Thirty-one patients were randomly assigned to either the experimental group or the comparison group. The experimental group followed a telerehabilitation program, while the comparison group received paper-and-pencil instructions for the home program weekly for three weeks. In the experimental group, the level of fear of falling and performance of instrumental activities of daily living improved significantly in the post-intervention period and at follow-up. This study supports the potential use of telerehabilitation for adults after hip fracture surgery.[20]

The study by Mora-Traverso et al. (2024) in Spain analyzed the efficacy of telerehabilitation on quality of life, psychological factors, and physical condition in patients who had suffered a hip fracture. The study included 64 patients. The intervention group received multidisciplinary telerehabilitation at home for 12 weeks, while the control group received traditional care and rehabilitation. Outcomes measured included patients' quality of life using the EuroQol Questionnaire (EQ-5D), psychological factors (anxiety and depression) using the *Hospital Anxiety and Depression Scale* (HADS), and fitness level assessed with the *International Fitness Scale*. The telerehabilitation group showed an increase in quality of life, while the control group's score worsened after three months. The total HADS score decreased more in the telerehabilitation group than in the control group. Additionally, the telerehabilitation group recovered a fitness level closer to that at the time of the hip fracture compared to the control group ($p = 0.022$). The telerehabilitation program appears to be a promising treatment to improve the quality of life and psychological factors (anxiety and depression) of older adults after a hip fracture, as well as to help them regain their previous level of physical fitness.[21]

DISCUSSION

The results obtained indicate that telerehabilitation is a valuable tool for use in patients with hip fractures.

These findings are consistent with those of similar studies, such as the 2021 study by Ariza-Vega et al., which explored family caregivers' perspectives on the recovery process of older adults with hip fractures and described the experiences of caregivers who used telerehabilitation or home care. Forty-four caregivers were interviewed. Caregivers preferred the telerehabilitation program over in-person rehabilitation because it improved post-fracture recovery, helped them acquire skills for home management, and was more convenient in terms of time, transportation, and cost.[22]

In 2023, Tsuge et al. conducted a systematic review similar to ours, aiming to determine the efficacy of telerehabilitation in patients after hip fracture surgery through a systematic review and meta-analysis. Data were collected until mid-2022. Their results were similar to ours regarding the efficacy of rehabilitation and further suggested that telerehabilitation could boost patients' confidence in performing activities of daily living without fear of falling.[23]

Another similar review was conducted by Bramanti et al. in 2023. They also analyzed the safety and efficacy of telerehabilitation in hip fracture patients. Their conclusions align with ours, finding that telerehabilitation is safe, effective, well-tolerated by patients, and not inferior to conventional physical therapy. Additionally, they highlighted its positive role in psychological rehabilitation, the prevention of complications, and the maintenance of achieved goals.[24]

The limitations of this study include those inherent to the search strategies selected for this systematic review, such as the language restriction to Spanish and English, which may have led to the exclusion of relevant articles. However, appropriate thesauri were used during the database searches. Additionally, many clinical trials did not specify the exact form of telerehabilitation used, potentially leading to uncontrolled variations across studies. This, along with incomplete data in some of the articles reviewed, limits the scope of the analysisDespite the promising results obtained, further research is needed to establish a unified protocol regarding frequency, session duration, program duration, and the number of sessions, supported by long-term follow-up of patients. Randomized controlled clinical studies analyzing potential synergistic effects with other therapies or treatments are also necessary. This approach will enable healthcare professionals to provide the best care based on the latest scientific evidence.

CONCLUSIONS

Telerehabilitation is effective for patients recovering from hip fracture surgery. This rehabilitation method improves the *Functional Independence Measure*, exercise self-efficacy, range of motion, quality of life, fear of falling, and performance of instrumental activities of daily living. It is also effective in reducing anxiety and depression, increasing patient satisfaction, and promoting the recovery of pre-fracture fitness levels.

Conflict of interest: The authors declare no conflicts of interest.

S. Martínez-Pizarro ORCID ID: https://orcid.org/0000-0003-3070-8299

REFERENCES

1. Veronese N, Maggi S. Epidemiology and social costs of hip fracture. *Injury* 2018;49(8):1458-60. https://doi.org/10.1016/j.injury.2018.04.015
2. Bhandari M, Swiontkowski M. Management of acute hip fracture. *N Engl J Med* 2017;377(21):2053-62. https://doi.org/10.1056/NEJMcp1611090
3. Brink O. Hip fracture clearance: How much optimisation is necessary? *Injury* 2020;51Suppl 2:S111-S117. https://doi.org/10.1016/j.injury.2020.02.046
4. Li L, Bennett-Brown K, Morgan C, Dattani R. Hip fractures. *Br J Hosp Med (Lond)* 2020;81(8):1-10. https://doi.org/10.12968/hmed.2020.0215
5. Dapaah D, Martel DR, Iranmanesh F, Seelemann C, Laing AC, Willett T. Fracture toughness: Bridging the gap between hip fracture and fracture risk assessment. *Curr Osteoporos Rep* 2023;21(3):253-65. https://doi.org/10.1007/s11914-023-00789-4
6. Katsanos S, Sioutis S, Reppas L, Mitsiokapa E, Tsatsaragkou A, Mastrokalos D, et al. What do hip fracture patients die from? *Eur J Orthop Surg Traumatol* 2023;33(4):751-7. https://doi.org/10.1007/s00590-022-03250-x
7. Loggers SAI, Van Lieshout EMM, Joosse P, Verhofstad MHJ, Willems HC. Prognosis of nonoperative treatment in elderly patients with a hip fracture: A systematic review and meta-analysis. *Injury* 2020;51(11):2407-13. https://doi.org/10.1016/j.injury.2020.08.027
8. Inoue T, Maeda K, Nagano A, Shimizu A, Ueshima J, Murotani K, et al. Undernutrition, sarcopenia, and frailty in fragility hip fracture: Advanced strategies for improving clinical outcomes. *Nutrients* 2020;12(12):3743. https://doi.org/10.3390/nu12123743

9. Fairhall NJ, Dyer SM, Mak JC, Diong J, Kwok WS, Sherrington C. Interventions for improving mobility after hip fracture surgery in adults. *Cochrane Database Syst Rev* 2022;9(9):CD001704. https://doi.org/10.1002/14651858.CD001704.pub5
10. Griffiths R, Babu S, Dixon P, Freeman N, Hurford D, Kelleher E, et al. Guideline for the management of hip fractures 2020: Guideline by the Association of Anaesthetists. *Anaesthesia* 2021;76(2):225-37. https://doi.org/10.1111/anae.15291
11. Romero Pisonero E, Mora Fernández J. Multidisciplinary geriatric rehabilitation in the patient with hip fracture and dementia. *Rev Esp Geriatr Gerontol* 2019;54(4):220-9. https://doi.org/10.1016/j.regg.2018.11.001
12. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *J Clin Epidemiol* 2021;134:178-89. https://doi.org/10.1016/j.jclinepi.2021.03.001
13. Mamédio da Costa Santos C, Andrucioli de Mattos Pimenta C, Cuce Nobre MR. The PICO strategy for the research question construction and evidence research. *Rev Lat Am Enfermagem* 2007;15(3):508-11. https://doi.org/10.1590/s0104-11692007000300023
14. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch WA (eds). *Cochrane Handbook for Systematic Reviews of Interventions*. 2nd ed. Chichester (UK): John Wiley & Sons; 2019.
15. Aguayo-Albasini JL, Flores-Pastor B, Soria-Aledo V. Sistema GRADE: Clasificación de la calidad de la evidencia y graduación de la fuerza de la recomendación. *Cirugía Española* 2014;92(2):82-8. https://doi.org/10.1016/j.ciresp.2013.08.002
16. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan—a web and mobile app for systematic reviews. *Syst Rev* 2016;5(1):210. https://doi.org/10.1186/s13643-016-0384-4
17. Bedra M, Finkelstein J. Feasibility of post-acute hip fracture telerehabilitation in older adults. *Stud Health Technol Inform* 2015;210:469-73. PMID: 25991191
18. Gilboa Y, Maeir T, Karni S, Eisenberg ME, Liebergall M, Schwartz I, et al. Effectiveness of a tele- rehabilitation intervention to improve performance and reduce morbidity for people post hip fracture study protocol for a randomized controlled trial. *BMC Geriatr* 2019;19(1):135. https://doi.org/10.1186/s12877-019-1141-z
19. Ortiz-Piña M, Molina-Garcia P, Femia P, Ashe MC, Martín-Martín L, Salazar-Graván S, et al. Effect of tele-rehabilitation compared with home-based in-person rehabilitation for older adult's function after hip fracture. *Int J Environ Res Public Health* 2021;18(10):5493. https://doi.org/10.3390/ijerph18105493
20. Li CT, Hung GK, Fong KN, Gonzalez PC, Wah SH, Tsang HW. Effects of home-based occupational therapy telerehabilitation via smartphone for outpatients after hip fracture surgery: A feasibility randomised controlled study. *J Telemed Telecare* 2022;28(4):239-47. https://doi.org/10.1177/1357633X20932434
21. Mora-Traverso M, Prieto-Moreno R, Molina-Garcia P, Salas-Fariña Z, Martín-Martín L, Martín- Matillas M, et al. Effects of the @ctivehip telerehabilitation program on the quality of life, psychological factors and fitness level of patients with hip fracture. *J Telemed Telecare* 2024;30(3):549-58. https://doi.org/10.1177/1357633X211073256
22. Ariza-Vega P, Castillo-Pérez H, Ortiz-Piña M, Ziden L, Palomino-Vidal J, Ashe MC. The journey of recovery: Caregivers' perspectives from a hip fracture telerehabilitation clinical trial. *Phys Ther* 2021;101(3):pzaa220. https://doi.org/10.1093/ptj/pzaa220
23. Tsuge T, Yamamoto N, Taito S, Miura T, Shiratsuchi D, Yorifuji T. Efficacy of telerehabilitation for patients after hip fracture surgery: A systematic review and meta-analysis. *J Telemed Telecare* 2023 Jul 7:1357633X231181632. https://doi.org/10.1177/1357633X231181632
24. Bramanti A, Ciurleo R, Vecchione C, Turolla A, Piramide N, Ciccarelli M, et al. Telerehabilitation: A solution for patients after hip fracture? *Transl Med UniSa* 2024;26(1):30-7. https://doi.org/10.37825/2239-9747.1048

A Discussion on Swischuk's Line. Literature Review

Claudio A. Fernández,[*] María Gabriela Miranda,[*,] María Emilia Moreiro[*,**]**
[*]*Orthopedics and Traumatology Service, Hospital de Niños de La Plata, Buenos Aires, Argentina.*
[**]*School of Medical Sciences, Universidad Nacional de La Plata, Buenos Aires, Argentina.*

ABSTRACT

Introduction: Traumatic injuries to the upper cervical spine are prevalent in young children. In 1977, Leonard Swischuk published an article on a cervical spinolaminar line to determine the physiological or pathological relationship between the second and third cervical vertebrae (C2-C3). The purpose of this study is to review the available literature on the indications and diagnostic limitations of this line, illustrating this with our own clinical examples. **Materials and Methods:** We conducted bibliographic research on pediatric cervical spinal trauma including the following databases: PubMed (Medline, MedlinePlus and Cochrane), Elsevier, VHL Virtual Health Library of Bireme (which includes Lilacs) and the AAOT Database. In addition, a manual search was carried out, including citations from recently published references and specialty textbook chapters. **Results:** Out of 72 articles, we selected 39 that addressed current epidemiological aspects, as well as others that focused on Swischuk's line and upper cervical spine injuries, which were mostly case reports. **Conclusion:** Swischuk's line is an effective diagnostic tool for evaluating children's spines after trauma or in some syndromic diseases. However, it may not be sensitive in some cases, such as C2-C3 subluxation or facet dislocation. Other complementary radiodiagnostic measures should be applied.

Keywords: Children; Swischuk line; C2-C3 cervical instability.
Level of Evidence: IV

Una discusión sobre la línea espinolaminar de Swischuk. Revisión bibliográfica

RESUMEN

Introducción: Las lesiones traumáticas del raquis cervical superior son prevalentes en la primera y segunda infancia. En 1977, Leonard Swischuk publicó un artículo sobre una línea espinolaminar cervical a efectos de determinar la relación, fisiológica o patológica, entre las vértebras cervicales C2-C3. El objetivo de este artículo es presentar una revisión bibliográfica sobre las indicaciones y las limitaciones diagnósticas de la línea de Swischuk, con ilustración de casos clínicos propios. **Materiales y Métodos:** Se efectuó una investigación bibliográfica sobre el trauma espinal cervical en pediatría que incluyó las bases de datos PubMed (Medline, MedlinePLus y Cochrane), Elsevier, BVS Biblioteca Virtual en Salud de Bireme (que incluye Lilacs) y la correspondiente a la AAOT. También se llevó a cabo una indagación manual o no electrónica por citas de referencias de capítulos de libros de texto de la especialidad de publicación reciente. **Resultados:** Sobre 72 artículos, se seleccionaron 39 relacionados con aspectos epidemiológicos actuales, y otros específicos sobre la línea de Swischuk y lesiones del raquis cervical superior, estos últimos mayoritariamente reportes de casos. **Conclusión:** La línea de Swischuk es una herramienta diagnóstica útil para evaluar la columna cervical infantil en casos de traumatismo y en algunas entidades sindrómicas. Sin embargo, puede no ser sensible en algunas situaciones de subluxación o luxación facetaria C2-C3. Se deberían adicionar otras medidas complementarias de radiodiagnóstico.

Palabras clave: Niños; línea de Swischuk; inestabilidad cervical C2-C3.
Nivel de Evidencia: IV

INTRODUCTION

Traumatic injuries of the cervical spine in childhood have an incidence of 1.5% and a prevalence of over 80%, with a varying distribution according to age: 72.7% in children up to 3 years old, 47.8% between 3 and 8 years old, and 29% thereafter.[1-4] In other words, there is a strong correlation between age and the frequency of high cervical traumatic injuries, with a male-to-female sex ratio of 1.6:1.[1] Several anatomical and physiological fac-

Received on January 4th, 2024. Accepted after evaluation on June 7th, 2024 • Dr. CLAUDIO A. FERNÁNDEZ • claudioalfredofernandez619@gmail.com https://orcid.org/0000-0003-2350-3885
How to cite this article: Fernández CA, Miranda MG, Moreiro ME. A Discussion on Swischuk's Line. Literature Review. *Rev Asoc Argent Ortop Traumatol* 2024;89(4):393-402. https://doi.org/10.15417/issn.1852-7434.2024.89.4.1897

tors make this region more susceptible to trauma: tissue hyperlaxity, the locking stability of the atlanto-occipital joint, lower muscle tone, and cervico-cephalic volume disproportion. A critical factor is the progressive inclination of the facet joints, which are angled at 30° in the first years of life and 70° in the prepubertal stage. The C2-C3 disc serves as the fulcrum or transitional area between two mobile segments, the craniocervical and subaxial spine. In the early years of life, the upper cervical spine is often the site of ligament injuries, with a prevalence estimated between 25% and 44%.[5] The causes include traffic accidents, falls, sports injuries, non-accidental trauma, and obstructed labor.[2,5-8] The probability of neurological involvement ranges from 35% to 60%, but, unlike in adults, the prognosis for recovery is more favorable.[7,9,10] However, the likelihood of death is significant in early and second childhood, ranging from 16% to 18%, usually associated with traumatic brain injury.[3,9] Several *post mortem* anatomical pathology investigations have documented a variety of injury patterns.[11,12] According to the US National Pediatric Trauma Registry, 50% of these patients showed no radiographic evidence of injury, constituting the so-called SCIWORA (*Spinal Cord Injury Without Radiographic Abnormality*). [1]

The uncertainty generated by certain radiographic aspects of the upper cervical spine in the context of trauma led Leonard Swischuk, a Professor of Radiology in Texas, USA, to publish an article in *Radiology* in 1977. He prospectively investigated the usefulness of a line drawn on radiographs of the upper cervical spine in children, known as the spinolaminar line, or Swischuk's line (SL), whose main objective was to differentiate physiological subluxation from pathological subluxation in the C2-C3 segment, and to diagnose or raise suspicion of isthmic spondylolisthesis of the axis (hangman's lesion) (Figures 1 and 2).[13] To achieve this, he drew a line on a strict lateral radiograph, extending from the spinolaminar junction of the atlas to that of C3. Under normal conditions, the spinolaminar cortex of C2 should align with this straight line, with a tolerance of 1.5 to 2 mm in the sagittal plane, both anteriorly and posteriorly. Cephalically, SL continues harmoniously with the opisthion (Figure 1).

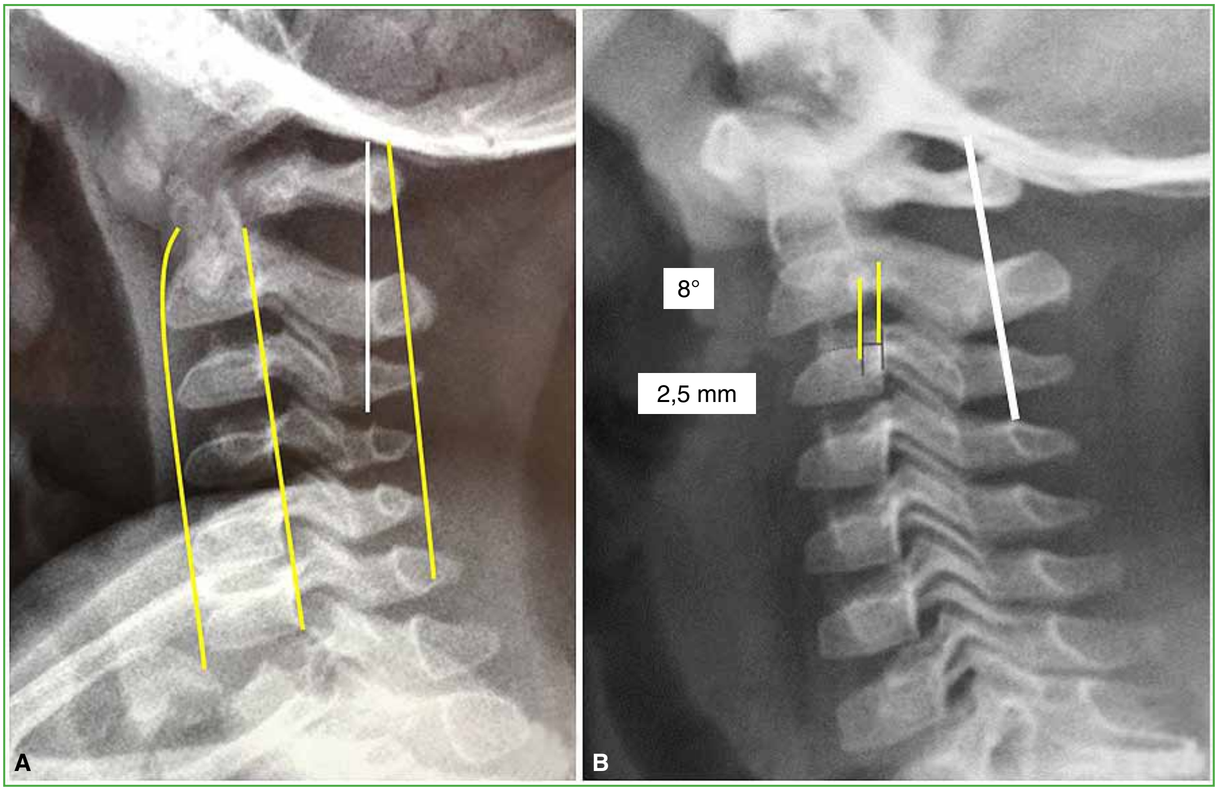


Figure 1. Lateral radiograph of the cervical spine of a 2-year-old boy. **A.** Physiological image: sagittal lines of the vertebral bodies, spinous processes (in yellow) and Swischuk's line (in white), which continues cephalad to the opisthion.
B. Physiological displacement in a 3-year-old child, where the spinolaminar cortices of the first three cervical vertebrae are located above Swischuk's line. There is very mild kyphosis and a C2-C3 displacement of 2.5 mm (within normal parameters).

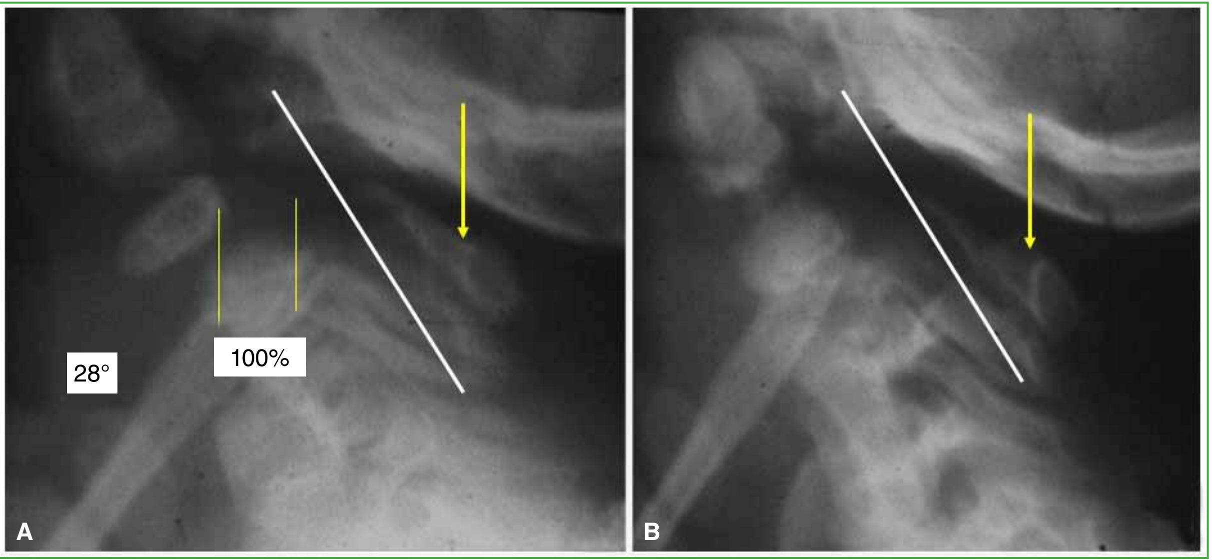


Figure 2. Cervical spine radiograph of a 2-year-old girl following high-energy trauma, showing axis spondylolisthesis without neurological damage. **A.** The axis spinolaminar cortex is markedly posterior to Swischuk's line (white arrow), with 100% displacement of the C2 vertebra and 28° of kyphosis. **B.** Post-reduction under general anesthesia with Minerva plaster cast.

In doubtful situations, a radiographic exposure with slight neck extension should provide an image of absolute normality.[13-15] This radiographic parameter is routinely used by orthopedic physicians in pediatric emergency settings, who attribute to it an almost axiomatic predictive value, supported by numerous publications.[12,16-21] Although the SL was originally drawn on a radiograph, it can also be applied to other imaging studies, such as computed tomography (CT) and magnetic resonance imaging (MRI) (Figure 3).

