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RAAOT-ACARO Special Issue

Fernando Comba
President of the Asociación Argentina para el Estudio de la Cadera y la Rodilla [Argentine Association for the Study of the Hip and Knee] (ACARO)

It is an honor for me to present this new special edition of ACARO in our Journal of the Argentine Association of Orthopedics and Traumatology. This joint initiative of mutual collaboration is now in its fourth edition. It serves as a tool for disseminating the results and advances of the physicians who form part of our society, while also highlighting the importance of publication and continuous research within our national context.

The ability to share knowledge and experience through research and publication is fundamental to the advancement of medicine. This special issue exemplifies our Association's commitment to pursuing excellence and innovation in hip and knee surgery. Each article represents the individual and collective efforts of the authors to improve clinical practices and, ultimately, the quality of life of our patients.

Most of the papers were presented at our last congress, following the logical progression from presentation to publication. However, I must acknowledge that this transition between presenting and publishing is not always achieved. The number of presentations is significantly higher than the number of papers that undergo the editorial process and peer review necessary for publication.

I believe we must continue encouraging our young professionals to actively participate in the research and publication process. They are the future of our specialty. Their enthusiasm, creativity, and scientific rigor are vital for maintaining the innovative drive that defines our Association. Regardless of where they practice, systematically recording their patients and procedures, continually updating their knowledge through accessible tools, and engaging in national or regional scientific activities will be the pillars that enable them to contribute actively to our Associations' scholarly outlets.

The key incentive is to continue viewing publication as an essential tool for the professional development of every physician. Not only does it contribute to the advancement of knowledge, but it also strengthens one's career and enhances the reputation of our specialty.

I am deeply grateful to all the authors, co-authors, and editorial staff who have made this publication possible. I hope you enjoy this special edition and that it inspires everyone to continue contributing to the enrichment of our discipline.

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Total Hip Arthroplasty in Patients with Crowe Grades II, III, and IV Developmental Dysplasia of the Hip: Evaluation of Different Acetabular Reconstruction Techniques. Clinical and Functional Outcomes and Radiographic Analysis

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ABSTRACT

Introduction: Developmental dysplasia of the hip (DDH) is one of the leading causes of hip osteoarthritis, particularly in young patients. Total hip arthroplasty (THA) is an effective treatment to alleviate pain and improve function in these patients. However, anatomical deformities and the variability in the presentation of DDH make these surgeries challenging. **Objectives:** To evaluate the clinical and functional outcomes of THA in patients with Crowe grades II, III, and IV DDH and to analyze the acetabular reconstruction techniques used. **Methods:** This retrospective study included patients who underwent THA between 2008 and 2023. Patients were assessed using the Harris Hip Score and radiographic imaging. Statistical analyses were performed to compare outcomes and evaluate the relationship between age and postoperative progress. **Results:** The sample included 50 patients with Crowe grades II, III, and IV DDH. Of the patients, 78% were female, with a mean age of 47.24 years. Crowe grade II DDH was found in 49.12% of the patients. The most common acetabular reconstruction technique was medialization (58%). There was no significant relationship between age and clinical outcomes. Postoperative complication rates were similar across age groups. **Conclusions:** This study suggests that age does not significantly influence THA outcomes in patients with Crowe grades II, III, and IV DDH. The choice of acetabular reconstruction technique should be individualized for each case.

Keywords: Developmental dysplasia of the hip; Crowe classification; Total hip arthroplasty.

Level of Evidence: IV

Artroplastia total de cadera en pacientes con displasia congénita de cadera grados II, III y IV de Crowe. Evaluación del manejo acetabular: resultados clínico-funcionales y análisis radiográfico

RESUMEN

Introducción: La displasia congénita de cadera (DCC) es la causa principal de osteoartritis de cadera, especialmente en pacientes jóvenes. La artroplastia total de cadera (ATC) es un tratamiento eficaz para aliviar el dolor y mejorar la función de estos pacientes. Sin embargo, las deformidades anatómicas y la variabilidad en la presentación de la DCC hacen que estas cirugías sean desafiantes. **Objetivos:** Evaluar los resultados clínicos y funcionales de la ATC en pacientes con DCC grados II, III y IV de Crowe, y analizar las técnicas de reconstrucción acetabular utilizadas. **Materiales y Métodos:** Estudio retrospectivo en pacientes sometidos a una ATC entre 2008 y 2023. Los pacientes fueron evaluados con el Harris Hip Score y radiografías. Se utilizaron análisis estadísticos para comparar resultados y evaluar la relación entre la edad y la evolución posquirúrgica. **Resultados:** La muestra incluyó a 50 pacientes con DCC grados II, III y IV de Crowe. El 78% eran mujeres y la media de la edad era de 47.24 años. El 49,12% tenía DCC grado II de Crowe. La técnica de reconstrucción acetabular más común fue la medialización (58%). No se halló una relación significativa entre la edad y los resultados clínicos. La tasa de complicaciones posquirúrgicas fue similar en ambos grupos etarios. **Conclusiones:** Este estudio sugiere que la edad no influye significativamente en los resultados de la ATC en pacientes con DCC grados II, III y IV de Crowe. La elección de la técnica de reconstrucción acetabular debe adaptarse a cada caso.

Palabras clave: Displasia de cadera; clasificación de Crowe; artroplastia total de cadera.

Nivel de Evidencia: IV

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INTRODUCTION

Developmental dysplasia of the hip (DDH) is a leading cause of secondary osteoarthritis of the hip, particularly in young patients. It often results in significant pain and loss of function. Total hip arthroplasty (THA) is the most effective treatment for relieving pain, restoring joint function, and correcting leg length discrepancies in these patients.[1] DDH is a congenital condition characterized by joint incongruity due to inadequate development of the acetabulum, often accompanied by chronic dislocation of the femoral head.[2]

THA presents a challenging procedure for orthopedic surgeons in these cases. Various anatomical variations on both the femoral and acetabular sides increase the complexity of the surgical technique. Surgeons may encounter a narrow femoral canal, excessive femoral anteversion, coxa valga, a hypoplastic and retroverted greater trochanter, and a hypoplastic acetabulum with more anteversion than usual. Additionally, soft tissue contractures around the joint due to chronic dislocation further complicate the procedure.[3]

Despite these morphological alterations, special attention must be given to the patient's age, as DDH often affects young individuals who may require future surgical revisions. [4]

Restoring the anatomical center of rotation of the hip yields favorable biomechanical outcomes in THA for patients with DDH. To achieve this, femoral shortening through osteotomies is often necessary. This allows proper reduction while preventing excessive limb lengthening and reducing the risk of sciatic neuropraxia.[1,3]

OBJECTIVE

To evaluate the clinical and functional outcomes of THA in patients with Crowe classification grades II, III, and IV DDH.

MATERIALS AND METHODS

A retrospective, descriptive, observational study was conducted with patients who underwent total hip arthroplasty (THA) for Crowe classification grades II, III, and IV developmental dysplasia of the hip (DDH) at both sites of Sanatorio Allende, between 2008 and 2023.

Patients with Crowe grade I DDH were excluded. To facilitate the analysis of results, the sample was divided into two groups: patients aged ≤46 years (group 1) and those >46 years (group 2).

Surgical planning included radiographic and functional evaluations using the Harris Hip Score (HHS). Preoperative radiographs were used to determine femoral head migration, measured by comparing the vertical distance from the center of rotation to a horizontal line joining the distal edges of both teardrops.

Surgery was performed with patients in the lateral decubitus position using a posterolateral approach. Postoperatively, a progressive 50% weight-bearing protocol on the affected leg with a walker was recommended for the first 6 weeks. All patients followed strict hip mobility precautions, specifically limiting flexion, abduction, and internal rotation. Antibiotic prophylaxis was administered preoperatively and in the immediate postoperative period, with antithrombotic prophylaxis given for 28 days.

Follow-up evaluations were conducted at 3 and 6 weeks, 3 months, and annually. The HHS was used immediately postoperatively, and radiographs were taken at 3 months and yearly. Postoperative radiographs were used to assess the orientation of the acetabular cup in the sagittal and coronal planes and to check for areas of radiolucency on the acetabular side (DeLee and Charnley zones). Acetabular cup loosening was defined as a >2 mm change in the horizontal or vertical position, accompanied by an adjacent radiolucent zone or a radiolucent zone >3 mm.

Lower limb length discrepancy correction, the occurrence of complications (sciatic nerve neuropraxia, instability, infection), and the time to femoral osteotomy consolidation were also evaluated.

Statistical analysis

Fisher's exact test was used to compare categorical variables between groups. Numerical variables were analyzed using Student's t-test or the Wilcoxon test, depending on the data distribution. The relationship between age and HHS variation was assessed using simple linear regression.

Kaplan-Meier survival curves were constructed to compare prognoses between groups, and the log-rank test was applied. A p-value <0.05 was considered statistically significant. All analyses were performed using the RStudio software.

Ethical aspects

This study carries minimal risk as it is observational, classifying it as a category II study according to the World Health Organization. The patients' personal data were protected in accordance with Law 25,326 (Data Protection Law), specifically Article 8 regarding data registry and Habeas Data, ensuring the confidentiality of both personal and professional information. The study adhered to the guidelines of Good Clinical Practice and the principles outlined in the Declaration of Helsinki, including its respective updates. This project was approved by the Research Ethics Committee of Sanatorio Allende, Córdoba, Argentina.

RESULTS

A sample of 50 patients with Crowe grade II, III, and IV DDH who underwent THA at Sanatorio Allende between 2008 and 2023 was evaluated. Of these, 78% (39 patients) were women, and the mean age was 47.24 ± 12.88 years. The distribution of Crowe grades was as follows: 49.12% had grade II DDH (24 cases), 36.84% had grade III (18 cases), and 14.04% had grade IV (8 cases).

Regarding the surgical management of the acetabulum, 58% (29 cases) underwent medialization, 38% (18 cases) were treated with the high hip center technique, and 8% (3 cases) required bone grafting (Figure 1). The sample was divided into two groups: patients aged ≤46 years (group 1) and those >46 years (group 2) (Table).

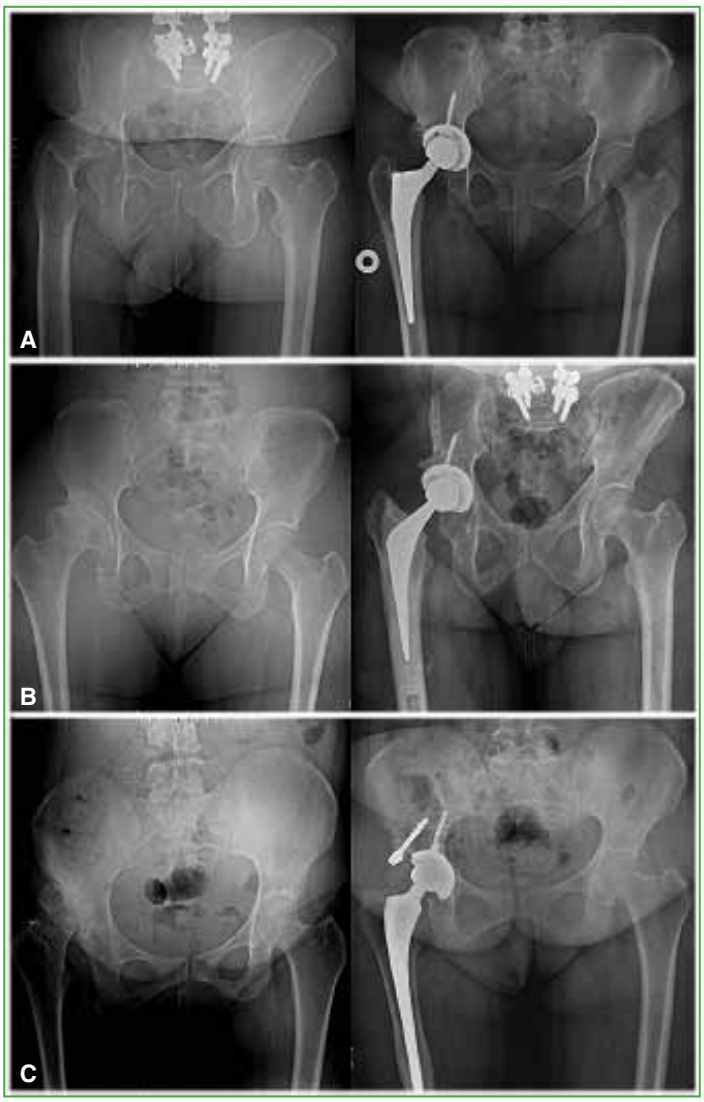

Figure 1. Preoperative (left column) and postoperative (right column) radiographs according to acetabular management technique: medialization (**A**), high hip center (**B**), and bone grafting (**C**).

Table. Characteristics of the groups

	age ≤46 years (n = 27)	age >46 years (n = 23)	p
Bilateral (%)	3 (11.1)	5 (21.7)	0.5
Preoperative HHS ± SD	47.3 ± 6.7	48.4 ± 6.7	0.6
Postoperative HHS ± SD	94 ± 6	91.7 ± 8.7	0.3
Complications (%) Loosening HHS <70 Infection	8 (29.6) 6 (22.2) 0 2 (7.4)	3 (13.0) 2 (8.7) 1 (4.3) 0	0.3
Follow-up (days ± SD)	1327 ± 1300	1507 ± 1626	0.7

HHS = *Harris Hip Score*; SD = standard deviation.

Simple linear regression analysis showed no statistically significant relationship between age and post-surgical Harris Hip Score (HHS) ($p<0.2$). This indicates that HHS improvement after THA was independent of age (Figure 2).

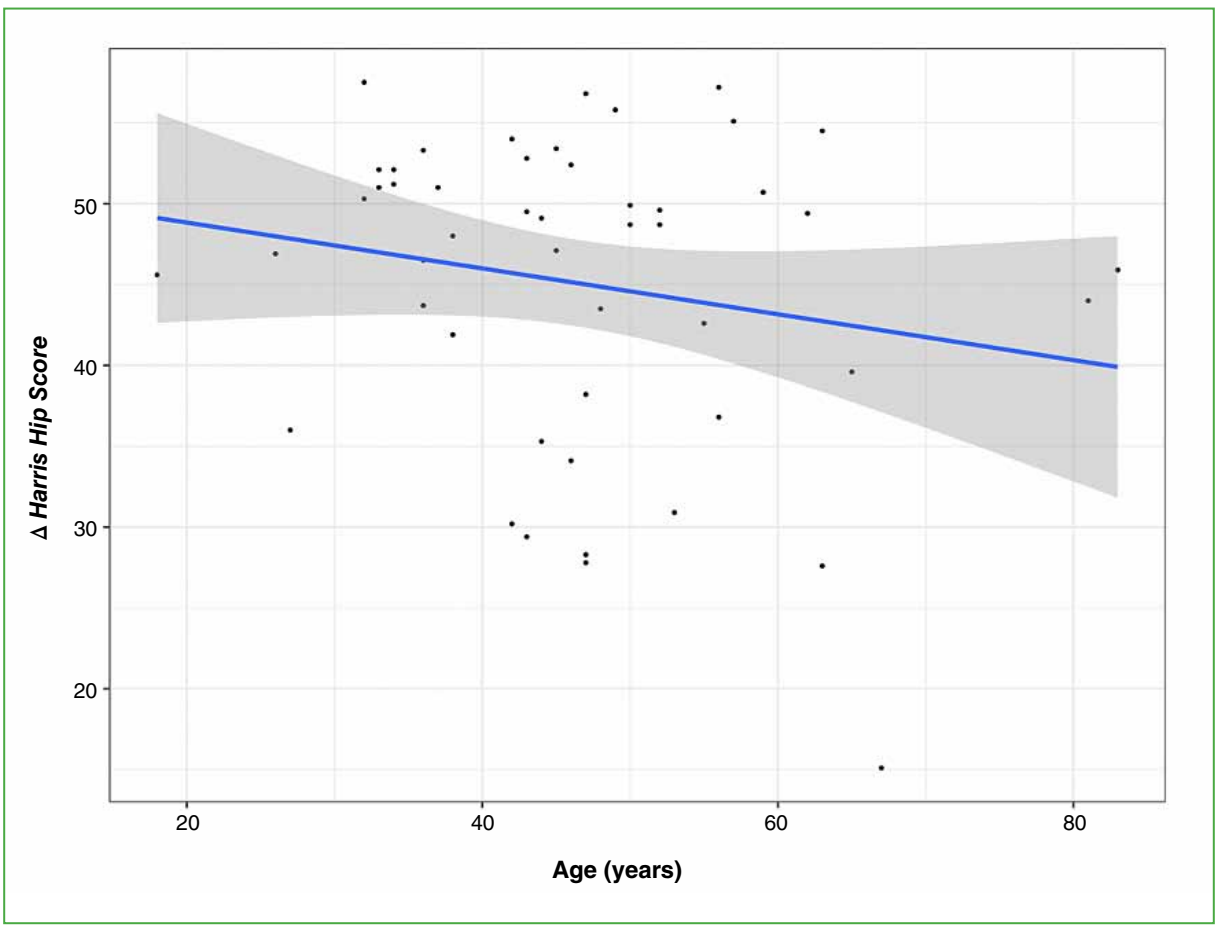

Figure 2. Scatter plot. Age (years) vs. Δ *Harris Hip Score.*

To evaluate the survival rate of the prosthesis in both groups, the Kaplan-Meier curve was used, which showed no statistically significant differences between the groups concerning post-surgical complications that could lead to prosthesis failure (p = 0.072) (Figure 3).

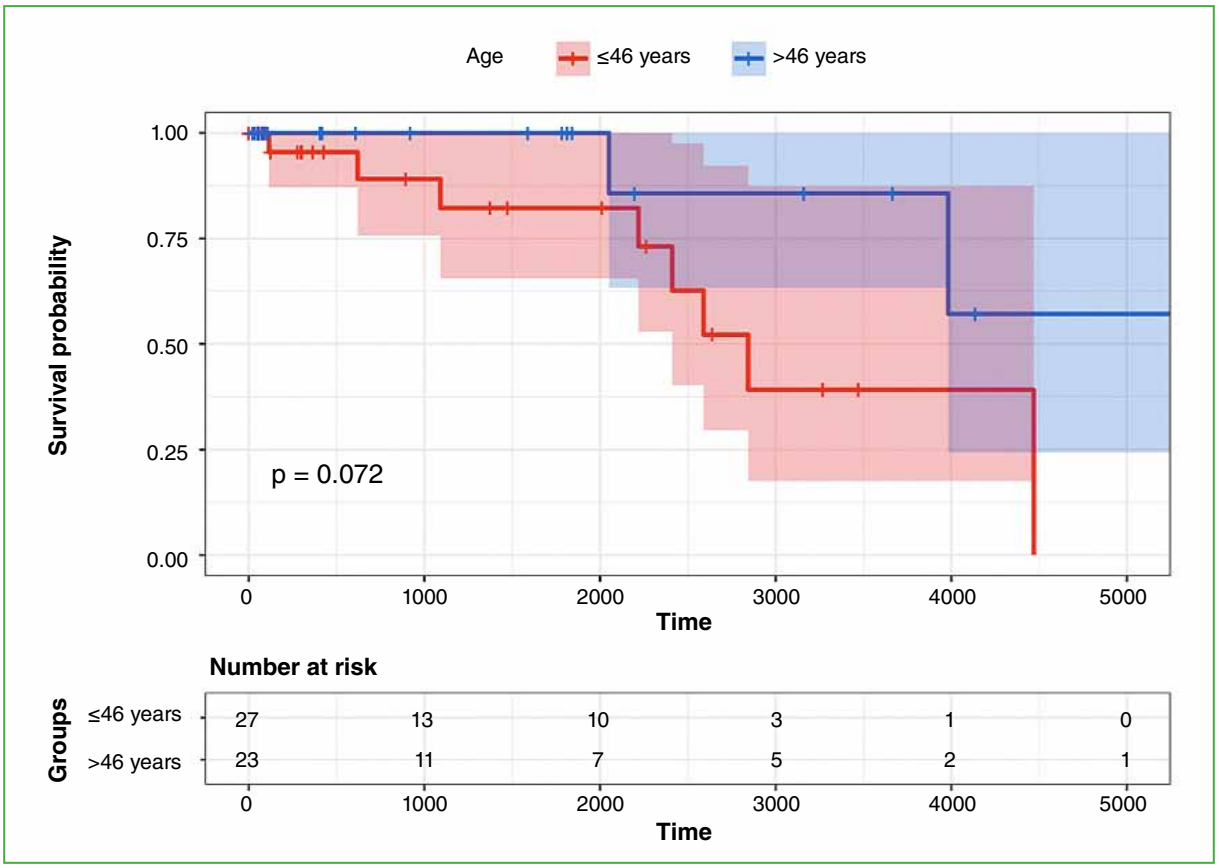

Figure 3. Kaplan-Meier curve.

A total of 11 patients experienced complications. There were eight cases of loosening, identified by radiolucency on the acetabular side (DeLee and Charnley areas). Only one of these patients required revision surgery, while the others remained asymptomatic. Two cases of infection occurred—one treated with single-stage revision, and the other required a two-stage revision with the placement of a cement spacer with antibiotics followed by THA in a subsequent procedure. Only one patient had a post-surgical HHS <70 and was treated with analgesics and physiotherapy.

DISCUSSION

Total hip arthroplasty (THA) in patients with developmental dysplasia of the hip (DDH) remains a significant challenge for hip arthroplasty specialists. In our study, we evaluated the clinical and functional outcomes of patients undergoing THA for Crowe grades II, III, and IV DDH. Although no statistically significant relationship between age and the various outcome variables was found, our findings align with several previous studies.[5,6] These studies also suggest that age does not appear to be a decisive factor in the short-term outcomes of THA in patients with DDH.

The most commonly used acetabular reconstruction technique was medialization, which was predominantly employed in patients with Crowe grade II DDH (49.12%).

Jasty and Harris report that for patients with Crowe grades I and II DDH, the surgical technique generally does not require extensive modification or special procedures. They argue that medialization of the acetabular implant in

such patients is often sufficient to achieve good coverage and bone contact for the prosthesis. However, in patients with Crowe grades III and IV DDH, due to soft tissue contracture and lower limb length discrepancy, additional surgical measures—such as moving the rotational center superiorly or performing femoral osteotomies—are often necessary to achieve optimal postoperative outcomes.[7] This approach is supported by previous research that has demonstrated satisfactory outcomes in terms of pain relief and functional improvement in patients with Crowe II, III, and IV DDH.[8,9] Delp and Maloney, as well as Makita et al., report favorable outcomes using the high hip center and bone grafting techniques, emphasizing the importance of tailoring the surgical approach to each patient's specific anatomy and needs.[10,11]

Regarding postoperative complications of THA in patients with DDH, common issues include loosening of the implant (both femoral and acetabular), infection, and functional disability of the joint. Functional disability was assessed using the Harris Hip Score (HHS) before surgery and at the final follow-up. Akbaba et al. also used the HHS to measure postoperative function, categorizing scores <70 as poor, 71–80 as acceptable, 81–90 as good, and >90 as excellent.[12] In our study, we classified scores below 70 as indicative of postoperative complications related to functional disability of the prosthesis.

Our analysis of prosthesis lifespan revealed no significant differences in postoperative complication rates between age groups. These findings are consistent with existing literature, which suggests that age is not an independent risk factor for postoperative complications in THA.[13,14] However, it is important to recognize that complications may be influenced by multiple factors, including pre-existing comorbidities and the specific surgical technique used, which should be considered during clinical evaluation.

Our study has limitations, including the relatively small sample size and limited follow-up period. The absence of significant differences in some comparisons may be attributable to the limited statistical power in a small cohort. Further research with larger sample sizes and longer follow-up periods is needed to fully assess the influence of age and acetabular reconstruction techniques on outcomes in patients with DDH.

CONCLUSIONS

Our results suggest that age at the time of surgery does not appear to be a significant factor in determining the immediate outcomes or postoperative complications of total hip arthroplasty (THA) in patients with Crowe grades II, III, and IV developmental dysplasia of the hip (DDH). Additionally, our findings highlight that the choice of acetabular reconstruction technique should be based on an individualized assessment of each patient. However, it is important to acknowledge the limitations of this study and that future studies with larger cohorts and longer follow-up periods are needed to confirm these results and provide more robust clinical guidance for managing this patient population.

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

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Thromboprophylaxis Treatment Does Not Affect Hemoglobin and Hematocrit Levels After Elective Total Hip Arthroplasty

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ABSTRACT

Background: Postoperative anemia is a significant complication in patients undergoing total hip arthroplasty (THA). The primary objective of this study was to evaluate the prevalence of postoperative anemia in patients undergoing elective THA and to determine whether there is a relationship with the thromboprophylactic treatment used. **Materials and Methods:** This was a prospective randomized trial. A total of 358 patients who underwent elective THA between February 2019 and January 2022 were included. Patients were divided into three groups receiving daily thromboprophylaxis: rivaroxaban 10 mg, enoxaparin sodium 40 mg, or aspirin 100 mg. **Results:** No confirmed cases of thromboembolic disease or severe bleeding were reported. Hemoglobin and hematocrit levels were consistent across all treatment groups, with no statistically significant differences. There were no differences in complication rates among the groups. However, iron supplementation was significantly higher in the enoxaparin group (p = 0.041). In the ordinal regression model, the incidence of anemia was associated with age (OR 1.02, 95% CI 1.00-1.05, p = 0.04), male sex (OR 0.33, 95% CI 0.19-0.56, p < 0.01), and the presence of any comorbidity (OR 0.49, 95% CI 0.28-0.85, p = 0.012). **Conclusions:** The thromboprophylaxis treatments evaluated in this study had no impact on the development of postoperative anemia in patients undergoing THA. Male sex, age, and the presence of comorbidities appear to be the factors most negatively influencing the development of anemia. No significant differences were found in the safety profiles of the three thromboprophylaxis therapies.

Keywords: Anemia; hip; arthroplasty; thromboprophylaxis.

Level of Evidence: II

El tratamiento trombofiláctico no afecta los niveles de hemoglobina y hematocrito luego de una artroplastia total de cadera

RESUMEN

Introducción: La anemia posoperatoria es una complicación importante en pacientes sometidos a una artroplastia total de cadera (ATC). El objetivo principal de este estudio fue evaluar la prevalencia de anemia posoperatoria en pacientes sometidos a una ATC programada y determinar si está relacionada con el tratamiento tromboprofiláctico administrado. **Materiales y Métodos:** Ensayo prospectivo aleatorizado. Se incluyó a 358 pacientes sometidos a una ATC programada entre febrero de 2019 y enero de 2022, que fueron divididos en 3 grupos para recibir: rivaroxabán 10 mg, enoxaparina sódica 40 mg o aspirina 100 mg como estrategia de tromboprofilaxis diaria. **Resultados:** No hubo casos de enfermedad tromboembólica confirmada ni de hemorragia grave. Los niveles de hemoglobina y hematocrito fueron similares en todos los grupos de tratamiento, sin diferencias estadísticamente significativas. No se hallaron diferencias en la incidencia de complicaciones. La suplementación con hierro fue significativamente mayor en el grupo de enoxaparina (p = 0,041). La incidencia de anemia en el modelo de regresión ordinal se asoció con la edad (OR 1,02; IC95% 1,00-1,05; p 0,04), el sexo masculino (OR 0,33; IC95% 0,19-0,56; p <0,01) y la presencia de una comorbilidad (OR 0,49; IC95% 0,28-0,85; p 0,012). **Conclusiones:** La tromboprofilaxis utilizada no tiene impacto en el desarrollo de la anemia posoperatoria en pacientes sometidos a una ATC. El sexo masculino, la edad y la presencia de alguna comorbilidad parecen ser los factores que influyen negativamente en la anemia. No hubo diferencias significativas en el perfil de seguridad de estas tres terapias de tromboprofilaxis.

Palabras clave: Anemia; cadera; artroplastia; tromboprofilaxis.

Nivel de Evidencia: II

Received on May 15th, 2024. Accepted after evaluation on July 10th, 2024 • Dr. SANTIAGO L. IGLESIAS • santiglesias07@hotmail.com https://orcid.org/0000-0001-6698-2914

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INTRODUCTION

Complications following total hip arthroplasty (THA) prolong hospital stays and subsequently increase healthcare costs.[1] Postoperative anemia is a significant complication in patients undergoing THA, affecting one-third of patients, particularly those of advanced age.[2] The prevalence of preoperative anemia is estimated at 24.9% (± 9%), while postoperative anemia occurs in about 51% (± 10%).[3]

Numerous studies have demonstrated the association between anemia and an increase in postoperative complications, including infection, death, decreased function, and extended hospital stays, irrespective of patients' preexisting comorbidities. [4]

Traditionally, the treatment of postoperative anemia has focused on blood transfusions, which can result in a range of complications, including allergic reactions, circulatory overload, pulmonary thromboembolism, immunosuppression, surgical site infection, and prolonged hospitalization.[5]

THA is a major risk factor for postoperative venous thromboembolic disease (VTE); therefore, anticoagulant thromboprophylaxis is strongly recommended to prevent this serious complication. The appropriate use of thromboprophylaxis significantly reduces the risk of postoperative VTE. However, it remains unclear whether anticoagulant thromboprophylaxis can also influence the development of postoperative anemia in these patients.[6]

The primary objective of this study was to evaluate the prevalence of postoperative anemia in patients undergoing elective THA at our institutionand to explore whether there is an association between the pharmacological thromboprophylaxis strategy used and the incidence of postoperative anemia. Secondary objectives included determining whether there is a correlation between anemia and preexisting comorbidities or surgical duration, assessing the need for transfusion or other medical interventions, and identifying any increase in wound complications—such as hematoma, bleeding, surgical site infection, or VTE—based on the thromboprophylaxis administered. Furthermore, the study evaluated whether aspirin is a safe thromboprophylactic method for patients undergoing THA.

MATERIALS AND METHODS

Men and women >18 years of age who underwent elective THA between February 2019 and January 2022 were included in the study. Pregnant or breastfeeding women, those with active bleeding or a high risk of bleeding, those with contraindications to enoxaparin prophylaxis, or conditions requiring an adjusted enoxaparin dose were excluded. Additional exclusion criteria included: body mass index >40, significant liver disease, severe renal dysfunction (creatinine clearance <30 ml/min), concomitant use of protease inhibitors for the treatment of HIV infection, or the need for anticoagulant therapy that could not be discontinued.

A prospective, randomized trial was conducted at two sites of a high-complexity hospital. Before surgery, patients were randomly assigned to a study group using permuted blocks via a central telephone system with a computer-generated randomization list. Patients were assigned to receive one of the following thromboprophylaxis strategies: 10 mg of oral rivaroxaban once daily, 40 mg of subcutaneous enoxaparin sodium, or 100 mg of oral aspirin. Thromboprophylactic treatment was administered to all three groups for a period of 28 days after surgery.

All participants received subarachnoid spinal anesthesia for the surgical procedure and a weight-adjusted dose of tranexamic acid (20 mg/kg) 30 minutes before the surgical incision. During the first four days, all patients received thromboprophylaxis with 40 mg of enoxaparin, after which each patient continued with the medication to which they were randomized. Enoxaparin administration began 12 hours after wound closure in patients without bleeding complications in the immediate postoperative period. Thereafter, the study drugs were administered every 24 hours (within a range of 22-26 hours) in the evening, continuing until day 28 after surgery (with the day of surgery designated as day 1).

A Doppler ultrasound of the lower limbs was ordered only if the patient exhibited clinical signs suggestive of deep vein thrombosis. Patients attended a follow-up visit 21 days (±1) after surgery to assess the surgical wound. On day 28, a telephone consultation was conducted, after which the study drug was discontinued.

The study was designed by the investigators and conducted in accordance with the Declaration of Helsinki and local regulations. The protocol was reviewed and approved by the institutional review board, and written informed consent was obtained from all patients prior to randomization.

All outcomes were evaluated by independent central adjudication committees whose members were blinded to the patients' group allocations. The primary endpoint was the appearance of deep vein thrombosis, nonfatal pulmonary embolism, or death from any cause up to 28 days after surgery.

The primary safety outcome was the incidence of major bleeding that occurred after the first dose of the study drug and up to two days after the last dose. Major bleeding was defined as bleeding that was fatal, occurred in a critical organ (e.g., retroperitoneal, intracranial, intraocular, or intraspinal), required reoperation, or occurred at a clinically evident extraoperative site and was associated with a hemoglobin drop of at least 2 g/dL or required the transfusion of 2 or more units of whole blood or packed red blood cells. Additional safety outcomes included any bleeding during treatment, non-major bleeding during treatment, hemorrhagic wound complications (such as excessive wound hematoma or reported bleeding at the surgical site), any bleeding that began after the first dose of the study drug and continued up to two days after the last dose, adverse events, and death.

Laboratory tests were performed before surgery and 24 hours after surgery to evaluate hemoglobin and hematocrit levels. Patients were classified according to the World Health Organization's severity classification: no anemia (>12 g/dL), mild anemia (10-12 g/dL), moderate anemia (8-9.9 g/dL), and severe anemia (<8 g/dL). Patients were evaluated by physicians from the Hematology Service, who determined whether anemia treatment was necessary. At 21 days postoperatively, another set of tests was performed to assess hematocrit and hemoglobin levels and their variation compared to preoperative values and those obtained 24 hours after surgery, evaluating hemoglobin recovery following THA.

Statistical analysis

Categorical variables are presented as proportions and absolute numbers, while continuous variables are expressed as mean and standard deviation or as median and interquartile range (IQR), depending on the data distribution. The Shapiro-Wilk test, histograms, and normal distribution plots were used to assess the distribution.

For bivariate analysis, numerical variables were compared using the t-test or Wilcoxon test, based on the data distribution, while categorical variables were compared using Pearson's chi-square test or Fisher's exact test, as appropriate.

The effect of the randomized drugs on hemoglobin levels at day 21 was analyzed using a multiple linear regression model adjusted for sociodemographic confounders, clinical history, and surgical characteristics.

Additionally, a multivariate ordinal logistic regression model was developed to evaluate the independent effect of the assigned drugs on the presence of different degrees of anemia at day 21, also adjusted for sociodemographic confounders, clinical history, and surgical characteristics. The associations are reported with their 95% confidence intervals (95% CI). A p-value of <0.05 was considered statistically significant.

All analyses were performed using STATA 13 software (StataCorp, Texas, USA).

RESULTS

Between February 2019 and January 2022, a total of 367 patients were enrolled in the study, with 358 patients included in the modified intention-to-treat population (Figure 1). The mean age of participants was 62.73 years (standard deviation 12.25), and 59.5% were male. There were no significant differences in demographic or surgical characteristics among the three groups, except for a trend toward older age in the enoxaparin group (Table 1). The mean duration of pharmacological antithrombotic prophylaxis was 28 days in all groups.

Efficacy endpoints

VTE was suspected in six patients: one in the enoxaparin group, two in the rivaroxaban group, and three in the aspirin group. However, Doppler ultrasound ruled out all cases, meaning no confirmed VTE occurred during the follow-up period.

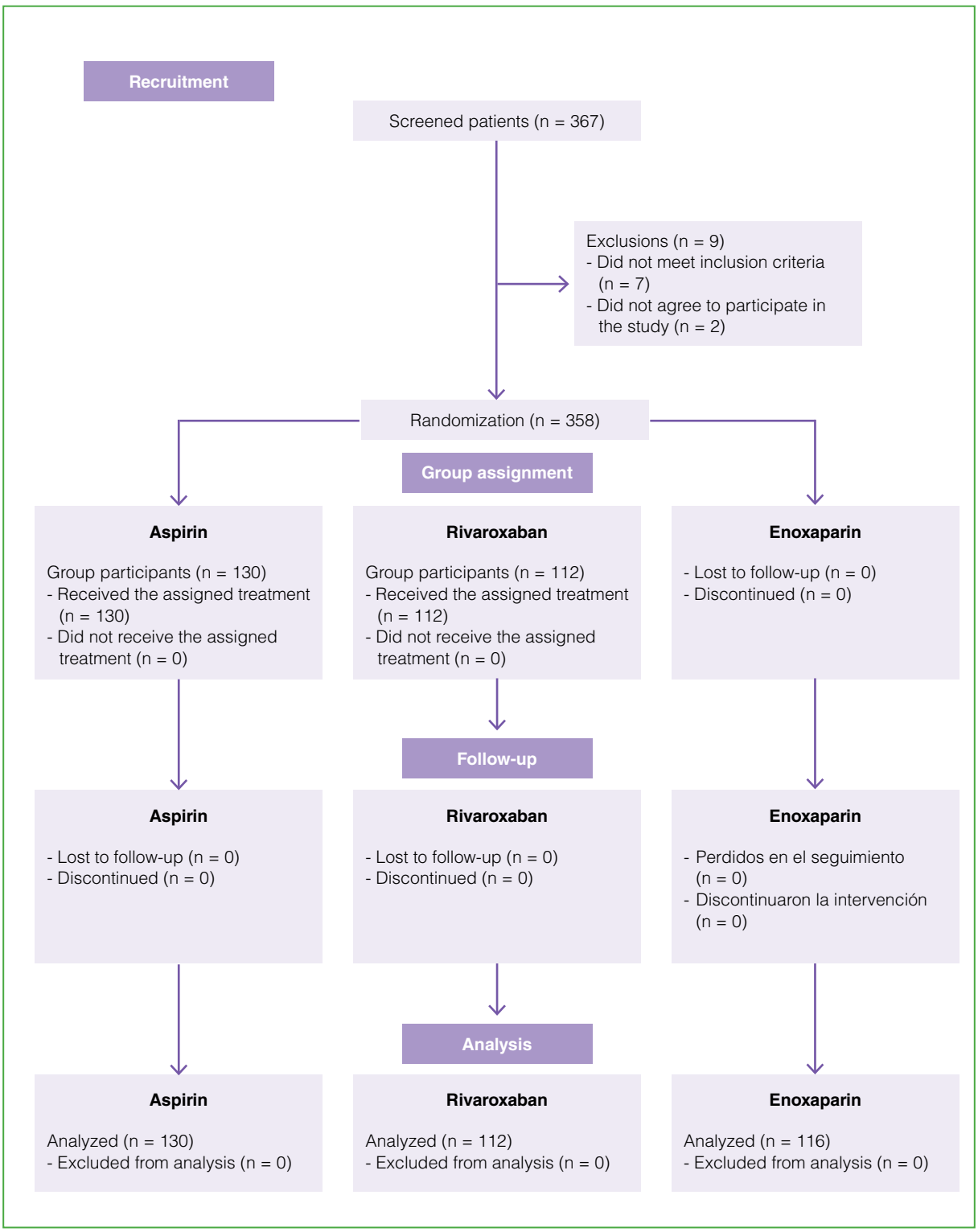

Figure 1. Elective total hip arthroplasty: anemia and thromboprophylaxis. Flow chart.

Table 1. Characteristics of the 358 patients included in the study.

	All n = 358	Enoxaparin n = 116	Rivaroxaban n = 112	Aspirin n = 130	p
Sex Female Male	 145 (40.5%) 213 (59.5%)	 52 (44.8%) 64 (55%)	 42 (37.5%) 70 (62.5%)	 51 (39.2%) 79 (60.8%)	0.49
Age, mean (SD)	62.7 (12.3)	65.2 (11.4)	61.5 (13.5)	61.6 (11.6)	0.032
Weight (kg), mean (SD)	83.5 (13.1)	84.3 (13.1)	83.4 (14.1)	82.9 (12.1)	0.69
BMI, mean (SD)	27.9 (3.7)	28.5 (4.0)	27.6 (3.4)	27.7 (3.6)	0.12
Operated side Right Left Bilateral	 192 (53.6%) 162 (45.3%) 4 (1.1%)	 60 (51.7%) 54 (46.6%) 1 (0.9%)	 60 (53.6%) 51 (45.5%) 2 (1.7%)	 72 (55.4%) 57 (43.8%) 1 (0.8%)	0.93
Hypertension	141 (39.4%)	43 (37.1%)	43 (38.4%)	55 (42.3%)	0.68
Diabetes	10 (2.8%)	5 (4.3%)	3 (2.7%)	2 (1.5%)	0.42
Dyslipemia	30 (8.4%)	12 (10.3%)	4 (3.6%)	14 (10.8%)	0.085
Heart disease	32 (8.9%)	15 (12.9%)	11 (9.8%)	6 (4.6%)	0.068
Obesity	7 (2.0%)	5 (4.3%)	1 (0.9%)	1 (0.8%)	0.083
Number of comorbidities None One Two	 117 (32.7%) 220 (61.5%) 21 (5.9%)	 29 (25.0%) 80 (69.0%) 7 (6.0%)	 46 (41.1%) 62 (55.4%) 4 (3.6%)	 42 (32.3%) 78 (60.0%) 10 (7.7%)	0.09
ASA Score 1 2 3	 34 (9.5%) 313 (87.7%) 10 (2.8%)	 7 (6.0%) 102 (87.9%) 7 (6.0%)	 17 (15.3%) 93 (83.8%) 1 (0.9%)	 10 (7.7%) 118 (90.8%) 2 (1.5%)	0.013
Type of prosthesis Uncemented Hybrid Cemented	 228 (63.7%) 126 (35.2%) 4 (1.1%)	 65 (56.0%) 49 (42.2%) 2 (1.7%)	 72 (64.3%) 40 (35.7%) 0 (0.0%)	 91 (70.0%) 37 (28.5%) 2 (1.5%)	0.13
Duration of surgery, mean (SD) (min)	97.5 (16.1)	99.0 (17.3)	97.1 (14.9)	96.5 (16.2)	0.45
Duration of hospitalization, mean (SD) (days)	1.7 (0.6)	1.9 (0.6)	1.8 (0.5)	1.6 (0.7)	<0.001

SD = standard deviation; BMI = body mass index; ASA = *American Society of Anesthesiologists*.