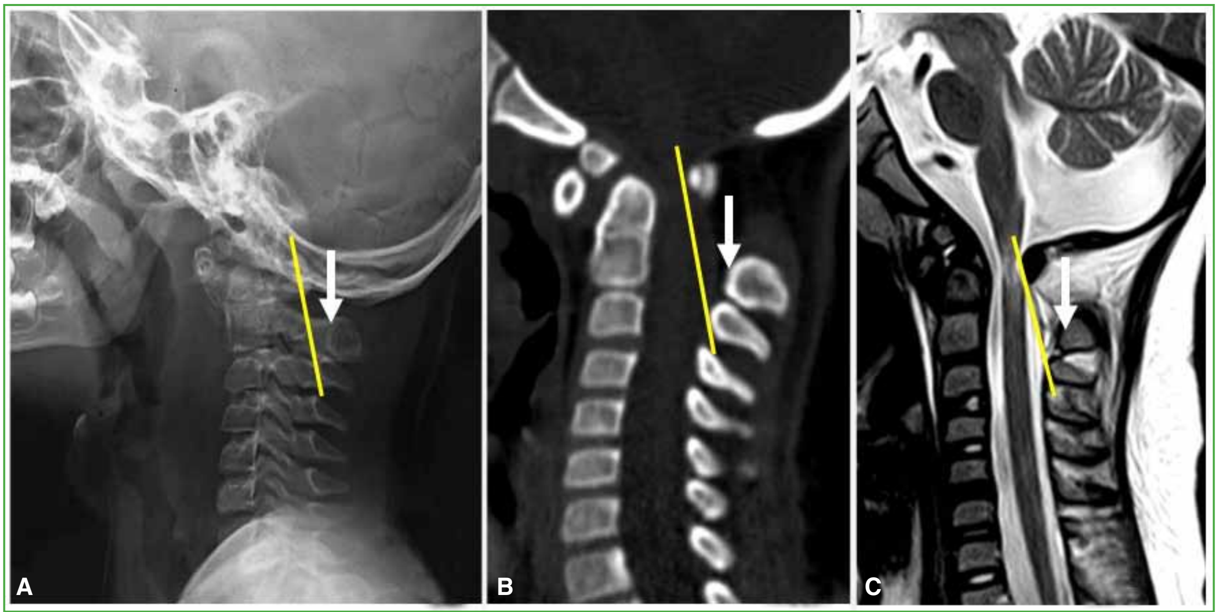


Figure 3. Six-year-old boy with Down syndrome: hypotonia of all four limbs exacerbated by trauma. **A-C.** Radiograph, CT and MRI of the skull base and upper cervical spine, respectively. The SL tracing shows retroposition of the spinolaminar line of the axis, severe C1-C2 instability, and lack of continuity of the SL with the opisthion. There is significant neuroaxis compression and myelomalacia.

Certain traumatic or congenital conditions outside the C2-C3 region, such as fractures or epiphysiolysis of the axis and C1-C2 sagittal instability, can significantly alter the SL (Figures 3 and 4). Observations made after the publication of Swischuk's article, along with insights from our daily practice, motivated this research, which aims to conduct a literature review on the interpretation and diagnostic limitations of the SL, supplemented with clinical case examples.

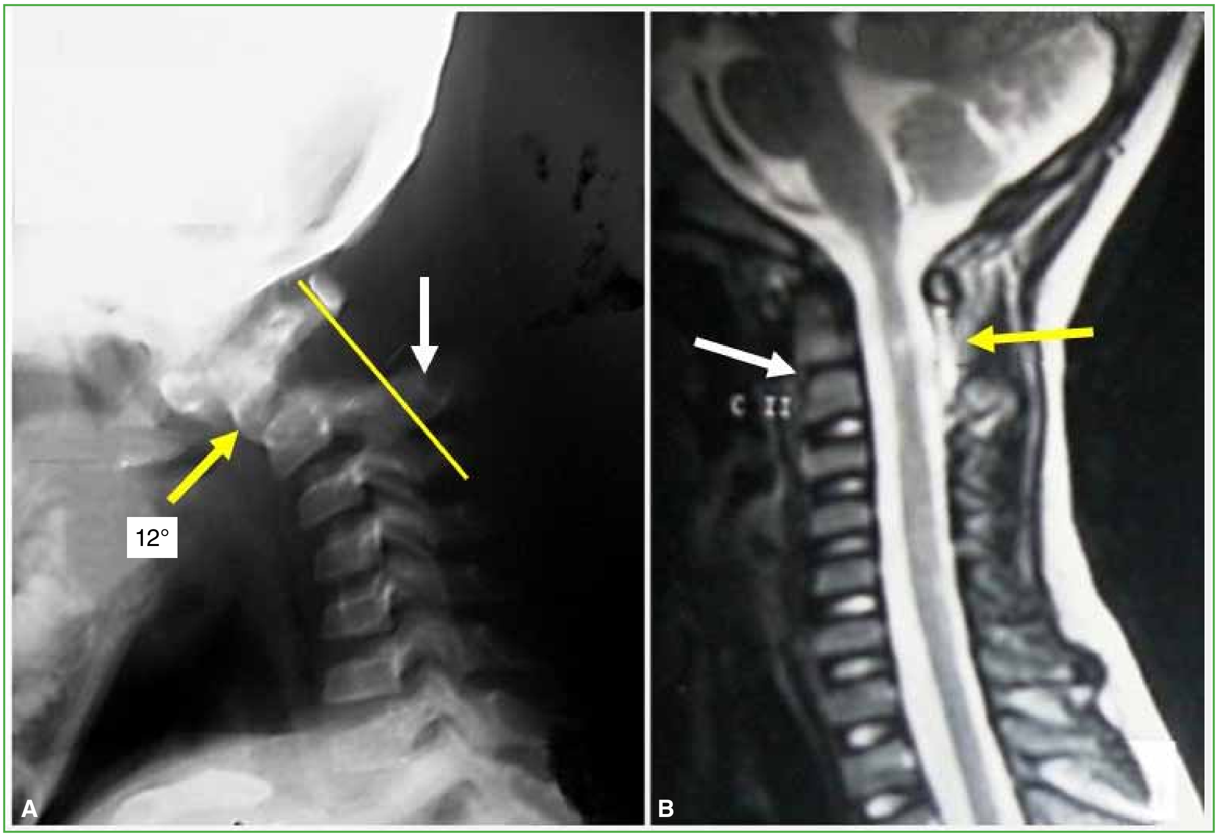


Figure 4. Four-year-old girl who fell from a height, presenting with Frankel D neurological status. Cervical spine images on admission. **A.** Radiograph: dentocentral epiphysiolysis of the axis in flexion, with anterior displacement of the odontoid process (yellow arrow). Kyphosis of 12 degrees, with the spinolaminar line of C2 clearly posterior to the SL (white arrow). **B.** MRI: separation of the dentocentral synchondrosis (white arrow), with posterior and intracanal fluid signal (yellow arrow) and edema of the bone marrow parenchyma.

MATERIALS AND METHODS

The AAOT Library conducted a search for bibliographic references in Spanish and English from 1977 (the year of Swischuk's publication) to the present, using the following databases: PubMed (Medline, MedlinePlus, and Cochrane), Elsevier, BVS Biblioteca Virtual en Salud de Bireme (including Lilacs), and the AAOT's own database. The keywords used were: *pediatric cervical spine injuries*, *Swischuk line*, *C2-C3 pseudosubluxation*, *C2-C3 dislocation in children*, and *false negative* or *false positive cases of the Swischuk line*. We also included articles that were not identified in the electronic search but were found through citation searches of other references, relevant classic historical publications, and chapters from current textbooks on childhood traumatic conditions of the cervical spine. We excluded duplicate publications, older publications on pediatric spinal trauma, those related to conditions not relevant to the search, and articles on vertical spinal disruption or diastasis, given their clear expression in imaging studies. This research is based on a systematic review of the literature.

RESULTS

Thirty-nine references were selected from a total of 72 (Figure 5). The selection included 13 articles on general epidemiological aspects of pediatric spinal trauma published in the last five years, which provided new evidence-based recommendations on the rational use of complementary studies.

Another 18 articles focused on the SL, including its physiological and pathological variants in retrospective clinical cases. However, we did not find any specific references addressing false negative or false positive cases of the Swischuk line. Over the 46 years following Swischuk's article, six pediatric cases of uni- or bilateral C2-C3 facet subluxation or dislocation have been published, four of which involved neurological spinal cord impairment and two were associated with severe traumatic brain injury.[6,13,22-25] Except for one child, all were younger than 10 years (mean age: 3 years; range 9 months to 8 years). Although variable, the neurological status improved in all cases after surgical stabilization, a result previously noted in the literature.[10] Except for two cases, the SL was either unaltered or not sensitive enough to detect instability, despite the presence of epiphysiolysis of the lower end of the axis and significant damage to the posterior capsuloligamentous complex (Table 1, Figures 6 and 7). Two of the eight textbooks consulted were considered classics[11,12] and six were the latest editions of reference books.[16-21] All replicated identical concepts regarding the tracing and diagnostic implications of the SL.

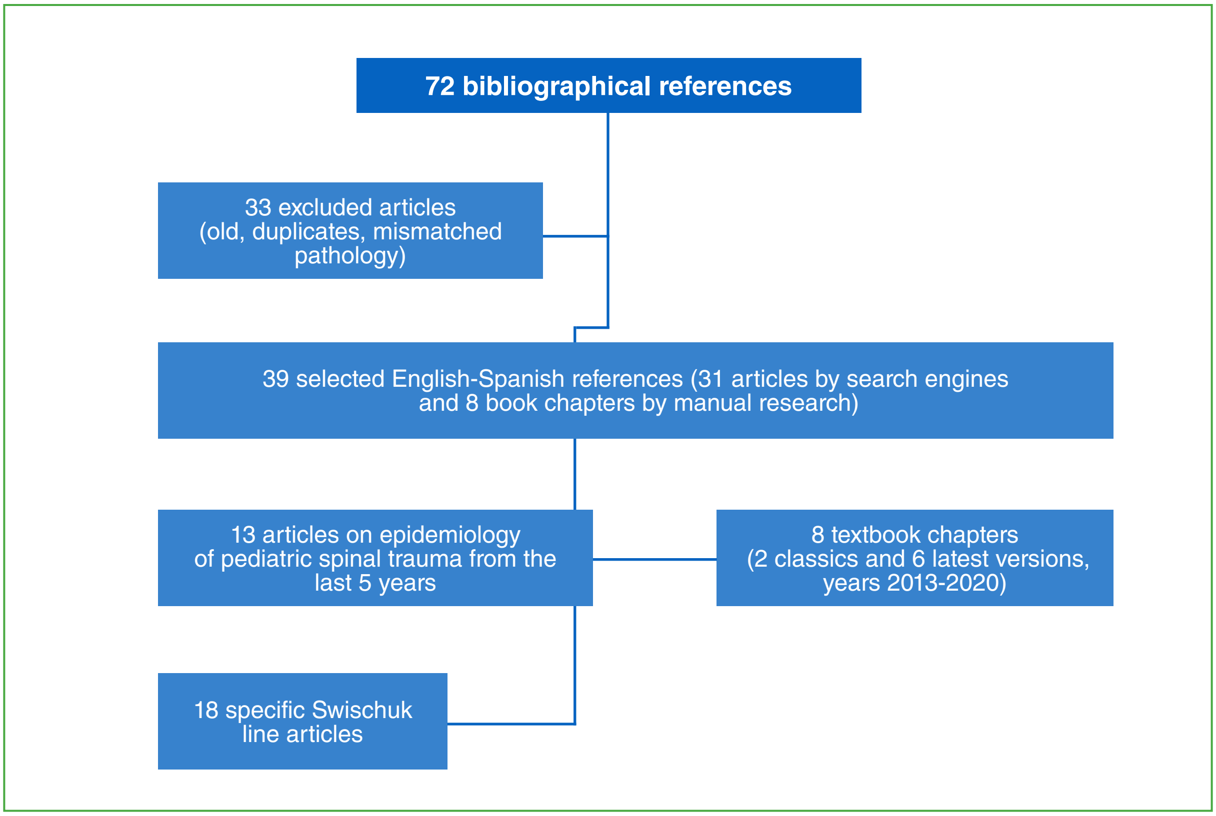


Figure 5. Flowchart of the literature search.

Table. Variability of Swischuk's line sensitivity in published pediatric cases of C2-C3 complex injuries.

	Author	Year	Cases	Age/Sex	C2-C3 Injury	Cause	SL Sensitivity	Neurological status	Treatment	Follow-up (months)
1	Jones and Hensinger [22]	1981	1	20 months/M	Chronic bilateral dislocation	Obstetric trauma	Yes	Severe hypotonia, flaccidity	Sublaminar wiring with C2-C3 wire	12
2	Hamoud and Abbas [2]	2014	1	23 months/M	Bilateral dislocation	Traffic accident	No	TBI, central deficit	C2-C3 Interspinous suture with Vicryl®2.0	63
3	Sellin et al. [34]	2014	1	13 years/F	Subluxation plus facet fracture	Fall	No	Normal	C2-C3 Facet osteosynthesis	14
4	O'Neill et al.[15]	2021	1	6 years/F	Unilateral subluxation	Sports accident	No	Normal	Reduction under general anesthesia plus halo vest	24
5	Zeng et al.[6]	2022	1	8 years/M	Bilateral dislocation	Traffic accident	Yes	Central deficit, spinal stenosis	C2-C3 Facet osteosynthesis with minifragments	8
6	Fernández et al. [24,25]	2023	1	9 months/F	Unilateral dislocation plus C2 fracture	Traffic accident	No	Central cord syndrome, diaphragm palsy.	C2-C3 sublaminar closure with Prolene®2.0 and facet osteosynthesis with minifragments	96

M = male; F = female; SL = Swischuk's line.

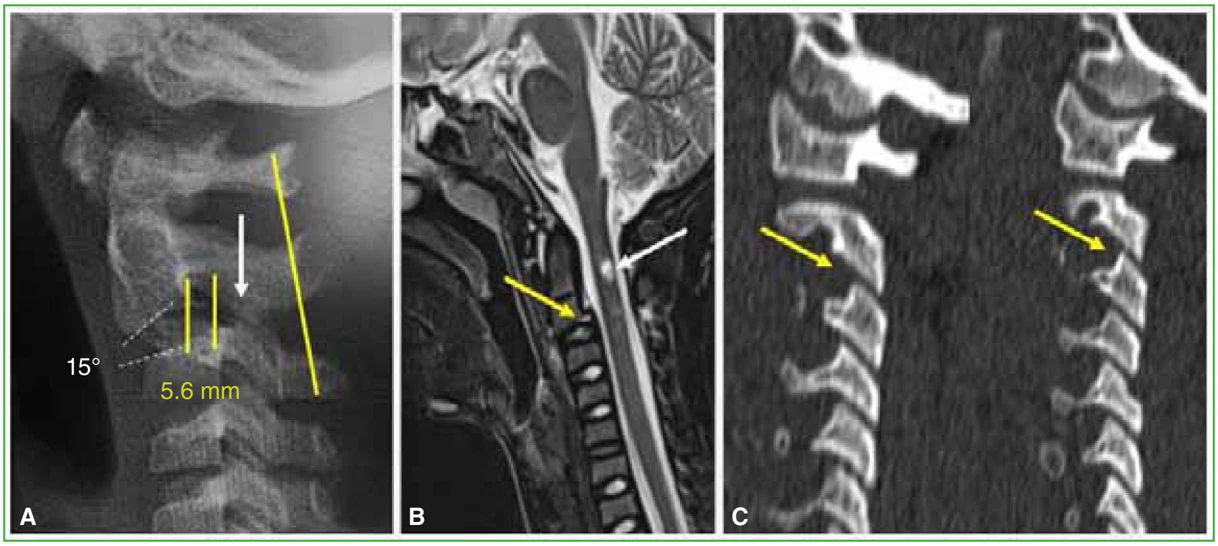


Figure 6. Eight-year-old boy involved in a frontal-impact car accident, presenting with pneumothorax, elevated intracranial pressure (eICP), and requiring mechanical ventilation for three days. The patient exhibited central cord syndrome and flaccid diparesis of the upper limbs with a C4-C5 level injury. Imaging studies of the cervical spine. **A.** Cervical spine radiograph: kyphosis of 15 degrees, sagittal displacement of 5.6 mm (vertical yellow lines) and normal SL tracing. **B.** MRI: Salter-Harris I epiphysiolysis of the axis (yellow arrow), with pre- and intervertebral fluid signal and intramedullary fluid signal. **C.** CT: sagittal paramedian sections showing subluxation of both C2-C3 facet joints.

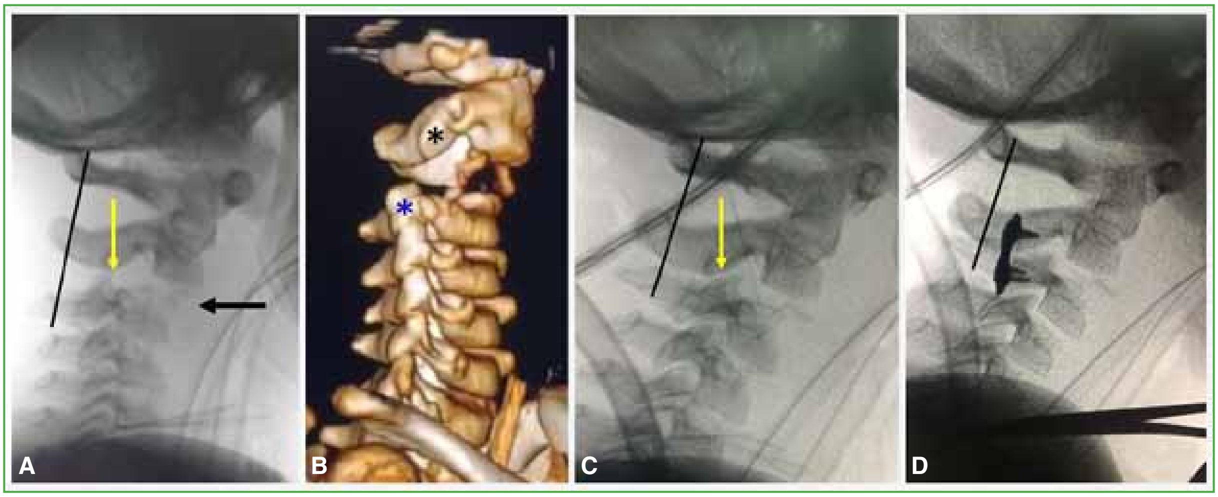


Figure 7. Four-year-old child seated on his mother's lap in the front passenger seat of a car with a seat belt fastened. The car was involved in a frontal collision, with airbag deployment impacting the child. The child presented with Frankel A neurological status on admission, with a metameric injury at the C3 level, diaphragmatic paralysis, hemopneumothorax, and elevated intracranial pressure (eICP). Lateral images of the cervical spine. **A.** Cervical spine radiograph: C2-C3 dislocation, with facet denudation (yellow arrow) and epiphysiolysis of the base of the axis with a small Thurstand-Holland fragment (Salter-Harris II). SL is not sensitive enough to detect this severe instability. **B.** 3D CT: Unlinking of the facets of C2 (black asterisk) and C3 (blue asterisk). **C.** Intraoperative radiograph: reduction showing an adequate facet relationship (yellow arrow). **D.** Posterior facet osteosynthesis with small fragment material.

DISCUSSION

The SL is one of the four lines drawn on a lateral cervical spine radiograph after trauma. Specifically, it is the proximal segment that relates the spinolaminar cortices of the first three vertebrae.[16,20] Some authors consider it to have higher diagnostic sensitivity than the sagittal delimiters of the vertebral bodies.[13] Swischuk emphasized its specificity in evaluating the C2-C3 relationship.[13,15] Its practical limitation lies in the lack of ossification of the posterior arch of atlas or its hypoplasia.[13] Anterior displacement of C2 over C3 or physiological subluxation occurs in approximately 22-40% of children under 8 years of age; a second hypermobile segment can be observed at the C3-C4 level in 14% of the same age group.[13,15,25,26,27,28] In 1952, Bailey specified that the physiological displacement of C2 over C3 was 2 mm to 3 mm, a value consistent with Swischuk's parameter.[11,13,15,27,29] Donalson published similar findings in 75% of children with acquired torticollis associated with concomitant C1-C2 rotation.[11] In pathological C2-C3 instability, there is excessive anterior displacement of the spinolaminar line in the axis, which may be traumatic or specifically related to Down syndrome.[30,31] As mentioned above, similar observations have been made in conditions outside the C2-C3 segment. Although Swischuk did not apply his method to these cases, it seems pertinent to describe it for general practitioners, who often encounter these patients in the emergency department and must address their uncertainty.

We found no publications addressing the lack of diagnostic sensitivity of the SL in some cases of C2-C3 instability. This observation is significant as it represents a false negative, meaning the diagnostic tool is not sensitive enough to detect the anomalous phenomenon. Moreover, in more than half of the published cases, the SL tracing was omitted, and Swischuk was not cited in the references. This is a paradox, given that his description is reiterated in numerous articles and textbooks on pediatric spinal trauma.

Finally, in cases of axis spondylolisthesis, the epicenter or fulcrum of motion migrates from the facet joints to the fracture sinus, leading to pathological C2-C3 subluxation. In this circumstance, the spinolaminar cortex of C2 is located posterior to the SL. Far from being pathognomonic, this observation has been reported in Grisel's syndrome of inflammatory etiology, where the C1-C2 relationship remains normal and the axis is undamaged..[33]

From our literature analysis and empirical observations, we can infer that the SL is a useful radiographic evaluation parameter, but it is insufficient and non-specific. Therefore, it would be advisable to incorporate other radiodiagnostic elements to confirm vertebral instability: translation of C2 over C3 greater than 4 mm or a percentage exceeding 25%, alteration of the axis in kyphosis, increase of the C2-C3 interspinous distance, loss of facet parallelism, and posterior widening of the disc space.[15,16,34] The indication for CT should be selective and justified based on the clinical-radiographic examination, particularly in cases of doubt regarding an abnormal facet relationship.[2,35] Its systematic use is not recommended, given the stochastic effect or carcinogenic effect of radiation in children, which results in one cancer for every 1,000 studies performed due to tissue radiosensitivity and long life expectancy.[3,36,37] For instance, the thyroid gland of a child under six years old receives 200 times more radiation with CT than with conventional radiographic exposures.[37] In a retrospective investigation of 773 polytraumatized pediatric patients evaluated with CT, the prevalence of spinal injury was 2.4%; thus, it was unnecessary in 97.6% of patients.[37] According to a recent expert consensus, CT is warranted as a matter of course when the Glasgow Coma Scale score on admission is ≤8, and it is not recommended when the score is higher.[36] MRI is recommended if there is no improvement or if clinical worsening occurs, but is not a routine methodology given the need for sedation, cost, and significant false positive rates.[36,38,39] Specialty books and many articles addressing cervical trauma in children express similar views regarding SL tracing and the conclusions drawn from it, although we did not find other observations or critical analyses.[9,12,16-21] Some of the works mentioned in this article warn about the potential risk of misinterpreting abnormal findings as normal, especially when the examiner is not an expert in spinal pathology. The main limitations of this study are its retrospective design and the small number of cases documented in the literature.

CONCLUSION

SL is useful for evaluating the upper cervical spine in early and middle childhood in cases of trauma and in some syndromic entities. However, it is not infallible or specific, does not exclude a C2-C3 facet subluxation or dislocation, and may be influenced by overlying segmental abnormalities. Therefore, other quantitative or qualitative radiodiagnostic measures should be incorporated.

Acknowledgments:
Dr. Patricio Manzone, for sharing the Case of Figure 4.

Conflict of interest: The authors declare no conflicts of interest.