Safety outcomes

No cases of major bleeding were reported during follow-up. Six patients (1.67%) required transfusions in the immediate postoperative period before receiving the study-specific medication. Of these, three were in the enoxaparin group and three were in the rivaroxaban group. However, the bleeding did not meet the criteria for major bleeding.

No significant differences were found in mean pre- and postoperative hemoglobin or hematocrit levels between the groups. Hemoglobin and hematocrit values were similar across all treatment groups, with no significant differences in their progression. Across the three groups, a mean decrease of 3 g/dL in hemoglobin was observed in the first postoperative control compared to preoperative values. The greatest decrease in hemoglobin and hematocrit occurred on day 2, with hemoglobin dropping by approximately 3 g/dL in all groups (Table 2, Figures 2 and 3).

Table 2. Comparison of hemoglobin levels throughout follow-up.

	Preoperative period	Day 1	Day 2	Day 21
Enoxaparin	13.95	11.50	11.14	12.30
Rivaroxaban	14.08	11.25	10.94	12.53
Aspirin	14.13	11.57	11.36	12.61
p	0.64	0.25	0.13	0.33

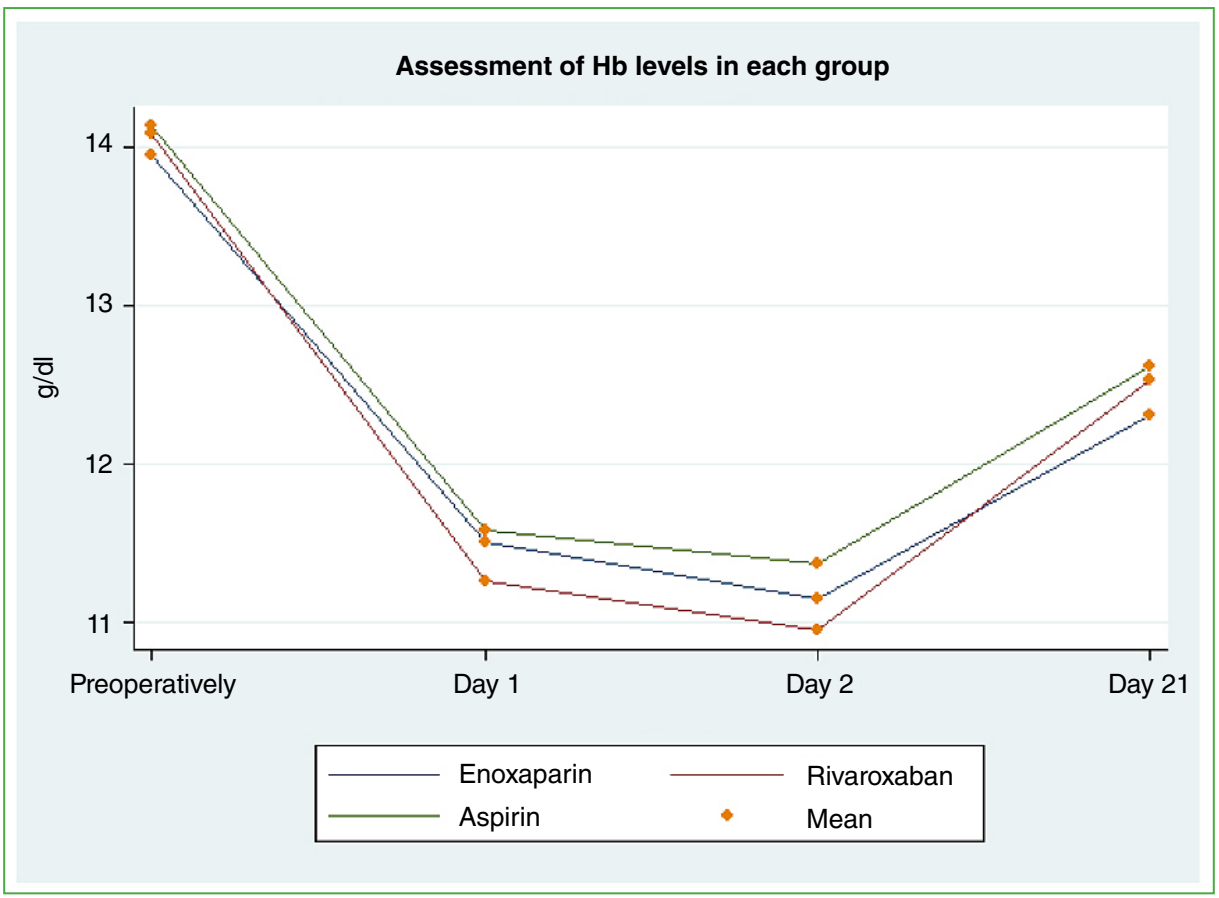

Figure 2. Assessment of hemoglobin (Hb) levels based on the assigned thromboprophylaxis treatment.

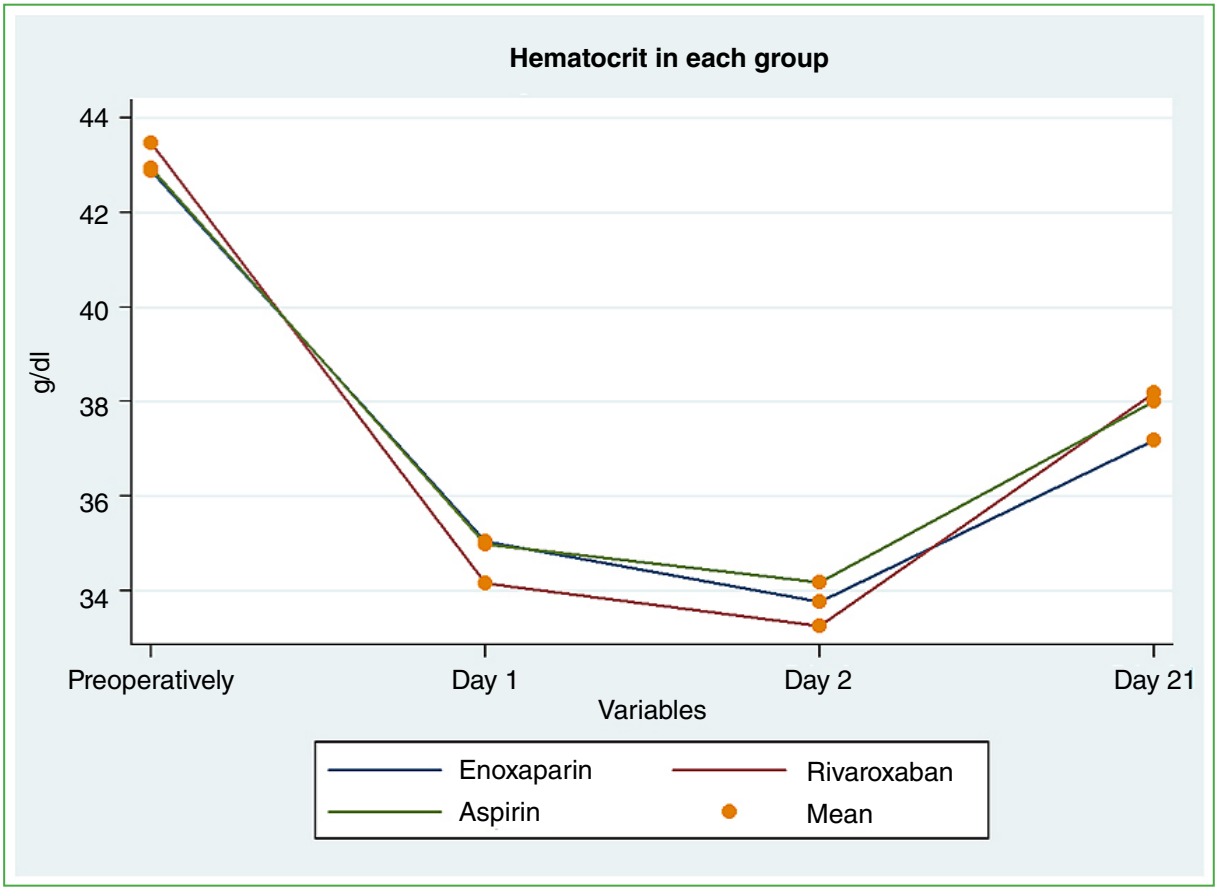

Figure 3. Assessment of hematocrit levels based on the assigned thromboprophylaxis treatment.

Other outcomes

The median hospitalization time for the study population was 2 days (IQR 1-2), with no significant differences between groups regarding the incidence of infection, hematoma, or wound bleeding.

The requirement for iron supplementation was significantly higher in the enoxaparin group (6 cases, 5.2%) compared to the rivaroxaban group (4 cases, 3.6%) and the aspirin group (0 cases, 0.0%) (p = 0.041) (Table 3).

Table 3. Comparative outcomes between arms.

	Enoxaparin (n = 116)	Rivaroxaban (n = 112)	Aspirin (n = 130)	p
21-day DVT symptoms	1 (0.9%)	2 (1.8%)	3 (2.3%)	0.67
Confirmed DVT	0 (0%)	0 (0%)	0 (0%)	-
Hemoglobin on day 21	12.3 (1.7)	12.5 (1.6)	12.6 (1.6)	0.34
transfusions	3 (2.6%)	3 (2.7%)	1 (0.8%)	0.47
Iron	6 (5.2%)	4 (3.6%)	0 (0.0%)	0.041
Bruising or bleeding	3 (2.6%)	6 (5.4%)	4 (3.1%)	0.49
Infections	2 (1.7%)	1 (0.9%)	2 (1.5%)	0.85

DVT = deep vein thrombosis.

In the model evaluating the effect of the treatment arms on hemoglobin levels at day 21 (Figure 4), men were found to have, on average, 1.04 g/dL more hemoglobin than women (95% CI 0.65-1.43; $p < 0.01$), a result expected due to physiological gender differences. Aside from this gender-based difference, no significant variation in hemoglobin levels at day 21 was observed between the three treatment arms, nor were there differences between the medication arms or other confounding factors studied (Table 4).

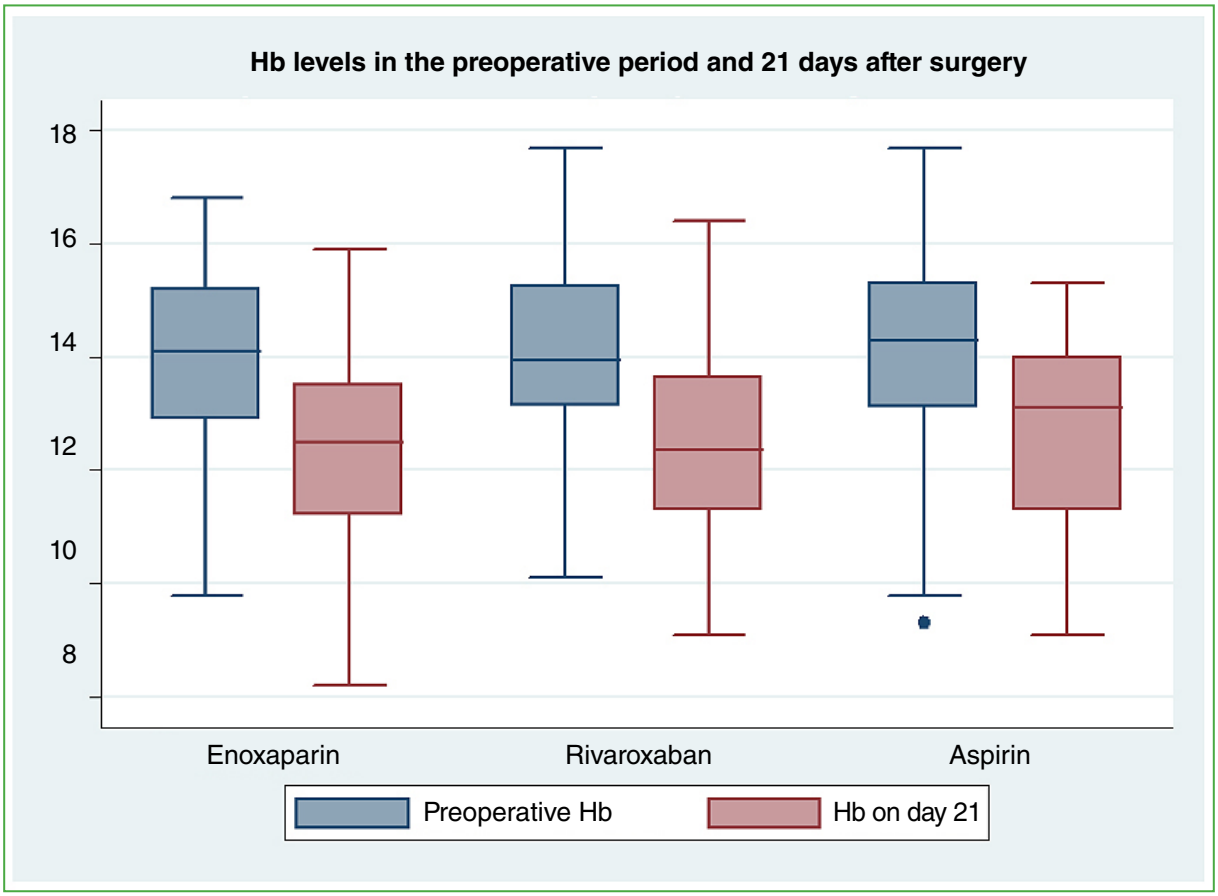

Figure 4. Box plot comparing hemoglobin (Hb) levels in the preoperative period and 21 days after surgery based on the assigned thromboprophylaxis treatment.

Table 4. Linear regression between demographic and clinical predictors and hemoglobin level 21 days after surgery.

	Coefficient	95%CI	p
Treatment arms			
Enoxaparin	Ref.	-	-
Rivaroxaban	0.098	(from -0.29 to 0.49)	0.62
Aspirin	0.17	(from -0.21 to 0.55)	0.38
Age	-0.009	(from -0.02 to 0.007)	0.25
Sex			
Female	Ref.	-	-
Male	1.04	(0.65-1.43)	**0.0001**
Comorbidities			
none	Ref.	-	-
1	-0.12	(from -0.52 to 0.27)	0.55
2 or more	-0.51	(from -1.26 to 0.23)	0.18
ASA Score			
1	Ref.	-	-
2	0.42	(from -0.18 to 1.02)	0.17
3	0.84	(from -0.29 to 1.99)	0.15
Type of prosthesis			
Uncemented	Ref.	-	-
Hybrid	-0.44	(from -0.89 to 0.01)	0.058
cemented	-0.73	(from -2.27 to 0.81)	0.35
Duration of Surgery	0.0004	from -0.009 to 0.10	0.93

ASA = *American Society of Anesthesiologists*; 95%CI = 95% confidence interval.

In the ordinal regression model analyzing the factors associated with the incidence and severity of anemia, the following characteristics were found to be significant: age (odds ratio [OR] 1.02; 95% CI 1.00-1.05; p = 0.04), male sex (OR 0.33; 95% CI 0.19-0.56; p < 0.01), and the presence of comorbidities (OR 0.49; 95% CI 0.28-0.85) (Figure 5, Table 5).

DISCUSSION

The development of anemia after scheduled total hip arthroplasty (THA) is a frequent complication associated with increased morbidity, prolonged hospital stay, higher health care costs, and a greater need for blood transfusion or iron supplementation. The occurrence of anemia may be influenced by the type of antithrombotic prophylaxis administered.

Postoperative anemia can be easily explained by acute blood loss and the inflammatory response triggered by the surgery, which disrupts erythropoiesis and iron metabolism, reducing iron availability as the body tries to compensate.[5] The incidence of postoperative anemia in our study population was similar to that reported by Sphan et al.[3] In our cohort, male sex, advanced age, and the presence of comorbidities were associated with a higher incidence or greater severity of anemia.

No statistically significant differences were observed in the decrease in hemoglobin after surgery among patients receiving enoxaparin, rivaroxaban, or aspirin as VTE prophylaxis. All three treatment options showed a similar safety profile in this regard. However, it is worth noting that laboratory follow-up was only extended until day 21 post-surgery, at which point hemoglobin and hematocrit levels had shown favorable recovery. In contrast, Bala et al.[7] reported differences in anemia rates among four drugs (factor Xa inhibitors, aspirin, low-molecular-weight heparin, and warfarin), with these differences persisting even up to 90 days post-surgery.

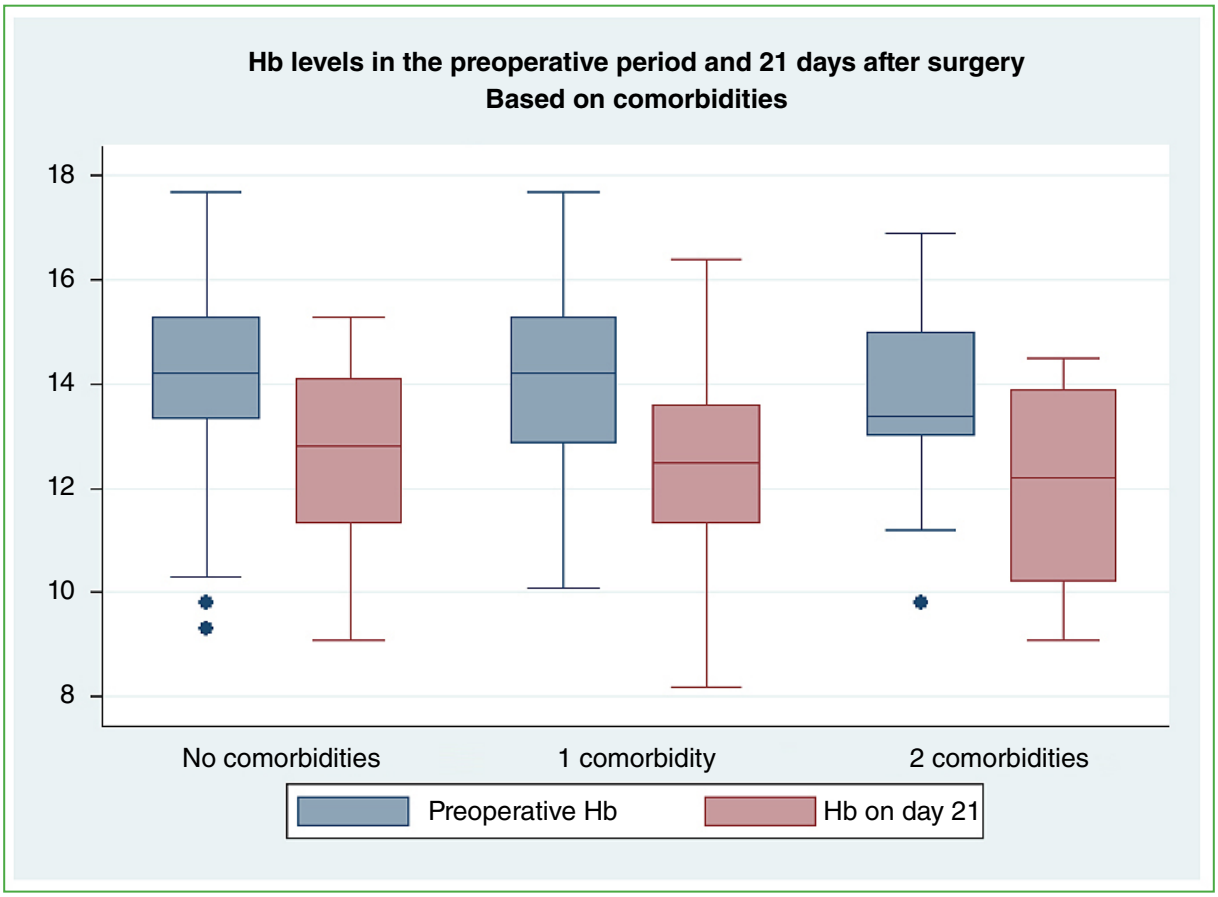

Figure 5. Box plot comparing hemoglobin (Hb) levels in the preoperative period and 21 days after surgery based on the presence or absence of comorbidities.

Traditionally, the correction of postoperative anemia has focused on blood transfusions, with the initial hemoglobin level consistently predicting the need for transfusion.[2] In our study, only six patients (1.67%)—three in the enoxaparin group and three in the rivaroxaban group—required a transfusion. This contrasts with the findings of Chen et al,[8] who reported that 38.5% of patients undergoing THA in a large hospital network required red blood cell transfusions immediately postoperatively, though with significant variation between surgeons.

Regarding the safety of the three VTE prophylactic therapies in our study, no thromboembolic events were observed. Thromboembolism was clinically suspected in six patients, but all cases were ruled out via Doppler ultrasound. A study by Tan et al.,[9] which compared the potency of anticoagulants (warfarin, low-molecular-weight heparin, and aspirin) for VTE prevention in 60,467 patients, found that aspirin was as effective as more potent anticoagulants. Our results align with those of a 2008 multicenter randomized clinical trial,[10] which concluded that rivaroxaban has a safety profile comparable to that of enoxaparin in the prevention of VTE after THA. Similarly, Matharu et al,[11] in their systematic review and meta-analysis of randomized controlled trials, found no significant differences in clinical efficacy and safety when comparing aspirin with other oral anticoagulants after joint replacement.

Our findings support the use of aspirin for VTE prophylaxis, as no patients in our series experienced thromboembolic events. These results are consistent with those of Muscatelli et al.[12] and Matharu et al.,[13] both of whom concluded that aspirin is not inferior to other anticoagulants in preventing VTE and related bleeding complications.

Table 5. Ordinal regression between demographic and clinical predictors and the level of anemia severity 21 days post-surgery

	OR	95%CI	p
Treatment arms			
Enoxaparin	Ref.	-	-
Rivaroxaban	1.00	(0.58-1.73)	0.98
Aspirin	0.73	(0.42-1.25)	0.25
Age	1.02	(1.00-1.05)	**0.04**
Sex			
Female	Ref.		-
Male	0.33	-(0.19-0.56)	**0.0001**
Comorbidities			
None	Ref.	-	-
1	0.49	(0.28-0.85)	**0.012**
2 or more	0.82	(0.30-2.26)	0.70
ASA Score			
1	Ref.	-	-
2	0.92	(0.39-2.13)	0.84
3	0.79	(0.16-3.81)	0.77
Type of prosthesis			
Uncemented	Ref.	-	-
Hybrid	1.26	(0.68-2.34)	0.46
Cemented	2.45	(0.35-17.31)	0.37
Duration of surgery	1.00	(0.99-1.02)	0.87

OR (*odds ratio*) = odds ratio; 95%CI = 95% confidence interval; ASA = *American Society of Anesthesiologists.*

A limitation of our study is that thrombotic events may have been underestimated due to the size of our cohort, as a larger study population would be needed to fully assess the efficacy of these three thromboprophylactic therapies. Randomized controlled trials or retrospective studies based on large administrative databases often lack the clinical observation, patient-specific data, and accurate complication reporting necessary for a thorough analysis. A strength of our study is that it was conducted in a single medical institution, allowing for detailed reporting of each of these factors.

CONCLUSIONS

The selection of a thromboprophylaxis agent following primary total hip arthroplasty (THA) remains a critical issue, as the ideal drug has yet to be identified. Based on our analysis of the three therapeutic options studied in our cohort—enoxaparin, rivaroxaban, and aspirin—for VTE prophylaxis after THA, we can conclude that the thromboprophylactic treatment administered does not influence the development of postoperative anemia. The factors that appear to negatively impact anemia outcomes are male sex, advanced age, and the presence of comorbidities. Additionally, no significant differences were observed in the safety profile of these three thromboprophylactic therapies with respect to thrombotic events following elective THA.

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

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Advanced Classification of Knee Osteoarthritis Using Artificial Intelligence Technologies

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ABSTRACT

Introduction: Knee osteoarthritis is a prevalent and debilitating musculoskeletal condition, particularly in the elderly. Early detection and accurate classification are crucial for improving patient outcomes. **Objective:** To investigate the application of artificial intelligence (AI) and computer vision for the automated detection and classification of knee osteoarthritis based on the Kellgren-Lawrence (KL) scale. Additionally, to develop and evaluate an automated system capable of accurately classifying the severity of the disease. **Materials and Methods:** A public dataset of radiographic knee images pre-classified according to the KL scale was used. The images were processed with LandingLens software, using the ConvNext architecture, a convolutional neural network. The model was trained with 995 images and was used to evaluate 240 trial images. **Results:** The model achieved an overall accuracy of 92.55% in classifying knee osteoarthritis according to the KL scale, with a sensitivity of 93.33%. Per-class accuracy was as follows: 97.87% for grade 0, 79.74% for grade 1, 88.68% for grade 2, 94.04% for grade 3, and 99.42% for grade 4. **Conclusions:** This study confirms the efficacy of AI and computer vision technologies in the automated detection of knee osteoarthritis. Integrating these technologies into clinical practice can enhance the efficiency and consistency of patient evaluations, ultimately leading to improved clinical outcomes and more personalized care.

Keywords: Artificial intelligence; osteoarthritis; knee classification; computer vision.

Level of Evidence: II

Clasificación avanzada de la artrosis de rodilla utilizando tecnologías de Inteligencia Artificial

RESUMEN

Introducción: La artrosis de rodilla es una enfermedad osteoarticular prevalente y debilitante, especialmente en adultos mayores. Su detección temprana y la clasificación precisa son cruciales para mejorar los resultados clínicos. **Objetivos:** Investigar el uso de la inteligencia artificial y la visión por computadora para la detección y clasificación automatizada de la artrosis de rodilla según la escala de Kellgren-Lawrence. Desarrollar un sistema automatizado y evaluar su precisión para clasificar la gravedad de la enfermedad. **Materiales y Métodos:** Se utilizó un conjunto de datos públicos con imágenes radiográficas de rodillas clasificadas según la escala de Kellgren-Lawrence. Las imágenes fueron procesadas con el programa LandingLens, empleando la arquitectura ConvNext, una red neuronal convolucional. El modelo fue entrenado con 995 imágenes y evaluado con 240 imágenes de prueba. **Resultados:** El modelo alcanzó una precisión global del 92,55% en la clasificación de la artrosis de rodilla, con una sensibilidad del 93,33%. La precisión por clase fue del 97,87% para el grado 0; 79,74% para el grado 1; 88,68% para el grado 2; 94,04% para el grado 3 y 99,42% para el grado 4. **Conclusiones:** El estudio confirma la eficacia de la inteligencia artificial y la visión por computadora en la detección automatizada de la artrosis de rodilla. La integración de estas tecnologías en la práctica clínica podría mejorar la eficiencia, la consistencia en la evaluación de los pacientes y los resultados clínicos, y así favorecer una atención médica más personalizada.

Palabras clave: Inteligencia artificial; artrosis; clasificación; visión por computadora.

Nivel de Evidencia: II

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INTRODUCTION

Osteoarthritis is the most common joint disorder among adults over 60 years of age in the United States. The prevalence of symptomatic knee osteoarthritis is approximately 10% in men and 13% in women.[1] The knee is undoubtedly one of the most affected joints, with estimates indicating that around 30% of people over 45 years old have radiographic evidence of this condition, and about half of them experience clinical symptoms.[2]

Common symptoms include joint pain, stiffness, and limited function, which negatively impact quality of life and are often associated with comorbidities such as cardiovascular disease, diabetes, hypertension, falls, fractures, and depression.[3] Managing this disease requires a multidisciplinary approach, including pain management, exercise, physiotherapy, and, in severe cases, surgical intervention to improve clinical outcomes and enhance patients' quality of life.[4]

In recent years, artificial intelligence (AI), particularly deep learning and convolutional neural networks (CNNs), has emerged as a powerful tool for improving the accuracy of knee osteoarthritis diagnosis and classification. These AI models can process large volumes of imaging data and learn complex features, enabling more accurate and objective classification of knee radiographs.[5,6]

Several CNN-based approaches have been developed for classifying and detecting knee osteoarthritis. These models have been trained to identify and classify X-ray images of the knee according to the Kellgren-Lawrence (KL) classification system, the most widely used method for determining osteoarthritis severity. Studies using various CNN architectures, such as VGG16, VGG19, ResNet50, YOLOv3, and EfficientNet-B5, have demonstrated high accuracy in classifying the severity of osteoarthritis.[7,8]

LandingLens, developed by Landing AI, is an advanced computer vision platform designed to simplify the creation, implementation, and management of AI models, even for users with no prior experience in AI or machine learning. This platform is particularly useful in industrial environments for tasks such as quality inspection and defect detection.

The software provides an intuitive interface that guides users through image uploading, labeling, training, and model deployment. It allows the development of computer vision models without requiring deep technical knowledge. Additionally, it supports continuous learning, enabling models to automatically update with new data. This ensures that models adapt to changing conditions and improve over time.

Radiographic grading systems for knee osteoarthritis vary in terms of reliability and sensitivity in detecting the severity of the disease. The most commonly evaluated systems include the Kellgren-Lawrence, International Knee Documentation Committee (IKDC), Ahlbäck, and Fairbank scales (Table 1).[9]

The Kellgren-Lawrence system is widely used and has proven reproducible, especially when assessing radiographic features such as osteophytes and joint space narrowing. The IKDC system, meanwhile, is known for its high interobserver and intraobserver reliability, making it one of the most dependable methods for evaluating knee osteoarthritis.

The Fairbank system, on the other hand, has the lowest reliability among the rating scales reviewed.[10,11]

While the Ahlbäck grading system shows good interobserver agreement, it lacks reliability, particularly when used without clinical or arthroscopic examination support.[12]

AI and computer vision provide opportunities to more effectively monitor disease progression, allowing for timely and personalized interventions. Early identification of knee osteoarthritis is critical to mitigating its effects. Early detection, coupled with patient education on exercise and weight management, can significantly reduce the symptoms of the disease.[13]

The integration of AI in the diagnosis and treatment of knee osteoarthritis marks a significant advancement in the field.

This paper aims to demonstrate how deep learning and computer vision techniques can be used to develop a model for detecting and classifying knee osteoarthritis based on the Kellgren-Lawrence classification.

Table 1. Knee osteoarthritis classification systems and their characteristics.

Classification	Grade and characteristics				
Kellgren-Lawrence	0: No JSN or reactive changes	1: Doubtful JSN, possible osteophytic lipping	2: Definite osteophytes, possible JSN	3: Moderate osteophytes, definite JSN, some sclerosis, possible bone-end deformity	4: Large osteophytes, marked JSN, severe sclerosis, definite bone ends deformity
IKDC	A: No JSN	B: >4 mm joint space; small osteophytes, slight sclerosis, or femoral condyle flattening	C: 2-4 mm joint space	D: <2 mm joint space	
Fairbank	0: Normal	1: Squaring of tibial margin	2: Flattening of femoral condyle, squaring and sclerosis of tibial margin	3: JSN, hypertrophic changes, or both	4: All of the characteristics at left, to a more severe degree
Brandt et al.	0: <25% JSN without secondary features (subchondral sclerosis, geodes, and osteophytes)	1: <25% JSN with secondary features or 25%-50% JSN without secondary features	2: 25%-50% JSN with secondary features or 50%-75% JSN without secondary features	3: 50%-75% JSN with secondary features or >75% JSN without secondary features	4: >75% JSN with secondary features
Ahlbäck	0: Normal	1: JSN† (with or without subchondral sclerosis).	2: Obliteration of joint space	3: Bone defect/ loss <5 mm	4: Bone defect and/or loss 5-10 mm
Jäger-Wirth	0: No osteoarthritis	1: Initial osteoarthritis, small osteophytes, minimal JSN	2: Moderate osteoarthritis, about 50% JSN	3: Medium-grade osteoarthritis	4: Heavy osteoarthritis

*JSN = joint space narrowing, IKDC = International Knee Documentation Committee.
†Joint space narrowing is <3 mm of the joint space or <50% of the other compartment.
From: Kohn MD, Sassoon AA, Fernando ND. Classifications in Brief: Kellgren-Lawrence Classification of Osteoarthritis. Clin Orthop Relat Res 2016;474(8):1886-93. https://doi.org/10.1007/s11999-016-4732-4.

OBJECTIVE

To develop an automated system for the detection and classification of knee osteoarthritis using the Kellgren-Lawrence scale and the IKDC questionnaire, using a computer vision-based AI program.

MATERIALS AND METHODS

A publicly available dataset containing medical images of patients with varying degrees of knee osteoarthritis (https://www.kaggle.com/datasets/shashwatwork/knee-osteoarthritis-dataset-with-severity) was used to develop a predictive model for the disease. These images had already been classified according to the Kellgren-Lawrence scale.

The images were uploaded to the LandingAI platform as supervised learning data.

To develop the model based on the Kellgren-Lawrence classification, 1,195 knee osteoarthritis images were used, divided into five groups according to their classification: 328 grade 0, 153 grade 1, 212 grade 2, 329 grade 3, and 173 grade 4 images. The training set consisted of 995 images, while 240 images were reserved for testing.

A machine learning model based on the ConvNext convolutional neural network architecture, with 16 million parameters, was implemented to perform the prediction. The model was trained for 15 epochs. To evaluate the model, a confusion matrix, accuracy, sensitivity for each class, and the F1 score were used.

RESULTS

The performance of the knee osteoarthritis classification model was evaluated using the Kellgren-Lawrence scale, which comprises five levels of severity: 0, 1, 2, 3, and 4. A dataset of 1,195 images was used to train and evaluate the model.

The model achieved an overall accuracy of 92.55%, demonstrating its ability to correctly classify the presence and severity of knee osteoarthritis in the majority of cases. This high level of accuracy suggests the model is reliable in distinguishing between different grades of osteoarthritis according to the Kellgren-Lawrence scale (Figure 1).

When evaluating per-class accuracy, the model achieved 97.87% accuracy for grade 0, correctly classifying 321 out of 328 images in this category. For grade 1, the accuracy was 79.74%, with 122 out of 153 images correctly classified. A higher accuracy was observed for grade 2 at 88.68%, with 188 out of 212 images correctly classified. For grade 3, the model attained an accuracy of 94.04%, correctly classifying 303 out of 329 images. Finally, for grade 4, the model achieved 99.42% accuracy, correctly classifying 172 out of 173 images (Figure 2).

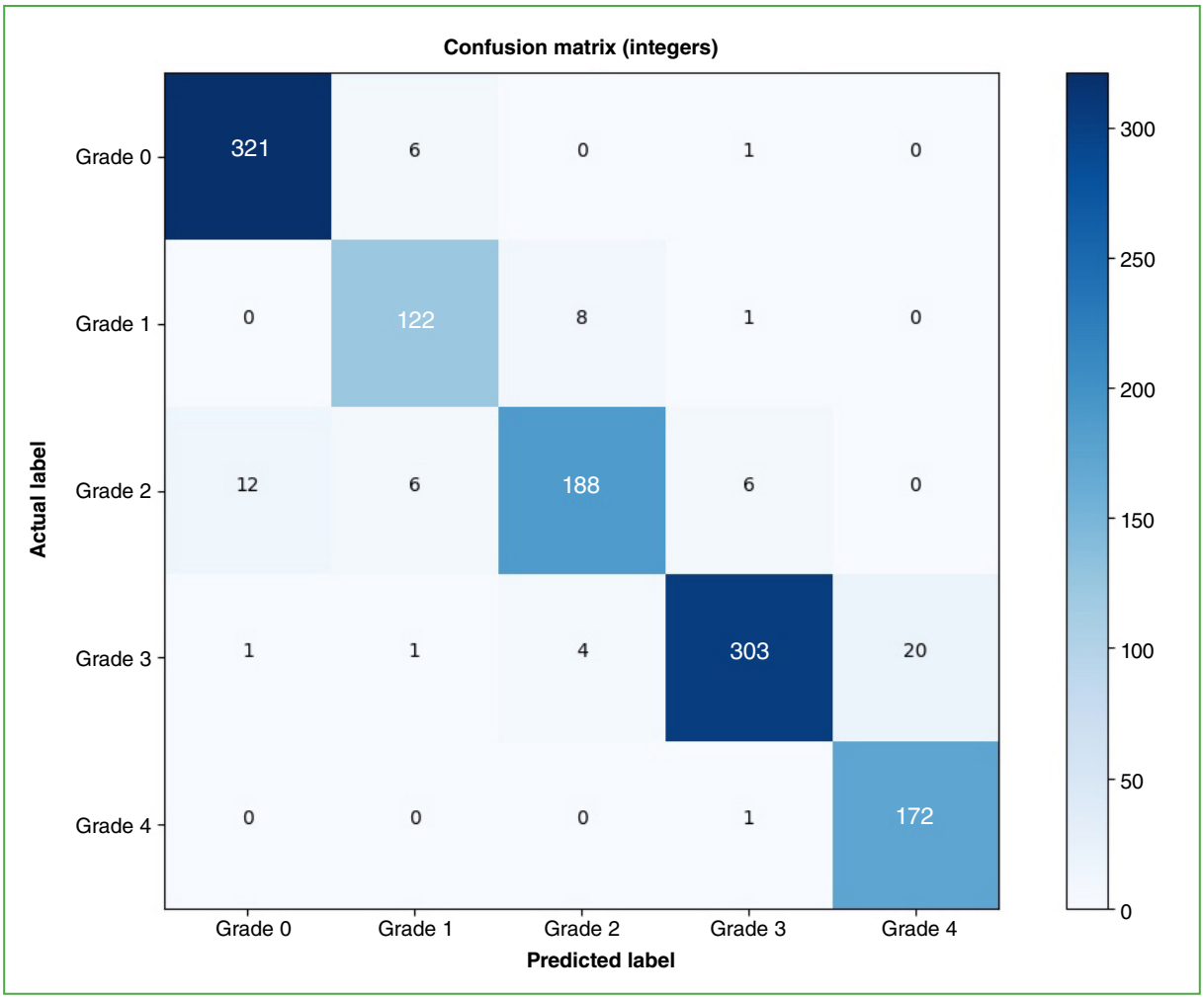

Figure 1. Confusion matrix for multi-class classification with integers. The matrix shows high classification accuracy, with 321/328, 122/153, 188/212, 303/329, and 172/173 images correctly classified for grades 0, 1, 2, 3, and 4, respectively. Misclassifications mainly occurred between adjacent classes.

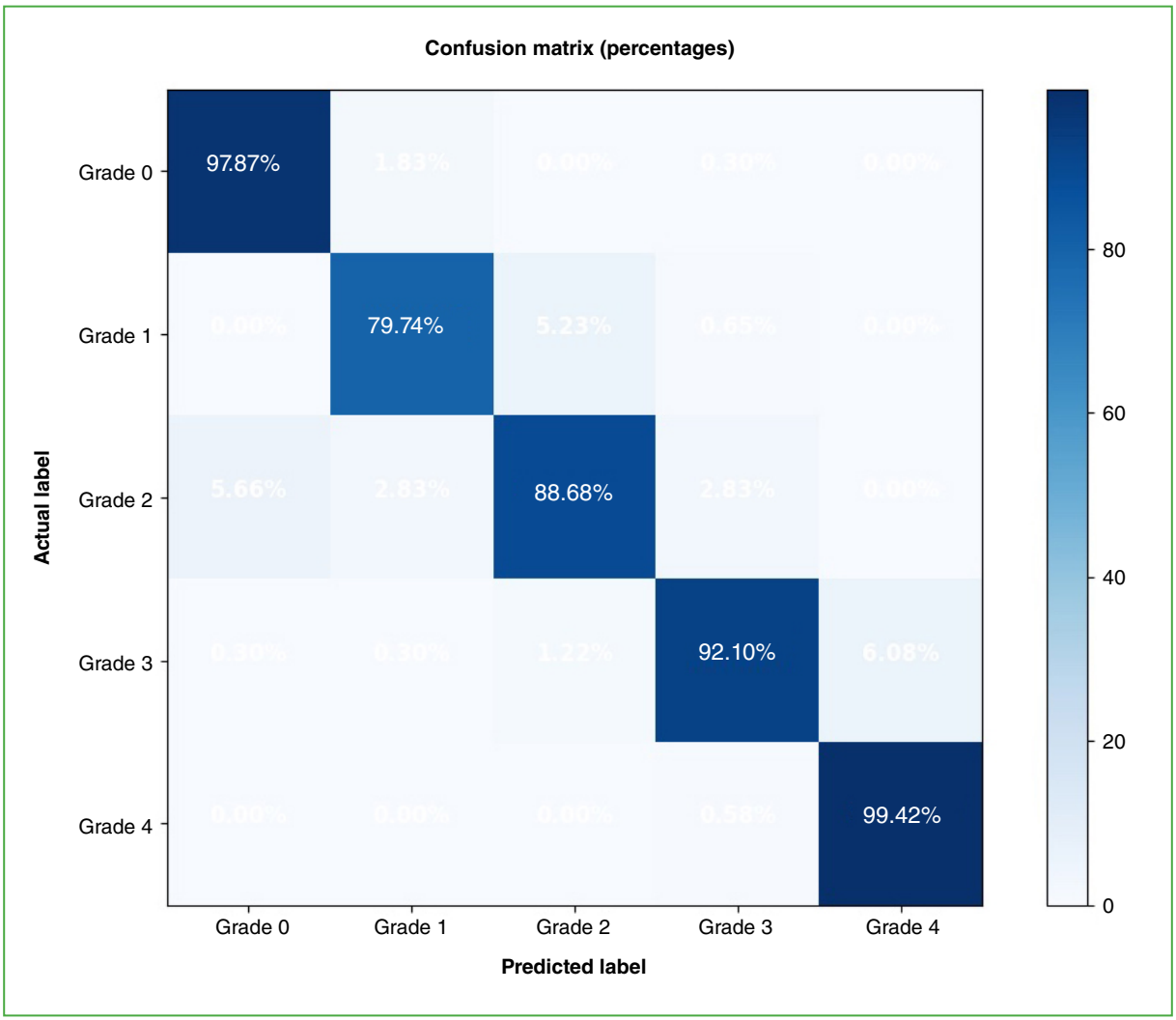

Figure 2. Confusion matrix for multi-class classification with percentage values. The percentage-based matrix indicates high classification accuracy: 97.87% for grade 0, 79.74% for grade 1, 88.68% for grade 2, 94.04% for grade 3, and 99.42% for grade 4. Misclassifications were mainly between adjacent grades.

The model's overall sensitivity was 94.23%, reflecting its capability to correctly identify most positive cases of knee osteoarthritis. Its specificity was 98.61%, indicating a strong ability to correctly identify negative cases. The F1 score, which balances accuracy and sensitivity, was 94.21%, confirming a good overall balance between the model's precision and robustness.

In Figure 3A, the model classifies all three radiographs as grade 0 with high accuracy. In Figure 3B, it can be seen how the heat map provides a useful tool for interpreting and visualizing the model's decision-making process, highlighting the areas of the image most relevant to the prediction. These heat maps are essential both for explaining the model's reasoning and for detecting potential issues in the training process or dataset. The same approach applies to other classification grades as well.

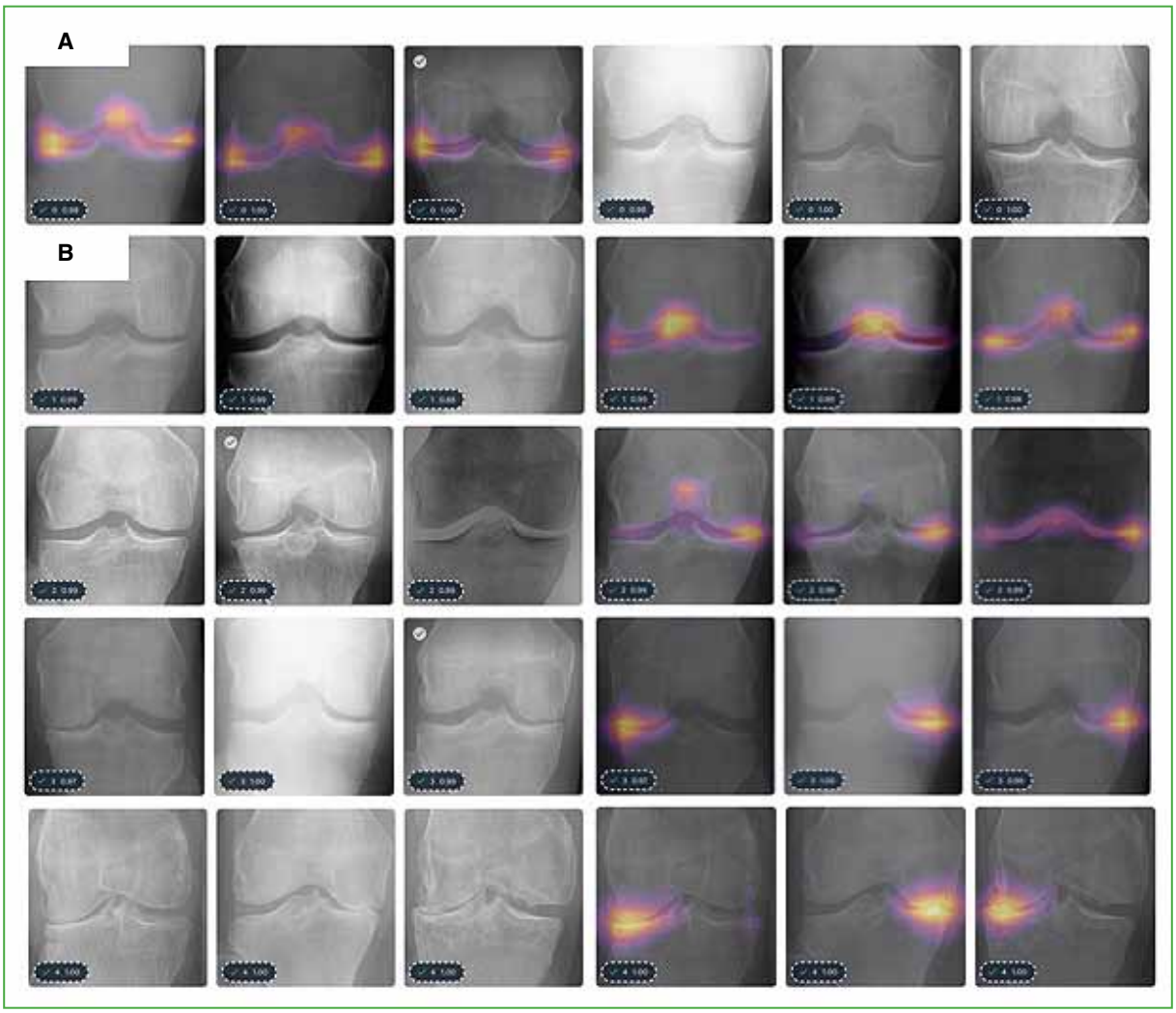

Figure 3. Heat map illustrating how the model detects areas affected by osteoarthritis and classifies the images according to the respective grades.

DISCUSSION

For many years, anteroposterior radiography has been the most effective method for classifying knee osteoarthritis for diagnostic purposes. The Kellgren-Lawrence classification system is widely used to determine disease progression and severity. However, the interpretation of these images can vary among evaluators, leading to inconsistencies in classification and, consequently, in treatment.[14]

Numerous studies have shown promising results using deep learning techniques and neural networks for the detection and classification of knee osteoarthritis. This field of AI offers an automated, objective alternative to the traditional visual interpretation of radiographic images by medical experts.

In a study by Sikkandar et al., a convolutional neural network was used for the automatic classification of knee osteoarthritis images, achieving an accuracy of 93.2% and a multiclass classification accuracy of 72.01%. This high level of accuracy suggests that convolutional neural networks can be highly effective in detecting and classifying knee osteoarthritis in radiographic images.[6]

Similarly, Deokar et al. developed an automatic knee osteoarthritis detection system based on feature extraction and neural networks, with an accuracy of 98.5% during the training stage and 92% during the testing stage. These results highlight the ability of neural networks to learn and generalize from complex features extracted from medical images.[15]

In our study, we investigated the efficacy of a computer vision-based approach for the automated detection and classification of knee osteoarthritis.

Using a dataset of 1,901 images, the model achieved remarkable accuracy and sensitivity in determining the degree of osteoarthritis. These results surpass those reported in studies by other authors using deep learning techniques and neural networks (Table 2). Without a doubt, these findings suggest that the application of computer vision techniques could offer an effective and practical alternative for evaluating knee osteoarthritis, providing accurate and rapid diagnoses that could significantly improve patient care.

Table 2. Comparison of accuracy, sensitivity and specificity results according to the number of images.

Study	Accuracy	Sensitivity	Specificity	Number of images analyzed
Brahim (2019)	82.98%	87.15%	80.65%	1024
Tiwari (2022)	93.69%	92.53%	92.87%	2068
Pongsakonpruttikul (2022)	81%	85%	85%	1650
Segura (2024)	**92.55%**	**94.23%**	**98.61%**	**1195**

The implementation of these technologies facilitates the automation of radiographic image analysis. Such programs can be trained to automatically identify and classify knee images according to osteoarthritis severity, using the Kellgren-Lawrence classification system as a standard. This not only improves diagnostic efficiency but also enhances accuracy, reducing inter-rater variability and providing clinical decision support.

CONCLUSIONS

The results of this study demonstrate the efficacy of AI and computer vision in the automated classification of knee osteoarthritis, achieving an accuracy of 92.55% and a sensitivity of 94.23%. These findings emphasize the potential of these technologies to support physicians in accurately diagnosing the disease, providing a valuable tool that can enhance both efficiency and consistency in patient evaluations.

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

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Impact of the Origin of Surgical Cement in Patients with Hip Fractures Treated with Arthroplasty. Comparative Study on 153 Patients

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ABSTRACT

Introduction: The objective of this study was to determine whether the use of national or imported cement has an impact on the clinical and radiological outcomes of a series of hip fracture patients treated with arthroplasty. **Materials and Methods:** We retrospectively analyzed 153 patients with hip fractures who were treated consecutively with arthroplasty (total or partial) between 2017 and 2019 at our center, with a minimum follow-up of 24 months. The patients were divided into two groups based on the origin of the cement, and we compared preoperative characteristics, functional outcomes (Parker index and Harris Hip Score - HHS), complications, mechanical loosening, and prosthetic survival. **Results:** In 99 cases (64.7%), national cement was used, and in 54 cases (35.3%), imported cement was used. There were 96 total hip arthroplasties (81 cemented and 15 hybrid) and 57 bipolar hemiarthroplasties. The mean follow-up was 47 ± 1.1 months. No significant differences were found between the groups in functional outcomes (Parker: 5.3 ± 0.4 vs. 5.5 ± 0.6; p = 0.88; HHS: 84.5 ± 6.6 vs. 85.9 ± 7.5; p = 0.28), complication rates (6% vs. 5.5%; p = 0.99), revisions (2.6% vs. 1.9%; p = 0.69), or prosthetic survival (96% vs. 94.5%; p = 0.69). **Conclusion:** The results of this study suggest that the origin of surgical cement does not significantly affect clinical or radiological outcomes in patients undergoing total or partial hip arthroplasty for hip fracture.

Keywords: Hip fracture; hip arthroplasty; bipolar hemiarthroplasty; surgical bone cement.
Level of Evidence: III

Impacto del origen del cemento quirúrgico en pacientes con fractura de cadera tratados con artroplastia. Estudio comparativo de 153 pacientes

RESUMEN

Objetivo: Determinar si el uso de cemento nacional o importado impacta en los resultados clínico-radiográficos de una serie de pacientes con fractura de cadera tratados con artroplastia. **Materiales y Métodos:** Se analizó, de manera retrospectiva, a 153 pacientes con fractura de cadera tratados consecutivamente con una artroplastia (total o parcial), entre 2017 y 2019, en nuestro hospital, y un seguimiento mínimo de 24 meses. Se dividió a la serie en dos grupos según el origen del cemento y se compararon las siguientes variables: características preoperatorias, resultados funcionales (índice de Parker y HHS), complicaciones, aflojamiento mecánico y supervivencia de la prótesis. **Resultados:** En 99 (64,7%) casos, se utilizó cemento de origen nacional y, en 54 (35,3%), importado. Noventa y seis eran artroplastias totales (81 cementadas y 15 hibridas) y 57, hemiartroplastias bipolares. La media de seguimiento fue de 47 ± 1.1 meses. No se hallaron diferencias significativas entre los grupos en cuanto a los resultados funcionales (Parker 5,3 ± 0,4 vs. 5,5 ± 0,6; p = 0,88; HHS 84,5 ± 6,6 vs. 85,9 ± 7,5; p = 0,28), la tasa de complicaciones (6% vs. 5,5%; p = 0,99), las revisiones (2,6% vs. 1,9%; p = 0,69), ni la supervivencia de la prótesis (96% vs. 94,5%; p = 0,69). **Conclusión:** Los resultados sugieren que el origen de fabricación del cemento no afecta significativamente los resultados clínico-radiográficos luego de una artroplastia total o parcial por fractura de cadera.

Palabras clave: Fractura de cadera; artroplastia de cadera; hemiartroplastia bipolar; cemento óseo quirúrgico.
Nivel de Evidencia: III

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INTRODUCTION

Hip fractures significantly impact patient morbidity and mortality, especially among older adults, and represent a global public health challenge.[1,2] In our country, the incidence of hip fractures is approximately 264 cases per 100.000 inhabitants, with a predominance in females (3:1).[3,4]

Arthroplasty (total or partial) is a common treatment option for hip fractures.[5-7] Surgeons can choose between three types of prosthesis fixation in arthroplasty: cemented, uncemented, or hybrid fixation (uncemented cup and cemented stem). This decision largely depends on the patient's characteristics and the surgeon's experience.[5-9] Although the use of cementless components has increased in recent decades, there is no definitive consensus on the best fixation method, as both hybrid and cemented fixation have shown excellent outcomes with 15- to 20-year follow-ups.[8-13]

In Argentina, surgical cements from both domestic and imported manufacturers are available, but to our knowledge, no studies have evaluated the outcomes of hip arthroplasty based on the origin of the cements. Therefore, the purpose of this study was to evaluate the clinical-functional and radiographic outcomes of hip fracture patients treated with arthroplasty, comparing the use of domestic and imported cements.

Our study hypothesizes that the origin of the cement does not significantly affect clinical outcomes.

MATERIALS AND METHODS

We conducted an observational, analytical cohort study. We retrospectively analyzed patients who underwent hip fracture surgery in our department between January 2017 and December 2019. The study was approved by our hospital's Institutional Review Board.

Inclusion criteria were patients with hip fractures treated with total or partial (bipolar) hip arthroplasty, where at least one component (cup or stem) was cemented, and who completed a minimum follow-up of 24 months. Patients with pathological fractures, previous hip surgeries, or those referred from another center with prior treatment were excluded.

Out of the initial 311 patients identified, 158 were excluded for having exclusively uncemented components; 25, due to pathological fractures; 20, because of previous surgeries on the affected hip; and five, for not meeting the minimum follow-up requirement. The final series included 153 patients. Table 1 provides a general description of the cohort.

For the analysis, the series was divided into two groups: one group used domestically produced cement (Subiton, Laboratorios SL, Argentina) and the other used imported cement (Cemex Genta, Tecres, Somm, Italy). Both cements are low-viscosity.

Surgical Technique

All surgeries were performed in a laminar airflow operating room under hypotensive spinal anesthesia. Antibiotic prophylaxis was administered with 1 g of intravenous cefazolin 30 minutes before the skin incision, along with a dose of tranexamic acid during anesthesia induction. All patients were placed in the supine position and operated on using an anterolateral approach (Bauer).[14] Cup cementing was performed using an ad hoc impactor to pressurize the cement and ensure regularity of the cement mantle.

For the femoral stems, either second- or third-generation cementing techniques were used, depending on availability, patient characteristics, and the surgeon's preference.

Antithrombotic prophylaxis was administered with 40 mg of subcutaneous low-molecular-weight heparin for 30 days.

Postoperative rehabilitation began with sitting on the first postoperative day, with isometric exercises. Walking with a walker was initiated on the second postoperative day. Patients were advised to use a walker or two forearm crutches for the first three weeks, followed by a single cane for the next three weeks. Postoperative follow-ups were scheduled at 3 and 6 weeks, 3, 6, and 12 months, and then annually.

Clinical Analysis

Clinical and functional assessments were performed using the Parker Mobility Score to compare pre- and postoperative function,[15] and the Harris Hip Score (HHS) at the end of the follow-up period.[16]

Table 1. Description of the patients included in the study

Variables	(n = 153)
Sex, n (%) Female Male	 120 (78.5) 33 (21.5)
Age, median (range)	82.85 (76.5-88.5)
Diagnosis, n (%) Lateral fracture Medial fracture	 72 (47.0) 81 (53.0)
CCI, n (%) ≤4 >5	 92 (60.0) 61 (40.0)
ASA, n (%) I-II III-IV	 87 (56.9) 66 (43.1)
Comorbidities, n (%) Diabetes Renal failure Obesity Rheumatoid arthritis Other	 19 (12.4) 10 (6.5) 9 (5.9) 10 (6.5) 105 (68.6)
Preoperative Parker score, median (range)	5.6 (1.0-9.0)
Total arthroplasties, n (%) Cemented Hybrid Bipolar hemiarthroplasty, n (%)	96 (62.7) 81 (52.9) 15 (9.8) 57 (37.2)

CCI = Charlson comorbidity index, ASA = *American Association of Anesthesiologists*.

Radiographic Analysis

Anteroposterior and lateral projections of both hips were used for radiographic evaluation. In the immediate postoperative images, the quality of stem cementation was assessed according to Barrack's classification. [17]

The presence of radiolucent lines around the implants and their location were classified based on the zones described by DeLee-Charnley and by Gruen.[18]

Loosening of the cemented acetabular component was evaluated using the DeLee-Charnley and Hodgkinson criteria.[18] Loosening was defined as the presence of radiolucent lines in all three zones or evidence of implant migration.[19,20] The Harris criteria were used to assess loosening of the femoral stems.[21]

At the end of the follow-up period, the rate of loosening and prosthesis survival were determined, with prosthesis revision for any cause as the cut-off point. Complication and mortality rates were also recorded at the end of the study.

Statistical Analysis

Qualitative variables are expressed as percentages and frequencies, while numerical variables are reported as means and standard deviations or medians and interquartile ranges, depending on their distribution. Continuous variables were compared using the Student's t-test, while categorical variables were analyzed using the chi-square test (or Fisher's exact test, if necessary) or ANOVA. Prosthesis survival was calculated using the Kaplan-Meier method. A p-value of <0.05 was considered statistically significant.

All data were recorded in an Excel spreadsheet (Redmond, WA, USA), and statistical calculations were performed using GraphPad Prism 9.0 (La Jolla, CA, USA).

RESULTS

Domestic cement was used in 99 patients (64.7%), while imported cement was used in 54 patients (35.3%). When comparing preoperative characteristics, a significantly higher percentage of patients in the domestic cement group had a Charlson comorbidity index >5 (p = 0.0002) (Table 2).

Table 2. Comparative analysis between groups of patients with domestic or imported cement.

Variable	Domestic cement (n = 99)	Imported cement (n = 54)	p
Sex, n (%)			
Female	76 (76.5)	44 (81.0)	0.45
Male	23 (23.5)	10 (19.0)	
Age (mean, SD)	83.7 ± 6.7	82.1 ± 5.9	0.85
Diagnosis, n (%)			
Lateral fracture	42 (42.5)	30 (55.0)	0.85
Medial fracture	57 (57.5)	24 (45.0)	
CCI, n (%)			
≤4	49 (49.5)	43 (79.0)	0.0002
>5	50 (50.5)	11 (21.0)	
ASA, n (%)			
I-II	53 (53.5)	34 (63.0)	0.26
III-IV	46 (46.5)	20 (37.0)	
Comorbidities, n (%)			
Diabetes	14 (14.5)	5 (9.0)	0.38
Renal failure	7 (7.5)	3 (5.0)	0.71
Obesity	7 (7.5)	2 (3.0)	0.39
Rheumatoid arthritis	5 (5.5)	5 (9.0)	0.31
Total arthroplasties, n (%)	60 (60.6)	36 (66.6)	
Hybrid	10 (10.1)	5 (9.2)	0.72
Total cementation	50 (50.5)	31 (57.4)	
Bipolar hemiarthroplasty, n (%)	38 (38.8)	19 (35.18)	
Follow-up, months (mean, SD)	48 ± 3.1	46 ± 2.6	0.54

SD = standard deviation; CCI = Charlson comorbidity index; ASA = *American Association of Anesthesiologists*.

Clinical-Functional Outcomes

There were no significant differences in preoperative (domestic 5.9 ± 0.7 vs. imported 5.7 ± 0.9; p = 0.78) or postoperative (domestic 5.3 ± 0.4 vs. imported 5.5 ± 0.6; p = 0.88) Parker scores between the two groups.

The mean Harris Hip Score (HHS) at the conclusion of the study was 88.9 ± 6.7, with no significant differences between the domestic (84.5 ± 6.6) and imported (85.9 ± 7.5) cement groups (p = 0.28).

Radiographic Outcomes

Thirty (37%) of the 81 cemented cups exhibited demarcation lines at the end of follow-up: 28 in zone 1 and two in zones 1-3, all of which measured less than 1 mm.

Regarding the stems, nine (5.9%) showed demarcation: six in zone 2 and three in zones 2 and 6, with no progression by the end of the study. No significant differences were found between the groups concerning the incidence of demarcation in either acetabular cups or stems (Table 3).

Table 3. Comparative radiographic outcomes.

Variable	Domestic cement (n = 99)	Imported cement (n = 54)	p
Dorr classification, n (%)			
A	4 (4.5)	3 (5.5)	
B	35 (35.5)	21 (38.0)	0.80
C	60 (60.0)	30 (55.5)	
Antibiotic-loaded cement, n (%)	95 (95.6)	50 (92.6)	0.37
Quality of cementation, n (%)			
Barrack A	59 (59.5)	31 (57.4)	0.79
Barrack B	40 (40.5)	23 (42.6)	
Demarcation, n (%)			
Cup	19 (38.0)	11 (35.5)	0.86
Stem	5 (5.0)	4 (7.4)	0.35

Complications, Revisions, and Mortality

There were nine (5.9%) complications: six (6%) in the domestic cement group and three (5.4%) in the imported cement group, with no significant difference between the two (p = 0.99) (Table 4). There were seven (4.6%) revisions: four (2.6%) in the domestic cement group and three (1.9%) in the imported cement group, with no significant difference (p = 0.69). Two (2%) patients in the domestic cement group and one (1.8%) in the imported cement group developed periprosthetic infections at 8, 11, and 16 months, respectively. All were treated with two-stage revision surgeries that successfully eradicated the infections. Three patients experienced periprosthetic fractures due to falls: two (2%) in the domestic cement group, requiring prosthesis replacement, while the remaining patient was treated with osteosynthesis.

In the imported cement group, there was one case (1.8%) of dislocation, which required revision surgery with the placement of a dual mobility cup; no recurrences were noted by the end of the study.

Table 4. Comparison of complication rates.

Complications n (%)	Domestic cement (n = 99)	Imported cement (n = 54)	p
Periprosthetic infection	2 (2.0)	1 (1.8)	0.99
Dislocation	0 (0.0)	1 (1.8)	0.12
Aseptic loosening	0 (0.0)	0 (0.0)	-
Periprosthetic fracture	2 (2.0)	1 (1.8)	0.99
Cement syndrome	0 (0.0)	0 (0.0)	-
Deep vein thrombosis	2 (2.0)	0 (0.0)	0.54

The overall mortality rate for the series was 4.6% (n = 7). Three patients (7%) in the domestic cement group and four (7.4%) in the imported cement group died (p = 0.25). The overall prosthesis survival rate was 95.4% (96% in the domestic cement group and 94.5% in the imported cement group) (p = 0.69). No significant differences in prosthesis survival were observed at 30 days (p = 0.66), at one year (p = 0.70), or at the end of the study (p = 0.69) (Figure).

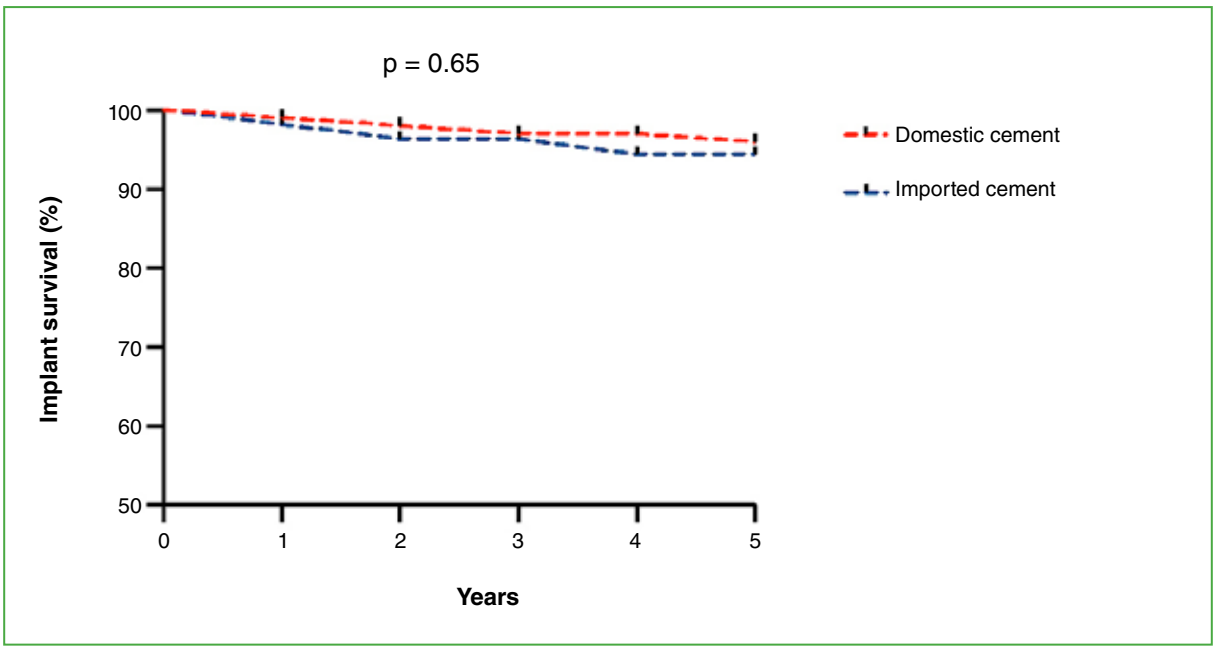

Figure. Survival analysis with the Kaplan-Meier method, without significant differences.

DISCUSSION

The most important finding of our study is that there was no significant difference in clinical-radiographic outcomes or prosthesis survival between domestic and imported cement used in hip fractures treated with arthroplasty. This supports our initial hypothesis.

Although the use of cementless components in hip arthroplasty has increased in recent decades,[22] several authors have reported excellent short-, medium-, and long-term outcomes with cemented replacements. Liu et al.[22] observed that the Harris Hip Score (HHS) was significantly higher in the cemented group compared to the cementless group (cementless 74.09 ± 6.23 vs. cemented 79.01 ± 10.21, p = 0.012) in 461 hip arthroplasties with a minimum follow-up of 5 years. Similarly, Mao et al.[23] reported on 268 patients treated with cemented vs. cementless hip arthroplasty with a minimum follow-up of 5 years, showing HHS scores of 79.39 ± 16.92 vs. 74.18 ± 17.55 (cemented vs. cementless, respectively, p = 0.011).

In our study, in line with the findings of these authors,[22,23] patients returned to their pre-fracture activity levels, one of the main goals of treatment, and achieved good functional outcomes at the end of follow-up. Furthermore, no significant differences were observed in these scores based on the origin of the cement, which we attribute primarily to proper surgical technique. At the end of the study, 37% of the acetabular cups showed signs of demarcation, but no progression was observed. Ritter et al.[24] reported that early signs of demarcation around cemented cups could increase the likelihood of early loosening by almost 28%. However, Takaoka et al.[25] conducted a radiographic analysis of 187 hip arthroplasties and found radiolucent lines around the cups in 21.2% of cases after 12 months or longer, with none progressing during an average follow-up of 13 years. These lines had no impact on functional outcomes or prosthesis survival.

One of the most common long-term complications of cemented stems is mechanical loosening.[26] Beckenbaugh et al.[27] described loosening rates of 20-24% after 5 years of follow-up, increasing to 40% after 10 years. In our study, no mechanical loosening was recorded, although the rate of demarcation around the stems was 5.9%. This may be related to the relatively short follow-up in our series. There were no significant differences in the incidence of demarcation between the acetabular components (domestic 38% vs. imported 35.5%; p = 0.86) or the femoral components (domestic 5% vs. imported 7.5%; p = 0.35).

The use of cemented components has been associated with complications such as "cement disease"[28] or "cement-bone implantation syndrome".[29] In this study, no cases of this syndrome were observed, which may be attributed to its low incidence (approximately 2-5%)[29] and the relatively small sample size. The overall complication rate in our study was 5.9% (n = 9), with no direct relationship to the origin of the cement. The domestic cement group showed a slightly higher complication rate (6% vs. 5.4%), but this difference was not statistically significant (p = 0.99). This could be related to the significantly higher percentage of patients with a Charlson comorbidity index >5 in the domestic cement group.[30,31] This contrasts with Espehaug et al.,[32] who analyzed 17,323 arthroplasties and found that the adjusted 10-year failure rate ranged from 5.9% for PALACOS®-fixed implants containing gentamicin to 17% for those fixed with CMW3®. The estimated overall prosthesis survival rate in our study was 95.4% after an average follow-up of almost 5 years, with similar rates in both the domestic cement group (96%) and the imported cement group (94.5%). These findings are consistent with Hailer et al.,[33] who analyzed 170,413 arthroplasties from the Swedish registry and found a 94% survival rate after 10 years. Likewise, Kam et al.[34] reported a survival rate of 88% in a study of 168 patients with cemented arthroplasties followed for 18 years. We believe that the high prosthesis survival rate observed in our study is related to the appropriate surgical technique, as all patients, regardless of the cement's origin, had good cementation quality (Barrack A or B).

To our knowledge, this is the first study to perform a sub analysis of the results of cemented arthroplasty according to the origin of cement manufacture.

To our knowledge, this is the first study to conduct a sub analysis of cemented arthroplasty outcomes based on the origin of cement manufacture.

Our study has some limitations, including its retrospective design and the relatively small sample size. It is important to note that these are preliminary short-term results. Additionally, the findings may be influenced by the fact that the study was conducted in a high-volume arthroplasty center with surgeons experienced in this type of procedure. However, we believe this study provides a foundation for future research that can establish more definitive conclusions with a higher level of evidence.

CONCLUSIONS

The use of cemented components remains a viable strategy for hip fracture arthroplasty, with excellent short- and medium-term outcomes and survival rates. The findings of this study suggest that the manufacturing origin of the cement (domestic or imported) does not significantly impact outcomes. We will continue to analyze this series to establish long-term results.

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

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Is The Dislocation of Hemiarthroplasty Resolved?

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ABSTRACT

Introduction: Hip hemiarthroplasty dislocation is a challenging complication due to patient frailty, associated comorbidities, and poor bone and soft tissue quality. **Materials and Methods:** We studied 28 cases of dislocation after hemiarthroplasty and compared them with 56 control patients, with a follow-up period of one year. Closed reduction under general anesthesia was performed in 26 cases. The study analyzed recurrence episodes of dislocation, considering various factors influencing instability recurrence. **Results:** Among the 28 patients who experienced dislocation after hemiarthroplasty, the overall mortality rate was 42% within the first 12 months, compared to 21% in the control group ($p < 0.001$). Recurrence following the initial reduction occurred in 12 cases (42%). Dislocations resulting from trauma had a lower recurrence risk than those occurring spontaneously or with minor trauma, with an odds ratio (OR) of 11. Similarly, dislocations in patients with moderate to severe cognitive decline had a higher recurrence risk compared to those without cognitive impairment, with an OR of 5.5. **Conclusions:** Hemiarthroplasty dislocation is associated with a significantly increased mortality rate. While closed reduction under general anesthesia is often considered the preferred management approach, it carries a high failure rate, particularly in patients with moderate to severe cognitive decline or in cases of spontaneous dislocation.

Keywords: Hemiarthroplasty; dislocation; reduction; recurrence.

Level of Evidence: III

¿Está la luxación de la hemiartroplastia resuelta?

RESUMEN

Introducción: La luxación de la hemiartroplastia tras una fractura de cadera es una complicación difícil de tratar debido la comorbilidad asociada en este tipo de pacientes, la pobre calidad del hueso y las partes blandas. **Materiales y Métodos:** Se evaluaron 28 casos de luxación tras una hemiartroplastia. Se comparó la mortalidad con la de 56 controles, en un seguimiento mínimo de un año. En todos los casos, se intentó una reducción cerrada bajo anestesia general, que fue exitosa en 26 pacientes. Se analizaron los episodios de recurrencia de la luxación, considerando los diferentes factores que pueden influir en ella. **Resultados:** La tasa de mortalidad global de los 28 pacientes con luxación fue del 42% en los primeros 12 meses frente al 21% en el grupo de control ($p <0,001$). Hubo 12 casos (42%) de recurrencia tras la reducción cerrada inicial. El riesgo de recurrencia es menor cuando las luxaciones se producen por un traumatismo que si ocurren espontáneamente o con traumatismos menores. Asimismo, el riesgo de recurrencia de las luxaciones en pacientes con deterioro cognitivo moderado o severo es más alto. **Conclusiones:** La luxación tras una hemiartroplastia se asocia con un incremento significativo de la mortalidad. Aunque la reducción cerrada bajo anestesia general se considera de elección en la mayoría de los casos, la tasa de fracaso es alta, sobre todo en pacientes con deterioro cognitivo moderado severo o tras luxaciones atraumáticas.

Palabras clave: Hemiartroplastia; luxación; reducción; recurrencia.

Nivel de Evidencia: III

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INTRODUCTION

Partial hip replacement or hemiarthroplasty is the most common treatment for subcapital femur fractures in elderly patients in our setting,[1] primarily because it is less invasive, less demanding surgically, and has a lower complication rate compared to total hip replacement.[2]

Dislocation of hemiarthroplasty is a complication with an incidence ranging from 1% to 14%,[3] but it can have devastating consequences for this type of patient. Studies have shown an annual decline in function,[4] and this complication has been associated with an increase in mortality of up to 65% within the first year, rising to 75% if the dislocation recurs.[5]

Several risk factors have been associated with dislocation, such as cognitive impairment, delayed surgery, surgical approach, and specific anatomical characteristics of the patient, including reduced acetabular depth and a decreased center-edge angle.[6]

The definitive treatment for prosthetic dislocation is often influenced by the high comorbidity rates in these older patients. Treatment options include:

1. Revision surgery of the femoral component (when malpositioning is identified).[7]

2. Conversion to total hip arthroplasty (when stability defects are assumed and implants with greater stability are required). These two procedures are more complex, carry higher postoperative risks, and are not free from the possibility of further dislocation episodes.

3. Girdlestone resection arthroplasty is another, albeit more aggressive, option. It results in a significant loss of function and persistent pain compared to other treatments. .[8] Despite the various treatment options, there is no strong scientific evidence to guide the management of this complication.

The aim of this study was to describe mortality and associated factors, particularly in cases of prosthesis dislocation. We also analyzed the outcomes of the treatments applied in each case to provide new insights into the individualized management of these patients.

MATERIALS AND METHODS

A retrospective case-control study was conducted involving 84 patients, including 28 cases of patients who underwent surgery in our center for dislocation after receiving a cemented hip prosthesis with a bipolar dome. The data were extracted from our center's digital database, and the study was approved by the hospital's Ethics Committee.

Cases

Patients included were those who had sustained an acute subcapital hip fracture and had undergone prosthetic surgery following the fracture. Patients who had undergone arthroplasty following failed osteosynthesis were excluded. All patients received a cemented hip prosthesis with a single 132° cervico-diaphyseal angle implant of the Coron type (Exactech®), with a bipolar dome. The surgeries were performed by various surgeons, including specialty residents. The surgical approach was posterior (Moore type in 26 cases) or anterolateral (modified Hardinge type in 2 cases).

Controls

A cohort of 56 consecutive patients who did not experience dislocations was selected from 2019 to 2021. These patients underwent surgery with the same implant and surgical approach (posterior or Hardinge) during the same period.

Clinical features

Data collected from our center's electronic clinical database included: age, cognitive impairment, sex, side of the fracture, comorbidities, time to surgery after hip fracture, time to dislocation, morbidity, *American Society of Anesthesiologists* (ASA) score, mortality, and affected side.

Physicians from the Orthogeriatrics Service assessed neuromuscular impairment, classifying patients with a score of ≥3 on the FRAIL scale (Fatigue, Resistance, Ambulation, Illnesses, Loss of Weight) as having neuromuscular impairment.

All patients were assessed during hospital admission and postoperatively by the Orthogeriatrics Service using a modified version of the Global Deterioration Scale (GDS). Patients were classified into four groups: 1) no cognitive

impairment; 2) mild cognitive impairment: evident memory decline and difficulties in daily activities, orientation, information retention, and maintaining attention; 3) moderate cognitive impairment:severe memory and functional issues, requiring assistance with instrumental daily activities; 4) severe cognitive impairment: constant dependence for basic activities, cognitive and functional decline, behavioral issues, ambulation disturbances, and delirium.

Indicated treatment

The time (in days) until dislocation and the number of dislocations were recorded. The different therapeutic strategies included: non-surgical management (leaving the dislocation untreated), closed reduction under general anesthesia, revision of the partial replacement, and conversion to a total hip replacement.

Cause of Dislocation

We analyzed the circumstances of the dislocations and classified them as either: *traumatic*, occurred due to a fall, sudden movement, or any incident involving abrupt adduction and rotation of the hip; and *atraumatic* or *spontaneous*, when the dislocation occurred without any significant trauma, such as during a transfer, changing beds, standing up from a chair, or when the dislocation went unnoticed, with no adduction or rotation involved.

Statistical Analysis

The statistical analysis was performed using SPSS version 26. Based on the hypothesis and the primary objective, the sample size was calculated using the GRANMO calculator for the estimation of two independent proportions. Equal numbers of patients were considered for each group, assuming a mortality rate of 29% in patients operated on for hip fractures without dislocation, and 44% in those who experienced dislocation.[9] A bilateral contrast was used, with an alpha risk of 0.05, a beta risk of 0.20, and a loss rate of 0.10. With this data, it was estimated that 21 patients would be required in each group to detect a statistically significant difference between the two proportions.

Descriptive Analysis. Qualitative variables are presented as absolute and relative frequencies. Quantitative variables are described as mean (± standard deviation) if they follow a normal distribution, or as median and interquartile range if they do not. For all variables, 95% confidence intervals (95% CI) are provided.

Bivariate Analysis. The SPSS program was used for bivariate analysis. Qualitative variables are described as percentages and analyzed using contingency tables. Statistical significance was calculated using the chi-square test (χ^2) and Fisher's exact test, with a p-value <0.05 considered significant. Quantitative variables are expressed as means and standard deviations, and comparisons were made using Student's t-test. Kaplan-Meier survival curves were also constructed.

RESULTS

A total of 84 patients were included in the study: 28 with dislocated hemiarthroplasties and 56 with non-dislocated hemiarthroplasties.

The 28 cases of hemiarthroplasty dislocation were treated as follows (Figure 1):

- 26 underwent closed reduction:
  - 14 reductions were successful.
  - 12 dislocated again, leading to the following definitive treatments:
    - One remained palliatively dislocated due to comorbidities precluding further anesthesia.
    - Five experienced another dislocation and underwent closed reduction again.
    - One underwent dome and stem replacement due to a technical defect.
    - Two underwent conversion to a total hip arthroplasty.
    - Three underwent Girdlestone resection arthroplasties.
- Two were not treated with closed reduction:
  - One patient with dislocation was treated with open reduction followed by revision surgery to a total hip arthroplasty.
  - One patient with dislocation died

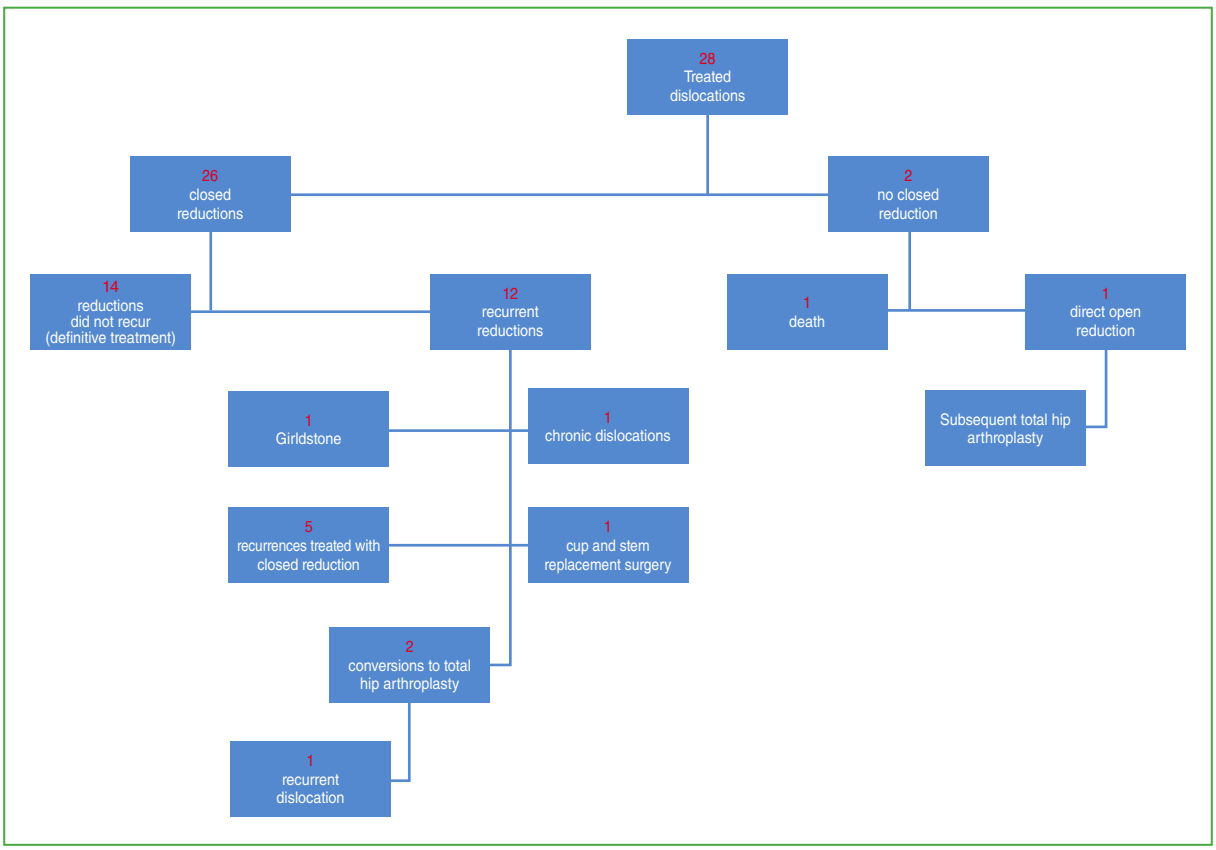

Figure 1. Acute and definitive treatment of hip hemiarthroplasty dislocations.