M. G. Miranda ORCID ID: https://orcid.org/0000-0003-4949-9407

M. E. Moreiro ORCID ID: https://orcid.org/0009-0000-5590-9738

REFERENCES

1. Patel JC, Tepas JJ III, Mollitt DL, Pieper P. Pediatric cervical spine injuries: defining the disease. *J Pediatr Surg* 2001;36(2):373-6. https://doi.org/10.1053/jpsu.2001.20720
2. Parada SA, Arrington ED, Kowalski KL, Molinari RW. Unilateral cervical facet dislocation in a 9-year-old boy. *Orthopedics* 2010;33(12):929. https://doi.org/10.3928/01477447-20101021-31
3. Copley PC, Tilliridou V, Kirby A, Jones J, Kandasamy J. Management of cervical spine trauma in children. *Eur J Trauma Emerg Surg* 2019;45(5):777-89. https://doi.org/10.1007/s00068-018-0992-x
4. Velasco Canziani JM, Saprizza S, Galli N, Otero N, García F. Luxofractura cervical en niños: revisión bibliográfica y caso clínico. *Rev Asoc Argent Ortop Traumatol* 2020;85(3):270-82. https://doi.org/ 10.15417/issn.1852-7434.2020.85.3.1007

5. Gopinathan NR, Viswanathan VK, Crawford AH. Cervical spine evaluation in pediatric trauma: A review and an update of current concepts. *Indian J Orthop* 2018;52(5):489-500. https://doi.org/10.4103/ortho.IJOrtho_607_17
6. Zeng J, Jiang H, Zhuo Y, Xu Y, Deng Z. A case report on a child with fracture and dislocation of the upper cervical spine accompanied by spinal cord injury. *Medicine (Baltimore)* 2022;101(30):e29717. https://doi.org/10.1097/MD.0000000000029717
7. Carreon LY, Glassman SD, Campbell MJ. Pediatric spine fractures: a review of 137 hospital admissions. *J Spinal Disord Tech* 2004;17(6):477-82. https://doi.org/10.1097/01.bsd.0000132290.50455.99
8. Corrado R, Tello C, Galaretto E, Balderrama S, Noel M, Francheri Wilson A, et al. Luxofractura de la columna cervical en un recién nacido: Informe de un caso. *Rev Asoc Argent Ortop Traumatol* 2010;75(1):73-6. Available at: https://www.aaot.org.ar/revista/2010/n1/art07.pdf?_gl=1*1mh1yt6*_ga*MTA1MDAwMTA1Ny4xNzE5ODc0Nzg3*_ga_BFFNBSGNHH*MTcxOTg3NDc4Ni4xLjAuMTcxOTg3NDc4Ni4wLjAuMA
9. Jones TM, Anderson PA, Noonan KJ. Pediatric cervical spine trauma. *J Am Acad Orthop Surg* 2011;19(10):600-11. https://doi.org/10.5435/00124635-201110000-00004
10. Wang MY, Hoh DJ, Leary SP, Griffith P, McComb JG. High rates of neurological improvement following severe traumatic pediatric spinal cord injury. *Spine* 2004;29(13):1493-7; E266. https://doi.org/10.1097/01.brs.0000129026.03194.0f
11. Ogden JA. Columna vertebral. In: Ogden JA. *Traumatismos del esqueleto en el niño*. Barcelona: Salvat Editores; 1986, pp. 397-422.
12. Lebwohl NH, Eismont J. Cervical spine injuries in children. In: Weinstein SL (ed). *The pediatric spine: Principles and practice*. New York: Raven Press, Ltd.; 1994, pp. 725-42.
13. Swischuk LE. Anterior displacement of C2 in children: physiologic or pathologic. *Radiology* 1977;122(3):759-63. https://doi.org/10.1148/122.3.759
14. Tabernero AM, Suñén Sánchez E, Peña Jiménez D, Loste Ramos A, Tabuenca Sánchez A, Chárlez Marco A, et al. Pseudoluxación C2-C3 en la infancia [Pseudoluxation C2-C3 in childhood]. *Rev Fac Cien Med Univ Nac Córdoba* 2017;74(3):288-92. https://doi.org/10.31053/1853. 0605.v74.n3.12863
15. O'Neill C, Wenzel A, Walterscheid Z, Carmouche J. Distinguishing pseudosubluxation from true injury: A case of C2-3 and C3-4 subluxation in a pediatric patient. *J Am Acad Orthop Surg Glob Res Rev* 2021;5(12). https://doi.org/10.5435/JAAOSGlobal-D-20-00238
16. Rathjen KE, Herring JA. Spinal injuries. En: Herring JA. *Tachdjian's pediatric orthopaedics,* 5th ed. Philadelphia: Elsevier Health Sciences; 2013, vol. 3, pp. 1224-44.
17. Ahmet A, Caglar Y. Pediatric cervical spine. En: Cumhur Oner F, Vaccaro AR, Vialle LR. *AOSpine masters series.* Volume 5: Cervical spine trauma. New York: Thieme Medical Publishers, Inc.; 2015, pp. 156-68.
18. Grigoriou E, Dormans JP. Pediatric spine trauma. En: Akbarnia BA, Thompson GH, Yazici M, El-Hawary R (eds). *The growing spine: Management of spinal disorders in young children.* 2nd ed. Berlín Heidelberg: Springer-Verlag; 2016, p. 359-82.
19. Loder RT. La columna cervical. In: Weinstein S. *Lovell y Winter Ortopedia pediátrica*. 7th ed. Venezuela: Amolca; 2017, pp. 821-93.
20. Remondino R. Patología traumática del raquis pediátrico. In: Calcagni E, Ramírez J. *Compendio de patología de la columna vertebral.* SILACO, 2018, Módulo 7: 193-204.
21. Warner WC, Hedequist DJ. Cervical spine injuries in children. In: Waters PM, Skags DL, Flynn JM (eds.). *Rockwood & Wilkin's fractures in children*. 9th ed. Philadelphia: Wolters Kluwer; 2020, pp. 1201-311.
22. Jones ET, Hensinger RN. C2-C3 dislocation in a child. *J Pediatr Orthop* 1981;1(4):419-22. https://doi.org/10.1097/01241398-198112000-00011
23. Hamoud K, Abbas J. A new technique for stabilization of injuries at C2-C3 in young children. *Injury* 2014;45(11):1791-5. https://doi.org/10.1016/j.injury.2014.05.027
24. Fernández CA, Moreiro ME, Miranda MG. Instrucción Ortopédica de Posgrado - Imágenes. Presentación del caso. *Rev Asoc Argent Ortop Traumatol* 2023;88(6):592-3. https://doi.org/10.15417/issn.1852-7434.2023.88.6.1827
25. Fernández CA, Moreiro ME, Miranda MG. Instrucción Ortopédica de Posgrado - Imágenes. Resolución del caso. *Rev Asoc Argent Ortop Traumatol* 2023;88(6):692-3. https://doi.org/10.15417/issn.1852-7434.2023.88.6.1828
26. Pellicer-Garcia V, Baeza-Oliete L, Miranda-Casas L, Bas T, Bas P. Pseudosubluxación C2-C3: un hallazgo radiológico frecuente en la infancia. *Revista Española de Cirugía Osteoarticular* 2009;44(239): 124-6. Available at: http://www.cirugia-osteoarticular.org/adaptingsystem/intercambio/revistas/articulos/2240_5%20Pellicer.pdf
27. Shaw M, Burnett H, Wilson A, Chan O. Pseudosubluxation of C2 on C3 in polytraumatized children--prevalence and significance. *Clin Radiol* 1999;54(6):377-80. https://doi.org/10.1053/crad.1999.0192

28. Baumann F, Ernstberger T, Neumann C, Nerlich M, Schroeder GD, Vaccaro AR, et al. Pediatric cervical spine injuries: A rare but challenging entity. *J Spinal Disord Tech* 2015;28(7):E377-84. https://doi.org/10.1097/BSD.0000000000000307
29. Brown P, Munigangaiah S, Davidson N, Bruce C, Trivedi J. A review of paediatric cervical spinal trauma. *Surgery (Oxford)* 2020;38(9):495-9. https://doi.org/10.1016/j.mpsur.2020.06.016
30. Al-Habib A, Al Aqeel A. C2/3 instability: unusual cause of cervical myelopathy in a child with Down syndrome. *Childs Nerv Syst* 2013;29(1):163-5. https://doi.org/10.1007/s00381-012-1950-2
31. Citow JS, Munshi I, Chang-Stroman T, Sullivan C, Frim DM. C2/3 instability in a child with Down's syndrome. Case report and discussion. *Pediatr Neurosurg* 1998;28(3):143-6. https://doi.org/10.1159/000028638
32. Rusin JA, Ruess L, Daulton RS. New C2 synchondrosal fracture classification system. *Pediatr Radiol* 2015;45(6):872-81. https://doi.org/10.1007/s00247-014-3224-5
33. Martínez-Lage JF, Morales T, Fernandez Cornejo V. Inflammatory C2-3 subluxation: a Grisel's syndrome variant. *Arch Dis Child* 2003;88(7):628-9. https://doi.org/10.1136/adc.88.7.628
34. Sellin JN, Shaikh K, Ryan SL, Brayton A, Fulkerson DH, Jea A. Clinical outcomes of the surgical treatment of isolated unilateral facet fractures, subluxations, and dislocations in the pediatric cervical spine: report of eight cases and review of the literature. *Childs Nerv Syst* 2014;30(7):1233-42. https://doi.org/10.1007/s00381-014-2395-6
35. Chen Y, Wang X, Chen D, Liu X. Surgical treatment for unilateral cervical facet dislocation in a young child aged 22 months old: a case report and review of the literature. *Eur Spine J* 2013;22(Suppl 3):S439-42. https://doi.org/10.1007/s00586-012-2590-7
36. Herman MJ, Brown KO, Sponseller PD, Phillips H, Petrucelli PM, Parikh DJ, et al. Pediatric Cervical Spine Clearance: A Consensus Statement and Algorithm from the Pediatric Cervical Spine Clearance Working Group. *J Bone Joint Surg Am* 2019;101(1):e1. https://doi.org/10.2106/JBJS.18.00217
37. Eren B, Karagoz Guzey F. Is spinal computed tomography necessary in pediatric trauma patients? *Pediatr Int* 2020;62(1):29-35. https://doi.org/10.1111/ped.14064
38. Pannu GS, Shah MP, Herman MJ. Cervical spine clearance in Pediatric Trauma Centers: The need for standardization and an evidence-based protocol. *J Pediatr Orthop* 2017;37(3):145-9. https://doi.org/10.1097/BPO.0000000000000806
39. Karlin LI, Jordan EM, Miller PE, Shore BJ. Prevertebral soft tissue thickness of the cervical spine in children: An insensitive but specific aid in the diagnosis of occult trauma. *J Pediatr Orthop* 2022;42(8):901-9. https://doi.org/10.1097/BPO.0000000000002218

Patellofemoral Instability in Children and Adolescents: Current Concepts Review

J. Javier Masquijo, Miguel Carabajal Mattar
Department of Pediatric Orthopedics and Traumatology, Sanatorio Allende, Córdoba, Argentina.

ABSTRACT
Patellofemoral instability (PFI) is a common knee disorder in the skeletally immature patient. PFI presents challenges in this patient population that require an understanding of anatomy and biomechanics to formulate a treatment plan aimed at preventing redislocation and facilitating return to activity. In this review, the different presentations and therapeutic alternatives will be analyzed, providing a practical guide for the comprehensive management of this complex clinical condition.
Keywords: Knee; patella; dislocation; patellofemoral instability; adolescent.
Level of Evidence: V

Inestabilidad patelofemoral en niños y adolescentes: revisión de conceptos actuales

RESUMEN
La inestabilidad patelofemoral es un trastorno frecuente de la rodilla en el paciente esqueléticamente inmaduro. Este cuadro plantea diversos desafíos en esta población que requieren una comprensión de la anatomía y la biomecánica para formular un plan de tratamiento que prevenga la reluxación y permita el regreso a las actividades. En esta revisión, se analizan las distintas formas de presentación y las alternativas terapéuticas, y se ofrece una guía práctica para el manejo integral de esta compleja condición clínica.
Palabras clave: Rodilla; rótula; luxación; inestabilidad patelofemoral; adolescente.
Nivel de Evidencia: V

INTRODUCTION

Patellofemoral instability (PFI) is a multifactorial condition that is disabling and causes chronic knee pain in children and adolescents. This disorder encompasses a broad spectrum of conditions ranging from mild subluxation to irreducible lateral dislocation. PFI is relatively common, affecting an estimated 5.8 to 29 out of every 100,000 children aged 10 to 17 years.[1] The first episode of dislocation usually occurs during the second decade of life and accounts for approximately 2% to 3% of all acute knee injuries.[2] Acute patellar dislocation (APD) is a debilitating condition, with the recurrence rate ranging from 8.6% to 88% after conservative treatment, depending on individual patient factors.[3-5] Several predisposing risk factors have been identified, including female sex, trochlear dysplasia, increased femoral anteversion, increased external tibial torsion, weakness of the vastus medialis obliquus muscle, increased Q-angle, increased TT-TG (tibial tuberosity-trochlear groove) distance (between the deepest portion of the anterior tibial tuberosity and the deepest portion of the femoral trochlea), ligament laxity, high patella and genu valgus.[6] The long-term risk of progressive cartilage damage after the first episode of dislocation is significant; patients are up to six times more likely to develop osteoarthritis between the ages of 30 and 40. [7]

Received on May 21st, 2024. Accepted after evaluation on May 28th, 2024 • Dr. J. JAVIER MASQUIJO • javimasquijo@yahoo.com.ar • https://orcid.org/0000-0001-9018-0612
How to cite this article: Masquijo JJ, Carabajal Mattar M. Patellofemoral Instability in Children and Adolescents: Current Concepts Review. *Rev Asoc Argent Ortop Traumatol* 2024;89(4): 403-415. https://doi.org/10.15417/issn.1852-7434.2024.89.4.1965

Currently, medial patellofemoral ligament reconstruction (MPFL) is the most common surgical treatment.[8,9] However, a subset of patients may require additional procedures to correct angular deviations, rotational disturbances, high patella, or distal malalignment. In this review, we discuss the various forms of presentation and therapeutic alternatives and provide practical guidance for the comprehensive management of this complex clinical condition.

ANATOMY OF THE MEDIAL PATELLOFEMORAL COMPLEX (MPFC)

The term MPFC is used to describe the main soft tissue stabilizer of the patella, consisting of fibers that insert into the patella (MPFL) and the quadriceps tendon (medial quadriceps tendon-femoral ligament). Despite its variable insertion into the extensor mechanism, the midpoint of this complex is located at the junction of the medial quadriceps tendon with the articular surface of the patella, indicating that both patellar tendon and quadriceps tendon attachments can be used for anatomic reconstruction.[10] The femoral origin is located in the "valley" formed between the adductor magnus tubercle and the medial epicondyle, leading some authors to suggest that it encompasses an area rather than a specific insertion point.[11-18]

From a biomechanical point of view, the most significant length changes of the MPFC occur between 0° and 20° of flexion, while more isometric behavior is observed between 20° and 90°. The attachment points along the extensor mechanism show diverse behaviors in relation to length, highlighting that the superior fibers of the medial quadriceps tendon-femoral ligament exhibit greater length variability throughout the range of motion.[19] Some studies suggest that, while the MPFL is the primary restrictor of lateral translation in early knee flexion, the medial quadriceps tendon-femoral ligament is responsible for preventing lateral translation in extension.[20]

In skeletally immature patients, the anatomy of the MPFC is similar to that of the adult population. The femoral insertion is located 6.9-8.5 mm distal to the physis, while the superior fibers of the MPFC insert 5-12 mm proximal to the superior pole of the patella, at the quadriceps tendon.[23-25]

DIAGNOSIS

The diagnosis of PFI is primarily established through clinical evaluation, including detailed patient anamnesis and physical examination, supplemented by imaging studies. A thorough in-office analysis helps categorize the patient into one of the possible clinical scenarios associated with the condition. However, interpreting radiographs and advanced studies is essential to evaluate the underlying anatomic factors that often accompany the different forms of PFI.

APD can result from indirect trauma, where the knee is subjected to a valgus force with internal rotation of the femur, or from direct trauma that displaces the patella laterally away from the femoral trochlea.[26] Patients usually seek medical attention after experiencing the first episode of dislocation and report pain at the insertion site of the MPFL, apprehension, and joint effusion. Patients with more chronic cases or multiple episodes of dislocation may report a sensation of instability or anterior knee pain. [27,28]

The physical examination should include a comprehensive evaluation of the lower limbs, including coronal and sagittal axis, limb length, rotational profile, and muscle strength. Specific maneuvers are recommended, such as the apprehension test, displacement test, J-sign, patellar tilt test, and patellofemoral tracking.[1,29] The assessment of generalized ligament laxity using the Beighton score[30] is an important decision-making tool in preoperative planning (Table).

Imaging evaluation should include AP, lateral, and axial radiographs of the patella. When a coronal alteration of the mechanical axis is suspected, it is important to add lower limb telemetry.[31-34] The evaluation of remnant growth is also essential.[35] MRI is the study of choice in patients with APD, since it allows the detection of osteochondral lesions, intra articular loose bodies that may go unnoticed in radiographs; soft tissue lesions and the morphology of the patellofemoral joint. MRI has been shown to be useful in measuring TT-TG distance and sagittal patellofemoral engagement index, and assessing the patient's rotational profile.[36-39] In our practice, we routinely order an MRI in the first episode, although we feel that it could be omitted in cases of low-energy dislocation when the patient presents clinically without joint effusion.

Table. Preoperative evaluation of the patient with patellofemoral instability.

Preoperative evaluation		
Physical examination		Description/significance
Inspection		
	Evaluation of soft tissue swelling and muscle atrophy	
	Evaluation of deformity in the coronal plane	Standing - genu valgum
	MMII length discrepancy assessment	Prone decubitus by segments (femur-tibia)
	Evaluation of the rotational profile	In prone position - external tibial torsion/femoral anteversion
	Knee range of motion	Normal: 0-130°
	Gait analysis	
	Evaluation of patellar tracking (J-sign)	Distal malalignment, trochlear dysplasia
	Assessment of generalized ligament laxity	Beighton's test (>6/9 abnormal)[30]
	Evaluation of syndromic features	Down's, Larsen's, Rubinstein-Taybi, nail-patella, Ehlers-Danlos, Marfan's, etc.
Palpation		
	Tap test	Intra articular effusion
	Pain/crepitations	Chondral injury in the patellofemoral joint
	Displacement test	> 2 quadrants: insufficiency of the medial stabilizers
	Tilt test	Retraction of the lateral retinaculum
	Q-angle	Distal misalignment
	Apprehension sign	Instability
	Extensor mechanism	Straight leg raise
	Additional knee tests	ACL, PCL, collateral ligaments and meniscus
Images		
	Radiographs: AP, lateral, and axial	Patellar height: Caton Deschamps/Normal Index <1.3[31]
		Ruling out fractures or the presence of foreign bodies.
		Skeletal maturity/bone age assessment
	Lower limb teleradiology	Assessment of misalignment (coronal and sagittal)
	Magnetic resonance imaging	Assessment of articular cartilage condition
		Determination of growth plate state (open/closing/closed)
		Bone contusion pattern identification
		TT-TG distance measurement[36]
		Calculation of the Sagittal Patellofemoral Engagement index[39]
		Evaluation of trochlear dysplasia
		Identification of associated injuries, such as meniscal lesions and additional ligament injuries

ACL = anterior cruciate ligament; PCL = posterior cruciate ligament; TT-TG (tibial tuberosity-trochlear groove).

Computed axial tomography has been used to study joint morphology and rotational plane deformities. It has recently been shown to be useful for examining trochlear dysplasia and for preoperative planning.[40] However, we do not routinely request it in the pediatric population due to the high radiation exposure and lower information yield compared to that of MRI.[41,42] In recent years, there has been a great deal of interest in risk stratification for recurrence after the first episode of APD.[43-45] The goal is to identify individuals at high risk of developing recurrent instability who may benefit from early surgery. As has been the case with other joints, risk stratification models for APD could eventually lead to better evidence-based treatment recommendations. [46,47]

CLASSIFICATION

There are four main forms of instability: I) first episode of dislocation: when the first traumatic event occurs. It can be subdivided into: A) without intra articular free fragment and B) with intraarticular free fragment; II) recurrent PFI: two or more repeated traumatic events. After the first episode, the events usually require less energy. There are predisposing anatomical factors, such as female sex, trochlear dysplasia, increased femoral anteversion, increased external tibial torsion, weakness of the vastus medialis oblique, increased Q-angle, increased TT-TG distance, ligament laxity, high patella and genu valgum; III) habitual/obligatory dislocation: episodes of dislocation at each knee flexion or extension with spontaneous reduction. It can be subdivided into: A) habitual dislocation in flexion and B) habitual dislocation in extension; IV) irreducible lateral dislocation: permanent dislocation not reducible manually.

TREATMENT

Acute patellar dislocation

Historically, patients suffering from a first episode of APD without the presence of intra-articular loose bodies have been managed with conservative treatment.[48] However, recent studies have questioned this approach, proposing stabilization of the patella in patients at high risk of recurrence.[49] The algorithm used by the authors of this article is detailed in Figure 1.

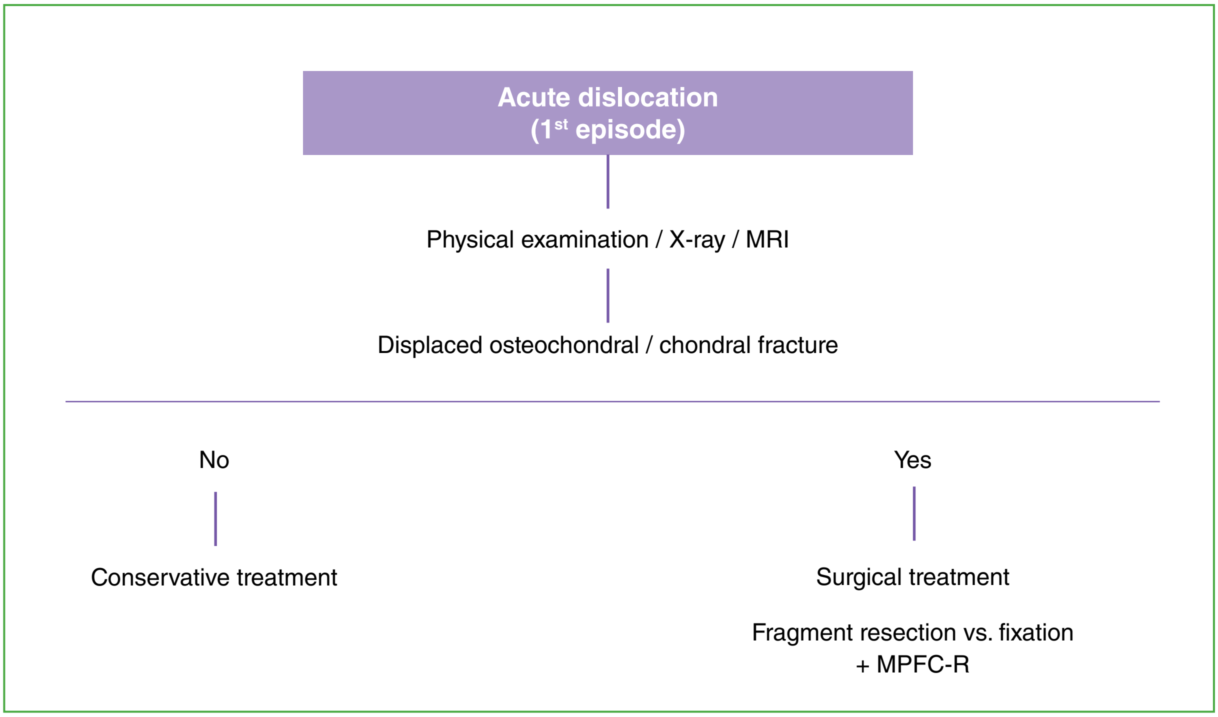


Figure 1. Therapeutic algorithm for patients with acute patellar dislocation.
MPFL-R = medial patellofemoral complex reconstruction.

Conservative treatment consists of a period of immobilization for 2 to 3 weeks followed by rehabilitation for 6-10 weeks. The goals of the rehabilitation program are divided into different stages:[50] 1) resolution of pain, effusion, and inflammation; 2) recovery of motion and flexibility; 3) recovery of muscle strength; 4) recovery of coordination and motor patterns; and 5) sport-specific athletic action.Return to activity is usually authorized around 12 weeks post-injury, once the patient is asymptomatic, with no effusion or tightness, and with quadriceps strength comparable to that of the contralateral lower limb.

According to published studies, functional outcomes and recurrence rates after conservative treatment are variable. Conservative treatment protocols differ significantly among authors, as do the functional scales used. Additionally, individual patient risk factors are not consistently reported, making comparisons between studies difficult. Palmu et al.[51] prospectively evaluated 71 patients under 16 years of age (74 knees) who had suffered a first episode of APD. Twenty-eight knees were treated conservatively and monitored for 14 years. Although the functional outcomes at the last follow-up were satisfactory in 75% of cases, 71% experienced at least one further episode of dislocation. Regalado et al.[52] analyzed the outcomes of 20 adolescents and found that nearly one in three (27%) were dissatisfied, with a re-dislocation rate of 35% at three years and 73% at six years. In a recent systematic review of 2,086 patients, Longo et al.[53] reported a mean Kujala score of 75.6 at follow-up <5 years and 87.5 at follow-up >5 years. The recurrence rate was 36.4%.