In the non-dislocated hemiarthroplasty group, 70% (n = 39) were women, compared to 68% (n = 19) in the dislocated group, with no statistically significant difference between the groups (p = 0.87). The mean age of patients with dislocations was 86.5 years (± 1.4), and 85 years (± 1.1) for those without dislocations, with no significant difference (p = 0.201). The operated side did not influence the occurrence of dislocation, with 50% (n = 28) of the non-dislocated group having right-sided hemiarthroplasties and 50% left-sided. In the dislocated group, 57% (n = 16) were right-sided and 43% (n = 12) left-sided, with no statistical significance. Seventy percent (n = 39) of patients without dislocation had no neuromuscular impairment, compared to 71% (n = 20) in the dislocated group, again with no statistical significance (p = 0.918). The percentage of prostheses operated on using the anterior (Hardinge) approach was 11% in both groups, with no significant difference between dislocated (n = 3) and non-dislocated cases (n = 6) (p = 1).

No differences (p = 0.112) were found in the mean weight of patients with non-dislocated hemiarthroplasties (64 ± 9 kg) and those with dislocated hemiarthroplasties (78 ± 85 kg). The mean height of patients with non-dislocated hemiarthroplasties was 156 cm (± 9), compared to 158.5 cm (± 12) in patients with dislocated hemiarthroplasties, with no statistically significant differences (p = 0.184).

The mean number of days from hip fracture to surgery was 3.18 in the non-dislocated group and 3.23 in the dislocated group, with no statistical significance (p > 0.05).

Sixty-nine percent (n = 20) of patients with dislocation experienced it within the first month after surgery, and all dislocations occurred within 90 days postoperatively.

The percentage of patients with mild, moderate, and severe cognitive impairment was higher in the dislocated group (Table 2). Twenty-nine percent (n = 16) of patients with non-dislocated arthroplasties had cognitive impairment versus 65% (n = 18) of those with dislocation, a statistically significant difference (p = 0.017) (Table 2). Additionally, 20% (n = 11) of patients without dislocation had moderate or severe impairment, versus 46% (n = 13) of those with dislocation, also a statistically significant difference (p = 0.01).

Table 1. Qualitative variables

Variables		Non-dislocated hemiarthroplasty		Dislocated hemiarthroplasty		p
Side	Right	28	50%	16	57%	0.537
	Left	28	50%	12	43%	
Sex	Male	17	30%	9	32%	0.87
	Female	39	70%	19	68%	
Approach	Posterior	50	89%	25	89%	1
	Lateral	6	11%	3	11%	
Neuromuscular impairment	Yes	17	30%	8	29%	0.918
	No	39	70%	20	71%	
Average age (years)		85		86.5		0.763
Total patients		56	100%	28	100%	

Table 2. Cognitive impairment.

Patients		Cognitive impairment			
		No	Mild	Moderate	Severe
No dislocation	Number	40	5	4	7
	%	71	9	7	13
Dislocation	Number	10	5	6	7
	%	36	18	21	25

Moreover, 67% (n = 8) of patients with recurrent dislocations and 19% (n = 3) of those without recurrence had moderate or severe cognitive impairment (odds ratio [OR] 5.5; 95%CI 1.047-28.9) (p = 0.027).

In terms of the cause of dislocation, spontaneous dislocations (due to minor trauma or postural changes) recurred in 55% of cases, while dislocations following trauma recurred in only one patient (14%). This difference was statistically significant (p = 0.04) (OR 1.9; 95%CI 1.1-3.4) (Table 3).

Table 3. Number and percentage of patients who suffered a single or recurrent dislocation, either traumatic or spontaneous.

Cause of dislocation		Recurrence		Total (100%)	
		No recurrence	Recurrence		
Traumatic	Number of patients	7	1	8	OR 1.9 (95%CI 1.1-3.4)
	Percentage	86%	14%	100%	
Spontaneous	Number of patients	9	11	20	
	% within recurrence	45%	55%	100%	
Total	Percentage	16	12	28	p = 0.04

OR = *odds ratio*; 95%CI = 95 % confidence interval.

Table 4 shows the mortality rate following hip hemiarthroplasty as a function of dislocation incidence. The 1-year mortality rate was higher in patients with dislocated prostheses (61%) compared to non-dislocated prostheses (23%) ($p < 0.001$) (OR 5; 95%CI 2-13.6). The 3-month mortality rate was also higher in patients with dislocation (36%) than in those without dislocation (21%) ($p = 0.04$) (OR 3.4; 95%CI 1.25-9.5). However, no difference was observed in the 1-month mortality rate, with 11% of dislocated patients and 7% of non-dislocated patients dying, which was not statistically significant.

By the end of the follow-up, 28.6% (n = 16) of patients with non-dislocated hemiarthroplasties and 68% (n = 19) of patients with dislocated prostheses had died ($p < 0.001$).

Table 4. Mortality 365 days, 90 days, and 30 days after dislocation of hip hemiarthroplasty.

	Final mortality		Mortality after 365 days		Mortality after 90 days		Mortality after 30 days		Total patients
	n	%	n	%	n	%	n	%	
Dislocated prostheses	19	68	17	61	10	36	3	1%	28 (100%)
Non-dislocated prostheses	16	29	13	23	12	21	4	7	56 (100%)
p	<0.001		<0.001		0.014		0.577		84

The cumulative 1-year survival of both groups was analyzed (Figure 2), showing a statistically significant reduction in survival function for patients with dislocated prostheses. Survival was significantly lower in patients with dislocation than in those without (log-rank < 0.001).

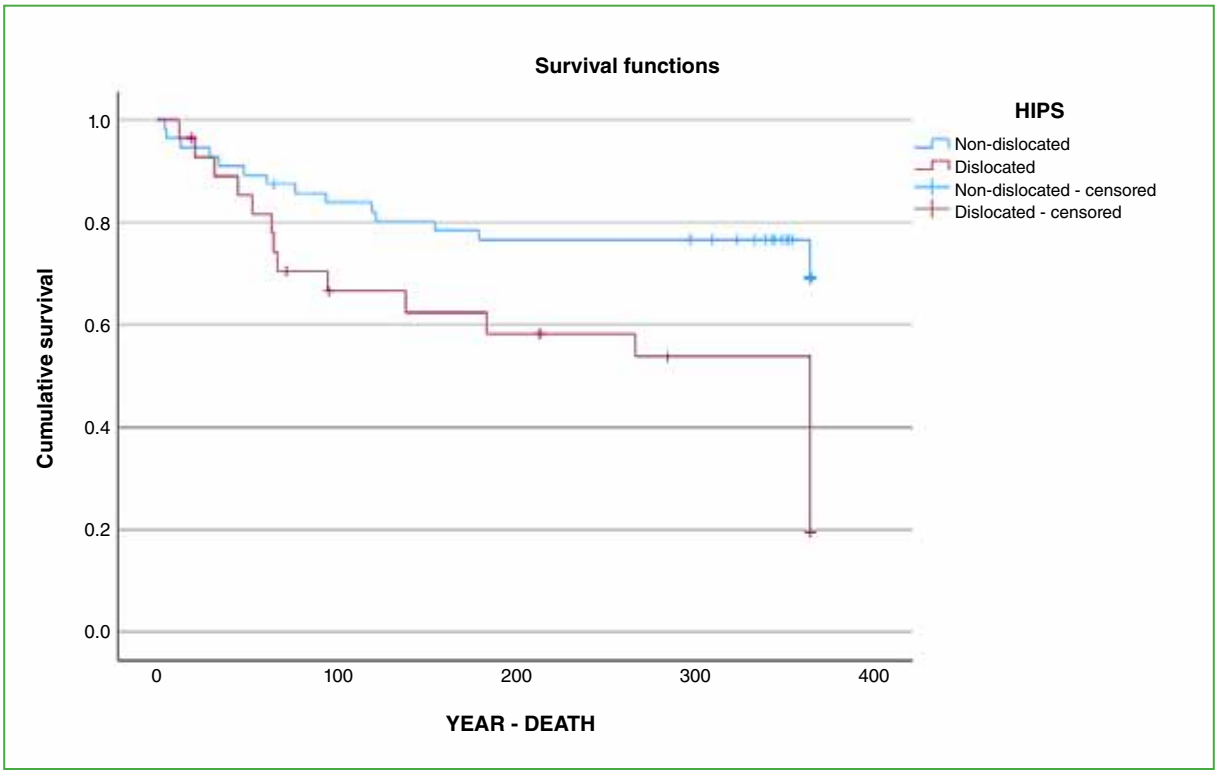

Figure 2. Kaplan-Meier curve comparing the survival of patients who suffered one or more episodes of dislocation and those without dislocation.

DISCUSSION

Dislocation of a partial hip replacement is an occasional complication, with a prevalence ranging from 1% to 14%, depending on the series.[2-5] Limited data on risk factors have been published, and factors such as the surgical approach[3,5,10] and the experience of the primary surgeon have been mentioned. Unwin and Thomas[11] even advised against the routine use of the posterior approach for this procedure, citing dislocation rates as high as 14.2% in the hands of inexperienced surgeons compared to 3.6% with the anterolateral approach. Several studies attribute this difference to the failure to repair the joint capsule and external rotators. In any case, no study has demonstrated that the posterior approach results in a lower dislocation rate than the anterolateral or anterior approaches. Furthermore, the use of total hip replacements appears to be associated with higher dislocation rates than hemiarthroplasty.[12] In a recent meta-analysis, none of the 12 randomized studies showed a dislocation rate favoring total hip replacements.

Delayed surgery has also been identified as a factor contributing to the increased risk of dislocation. Salem et al. reported that the risk of dislocation quadrupled when surgery was delayed for more than 24 hours.[9] However, in our series, a delay before primary surgery was not associated with an increased risk of dislocation.

It has been reported that patients with cognitive disease have a higher rate of postoperative dislocation. Ninh et al.[13] found a strong association between cognitive impairment and dislocation, with 54% of patients with dislocation having cognitive impairment, compared to 18.8% of those without dislocation. Our findings support this: 64% of patients with cognitive impairment experienced dislocation, compared to 29% of those without. Additionally, there was a significant association between moderate to severe dementia and the likelihood of recurrent dislocation (OR 5.5; 95%CI 1.04–28.9) after closed reduction.

Mortality associated with hip fractures has been linked to age, surgical delay, and comorbidities in these patients. Recent studies have found that hemiarthroplasty dislocation and residual instability increase mortality,[14] prolong hospitalization, and often require revision surgeries. Our results support these findings, with the mortality rate significantly higher at 3, 12, and 18 months in the dislocated group, especially at 3 months postoperatively.

Some studies attribute this to persistent dislocation and the use of procedures like resection arthroplasty, which result in significant loss of mobility and more intense pain. In our series, differences in mortality were observed between patients who experienced a single episode of dislocation and those who had multiple episodes, though the underlying reasons remain unclear. It is possible that the heterogeneity of treatments across different studies contributes to these differences.[7] There is limited data on how best to manage this complication, possibly due to the significant comorbidities associated with these patients, which restrict treatment options. Some series report dislocation recurrence rates exceeding 70% following closed reduction, even with post-reduction care.[2,10] Additionally, many patients are not candidates for reduction under general anesthesia. However, we believe these data should be interpreted cautiously, as reduction was successful in 26 out of 28 attempts (92%) in our series, though revision surgery was not free from further episodes of dislocation. Furthermore, it is important to note that 12 (42%) of the 26 patients who experienced multiple dislocations had greater comorbidities, including moderate or severe cognitive impairment (OR 4.4).

Resection arthroplasty was only performed in cases where both dislocation and infection were present, not as a treatment for isolated recurrent dislocation. This procedure has not been effective in relieving postoperative pain or improving function. In fact, it is associated with high mortality rates, persistent postoperative pain, and limited functional improvement compared to patients with chronic dislocation.

In our series, the traumatic context of dislocation emerged as a key factor in predicting recurrence. The risk of recurrence was significantly higher in patients who experienced spontaneous or unnoticed dislocations (OR 6.6). We believe that the occurrence of dislocation without trauma, or after minor trauma, may be due to malpositioning of components and substantial soft tissue defects. When cognitive impairment is factored in, as many as 63.9% of patients relapse after closed reduction.

Thus, we believe that efforts should focus on minimizing the risk of dislocation to improve patient outcomes. This requires selecting an appropriate surgical technique, avoiding the posterior approach, and favoring approaches that provide greater stability, such as the anterior and anterolateral approaches. Although the literature does not fully support the use of total hip replacements, we believe that acetabular implants, particularly dual-mobility implants, may be indicated, especially in patients with intraoperative instability. Additionally, we consider closed reduction under general anesthesia to be the initial treatment of choice in all patients, as it presents the lowest risk given the comorbidities common in this patient population.

One limitation of our study is that we could not determine the overall incidence of this complication. The routine use of the posterior approach at our center also prevented us from making comparisons in this regard. We were also unable to assess whether there was deterioration in functional status, as many of the patients who experienced dislocation had died. Another limitation is that it was not always possible to gather reliable data on the circumstances of the dislocation, as many patients were cognitively impaired and institutionalized, making their accounts less reliable.

CONCLUSIONS

We found a high risk of mortality associated with hemiarthroplasty dislocation, independent of patient comorbidities. Therefore, it is essential to employ a technique that ensures implant stability. Closed reduction under general anesthesia is successful in most cases and should be the first treatment option, particularly for frail patients. Patients with severe cognitive impairment who experience dislocation due to minor trauma, or no trauma at all, may benefit from revision surgery.

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

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Outcomes of Open Wedge High Tibial Osteotomy with Puddu Plate, with a Minimum Follow-up of 5 Years

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ABSTRACT

Objectives: To determine the survival rate of high tibial osteotomy for medial knee osteoarthritis and describe functional outcomes and the satisfaction rate. **Materials and Methods:** Observational, analytical study with retrospective data collection. A total of 51 patients were operated on between 2011 and 2017. Variables studied included age, sex, preoperative BMI, VAS for pre- and postoperative pain, WOMAC and Lysholm functional scores, SF-12 quality of life scores, satisfaction with the procedure, and conversion to arthroplasty. **Results:** The average age at the time of surgery was 55.7 years, with an average BMI of 29.7. Follow-up ranged from 5 to 11 years. We observed a statistically significant decrease in VAS scores from 7.96 ± 2.27 to 3.04 ± 2.73. The average survival time of the osteotomy was 10.53 years (95% CI, 9.6–11.4). Patient satisfaction was positive in 76.5% of cases, showing a statistically significant difference and better outcomes in the evaluated scores. The conversion rate to total knee arthroplasty (TKA) was 19.6%. There was no statistically significant relationship between conversion to TKA and the initial age, BMI, or VAS score. **Conclusions:** Open wedge high tibial osteotomy showed excellent outcomes with a minimum follow-up of 5 years, with a survival rate and conversion to arthroplasty comparable to international literature. There was a statistically significant reduction in pain according to VAS scores, and younger patients reported higher satisfaction with the procedure.

Keywords: Tibial valgus osteotomy; tibial opening wedge osteotomy; Puddu plate; genu varum; medial compartment osteoarthritis.
Level of Evidence: IV

Resultados de la osteotomía valguizante de apertura tibial con placa Puddu. Seguimiento mínimo de 5 años

RESUMEN

Objetivos: Determinar la supervivencia de la osteotomía valguizante tibial, en genu varo artrósico, y valorar los resultados funcionales y el grado de satisfacción. **Materiales y Métodos:** Estudio observacional, analítico con recolección retrospectiva de datos en 51 pacientes operados entre 2011 y 2017. Las variables estudiadas fueron: edad, sexo, índice de masa corporal preoperatorio, escala analógica visual para dolor pre y posoperatorio, puntajes funcionales WOMAC y Lysholm, SF-12, grado de satisfacción con el procedimiento y conversión a artroplastia. **Resultados:** El promedio de edad al operarse fue de 55.7 años, el índice de masa corporal, de 29,7. El seguimiento fue de 5 a 11 años. El puntaje de la escala analógica visual disminuyó de 7,96 ± 2,27 a 3,04 ± 2,73. El tiempo promedio de supervivencia de la osteotomía fue de 10.53 años (IC95% 9,6-11,4). El 76,5% estaba satisfecho con el procedimiento, se observaron una diferencia estadísticamente significativa y mejores resultados en los puntajes calculados. La tasa de conversión a artroplastia total de rodilla fue del 19,6%. No hubo una relación estadísticamente significativa entre la tasa de conversión a artroplastia total de rodilla y la edad, el índice de masa corporal o la escala analógica visual inicial. **Conclusiones:** Los resultados de la osteotomía fueron muy buenos a los 5 años de seguimiento mínimo y las tasas de supervivencia y conversión a artroplastia fueron comparable con las de la bibliografía internacional. Se destaca la disminución estadísticamente significativa del dolor y que los pacientes más jóvenes estaban más satisfechos con el procedimiento.

Palabras clave: Osteotomía valguizante de tibia; osteotomía tibial de apertura; placa Puddu; genu varo; artrosis de compartimento interno.
Nivel de Evidencia: IV

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INTRODUCTION

Tibial valgus osteotomy is an established procedure for the non-prosthetic treatment of arthritic genu varum in young, active patients and for medial osteochondral lesions.[1]

Over time, the treatment of this condition has evolved, and arthroplasties have been replaced by osteotomies. Over the past 20 years, osteotomies have been extensively studied and refined, with the best results seen in patients under 60 years of age, who have medial unicompartmental osteoarthritis and remain active at work.[2]

This procedure aims to decompress the medial compartment in the early stages and improve knee function by shifting the mechanical axis toward the Fujisawa point, located on the lateral tibial plateau, which should remain relatively intact.[3] This is achieved by overcorrecting the varus deviation to 2-6° of valgus. Two main approaches have been described: lateral closing wedge tibial osteotomies and medial opening wedge tibial osteotomies. Although successful, lateral closing wedge osteotomies are technically more demanding, carry a higher risk of serious complications, and can compromise the tibial bone stock for future prosthesis use. These factors have led to the growing popularity of medial opening wedge osteotomies between 1990 and 2000.[1,4,5]

Medial opening wedge tibial osteotomies are a safe procedure that provide good functional outcomes in the medium to long term, especially with the advent of new implants.[5] Among the fixation methods designed, the two most commonly used in our setting are the Puddu plate (Tibial Opening Wedge Osteotomy Plate, Arthrex Inc., Naples, Florida, USA) and the TomoFix system (TomoFix Plate, DePuy Synthes, West Chester, PA, USA) (Figure 1).

The Puddu plate uses the principle of dynamic compression and has two generations: the first with four conventional screws, and the second with two locking and two conventional screws. On the other hand, the TomoFix system consists of an anatomically designed implant that follows the principle of locking osteosynthesis. This system has been shown to provide greater resistance to compressive and rotational forces, allow biological consolidation without the need for bone grafting, and enable early rehabilitation with very good functional outcomes (Figure 1).[5-8]

Figure 1. Puddu and TomoFix plates (Images extracted from the implant suppliers' web catalogs).

Somewhat unfavorable outcomes have been reported for total knee arthroplasty (TKA) in younger patients, with revision rates of 35% in men aged 50-54 years and a median survival rate of 4.4 years in patients under 60. These outcomes are thought to be associated with work, leisure, and lifestyle activities.[9] Currently, the published survival rate for medial opening wedge tibial osteotomy is 94% at 5 years and 85% at 10 years.[10]

The primary objective of this study was to determine the survival time of tibial valgus osteotomy using the Puddu plate in a population of patients with arthritic genu varum, classified as Ahlbäck type 2. The endpoint for this study was defined as the time when patients required conversion to TKA. Secondary objectives were to evaluate postoperative functional outcomes and assess patient satisfaction with the procedure.

MATERIALS AND METHODS

This was an observational, analytical study with retrospective data collection. The population consisted of all patients with symptomatic Ahlbäck type 2 genu varum, treated with tibial valgus osteotomy using the Puddu plate by the same surgical team at a single center between January 2011 and December 2017, with a minimum follow-up of 5 years.

Data were collected through a review of medical records and telephone interviews. The interviews were conducted between August 2022 and March 2023, ensuring a minimum of 5 years after osteotomy. The following instruments were used: the SF12 (*Short Form 12 Health Survey*) questionnaire (for quality of life), the Lysholm scale (for function), the WOMAC (*Western Ontario and McMaster Universities Osteoarthritis Index*) questionnaire (for function), the visual analog scale (VAS) for pain, and a satisfaction survey regarding the procedure.

Variables were analyzed by two investigators who reviewed surgical descriptions, available preoperative and postoperative images (Figure 2), and assessed qualitative variables.

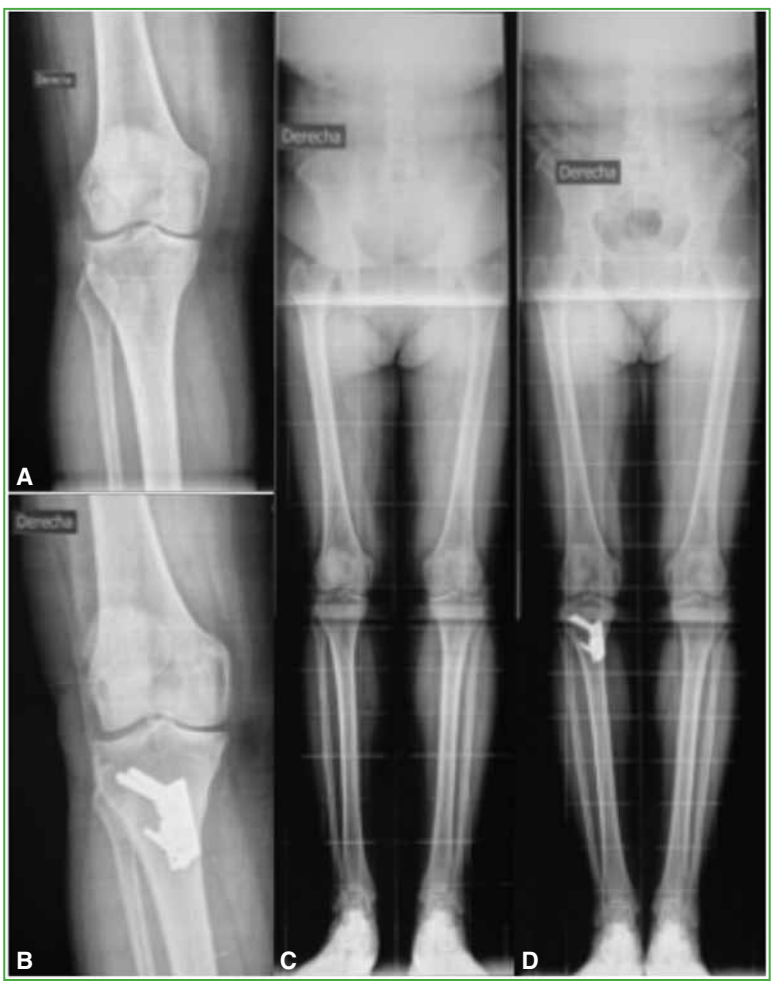

Figure 2. Female patient operated at 64 years of age. Anteroposterior weight-bearing radiograph of the knee before surgery (**A**) and at 8 years of follow-up (**B**). Goniometry before surgery (**C**) and at 8 years of follow-up (**D**).

Patient characteristics such as sex, age at surgery, height, and weight were recorded. During the telephone interview, patients were asked about their satisfaction with the procedure, their SF12 scores, Lysholm scale scores, and WOMAC scores.

Pain before and after the procedure was assessed using the VAS. For the preoperative VAS score, patients were asked to recall the pain they experienced prior to the osteotomy. For the postoperative VAS score, the pain at the time of the interview was considered for patients who still had the osteotomy, and the pain prior to TKA was considered for those who underwent the conversion. For other variables (Lysholm, SF12, and WOMAC), data were recorded at the time of the interview for those who still had the osteotomy, while retrospective data were used for patients who underwent TKA.

Radiographic analysis could not be performed on all patients, as radiographic digitization was not available during the early years of the study.

Possible complications, such as infections, thrombosis, nonunion, implant breakage, tibial plateau fracture, and implant intolerance, were recorded through the telephone interview, medical records, and radiographic analysis when applicable.

This study received institutional approval and was endorsed by the Ethics Committee. All patients provided informed consent.

Statistical Analysis

Data were entered into Microsoft Office Excel®. Qualitative variables are expressed as absolute and relative frequencies; associations between these variables were analyzed using the Chi-squared test or Fisher's exact test, as appropriate.

Quantitative variables are expressed as means with corresponding standard deviations. Non-parametric tests were used to compare means: the Wilcoxon rank-sum test or Mann-Whitney U test for two-group comparisons, depending on whether the data were paired, and the Kruskal-Wallis test for comparisons of more than two groups.

Data processing was carried out in the IBM SPSS Statistics V23.0 program. A significance level of 0.05 was considered for all inferential analyses.

RESULTS

Demographic data

The study population consisted of 51 patients: 31 women (61%) and 20 men (39%). A total of 51 procedures were performed: 25 on right knees (49%) and 26 on left knees (51%). The characteristics of the patients are detailed in Table 1. The reason for the intervention in all cases was to treat symptomatic degenerative genu varum, classified as Ahlbäck type 2. The mean age at the time of surgery was 55.7 ± 7.6 years.

The distribution according to body mass index (BMI) at the time of surgery was as follows: normal weight (6 patients, 11.8%), overweight (17 patients, 33.3%), and obese (28 patients, 54.9%).

Table 1. Characteristics of the patients in the sample.

Age (years)	55.7 ± 7.6
Initial weight (kg)	81.7 ± 13.8
Size (m)	1.66 ± 0.10
Initial body mass index	29.7 ± 4.7

Complications

Ten patients (19.6%) experienced one or more complications (Table 2). Five patients suffered a fracture of the lateral cortical hinge: in one case, the implant broke before consolidation, necessitating a second operation with a Puddu plate; one did not consolidate, requiring the placement of a TomoFix plate; and three achieved consolidation without problems. Four patients experienced intolerance to the implant, which was subsequently removed. Two patients developed deep vein thrombosis, which was successfully treated with medical management. One patient's osteotomy did not consolidate (as previously mentioned with the lateral cortical fracture), and another patient suffered a fracture of the external tibial plateau, which was treated with the same implant, deferring weight-bearing for a longer period. The overall evolution in these cases was excellent.

Table 2. Complications.

Complication	n	%
Lateral cortical hinge fracture	5	14.3
Intolerance after consolidation	4	11.6
Deep vein thrombosis	2	5.7
Implant breakage before consolidation	1	2.9
Lateral tibial plateau fracture	1	2.9
Nonunion	1	2.9

Clinical Scores Analyzed

The mean preoperative VAS score was 7.96 ± 2.27, which decreased to 3.04 ± 2.73 after surgery. This difference was significant ($p < 0.001$), indicating a clear reduction in pain scores following the procedure (Table 3, Figure 3).

Table 3. Pre- and postoperative variables analyzed, expressed as mean and confidence interval.

Variable		Mean (SD) or frequencies		p
Survival time (years)		10.53 (95% CI 9.6-11.4)		-
Would you undergo surgery again? (Yes)		39	76.5%	-
VAS score	Pre-op	7.96 ± 2.27		<0.001*
	Post-op	3.04 ± 2.73		
Lysholm Scale		72.9 ± 26.1		-
SF-12 Questionnaire (Physical)		44.3 ± 11.7		-
SF-12 Questionnaire (Mental)		59.4 ± 8.9		-
WOMAC Pain		4.22 ± 4.66		-
WOMAC Stiffness		1.29 ± 1.63		-
WOMAC Function		13.06 ± 15.95		-
WOMAC Total		18.06 ± 21.61		-

(*) Statistically significant value. (-) does not apply to p-value calculation since it cannot be compared. SD = standard deviation. VAS = visual analog scale. WOMAC = *Western Ontario and McMaster Universities Osteoarthritis Index.*

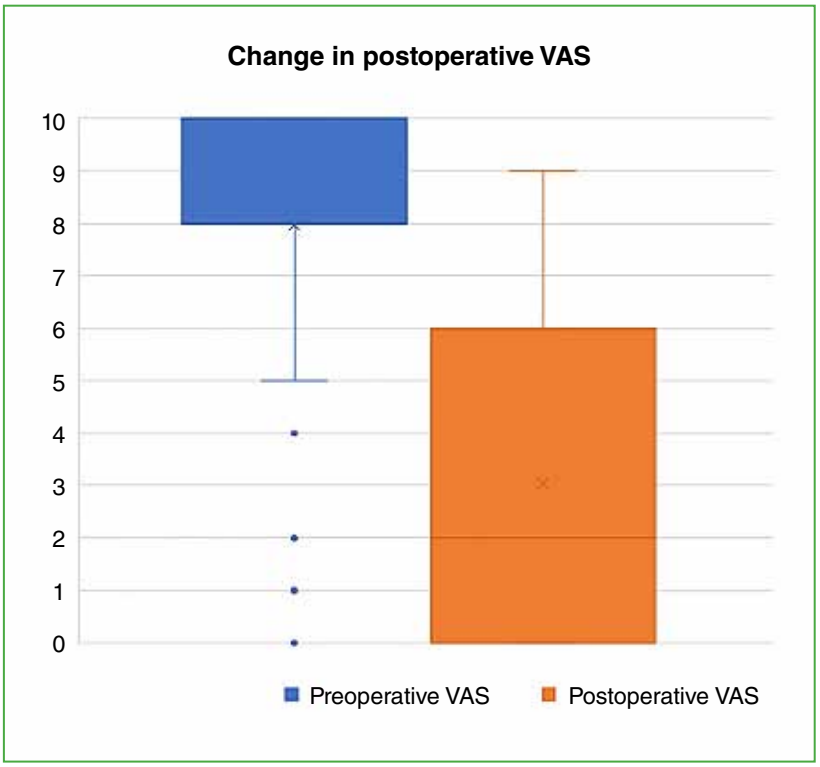

Figure 3. Box plot for the preoperative and postoperative visual analog scale variable.

The SF-12 questionnaire score at the end of follow-up showed a mean of 44.3 ± 11.7 for the Physical component and 59.4 ± 8.9 for the Mental component.

The mean WOMAC score at the end of follow-up was 18.06 ± 21.61, broken down into categories: 4.22 ± 4.66 (Pain), 1.29 ± 1.63 (Stiffness), and 13.06 ± 15.95 (Function).

The mean score on the Lysholm scale at the end of follow-up was 72.9 ± 26.1.

Intervention Survival Time

The median survival time post-intervention was 10.53 years (95% confidence interval [95% CI] 9.595-11.370). This calculation was based on the time at which conversion to total knee arthroplasty (TKA) became necessary due to the progression of degenerative disease and increasing pain.

Osteotomy survival rates were 86.3% (95% CI 76.9-95.7) at 5 years and 79.2% (95% CI 67.4-91.0) at 10 years.

Degree of satisfaction with the procedure

76.5% (39 patients) reported satisfaction with the procedure and indicated that they would undergo the surgery again. Reasons for dissatisfaction included difficulties in rehabilitation and postoperative pain. Table 4 presents the degree of satisfaction according to preoperative variables such as age, BMI, and preoperative VAS score. It was noted that patients who would not undergo surgery again had an average age of 59.8 years, which represents a statistically significant difference. No significant relationship was found between satisfaction rates and BMI or preoperative VAS scores.

Table 4. Degree of satisfaction according to preoperative variables.

Preoperative variables	Would you undergo surgery again?		p
	Yes (n = 39)	No (n =12)	
Age	54.4 ± 7.7	59.8 ± 5.9	0.037*
Body mass index	29.1 ± 4.6	31.7 ± 4.5	0.157
VAS score	7.9 ± 2.2	8.1 ± 2.7	0.434

(*) Statistically significant value. VAS = visual analog scale.

Table 5 illustrates the degree of satisfaction with the procedure according to postoperative variables. Notably, the significantly lower pain reported in the VAS after surgery among satisfied patients (those who would undergo surgery again) was 2.23 ± 2.19, while in those who were not satisfied (who would not undergo surgery again), it was 5.67 ± 2.71. Additionally, patients who were satisfied with the surgery had an average osteotomy survival that was three years longer (9.05 vs. 6.08) compared to those who were not satisfied.

Table 5. Degree of satisfaction according to postoperative variables.

Postoperative variables	Would you undergo surgery again?		p
	Yes (n = 39)	No (n = 12)	
VAS score	2.23 ± 2.19	5.67 ± 2.71	0.001*
Osteotomy survival time	9.05 ± 2.21	6.08 ± 3.15	0.003*
Lysholm Scale	78.41 ± 24.27	51.60 ± 22.75	0.003*
SF-12 Questionnaire (Physical)	46.58 ± 10.84	35.53 ± 11.20	0.010*
SF-12 Questionnaire (Mental)	60.91 ± 6.19	53.61 ± 14.69	0.080
WOMAC Pain	3.10 ± 4.14	8.60 ± 4.06	0.002*
WOMAC Stiffness	0.85 ± 1.39	3.00 ± 1.14	0.001*
WOMAC Function	9.41 ± 14.27	27.30 ± 14.62	0.001*

(*) Statistically significant value. VAS = visual analog scale. WOMAC = *Western Ontario and McMaster Universities Osteoarthritis Index*.

All analyzed scores, except for the SF-12 Mental component, demonstrated statistical significance in the values obtained between those who would undergo surgery again and those who would not. Thus, it can be concluded that those who would consider reoperation achieved better clinical outcomes, as well as longer osteotomy survival times.

Conversion to TKA

Ten patients (19.6%) required conversion to TKA. When comparing the rate of TKA based on the analyzed preoperative variables, no statistical significance was found; however, a higher rate of TKA was observed in patients with a BMI > 30, those older than 55 years, and those experiencing disabling pain (VAS > 7) (Table 5). Patients who would not consider reoperation had a higher rate of conversion to TKA, which was statistically significant (Table 6).

Table 6. Conversion rate to total knee arthroplasty as a function of preoperative variables and degree of satisfaction with the procedure.

		Conversion to total knee arthroplasty		p
		Yes (n = 10)	No (n = 41)	
Age >55	Yes (n = 29)	7	22	0.483
	No (n = 22)	3	19	
Body mass index >30	Yes (n = 27)	7	20	0.300
	No (n = 24)	3	21	
VAS score	Not disabling (n = 10)	0	10	0.178
	Invalidating (n = 41)	10	31	
Would you undergo surgery again?	Yes (n = 39)	3	36	0.001*
	No (n = 12)	7	5	

(*) Statistically significant value. VAS = visual analog scale.

DISCUSSION

There is consensus in the literature that the results of tibial valgus osteotomy are favorable in the first 5 to 10 years, but they tend to deteriorate after this period.[11] As previously mentioned, the aim of surgery is to slow down the degenerative process of the knee, improve pain and function, and delay early total knee arthroplasty (TKA) in occupationally active patients.[12-14] In our series, there was a statistically significant difference between the preoperative and postoperative VAS scores for pain. The mean preoperative VAS score was 7.96 ± 2.27, which decreased to 3.04 ± 2.73 postoperatively.

Regarding the average survival time of the osteotomy, different systematic reviews and meta-analyses have reported average results at 5 and 10 years (88.6%-97.1% and 64-94.8%, respectively).[2,10,15] In our population, the survival rate of the osteotomy was 86.3% at 5 years and 79.2% at 10 years, which is somewhat lower than in published international studies. Considering that the mean survival time was 10.53 years (95% CI 9.6-11.4), we believe that our result is acceptable, especially given that the average age of our population was 55.7 years at the time of surgery and that the average age of retirement in our country is between 60 and 65 years.

Concerning the relationship between conversion to TKA and osteotomy, 19.6% of patients required TKA. Historically, in 1984, Insall reported a conversion rate of 23% in patients who had previously undergone osteotomy, and more recent data retain this percentage.[1,13,15] It was not possible to determine a statistically significant relationship between the TKA rate and the analyzed preoperative variables; however, a higher rate of TKA was observed in patients with a BMI >30, those older than 55 years, and those experiencing severe pain (VAS >7). On the other hand, a statistically significant relationship was found between patients who would not return for surgery and those with a higher rate of TKA.

An important factor to consider when evaluating a surgical technique is the degree of patient satisfaction with the procedure. 76.5% of patients reported being satisfied and indicated that they would undergo the procedure again. This result is quite similar to those reported by Schallberger and Jacobi and Han et al. (85.2% and 80%, respectively).[13,14] Patients who would undergo reoperation were younger than those who would not, and this relationship was statistically significant. Although we did not observe statistically significant differences in BMI between satisfied and dissatisfied patients, both groups had a BMI in the overweight/obese range. Higher BMI levels can lead to a greater number of complications, such as an increased rate of pseudarthrosis due to the greater mechanical stress placed on the osteotomy; however, these conditions are not contraindications for the procedure.[16] Likewise, a BMI >28 is a factor that negatively impacts outcomes, as it can cause painful dysmetria in medial opening wedge osteotomies.[17] According to the ISAKOS consensus published in 2005, ideal candidates for osteotomy are those with a BMI <30.[18] In our sample, only 45.1% met this criterion.

The WOMAC questionnaire evaluates knee symptomatology and functionality, assessing pain, stiffness, and function. It comprises values ranging from 0 to 96, where lower values indicate better outcomes. The WOMAC score in our series at the end of follow-up was 18.06 ± 21.61. In patients operated on with TomoFix, Han et al. reported scores of 10.3 in satisfied patients and 14.4 in unsatisfied patients two years after the intervention.[14] Likewise, Han et al. and Saier et al. reported similar scores (8.1 and 11.4, respectively) in their series using TomoFix, with two years of follow-up. [5,19]

The Lysholm scale is widely used to measure knee symptoms and daily function and can be applied in various conditions. It consists of 8 items, with total scores ranging from 5 to 100; higher scores indicate fewer symptoms or better functional levels.[20] The mean Lysholm score at the end of our follow-up was 72.9 ± 26.1, which was somewhat lower than the scores reported by Saier et al. (with TomoFix) and Osti (with Puddu) (75.6 and 82.5, respectively).

The SF-12 questionnaire is an accepted tool for evaluating the patient's quality of life, assessing physical capacity related to specific issues and the psychological impact of these issues on interpersonal relationships. In our series, the mean scores at the end of follow-up were 44.3 ± 11.7 (Physical) and 59.4 ± 8.9 (Mental). These values can be compared with those from the studies by Hantes et al. and Jacquet (both using TomoFix) (49.3 and 42.5 [Physical]; 54.4 and 53.9 [Mental], respectively).[6,21]

Among the strengths of our study, we highlight that it comprises a cohort of patients treated by the same surgical team, which included an experienced knee surgeon who consistently employed the same surgical technique. We also emphasize that the study was conducted by two principal investigators who analyzed all surgical descriptions, preoperative and postoperative imaging, and qualitative variables separately. On the other hand, the weaknesses are based on the well-known limitations of retrospective analyses, including difficulty in obtaining complete data, variability in patient follow-up, and the loss of one patient who refused to participate in the survey.

CONCLUSIONS

In our series, the mean survival time of the osteotomy was 10.53 years, with an overall survival rate of 79.2% at 10 years and a conversion rate to TKA of 19.6%. A statistically significant relationship was found between the decrease in preoperative and postoperative pain according to VAS, with younger patients reporting higher satisfaction and a greater likelihood of undergoing surgery again. Conversely, there was a non-statistically significant increase in the rate of conversion to TKA in patients with a BMI >30, those older than 55 years, and those with a VAS score >7 for pain.

Therefore, we can conclude that, in our series, opening wedge high tibial osteotomy with Puddu plate yielded very satisfactory outcomes at 5 years of follow-up.

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

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Total Knee Arthroplasty: Posterior Stabilization vs. Posterior Cruciate Ligament Preservation. Clinical and Functional Evaluation

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ABSTRACT

Introduction: Despite the progress and numerous publications in recent years, the outcomes of posterior stabilized (PS) prosthetic designs versus those that preserve the posterior cruciate ligament (PCL) remain controversial. **Materials and Methods:** This is a consecutive retrospective series involving 164 patients surgically treated by the same surgical team. Eighty patients received cruciate-retaining (CR) prostheses, and 84 received PS designs. **Results:** The average age was 70 years. We identified 121 knees as grade 4 and 43 knees as grade 3 according to the Kellgren-Lawrence scale. The postoperative range of motion was 109.5° ± 10.5° in the CR group versus 110° ± 12° in the PS group (p = 0.50). No significant differences were found between the two groups in postoperative knee scores using the Knee Society Score (KSS): 84.7 ± 10 in the CR group versus 87 ± 10 in the PS group (p = 0.14). However, there was a significant difference in the functional score, with the CR group scoring 84 ± 12 versus 78.8 ± 17 in the PS group (p = 0.02). There were no significant differences in terms of patient satisfaction. **Conclusion:** In our study, we found no significant differences in clinical evaluation, pain, or patient satisfaction between cruciate-retaining prosthetic designs and those with posterior stabilization. However, there was a significant difference in functional evaluation using the KSS, favoring the CR group.

Keywords: Total knee arthroplasty; prosthetic design; posterior stabilization; cruciate-retaining.

Level of Evidence: III

Artroplastia total de rodilla: estabilización posterior vs. conservación del ligamento cruzado posterior. Evaluaciones clínica y funcional

RESUMEN

Introducción: Más allá del avance y de las numerosas publicaciones en los últimos años, los resultados de los diseños de prótesis estabilizada posterior vs. aquellos con conservación del ligamento cruzado posterior aún son controvertidos. **Materiales y Métodos:** Serie retrospectiva consecutiva de 164 pacientes operados por un mismo equipo. Ochenta cirugías con conservación del ligamento cruzado posterior y 84 con prótesis estabilizada posterior. **Resultados:** La edad promedio era de 70 años. Según la escala de Kellgren-Lawrence, 121 rodillas eran grado 4 y 43 rodillas, grado 3. El rango de movilidad posoperatorio fue de 109,5° ± 10,5° en el grupo de conservación del ligamento cruzado posterior y de 110° ± 12° en el grupo con prótesis estabilizada posterior (p = 0,50). Después de la cirugía, no se hallaron diferencias entre ambos grupos, en el KSS (84,7 ± 10 vs. 87 ± 10; p = 0,14), pero sí hubo una diferencia significativa en el KSS Funcional (84 ± 12 vs. 78,8 ± 17, respectivamente, p = 0,02). No se observó una diferencia significativa entre ambos grupos respecto de la satisfacción del paciente. **Conclusión:** No se hallaron diferencias significativas en cuanto a la evaluación clínica, el dolor y la satisfacción del paciente al utilizar un diseño con conservación del ligamento cruzado posterior o un diseño estabilizado posterior. Sí hubo una diferencia en el KSS Funcional a favor del grupo de conservación del ligamento cruzado posterior.

Palabras clave: Artroplastia total de rodilla; diseño protésico; estabilizado posterior; conservación ligamento cruzado posterior.

Nivel de Evidencia: III

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INTRODUCTION

Total knee arthroplasty (TKA) is one of the most common procedures in orthopedics. Despite advancements in prosthesis design and numerous publications in recent years, the debate over retaining the posterior cruciate ligament (PCL) continues. The outcomes of posterior stabilized prostheses (PS) versus cruciate-retaining designs remain controversial.[2,3]

Several studies have evaluated the kinematics and biomechanics of these designs, as well as their clinical and functional outcomes. Parsley et al. reported similar results in range of motion, functional scores, knee scores, and patient satisfaction when comparing both designs.[4] Similarly, Wünschel et al. studied strength and kinematics after TKA and found that preserving the PCL led to a more natural reproduction of knee movement, while the kinematics in posterior stabilized cases were determined by the design of the component.[5]

The PCL plays a crucial role in knee flexion. As the femoral insertion of the PCL is displaced anteriorly, it stresses the ligament and causes it to push the tibia posteriorly, a mechanism known as "rollback."[6] Resecting the PCL during surgery can create a 5 mm gap during flexion.[7] The goal of TKA is to replicate natural knee motion while maintaining stability throughout the range of motion. Various authors suggest that preserving the PCL can help achieve this stability.[7,8]

However, when selecting an implant, the surgeon must consider multiple factors, including the patient's clinical history, physical examination, intraoperative assessment of PCL degeneration, and personal preferences. As mentioned, several studies have analyzed the advantages of one design over the other,[9-12] but none have definitively established a clear difference between the two treatments.

Jacobs et al. reviewed eight randomized clinical trials and reported an 8° improvement in range of motion in favor of the PS group. However, they cautioned that these results should be interpreted carefully due to significant variability across the studies.[13]

Given the ongoing debate on this topic, we evaluated our experience with a series of patients treated with these designs.

OBJECTIVE

The objective was to perform a functional comparison between a consecutive series of patients undergoing TKA with two surgical techniques: preservation versus non-preservation of the PCL.

MATERIALS AND METHODS

We retrospectively analyzed a consecutive series of 164 patients operated on by the same surgical team from the Arthroscopy and Knee Prosthesis Sector of Hospital Italiano de Buenos Aires, a university hospital and tertiary care center.

All patients underwent TKA with an anterior approach. In 80 cases, a cruciate-retaining technique was performed using the same Optetrak® CR SLOPE prosthesis (Exactech®, Inc., Gainesville, FL, USA), while in 84 cases, a posterior stabilized design with an Optetrak® PS insert (Exactech®, Inc., Gainesville, FL, USA) was used (Figure 1). In all cases, cemented components were employed, and immediate full weight-bearing was permitted. All patients followed the same rehabilitation protocol, which focused on early mobilization under the supervision of a physiotherapist. The average hospital stay was 3 to 4 days, and patients followed a rehabilitation protocol three times a week for one month post-operation. Follow-up visits were conducted at 3 and 6 weeks, and at 3, 6, and 12 months.

Exclusion criteria included patients who required additional procedures or a more complex implant due to bone defects or bone quality, those with pre-existing conditions or neurological deficits affecting motor function (such as Parkinson's disease or post-polio syndrome), and patients with follow-up periods of less than 12 months.

Radiographs were analyzed preoperatively, and the degree of osteoarthritis was assessed using the Kellgren-Lawrence scale.

Outcome variables included the *Knee Society Score* (KSS), which evaluated both the knee and functional scores preoperatively and at one-year follow-up. Additionally, the visual analog scale, full range of motion, maximum flexion, and extension—measured with a goniometer—were recorded before and after surgery. The WOMAC (*Western Ontario and McMaster Universities Osteoarthritis Index*) questionnaire was also used, and postoperative patient satisfaction was assessed on a scale from 0 to 100, where 100 indicated maximum satisfaction.

Figure 1. **A.** Posterior stabilized prosthesis design. **B.** Posterior cruciate ligament-retaining design.

Statistical Analysis

Continuous variables are expressed as mean and standard deviation (SD) or as median and interquartile range, depending on the distribution observed. Categorical and ordinal variables are expressed as absolute and relative frequencies, along with confidence intervals. To compare the results between the two surgical techniques, as well as the pre- and postoperative outcomes, a paired samples t-test was used.

To assess the effect of the surgical technique (PCL preservation vs. non-preservation) on the outcome variables, linear regression was applied. The beta regression coefficient, reflecting the impact of using the cruciate-retaining technique compared to PS, is reported. To control for potential selection bias, a propensity score was created using logistic regression, with the surgical technique as the dependent variable. The model with the highest area under the curve (AUC) and lowest Akaike information criterion (AIC) was selected. The association between surgical technique and each outcome variable was adjusted using the propensity score.

A p-value of <0.05 was considered statistically significant. Statistical analysis was conducted using STATA version 13.0.

RESULTS

The average age of the cohort was 70 years. According to the Kellgren-Lawrence osteoarthritis scale, 121 knees were classified as grade 4 and 43 as grade 3.

The most common anatomical axis was varus deviation, found in 67.07% of cases (43.6% in the cruciate-retaining group and 56.3% in the PS group). Valgus deviation was present in 26.8% of cases (56.8% vs. 43.1%, respectively), while 6.1% had a normal axis. No significant differences were found between the groups with respect to alignment ($p = 0.134$). All patients had a minimum follow-up period of 12 months.

The descriptive variables of the population are detailed in Table 1.

Table 1. Description of the population based on the surgical technique employed

	Cruciate-retaining design	Posterior stabilized prosthesis	p
Age, average	68.9 (SD 7.45)	70.5 (SD 9.11)	0.222
Right side (%)	53	47	0.160
Body mass index, mean	28.7 (SD 5.02)	31.7 (SD 5.67)	0.005
Follow-up, months	20.3 (SD 8.22)	27.6 (SD 11.86)	0.001

PCL = posterior cruciate ligament; SD = standard deviation.

Range of Motion

The full range of motion was 105° ± 11° in the cruciate-retaining group and 102° ± 13.5° in the PS group preoperatively, increasing to 109.5° ± 10.5° and 110° ± 12°, respectively, postoperatively (p = 0.50) (Figure 2).

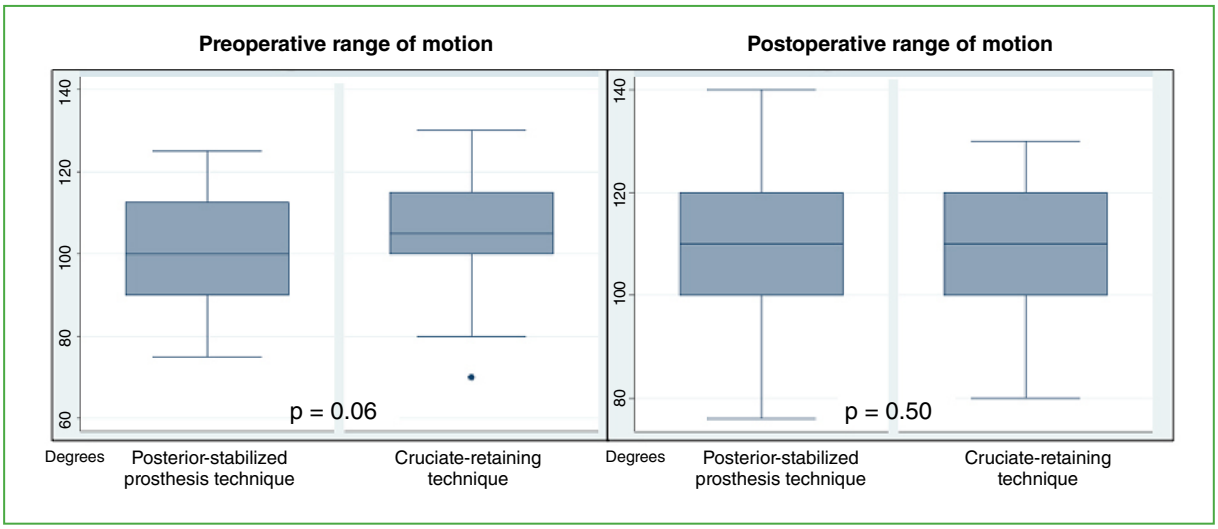

Figure 2. Comparison of preoperative and postoperative range of motion for both surgical techniques.

Preoperative flexion was 108° ± 10° in the cruciate-retaining group and 107° ± 12° in the PS group (p = 0.48). After surgery, flexion improved to 109.8° ± 9.9° in the cruciate-retaining group and 110.9° ± 11.7° in the PS group (p = 0.508).

Extension in the cruciate-retaining group was 2.8° ± 4.4° preoperatively and improved to 0.56° ± 1.5° at follow-up. In the PS group, extension was 4.9° ± 5.4° preoperatively and 0.53° ± 1.7° postoperatively. No significant differences were observed between the groups (p = 0.91) (Table 2).

Table 2. Preoperative and postoperative range of motion, flexion, and extension of both groups.

	Cruciate-retaining design	Posterior stabilized prosthesis	p
Preoperative range of motion	105.62° (SD 11.67°)	102° (SD 13.57°)	0.069
Postoperative range of motion	109.5° (SD 10.51°)	110.67° (SD 12.21°)	0.509
Preoperative flexion	108.25° (SD 10.37°)	107.01° (SD 12.10°)	0.483
Postoperative flexion	109.81° (SD 9.98°)	110.94° (SD 11.71°)	0.508
Preoperative extension	2.81° (SD 4.42°)	4.96° (SD 5.43°)	0.006
Postoperative extension	0.56° (SD 1.58°)	0.53° (SD 1.76°)	0.919

PCL = posterior cruciate ligament; SD = standard deviation.

Outcome Variables According to Surgical Technique

Pain

Pain was assessed using the visual analog scale (VAS). The cruciate-retaining group had a preoperative score of 8.68 (SD ± 0.94), while the PS group scored 8.09 (SD ± 1.36) (p = 0.001). After surgery, the pain score decreased to 1.82 (SD ± 1.43) in the cruciate-retaining group and 1.91 (SD ± 1.31) in the PS group (p = 0.67). Pain was also evaluated using the KSS (Figure 3).

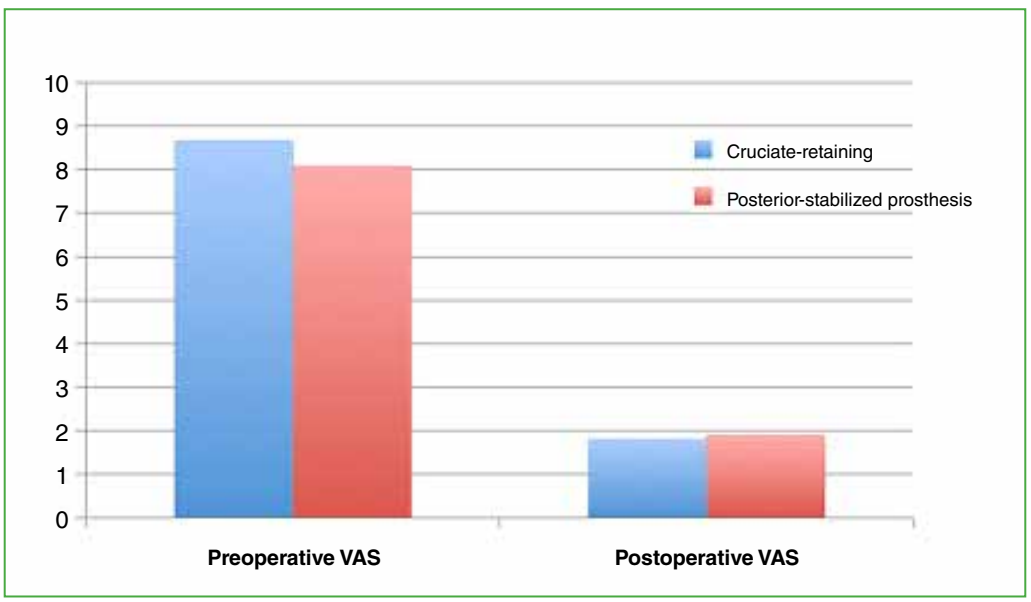

Figure 3. Preoperative and postoperative pain scores.

Functional Evaluation

Preoperative knee KSS was 44 ± 16 in the cruciate-retaining group and 45 ± 16 in the PS group (p = 0.82). The preoperative functional KSS was 53 ± 17 in the cruciate-retaining group compared to 46 ± 18 in the PS group (p = 0.02).

Postoperatively, no significant differences were found between the groups regarding knee KSS (84.7 ± 10 vs. 87 ± 10, respectively, p = 0.14). However, there was a significant difference in the functional KSS, with the cruciate-retaining group scoring 84 ± 12 compared to 78.8 ± 17 in the PS group (p = 0.02) (Figure 4).

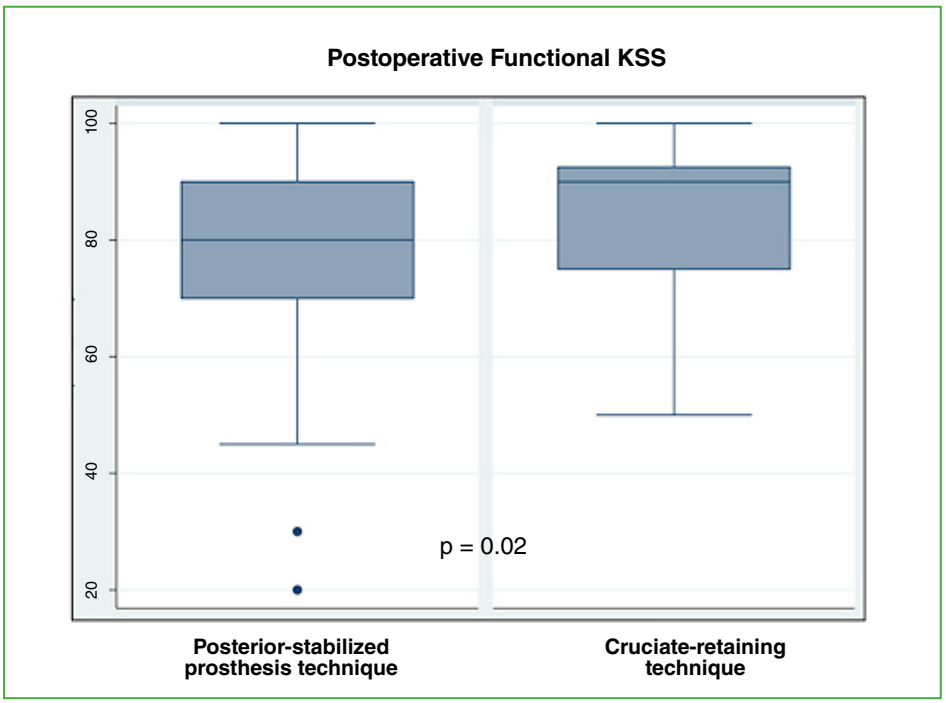

Figure 4. Functional KSS score for both surgical techniques.

The WOMAC questionnaire showed a preoperative score of 45 ± 12 in the cruciate-retaining group and 52 ± 18 in the PS group (p = 0.12). Postoperatively, there were no significant differences between the groups (14 ± 7 vs. 19 ± 14, respectively) (p = 0.10).

As seen in Table 3, all variables showed significant improvement after surgery.

Table 3. Details of outcome variables.

	Cruciate-retaining design			Posterior stabilized prosthesis		
	Preoperative	**Postoperative**	**p**	**Preoperative**	**Postoperative**	**p**
Range of motion	105.6°	109.5°	0.002	102°	110.6°	0.001
KSS (Knee)	44.8	87	0.001	44.4	84.7	0.001
KSS (Functional)	53.1	84.3	0.001	46.6	78.8	0.001
Visual analog scale	8.6	1.8	0.001	8	1.9	0.001

PCL = posterior cruciate ligament; KSS = Knee Society Score.

No clinically significant differences were observed in the effect of the cruciate-retaining technique compared to PS on any outcome variable before and after adjusting for the propensity score (Table 4).

Table 4. Effect of posterior cruciate ligament-retaining technique on postoperative functional assessment using propensity score-adjusted linear regression.

	Raw coefficient (95%CI)	PS-adjusted coefficient*
Postoperative range of motion	-1.18 (from -4.70 to 2.34)	-3.6 (from -7.48 to 0.23)
Postoperative subjective KSS	5.46** (0.73-10.19)	2.42 (from -2.82 to 7.65)
Postoperative objective KSS	-2.36 (from -5.51 to 0.79)	-4.41** (from -7.9 to 0.92)
Postoperative extension contracture	0.026 (from -0.49 to 0.54)	0.31 (from -0.25 to 0.89)
Postoperative flexion	-1.12 (from -4.49 to 2.23)	-3.05 (from -6.79 to 0.67)

*PS = propensity score constructed with body mass index, preoperative extension contracture, preoperative pain, and preoperative subjective KSS. **Results with p<0.05. 95%CI = 95% confidence interval.

Patient Satisfaction

Patient satisfaction was evaluated at the last follow-up. The average satisfaction score was 83.1 (SD ± 4.82) in the cruciate-retaining group and 81.9 (SD ± 5.94) in the PS group. No significant difference was observed between the two groups (p = 0.096).

DISCUSSION

Over the past decades, numerous studies, including systematic reviews and meta-analyses, have explored the differences in clinical outcomes between posterior cruciate ligament-retaining and posterior stabilized (PS) designs.[14,15] However, no consensus has been reached regarding whether one design is superior to the other. Traditionally, it has been argued that the PS design allows for a greater range of motion than the cruciate-retaining design.[16] This is because the PS design can avoid the paradoxical anterior translation during flexion, often observed in cruciate-retaining TKA, which may limit the flexion angle.[17] However, in our study, while the PS group achieved greater postoperative flexion, there was no major difference between the two prosthesis designs in terms of overall range of motion. This is consistent with recent findings by Yamamoto et al.[18] who reported no significant difference in postoperative range of motion between cruciate-retaining and PS designs, with both types showing a significant increase in postoperative flexion angle. Similarly, a meta-analysis by Berick et al.,[16] which included 1,265 knees from 12 randomized controlled trials, found that knee flexion and range of motion were significantly improved in knees with PS designs.

The literature is also inconsistent regarding postoperative pain and patient satisfaction. In a prospective, randomized study of 58 knees, Yagishita et al.[19] found no significant differences in the *Knee Society Score* (KSS) or visual analog scale (VAS) scores, but they did observe a higher degree of satisfaction in the PS group. These results are consistent with those from our series regarding the postoperative pain variable, while both groups had satisfaction levels above 80%. Singleton et al.[20] also found no differences in pain scores at 1 year, 5 years, and 10 years postoperatively.

In our series, no significant differences were found in functional outcomes as measured by the WOMAC questionnaire or the knee KSS. However, the Functional KSS favored the cruciate-retaining group. Singleton et al.[20] found no difference in overall functional improvement between cruciate-retaining and PS groups. They suggested that the slight improvements in knee range of motion provided by the PS design may translate into better functional outcomes and patient satisfaction in the short term. However, over time, patients may become more accustomed to their knee motion, and these differences tend to diminish.

Lützner et al.[21] also found similar intraoperative stability between the two designs, with no statistically significant differences. Despite the variations in femoral rollback, both PS and cruciate-retaining TKA designs have demonstrated improvements in both intraoperative and postoperative stability.

Our study has certain limitations: it is a retrospective series, has a relatively short follow-up, and lacks an assessment of kinematics or proprioception.

CONCLUSIONS

No significant differences were found in clinical outcomes, pain levels, or patient satisfaction between cruciate-retaining and PS prosthesis designs. However, there was a difference in the Functional KSS in favor of the cruciate-retaining group.

We consider the cruciate-retaining prosthetic design to be a viable option for TKA, as the clinical and functional outcomes are comparable to those of the PS design, with the added advantage of preserving more bone stock.

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

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Optimal Surface Roughness of an Implant to Generate Osseointegration and Biological Fixation

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ABSTRACT

Introduction: The use of rough surfaces for biological fixation in implants is an increasingly common alternative. The aim of this study is to determine the optimal surface roughness of an intramedullary implant to promote osseointegration and subsequent biological fixation, using thermal arc projection and rabbit femurs as a biological receptor model. **Materials and Methods:** Cylindrical intramedullary systems with rough titanium coatings were implanted with varying degrees of roughness to assess where optimal osseointegration occurs, using the femurs of six rabbits (unilateral). The osseointegration process was monitored through monthly radiographs and histopathological analysis of the femur specimens. **Results:** No migration or subsidence occurred in any of the implants. Radiographic evidence of osseointegration was observed in all femurs. Bone formation was established around all implants. However, a mechanical test to evaluate the strength of the adhesion to the bone could not be performed. **Conclusion:** Surfaces with a roughness >100 µm have shown a favorable biological response, demonstrating a direct bond between the implant surface and the bone.

Keywords: Roughness; osseointegration; titanium; thermal projection.

Rugosidad óptima de un implante para generar la osteointegración y la fijación biológica

RESUMEN

Introducción: El uso de superficies rugosas para la fijación biológica en implantes es una alternativa que se está usando cada vez con más frecuencia. El objetivo del estudio fue determinar la rugosidad óptima de un implante endomedular que permita la osteointegración y la consecuente fijación biológica, mediante la proyección térmica por arco utilizando fémures de conejos como modelo biológico receptor. **Materiales y Métodos:** Se implantaron sistemas endomedulares cilíndricos con recubrimiento rugoso de titanio y distinto rango de rugosidad en fémures de seis conejos (unilaterales) para determinar dónde se produce una mayor osteointegración. El proceso de osteointegración se evaluó con radiografías mensuales y estudios de anatomía patológica del fémur del espécimen. **Resultados:** No se produjo migración o subsidencia en ninguno de los implantes. Todos los fémures mostraron signos de osteointegración radiográfica. Se demostró la presencia de neoformación ósea establecida alrededor de todos los implantes. Sin embargo, no se pudo realizar un testeo mecánico para evaluar la fuerza de adhesión al hueso. **Conclusión:** Las superficies con rugosidades >100 µm proporcionan una respuesta biológica favorable con una unión directa entre la superficie de los implantes y el hueso.

Palabras clave: Rugosidad; osteointegración; titanio; proyección térmica.

INTRODUCTION

The long-term success of total hip arthroplasty depends on stable anchorage to the bone. To achieve lasting stability with cementless implants, osseointegration is essential for establishing permanent fixation, i.e., proper attachment of lamellar bone to the implant without fibrous tissue interposition.[1,2] The success of biological fixation primarily depends on meticulous surgical techniques, the type of material used, and the primary stability of

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the implant. The osseointegration process manifests as interdigitation within small pores (ingrowth) or through bone growth on a rough surface (ongrowth).[3,4] Research on osseointegration focuses on identifying suitable materials that promote this type of fixation. Various materials have been studied: from the Swedish school of Brånemark's introduction of dental implants with machined rough surfaces,[5] to the Swiss school of Schroeder's use of titanium plasma as an inert material, and hydroxyapatite as a bioactive material, to more recent innovations, such as tantalum rough surfaces, 3D printing of rough textures, and electron beam techniques. These developments are supported by a long history of intensive research, including laboratory (in vitro) and animal (in vivo) studies. [6,7]

To improve the quality of osseointegration, there has been an ongoing search for new elements, structures, and implant dimensions that can be used in demanding conditions to guarantee durability. The use of rough surfaces for biological fixation has become an increasingly common alternative. Recent research efforts have focused on identifying a rough material with an optimal structure to facilitate bone growth.[8] In all cases, the goal remains to achieve adequate osseointegration.

Experimental animal studies have demonstrated implant fixation through bone apposition and growth both on the surface and within porous systems. Current clinical reviews suggest radiological and histological evidence of bone growth in direct contact with the implant material and inside porous systems, thereby combining the bioactive properties of hydroxyapatite with the mechanical properties of metals, while avoiding the fragility issues of fully ceramic implants.[9] In modern total hip arthroplasty, femoral stems are typically made from various alloys, with titanium-aluminum-vanadium (Ti6Al4V, grade 5 titanium) being the preferred material for cementless femoral stems. This alloy offers several advantages over others, including superior biocompatibility, a low modulus of elasticity that closely resembles bone, and better load transmission (112,000 MPa), which supports favorable bone remodeling and enhances osseointegration. It also has relatively low toxicity at clinically encountered concentrations and is inert in physiological environments.[10,11] Furthermore, it allows bone to grow into its structure, providing robust biological fixation to the surrounding tissue. [12,13]

The aim of this study was to determine the optimal implant roughness and evaluate the intramedullary osseointegration process—resulting from biological fixation (secondary stabilization)—using implants created through thermal arc spraying. The study used rabbit femurs as a receptor model and investigated the bone-implant interface through radiographic and anatomical pathology analyses.

MATERIALS AND METHODS

Cylindrical intramedullary systems with rough titanium coatings were implanted in the femurs of six skeletally mature New Zealand rabbits, each weighing approximately 5 kg. Over a 12-week period, all surgical procedures were performed at Fundación Favaloro, where the project was presented to the Bioethics Committee and received approval.

For the characteristics mentioned, titanium-aluminum-vanadium alloy was chosen as the material, combined with a rough thermal spray coating. Thermal spraying is a process in which a metallic coating is applied through the deposition of molten particles, which are accelerated and sprayed at high pressure onto the surface of a base material or substrate. This process can be categorized into three main methods: flame spraying, arc spraying, and plasma spraying.

In this study, electric arc spraying was employed to generate the rough coating. This technique involves two titanium metal wires that serve as electrodes. When the wires come into contact, they create a short circuit that forms an electric arc,[14] causing the wires to melt and project as particles onto the previously shot-blasted substrate. The particles are spread depending on the system's compressed air, in an inert argon gas environment (Figure 1).

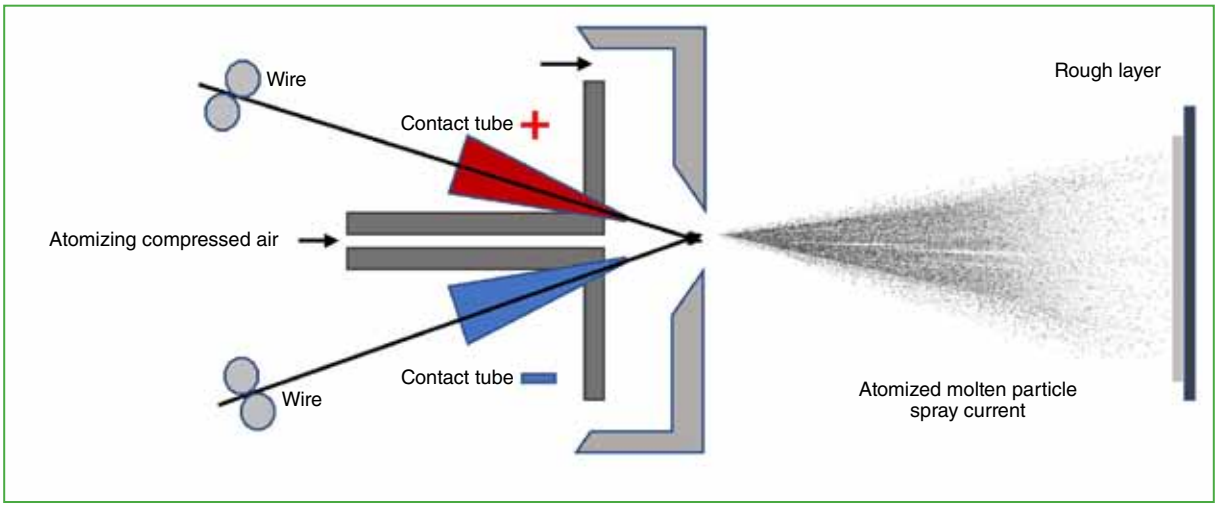

Figure 1. Schematic diagram of the electric arc spray system.

The resulting rough surface depends on the exposure time of the molten particles impacting the implant. Surface roughness was measured using a MITUTOYO model SJ 210 roughness meter (Figure 2), which quantifies the effective profile based on specific geometric characteristics. These measurements were corroborated by the National Institute of Industrial Technology and the School of Engineering of La Plata. The analysis included the distances between roughness peaks (Ra, the maximum distance between peaks over a baseline length) and the depth of roughness between peaks (Rt, the largest peak-to-valley distance across all baseline lengths) (Figure 3).

Figure 2. Mitutoyo surface roughness tester model SJ 210.

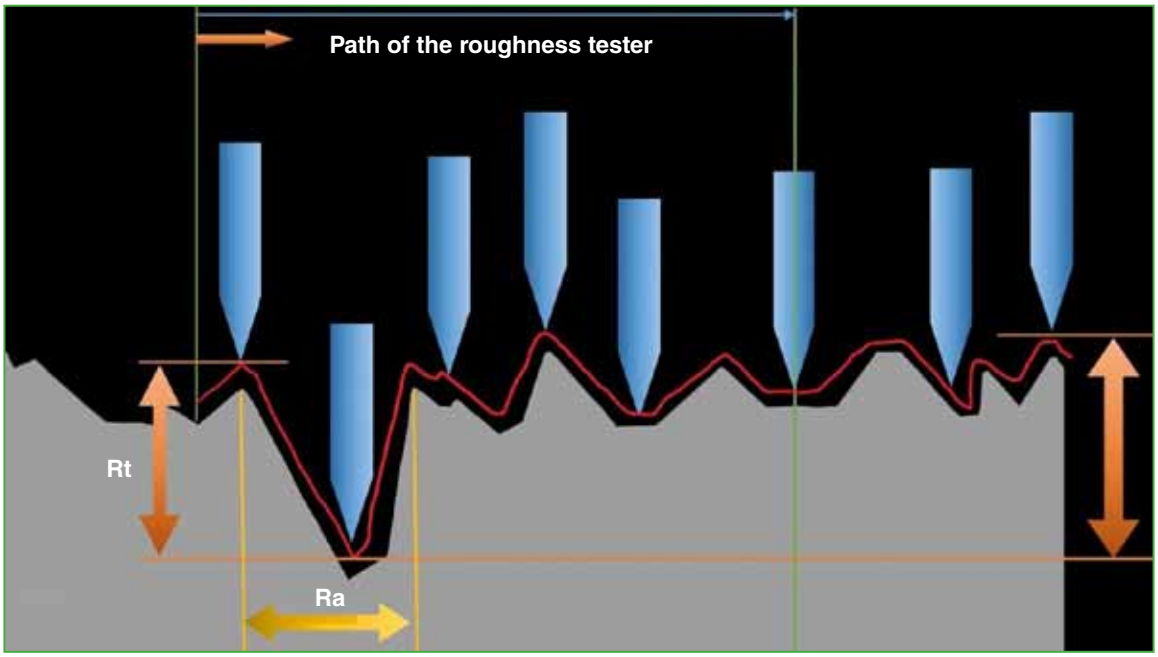

Figure 3. Path of the surface roughness tester for Ra and Rt measurement.
Ra = maximum peak-to-peak distance in a basic length; Rt = largest peak-to-valley distance of all basic lengths.

The intramedullary implants for the biological recipients were specifically designed for this study. Preoperative planning involved measuring the diameter of the proximal femur (metaphyseal-diaphyseal zones) of a prototype rabbit using full-size anteroposterior and lateral radiographs. As a result of this planning, titanium alloy implants with three diameters (3, 3.5, and 4 mm) and three lengths for each diameter (30, 35, and 40 mm) were created (Figure 4), providing a set of nine implants per rabbit (Figure 5).

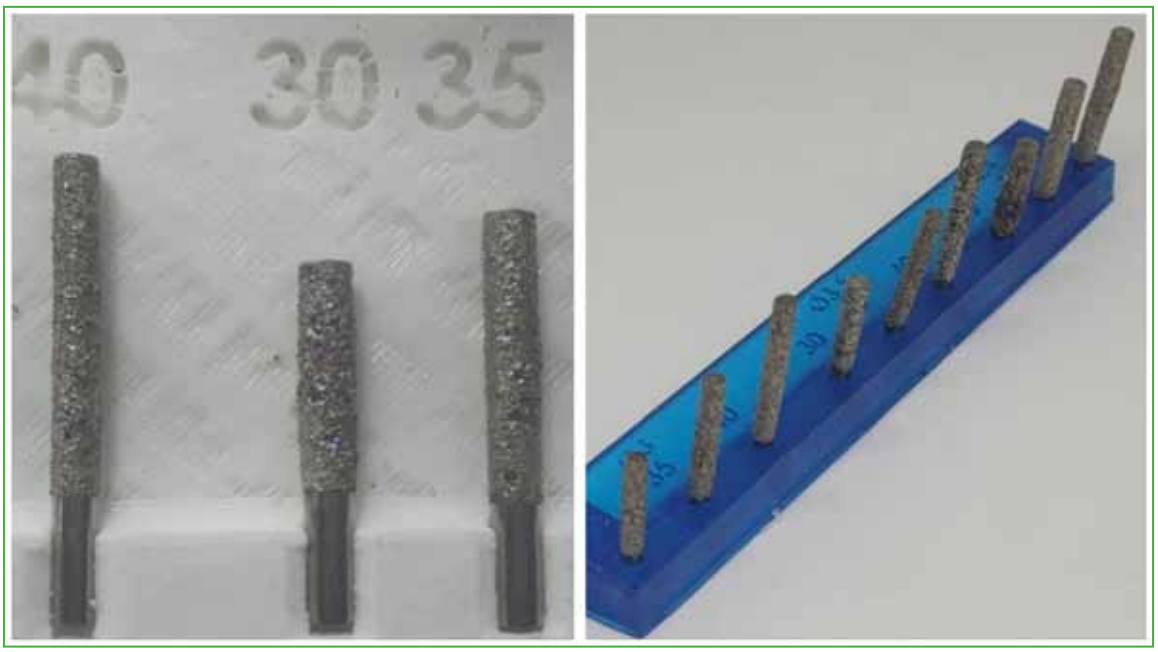

Figure 4. Titanium alloy implants used, with different lengths and diameters.

Figure 5. Individual placement set for each specimen.

To enhance precision, each stem was divided into two halves (anterior and posterior), marked to differentiate two surfaces. One half had an average roughness of 120 µm (range 100–150 µm), while the other half had a lower average roughness of 70 µm (range 30–90 µm). This division simplified the analysis of osseointegration in relation to roughness from an anatomical pathology perspective.

The osseointegration process was studied using monthly radiographs to identify union points according to Gruen's zone classification. At the end of the third month, an anatomical pathology study was conducted on the femurs. Each femur was individually fixed in 10% formaldehyde. The bones were then decalcified using Extra Decalcifier (Biopur Diagnostics, Biopur SRL, Rosario, Argentina) to extract bone fragments for study, preserving the bone-implant interface for subsequent eosin and hematoxylin staining. This analysis was performed using an optical microscope.

Radiographs were taken immediately postoperatively and again at 12 weeks after implantation to confirm proper implant placement and rule out fractures. Radiographs were also taken at the time of extraction to document successful implant incorporation (Figure 6). The rabbits were then euthanized, and femurs were collected from all animals. Radiographs of the extracted femurs were taken in anteroposterior and lateral projections, allowing analysis according to Gruen's zone classification to identify areas of bone growth (Figure 7).

During histological sampling, a macroscopic analysis was performed, revealing the growth of cancellous bone around the implants (Figure 8). A microscopic examination of the tissue surrounding the implants followed, with bone growth quantified based on the presence of mature bone and cortical osteogenesis in the intramedullary area.

At the time of euthanasia, after three months, all implants had satisfactorily osseointegrated.

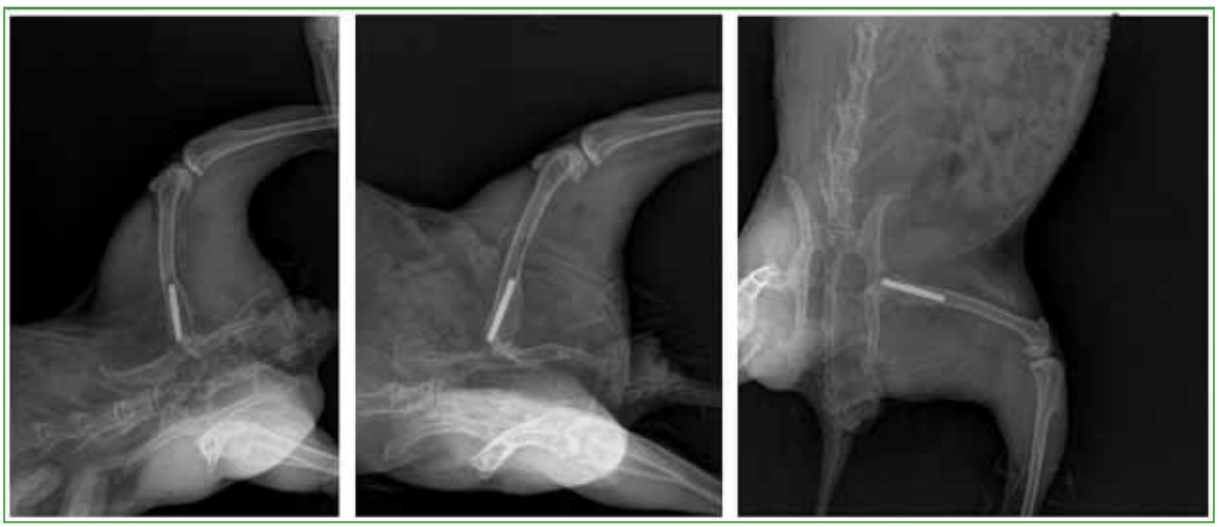

Figure 6. Immediate postoperative radiographs of the specimens.