Patients with an osteochondral fracture and one or more intra-articular loose bodies require surgical treatment. In these cases, the fragment should be evaluated for repositioning or removal based on its size, location, and viability. Osteochondral fragments >1 cm located on a weight-bearing articular surface typically require reduction and internal fixation (Figure 2), while smaller fragments can be removed.[54] In adolescents who experience a first episode of dislocation with an osteochondral fracture requiring excision or fixation, there is consensus that instability should be treated concurrently.[38,55] Additionally, there is evidence that MPFL reconstruction offers better results than repair techniques.[56]

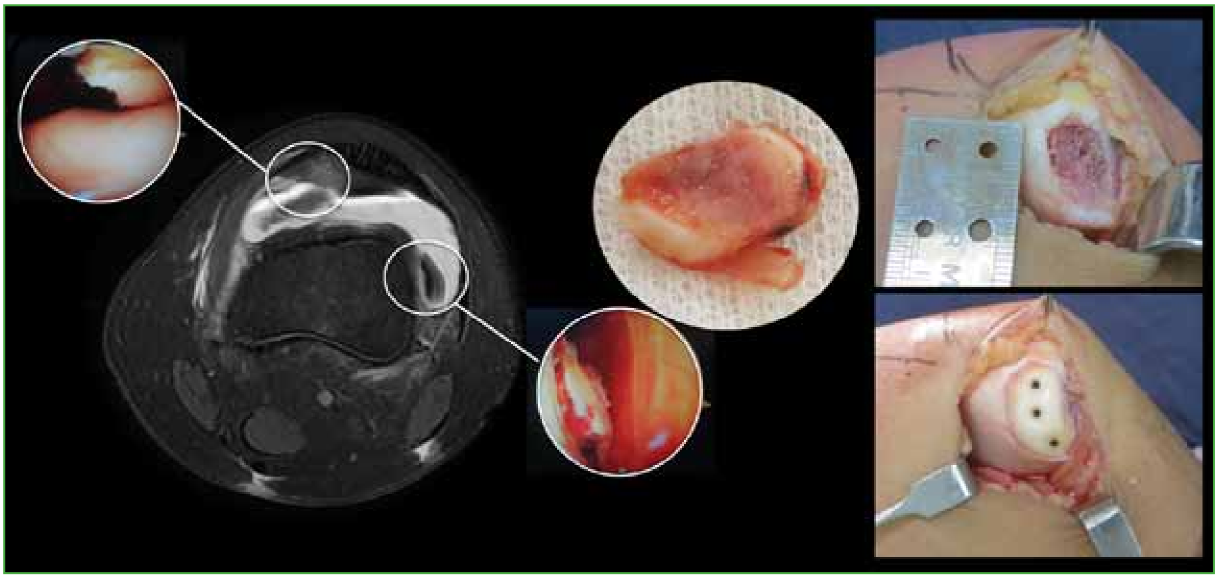


Figure 2. 13-year-old patient who suffered a first episode of dislocation and osteochondral fracture of the medial facet of the patella and underwent reduction and osteosynthesis with Smart Nails® (ConMed Linvatec Ltd., Tampere, Finland).

Recurring PFI

Recurrent PFI is defined as two or more episodes of dislocation. Multiple treatment options are available for this disorder, with the choice depending on the underlying cause of the instability and the degree of skeletal maturity. MPFL reconstruction has gained popularity due to its excellent outcomes.[57-59] However, certain associated anatomical factors, such as distal malalignment of the extensor apparatus, high patella, trochlear dysplasia, genu valgum, or rotational abnormalities, may create an unfavorable environment for grafting. When there is isolated failure of the medial stabilizers of the patella, reconstruction is the indicated treatment. In cases of distal malalignment, combining MPFL reconstruction with distal realignment of the extensor apparatus has yielded favorable outcomes. [60]

Medializing osteotomy of the anterior tibial tuberosity is a procedure designed to medialize the extensor apparatus and reduce contact forces at the patellofemoral joint in skeletally mature patients. However, in skeletally immature patients, this technique may cause damage to the growth plate, so realignment by subperiosteal patellar tendon transfer is preferred.[61] In cases of high patella, instability, and distal malalignment, it is appropriate to combine medialization and distalization of the extensor apparatus using soft tissue techniques or osteotomies, depending on the degree of skeletal maturity.

In skeletally immature patients with coronal plane alterations, such as genu valgum, our preference is to perform axis correction by guided growth with tension band plates. Subsequently, when this material is removed, we proceed to stabilization of the patella. If skeletal maturity has been reached, we opt for realignment by osteotomy followed by patella stabilization in a single surgery. It is essential to individualize the treatment according to the anatomical deformity, making the evaluation of predisposing factors indispensable for accurate management of this condition. The algorithm used by the authors is described in Figure 3.

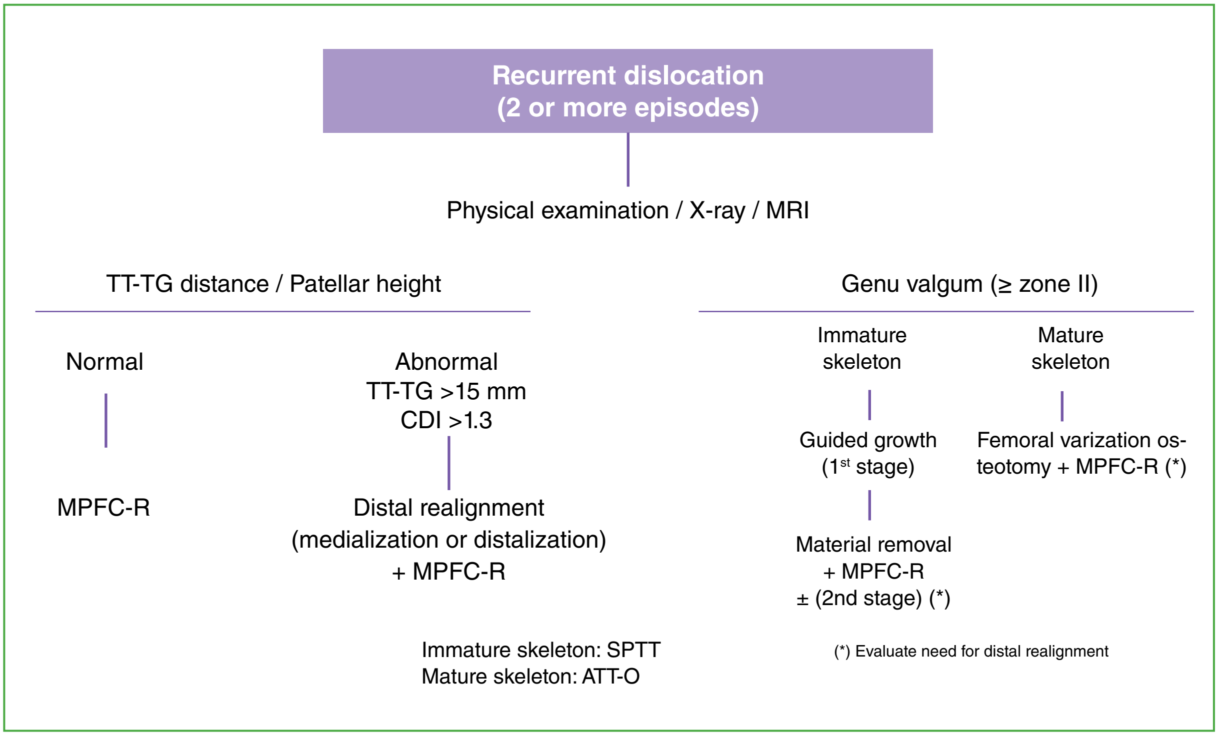


Figure 3. Therapeutic algorithm for patients with recurrent patellofemoral instability.
TT-TG (*tibial tuberosity-trochlear groove)* = distance between the deepest portion of the anterior tibial tuberosity and the deepest portion of the femoral trochlea; MPFL-R = medial patellofemoral complex reconstruction; SPTT = subperiosteal patellar tendon transfer; ATT-O = anterior tibial tubercle osteotomy.

Technique preferred by the authors

The patient is placed in the supine position. 1 g of cephalothin is administered intravenously as antibiotic prophylaxis, half an hour before the incision. Spinal anesthesia is administered, and a pneumatic tourniquet is placed. Asepsis and antisepsis of the area are performed, and surgical fields are placed according to the technique. The affected extremity is exsanguinated using an Esmarch bandage, and a tourniquet is applied at 250 mmHg. The superomedial patellar and femoral approaches, as well as the arthroscopic portals, are delineated with a sterile pen (Figure 4).

Figure 4. Reconstruction of the medial patellofemoral complex with semitendinosus allograft.

The classic anterolateral and anteromedial arthroscopic portals are created, and diagnostic arthroscopy is performed to identify loose bodies and evaluate the patellofemoral chondral surfaces. Any osteochondral or chondral lesions are addressed at this point. Preferred sources for allografts are the semitendinosus or fibularis longus. It is important to ensure that the allograft is at least 240 mm in length. After thawing, the allograft is washed with a mixture of antibiotics and saline containing 1 g of vancomycin in 1 liter of saline. Tension is applied to the allograft using the graft preparation board, and a stitch is placed on each side of the graft with Vicryl® #1. A 3 cm incision is made at the superomedial pole of the patella. Dissection is performed to visualize the medial border of the quadriceps tendon. The plane between the medial retinaculum and the joint capsule is identified, taking care not to damage the capsule. Fluoroscopy is used to accurately identify Schöttle's radiographic landmark in skeletally mature patients or in the epiphyseal region just distal to the growth plate in patients with an open physis. A guide is introduced in a proximal-to-distal (approximately 20°) and posterior-to-anterior direction. A 7 mm diameter drill bit is used at low speed to create a 25 mm femoral tunnel. The graft is secured in the femoral tunnel with a 7 x 25 mm PEEK (Polyether-Ether-Ketone) interference screw. It is recommended to fix the graft with the proximal end slightly longer than the distal end for proper fixation to the quadriceps tendon. Adequate graft fixation is confirmed by applying longitudinal tension to the graft. Using a hemostatic forceps, both ends of the graft are passed through the plane between the capsule and the medial retinaculum. During medial exposure of the patella, care is taken to avoid arthrotomy by leaving the junction of the synovial lining intact. A gouge is used to decorticate the surface of the medial border of the patella. A 3.5 mm anchor is placed at the junction of the proximal third and the distal two-thirds of the patella. A single anchor is used instead of one or two intraosseous tunnels to avoid creating a large defect that may increase the risk of patellar fracture. The patella is then centralized in the trochlea with the knee flexed at 30°-40°, and the length of the graft is adjusted and secured to the patella. An additional suture is made with Vicryl® #1 between the patella and the allograft tendon to reinforce the fixation. Next, with the knee in extension, the patella is checked to ensure that it can be manually moved one quadrant laterally, confirming the correction of instability without excessive pressure on the patellofemoral joint.

For fixation to the quadricipital tendon, a hole is created in the medial border of the tendon, 10-15 mm from the superior pole of the patella. The upper end of the allograft is passed through this hole and manually fixed with a FiberWire® suture. Patellar mobility is verified using the moving patellar apprehension test, and any excess graft is removed. The vastus medialis obliquus muscle is advanced and sutured to the medial border of the patella with Vicryl® #1 sutures. The area is thoroughly irrigated with saline, and the arthroscope is reintroduced to ensure adequate patellar tracking. After irrigation, the incisions are closed.

Crutches and a knee immobilizer are indicated for two weeks. Weight-bearing is allowed as tolerated with the leg in extension until adequate quadriceps control is achieved. Full range of motion exercises are allowed immediately. Return to sports and high-impact activities is generally authorized after six months and is subject to clinical and radiographic evaluations, which may vary depending on concomitant procedures. This authorization is granted once the patient is asymptomatic, with no effusion or apprehension, full range of motion, muscle strength symmetry close to 85% with respect to the contralateral limb, no objective instability during the examination, and excellent dynamic stability observed when performing sport-specific exercises without hesitation. In skeletally immature patients, standing lower limb radiographs (telemetry) are taken at one-year follow-up to evaluate possible growth disturbances.

Habitual dislocation

Habitual dislocation presents in two forms: a) in extension, where the patella spontaneously dislocates each time the knee is extended (usually between 0° and 30°), and b) in flexion, where dislocation occurs when the knee is flexed (usually between 60° and 90°). These cases are rare and tend to occur mainly during the first decade of life.[63]

Habitual dislocation in extension is characterized by distal misalignment of the extensor apparatus, observed through an increased TT-TG distance, high patella, and trochlear dysplasia.[64] Surgery for these cases should address distal realignment by medializing and distalizing the extensor apparatus, complemented by reconstruction of the medial stabilizers (Figure 5). In patients who have reached skeletal maturity and present with severe trochlear dysplasia, treatment may also include trochleoplasty.

Habitual dislocation in flexion is characterized by shortening and atrophy of the quadriceps tendon and severe retraction of the lateral structures (iliotibial band, lateral retinaculum, and vastus lateralis).[65,66] Additionally, these patients often have distal malalignment. Treatment of this subtype of instability usually begins with distal realignment and continues with elongation of the lateral retinaculum, followed by lengthening of the vastus lateralis tendon. If, after these steps, the patella continues to dislocate laterally during knee flexion, a formal Z-lengthening of the quadriceps tendon is performed to address the shortening of the extensor mechanism and neutralize the lateral force vector on the patella during knee flexion. This procedure should be complemented by reconstruction of the medial stabilizers.

Irreducible dislocation

Irreducible or fixed lateral dislocation is a rare condition in which the patella is located laterally to the external femoral condyle and cannot be manually repositioned onto the trochlea (Figure 6). This condition can manifest idiopathically or in association with other congenital conditions, such as Larsen syndrome, Rubinstein-Taybi syndrome, Down syndrome, nail-patella syndrome, chondrodysplasia punctata, fibular hemimelia, and arthrogryposis.[63] In both cases, the extensor apparatus may have a more lateral position, leading to flexion contracture, loss of active knee extension, external tibial rotation, shortening of the quadriceps, and severe contracture of the lateral structures.[67,68]

In these cases, the surgical approach is similar to that used for cases of habitual flexion instability (Figure 5).

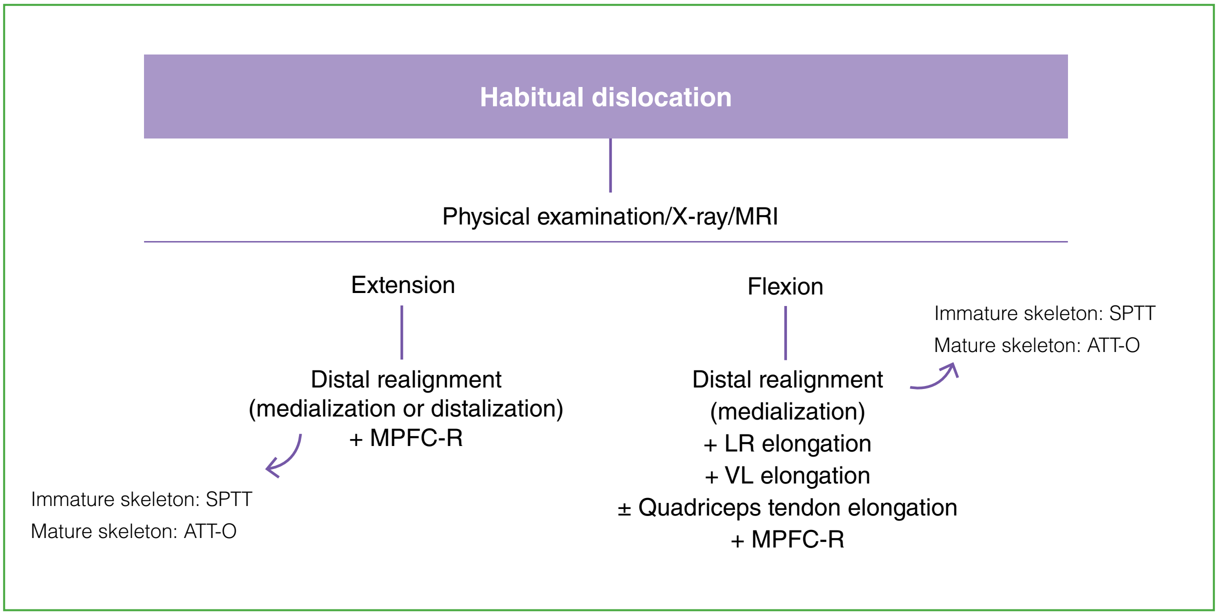


Figure 5. Therapeutic algorithm for patients with habitual dislocation in extension and flexion.
MRI = magnetic resonance imaging; MPFL-R = medial patellofemoral complex reconstruction; SPTT = subperiosteal patellar tendon transfer; ATT-O = anterior tibial tubercle osteotomy; LR = lateral retinaculum; VL = vastus lateralis.

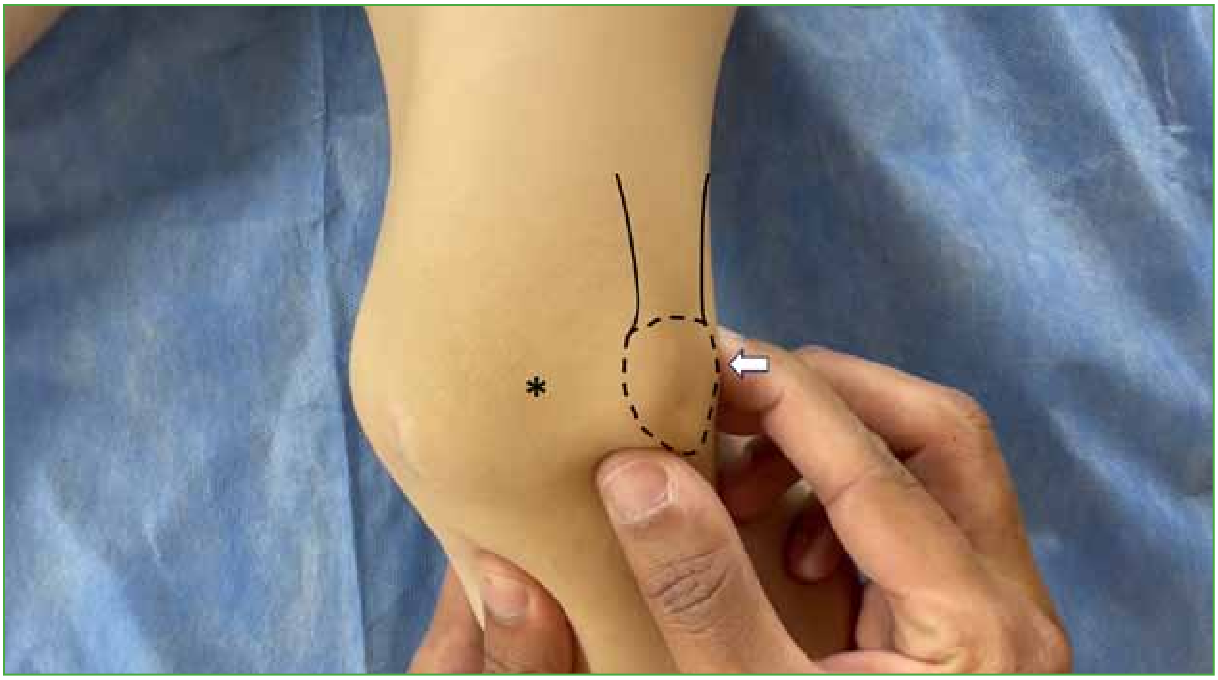


Figure 6. Fixed/irreducible lateral dislocation. The asterisk marks the center of the femoral trochlea and its relationship to the patella and extensor apparatus.

CONCLUSIONS

PFI is a common condition in children and adolescents. Its diverse presentations, variations in joint morphology, and associated factors make its management challenging. Accurate assessment and proper diagnosis are crucial to ensuring optimal joint function. Continued interest in better understanding this disorder and optimizing therapeutic approaches has contributed to improving the prognosis of these lesions in pediatric patients. Adopting an evidence-based approach and following diagnostic and therapeutic protocols will help provide patients with higher-quality treatment and reduce the incidence of complications, thereby promoting the development of their daily activities.

Conflict of interest: The authors declare no conflicts of interest.

M. Carabajal Mattar ORCID ID: https://orcid.org/0000-0002-0301-0867

REFERENCES

1. Dejour DH, Mesnard G, Giovannetti de Sanctis E. Updated treatment guidelines for patellar instability: “un menu à la carte”. *J Exp Orthop* 2021;8(1):109. https://doi.org/0.1186/s40634-021-00430-2
2. Waterman BR, Belmont PJ Jr, Owens BD. Patellar dislocation in the United States: role of sex, age, race, and athletic participation. *J Knee Surg* 2012;25(1):51-7. https://doi.org/10.1055/s-0031-1286199
3. Moiz M, Smith N, Smith TO, Chawla A, Thompson P, Metcalfe A. Clinical outcomes after the nonoperative management of lateral patellar dislocations: A systematic review. *Orthop J Sports Med* 2018;6(6):2325967118766275. https://doi.org/10.1177/2325967118766275
4. Lewallen LW, McIntosh AL, Dahm DL. Predictors of recurrent instability after acute patellofemoral dislocation in pediatric and adolescent patients. *Am J Sports Med* 2013;41(3):575-81. https://doi.org/10.1177/0363546512472873
5. Christensen TC, Sanders TL, Pareek A, Mohan R, Dahm DL, Krych AJ. Risk factors and time to recurrent ipsilateral and contralateral patellar dislocations. *Am J Sports Med* 2017;45(9):2105-10. https://doi.org/10.1177/0363546517704178
6. Willis RB, Firth G. Traumatic patellar dislocation: loose bodies and the MPFL. *J Pediatr Orthop* 2012;32 Suppl 1:S47-51. https://doi.org/10.1097/BPO.0b013e318256107b
7. Sanders TL, Pareek A, Johnson NR, Stuart MJ, Dahm DL, Krych AJ. Patellofemoral arthritis after lateral patellar dislocation: A matched population-based analysis. *Am J Sports Med* 2017;45(5):1012-7. https://doi.org/10.1177/0363546516680604
8. Tuxøe JI, Teir M, Winge S, Nielsen PL. The medial patellofemoral ligament: a dissection study. *Knee Surg Sports Traumatol Arthrosc* 2002;10(3):138-40. https://doi.org/10.1007/s00167-001-0261-z
9. Smirk C, Morris H. The anatomy and reconstruction of the medial patellofemoral ligament. *Knee* 2003;10(3):221-7. https://doi.org/10.1016/s0968-0160(03)00038-3
10. Velasquez Hammerle MV, Tanaka MJ. Medial patellofemoral reconstruction techniques for patellar instability. *Arthroscopy* 2023;39(6):1373-5. https://doi.org/10.1016/j.arthro.2023.01.006
11. Placella G, Tei MM, Sebastiani E, Criscenti G, Speziali A, Mazzola C, et al. Shape and size of the medial patellofemoral ligament for the best surgical reconstruction: a human cadaveric study. *Knee Surg Sports Traumatol Arthrosc* 2014;22(10):2327-33. https://doi.org/10.1007/s00167-014-3207-y
12. Nomura E, Inoue M, Osada N. Anatomical analysis of the medial patellofemoral ligament of the knee, especially the femoral attachment. *Knee Surg Sports Traumatol Arthrosc* 2005;13(7):510-5. https://doi.org/10.1007/s00167-004-0607-4
13. Baldwin JL. The anatomy of the medial patellofemoral ligament. *Am J Sports Med* 2009;37(12):2355-61. https://doi.org/10.1177/0363546509339909
14. Kang HJ, Wang F, Chen BC, Su YL, Zhang ZC, Yan CB. Functional bundles of the medial patellofemoral ligament. *Knee Surg Sports Traumatol Arthrosc* 2010;18(11):1511-6. https://doi.org/10.1007/s00167-010-1090-8

15. Philippot R, Chouteau J, Wegrzyn J, Testa R, Fessy MH, Moyen B. Medial patellofemoral ligament anatomy: implications for its surgical reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2009;17(5):475-9. https://doi.org/10.1007/s00167-009-0722-3
16. Schöttle PB, Schmeling A, Rosenstiel N, Weiler A. Radiographic landmarks for femoral tunnel placement in medial patellofemoral ligament reconstruction. *Am J Sports Med* 2007;35(5):801-4. https://doi.org/10.1177/0363546506296415
17. Stephen JM, Lumpaopong P, Deehan DJ, Kader D, Amis AA. The medial patellofemoral ligament: location of femoral attachment and length change patterns resulting from anatomic and nonanatomic attachments. *Am J Sports Med* 2012;40(8):1871-9. https://doi.org/10.1177/0363546512449998
18. Farrow LD, Alentado VJ, Abdulnabi Z, Gilmore A, Liu RW. The relationship of the medial patellofemoral ligament attachment to the distal femoral physis. *Am J Sports Med* 2014;42(9):2214-8. https://doi.org/10.1177/0363546514539917
19. Huddleston HP, Campbell KJ, Madden BT, Christian DR, Chahla J, Farr J, et al. The quadriceps insertion of the medial patellofemoral complex demonstrates the greatest anisometry through flexion. *Knee Surg Sports Traumatol Arthrosc* 2021;29(3):757-63. https://doi.org/10.1007/s00167-020-05999-2
20. Christian DR, Redondo ML, Cancienne JM, Shewman EF, Farr J, Cole BJ, et al. Differential contributions of the quadriceps and patellar attachments of the proximal medial patellar restraints to resisting lateral patellar translation. *Arthroscopy* 2020;36(6):1670-6. https://doi.org/10.1016/j.arthro.2020.01.058
21. Tanaka MJ, Chahla J, Farr J 2nd, LaPrade RF, Arendt EA, Sanchis-Alfonso V, et al. Recognition of evolving medial patellofemoral anatomy provides insight for reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2019;27(8):2537-50. https://doi.org/10.1007/s00167-018-5266-y. Erratum in: *Knee Surg Sports Traumatol Arthrosc* 2018 Nov 23; PMID: 30370440
22. Sochacki KR, Shea KG, Varshneya K, Safran MR, Abrams GD, Donahue J, et al. Relationship of the medial patellofemoral ligament origin on the distal femur to the distal femoral physis: A systematic review. *Am J Sports Med* 2021;49(1):261-6. https://doi.org/10.1177/0363546520904685
23. Baskar D, Stavinoha TJ, Sanchez M, Gupta A, Randhawa SD, Rohde MS, et al. Quantifying the relationship between the medial quadriceps tendon-femoral ligament and patellar borders: A pediatric cadaveric study. *Am J Sports Med* 2022;50(9):2433-8. https://doi.org/10.1177/03635465221103250
24. Shea KG, Polousky JD, Jacobs JC Jr, Ganley TJ, Aoki SK, Grimm NL, et al. The patellar insertion of the medial patellofemoral ligament in children: a cadaveric study. *J Pediatr Orthop* 2015;35(4):e31-5. https://doi.org/10.1097/BPO.0000000000000399
25. Stavinoha TJ, Shea KG. Physeal sparing approaches for MPFL reconstruction. *Curr Rev Musculoskelet Med* 2023;16(12):598-606. https://doi.org/10.1007/s12178-023-09864-w
26. Khormaee S, Kramer DE, Yen YM, Heyworth BE. Evaluation and management of patellar instability in pediatric and adolescent athletes. *Sports Health* 2015;7(2):115-23. https://doi.org/10.1177/1941738114543073
27. Stefancin JJ, Parker RD. First-time traumatic patellar dislocation: a systematic review. *Clin Orthop Relat Res* 2007;455:93-101. https://doi.org/10.1097/BLO.0b013e31802eb40a
28. Gruskay JA, Strickland SM, Casey E, Chiaia TA, Green DW, Gomoll AH. Team approach: Patellofemoral instability in the skeletally immature. *JBJS Rev* 2019;7(7):e10. https://doi.org/10.2106/JBJS.RVW.18.00159
29. Lin KM, Thacher R, Apostolakos JM, Heath MR, Mackie AT, Fabricant PD. Implant-mediated guided growth for coronal plane angular deformity in the pediatric patient with patellofemoral instability. *Arthrosc Tech* 2021;10(3):e913-e924. https://doi.org/10.1016/j.eats.2020.11.012
30. Beighton P, Solomon L, Soskolne CL. Articular mobility in an African population. *Ann Rheum Dis* 1973;32(5):413-8. https://doi.org/10.1136/ard.32.5.413
31. Caton J, Deschamps G, Chambat P, Lerat JL, Dejour H. Les rotules basses. A propos de 128 observations [Patella infera. Apropos of 128 cases]. *Rev Chir Orthop Reparatrice Appar Mot* 1982;68(5):317-25. PMID: 6216535
32. Dejour H, Walch G, Nove-Josserand L, Guier C. Factors of patellar instability: an anatomic radiographic study. *Knee Surg Sports Traumatol Arthrosc* 1994;2(1):19-26. https://doi.org/10.1007/BF01552649
33. DeFroda SF, Gil JA, Boulos A, Cruz AI Jr. Diagnosis and management of traumatic patellar instability in the pediatric patient. *Orthopedics* 2017;40(5):e749-e757. https://doi.org/10.3928/01477447-20170602-04
34. Lippacher S, Reichel H, Nelitz M. Radiological criteria for trochlear dysplasia in children and adolescents. *J Pediatr Orthop B* 2011;20(5):341-4. https://doi.org/10.1097/BPB.0b013e3283474c8b
35. Furdock RJ, Sun KJ, Ren B, Folkman M, Glotzbecker MP, Son-Hing JP, et al. The reliability of the modified Fels Knee Skeletal Maturity System. *J Pediatr Orthop* 2024;44(2):e192-e196. https://doi.org/10.1097/BPO.0000000000002553

36. Masquijo JJ, Altube G, Ferreyra A, Allende V, Torres-Gomez A. Precisión de la resonancia magnética para la medición de la distancia TT-TG en adolescentes. *Artroscopia* [Internet] 2013;20(1):7-10. Disponible en: https://www.revistaartroscopia.com.ar/ediciones-anteriores/images/artroscopia/volumen-20-nro-1/20_01_02.pdf
37. Steensen RN, Bentley JC, Trinh TQ, Backes JR, Wiltfong RE. The prevalence and combined prevalences of anatomic factors associated with recurrent patellar dislocation: a magnetic resonance imaging study. *Am J Sports Med* 2015;43(4):921-7. https://doi.org/10.1177/0363546514563904
38. Diederichs G, Köhlitz T, Kornaropoulos E, Heller MO, Vollnberg B, Scheffler S. Magnetic resonance imaging analysis of rotational alignment in patients with patellar dislocations. *Am J Sports Med* 2013;41(1):51-7. https://doi.org/10.1177/0363546512464691
39. Dejour D, Ferrua P, Ntagiopoulos PG, Radier C, Hulet C, Rémy F, et al. The introduction of a new MRI index to evaluate sagittal patellofemoral engagement. *Orthop Traumatol Surg Res* 2013;99(8 Suppl):S391-8. https://doi.org/10.1016/j.otsr.2013.10.008
40. Levy BJ, Tanaka MJ, Fulkerson JP. Current concepts regarding patellofemoral trochlear dysplasia. *Am J Sports Med* 2021;49(6):1642-50. https://doi.org/10.1177/0363546520958423
41. Parikh SN, Schlechter JA, Veerkamp MW, Stacey JD, Gupta R, Pendleton AM, et al. Consensus-based guidelines for management of first-time patellar dislocation in adolescents. *J Pediatr Orthop* 2024;44(4):e369-e374. https://doi.org/10.1097/BPO.0000000000002616
42. Seeley M, Bowman KF, Walsh C, Sabb BJ, Vanderhave KL. Magnetic resonance imaging of acute patellar dislocation in children: patterns of injury and risk factors for recurrence. *J Pediatr Orthop* 2012;32(2):145-55. https://doi.org/10.1097/BPO.0b013e3182471ac2
43. Balcarek P, Oberthür S, Hopfensitz S, Frosch S, Walde TA, Wachowski MM, et al. Which patellae are likely to redislocate? *Knee Surg Sports Traumatol Arthrosc* 2014;22(10):2308-14. https://doi.org/10.1007/s00167-013-2650-5
44. Jaquith BP, Parikh SN. Predictors of recurrent patellar instability in children and adolescents after first-time dislocation. *J Pediatr Orthop* 2017;37(7):484-90. https://doi.org/10.1097/BPO.0000000000000674
45. Lewallen L, McIntosh A, Dahm D. First-time patellofemoral dislocation: Risk factors for recurrent instability. *J Knee Surg* 2015;28(4):303-9. https://doi.org/10.1055/s-0034-1398373
46. Hevesi M, Heidenreich MJ, Camp CL, Hewett TE, Stuart MJ, Dahm DL, et al. The recurrent instability of the patella score: a statistically based model for prediction of long-term recurrence risk after first-time dislocation. *Arthroscopy* 2019;35(2):537-43. https://doi.org/10.1016/j.arthro.2018.09.017
47. Sherman SL. Editorial commentary: Risk stratification is the new "standard of care" following first-time patellar dislocation. *Arthroscopy* 2019;35(8):2482-3. https://doi.org/10.1016/j.arthro.2019.05.039
48. Shubin Stein BE, Gruber S, Brady JM. MPFL in first-time dislocators. *Curr Rev Musculoskelet Med* 2018;11(2):182-7. https://doi.org/10.1007/s12178-018-9473-4
49. Rund JM, Hinckel BB, Sherman SL. Acute patellofemoral dislocation: Controversial decision-making. *Curr Rev Musculoskelet Med* 2021;14(1):82-7. https://doi.org/10.1007/s12178-020-09687-z
50. Respizzi S, Cavallin R. First patellar dislocation: from conservative treatment to return to sport. *Joints* 2014;2(3):141-5. https://doi.org/10.11138/jts/2014.2.3.141
51. Palmu S, Kallio PE, Donell ST, Helenius I, Nietosvaara Y. Acute patellar dislocation in children and adolescents: a randomized clinical trial. *J Bone Joint Surg Am* 2008;90(3):463-70. https://doi.org/10.2106/JBJS.G.00072
52. Regalado G, Lintula H, Kokki H, Kröger H, Väätäinen U, Eskelinen M. Six-year outcome after non-surgical versus surgical treatment of acute primary patellar dislocation in adolescents: a prospective randomized trial. *Knee Surg Sports Traumatol Arthrosc* 2016;24(1):6-11. https://doi.org/10.1007/s00167-014-3271-3
53. Longo UG, Ciuffreda M, Locher J, Berton A, Salvatore G, Denaro V. Treatment of primary acute patellar dislocation: Systematic review and quantitative synthesis of the literature. *Clin J Sport Med* 2017;27(6):511-23. https://doi.org/10.1097/JSM.0000000000000410
54. Bauer KL. Osteochondral injuries of the knee in pediatric patients. *J Knee Surg* 2018;31(5):382-91. https://doi.org/10.1055/s-0038-1625956
55. Liu JN, Steinhaus ME, Kalbian IL, Post WR, Green DW, Strickland SM, et al. Patellar instability management: A survey of the International Patellofemoral Study Group. *Am J Sports Med* 2018;46(13):3299-3306. https://doi.org/10.1177/0363546517732045
56. Puzzitiello RN, Waterman B, Agarwalla A, Zuke W, Cole BJ, Verma NN, et al. Primary medial patellofemoral ligament repair versus reconstruction: Rates and risk factors for instability recurrence in a young, active patient population. *Arthroscopy* 2019;35(10):2909-15. https://doi.org/10.1016/j.arthro.2019.05.007

57. Howells NR, Barnett AJ, Ahearn N, Ansari A, Eldridge JD. Medial patellofemoral ligament reconstruction: a prospective outcome assessment of a large single centre series. *J Bone Joint Surg Br* 2012;94(9):1202-8. https://doi.org/10.1302/0301-620X.94B9.28738
58. Fisher B, Nyland J, Brand E, Curtin B. Medial patellofemoral ligament reconstruction for recurrent patellar dislocation: a systematic review including rehabilitation and return-to-sports efficacy. *Arthroscopy* 2010;26(10):1384-94. https://doi.org/10.1016/j.arthro.2010.04.005
59. Nelitz M, Dreyhaupt J, Reichel H, Woelfle J, Lippacher S. Anatomic reconstruction of the medial patellofemoral ligament in children and adolescents with open growth plates: surgical technique and clinical outcome. *Am J Sports Med* 2013;41(1):58-63. https://doi.org/10.1177/0363546512463683
60. Damasena I, Blythe M, Wysocki D, Kelly D, Annear P. Medial patellofemoral ligament reconstruction combined with distal realignment for recurrent dislocations of the patella: 5-year results of a randomized controlled trial. *Am J Sports Med* 2017;45(2):369-76. https://doi.org/10.1177/0363546516666352
61. Masquijo JJ. Transferencia subperióstica del tendón rotuliano para realineación distal en pacientes esqueléticamente inmaduros con inestabilidad patelofemoral. *Artroscopia* [Internet] 2021;28(3):227-31. Disponible en: https://www.revistaartroscopia.com.ar/index.php/revista/issue/view/8/AR_28_03
62. Masquijo J, Parikh SN, Kothari A. Evaluation of the optimal femoral fixation site for medial patellofemoral ligament reconstruction in the skeletally immature patient. *Orthopedics* 2023;46(2):108-13. https://doi.org/10.3928/01477447-20221031-07
63. Hire JM, Parikh SN. 4-in-1 quadricepsplasty for fixed and habitual dislocation of patella. *Arthrosc Tech* 2022;11(4):e537-e544. https://doi.org/10.1016/j.eats.2021.12.004
64. Parikh SN, Lykissas MG. Classification of lateral patellar instability in children and adolescents. *Orthop Clin North Am* 2016;47(1):145-52. https://doi.org/10.1016/j.ocl.2015.08.016
65. Ellsworth B, Hidalgo Perea S, Green DW. Stepwise lengthening of the quadriceps extensor mechanism for severe obligatory and fixed patella dislocators. *Arthrosc Tech* 2021;10(5):e1327-31. https://doi.org/10.1016/j.eats.2021.01.034
66. Danino B, Deliberato D, Abousamra O, Singh S, Klingele K. Four-in-One extensor realignment for the treatment of obligatory or fixed, lateral patellar instability in skeletally immature knee. *J Pediatr Orthop* 2020;40(9):503-8. https://doi.org/10.1097/BPO.0000000000001610
67. Imbergamo C, Coene R, Milewski M. Management of fixed dislocation of the patella: Current concept review. *J POSNA* 2020;2(2):122. https://doi.org/10.55275/JPOSNA-2020-122
68. Grisdela PT, Paschos N, Tanaka MJ. Fixed (congenital) patellar dislocation. *Clin Sports Med* 2022;41(1):123-36. https://doi.org/10.1016/j.csm.2021.07.010

Extensor Digitorum Brevis Manus, a Differential Diagnosis

Carolina Abril-Botero,[*] Tomás Martínez-Villegas[**]
[*]*Universidad de Antioquia, School of Medicine, Specialization in Orthopedics and Traumatology, Medellin, Colombia.*
[**]*Universidad Pontificia Bolivariana, School of Medicine, Orthopedics and Traumatology and Surgery of the Hand, Medellin, Colombia.*

ABSTRACT
The extensor digitorum brevis manus muscle is a variant of the hand extensors. It is a supernumerary muscle on the dorsum of the wrist, located in the fourth extensor compartment. It is usually asymptomatic, but when it causes discomfort, it manifests as a painful mass. When it is symptomatic, surgical treatment is recommended, which may include muscle excision or extensor retinaculum release. We present a 30-year-old patient with a painful mass on the dorsum of the left hand; clinically, a ganglion was suspected and scheduled for surgical resection. She underwent surgery and was diagnosed with symptomatic EDBM, which was treated with extensor retinaculum release. EDBM was found incidentally in a cadaveric dissection; therefore, its true incidence is unknown. EDBM originates in the wrist joint capsule, below the dorsal radiocarpal ligament; its distal insertion is the ulnar side of the extensor mechanism in the metacarpophalangeal joint where it is present. Innervated by the posterior interosseous, research has shown that its purpose is to extend and deviate the finger towards the side where it is inserted. This case is particularly interesting given the scarcity of information on its incidence and prevalence, with the majority of that information coming from postmortem reports.
Keywords: Myotomy; hand surgery; muscles.
Level of Evidence: IV

Extensor digitorum brevis manus, un diagnóstico diferencial

RESUMEN
El músculo *extensor digitorum brevis manus* es una variante de los extensores de la mano. Se trata de un músculo supernumerario en el dorso de la muñeca ubicado en el cuarto compartimento extensor. Suele ser asintomático, pero ocasionalmente se presenta como una masa dolorosa; en estos casos, está indicado el tratamiento quirúrgico que consiste en la resección del músculo o la liberación del retináculo extensor del cuarto compartimento.
Presentamos a una paciente de 30 años, con una masa dolorosa en el dorso de la mano izquierda. Según las evaluaciones clínica y ecográfica, se sospechó un ganglión y se programó la resección quirúrgica. En la cirugía, se encontró tejido muscular compatible clínicamente con el *extensor digitorum brevis manus*, y se liberó el retináculo extensor. Los estudios publicados sobre su incidencia y prevalencia son escasos y, en su mayoría, se trata de informes *post mortem*, por lo que este caso presentado reviste particular interés.
Palabras clave: Miotomía; cirugía de mano; músculos.
Nivel de Evidencia: IV

INTRODUCTION

The *extensor digitorum brevis manus* (EDBM) was first described by the anatomist Bernhard Albinus in the 18th century, who referred to it as the *extensor brevis digiti indicis vel medii in*.[1] The term EDBM was first used in 1875 and has since become the most widely accepted name.[2] The EDBM is an uncommon accessory muscle of the dorsum of the hand, located in the fourth extensor compartment of the wrist, with a low incidence, varying between 1% and 10%. [3]

EDBM patients are usually asymptomatic, so its incidence is likely underestimated and primarily based on *post-mortem* findings. [4]

Received on November 19th, 2023. Accepted after evaluation on February 20th, 2024 • Dr. CAROLINA ABRIL-BOTERO • maria.abril@udea.edu.co ID https://orcid.org/0000-0002-8499-9741
How to cite this article: Abril-Botero C, Martínez-Villegas T. Extensor Digitorum Brevis Manus, a Differential Diagnosis. *Rev Asoc Argent Ortop Traumatol* 2024;89(4):416-418. https://doi.org/10.15417/issn.1852-7434.2024.89.4.1849

From an embryological perspective, the precursor muscle of the hand extensors differentiates into superficial, deep, and radial portions. The deep portion undergoes the most changes, leading to the greatest number of anatomical variants, including the EDBM, which arises from the unstable and deep portion of the extensor precursors.[2]

We present an atypical case of a symptomatic EDBM, diagnosed incidentally after a false positive diagnosis of a dorsal ganglion of the wrist.

CLINICAL CASE

A 30-year-old woman consulted the Hand Surgery Service with a four-month history of a painful mass on the dorsum of her left hand. Given the clinical suspicion of a dorsal ganglion of the wrist, confirmed by ultrasound, and due to the symptoms, surgical resection was scheduled.

During the operation, macroscopic evaluation revealed a mass of muscle tissue located on the dorsum of the hand, clinically compatible with the EDBM muscle (Figure). The pathology study revealed the presence of striated muscle tissue in longitudinal bundles of typical appearance, confirming the suspicion of an accessory extensor muscle.

Figure. Images of accessory extensor muscle tissue compatible with *extensor digitorum brevis manus*.

DISCUSSION

The EDBM is an aberrant extensor of the fingers, located on the dorsum of the hand or wrist, and is detected in approximately 2-3% of the population, with a slight predominance in males.[5] The most common presentation involves a fascicle of the extensor tendon of the index finger arising from the dorsal radiocarpal ligaments. The second most common presentation is the muscle inserting into the third finger. [3]

Classifications of this accessory muscle have been developed. Ogura and Gama's classification categorizes EDBM into three groups based on its insertion relative to the extensor indicis proprius: Group I, EDBM attached to the index finger at the dorsal aponeurosis, without the extensor indicis proprius; Group II, EDBM attached to the index finger along with the extensor indicis proprius; and Group III, EDBM attached to the third metacarpal, contributing to the extension of that finger. [2]

The presence of this accessory muscle does not usually cause symptoms, as reported by Shereen et al.[2] However, it can occasionally cause pain and a palpable mass, with mechanical restriction primarily during wrist extension, as seen in our patient. [3]

In 1999, Hayashi et al. coined the term "fourth compartment syndrome" to describe dorsal wrist pain with five possible causes: EDBM, dorsal ganglion, abnormal extensor indicis muscle, tenosynovitis, and carpal bone abnormalities or deformities. In our case, EDBM emerged as the differential diagnosis during surgery, since the initial diagnosis was a dorsal ganglion of the wrist.[2]

Few cases of surgical management of symptomatic EDBM have been described. Surgical options include decompression of the extensor retinaculum or complete resection of the muscle.[6] If retinaculum decompression is chosen, another intervention may be required due to persistent symptoms, as noted by Waterman et al. Ogura et al. proposed a management algorithm based on their classification: for groups I and IIA, where the extensor indicis proprius is absent, retinaculum release is recommended without complete muscle resection; for groups IIB, IIC, and III, complete muscle resection is advised.[2]

CONCLUSIONS

Based on the information presented in this clinical case, we can conclude that there is a notable lack of information in the literature regarding abnormal extensor muscles of the wrist that can cause symptoms and lead to consultations with orthopedic specialists. Furthermore, this gap in knowledge means there is no established evidence on the ideal management of these patients.

Conflict of interest: The authors declare no conflicts of interest.

T. Martínez-Villegas ORCID ID: https://orcid.org/0000-0003-1694-3161

REFERENCES

1. Albinus BS. De extensore digitorum brevis manus. *Academicarum Annotationum* 1758;IV:28-9.
2. Shereen R, Loukas M, Tubbs RS. Extensor digitorum brevis manus: A comprehensive review of this variant muscle of the dorsal hand. *Cureus* [Internet] 2017. Available at: https://doi.org/10.7759/cureus.1568
3. Martínez Martínez F, Moreno Fernández JM, García Hortelano S, Rotella PS. Músculo extensor anómalo de la mano: "Extensor digitiforme brevis manus". *Rev Asoc Argent Ortop Traumatol* (Supl) [Internet] 2016;81(1):6. Available at: https://doi.org/10.15417/2525-1015.2016.81.649
4. Fernández Díez E, Marti E, Redondo Sedano J, Castellano Yáñez C, Gómez Sánchez A, Proaño Landazuri SM, et al. Extensor digitorum brevis manus bilateral. *Cir Pediatr* [Internet] 2023;36(2):90-2. Available at: https://doi.org/10.54847/cp.2023.02.08
5. Ranade AV, Rai R, Prabhu LV, Rajanigandha V, Prakash, Janardhanan JP, et al. Incidence of extensor digitorum brevis manus muscle. *Hand (N Y)* [Internet] 2008;3(4):320-3. Available at: https://doi.org/10.1007/s11552-008-9111-5
6. Waterman BR, Dunn JC, Kusnezov N, Romano D, Pirela-Cruz MA. Surgical management of symptomatic extensor digitorum brevis Manus: A proposed algorithm for treatment. *Mil Med* [Internet] 2015;180(10):e1115-7. Available at: https://doi.org/10.7205/milmed-d-14-00697

Wagstaffe-Le Fort Fracture in a Patient With an Ankle Fracture-Dislocation. Quadrimalleolar Equivalent. Case Report

Juan Manuel Romero Ante, Felipe Carrasco Vélez
Orthopedics and Traumatology Service, Hospital Alma Máter de Antioquia, Medellín, Colombia.