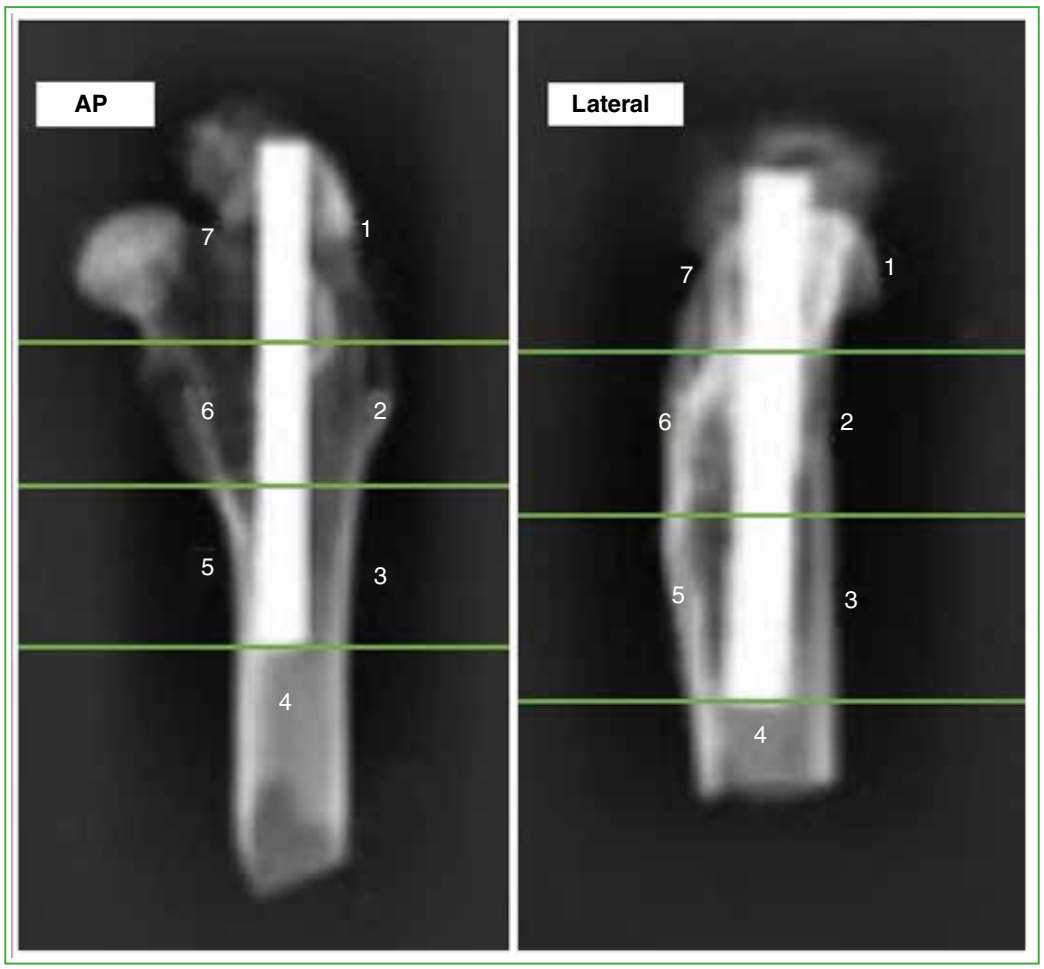

Figure 7. Division of the proximal femur according to Gruen's classification to determine the areas of union in the AP and lateral projections.

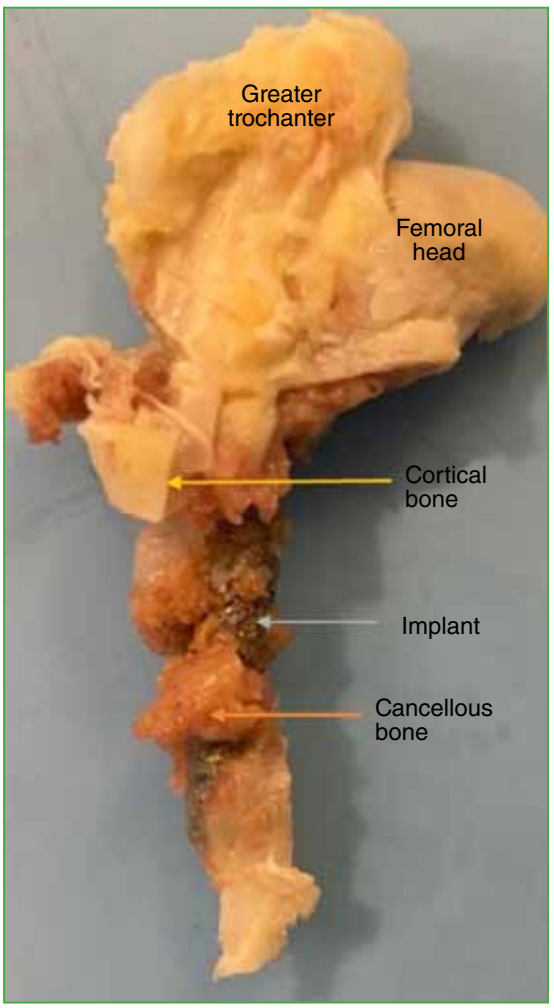

Figure 8. Cancellous bone growth around the implant.

Surgical Technique

Anesthetic induction was achieved using xylazine (5 mg/kg) and ketamine (25 mg/kg) administered intramuscularly, followed by intubation and oxygen support. Maintenance of anesthesia was provided intravenously (via the marginal ear vein) as needed, using a combination of xylazine, ketamine, and lidocaine. Continuous anesthetic monitoring and veterinary clinical oversight were maintained.

A sterile procedure was followed throughout the surgery. The operative site was shaved and disinfected. A 3 cm lateral approach was made, and the proximal femoral canal was prepared using trial rasps. The final implant diameter was selected based on the size of each rabbit's intramedullary canal. Implants were placed unilaterally, with the contralateral femur serving as a control. During the procedure, antibiotic prophylaxis was administered (cefazolin 20 mg/kg intramuscularly).

Postoperatively, the animals were inspected daily for clinical signs of complications or adverse reactions. Limb weight-bearing began from the first day of recovery, with no external support applied to the operated limb. The animals naturally adapted to weight-bearing on the operated femur, progressing to full weight-bearing.

Radiographic assessments were performed immediately postoperatively and then monthly for 12 weeks following implant placement. The treated femurs were radiographed in anteroposterior and lateral projections under anesthesia. During this period, adverse reactions or infections were also monitored.

After the last radiographic study, the animals were euthanized using an overdose of anesthesia, and the entire femur with the implant was collected for analysis. For histological examination, bone fragments were taken, after decalcification, from the areas of osseointegration observed on the radiographs.

RESULTS

No evidence of infection or other complications was detected in any of the specimens.

Clinical-Radiographic Analysis

All rabbits achieved progressive partial weight-bearing on the operated limb by the second postoperative day, without complications. By the fifth day, full weight-bearing was observed in all subjects.

No migration or subsidence was observed in any of the implants. In the anteroposterior projection, attachment points were predominantly visualized in zones 2 and 5, followed by zones 3 and 6 (Table 1).

Table 1. Radiographic location of the bone-implant junction areas. AP view.

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
Femur 1		x			x		x
Femur 2		x			x	x	
Femur 3		x	x		x	x	
Femur 4		x	x		x		
Femur 5		x			x		
Femur 6		x	x		x	x	

The lateral projection showed junction points in zones 2, 3, and 6 (Table 2). No radiolucency or pedestal signs were detected around the implants. All femurs showed radiographic signs of osseointegration. Therefore, by 12 weeks post-surgery, adequate fixation of the implants was evident on the radiographs.

Table 2. Radiographic location of the bone-implant junction areas. Lateral view.

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
Femur 1		x	x		x		
Femur 2		x				x	
Femur 3		x	x			x	
Femur 4		x	x			x	
Femur 5		x				x	
Femur 6		x	x			x	

The thermal arc spraying technique allowed for a more accurate recording of the areas where osseointegration occurred (Table 3). It was observed that the half of the cylinder with a roughness of 100-150 µm demonstrated greater osseointegration compared to the smoother half, which correlated with the radiographic and histological findings.

Table 3. Measurement of the maximum and minimum roughness of the implants used.

Rabbit 1		**Rabbit 2**		**Rabbit 3**	
Diameter	3.5 mm	Diameter	3.5 mm	Diameter	3.5 mm
Length	35 mm	Length	35 mm	Length	35 mm
Minimum roughness	**Maximum roughness**	**Minimum roughness**	**Maximum roughness**	**Minimum roughness**	**Maximum roughness**
11.59 µm	84.36 µm	7.35 µm	47.11 µm	4.61 µm	44.65 µm
7.19 µm	97.74 µm	6.12 µm	51.12 µm	6.94 µm	50.26 µm
8.56 µm	75.39 µm	9.58 µm	72.72 µm	9.38 µm	79.91 µm
Rabbit 4		**Rabbit 5**		**Rabbit 6**	
Diameter	3.5 mm	Diameter	3.5 mm	Diameter	3.5 mm
Length	35 mm	Length	35 mm	Length	35 mm
Minimum roughness	**Maximum roughness**	**Minimum roughness**	**Maximum roughness**	**Minimum roughness**	**Maximum roughness**
6.98 µm	83.03 µm	10.38 µm	137.84 µm	6.82 µm	78.35 µm
9.88 µm	53.47 µm	4.00 µm	42.77 µm	6.07 µm	54.39 µm
5.89 µm	59.20 µm	6.64 µm	82.32 µm	5.01 µm	56.18 µm

Histological Analysis

Histologically, all implants demonstrated newly formed bone tissue. Bone formation was particularly prominent in areas where the implant roughness ranged between 100 and 150 µm (Figure 9). In most samples, mature compact bone with concentric lamellae was clearly observed, along with areas of bone remodeling at the implant contact zone.

In regions with roughness below 100 µm, less mature bone development was noted at 12 weeks. However, areas of vascularized osteoid matrix formation were observed, indicating future bone formation and subsequent osseointegration (Figure 10). Overall, the results showed more new bone tissue in areas with roughness greater than 100 µm. The presence of established bone neoformation was demonstrated around all implants, though mechanical testing to assess the strength of bone adhesion could not be performed.

These findings suggest that increased roughness leads to greater osseointegration.

DISCUSSION

Hara et al.[15] demonstrated that porous titanium alloy implants with pore sizes of 500, 640, and 800 µm exhibit high bone ingrowth rates, which contributed to stronger bone bonding to these implants. However, the 1000 µm pore size resulted in a smaller bone area and a lower bone ingrowth rate at 12 weeks post-implantation, suggesting that a 1000 µm pore size may be too large to promote optimal bone ingrowth. Their findings suggest that the upper limit for optimal pore size is around 800 µm for porous titanium alloy implants.

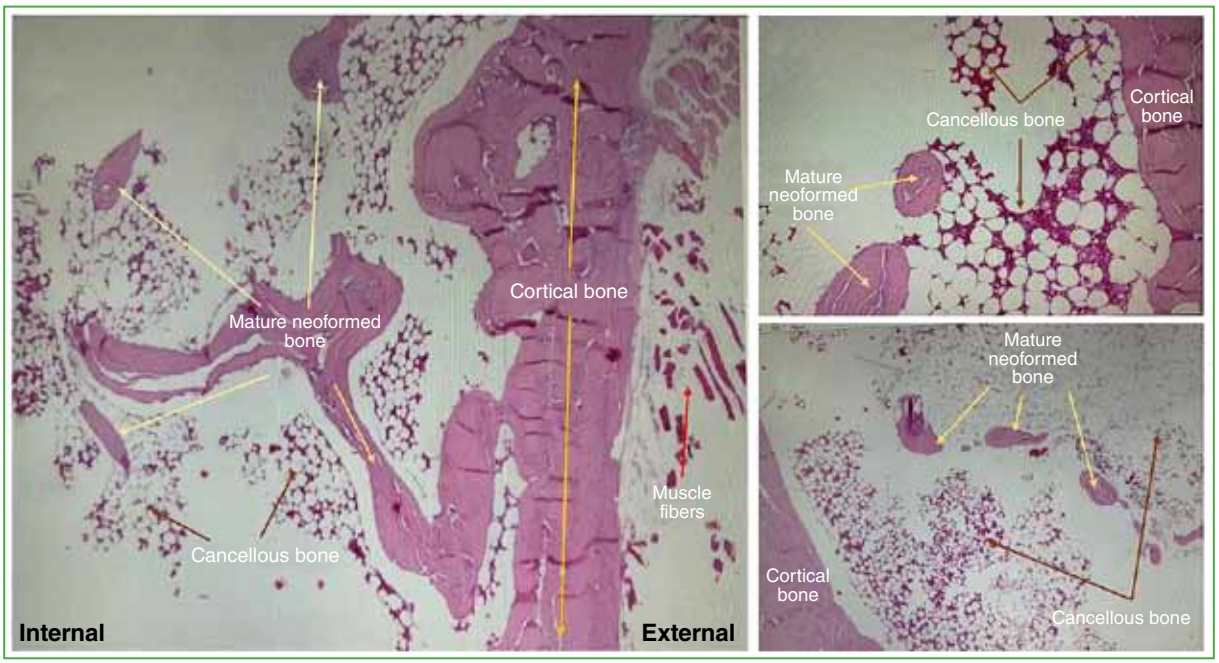

Figure 9. Histological analysis at 10x10 magnification. Mature neoformed bone is observed between the cancellous bone, which is in contact with the implant surface, indicating bone growth within the roughness.

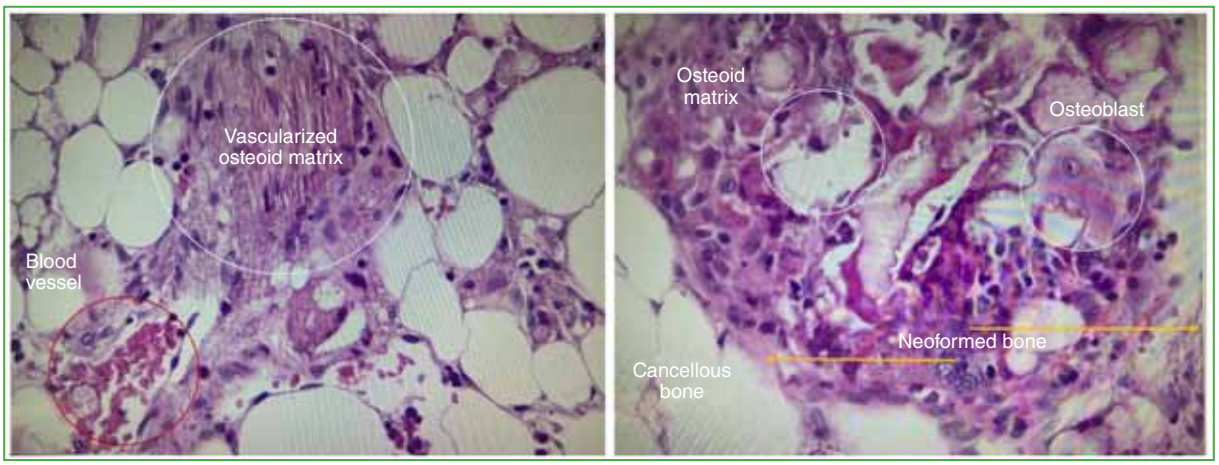

Figure 10. Histological analysis at 10x40 magnification. Tissue is visualized in a state prior to the formation of mature compact bone and osteoid matrix, osteoblasts and blood vessels.

In contrast, Hulbert et al.[16] investigated osseointegration in roughened implants generated through arc spraying and found that osteonal development requires a minimum roughness diameter between 150 and 200 µm for ceramic implants.

Similarly, several studies by Klawitter et al.[17] observed that viable osteons tend to form only when roughness sizes are between 140 and 200 µm.

Li et al.[18] reported that laser-treated surfaces require pores of at least 140 µm in diameter for osteon formation in a transcortical rabbit model.

Götz et al.[19] confirmed that bone remodeling occurs in pores with diameters of 100 µm, though with a noticeable time delay compared to larger pores. The delayed bone remodeling in 100 µm pores might compromise mechanical stability in the early weeks post-implantation, relative to implants with larger pores. Interestingly, pores of 300 µm were found to be inferior to 200 µm pores in terms of bone-to-implant contact, suggesting that larger roughness could slow osseointegration.

Our study clearly demonstrated that the greatest osseointegration occurred in areas with roughness around 100 µm. However, smaller diameter roughnesses also showed evidence of osteoid matrix formation—a precursor tissue to mature bone—which may suggest ongoing bone-implant integration, regardless of roughness size.

There are inherent limitations in the design of animal studies. As previously mentioned, the proximal femoral intramedullary implant model was developed to evaluate implant material and surface properties without the added variability of mechanical testing. Thus, this model is aimed at assessing the host's initial response to the implant and the osseointegration capacity generated upon implant contact.

The rabbits used in the study were young adults (skeletally mature), providing a bone bed that healed well due to their youth. However, the non-weight-bearing nature of the model may have introduced a favorable bias in bone ingrowth data.

Additionally, the two-dimensional assessment of bone growth rates may vary depending on section selection. A three-dimensional evaluation using computed microtomography is recommended for a more accurate assessment of bone growth. Although the small number of subjects for histological examination was a limitation, similar bone growth patterns were observed in all samples. Future studies should focus on quantifying the relationship between bone bond strength and histological bone growth.

A key strength of this study is that, to the authors' knowledge, there are no national studies in Argentina that have described the surface properties of metal produced by thermal spraying, its biological characteristics, and its osseointegration capacity in endoprostheses.

CONCLUSIONS

The surface of an implant plays a critical role in osseointegration. In this study, surfaces with roughness greater than 100 µm elicited a favorable biological response, resulting in a direct bond between the implant and bone. While this study identified osseointegration at the morphological level, future research should aim to correlate these observations with biomechanical evaluations of the implants. Expanding this research to a weight-bearing model, which would impose greater demands on the implants, would help confirm the tentative conclusions we have drawn.

Conflict of interest: Dr. Carlos A. Vega is a consultant to IMECO S. A. The the rest of the authors declare no conflicts of interest. This work was funded by IMECO S.A.

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Hip Ankylosis Caused by Heterotopic Ossification: A Case Report

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ABSTRACT

We present the case of a 59-year-old patient with heterotopic ossification in the right hip. This condition developed as a result of right hemiplegia secondary to a traumatic brain injury sustained in a traffic accident. Subsequently, the patient suffered an intracapsular fracture of the left hip, which required joint replacement surgery. Due to the patient's neurological limitations and postoperative immobility, Brooker grade IV heterotopic ossification with ankylosis developed in the non-operated hip. Surgical resection of the ossification was necessary, and it was found to be highly vascularized and in close proximity to the pelvic neurovascular bundle. Postoperatively, the patient was treated with radiation therapy and non-steroidal anti-inflammatory drugs. At the one-year follow-up, significant improvements in range of motion and independence were observed, with no signs of recurrence.

Keywords: Heterotopic ossification; hip; hip replacement; Brooker.
Level of Evidence: IV

Anquilosis de cadera por osificación heterotópica: reporte de un caso

RESUMEN

Se presenta el caso de un paciente de 59 años con una osificación heterotópica en la cadera derecha. Este trastorno se desarrolló como resultado de una hemiplejia derecha secundaria a un traumatismo craneoencefálico sufrido en un accidente de tránsito. Posteriormente, el paciente sufrió una fractura intracapsular en la cadera izquierda que requirió una cirugía de reemplazo articular. Debido a sus limitaciones, derivadas de su condición neurológica y el reposo posoperatorio, se desarrolló una osificación heterotópica grado IV de Brooker, con anquilosis en la cadera no operada. Esta osificación requirió una resección quirúrgica, se detectó una notoria vascularización y proximidad al paquete neurovascular inguinal. Luego de la cirugía, el paciente recibió radioterapia y antinflamatorios no esteroides. Se observó una notable mejoría en los arcos de movilidad y en la independencia durante el seguimiento de un año, sin evidencia de recurrencias.

Palabras clave: Osificación heterotópica; cadera; reemplazo articular de cadera; clasificación de Brooker.
Nivel de Evidencia: IV

INTRODUCTION

Heterotopic ossification (HO) is defined as the formation of lamellar bone in non-skeletal tissues, such as muscles, tendons, or other soft tissues. Although its etiology remains unknown, it is frequently observed in bedridden patients, those with traumatic brain injury (TBI), spinal cord injuries, or those who have undergone orthopedic surgery, as well as individuals experiencing tissue hypoxia, inflammatory states, burns, or who have a genetic predisposition.[1] HO was first described in 1883 by Reidel, but it was not until 1918 that Dejerine and Ceillier noted a higher prevalence of HO among soldiers who had suffered spinal cord trauma during World War I.[2]

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The annual prevalence of HO is approximately 1.3% over a 10-year period, with the most frequently affected joints being the hip (89.4%), knee (15.7%), elbow (14.5%), and shoulder (8.5%). Typically, the condition correlates with the side of the body that experienced trauma or neurological sequelae: in 83% of cases, HO is ipsilateral; in 14.9%, it is bilateral; and in 2.12%, it is contralateral. [3]

The absence of specific signs and symptoms makes HO a diagnostic challenge, especially in its early stages. Early-stage HO may present with pain, fever, edema, erythema, and mild reduction in the range of motion. At this stage, it can be mistaken for soft tissue infections, cellulitis, thrombophlebitis, or osteomyelitis. Eventually, it can lead to severe restriction of motion and complete joint ankylosis. [2]

We present a clinical case of severe spontaneous HO of the hip, of atraumatic origin, secondary to immobility and hemiplegia due to TBI in a 59-year-old patient.

CLINICAL CASE

The patient is a 59-year-old man who sustained a severe TBI in a motorcycle accident on January 21, 2021. The accident required a craniotomy and drainage of an intraparenchymal hematoma in the left temporoparietal region. As a result of the accident, he developed right hemiplegia and mixed aphasia with a predominance of motor impairment. In March 2021, the patient experienced a seizure that caused a fall, resulting in an intracapsular fracture of the left hip. At another medical center, he underwent hip replacement surgery with a dual-mobility cup prosthesis.

He was later referred to the specialized hip team for evaluation. Radiographic follow-ups revealed a bony bridging formation of HO extending from the femoral neck to the iliac wing on the non-operated hip. This condition was classified as Brooker grade IV HO, attributed to immobility and hemiplegia, leading to ankylosis and a flexion contracture limiting the range of motion to 45°. This restriction made sitting, independent mobilization, and walking difficult.

A pelvic CT scan was requested to assist in treatment planning, and the patient was evaluated by the Physiatry and Anesthesiology teams (Figure 1).

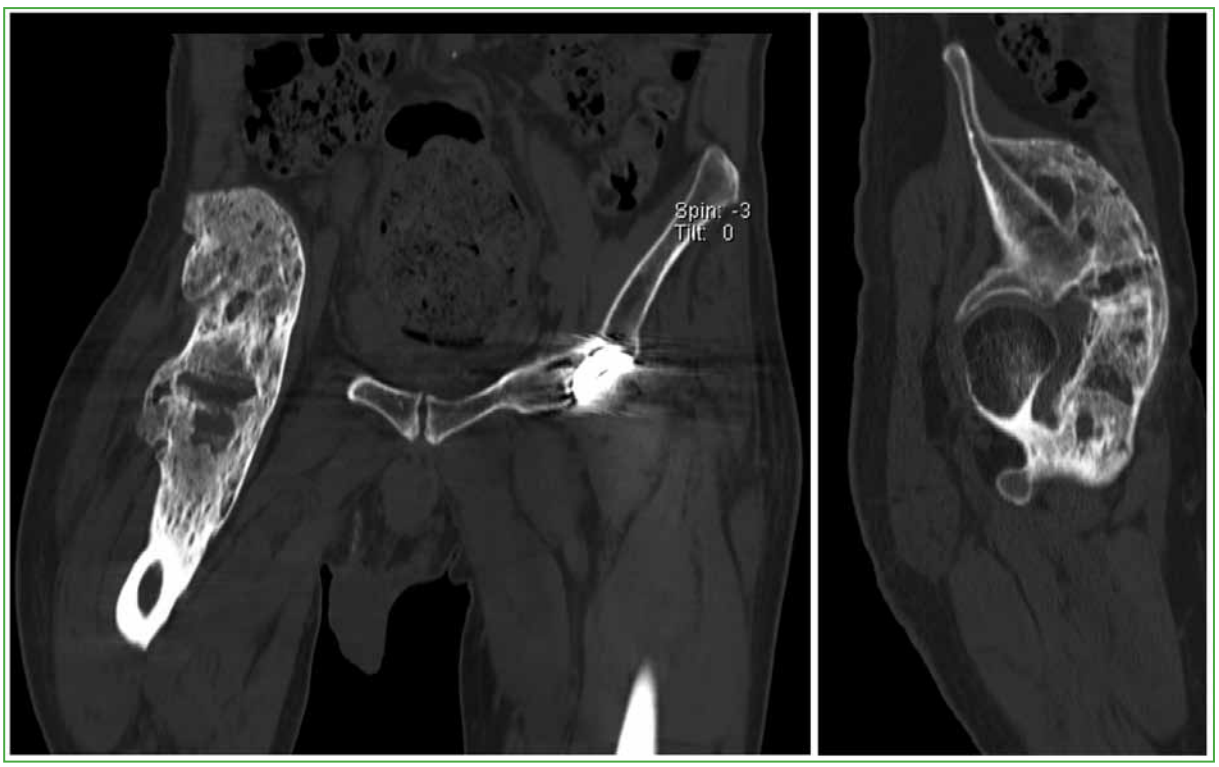

Figure 1. Computed tomography of the pelvis. Heterotopic ossification formation with bony bridging from the femoral neck to the iliac crest at the level of the non-operated hip. Brooker classification grade IV. [8]

The Physiatry team recommended starting physical therapy, along with the application of local antispasticity treatment to the hamstring muscles, in order to improve the gait pattern. While there was some improvement, the patient did not achieve independent walking. As a result, the decision was made to proceed with surgical resection of the HO, performed by the hip surgery and orthopedic oncology team.

During surgery, a Brooker grade IV HO was confirmed, with involvement from the acetabular rim to the lesser trochanter of the right hip, and significant vascularity was noted within the lesion. An iliofemoral approach to the right hip was made, during which the vessels and femoral nerve were identified and retracted medially. Proximal and distal dissection was performed to locate both foci of ossification, followed by a central osteotomy. The medial third and distal region were resected, and an additional osteotomy was performed at the level of the lesser trochanter. The hip capsule was exposed, and a proximal osteotomy was performed, removing the ossification en bloc. The range of motion was then reassessed, showing significant improvement, and hip stability was confirmed (Figure 2). The procedure concluded with the application of hydrogen peroxide, irrigation with 3000 cc of 0.9% saline, meticulous hemostasis, and the use of bone wax. Two Spongostan® sponges were left in place due to significant bleeding, necessitating observation in the Intensive Care Unit. The patient received a transfusion of 5 units of red blood cells, 3 units of fresh plasma, and an apheresis of platelets, in addition to vasopressor support.

A consultation with the radiotherapy team resulted in a recommendation for 3D conformal radiotherapy to the hip. Celecoxib was prescribed for 30 days.

Figure 2. A. Flexion contracture, before surgery, under general anesthesia. **B.** Recovery of extension in the immediate postoperative period.

Immediate post-operative radiographic follow-up and imaging three months later (Figures 3 and 4) confirmed complete resection of the ossification. Clinically, one year after surgery, the patient demonstrated marked improvement in the range of motion, achieving full extension and 110° of flexion. He resumed walking with the aid of a walker and continues physical therapy and quadriceps strengthening under the supervision of the Physiatry team, with no additional pain or complications to date.

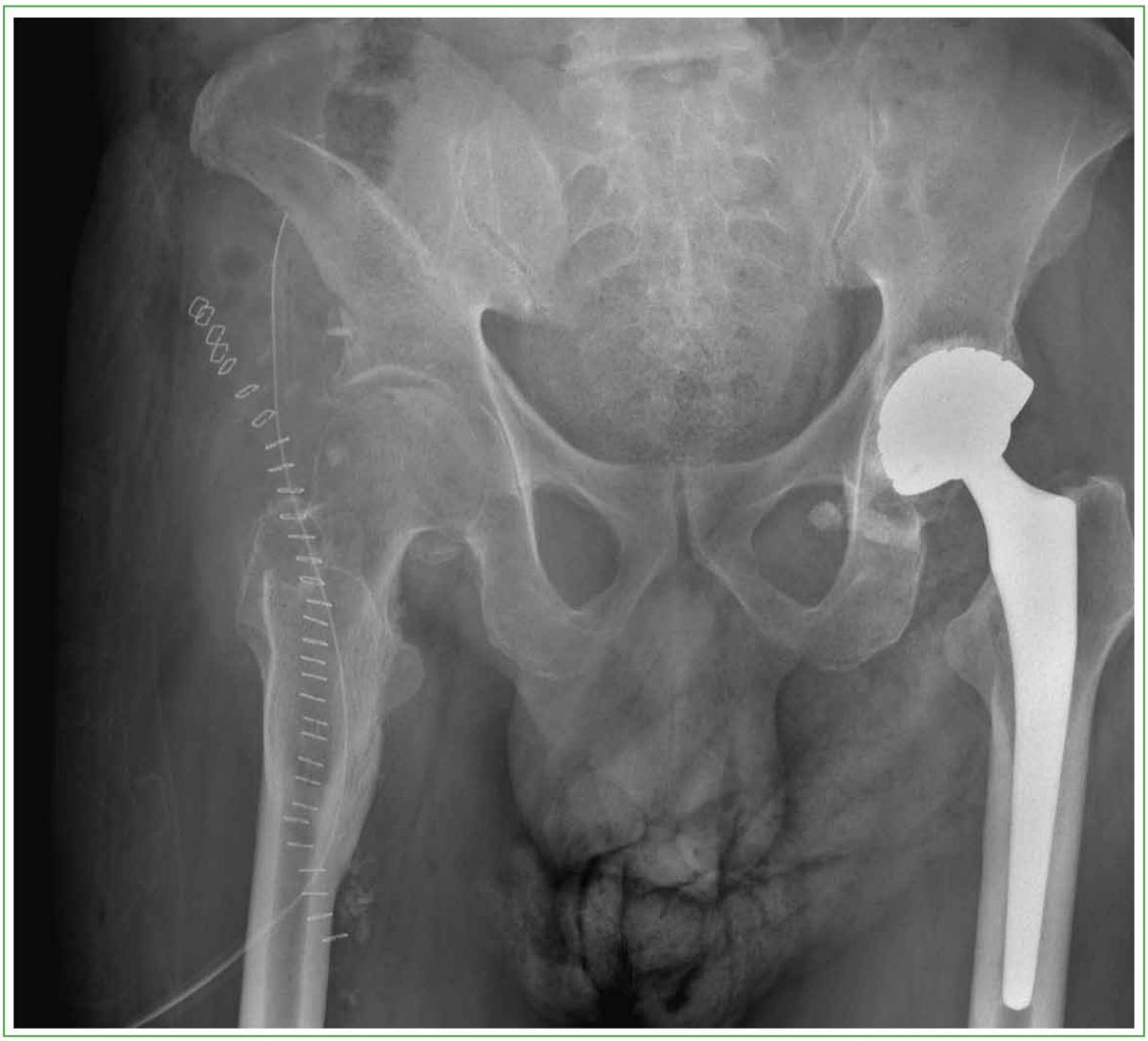

Figure 3. Anteroposterior follow-up radiograph of the pelvis in the immediate postoperative period. Wide bone resection and recovery of normal anatomy.

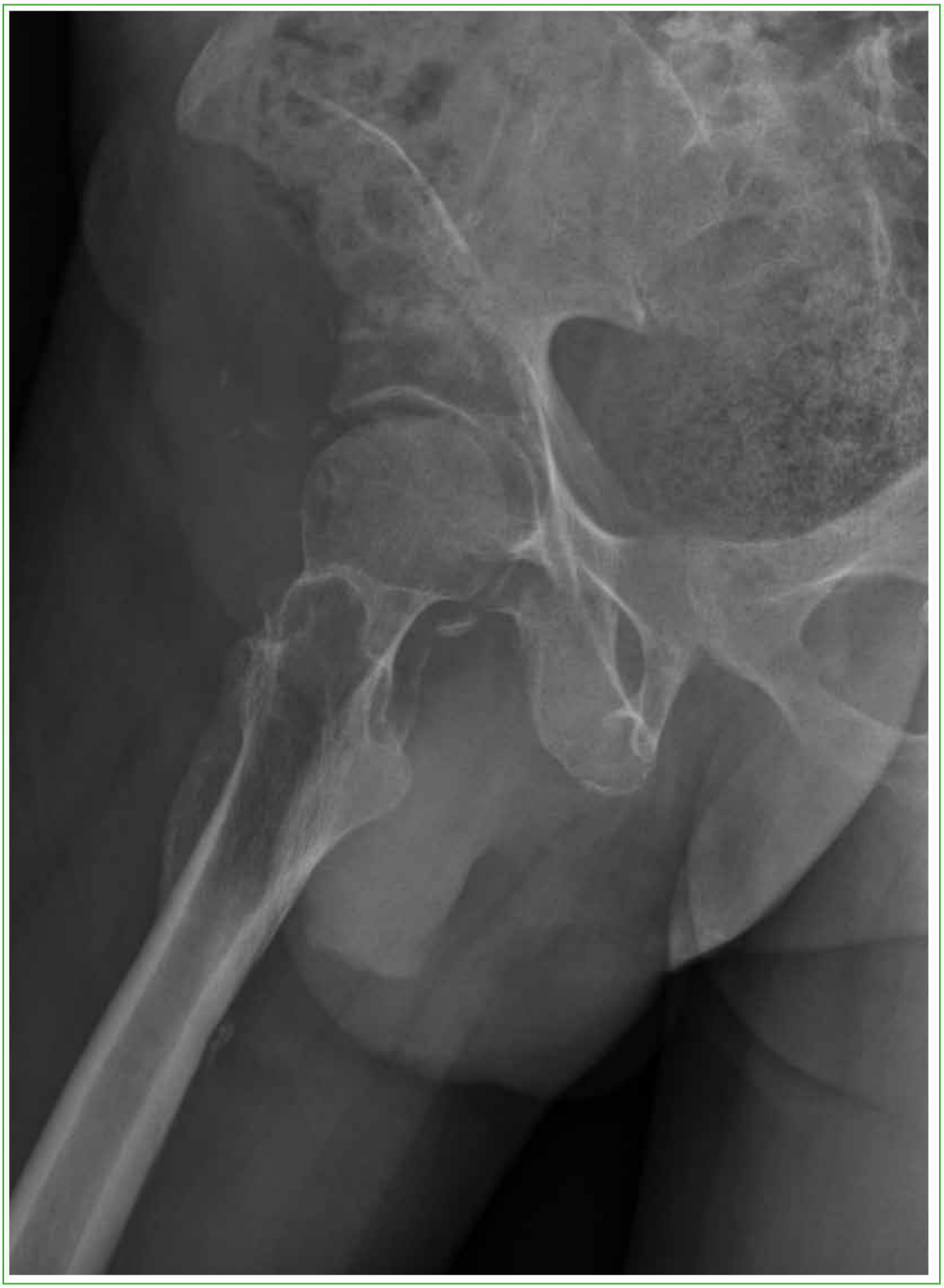

Figure 4. Follow-up radiograph three months after surgery. Resection and preserved anatomy.

DISCUSSION

Heterotopic ossification (HO), also known as hypertrophic osteoarthropathy or myositis ossificans, is a common condition characterized by the ectopic formation of bone tissue in soft tissues. It can be classified by both etiology and severity. In terms of etiology, it may be congenital or acquired. Among congenital conditions, fibrodysplasia ossificans progressiva and progressive osseous heteroplasia are specifically associated with extensive ectopic bone formation. However, causes of acquired origin are more prevalent, occurring in 44% of patients undergoing arthroscopy or hip replacement, 10-20% of those with central nervous system or spinal cord injuries, and 4% of those with burns affecting more than 30% of their body surface.[4-6] DeBaun et al. reported rates of up to 90% and 40% of HO in patients undergoing total hip arthroplasty and open reduction with internal fixation of the hip, respectively.[7] In terms of severity, the Brooker classification has historically been used to assess the level of ossification, with grade IV representing the most severe form, including bony ankylosis of the joint (Table).[8]

Table. Brooker's classification

Type I	Bone islands within soft tissues
Type II	Ossification originating from the pelvis or proximal femur, leaving at least 1 cm between opposing bone surfaces
Type III	Ossification originating from the pelvis or proximal femur, reducing the space between opposing bone surfaces to less than 1 cm
Type IV	Ossification that makes a complete bridge between the proximal femur and the pelvis (bone ankylosis).

The pathophysiological mechanisms underlying HO formation are not yet fully understood. The literature suggests a variety of possible precursor cells, including myosatellite cells, smooth-muscle cells, and even endothelial cells.[9] The presence of multipotent cells in local tissues has been identified as a trigger for this condition. HO formation requires an inducing agent, an osteogenic precursor, and a conducive environment for osteogenesis.[9] Bidner et al. propose that dysregulation of the immune system leads to an uncontrolled inflammatory response, which releases factors that promote HO.[10] Further research by Salisbury et al. identifies bone morphogenetic protein 2 as a proinflammatory agent that stimulates the release of substance P and calcitonin gene-related peptide from sensory nerves.[11] Other proposed contributors include prostaglandins, specifically prostaglandin E2, which mediates progenitor cell differentiation, as well as tissue hypoxia and imbalances between parathyroid hormone and calcitonin.[2] Kurer et al. conducted a study using blood samples from four paraplegic patients with HO and four without. The samples were incubated with human osteoblasts in tissue culture, and their metabolic activity was quantitatively measured. The results showed that patients with abnormal bone formation had significantly higher levels of factors stimulating osteoblastic activity, potentially contributing to HO pathogenesis.[12] A review by Cholok et al. highlights the involvement of multiple potential cell lineages and signaling pathways, underscoring the current lack of comprehensive understanding of HO formation.[13] In summary, the exact mechanisms underlying HO remain unclear and require further investigation.

Computed tomography (CT) optimizes preoperative planning by providing enhanced three-dimensional visualization of HO in relation to relevant anatomical landmarks. In certain cases, magnetic resonance imaging (MRI) may be necessary to define more precisely the extent of neurovascular or local soft tissue involvement. These imaging studies are most effective when HO is located near anatomical structures within the potential operative field.[14]

Multiple pharmacological and non-pharmacological interventions have been described for preventing HO. These include non-steroidal anti-inflammatory drugs (NSAIDs), both selective and non-selective, radiotherapy, physiotherapy, and combinations of these strategies.

Selective and Non-selective Non-steroidal Anti-inflammatory Drugs

NSAIDs prevent HO by inhibiting the osteogenic differentiation of progenitor cells. Prostaglandin E2 plays an important role in HO formation, fracture healing, and bone regeneration.[15,16] Numerous dosing regimens are used; indomethacin is the most common non-selective NSAID for HO prophylaxis in patients undergoing total hip arthroplasty. A dose of 75-100 mg/day is typically administered 24-48 hours before surgery and continued for 7-14 days.[17] A large meta-analysis, which included both randomized clinical trials and observational studies, found that both selective and non-selective NSAIDs reduced the risk of HO after total hip arthroplasty compared with placebo (odds ratio [OR] -1.35; 95% confidence interval [CI] -1.83 to -0.86, and OR -1.58; 95% CI -2.41 to -0.75, respectively).[18]

While NSAIDs are effective for HO prophylaxis, their impact on fracture healing should also be considered. HO prophylaxis with indomethacin increases the risk of pseudarthrosis in long bones and exposes patients who are also on anticoagulation therapy for other medical conditions to a higher risk of bleeding. Given these risks, NSAIDs should be administered with caution following orthopedic injuries due to the potential risk of pseudarthrosis. Consideration should be given to using NSAIDs alongside proton pump inhibitors to reduce the risk of gastroduodenal injury and subsequent gastrointestinal bleeding. The optimal timing, dosage, and duration of NSAID therapy for HO prophylaxis remain to be determined.