ABSTRACT
In this article, we present the case of a patient who suffered a fracture-dislocation of the left ankle with trimalleolar involvement. However, the preoperative tomography revealed the additional involvement of the Wagstaffe-Le Fort tubercle, so it was decided to approach it as a quadrimalleolar equivalent different from those previously described, with involvement of the anterolateral fragment of the tibia (Tillaux-Chaput). This case allows for a 360° approach to ankle injuries that disrupt joint congruence, and an osteo-ligament analysis is proposed for its definitive treatment, prioritizing anatomical repairs to reduce the need for syndesmotic transfixation, without compromising surgical outcomes.
Keywords: Ankle fracture; Wagstaffe-Le Fort; anteroinferior tibiofibular ligament; trimalleolar fracture-dislocation; malleolus; quadrimalleolar.
Level of Evidence: IV

Fractura del fragmento de Wagstaffe-Le Fort en un paciente con luxofractura de tobillo. Equivalente cuadrimaleolar. Reporte de un caso

RESUMEN
Se presenta el caso de una paciente que sufre una luxofractura del tobillo izquierdo con compromiso trimaleolar, pero, en la tomografía computarizada prequirúrgica, se documenta el compromiso adicional del tubérculo de Wagstaffe-Le Fort, por lo que se decide considerarlo como un equivalente cuadrimaleolar diferente de los descritos previamente con el compromiso del fragmento anterolateral de la tibia (Tillaux-Chaput). Este caso permite un enfoque de 360° de las lesiones de tobillo que afectan la congruencia articular y se propone un análisis osteo-ligamentario para su tratamiento definitivo, favoreciendo las reparaciones anatómicas para disminuir la necesidad de fijaciones transindesmales sin afectar el desenlace quirúrgico.
Palabras clave: Fractura de tobillo; Wagstaffe-Le Fort; ligamento tibioperoneo anteroinferior; luxofractura trimaleolar; maléolo; cuadrimaleolar.
Nivel de Evidencia: IV

INTRODUCTION

The ankle joint is made up of a set of bone and ligament structures that work in perfect harmony and allow many of the activities of daily life, work and sports. The distal segments of the tibia (the plafond and medial malleolus) articulate with the fibula (lateral malleolus) and the talus, resulting in three joints: distal tibiofibular, tibiotalar syndesmosis, and talofibular, each with their own static ligament stabilizers.. [1]

Over the years, other structures that form part of this joint have been described separately and progressively. Destot[2] described the posterior lip of the tibia, referring to it as the third malleolus and known today as Volkmann's malleolus. In 1907, Chaput[3] described the anterolateral region of the tibia or Tillaux-Chaput tubercle, structures of vital importance for the stabilization of the ankle, since they serve as the tibial insertion point for the ligaments

Received on January 21st, 2024. Accepted after evaluation on April 18th, 2024 • Dr. JUAN MANUEL ROMERO ANTE • juanmaro04041977@gmail.com https://orcid.org/0000-0002-9390-9496
How to cite this article: Romero Ante JM, Carrasco Vélez F. Wagstaffe-Le Fort Fracture in a Patient With an Ankle Fracture-Dislocation. Quadrimalleolar Equivalent. Case Report. *Rev Asoc Argent Ortop Traumatol* 2024;89(4):419-424. https://doi.org/10.15417/issn.1852-7434.2024.89.4.1915

that stabilize the syndesmosis: posterior-inferior tibiofibular ligament (PITFL) and anterior-inferior tibiofibular ligament (AITFL), respectively.

The ankle syndesmosis is defined as the distal joint between the tibia and fibula, typically stabilized by the AITFL, the posterior-inferior tibiofibular ligament and the interosseous and transverse ligaments.[1]

In 1875, Wagstaffe described, for the first time, an avulsion fracture of the anterior region of the fibula. Later, in 1886, Le Fort described the same vertical fractures of the anteromedial portion of the fibula corresponding to the anatomical fibular insertion site of the AITFL, and introduced, for the first time, the description of the fractures known as Wagstaffe-Le Fort fractures.[4]

In 1932, Henderson coined the term trimalleolar fracture to refer to fractures involving fragments of the medial and lateral malleoli and the posterior tibial lip or Volkmann's fragment or posterior malleolus. Then, in 1996, Van Laarhoven used the term "fourth malleolus" for fractures involving, in addition, the Tillaux-Chaput fragment.[5] According to the above, the biomechanical compromise provided by the tibial disinsertion of the AITFL can also be represented by avulsions of the Wagstaffe-Le Fort tubercle, allowing us to refer to fractures involving the three main malleoli and the anterior region of the fibula as quadrimalleolar equivalents, as well as fractures involving the anterolateral region of the distal tibia.

Few studies have been conducted to record the occurrence and characteristics of quadrimalleolar lesions, as well as the most recommended treatment. Due to the above, we present a case that was documented and treated as a quadrimalleolar equivalent, with special emphasis on the anatomical repair of the bone and ligament components to provide adequate stability to the tibiofibular syndesmosis without using transfixation in this anatomical segment.

CLINICAL CASE

A 54-year-old woman came to the Emergency Department after a fall from a chair of approximately 60 cm in height. She reported trauma to the left ankle only and severe pain, edema around both malleoli, marked deformity and inability to stand and walk. On physical examination, the patient's general condition was good, with no skin wounds, with ecchymosis around both malleoli, edema and deformity in the left ankle, pain on palpation of both malleoli, preserved sensitivity in the territories of the sensory nerves of the foot, no paresis in the toe flexors or extensors, and normal distal pulses and capillary refill time in all toes. She reported that she had epilepsy and that Neurology had adequately treated her ailment, but she denied having had any surgery.

The patient was admitted with plain anteroposterior and lateral radiographs of the left ankle showing a trimalleolar fracture with lateral translation of the talus (Figure 1). After analysis of the images, a trimalleolar fracture-dislocation of the left ankle was diagnosed. The patient underwent closed reduction with pharmacological sedation by the Emergency Medicine Department. She was immobilized with a posterior splint.

After the procedure, there were no changes in the neurological or vascular physical examination of the extremity and a simple CT scan of the right ankle was requested to characterize the lesions and for surgical planning. In the control images, the trimalleolar involvement already described was observed with an additional component in the anteromedial and distal region of the fibula corresponding to a Wagstaffe-Le Fort fracture (Figure 2); therefore, it was decided to consider the injury as a quadrimalleolar equivalent. Osteosynthesis and ligament reconstruction were performed and the patient was discharged with analgesics and recommendations to reduce edema.

The patient attended the surgical service two weeks after discharge. The soft tissue status was evaluated prior to admission in the operating room and a positive wrinkle sign was documented, with no vesicles or lesions contraindicating the procedure.

The surgery was performed under regional anesthesia. Antibiotic prophylaxis was administered with 2 g of cefazolin, 30 min before the skin incision. The patient was placed in the right lateral decubitus position and the surgical site was washed with alcohol and chlorhexidine soap according to the institutional infection prevention protocol.

The posterior malleolus was reduced and fixated under direct vision using a posterolateral approach to the ankle, followed by reduction and stabilization using an anatomical plate in the distal fibula. Then, through an anterolateral approach to the ankle, the fractured Wagstaffe-Le Fort fragment was identified with its ligamentous insertion intact, it was stabilized with an anchoring suture to the bone, and the recovery of AITFL tension was verified (Figure 3).

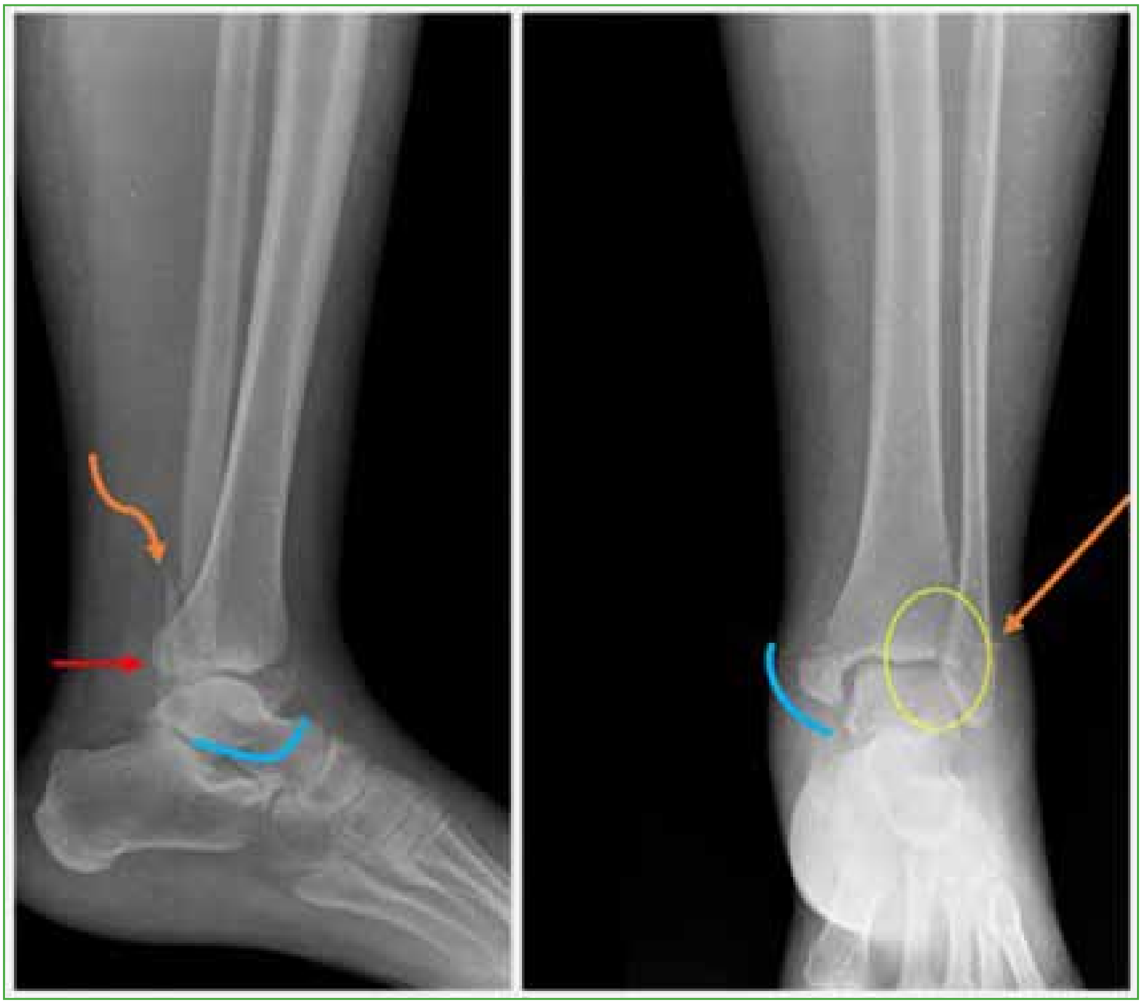


Figure 1. Initial lateral and anteroposterior radiographs of the left ankle. Fracture of fibula (orange arrow), fracture of the medial malleolus (blue curve), fracture of the posterior malleolus (red arrow) and lateralization of the talus (yellow oval).

Figure 2. Initial computed tomography of the left ankle. Wagstaffe-Le Fort fragment, increased anterior and sagittal translation of the distal fibula in the axial section.

Figure 3. Anterolateral approach. Note the rotated and displaced Wagstaffe-Le Fort fragment.

The patient was positioned supine, and a medial approach to the ankle was performed to achieve anatomical reduction of the medial malleolus, followed by fixation with cannulated screws. The outcome was satisfactory according to the image intensifier evaluation. Dynamic evaluation of the integrity of the syndesmosis was performed and no increase in the medial clear space was detected after the forced external rotation maneuver or Cotton test.

The patient remained hospitalized for pain management and for a CT scan in which adequate reduction of the fractures was observed, with no loss of tibiotalar congruence (Figure 4). After four weeks of physical therapy without weight-bearing, evolution was adequate, followed by progressive limb weight-bearing. After six months, she had a pain-free gait and an AOFAS score of 82. The fractures had healed (Figure 5).

Figure 4. Control computed tomography of the left ankle. Anchor suture (red circle), Wagstaffe-Le Fort fragment (blue arrow), and reduced anterior cortex (yellow arrow).

Figure 5. Anteroposterior and lateral radiographs of the left ankle, control at 6 months. Complete consolidation.

DISCUSSION

Injuries affecting the syndesmosis may compromise the bone integrity of the tibia or fibula, their respective ligamentous structures, or both components. These injuries alter the anatomy and biomechanics of the ankle in a way that, after surgical stabilization, residual widenings of more than 1 mm decrease the tibiotalar contact area by 42%, altering the patterns of support and distribution of mechanical loads on the joint and predisposing to the development of long-term pain and premature degenerative changes.[6]

It has been demonstrated that instability in external rotation of the distal tibiofibular joint increases by 24% with an AITFL tear and by up to 11% with a tear of the posterior-inferior tibiofibular ligament;[7] thus, anatomical reduction is defined as the physiological bone restoration of the ankle and the recovery of physiological tension of the ligaments that comprise the ankle.[8]

According to the literature, fractures with avulsion of the AITFL are not rare; they are detected in up to 25.8% of unstable ankle injuries requiring surgical management, and their diagnosis increases significantly when a CT scan is requested. In addition, a correlation has been demonstrated between Danis-Weber type B and C fractures with Wagstaffe-Le Fort type II and III injuries, respectively.[4] Likewise, the size of the avulsed fragment determines the type of fixation, although there is still no clear consensus. Fragments larger than 5 mm could be fixed with a 2.7 mm screw with a washer;[9] however, for small fragments that cannot be fixed by screws, the use of transosseous sutures or anchor sutures for anatomic repair is a reasonable option, offering a good biological and mechanical support that should be considered by surgeons.[5]

Bone and ligament stabilization of unstable ankle injuries has been shown to reduce the need for syndesmotic transfixation in up to 83% of cases.[10]

In our case, we present a quadrimalleolar-equivalent injury, as it consists of a type II posterior malleolus fracture according to the Bartoníček and Rammelt classification, a type C medial malleolus fracture according to the Herscovici classification, a type B fibula fracture according to the Danis-Weber classification, and an avulsed fibula fracture of the Wagstaffe-Le Fort fragment according to the Park type II classification.

In this patient, a 360° approach was used, thus achieving the reduction and fixation of each of the components, achieving anatomical reduction and avoiding additional fixation of the syndesmosis with a rigid or dynamic system.

CONCLUSIONS

Fracture with avulsion of the AITFL at its fibular insertion or Wagstaffe-Le Fort injury should be suspected, ideally diagnosed with computed tomography, and properly stabilized. This will enable the management and approach of unstable ankle injuries from a 360° perspective, resulting in proper reconstruction of the bone and ligament anatomy as a more anatomical treatment method than simply using reduction clamps and position screws, which cause high rates of malreduction.

Conflict of interest: The authors declare no conflicts of interest.

F. Carrasco Velez ORCID ID: https://orcid.org/0000-0003-3831-5115

REFERENCES

1. Hermans JJ, Beumer A, de Jong TAW, Kleinrensink G-J. Anatomy of the distal tibiofibular syndesmosis in adults: a pictorial essay with a multimodality approach. *J Anat* 2010;217(6):633-45. https://doi.org/10.1111/j.1469-7580.2010.01302.x
2. Destot E. *Traumatismes du pied et rayons X. Malleoles, astragale, calcaneum, avant-pied*. Paris: Masson; 1911, p. 1-10.
3. Chaput V. *Les fractures malléolaires du cou-de-pied et les accidents du travail*. Paris: Masson; 1907.
4. Birnie MFN, van Schilt KLJ, Sanders FRK, Kloen P, Schepers T. Anterior inferior tibiofibular ligament avulsion fractures in operatively treated ankle fractures: a retrospective analysis. *Arch Orthop Trauma Surg* 2019;139(6):787-93. https://doi.org/10.1007/s00402-019-03138-2
5. Rammelt S, Bartoníček J, Kroker L, Neumann AP. Surgical fixation of quadrimalleolar fractures of the ankle. *J Orthop Trauma* 2021;35(6):e216-e222. https://doi.org/10.1097/BOT.0000000000001915
6. Clare MP, Berkowitz MJ. Revision open reduction and internal fixation of ankle and syndesmosis malunions. *Instr Course Lect* 2019;68:265-74. PMID: 32032064
7. Akoh CC, Phisitkul P. Anatomic ligament repairs of syndesmotic injuries. *Orthop Clin North Am* 2019;50:401-14. https://doi.org/10.1016/j.ocl.2019.02.004
8. Regauer M, Mackay G, Nelson O, Böcker W, Ehrnthaller C. Evidence-based surgical treatment algorithm for unstable syndesmotic injuries. *J Clin Med* 2022;11(2):331. https://doi.org/10.3390/jcm11020331
9. Diallo J, Wagener J, Schweizer C, Lang TH, Ruiz R, Hintermann B. Intraoperative findings of lateral ligament avulsion fractures and outcome after refixation to the fibula. *Foot Ankle Int* 2018;39(6):669-73. https://doi.org/10.1177/1071100718760273
10. Bae KJ, Kang S-B, Kim K, Lee J, Go TW. Reduction and fixation of anterior inferior tibiofibular ligament avulsion fracture without syndesmotic screw fixation in rotational ankle fracture. *J Int Med Res* 2019;48(4):1-15. https://doi.org/10.1177/0300060519882550

Anterior Interosseous Nerve Syndrome Secondary to Diaphyseal Humerus Fracture in Adults

Gonzalo Viollaz, Juan Ramallo
Department of Traumatology and Orthopedics, Hospital Británico de Buenos Aires, Autonomous City of Buenos Aires, Argentina.

ABSTRACT
Diaphyseal fractures of the humerus are associated with radial nerve injuries in up to 17% of adult patients. However, median nerve involvement is rarely reported. We present a median nerve injury affecting primarily fibers of the anterior interosseous nerve in the context of a humerus diaphyseal fracture in an adult patient. This report focuses on the clinical presentation, treatment, and evolution.
Keywords: Anterior interosseous nerve; humeral fracture; adults.
Level of Evidence: IV

Lesión del nervio interóseo anterior secundaria a una fractura diafisaria de húmero en un adulto

RESUMEN
Las fracturas diafisarias de húmero en los adultos pueden acompañarse de lesiones en el nervio radial (hasta el 17% de los casos). Sin embargo, es extremadamente infrecuente la afectación del nervio mediano luego de estas fracturas. Presentamos a un paciente adulto que sufrió una lesión en continuidad del nervio mediano luego de una fractura cerrada de húmero, con compromiso fundamental de las fibras correspondientes al nervio interóseo anterior. Se detallan la presentación clínica, el tratamiento y la evolución.
Palabras clave: Nervio interóseo anterior; fractura de húmero; adultos.
Nivel de Evidencia: IV

INTRODUCTION

Humerus fractures can be associated with nerve injuries. Radial nerve involvement is the most frequent neurological complication following a long bone fracture.[1] Less frequently, lesions of the anterior interosseous nerve, a branch of the median nerve, have been reported in children as a complication of supracondylar fractures.[2] However, median nerve palsy following a closed diaphyseal fracture of the humerus in an adult is exceptionally rare.

We found only two published reports describing this injury. Therefore, the aim of this article is to present a case of interosseous nerve palsy resulting from a diaphyseal humeral fracture, along with its presentation and treatment.

CLINICAL CASE

A 50-year-old man with no significant medical history presented to the clinic with a diagnosis of a closed fracture of the left humerus, which had occurred 24 hours earlier. He exhibited an abnormal position of the affected hand and an inability to make a fist, which had developed suddenly following a fall. He had not sustained injuries to any other anatomical site, and examination of the cervical spine revealed no notable abnormalities.

Received on February 7th, 2024. Accepted after evaluation on May 5th, 2024 • Dr. GONZALO VIOLLAZ • gonzaloviollaz@gmail.com ID https://orcid.org/0000-0002-4573-883X

How to cite this article: Viollaz G, Ramallo J. Anterior Interosseous Nerve Syndrome Secondary to Diaphyseal Humerus Fracture in Adults. *Rev Asoc Argent Ortop Traumatol* 2024;89(4):425-430. https://doi.org/10.15417/issn.1852-7434.2024.89.4.1923

On physical examination, the patient displayed an extension posture of the thumb and index finger, with an inability to actively flex the interphalangeal joint of the thumb and the distal interphalangeal joint of the index finger (*Medical Research Council* grade M0). However, the tenodesis effect was preserved in all fingers, indicating muscle-tendon continuity. Active range of motion was observed in the remaining fingers, wrist, elbow, and shoulder, with minor limitations expected due to the pain associated with the humerus fracture.

Tinel's sign along the nerve pathway of the arm and forearm was negative. Sensitivity was slightly reduced in the median nerve territory (S4 of the *Medical Research Council*) (Figure 1). The vascular examination revealed no abnormalities.

Figure 1. Initial presentation. Extension position of the thumb and index finger, with inability to actively flex the interphalangeal joint of the thumb and distal interphalangeal joint of the index finger.

The findings were interpreted as a closed median nerve lesion, with significant damage to the fibers corresponding to the anterior interosseous nerve (which innervates the flexor pollicis longus muscle, flexor digitorum profundus, and pronator quadratus).

Anteroposterior and lateral radiographs of the humerus revealed a diaphyseal fracture of the left humerus (OTA/AO 12A1; Figure 2).

Figure 2. Anteroposterior and lateral radiographs of the arm. Spiral humerus fracture, AO12A1.

The condition was interpreted as a traction injury of the median nerve, classified as type I-III according to the Sunderland classification, with primary involvement of the fibers corresponding to the anterior interosseous nerve. Surgical treatment of the fracture was carried out using osteosynthesis with an intramedullary nail, and a conservative approach was chosen for managing the neurological injury.

At the first follow-up seven days after surgery, slight interphalangeal mobility of the thumb and index finger was observed (M1 according to the *Medical Research Council*). The wounds healed properly, and the patient began physical therapy two weeks after surgery.

During follow-up, progressive and consistent functional improvement in active flexion of the thumb and index finger was observed. The fracture consolidated nine weeks after surgery (Figure 3).

Figure 3. Anteroposterior arm radiograph and lateral control radiograph after 9 weeks. Radiographic consolidation.

Four weeks after surgery, a neurophysiological study, including electromyography and nerve conduction velocity testing, was performed to assess the extent of the injury and provide a definitive prognosis. An axonal injury, classified as Sunderland type II-III, with continuity of the fascicles corresponding to the flexor pollicis longus and flexor digitorum profundus of the index finger, with significant reinnervation, was confirmed.

After 12 weeks, the ability to clench a fist and perform a two-point pinch had been restored, along with functional shoulder abduction and elevation, as observed during the same clinical examination (Figures 4 and 5).

Figure 4. Functional changes 12 weeks after surgery.

Figure 5. Functional evaluation of the shoulder 12 weeks after surgery.

DISCUSSION

Nerve injuries secondary to humerus fractures are frequent complications. In 2-17% of cases, radial nerve injuries occur due to the close proximity of the nerve along its path.[1]

Similarly, involvement of the anterior interosseous nerve has been reported in 6-16% of supracondylar humerus fractures in the pediatric population, making it the most frequent complication associated with these fractures.[3]

However, median nerve palsy following a closed humerus fracture in adults is rare and typically occurs in isolated cases.

In 2013, Pongowski and Panasiuk described anterior interosseous nerve palsy following a supracondylar humerus fracture in a 24-year-old woman.[4] That same year, Tanagho et al. reported a similar complication secondary to a proximal humerus fracture in an 87-year-old female patient.[5]

Only two cases involving diaphyseal fractures have been documented: one by Manicol in 1978, involving a 10-year-old patient,[6] and another by Apergis et al. in 1998, involving a 19-year-old patient.[7] Both cases featured short transverse/oblique fractures with overriding of one medial bone segment over the other.

In 1978, Sunderland described how the fascicles of the anterior interosseous nerve could be distinguished from their emergence in the brachial plexus. These nerve fibers are situated in the posterolateral portion of the nerve and are particularly susceptible to compression and traction along their path.[8] Finally, as Vincelet observed in laboratory-induced supracondylar fractures, the posterior interosseous nerve may be more affected in these fractures due to its attachment to the interosseous membrane, which limits the nerve's ability to slide after traction.

Another controversy arises regarding the need to explore these lesions. In the case of the radial nerve, opinions are divided. Some advocate for early exploration to achieve a rapid diagnosis and initiate early management.[9,10] However, those in favor of expectant management argue that spontaneous recovery is most common, with similar outcomes even after delayed exploration. For this reason, they recommend watchful waiting for 16-18 weeks.[11-13] In all reported cases, functional restoration occurred spontaneously between the third and sixth month, without the need for surgical exploration.

Based on previous experience with radial nerve injuries following these fractures, we opted to observe these injuries for a prudent period of time.

Finally, we did not request neurophysiological studies upon the patient's admission but instead performed them in the third week after the injury to better quantify its extent. [14]

CONCLUSIONS

Due to the limited experience with this type of lesion and its infrequent occurrence, it is not possible to draw definitive conclusions on the best management approach. However, we believe that observation and expectant management without surgical exploration are advisable unless there is a vascular injury, evidence of overriding on radiographic images, or bone exposure/penetrating injury. Additionally, we believe that neurophysiological studies are useful for confirming the clinical diagnosis and aiding in the follow-up process to inform decision-making.

Conflict of interest: The authors declare no conflicts of interest.

J. Ramallo ORCID ID: https://orcid.org/0000-0001-7907-5854

REFERENCES

1. Shao YC, Harwood P, Grotz MRW, Limb D, Giannoudis PV. Radial nerve palsy associated with fractures of the shaft of the humerus: a systematic review. *J Bone Joint Surg Br* 2005;87(12):1647-52. https://doi.org/10.1302/0301-620X.87B12.16132
2. Spinner M, Schreiber SN. Anterior interosseous-nerve paralysis as a complication of supracondylar fractures of the humerus in children. *J Bone Joint Surg Am* 1969;51:1584-90. PMID: 5357177
3. Cramer KE, Green NE, Devito DP. Incidence of interosseous nerve palsy in supracondylar humerus fractures in children. *J Pediatr Orthop* 1993;13(4):502-5. https://doi.org/10.1097/01241398-199307000-00015
4. Pongowski B, Panasiuk M. Anterior interosseous nerve palsy after supracondylar fracture of humerus in adult. Case report. *Orthop Traumatol Rehabil* 2013;15(4):363-8. https://doi.org/10.5604/15093492.1073836
5. Tanagho A, Elgamal T, Ansara S. Anterior interosseous nerve palsy as a complication of proximal humerus fracture. *Orthopedics* 2013;36(10):e1330-2. https://doi.org/10.3928/01477447-20130920-29
6. Manicol MF. Roentenographic evidence of median-nerve entrapment in a greenstick humeral fracture. *J Bone Joint Surg Am* 1978;60(7):998-1000. PMID: 701352
7. Apergis E, Aktipis D, Giota A, Kastanis G, Nteimentes G, Papanikolaou A. Median nerve palsy after humeral shaft fracture: Case report. *J Trauma* 1998;45(4):825-6. https://doi.org/10.1097/00005373-199810000-00040
8. Sunderland S. *Nerves and nerve injuries.* 2nd ed. New York: Churchill Livingstone; 1978, p. 656-90.
9. Foster RJ, Swiontkowski MF, Bach AW, Sack JT. Radial nerve palsy caused by open humeral shaft fractures. *J Hand Surg Am* 1993;18(1):121-4. https://doi.org/10.1016/0363-5023(93)90255-2

10. Dabezies EJ, Banta CJ 2nd, Murphy CP, d´Ambrosia RD. Plate fixation of the humeral shaft for acute fractures, with and without radial nerve injuries. *J Orthop Trauma* 1992;6(1):10-3. PMID: 1556609
11. Larsen LB, Barfred T. Radial nerve palsy after simple fracture of the humerus. *Scand J Plast Reconstr Surg* 2000;34(4):363-6. https://doi.org/10.1080/028443100750059156
12. Bumbasirević M, Lesić A, Bumbasirević V, Cobeljić G, Milosević I, Atkinson HDE. The management of humeral shaft fractures with associated radial nerve palsy: a review of 117 cases. *Arch Orthop Trauma Surg* 2010;130(4):519-22. https://doi.org/10.1007/s00402-009-0951-4
13. Ekholm R, Ponzer S, Törnkvist H, Adami J, Tindermark J. Primary radial nerve palsy in patients with acute humeral shaft fractures. *J Orthop Trauma* 2008;22(6):408-14. https://doi.org/10.1097/BOT.0b013e318177eb06
14. Bergquist ER, Hammert WC. Timing and appropriate use of electrodiagnostic studies. *Hand Clin* 2013;29:363-70. https://doi.org/10.1016/j.hcl.2013.04.005

Orthobiologics 2024: Definition, Manufacturing, and Mechanism of Action of the Most Commonly Used Alternatives Currently Used in Orthopedics

Luciano Rossi,* Lorena Levi**
*Orthopedics and Traumatology Department, Hospital Italiano de Buenos Aires, Autonomous City of Buenos Aires, Argentina.
**Scientific Director, Laboratorio Regenerar, Autonomous City of Buenos Aires, Argentina

ABSTRACT
Orthobiologics is emerging as a new subspecialty of orthopedics, with gradual acceptance. While platelet-rich plasma (PRP) and bone marrow concentrate (BMC) provided the initial catalyst for the widespread use of biological therapies in orthopedics due to their ease of preparation and application, there have been significant advances in the last decade, with numerous clinical evidence emerging on the outcomes of other promising biological therapies such as platelet lysate, adipose-derived stromal vascular fraction cells (SVF), and cell cultures. The following article aims to describe the most widely used biological therapies currently used in orthopedics, with special emphasis on their manufacturing process, composition, and mechanism of action.
Keywords: Orthobiologics; platelet-rich plasma; bone marrow concentrate; cell cultures; adipose-derived mesenchymal cells.
Level of Evidence: V

Ortobiológicos 2024: definición, elaboración y mecanismo de acción de las alternativas más utilizadas hoy en Ortopedia

RESUMEN
La ortobiología está emergiendo como una nueva subespecialidad de la Ortopedia, con una aceptación gradual. Si bien el primer impulso del uso masivo de las terapias biológicas en Ortopedia vino de la mano del plasma rico en plaquetas y el concentrado de médula ósea por su elaboración y aplicación fáciles; en la última década,se han producido avances importantes y ha surgido numerosa evidencia clínica sobre los resultados de otras terapias biológicas prometedoras, como el lisado plaquetario, las células mesenquimales derivadas del tejido adiposo y los cultivos celulares. Este artículo tiene como objetivo describir las terapias biológicas más utilizadas actualmente en Ortopedia, con especial énfasis en su proceso de elaboración, su composición y mecanismo de acción.
Palabras clave: Ortobiológicos; plasma rico en plaquetas; concentrado de médula ósea; cultivos celulares; células mesenquimales derivadas del tejido adiposo.
Nivel de Evidencia: V

INTRODUCTION

The term "Orthobiologics" refers to a type of orthopedic treatment that uses natural substances derived from the body for the healing of musculoskeletal and degenerative injuries. It is essentially a combination of two words: "ortho," relating to Orthopedics, and "biologics," referring to substances derived from the body itself (not to be confused with the pharmaceutical industry's use of the term, which refers to a category of drugs derived from living organisms using recombinant DNA technology). Over the last 20 years, orthobiologics has gradually emerged

Received on February 2nd, 2024. Accepted after evaluation on May 25th, 2024 • Dr. LUCIANO ROSSI • luciano.rossi@hospitalitaliano.org.ar https://orcid.org/0000-0002-1397-2402
How to cite this article: Rossi L, Levi L. Orthobiologics 2024: Definition, Manufacturing, and Mechanism of Action of the Most Commonly Used Alternatives Currently Used in Orthopedics. *Rev Asoc Argent Ortop Traumatol* 2024;89(4):431-439. https://doi.org/10.15417/issn.1852-7434.2024.89.4.1920

as a new subspecialty of Orthopedics, with a mix of enthusiasm, hope, and some disappointments. Orthobiologics is a clear example of the advancement of translational medicine, where promising laboratory discoveries have been turned into concrete clinical applications. This has led to the publication of an exponential number of clinical trials and meta-analyses in the last decade, covering common musculoskeletal diseases such as osteoarthritis, tendinopathies, and cartilage lesions, among others.[1-5]

While the initial push for the widespread use of biological therapies in orthopedics came from platelet-rich plasma (PRP) and bone marrow concentrate due to their ease of preparation and application, the last decade has seen significant advances. Much clinical evidence has emerged on the outcomes of other promising biological therapies, such as platelet lysate (PL), adipose-derived stromal vascular fraction cells, and cell cultures.

The purpose of this article is to describe the most widely used biological therapies currently employed in Orthopedics, with a particular focus on their manufacturing process, composition, and mechanism of action.

PLATELET-RICH PLASMA

PRP is an autologous biological product obtained from blood through differential centrifugation. It aids in natural tissue regeneration, as it contains growth factors such as fibroblast growth factor type 2, platelet-derived growth factor, tissue growth factor β, vascular endothelial growth factor, and insulin-like growth factor,[6-8] among others, which bind to the plasma membrane of mesenchymal cells to trigger their proliferation and activation.[9] This binding generates positive feedback in the microenvironment, causing more platelet rupture, the release of growth factors, and subsequent binding of the growth factors to the cell membrane. This results in further proliferation and differentiation until the inflammatory response is inhibited and regeneration is achieved.[10] These components not only regulate cell migration and proliferation but also contribute to angiogenesis and tissue remodeling, creating a favorable microenvironment that enhances tissue repair and regeneration.

Growth factors are crucial to this process. They initiate regeneration by inhibiting apoptosis, producing anabolic and anti-inflammatory effects, and activating cell proliferation and differentiation.[11]

Once platelet activation occurs after injury, the factors are secreted and bind to target cells to stimulate cell proliferation, neovascularization, matrix formation, and collagen synthesis.[5,6,12] In the case of bone regeneration, for example, platelet-derived growth factor binds to the plasma membrane of bone cells to stimulate remodeling, mitosis, and phagocytosis of damaged tissue.[13,14] Tissue growth factor β has been shown to regulate proliferation, differentiation, chemotaxis, and adhesion to progenitor cells. It is also a potent inducer of chondrogenesis, positively regulating type II collagen production in mesenchymal stem cells.[15] Both chondrocytes and osteoblasts possess membrane receptors for tissue growth factor β, supporting the theory that this molecule plays a significant role in the process of bone and cartilage regeneration.[16] Vascular endothelial growth factor plays a critical role in angiogenesis and cartilage regeneration.[17,18] Furthermore, it acts synergistically with osteogenic proteins, such as BMO4 and BMO2, aiding in cell recruitment, prolonging survival, stimulating angiogenesis, and accelerating cartilage resorption and bone mineralization.[19,20]

To obtain PRP, a blood sample is needed, which is then concentrated five times through a series of differential centrifugations, from which the phase containing the concentrated platelets is taken (Figure 1). If indicated, the lymphocyte fraction can also be included to assist in the regenerative process. The platelet count and clotting time are determined from the obtained fraction, with the values provided in a certificate of analysis along with the prepared product, ready to be injected into the patient.

The entire process is conducted under type II biosafety laboratory conditions, adhering to all necessary sterilization protocols. This product can be obtained in approximately two hours and serves as a good alternative for treatments that need to be done quickly.

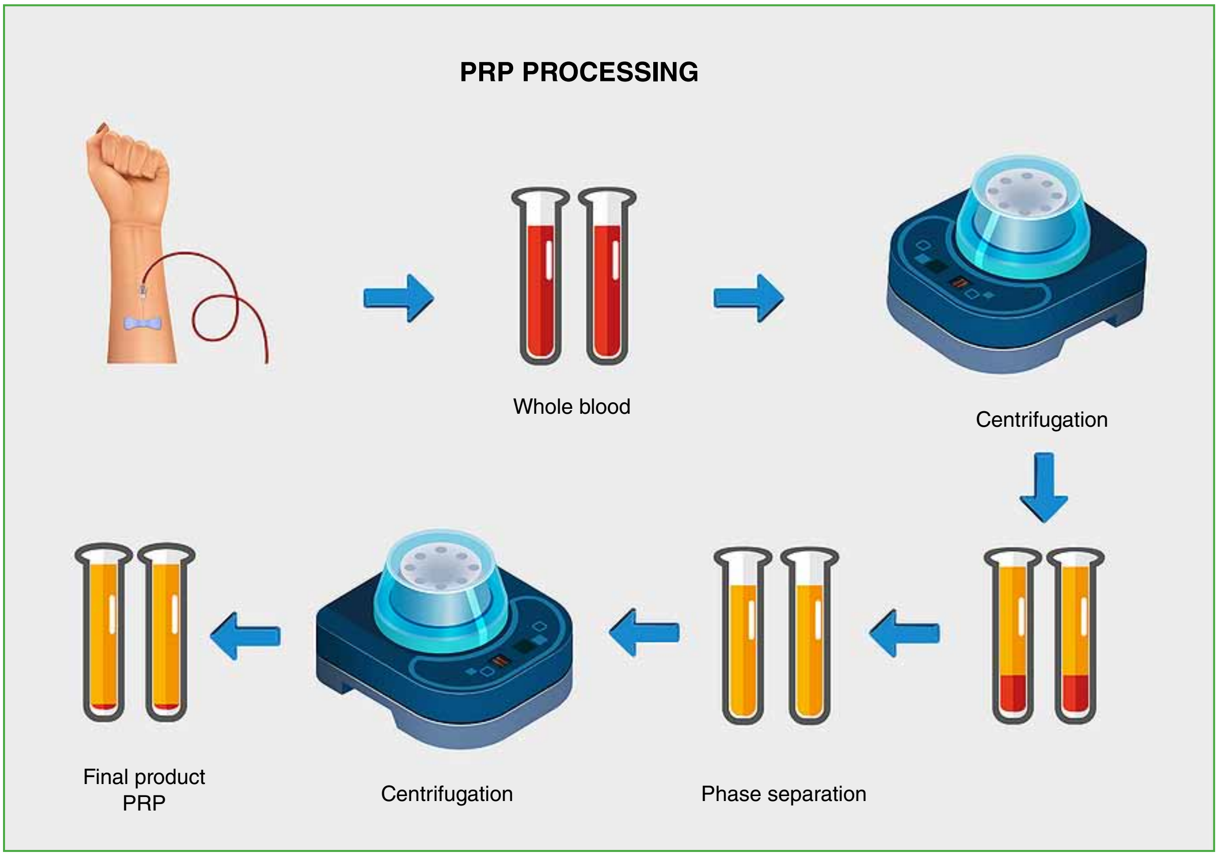


Figure 1. Platelet-rich plasma (PRP) processing. PRP is obtained through a sequence of differential centrifugations from a peripheral blood sample. The final product is applied locally to the area of injury.

PLATELET LYSATE

PL is one of the richest sources of bioactive molecules that can be obtained from a peripheral blood sample. It is considered the evolution of PRP, as both cell proliferation and stem cell differentiation is significantly higher when used in combination. Instead of being a platelet concentrate, it is a concentrate of autologous growth factors obtained from the same individual. In recent years, it has gained increased attention because its preparation is acellular, thus reducing the consequences of immunogenicity while containing high concentrations of growth factors and cytokines. It can be cryopreserved and stored for long periods, unlike PRP, which cannot be exposed to temperatures lower than 4°C, as the platelet mixture is extremely sensitive to temperature.[21,22]

To obtain PL, it is necessary, as in PRP, to have a blood sample collected in the presence of anticoagulants.[23] Similar to PRP, the sample must be sent to the laboratory for processing. PL is obtained through a combination of differential centrifugation interspersed with mechanical or chemical lysis of the platelets, followed by the purification of the obtained factors (Figure 2). This process takes about 8 hours in the laboratory, so it is convenient to perform it overnight.

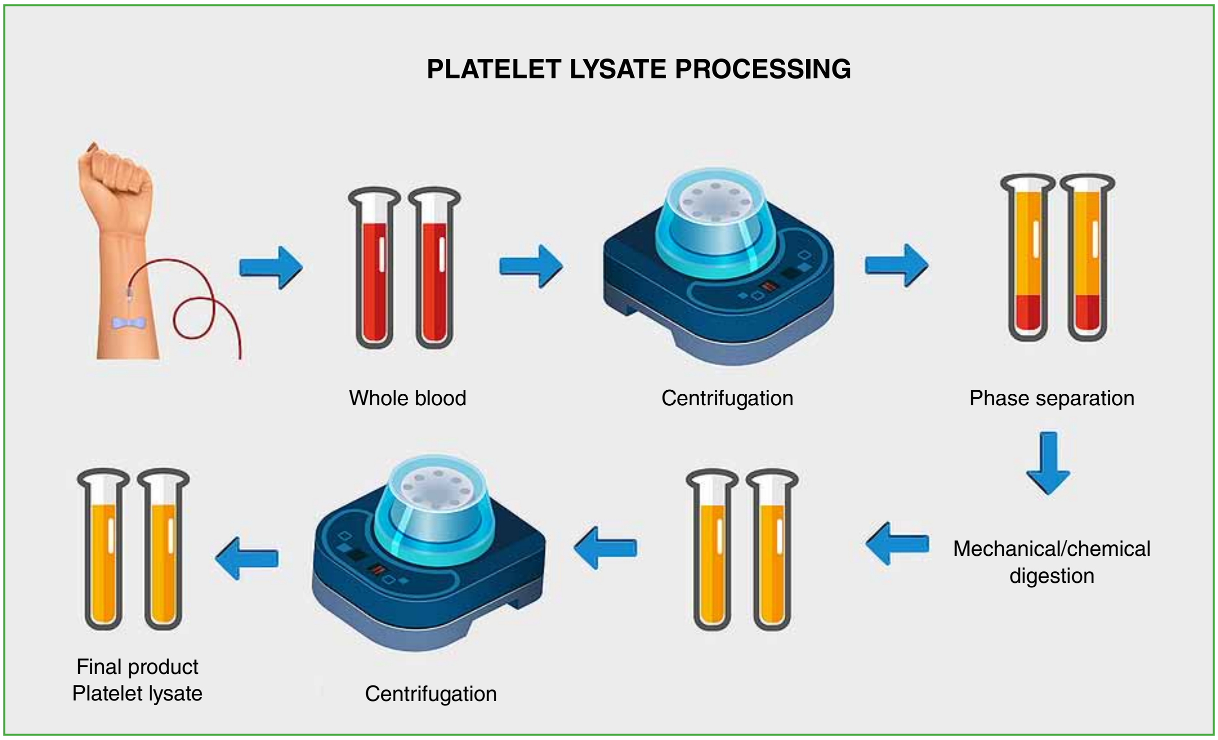


Figure 2. Platelet lysate processing. Platelet lysate is obtained through a sequence of differential centrifugations from a peripheral blood sample. Because it can be stored, a single extraction can be performed for all applications, and the doses to be used can be preserved. Like PRP, the final product is applied locally to the area of injury.

In general, the physician obtains the sample from the patient the day before it is to be used and sends it to the laboratory. Immediately prior to delivery, the product undergoes a final procedure to ensure the quality and potency of the PL. The sample is delivered to the physician's office just a few minutes before the consultation, ready to be injected into the patient, along with a certificate of analysis containing the initial platelet count prior to lysis and clotting time control.

Like PRP, the entire product is manufactured in a Type II biosafety laboratory under the strictest biosafety conditions and controls.

One of the significant advantages of PL over PRP is that it can be stored. This means that if the patient is to receive more than one application, a single blood collection can be made, taking into account the volume necessary for all applications. The professional will be able to schedule the applications in a more orderly manner and will only need to notify the laboratory a few days in advance so that the sample will be available and ready to use just minutes before the medical consultation.

CELL CONCENTRATE

Cell concentrate is a heterogeneous composition of cells, including, among others, endogenous mesenchymal stem cells, and can be used in regenerative medicine. It can reduce apoptosis of surrounding cells, inflammation and fibrosis by activating physiological regenerative mechanisms through cell proliferation and differentiation. In addition, it has the potential to differentiate into multiple lineages, including osteoblasts, adipocytes, myoblasts, and epithelial cells. It can contribute to angiogenesis in a paracrine and autocrine manner[24] and modulates the inflammatory response, collaborating with the recruitment of molecules to the site of injury.[25]

PRP and cell concentrate, whether derived from bone marrow or adipose tissue, have been shown to have synergistic and complementary effects on tissue regeneration.[26,27]

Cell concentrate can be obtained from bone marrow (bone marrow concentrate) or adipose tissue (vascular stromal fraction). In both cases, a concentrate of nucleated cells is obtained, from which a specific and unique population of fibroblasts, endothelial cells, immune cells, hematopoietic cells, pericytes, vascular cells, and mesenchymal cells, among others, is derived. The difference between these tissues lies in the concentration of mesenchymal cells; adipose tissue has a concentration of mesenchymal stem cells of about 3%, while the concentration in bone marrow is significantly lower.

Another consideration when choosing the type of sample to use is the method of tissue collection. In the case of bone marrow, it may be obtained from the iliac crest, sternum, or any other bone of the practitioner's choice, usually in the operating room under general anesthesia. Conversely, adipose tissue is extracted in a doctor's office, without the need for preparation, under local anesthesia at the collection site.

To obtain bone marrow, at least 60 ml of tissue must be processed in a syringe containing heparin. It is then sent to the laboratory for processing, which takes approximately 4 hours. This product is obtained through differential centrifugation (Figure 3). The final product is composed of a concentrate called bone marrow concentrate, composed of nucleated cells such as fibroblasts, immune cells, endothelial cells, and mesenchymal cells. It is delivered to the office or operating room a few minutes before application, with a certificate of analysis indicating the total number of nucleated cells, the percentage of cell viability, the total volume delivered, and the medium in which it is resuspended (physiological solution, PL, PRP, etc.). This product cannot be stored and must be used within 6 hours.

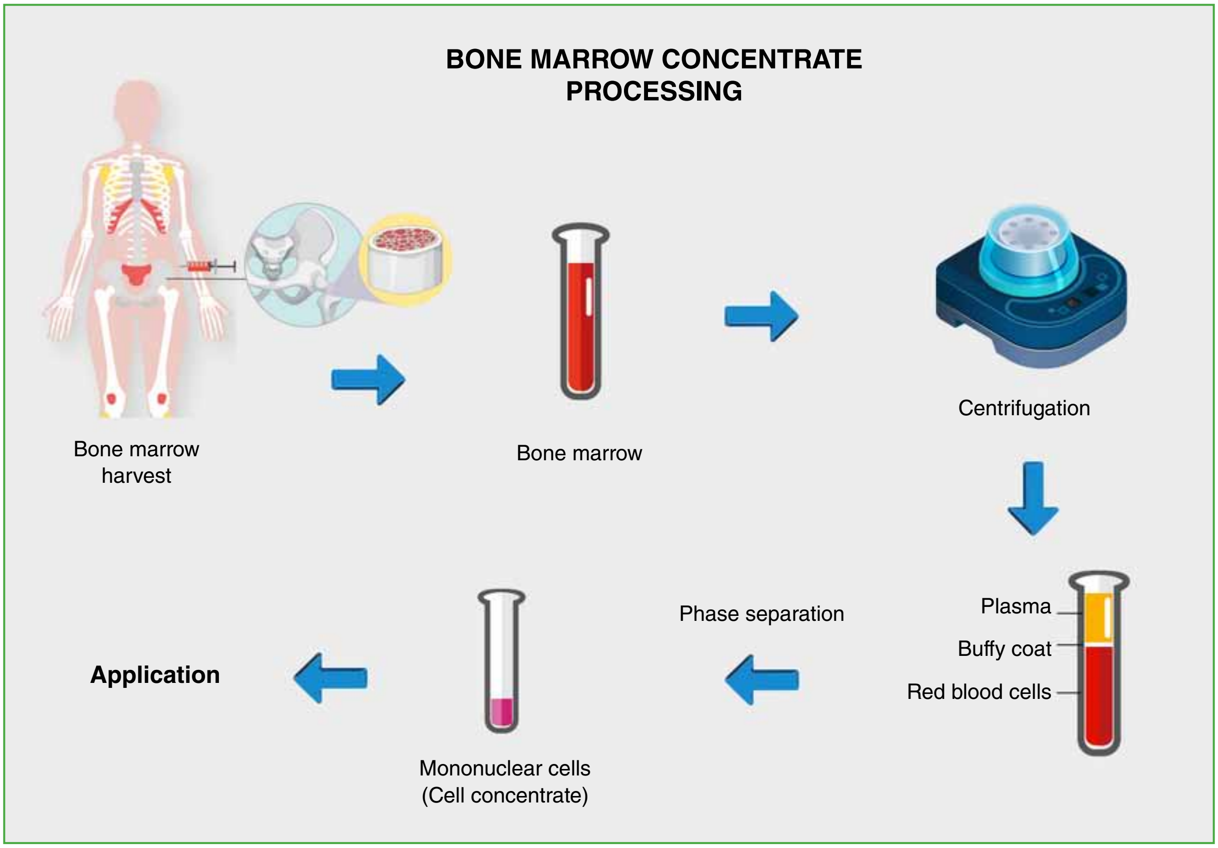


Figure 3. Processing of bone marrow concentrate. Bone marrow concentrate is obtained through centrifugation of a bone marrow sample. The buffy coat is isolated for application and contains a concentrate of nucleated cells, including mesenchymal cells.