Radiotherapy

Radiation therapy has shown good results in the hip; however, the effectiveness of radiation prophylaxis in joints other than the hip has not been adequately studied. Radiation can be administered at a dose of 700-800 cGy in a single fraction, from 24 hours preoperatively to 48-72 hours postoperatively.[21] Both preoperative and postoperative radiation have been found to be equally effective in the hip, with no significant differences in complication rates.[22] Although no cases of malignancy have been reported following prophylactic radiation, it remains a theoretical risk. Additional potential side effects include progressive soft tissue contracture, delayed wound healing, pseudarthrosis, and inhibition of press-fit hip implant ingrowth. [23]

Physical Therapy

There are differing opinions on the value of physical therapy in the treatment of HO, as there is no clear evidence regarding the effect of joint motion on the progression of the condition. Some believe that excessive movement immediately after injury exacerbates HO, while others argue that the condition progresses due to insufficient movement. Although there is no consensus, physical therapy may be beneficial when worsening range of motion begins to limit daily function.[24]

In a meta-analysis comparing radiotherapy and NSAIDs for the prevention of HO after major hip surgeries, Pakos et al. found that radiotherapy tended to be more effective than NSAIDs in preventing Brooker grade III or IV HO (relative risk 0.42; 95% confidence interval [CI] 0.18-0.97) or any grade of HO (relative risk 0.75; 95% CI 0.37-1.71). However, there was significant heterogeneity between studies in the latter analysis. The overall absolute risk difference for Brooker grade III or IV was small (-1.18%; 95% CI -2.45% to 0.09%).[25]

CONCLUSIONS

HO is a significant concern in patients with the aforementioned risk factors. Despite the multiple theories surrounding its pathophysiology, the impact of HO can be severe in advanced stages, potentially leading to bony ankylosis that severely limits joint mobility, as seen in the presented patient with severe atraumatic HO secondary to rest and hemiplegia due to traumatic brain injury (TBI). Therefore, comprehensive medical management—including physiotherapy, NSAIDs, and radiotherapy—is essential to reduce the risk, progression, and recurrence of HO. Additionally, surgical intervention should be considered a crucial option, as it becomes the mainstay treatment to improve quality of life and mobility.

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Loosening of Total Knee Arthroplasty Associated with Pigmented Villonodular Synovitis: Case Presentation and Literature Review

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ABSTRACT
Introduction: Pigmented villonodular synovitis (PVNS) in patients with total knee arthroplasty (TKA) is a rare condition with an unclear etiology that can cause pain, hemarthrosis, or, less commonly, prosthetic loosening. We present the case of a 54-year-old male patient with a left TKA who developed pain and joint effusion three months postoperatively. Radiographs showed signs of loosening, and due to suspicion of infection, a two-stage revision surgery was performed one year after the initial procedure. Pathological synovial tissue was identified, and a radical synovectomy was carried out during the first stage of revision. Histopathological analysis confirmed PVNS. At three years postoperatively, the patient exhibited satisfactory functional recovery with no signs of recurrence. **Conclusion:** Considering PVNS as a differential diagnosis in cases of postoperative pain and hemarthrosis is crucial for early diagnosis and appropriate treatment.
Keywords: Pigmented villonodular synovitis; total knee arthroplasty; revision total knee arthroplasty; hemarthrosis.
Level of Evidence: IV

Aflojamiento de la artroplastia total de rodilla asociado a sinovitis vellonodular pigmentada. Presentación de un caso y revisión bibliográfica

RESUMEN
Introducción: La sinovitis vellonodular pigmentada en pacientes sometidos a una artroplastia total de rodilla es un cuadro muy raro, de causa poco clara, que puede provocar dolor, hemartrosis o, con menos frecuencia, aflojamiento de la prótesis. Presentamos el caso de un hombre de 54 años sometido a una artroplastia total de rodilla izquierda, que evolucionó con dolor y derrame articular a los tres meses de la operación. En las radiografías, se observaron signos de aflojamiento y, ante la sospecha de infección, se indicó la revisión en dos tiempos al año de la cirugía. Se detectó alteración del tejido sinovial y se procedió a la sinovectomía radical durante el primer tiempo quirúrgico. El análisis histopatológico confirmó una sinovitis vellonodular pigmentada. A los tres años de la cirugía, la recuperación funcional y clínica era satisfactoria, sin recurrencias. **Conclusión:** Es esencial sospechar una sinovitis vellonodular pigmentada como alternativa diagnóstica en casos de dolor y hemartrosis, para llegar a un diagnóstico precoz y brindar un tratamiento apropiado.
Palabras clave: Sinovitis vellonodular pigmentada; artroplastia total de rodilla; revisión de artroplastia total de rodilla; hemartrosis.
Nivel de Evidencia: IV

INTRODUCTION

Pigmented villonodular synovitis (PVNS) was first described by Chassignac in 1852 as a nodular lesion in the sheath of a flexor tendon of the hand.[1] In 1864, its localized form was described in the knee.[2] PVNS is a benign disease of the synovial tissue, characterized by low incidence but local aggressive potential. It can be localized either intra- or extra-articularly, with the intra-articular form further classified into localized or diffuse types.[1,2] The knee is the most commonly affected joint, followed by the hip, ankle, and shoulder.[1] The true etiology of PVNS remains unclear, though hypotheses suggest chronic synovial inflammation triggered by microtrauma, recurrent

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hemarthrosis, or metabolic changes as potential causes.[1] In recent years, increasing evidence supports the possibility of a neoplastic origin for PVNS.[1,3] Genetic studies have identified chromosomal translocations that enhance cytokine expression, promoting the proliferation and differentiation of cells involved in PVNS, such as macrophages and multinucleated giant cells, which synthesize tissue-destructive molecules.[1] Clinically, PVNS typically presents with pain, joint effusion, and, less commonly, stiffness or a palpable mass.[1,2] MRI is the imaging modality of choice, while histopathological analysis confirms the diagnosis, revealing papillary synovial hyperplasia composed of multinucleated and mononucleated histiocyte-like giant cells with hemosiderin deposits.[1,3] Treatment varies depending on the form, clinical presentation, and disease progression, but synovectomy—either open or arthroscopic—is the standard intervention, often supplemented by radiotherapy or biological therapies that target cell signaling pathways.[1]

In patients with joint replacements, chronic synovitis may develop due to a reaction to polymer particles from polyethylene, cement, metal, ceramic, or corrosion, mimicking PVNS.[3-5] However, PVNS following total knee arthroplasty (TKA) is exceedingly rare, and its etiology remains unclear.[6-9] Several hypotheses have been proposed: some suggest that PVNS arises spontaneously, with no direct relation to the prosthetic implant, thus presenting the same risk as a native knee; others propose that an irritative stimulus may induce chronic synovitis, leading to recurrent hemorrhage and hemosiderin deposition.[6,7,9-11]

In these patients, PVNS may manifest as pain, hemarthrosis, or prosthetic loosening. The recommended treatment is radical synovectomy to minimize the risk of recurrence.[6-8]

Evidence regarding PVNS in patients with TKA is limited to case reports. We present a case of early prosthetic loosening following TKA due to PVNS, along with a review of the literature.

CLINICAL CASE

A 54-year-old man who had undergone a right TKA one year earlier required mobilization under anesthesia one month post-surgery at our center. He initially presented with severe left knee pain, which severely limited his daily activities and had not improved despite six months of conservative treatment. On physical examination, his range of motion was 0° to 100°, with no coronal or sagittal instability. Preoperative pain, assessed using the visual analog scale (VAS), was 9/10, and his preoperative Knee Society Score (KSS) was 44/60.[12] Anteroposterior and lateral radiographs of the knee confirmed a diagnosis of genu varum osteoarthritis (Figure 1).

A left TKA was performed using a standard anterior approach with medial parapatellar arthrotomy. No macroscopic abnormalities of the synovial tissue were observed, so no resection was performed. A cemented posterior-stabilized prosthesis was implanted without patellar resurfacing (FHK®, FH ORTHO, France). Proper alignment and stability in extension, flexion, and mid-flexion were achieved (Figure 2).

Three months postoperatively, the patient experienced pain both at rest and during activity, recurrent joint effusion, a mass in the subquadricipital recess, and limited flexion to 90° (Figure 3). The surgical wound had healed, with no signs of erythema or increased temperature, and no coronal or sagittal plane instability was detected. Given the failure of analgesics and physical therapy, arthrocentesis was performed six months after surgery, yielding hemorrhagic fluid without bacterial growth. Seven months postoperatively, follow-up radiographs revealed a radiolucent area in zones 1-2 of the Knee Society classification, suggestive of early prosthetic loosening.[13] (Figure 4).

The patient subsequently experienced intermittent low-grade fever (up to 37.5°C), and laboratory tests showed elevated acute phase reactants: erythrocyte sedimentation rate (ESR) of 35 mm/h (normal range: 2-20) and C-reactive protein (CRP) of 22 mg/L (normal value: <7). Considering the mechanical pain, joint effusion, low-grade fever, radiolucent findings, and altered infection markers, the case was interpreted as possible septic loosening. A two-stage revision surgery was planned. The first stage was performed one year after the initial TKA. Intraoperatively, hypertrophic, hyperemic, and brownish-pigmented synovial tissue was observed (Figure 5). Both prosthetic components were loose, but there were no signs of polyethylene or prosthetic material wear. With improved exposure, radical synovectomy was completed, and multiple bone, periprosthetic tissue, and interface samples were taken for culture and histopathologic analysis. A handmade articulating spacer composed of antibiotic-loaded cement (tobramycin and vancomycin) was placed. *Staphylococcus epidermidis* was isolated from one of the culture samples. Despite this finding, in consultation with the infectious disease team, antibiotic therapy was administered per the periprosthetic infection protocol. Three weeks later, the histopathological study confirmed a diagnosis of PVNS (Figure 6).

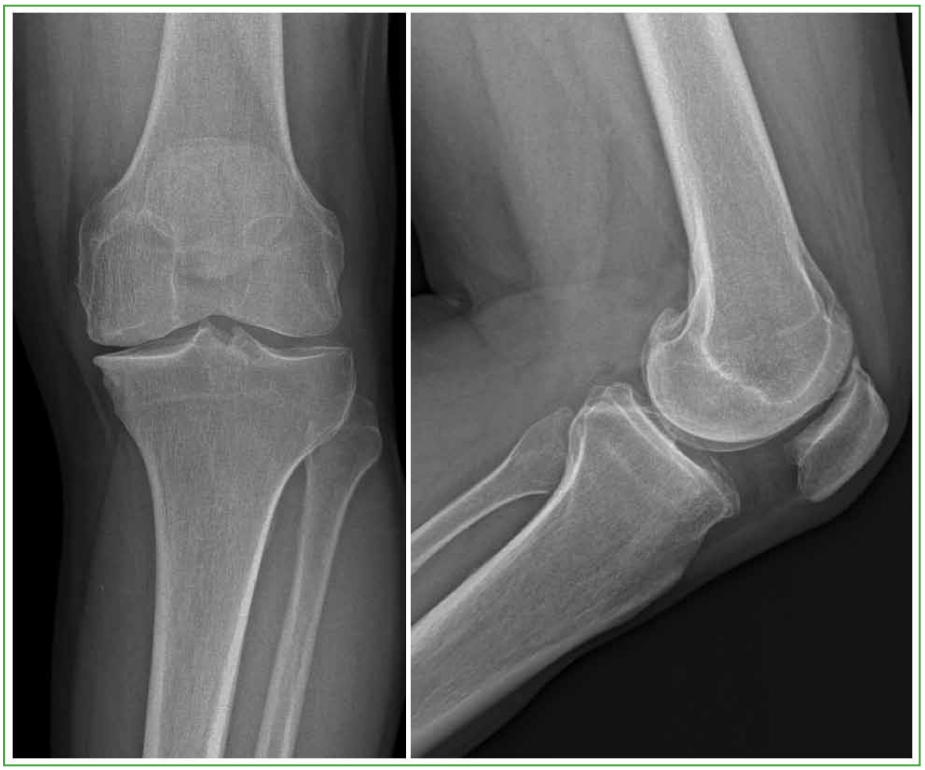

Figure 1. Anteroposterior and lateral radiographs of the left knee. Knee osteoarthritis is observed with greater involvement of the medial compartment.

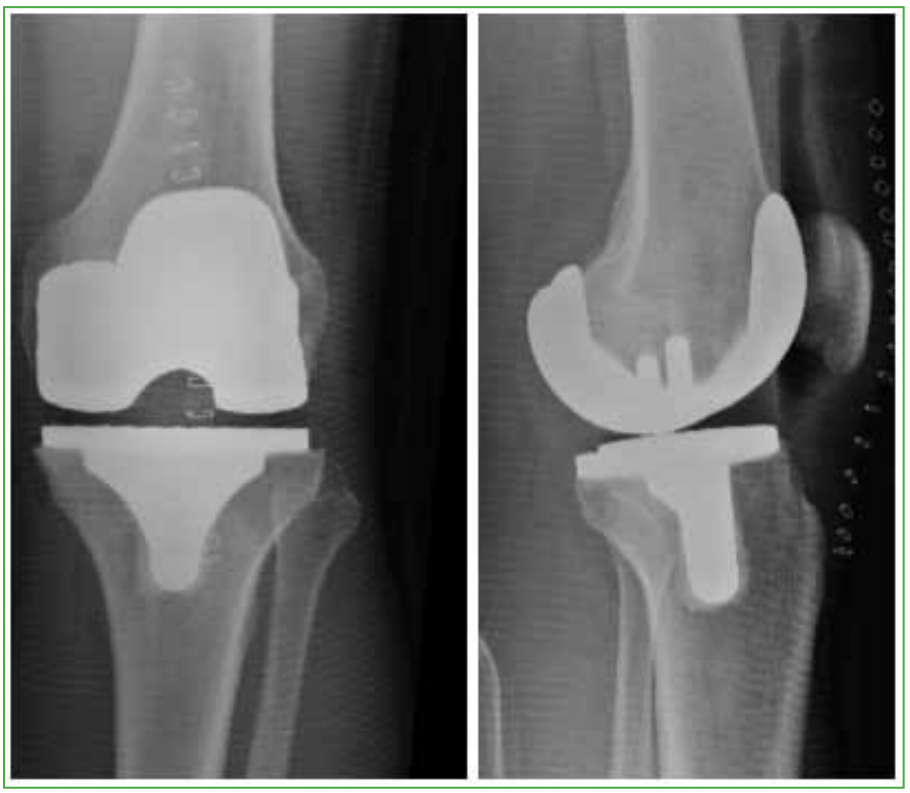

Figure 2. Anteroposterior and lateral radiographs of the left knee in the immediate postoperative period.

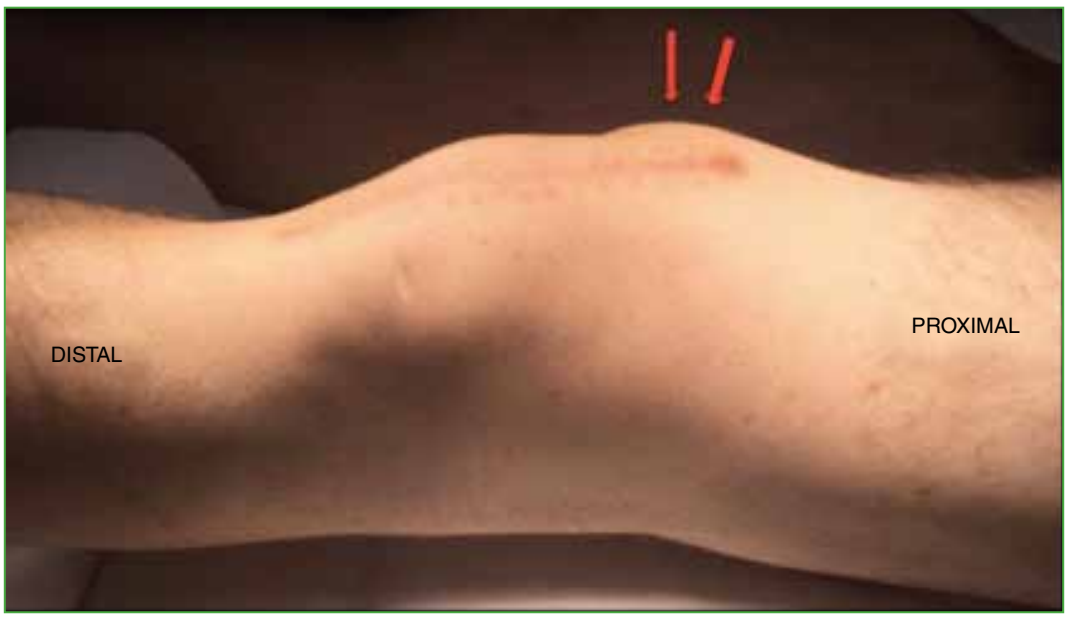

Figure 3. Clinical image three months after surgery. The arrows show the joint effusion in the subquadricipital recess.

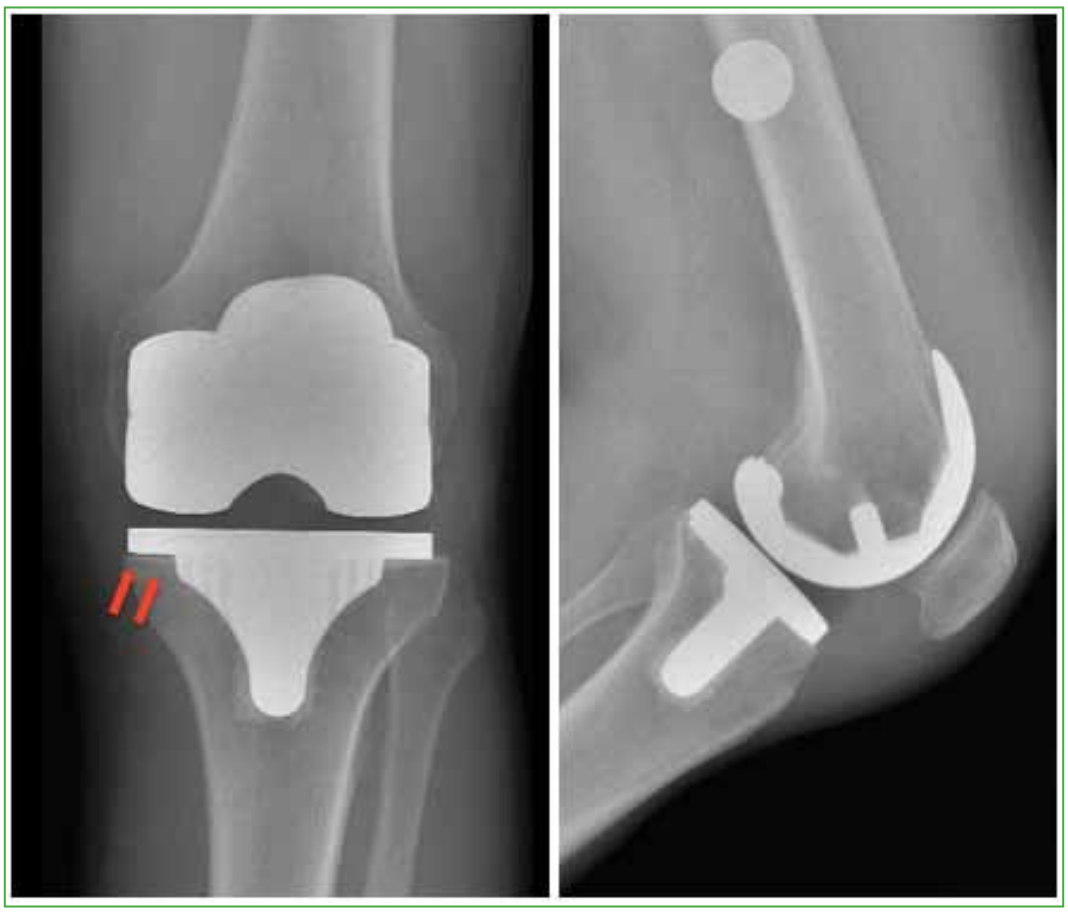

Figure 4. Anteroposterior and lateral radiographs of the left knee. A radiolucent image is observed, in the AP projection, in zones 1 and 2 of the Knee Society classification.

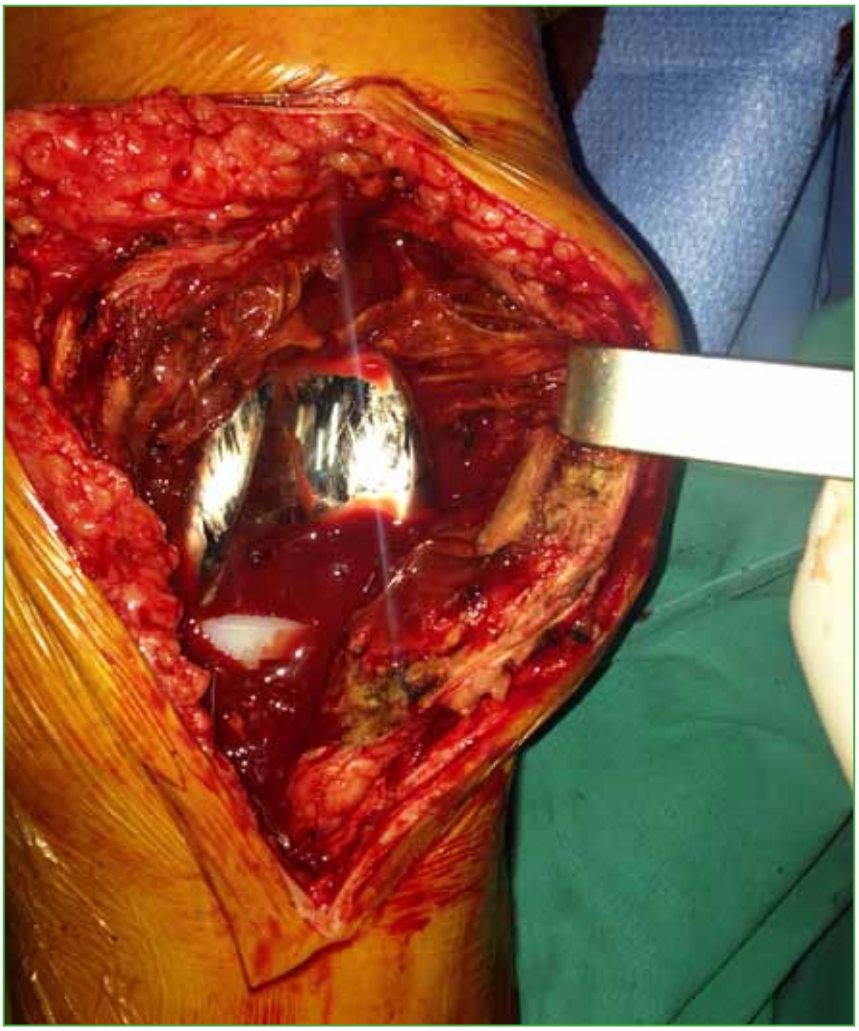

Figure 5. Intraoperative image during the first stage of revision. Hypertrophic and brownish synovial tissue is observed.

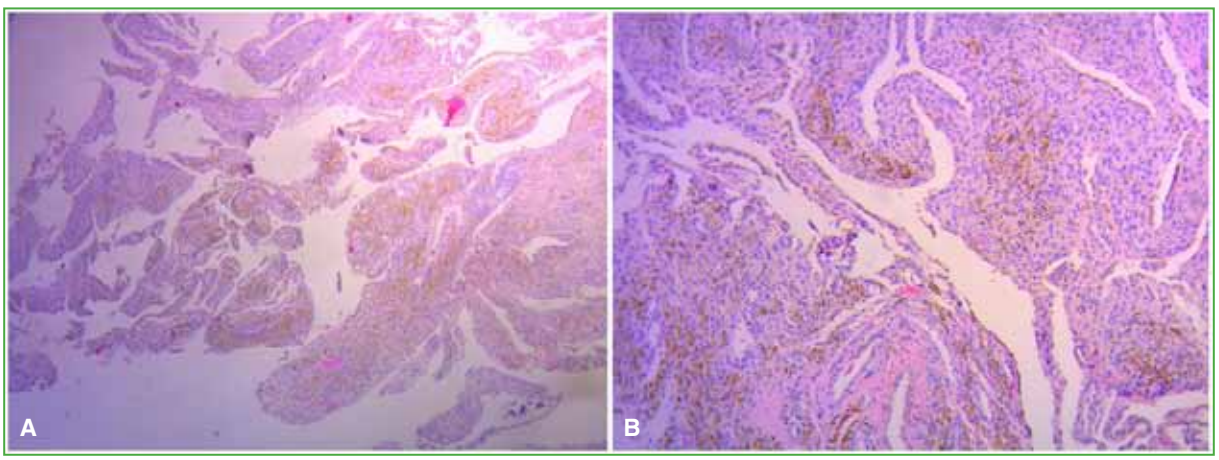

Figure 6. Images of the histological study. The villonodular architecture is observed (**A**) composed of polygonal synovial cells, macrophages and multinucleated giant cells loaded with hemosiderin, and fibrous stroma (**B**). Hematoxylin-eosin staining at x4 (**A**) and x10 (**B**) magnification.

The patient continued antibiotic therapy for seven weeks. At week 10, given the favorable clinical course and reduced infection markers, the second stage of revision surgery was performed. No pathological changes were observed in the periprosthetic tissue, as confirmed by histopathological analysis. The spacer was removed, and a cemented revision prosthesis with a constrained liner and stems was implanted in both the femur and tibia (Triathlon®, Stryker, USA) (Figure 7).

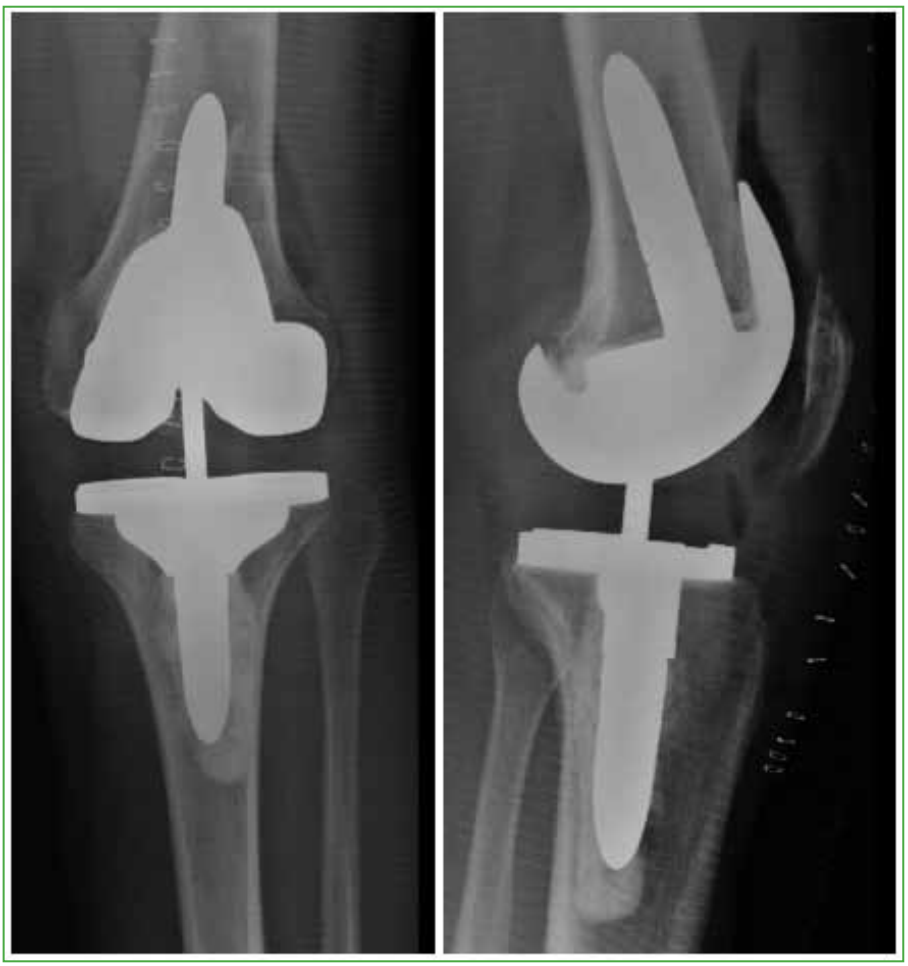

Figure 7. Anteroposterior and lateral radiographs of the left knee after the second stage of revision.

The patient's postoperative course was satisfactory, and he resumed daily activities without pain. At the three-year follow-up, he exhibited mild chronic swelling in the subquadricipital recess, which was not painful. His range of motion was 0° to 110°, with a VAS pain score of 2/10 and a Knee Society Score of 92/90. Radiographs showed no signs of prosthetic loosening.

DISCUSSION

In our patient, PVNS after TKA presented clinically with recurrent joint pain and effusion three months postoperatively. Radiographs revealed a new radiolucent area around the tibial baseplate, interpreted as prosthetic loosening. One year after the initial surgery, the patient underwent a radical synovectomy and two-stage revision for suspected septic loosening, with histological analysis confirming the diagnosis of PVNS.

To our knowledge, publications on PVNS in knee replacement patients are limited to case reports. Hypotheses regarding the occurrence of PVNS in joint replacement patients are varied. Some suggest that its appearance is spontaneous, unrelated to the TKA, while others propose that the trauma of surgery may predispose the patient to PVNS.[10,11,14] The most widely accepted—though debated—hypothesis posits that chronic synovitis forms the basis for PVNS, exacerbated by inflammatory, immunological, or toxic reactions, along with recurrent hemorrhages caused by microtrauma. These microtraumas may result from soft tissue friction due to clinical or subclinical instability, poor implant positioning, or oversized implants.[6-8,15]

In 2004, a consensus classification of periprosthetic and neo-synovial membranes (formerly referred to as "synovial-like interface membranes") was established in Germany. This classification categorizes aseptic and septic implant failures based on easily reproducible histopathological criteria.[16] It has gained international recognition and has evolved through successive updates to the version known today, summarized in Table 1.[4]

Table 1. Types of periprosthetic tissue pathology recognized in conventional histological examination.[4]

Type I	Neo-synovial/periprosthetic membrane of particle-induced type
Type II	Neo-synovial/periprosthetic membrane of infectious type
Type III	Neo-synovial/periprosthetic membrane of combined type
Type IV	Neo-synovial/periprosthetic membrane of fibrous type without particles
Type V	Endoprosthesis-induced arthrofibrosis
Type VI	Bone diseases

The most common type of periprosthetic membrane is particle-induced (type I), characterized by synovial hyperplasia with macrophages and multinucleated cells containing polyethylene, cement, metal, or wear debris particles, along with variable lymphocytic infiltrates and particle-induced necrosis.[4] Another type is the PVNS-like membrane, which is distinguished by the presence of wear particles, villonodular histological architecture, and giant multinucleated cells from foreign body reactions, with minimal or no hemosiderin deposits.[3] Conversely, true PVNS membranes exhibit villonodular architecture, contain multinucleated and mononucleated cells and a fibroblastic stroma, lack wear particles, and show clear hemosiderin deposits.[3,6,7] Despite clear histopathological differences, these membranes can be clinically indistinguishable, all presenting with pain, joint effusion, and limited range of motion.[5,6,17] They can also cause aseptic loosening due to macrophage activation and the release of proinflammatory cytokines, which stimulate osteoclasts and other inflammatory cells. Distinguishing between these membranes is crucial because PVNS has a higher recurrence risk (up to 50%) compared to other types, which are more manageable by addressing the underlying stimuli.[1,18]

The published cases share similarities with ours. In all, the synovium appeared benign during the initial TKA or unicompartmental replacement surgery, supporting the theory that PVNS develops postoperatively.[6-11,15,17,18] Clinical manifestations were similar, characterized by pain of insidious onset over several months, joint effusion, limited range of motion, and occasionally a palpable mass.[6,7,11] However, unlike our case, where symptoms began three months postoperatively, other reported cases developed symptoms between one and nine years after surgery. Many patients, including ours, were initially evaluated for suspected periprosthetic infection, underwent arthrocentesis, and hemorrhagic fluid was collected without bacterial identification.[6,9,10] Due to poor response to conservative treatment, surgery was performed in all cases, either arthroscopically or through open surgery. Localized or diffuse brown or yellow hypertrophic synovial tissue was resected, and in some cases, prosthetic revision was carried out based on intraoperative findings.[6,7,9,17,18] Notably, no polyethylene wear was

observed in almost all cases, supporting the concept that PVNS does not involve wear particles in histological studies.[6,8,9,11,15] Histopathological confirmation of PVNS was achieved in all cases, with no recurrences reported, although follow-up periods varied. The key findings from published cases are summarized in Table 2.

Table 2. Summary of case reports of pigmented villonodular synovitis in patients with knee joint replacement.

Author (year)	Patient	Clinical manifestations/Studies	Treatment/Results
Ballard et al.[10] (1993).	- 67-year-old man - Right primary cemented TKA, 9 years before	- Diffuse knee pain and joint effusion of 2 months of evolution. - Hemorrhagic arthrocentesis without germ isolation	- Extensive open synovectomy - Diffuse PVNS - Good evolution, no recurrence six months after surgery.
Bunting et al.[11] (2007).	- 72-year-old woman - Right primary cemented TKA, 2 years before	- Pain and joint effusion of 7 months of evolution	- Arthroscopic synovectomy - Localized PVNS - Good evolution, no recurrence in the postoperative period.
Mohanlal et al.[17] (2009).	- 69 year old man - Right UKA, 5 years before	- Anterior knee pain and joint effusion of 1 year of evolution.	- Arthroscopic synovectomy, then revision to TKA - PVNS - Good evolution, no recurrence in the postoperative period.
Oni and Cavallo[9] (2011).	- 74 year old man - Left primary cemented TKA, 18 months before	- Anterior knee pain and joint effusion of 1 month of evolution. - Hemorrhagic arthrocentesis without germ isolation	- Extensive arthroscopic synovectomy - Diffuse PVNS - Good evolution, with no recurrence 6 months after surgery.
Chung and Park[8] (2011)	- 74-year-old woman - Left primary cemented TKA, 5 years before	- Knee pain and joint effusion of 1 month of evolution. - Radiographic signs of osteolysis	- Single-stage revision with radical synovectomy - Localized PVNS - Good evolution, no recurrence in the postoperative period.
Onodera et al.[15] (2012).	- 61-year-old woman - Right UKA, 5 years before	- Knee pain and joint effusion of 3 years of evolution. - Hemorrhagic arthrocentesis without germ isolation and MRI compatible with PVNS.	- Arthroscopic synovectomy - Localized PVNS - Good evolution, no recurrence one year after surgery.
Camp et al.[7] (2016).	- 64-year-old woman - Right primary cemented TKA, 9 years before - Antiphospholipid syndrome anticoagulation	- Generalized knee pain of 1 year of evolution - Instability in flexion - Polyethylene wear and loosening (osteolysis) - Pseudarthrosis of patellar fracture	- Extensive synovectomy, partial patellectomy and TKA revision - Diffuse PVNS - Good evolution, no recurrence 18 months after surgery.
Zhang et al.[18] (2016).	- 67-year-old man - Left primary cemented TKA, 6 years before - Pulmonary sarcoidosis of 10 years of evolution	- Revision with polyethylene replacement, 3 years after index surgery - Diffuse knee pain and joint effusion	- Two-stage revision with radical synovectomy - Diffuse PVNS and sarcoid granuloma - Good evolution, no recurrence 10 months after surgery.
Kia et al.[6] (2018).	- 62-year-old woman - Right primary cemented TKA, 4 years before	- Recurrent joint effusion and chronic anterior pain - One year after surgery, arthroscopic resection of Hoffa's fat pad, without synovial alterations. - Hemorrhagic arthrocentesis without germ isolation and MRI compatible with PVNS.	- Extensive synovectomy and polyethylene replacement - Diffuse PVNS - Good evolution, no recurrence one year after surgery.
Our study (2024)	- 54 year-old man - Left primary cemented TKA, 1 year before	- Diffuse pain and joint effusion of 9 months of evolution. - Hemorrhagic arthrocentesis without germ isolation	- Two-stage revision with radical synovectomy - Diffuse PVNS - Good evolution, with no recurrence 3 months after surgery.

TKA = total knee arthroplasty; UKA = unicompartmental knee arthroplasty; MRI = magnetic resonance imaging; PVNS = pigmented villonodular synovitis.

The main concern with PVNS is its potential for recurrence, which can present more aggressively, as well as the complications associated with treating PVNS in joint replacement patients. Recurrence rates for PVNS in native knees vary depending on whether the disease is diffuse (8-30%) or localized (18-60%).[1,18] To prevent recurrence, complete synovectomy is crucial and can be complemented by radiotherapy or biological therapies, particularly in cases of prior recurrence or high recurrence risk.[1,7] In our case, a radical synovectomy was performed alongside a two-stage revision for suspected early septic loosening, with no recurrences over a three-year follow-up.

Camp et al. performed a single-stage revision for instability and aseptic loosening, incorporating a radical synovectomy and partial patellectomy with quadricipital tendon reinsertion for a previous patellar pseudarthrosis.[7] These authors emphasized that component revision allows for a more thorough synovectomy. However, some cases were treated with arthroscopic synovectomy, achieving good disease control.[9,11,17]

Due to the limited evidence available, published studies on PVNS in TKA patients can help guide the management of cases like ours. In such patients, TKA is indicated to control the disease in severe or recurrent cases and to restore joint function lost due to PVNS-induced damage.[19,20] Surgical goals include resecting all pathological synovial tissue, which may adhere to ligaments or tendons, often necessitating the use of more constrained prostheses.[21] Some studies also suggest radiotherapy or biological therapies to prevent recurrence, with a reported recurrence rate of 11-13% over an average six-year follow-up.[20] From a clinical and functional point of view, patients typically show marked improvement after surgery, although there is an elevated risk of stiffness, infection, and, in some cases, aseptic loosening.[22]

Although this paper presents only one case, we believe it is crucial to recognize the possibility of PVNS in patients with TKA. PVNS should always be suspected in patients with pain associated with recurrent joint effusion, and it is essential to differentiate it from low-virulence infections. We recommend evaluating these cases with radiography and arthrocentesis, where findings may include osteolysis and hemorrhagic synovial fluid without germ isolation. If diagnostic uncertainty persists, MRI with a metal artifact reduction sequence can be used, which may reveal hypointense signal synovitis. Another option is diagnostic arthroscopy, which allows for sampling and debridement of pathological synovial tissue. However, in cases where loosening or infection is suspected, a revision surgery with radical synovectomy should be performed in the same surgical procedure.

CONCLUSION

PVNS in TKA patients is an exceedingly rare condition of uncertain etiology that negatively affects patient function and satisfaction. It is crucial to consider PVNS as a differential diagnosis in cases of pain and hemarthrosis to enable early diagnosis and timely treatment.

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Synovial Sarcoma of the Knee: Case Report

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ABSTRACT
We present the case of a 22-year-old patient with chronic medial pain in the left knee, initially interpreted as a meniscal syndrome, who was later diagnosed with intra-articular synovial sarcoma (SS) after undergoing various diagnostic studies. Magnetic resonance imaging (MRI) at the time of consultation revealed a well-circumscribed, homogeneous mass with nonspecific characteristics in the medial compartment of the knee. Subsequent histological examination confirmed that the lesion was a synovial sarcoma originating from the synovial membrane. After review by a multidisciplinary team, wide resection of the lesion was performed, followed by ligament and capsular reconstruction. Synovial sarcoma is a rare mesenchymal tumor, accounting for less than 10% of soft tissue sarcomas. Its nonspecific MRI characteristics, along with ambiguous symptoms, make early diagnosis challenging. This condition should be considered in the differential diagnosis of nonspecific joint pain, especially when imaging findings do not align with more common pathologies.
Keywords: Synovial sarcoma; knee pain; intra-articular tumor; soft tissue sarcoma; mesenchymal tumor.
Level of Evidence: IV

Sarcoma sinovial de rodilla: Reporte de un caso

RESUMEN
Presentamos el caso de una paciente de 22 años con dolor crónico medial en la rodilla izquierda que inicialmente fue interpretado como un síndrome meniscal y, luego de diversos estudios, se diagnosticó como un sarcoma sinovial intrarticular. La resonancia magnética realizada en el momento de la consulta mostraba una masa homogénea bien circunscrita y de características inespecíficas dentro del compartimento interno de la rodilla. En el examen histológico posterior, se informó que dicha lesión se correspondía a un sarcoma sinovial que surgía de la membrana sinovial de esa articulación. Tras presentar el caso en un ateneo multidisciplinario, se procedió a la resección amplia de la lesión como único tratamiento y a la posterior reconstrucción ligamentaria y capsular. El sarcoma sinovial es un tumor mesenquimatoso raro que representa <10% de los sarcomas de partes blandas. Las características inespecíficas de la resonancia magnética, así como sus manifestaciones clínicas plantean un desafío en el diagnóstico precoz. Este cuadro debe considerarse dentro de los diagnósticos diferenciales ante dolores articulares inespecíficos y cuando las imágenes no son características de otras enfermedades.
Palabras clave: Sarcoma sinovial; dolor de rodilla; tumor intrarticular; tumor de partes blandas; tumor mesenquimatoso.
Nivel de Evidencia: IV

INTRODUCTION

Synovial sarcoma (SS) is a malignant mesenchymal spindle cell tumor characterized by variable epithelial differentiation and uncertain histogenesis, which can be monophasic or biphasic, and represents less than 10% of soft tissue sarcomas. Intra-articular SS, however, is extremely rare.[1,2]

SS typically affects patients between the ages of 15 and 35, with a slight male predominance. Although it has been reported in almost all anatomical locations, about 90% of SS cases originate in the periarticular tissue and tendon sheath of the extremities, with the knee being the most frequently affected site.[2] Due to its slow growth and nonspecific clinical and radiologic features, the diagnosis and treatment of intra-articular SS are often delayed.[3-5] While larger lesions tend to appear more heterogeneous on magnetic resonance imaging (MRI), smaller SS le-

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sions (<5 cm) may present with well-demarcated margins and homogeneous signal intensity, mimicking benign conditions such as intra-articular localized nodular synovitis.[5] Therefore, it is important to consider SS within the differential diagnoses when faced with this type of presentation.