For the adipose tissue concentrate (called stromal vascular fraction), at least 1 g of fat should be obtained and taken to the laboratory for processing. The processing time is about 5 hours; for this reason, the sample is usually taken the day before application (Figure 4). The final sample is sent to the office or operating room, ensuring that cell viability and cell number remain stable for up to 6 hours after processing.

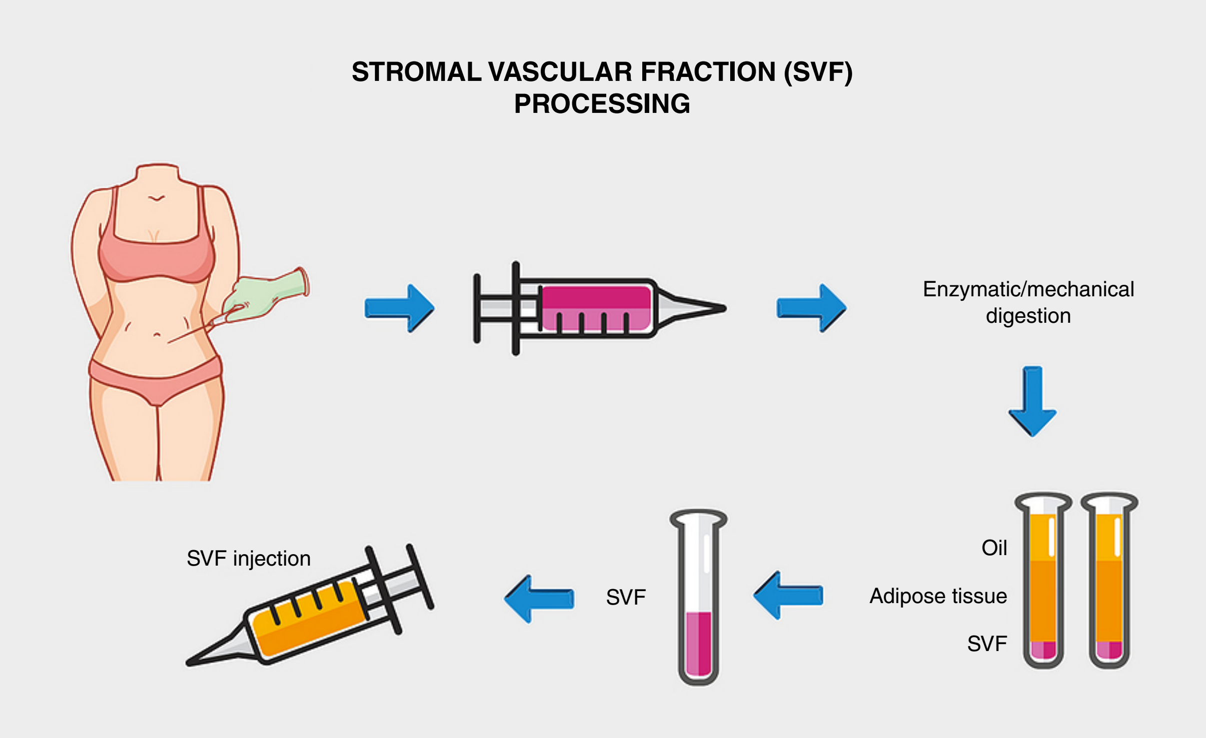


Figure 4. Processing of the stromal vascular fraction from adipose tissue. Adipose tissue is subjected to mechanical and enzymatic digestion. It can be obtained through a small incision to remove a tissue fragment or by liposuction. Like bone marrow concentrate, it contains a population of mononuclear cells, including mesenchymal cells. The final product is applied to the area of the lesion and can be combined with platelet lysate or PRP to enhance its effect.

The rationale for combining PRP with cell concentrates is based on the fact that PRP provides an optimal microenvironment in which cells can trigger cell proliferation and differentiation[2,9,18] and can act as a biomaterial to attract and retain mesenchymal stem cells on-site for longer.[19,20]

CELL CULTURE

Cell culture can be obtained from multiple tissues, such as adipose tissue,[24] using a minimally invasive technique. In this way, mesenchymal stem cells have become important candidates for therapies based on regenerative medicine and tissue engineering.[23] These cells are used for the treatment of various cell types, such as bone,[17,18] cartilage,[19] tendon,[20,21] and muscle.[22,24]

The advantage of cell culture over any of the cell concentrates is that the cell population is 95% pure mesenchymal stem cells, ensuring that all cells will participate in the regenerative process. They are usually combined with PL or PRP to achieve a synergistic effect.

The number of cells to be used varies according to the protocol chosen by the professional, as well as the size of the lesion and the organ involved.

The processing time is approximately one month to reach the required cell number (Figure 5). It has been demonstrated that this biological product is the most effective for tissue regeneration, with effects that are maintained longer than with other methods.[23,26]

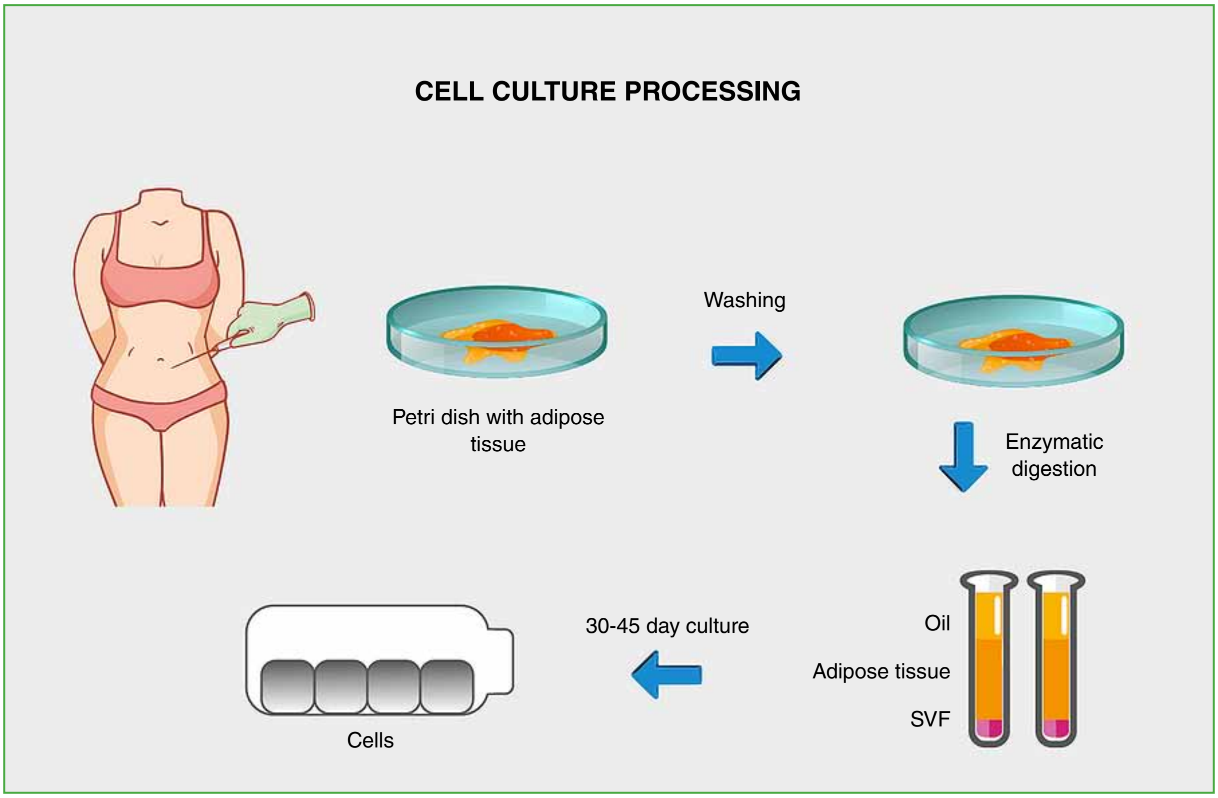


Figure 5. Processing of cell culture from adipose tissue. Once the stromal vascular fraction is obtained, the use of differential media favors the growth of stem cells over other cell types. The cells are cultured until a population composed of 95-98% mesenchymal cells is achieved. Since the product can be cryopreserved, it is possible to process more than one dose to avoid additional removal of adipose tissue.

CONCLUSION AND OUTLOOK

The thought process of the trauma surgeon is clearly shifting from purely mechanically oriented interventions to incorporating and respecting biology. Orthobiologic agents such as PRP, bone marrow-derived connective tissue progenitor cells, adipose tissue, and cell cultures have enormous potential to address deficiencies in soft tissue healing. The main current limitation is the variability in the composition and biological activity of orthobiologic formulations, which makes it difficult to choose the optimal treatment for a specific tissue or disease. Current data suggest that orthobiologics "modify symptoms," but there is little evidence that they can lead to true tissue regeneration ("modify structure"). Current basic science research lines are directed toward a precise understanding of the underlying cellular and molecular mechanisms of tissue degeneration and repair. This understanding will allow for a more targeted therapeutic approach in which we can choose the optimal orthobiologic treatment for specific orthopedic problems. Emerging therapies, such as the use of exosomes and gene therapy approaches, hold great promise as improved methods to both treat symptoms and influence tissue regeneration.

Conflict of interest: Dr. L. Rossi declares no conflicts of interest. Dr. L. Levi is the Scientific Director of Regenerar Laboratory.

L. Levi ORCID ID: https://orcid.org/0009-0003-5809-1339

REFERENCES

1. Kruel AVS, Ribeiro LL, Gusmão PD, Huber SC, Lana JFSD. Orthobiologics in the treatment of hip disorders. *World J Stem Cells* 2021;13(4):304-16. https://doi.org/10.4252/wjsc.v13.i4.304
2. Van Schaik KD, Lee KS. Orthobiologics: Diagnosis and treatment of common tendinopathies. *Semin Musculoskelet Radiol* 2021;25(6):735-44. https://doi.org/10.1055/s-0041-1735475
3. Rauck RC, Eliasberg CD, Rodeo S, Rodeo SA. Orthobiologics for the management of early arthritis in the middle-aged athlete. *Sports Med Arthrosc Rev* 2022;30(2):e9-e16. https://doi.org/10.1097/JSA.0000000000000337
4. Panero AJ, Everts PA, Nakagawa H, Sussman W, Qin X. Basic science of allograft orthobiologics. *Phys Med Rehabil Clin N Am* 2023;34(1):49-61. https://doi.org/10.1016/j.pmr.2022.08.005
5. Marx R, Carlson E, Eichstaedt R, Schimmele SR, Strauss JE, Georgeff KR. Platelet-rich plasma: growth factor enhancement for bone grafts. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1998;85(6):638-46. https://doi.org/10.1016/s1079-2104(98)90029-4
6. Marx R. Platelet-rich plasma (PRP): what is PRP and what is not PRP? *Implant Dent* 2001;10(4):225-8. https://doi.org/10.1097/00008505-200110000-00002
7. Malhotra A, Pelletier M, Yu Y, Walsh W. Can platelet-rich plasma (PRP) improve bone healing? A comparison between the theory and experimental outcomes. *Arch Orthop Trauma Surg* 2013;133(2):153-65. https://doi.org/10.1007/s00402-012-1641-1
8. Xin W, Wen J, Yaqiong Z, Yongqiang H, Yanxu Z, Xueli S, et al. Platelet-rich plasma therapy in the treatment of diseases associated with orthopedic injuries. *Tissue Eng Part B Rev* 2020;26(6):571-85. https://doi.org/10.1089/ten.TEB.2019.0292
9. Zheng C, Zhu Q, Liu X, Huang X, He C, Jiang L, et al. Effect of platelet-rich plasma (PRP) concentration on proliferation, neurotrophic function and migration of Schwann cells *in vitro*. *J Tissue Eng Regen Med* 2016;10(5):428-3. https://doi.org/10.1002/term.1756
10. Anitua E, Prado R, Orive G. Allogeneic platelet rich plasma: at the dawn of an off-the-shelf therapy? *Trends Biotechnol* 2017;35(2):91-3. https://doi.org/10.1016/j.tibtech.2016.11.001
11. Everts P, Onishi K, Jayaram P, Lana JF, Mautner K. Platelet-rich plasma: New performance understandings and therapeutic considerations in 2020. *Int J Mol Sci* 2020;21(20):7794. https://doi.org/10.3390/ijms21207794
12. Marx R. Platelet-rich plasma: evidence to support its use. *J Oral Maxillofac Surg* 2004;62(4):489-96. https://doi.org/10.1016/j.joms.2003.12.003
13. Heldin C, Westermark B. PDGF-like growth factors in autocrine stimulation of growth. *J Cell Physiol Suppl* 1987;133(Suppl 5):31-4. https://doi.org/10.1002/jcp.1041330407
14. Andrew J, Hoyland J, Freemont A, Marsh D. Platelet-derived growth factor expression in normally healing human fractures. *Bone* 1995;16(4):455-60. https://doi.org/10.1016/8756-3282(95)90191-4
15. Barry F, Boynton R, Liu B, Murphy J. Chondrogenic differentiation of mesenchymal stem cells from bone marrow: differentiation-dependent gene expression of matrix components. *Exp Cell Res* 2001;268(2):189-200. https://doi.org/10.1006/excr.2001.5278
16. Lieberman J, Daluiski A, Einhorn T. The role of growth factors in the repair of bone biology and clinical applications. *J Bone Joint Surg* 2002;84(6):1032-44. https://doi.org/10.2106/00004623-200206000-00022
17. Gerber H, Vu T, Ryan A, Kowalski J, Werb Z, FerraraN. VEGF couples' hypertrophic cartilage remodeling, ossification and angiogenesis during endochondral bone formation. *Nat Med* 1999;5(6):623-8. https://doi.org/10.1038/9467
18. Maes C, Stockmans I, Moermans K, Van Looveren R, Smets N, Carmeliet P, et al. Soluble VEGF isoforms are essential for establishingepiphyseal vascularization and regulating chondrocyte development and survival. *J Clin Invest* 2004;113(2):188-99. https://doi.org/10.1172/JCI19383

19. Bethany EL, Kisiday JD, Bahney CS, Ehrhart NP, Goodrich LR. The platelet-rich plasma and mesenchymal stem cell milieu: A review of therapeutic effects on bone healing. *J Orthop Res* 2020;38(12):2539-50. https://doi.org/10.1002/jor.24786
20. da Fonseca L, Silva Santos G, Cares Huber S, Mazzini Setti T, Setti T, Lana FJ. Human platelet lysate - A potent (and overlooked) orthobiologic. *J Clin Orthop Trauma* 2021;21:101534. https://doi.org/10.1016/j.jcot.2021.101534
21. Magalon J, Chateau AL, Bertrand B, Louis ML, Silvestre A, Giraudo L, et al. DEPA classification: A proposal for standardising PRP use and a retrospective application of available devices. *BMJ Open Sport Exerc Med* 2016;2(1):e000060. https://doi.org/10.1136/bmjsem-2015-000060
22. Kolaparthy LK, Sanivarapu S, Moogla S, Kutcham RS. Adipose tissue-adequate, accessible regenerative material. *Int J Stem Cells* 2015;8(2):121-7. https://doi.org/10.15283/ijsc.2015.8.2.121
23. Caplan AI, Dennis JE. Mesenchymal stem cells as trophic mediators. *J Cell Biochem* 2006;98(5):1076-84. https://doi.org/10.1002/jcb.20886
24. Kim SJ, Kim EK, Kim SJ, Song DH. Effects of bone marrow aspirate concentrate and platelet-rich plasma on patients with partial tear of the rotator cuff tendon. *J Orthop Surg Res* 2018;13(1):1-7. https://doi.org/10.1186/s13018-017-0693-x
25. Zhao T, Yan W, Xu K, Qi Y, Dai X, Shi Z. Combined treatment with platelet-rich plasma and brain-derived neurotrophic factor-overexpressing bone marrow stromal cells supports axonal remyelination in a rat spinal cord hemi-section model. *Cytotherapy* 2013;15(7):792-804. https://doi.org/10.1016/j.jcyt.2013.04.004
26. Tsuji W. Adipose-derived stem cells: Implications in tissue regeneration. *World J Stem Cells* 2014;6(3):312-21. https://doi.org/10.4252/wjsc.v6.i3.312
27. Hede K, Christensen BB, Jensen J, Foldager CB, Lind M. Combined bone marrow aspirate and platelet-rich plasma for cartilage repair: Two-year clinical results. *Cartilage* 2019;13(1_suppl):937S-947S. https://doi.org/10.1177/1947603519876329

Academician Dr. Eduardo A. Zancolli (1924-2024)

On May 20, our beloved Master passed away.

First and foremost, I must provide a brief summary of his impressive career, so future generations will understand the true extent of his tireless work and unique professional legacy.

Born in Chivilcoy, Buenos Aires, he graduated as a physician on August 1, 1949, from the School of Medicine at the Universidad de Buenos Aires. He began his career as a concurrent physician in General Surgery at Room VI of Hospital Rawson (Escuela Quirúrgica

Municipal para Graduados), where he had the privilege of learning from his esteemed mentors, Dr. Ricardo Finochietto and Dr. Leoncio Fernandez, who profoundly influenced his entire professional journey.

He then pursued advanced training in Orthopedics and Traumatology in the United States, rotating through the Campbell Clinic (Memphis, Tennessee), Passavant Memorial Hospital (Chicago), Hospital for Special Surgery (New York), and the Rehabilitation Center (Warm Springs, Georgia).

Upon returning to Argentina, he put his knowledge in spine surgery into practice. His tireless dedication to his work led to some friction with Dr. Ricardo, who was concerned about the high number of hospitalized patients. This led to a shift in focus toward treating outpatient conditions, which ignited his profound passion for hand surgery. Any branch of surgery he chose would have been significant, but hand surgery became his true calling.

Remarkably, at just 28 years old and only four years into his career, Finochietto appointed him as the "Chief of the Orthopedics and Traumatology Service" at the Policlínico de San Martín in Buenos Aires. Finochietto clearly recognized the exceptional qualities in this young doctor and supported him in that role.

He later worked at Hospital de Lanús, Hospital Ramos Mejía, and Instituto del Quemado, and was appointed "Head of Unit" of Ward 14 at Hospital Rawson. He then became the "Head of the Orthopedics and Traumatology Service" at the same hospital but resigned in 1977 due to the political and economic turmoil in the country.

Ironically, since 1960, he had already been appointed Honorary Consultant at the Instituto Nacional de Rehabilitación Psicofísica de Buenos Aires [*National Institute of Psychophysical Rehabilitation of Buenos Aires*], where he won the position of "Head of the Department of Surgery" through a competitive process. Here, he developed an Orthopedic Surgery Service with global recognition and began forming his Surgical School, training numerous disciples over time.

He served as Consultant of Orthopedics and Traumatology at Sanatorio Trinidad Palermo (Buenos Aires), Director of Resident Doctors and Consultant of Orthopedics and Traumatology at Hospital Naval "Pedro Mallo" (Buenos Aires), and Consultant of the Hand Service at Sanatorio Finochietto. Additionally, he was a Professor of Orthopedics and Traumatology at Universidad del Salvador (USAL) and Universidad de Ciencias Sociales y Empresariales (UCES), and Honorary Director of the Specialist Program of the AACM.

Among his many academic titles and honors, he was:

Full Member (Site No. 9) of the National Academy of Medicine

Corresponding Member of the Academy of Medical Sciences of Córdoba

Dr. JUAN CARLOS CAGNONE • juancarloscagnone@gmail.com ID https://orcid.org/0000-0002-4394-2060

How to cite this article: Cagnone JC. Obituary. Academician Dr. Eduardo A. Zancolli (1924-2024). *Rev Asoc Argent Ortop Traumatol* 2024;89(4):440-441. https://doi.org/10.15417/issn.1853-7434.2024.89.4.1999

First President and Founding Member of the South American Federation of Hand Surgery and the Argentinean Association of Hand Surgery (FSCM-AACM)

President of the Argentine Association of Orthopedics and Traumatology (AAOT)

President of the Argentine Congress of the Argentine Association for the Study of the Hip and Knee (ACARO)

Master Surgeon of the Enrique and Ricardo Finochietto Municipal Surgical School for Graduates in Orthopedics and Traumatology (AAOT)

Master of the Anatomy of the Locomotor System (Cabal)

Corresponding and Honorary Member of Orthopedic and Traumatology Societies in the USA, Venezuela, Peru, and Costa Rica

Corresponding and Honorary Member of Hand Surgery Societies in the USA, France, South Africa, England, Spain, Chile, Costa Rica, Bolivia, Venezuela, Australia, Uruguay, and Brazil

Visiting Professor at New York Hospital (USA), Cornell University (USA), Stanford and Irvine (California, USA), Louisville (USA), Australian Society for Surgery of the Hand Congress, and Harvard Medical School (Boston, USA).

He gave, by invitation, 161 lectures abroad and 210 in Argentina, and published 142 scientific articles in the specialty, with 9 awards received.

He delivered 161 lectures abroad and 210 in Argentina, and published 142 scientific articles in his field, receiving 9 awards. His books, including *Bases estructurales y dinámicas de la cirugía de la mano* (two editions out of print), *Atlas de anatomía quirúrgica de la mano* (English and Spanish), and *Anatomía quirúrgica de la mano. Atlas ilustrado*, reflect his lifetime commitment to medicine and his selfless desire to help others.

His true legacy, however, extends beyond scientific achievements. He imparted broad and wise teachings through his example in various aspects of his life. As an exemplary father, he and his inseparable Aurora built a family grounded in strong ethical and moral principles, demonstrating unique solidarity that embraced everyone around them in times of need.

Their refined genetics, honed by their own sacrifices, are evident in Eduardo Rafael and Eduardo Pablo, who follow in their footsteps with full recognition from the medical community.

A tireless worker and reader, he often remarked that “the weekend was for studying,” which is why many Sunday mornings found him dissecting and drawing, driven by a passion for understanding anatomy. His dedication to learning and teaching was shared with his friend Elbio Cozzi.

His quest for knowledge and discomfort with the unknown fueled his progress. He believed that “classifying diseases was a way to discover what was missing.” He emphasized that “when faced with different therapeutic methods with equal results, the simplest was the best,” a principle that simplified methods and demystified skill.

His respect for his colleagues and the profession was based on recognizing merit without bias. His humility and the focus on patient welfare were paramount. This approach allowed him to share his knowledge generously, particularly with younger colleagues, teaching them to draw as a way to learn surgery, and assuring them that “whoever knew how to draw could learn how to operate.”

His primary concern was to teach us to think creatively and strive to “operate in a state of Grace,” free from preconceptions and always pushing the boundaries of what is known. This characteristic was evident in both his work and that of his disciples.

In closing, I hope this remembrance reflects the sentiments of many who wish to pay their respects.

As Dr. Ricardo Finochietto once told a young Julio Taleisnik, “You see that boy who is studying there? He is Dr. Eduardo A. Zancolli. Remember that name... He will be one of the greatest Orthopedists in the world.” Clearly, Finochietto was right.

Rest in peace dear Maestro, task accomplished.

Dr. Juan C. Cagnone
Sanatorio Finochietto
Autonomous City of Buenos Aires