CLINICAL CASE

A 22-year-old woman presented to our center for the first time in August 2020, seeking a second opinion for chronic medial pain in her left knee, which worsened after physical activity. She had been evaluated by an orthopedic surgeon approximately 12 months earlier and underwent several tests, including an MRI that was initially reported as normal.

Upon review of that MRI, a rounded hyperintense image measuring approximately 5 x 7 x 5 mm was observed on T1 and T2 sequences, located at the anteromedial border of the knee (Figure 1).

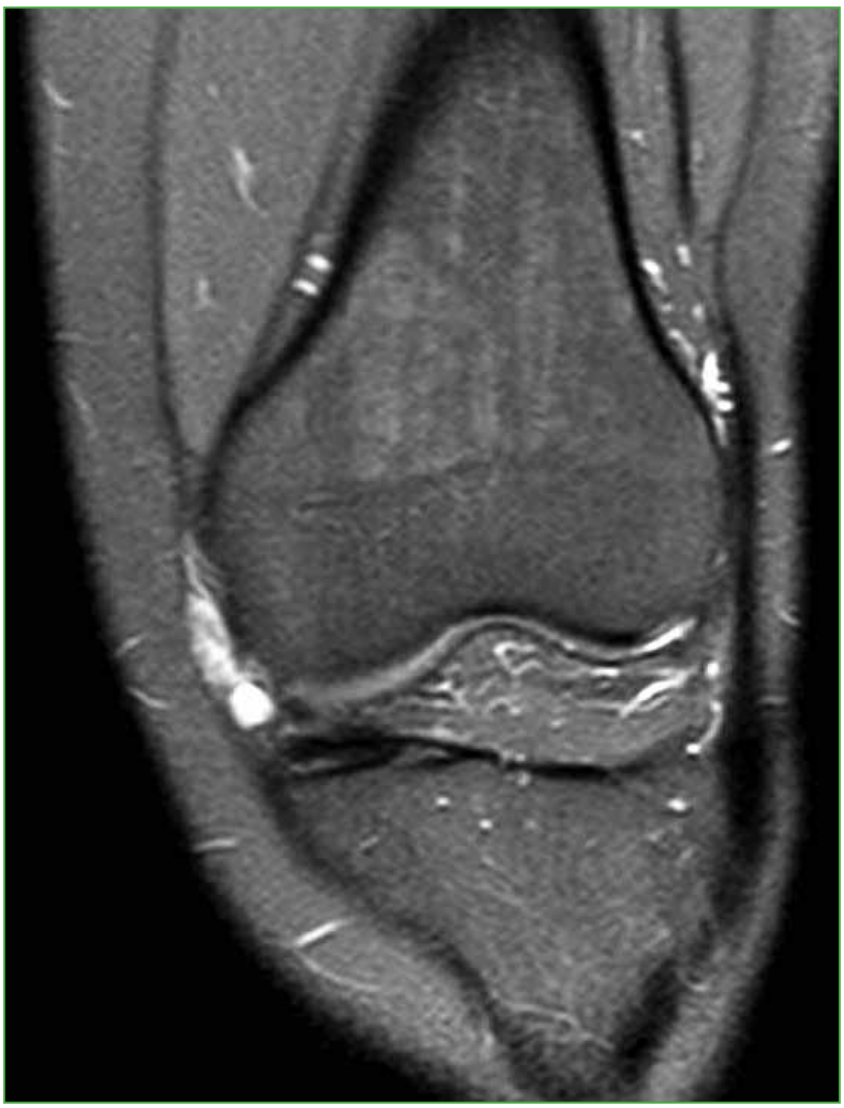

Figure 1. MRI. Hyperintense rounded image in T1 and T2 sequences measuring approximately 5 x 7 x 5 mm in the anteromedial border of the knee, not initially diagnosed.

The patient reported that she continued experiencing pain, which had persisted for 18 months, without any history of trauma. She described the pain as dull and located in the medial aspect of the knee, slightly anterior.

On physical examination, frank ligament laxity and mild joint effusion were noted, without signs of erythema or inflammation (phlogosis). Strength was preserved, and the neurovascular assessment was normal.

At this time, a new set of radiographs, Doppler ultrasound, and MRI were ordered. The radiographs showed no significant findings. However, the ultrasound revealed a "cystic solid mixed nodular process with proximal calcification, measuring approximately 22 x 5 mm, seemingly associated with the patellofemoral joint and suggestive of synovial origin" (Figure 2). The MRI displayed the same lesion as before, now measuring 16 x 18 x 21 mm, still hyperintense on T1 and T2 sequences (Figure 3).

Given these findings, an ultrasound-guided needle biopsy was performed, and immunohistochemical staining of the specimen was carried out. Microscopy revealed a spindle cell neoplasm with ovoid nuclei and elongated cytoplasm, arranged in dense, converging fascicles, accompanied by blood vessels. Isolated mitotic figures were also observed.

Immunohistochemistry results were as follows: S100, focal positive; CK AE1/AE3, negative; CK7, negative; EMA, focal positive; CD99, positive; CD34, positive in vascular structures; Bcl-2, positive; desmin, negative; AML, negative; SOX10, focal positive. These immunophenotypic findings were compatible with monophasic SS.

The case was presented at a multidisciplinary meeting, and in collaboration with the Oncology Department, it was decided that wide resection of the lesion would be the sole treatment.

A medial longitudinal approach was performed, including resection of the biopsy tract. The tumor was excised with wide margins, including the knee joint capsule as the deep margin, and resecting the medial patellofemoral ligament along with a portion of the medial collateral ligament. The specimen was sent for intraoperative frozen section analysis, which confirmed clean margins.

Next, a fascia lata and hamstring graft (gracilis and semitendinosus) was harvested from the same knee. The anteromedial knee capsule was reconstructed using the fascia graft, anchored with five suture anchors, following a technique similar to Gallie's capsular reconstruction for recurrent shoulder instability.[6] In a second stage, the medial ligament was plicated using a semitendinosus graft, with femoral and tibial fixation achieved using 7 x 20 mm interference screws. The posteromedial capsule was then plicated and secured with a 5 mm suture anchor, followed by plication of the medial patellofemoral ligament with another 5 mm suture anchor (Figure 4). Intraoperative maneuvers confirmed good joint stability.

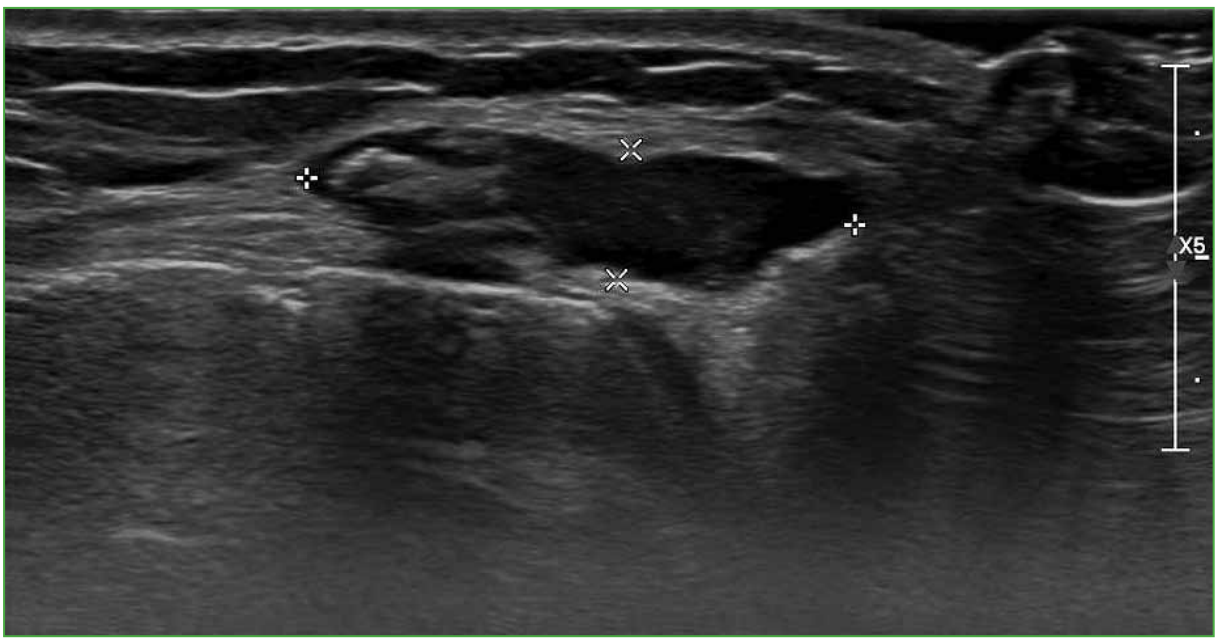

Figure 2. Doppler ultrasound reported as "cystic solid mixed nodular process with proximal calcification, measuring approximately 22 x 5 mm, appearing to be in relation to the patellofemoral joint, suggestive of synovial origin."

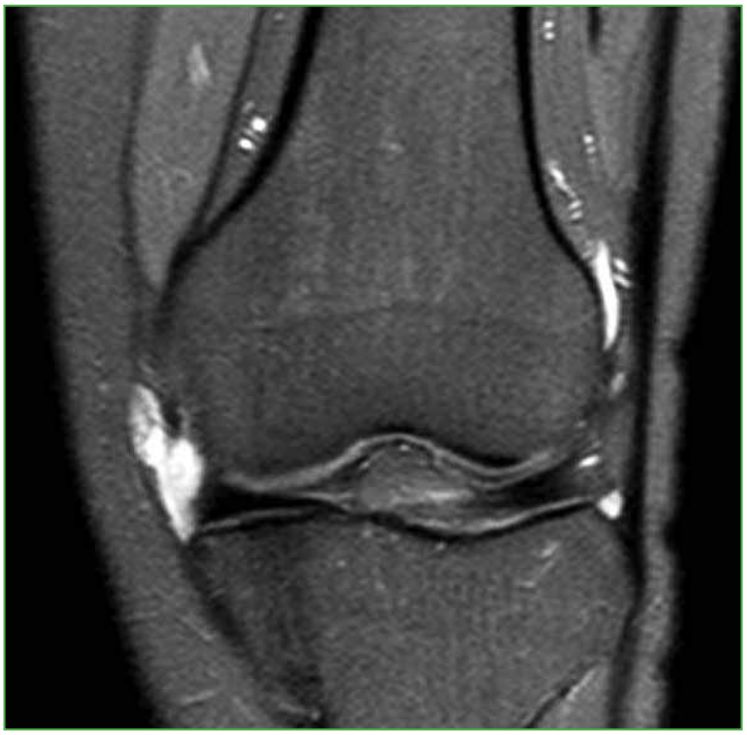

Figure 3. MRI. The same image already described, now measuring 16 x 18 x 21 mm, also hyperintense in T1 and T2 sequences.

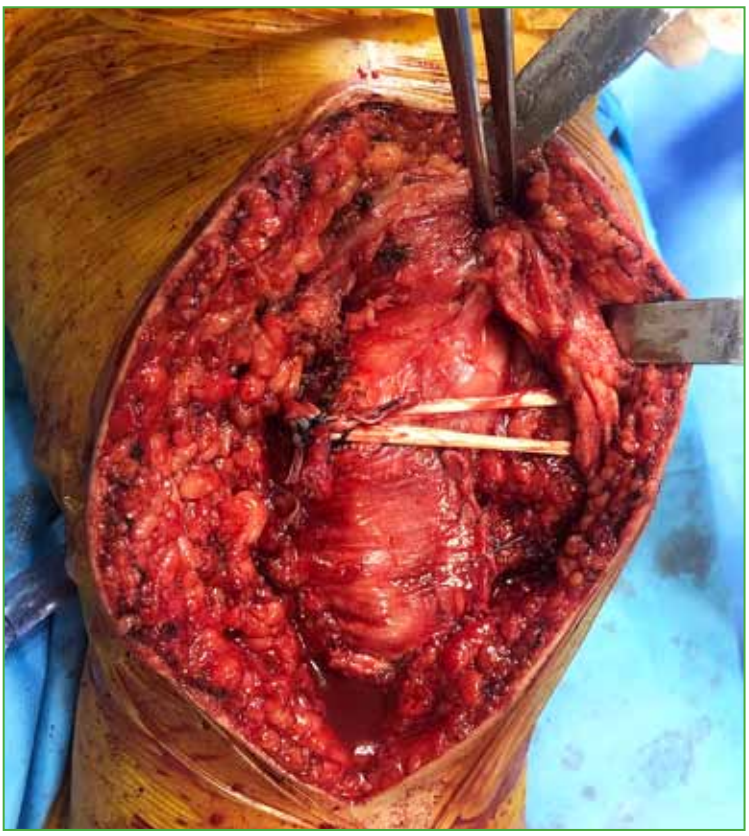

Figure 4. Reconstruction of the anteromedial knee capsule with fascia graft using 5 suture anchors.

Postoperatively, the patient was fitted with a knee immobilizer and allowed partial weight-bearing for six weeks. Supervised passive knee flexion exercises were initiated with a kinesiologist, gradually achieving 90° of flexion. After this period, exercises were advanced based on tolerance.

DISCUSSION

Synovial sarcoma (SS) typically presents as a periarticular soft tissue mass in adolescent and young adult patients.[7] Its etiology remains unknown, though several risk factors have been identified, including genetic syndromes, prior radiotherapy or chemotherapy, chemical carcinogens, chronic lymphedema, and persistent irritation.[3]

From an oncological standpoint, SS is classified as a high-grade sarcoma, characterized by slow tumor growth and a tendency to invade surrounding structures. Children and adolescents with low-grade SS who undergo surgical excision have an event-free survival rate of 72-90% at five years.[8]

SS most often arises near a joint, usually within 5 cm of the periarticular area, and predominantly affects the lower extremities, particularly around the knee. [9]

Multiple authors have described the radiographic characteristics of SS, although no pathognomonic features exist.[7,8] MRI is the imaging modality of choice for assessing intra-articular SS, as well as for determining tumor size, regional invasion, and involvement of adjacent structures. These tumors typically appear as heterogeneous hemorrhagic soft tissue masses with internal calcifications (present in approximately one-third of cases) and are hyperintense on MRI.[7] However, these findings are more specific in tumors larger than 5 cm. Tumors smaller than 5 cm may exhibit homogeneous signal intensity and well-demarcated margins, making diagnosis more challenging.

SS has four histologic subtypes: the biphasic type (20-30%) consisting of both epithelial and spindle cell components; the monophasic spindle cell type (50-60%); the monophasic epithelial cell type (<5%); and the poorly differentiated type (10-15%), which consists of round cells. In our patient, the tumor was of the monophasic spindle cell type, characterized by dense cords of spindle cells, small to medium in size, with pale nuclei, sparse cytoplasm, and indistinct cell borders. This is the most common histologic subtype of SS.[10]

The differential diagnosis of SS includes nodular synovitis, fibromatosis, solitary fibrous tumor, malignant peripheral nerve sheath tumor, Ewing's sarcoma, and rhabdomyosarcoma.

Various treatment options for SS have been proposed, including complete tumor excision or resection, chemotherapy (doxorubicin and ifosfamide), radiotherapy, amputation, or combinations of these therapies. Patients who undergo complete surgical resection with optimal margins, as in the case performed at our center, and who have adequate follow-up, have been reported to survive without disease recurrence for periods ranging from one to 12.5 years post-diagnosis.[8]

CONCLUSIONS

Synovial sarcoma often presents as a diagnostically challenging joint lesion. It is crucial for orthopedic surgeons to recognize cases such as the one described here to maintain a high index of suspicion when confronted with lesions of unknown etiology. In patients with prolonged unexplained knee pain or joint stiffness, intra-articular SS should be considered as part of the differential diagnosis. A biopsy in suspicious cases can help avoid delays in diagnosis and enable prompt definitive treatment.

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

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Preoperative Patient Optimization Before Hip or Knee Arthroplasty: Part 2

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ABSTRACT
Hip and knee arthroplasty are effective procedures for treating degenerative joint diseases when conservative treatments have failed. The purpose of this article is to further analyze modifiable risk factors in patients prior to surgery, with the aim of reducing postoperative complications. These factors include obesity, malnutrition, smoking, diabetes, anemia, opioid use, vitamin D deficiency, chronic renal failure, colonization by methicillin-resistant Staphylococcus, and inflammatory arthropathies. By addressing and optimizing these factors, surgeons can significantly reduce the risk of complications.
Keywords: Optimization; hip and knee arthroplasty; risk factors.
Level of Evidence: IV

Optimización preoperatoria del paciente para una artroplastia de cadera o rodilla: parte 2

RESUMEN
Las artroplastias de cadera y rodilla son procedimientos eficaces para el tratamiento de la enfermedad articular degenerativa cuando el abordaje conservador ha fracasado. El propósito de este artículo es continuar analizando los factores de riesgo modificables en un paciente antes de la cirugía, con el objetivo de disminuir las complicaciones posquirúrgicas. Estos factores incluyen obesidad, malnutrición, tabaquismo, diabetes, anemia, consumo de opioides, deficiencia de vitamina D, insuficiencia renal crónica, colonización por *S. aureus* resistente a la meticilina y artropatías inflamatorias. Si los cirujanos conseguimos mejoras o contrarrestar estos factores podremos reducir el riesgo de complicaciones.
Palabras clave: Optimización; artroplastias de cadera y rodilla; factores de riesgo.
Nivel de Evidencia: IV

INTRODUCTION

Total hip arthroplasty (THA) and total knee arthroplasty (TKA) are effective surgeries for improving the quality of life in patients with degenerative joint disease. However, complications arising from these surgeries can be catastrophic.[1] Some studies[2-4] report that modifiable risk factors can increase the likelihood of such complications. These include obesity, malnutrition, smoking, diabetes, anemia, opioid use, vitamin D deficiency, chronic renal failure, methicillin-resistant *Staphylococcus aureus* (MRSA) colonization, and inflammatory arthropathies.

In 2022, we published the first part of this update, which analyzed the first five risk factors mentioned above.[5]

The purpose of this second part is to address the remaining risk factors and potential countermeasures. It should be noted that these measures have varying levels of supporting evidence, with some still inconclusive, but each will be analyzed in detail.

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OPIOID USE

Opioids are powerful analgesic drugs used to relieve severe acute pain, such as pain associated with major trauma or surgery. Their use has been increasing, as have the negative consequences associated with them.

Overuse of this class of drugs has reached epidemic levels in the United States. According to the *Centers for Disease Control and Prevention*, nearly 218,000 people died from overdoses related to prescription opioids between 1999 and 2017.[6]

Multiple studies have shown more complex postoperative outcomes in individuals who use opioids prior to THA or TKA. For example, Rozell et al. examined 802 patients who underwent THA and TKA and observed that the more opioids a patient used before surgery, the more likely they were to require opioids postoperatively. This increased the likelihood of complications such as hypotension, decreased urine output, the need for supplemental oxygen, prolonged hospital stays, and a higher risk of systemic infections caused by multidrug-resistant pathogens. Additionally, these patients were 2.5 times more likely to continue using opioids for 3 months post-surgery.[7] Zywiel et al. evaluated 49 patients who regularly used opioids for pain control prior to TKA and compared them to a group of non-opioid users. They reported more cases of arthroscopic revision for unexplained pain (5 vs. 0), more referrals to pain management specialists (10 vs. 0), and longer hospital stays (4.3 vs. 3.4 days).[8] Goesling et al. also confirmed the greater likelihood of postoperative opioid use in patients who had used opioids preoperatively. [9]

Moreover, the *Second International Consensus on Musculoskeletal Infections* (ICM) identified a link between opioid use and an increased risk of periprosthetic joint infection. In vitro studies and animal models have shown that opioids exert immunosuppressive effects, modulating both the adaptive and innate immune systems.

The *American Association of Hip and Knee Surgeons* recommends restricting the use of opioids for the treatment of hip and knee osteoarthritis to exceptional cases. They explicitly state that opioids should not be the first-line treatment for acute or chronic symptoms of osteoarthritis and should only be considered when other therapies have failed and surgery is not an option.

Patients requiring opioids should also be informed about the associated risks, have their doses and prescription duration limited, and be referred to pain specialists if prolonged use is necessary.[10]

VITAMIN D DEFICIENCY

Vitamin D promotes proper bone metabolism by maintaining parathyroid hormone at physiologically appropriate levels, stimulating osteoblastic activity, and promoting bone mineralization. It also exerts multiple effects on muscle activity. The active form, $1,25(OH)_2D$, can be produced locally in muscle cells, where it modulates myocyte function by regulating gene transcription and promoting the synthesis of new proteins, thereby strengthening each muscle fiber. This mechanism is associated with a reduced risk of falls and, consequently, a decreased incidence of fractures.[11] Another important function of vitamin D is its activation of the innate immune system, which helps fight bacterial infections through the intracrine regulation of monocytes, the activation of macrophages, and the modulation of antimicrobial peptides and cytokine production. It also activates the adaptive immune response through paracrine regulation in dendritic cells, T-helper lymphocytes, and B cells. Therefore, vitamin D plays a significant role in preventing periprosthetic infections.

The primary metabolite of vitamin D, 25(OH)D, is measured to assess vitamin D status in patients, with classifications and values shown in Table 1.

Vitamin D toxicity typically does not occur until 25(OH)D levels exceed 150 ng/mL.[12] Vitamin D deficiency has been associated with poor outcomes after THA or TKA, such as periprosthetic infection and longer hospital stays.[13] In a study by Sigurdardottir et al. involving 738 patients undergoing THA and TKA, the risk of surgical site infection was 0.85 times higher in patients with vitamin D levels ≤50 mmol/L, and 16% of patients had insufficient preoperative vitamin D levels.[14] Brambilla et al. conducted a systematic review of eight articles that examined the association between prosthetic surgery, vitamin D, and postsurgical outcomes. The review included six prospective observational studies and two retrospective case series, all of which reported preoperative vitamin D deficiency in patients undergoing THA or TKA, with prevalence rates ranging from 7.5% to 62.9%. Hypovitaminosis D was associated with at least one negative short-term outcome in 62% of the studies.[15] Weintraub et al. evaluated the

administration of 50,000 IU of vitamin D to 107 patients on the day of TKA to assess function, postsurgical outcomes, and complications. However, the study did not demonstrate statistically significant differences compared to patients receiving a placebo.[16] Mouli et al. compared two vitamin D administration protocols in 174 patients with vitamin D deficiency (25(OH)D <30 ng/mL) prior to TKA. The first protocol involved daily supplementation with D3 on a sliding scale from 1,000 to 6,000 IU, while the second protocol included a loading dose of 50,000 IU weekly for 4 weeks, followed by 2,000 IU daily. Vitamin D deficiency was corrected in 73.3% of the loading dose group (second protocol) and in 42.4% of the low daily dose group (first protocol) (p<0.001).[17] Morrison et al. found an association between vitamin D supplementation and reduced levels of interleukin 6 and interleukin 10 on the first and second days post-surgery. However, their results were based solely on patients undergoing TKA, so they could not definitively determine whether vitamin D insufficiency was a modifiable factor that could improve outcomes in hip or knee prosthetic surgeries.[18]

Table 1. Classification according to vitamin D values

Ranking	Value
Normal	40-60 ng/ml
Enough	25(OH)D >30 ng/ml
Insufficient	25(OH)D 21-29 ng/ml
Deficient	25(OH)D <20 ng/ml

Although we do not yet have compelling evidence to establish precise guidelines for preoperative vitamin D management, the ICM suggests that vitamin D deficiency may increase the risk of surgical site infections and periprosthetic joint infections in patients undergoing orthopedic procedures by impairing vitamin D-mediated innate and adaptive immune responses. Supplementation prior to surgery may enhance immune system function and potentially reduce the incidence of periprosthetic joint infections.

CHRONIC KIDNEY DISEASE (CKD)

CKD is defined by the presence of renal damage or decreased renal function for a period of three or more months, regardless of the underlying cause. Glomerular filtration rate (GFR), with a normal value of 125 ml/min/1.73 m², is the best indicator of renal function. Table 2 presents the classification of CKD based on GFR values.[19,20]

Table 2. Classification of chronic kidney disease according to glomerular filtration rate.

Grade	Value
Mild insufficiency	89-60 ml/min/1.73 m^2
Moderate insufficiency	59-30 ml/min/1.73 m^2
Severe insufficiency	29-15 ml/min/1.73 m^2
Dialysis	<15 ml/min/1.73 m^2

Between 10% and 20% of patients undergoing elective THA and TKA have moderate CKD.[21] In a Finnish study involving 18,575 patients undergoing THA and TKA, the mean survival time of each patient, based on CKD severity, was 11 years for mild cases, 9 years for moderate cases, and 6 years for severe cases (p = 0.001). The risk of death increased 1.9, 3.8, and 8.1 times, respectively, for each level of CKD severity.

CKD associated with diabetes demonstrated a synergistic effect on mortality risk compared to CKD alone (odds ratio [OR] = 8.15).[22] Fox et al. compared complications in patients undergoing arthroplasty with and without CKD and found a higher incidence of hematoma, wound infection, and cardiac, urinary, and pulmonary complications (Table 3).[23]

Table 3. Complications in arthroplasty according to the presence or absence of chronic kidney disease (CKD).

	Arthroplasty with CKD	Arthroplasty without CKD	p
Hematoma	2.5%	0.8%	<0.0001
Wound infection	0.7%	0.4%	<0.0319
Cardiac complications	1.3%	0.6%	<0.0067
Urinary complications	3.9%	2%	<0.0001
Pulmonary complications	2.2%	0.5%	<0.0001

Few studies specifically analyze the relationship between CKD and implant survival. Jämsä et al. evaluated 18,979 patients and found no significant differences in all-cause or septic revision rates across different CKD stages. These findings remained unchanged when diabetes and body mass index were accounted for. Lee et al. conducted a study using data from the Taiwanese national healthcare system, examining complications in THA and TKA. They observed that CKD patients had a higher incidence of periprosthetic infections at 1, 3, and 6 months, as well as at 1 year post-surgery. Additionally, these patients were more likely to experience aseptic loosening within 1 year of follow-up. [24,25]

The ICM indicates that patients with CKD have an increased risk of surgical site infection but require stratification to adequately assess their risk. Current evidence suggests that CKD patients requiring hemodialysis have worse outcomes than those who do not require hemodialysis or renal transplantation.

Given the reduced risks of surgical site and periprosthetic joint infections after surgery, patients on hemodialysis should be evaluated for renal transplantation prior to undergoing total arthroplasty.

COLONIZATION BY METHICILLIN-RESISTANT *S. AUREUS*

Staphylococcus aureus is a common microorganism responsible for joint prosthesis infections, and there is an established biological correlation between preoperative colonization and infection.[26] Sousa et al. detected an *S. aureus* colonization rate of 22.2%with only 0.8% being methicillin-resistant *S. aureus* (MRSA). The rate of joint prosthesis infections was higher, though not significantly, in *S. aureus* carriers compared to non-carriers (3.9% vs. 2.0%).[27] Ashkenazi et al. retrospectively analyzed 711 patients undergoing total arthroplasties and found that patients with MRSA had longer hospital stays (p = 0.008), lower odds of discharge (p = 0.003), and higher levels of readmission at 30 days (p = 0.030) and 90 days (p = 0.033) compared to patients with methicillin-sensitive *S. aureus* (MSSA). However, major and minor complications at 90 days were comparable between the groups. Rates of septic revisions were higher in MRSA patients (p = 0.049).[28]

At the Cleveland Clinic, Santana et al. found that patients with MRSA had an increased hospital stay of more than one day (odds ratio [OR] = 1.88), and patients with a high body mass index were at a greater risk of colonization (OR = 1.36), with statistically significant results for both cohorts of total hip arthroplasty (THA) and total

knee arthroplasty (TKA).[29] It is unclear whether the increased risk of infection is related to the immune status of the MRSA-carrying patient or to their comorbidities, such as diabetes, chronic kidney disease (CKD), or immunosuppression. However, the presence of an endogenous pathway for the onset of surgical site infection is recognized. Notably, MRSA infections can also occur in non-carrier patients, potentially related to the healthcare institution where the patient is hospitalized and the geographical epidemiological context.[30]

Several methods for detecting MRSA carriers have been described, including standard culture techniques, but their sensitivity is highly variable and depends on the number of samples taken and the sampling methods employed. Detection from various body sites increases sensitivity in identifying carriers, and the use of nasal swabs as a substitute for colonization testing can identify two-thirds of MRSA carriers. Polymerase chain reaction techniques provide faster results but are more expensive, and their advantages over traditional cultures are inconsistent.[30] The most frequent site of colonization is the nostrils. Nasal decolonization has been shown to reduce the MRSA/MSSA bioburden, which could decrease the rate of periprosthetic infection; however, the evidence is limited to studies with low external validity.

Several options are available for decolonization, such as:

- Mupirocin ointment: This bactericidal agent has a prolonged action and is applied in the nostrils twice a day for 5 days before surgery. Its advantages include low cost and high efficacy, with a decolonization rate of 94% after one week. However, in 3.3% of cases, it can lead to residual antimicrobial resistance, and this rate increases ninefold with previous use. Another disadvantage is the requirement for application twice a day for five days, which may reduce compliance with therapy; nevertheless, it remains the most commonly used nasal decolonization strategy for MRSA/MSSA.[31,32]
- Povidone iodine: Applied to the nostrils in a 5% solution 1 hour before surgery, this agent aims to improve patient compliance and reduce bacterial resistance. Unlike mupirocin, povidone iodine provides bacterial suppression for up to 12 hours after application. Although it has been studied less than mupirocin, some studies have demonstrated that it achieves similar results in reducing acute infections.[33]
- Alcohol- and chlorhexidine-based solutions: Recently introduced, these agents aim to enhance patient compliance, combat the emergence of bacterial resistance, and can be administered in a single dose.[34]

Despite these findings, larger and better-designed studies are necessary to demonstrate that routine screening and decolonization are cost-effective and feasible.

In light of this information, the ICM has been unable to make a definitive recommendation regarding the routine implementation of preoperative protocols for the detection and decolonization of *S. aureus*, as the literature on this subject is contradictory. Furthermore, the ICM has not made a conclusive recommendation on individual versus universal treatment, although the universal treatment strategy appears to be the easiest to implement; consequently, the application of this prophylaxis remains somewhat empirical.

INFLAMMATORY ARTHROPATHIES

Total hip arthroplasty (THA) and total knee arthroplasty (TKA) are widely used procedures for patients with advanced-stage symptomatic arthritis. Inflammatory diseases, such as rheumatoid arthritis, systemic lupus erythematosus, and spondyloarthritis—including ankylosing spondylitis and psoriatic arthritis—expose patients to an increased risk of adverse events after surgery, including deep vein thrombosis, pulmonary thromboembolism, acute myocardial infarction, stroke, and infections. [35,36]

In addition to the inflammatory arthropathy itself, many patients are also treated with biologics, which further complicates their surgical risk profile. According to Galloway et al., the use of these agents increases the risk of infections, with the highest risk occurring at the onset of treatment, subsequently decreasing to levels comparable to those of patients with rheumatoid arthritis not treated with biologics.[37] In a Danish study, patients treated with biologics had a hazard ratio of 1.35 for infection and 4.82 for deep vein thrombosis compared to patients with rheumatoid arthritis receiving different treatment regimens. When compared to patients with rheumatoid arthritis who did not receive biologic therapy and patients without inflammatory diseases, no increased risk of acute myocardial infarction or postoperative stroke was observed.[36]

The risk of superficial or deep periprosthetic infection increases after surgery in individuals with inflammatory diseases. For example, patients with rheumatoid arthritis face a 50% higher risk of infection than those without this underlying condition. For this reason, preventing infection in these patients is a top priority.

Given these significant complications, in 2022, the *American College of Rheumatology*, together with the *American Association of Hip and Knee Surgeons*, updated the guidelines for the perioperative management of biologic agents in patients undergoing elective TKA and THA. It is essential for healthcare providers to be familiar with these management strategies. This update is summarized in Tables 4 and 5. Generally, the administration of biologic drugs should be interrupted one life cycle prior to surgery, depending on the specific drug, and can be resumed after uncomplicated wound healing, while non-biologic drugs can continue during the perioperative period.[38]

Table 4. Medications that can be administered in the perioperative period

Disease-modifying antirheumatic drugs	Dose interval	Time of surgery since last dose
Methotrexate	Weekly	At any time
Sulfasalazine	Once or twice/day	At any time
Hydroxychloroquine	Once or twice/day	At any time
Leflunomide	Daily	At any time
Doxycycline	Daily	At any time
Apremilast	Twice/day	At any time
Mycophenolate mofetil	Twice/day	At any time
Azathioprine	Once or twice/day	At any time
Cyclosporine	Twice/day	At any time
Tacrolimus	Twice/day	At any time
Rituximab	Intravenous, every 4-6 months	4-6 months
Belimumab	Weekly	At any time
Anifrolumab	Intravenous, every 4 weeks	4 weeks
Voclosporin	Twice/day	Ongoing

Table 5. Medications to be discontinued prior to surgery (only those available in Argentina)

Biological drugs	Dose interval	Recommended time of surgery since last dose of medication
Adalimumab (HUMIRA®)	Every 2 weeks	3 weeks
Etanercept (ENBREL®)	Every week	2 weeks

FINAL CONSIDERATIONS

In light of the aforementioned points, it is evident that there remains a lack of precise evidence regarding the management of some modifiable risk factors. We primarily rely on measures suggested by associations or consensus guidelines, which are often not supported by high-quality studies. Given the moderate or low level of evidence available, we believe it is the responsibility of each surgeon to stay informed and ensure the multidisciplinary management of each patient, involving the relevant specialties as appropriate for each case.

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Extraction of Fixed Uncemented Stems Using Slot Osteotomy: Technical Note

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ABSTRACT
The removal of a fixed uncemented femoral stem during revision surgery is a challenging task, even for experienced surgeons. The most well-known and commonly used technique is the extended trochanteric osteotomy (ETO), but it is not without complications. Therefore, the aim of this report is to describe the slot osteotomy technique for the extraction of fixed uncemented stems as a less invasive yet highly effective alternative to ETO.
Keywords: Hip; total hip replacement; revision surgery; femoral stem revision.
Level of Evidence: IV

Extracción de tallos no cementados fijos mediante osteotomía en ranura. Nota técnica

RESUMEN
La extracción de un tallo femoral no cementado fijo en la cirugía de revisión es una tarea desafiante para los cirujanos, aun en manos experimentadas. La técnica más difundida y ampliamente utilizada es la osteotomía trocantérica extendida, la cual no está exenta de complicaciones. Dicho esto, el objetivo de esta nota técnica es realizar una descripción de la técnica de osteotomía en ranura para la extracción de tallos no cementados fijos, como una alternativa menos invasiva, pero, a su vez, muy útil, a la osteotomía trocantérica extendida.
Palabras clave: Cadera; reemplazo total de cadera; cirugía de revisión; revisión de tallo femoral.
Nivel de Evidencia: IV

INTRODUCTION

In femoral revision surgery, the removal of a partially or completely fixed uncemented stem is a complex and laborious process, accounting for a significant portion of the total surgical time. The most widely used techniques for femoral stem removal are Wagner's transfemoral osteotomy[1] and, primarily, the extended trochanteric osteotomy (ETO), first described by Glassman et al.[2] and later validated by Younger et al. for the removal of cementless stems with proximal porous coating.[3]

The main advantage of ETO is the direct visualization of the entire stem, which reduces the risk of intraoperative periprosthetic fractures or perforations. However, the procedure is not without complications. The reported rates of pseudarthrosis range from 5% to 11%, while proximal migration of the osteotomized fragment reaches 6.6%. Additionally, complications such as cerclage wire breakage, trochanteric bursitis, and abductor muscle weakness have been documented.[4-6] This technique also imposes limitations on the use of distal fixation implants.

A valuable alternative to ETO is the slot osteotomy (SO), first described by Bauze et al.[7] and later refined through various modifications.[8] This technique involves a single cut on the posterior aspect of the femur, adjacent to the linea aspera. Its key advantage is that it preserves the abductor mechanism, maintains bone stock, and carries an almost negligible risk of pseudarthrosis, as it involves an isolated, incomplete, monocortical cut supported by a cerclage wire. Furthermore, because no secondary fragment is generated, there is no risk of migration. Unlike

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ETO, this osteotomy allows for femoral reconstruction with a metaphyseal or distal fixation stem.

The aim of this article is to describe the SO surgical technique for the removal of partially or completely fixed uncemented stems as an alternative to ETO.

SURGICAL TECHNIQUE (Video)

With the patient in the lateral decubitus position, a posterolateral approach is made to the affected hip, preferably using the previous surgical scar, if feasible. After dislocating and removing the femoral head, the proximal metaphysis is adequately exposed to assess the interface between the prosthesis and the femur, clearly identifying the greater and lesser trochanters. Next, to release the stem proximally, a Lambotte or thin osteotome is placed at the interface and directed distally, maintaining close contact with the prosthesis. Care should be taken not to apply excessive force to avoid fractures (Figure 1).

Figure 1. Proximal release using a Lambotte or thin osteotome at the interface between the bone and the femoral component.

If the femoral component cannot be removed, a minimally invasive posterior slot osteotomy (SO) is performed using an oscillating saw or chisel. The cut is aligned with the posterior border of the vastus lateralis and positioned slightly lateral to the linea aspera. The osteotomy is performed incompletely, monocortically, with a length of 5 to 10 cm, depending on the design of the stem to be removed, and extends proximally to reach the level of the neck osteotomy. It is essential to emphasize that the osteotomy should not be directed towards the greater trochanter, in order to preserve the insertion of the gluteal and pelvic rotator tendons (Figure 2).

Figure 2. Incomplete, monocortical slotted femoral osteotomy, measuring between 5 and 10 cm in length.

Next, two chisels, up to 2 cm wide, are inserted through the osteotomy and placed perpendicularly on both sides of the stem. Gentle lever maneuvers are performed from medial to lateral and from lateral to medial, aiming to release the junctional interface between the bone and the femoral stem. The stem is progressively loosened by dilating the previously virtual cavity in the metaphyseal-diaphyseal region of the prosthetic interface (Figure 3).

Finally, the stem is impacted from the osteotomy or proximally from the prosthetic taper. If it remains fixed, the process may be repeated in the same order until all adhesions between the stem and the femur are released (Figure 4).

After removal, the necessary cerclage wires are placed according to the size of the osteotomy. The femur can then be reconstructed using a metaphyseal fixation stem, following standard techniques commonly described for this procedure.

Figure 3. Stem release maneuver by dilating the metaphyseal-diaphyseal region of the prosthetic interface.

Figure 4. Stem release maneuver: (**A**) from the slot osteotomy or (**B**) from the prosthetic taper.

Postoperative Rehabilitation Protocol

If distal fixation implants were used during the revision surgery, full weight-bearing is recommended as tolerated by the patient. On the other hand, if metaphyseal fixation components were used, partial weight-bearing with crutches or a walker is advised for up to 45 days postoperatively, limiting weight-bearing to a maximum of 20 kg. Mobility exercises, including fixed flexion up to 90°, external rotation up to 30°, and abduction up to 30°, are recommended, while internal rotation should be avoided. Isometric contraction of the gluteus medius is encouraged. Full weight-bearing is authorized six weeks after surgery, based on the evaluation of control radiographs, though there is no standardized protocol. During the first month, the use of a crutch is suggested, with a gradual progression towards unassisted ambulation.

Complications Associated With Slot Osteotomy

SO is a reproducible and versatile technique, and no specific complications associated with it have been reported. As it involves an incomplete, monocortical osteotomy protected with a cerclage wire, there is minimal risk of pseudarthrosis. However, in cases where the osteotomy extends due to untimely maneuvers with chisels during the release of the bone-stem interface, it may behave similarly to an extended trochanteric osteotomy (ETO).

Tips and Tricks

- Planning the surgery with calibrated radiographs is essential to estimate the appropriate length of the slot osteotomy (SO).
- Avoid directing the SO towards the greater trochanter.
- Be mindful not to compromise the insertions of the vastus lateralis and abductors; the linea aspera serves as a useful reference point.
- If the proximal stem is loose, extending the osteotomy to the level of the femoral neck cut may be unnecessary.
- Applying a cerclage wire distal to the osteotomy is highly effective in preventing extension during stress maneuvers, especially in patients with poor bone quality.
- When performing the osteotomy with chisels, it is advisable to pre-mark the osteotomy line with multiple perforations using a fine drill bit or dowel.
- If a cemented stem is planned, it is crucial to prevent cement from entering the edges of the slot. In case of cement leakage, it must be completely removed from the slot, as this could impede proper consolidation.

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