

Clinical and Radiographic Evaluation of the OMICRON 2® Total Knee Prosthesis: A Multicenter Study With Long-Term Follow-up

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ABSTRACT

Introduction: Total knee arthroplasty is the ideal treatment for severe osteoarthritis. The OMICRON 2® system, introduced in Argentina in 2009, incorporated improvements in implant design and instrumentation to optimize and prolong implant survival.

Materials and Methods: A retrospective, longitudinal, observational study included 1,346 total knee arthroplasties performed between 2009 and 2024 at three hospitals in the province of Buenos Aires. Complete clinical and radiographic follow-up data are presented for 616 patients. The Knee Society Score (KSS) and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) were used to assess function over time, together with standardized radiographs. Implant survival was defined as retention of the implant without revision and was assessed using Kaplan-Meier curves. **Results:** The mean age was 71.6 years. The most common diagnosis was primary knee osteoarthritis (86%). Implant survival at 15 years was 92.4%. The KSS improved from 37.5 preoperatively to 85.1 at 15 years, and the WOMAC score improved from 89.2 to 15.5 over the same period. At the end of follow-up, 89.8% of patients had no signs of loosening, and only 2% showed minimal femoral changes. Complications included infections (2.7%), septic loosening, periprosthetic fractures, and instability. **Conclusion:** The OMICRON 2® system demonstrated good clinical and radiographic performance, with high long-term implant survival, and is a reliable option for total knee arthroplasty.

Keywords: Knee arthroplasty; osteoarthritis; OMICRON 2®; survival.

Level of Evidence: IV

Análisis clínico-radiológico de la prótesis total de rodilla OMICRON 2®. Estudio multicéntrico con seguimiento a largo plazo.

RESUMEN

Introducción: La artroplastia total de rodilla es el tratamiento ideal para la artrosis severa. El sistema OMICRON 2®, introducido en la Argentina, en 2009, desarrolló mejoras en el diseño e instrumental destinadas a optimizar y aumentar la supervivencia del implante. **Materiales y Métodos:** Se llevó a cabo un estudio observacional, longitudinal y retrospectivo sobre 1346 artroplastias totales de rodilla realizadas entre 2009 y 2024, en tres hospitales de la provincia de Buenos Aires. Presentamos el seguimiento clínico-radiológico completo de 616 pacientes. Se utilizaron los cuestionarios KSS y WOMAC para valorar la funcionalidad en el tiempo con radiografías estandarizadas. La supervivencia se definió como la permanencia del implante en el sitio, sin revisión, evaluado mediante curvas de Kaplan-Meier. **Resultados:** La media de edad era de 71.6 años. El diagnóstico más frecuente fue gonartrosis primaria (86%). La supervivencia del implante a los 15 años fue del 92,4%. El puntaje KSS mejoró de 37,5 antes de la cirugía a 85,1 a los 15 años, y el puntaje WOMAC, de 89,2 a 15,5. El 89,8% no tenía signos de aflojamiento al final del seguimiento; solo un 2% presentó cambios mínimos femorales. Las complicaciones fueron infecciones (2,7%), aflojamiento séptico, fracturas periprotésicas e inestabilidad. **Conclusión:** El sistema OMICRON 2® tuvo un buen rendimiento clínico y radiológico, con una alta supervivencia a largo plazo; es una opción confiable en la artroplastia total de rodilla.

Palabras clave: Artroplastia de rodilla; artrosis; OMICRON 2®; supervivencia.

Nivel de Evidencia: IV

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How to cite this article: Vega C, Moruno F, Megey J, Jimenez W, Satragno CF. Clinical and Radiographic Evaluation of the OMICRON 2® Total Knee Prosthesis: A Multicenter Study With Long-Term Follow-up. *Rev Asoc Argent Ortop Traumatol* 2026;91(5):427-437. <https://doi.org/10.15417/issn.1852-7434.2026.91.5.2225>

INTRODUCTION

Total knee arthroplasty (TKA) is currently the gold standard for treating severe osteoarthritis.^{1,2} As the procedure has become increasingly common over the past 30 years, implants and instrumentation have improved significantly.³ Outcomes are assessed using several variables, including implant survival, kinematics, function, and patient satisfaction.⁴⁻⁶

The profile of patients considered candidates for TKA varies widely across publications in terms of age and disease progression, with increasingly younger patients undergoing the procedure.^{7,8}

For patients with osteoarthritis who have a life expectancy of 20–40 years, reliable long-term follow-up data on TKA provide a sound basis for decision-making. Long-term follow-up studies of TKA performed within the past decade therefore warrant greater attention, despite the logistical challenges and limitations.^{9,10} Evidence on implants with an established record of long-term use can also help assess the quality and performance of new devices.¹¹

Implant designers and surgeons continue to develop new implants and surgical techniques that may increase implant survival and improve outcomes after TKA.

The OMICRON 2® TKA system, manufactured by Ortopedia IMECO S.A., was introduced to the Argentine market in 2009 with certification from the National Administration of Drugs, Food and Medical Devices (ANMAT). It has since been distributed nationwide.

This study aimed to evaluate the long-term clinical and radiographic outcomes and implant survival rates of the OMICRON 2® knee prosthesis.

MATERIALS AND METHODS

Implant

The implant has a posterior-stabilized design with an integrated post that compensates for the absence of the posterior cruciate ligament (Figure 1).



Figure 1. OMICRON 2® prosthesis.

The design was refined from its predecessor, the OMICRON 1® prosthesis, to achieve mechanical alignment while balancing bone resection (bone balancing) with the balancing of ligamentous and capsular structures (gap balancing). It features more anatomically shaped components designed for cemented fixation.

The femoral components are made of a cobalt-chromium-molybdenum alloy and have a single radius of rotation to improve tibiofemoral joint congruity. The femoral component was modified to provide a more anatomical shape and trochlear orientation, with distinct right and left components. The trochlear groove was deepened to allow smoother patellar tracking. A smaller intercondylar box, proportional to the size of the femoral component, helps preserve bone stock.

The tibial components are also made of a cobalt-chromium-molybdenum alloy and are modular, with a short central stem.

The tibial baseplate is bilaterally symmetrical, with curved posterior edges that provide an appropriate fit to the tibia (Figure 2).

The keel has two antirotation fins and is smaller than that of the previous implant. The inner surface of the femoral component and the undersurface of the tibial component are macrotextured to improve cement fixation (Figure 3).

Figure 2. Tibial baseplate of the OMICRON 2® prosthesis.



Figure 3. Macrotextured surfaces for cemented fixation of the OMICRON 2® prosthesis.



The polyethylene is highly cross-linked to prevent early wear and incorporates 3° of posterior slope. Femoral alignment was established using an intramedullary guide, and tibial alignment using an extramedullary guide. The posterior slope could be increased to 7° according to the patient's characteristics and the surgeon's judgment.

The instrumentation is based on an anatomical technique guided by mechanical alignment, allowing sequential soft tissue release.

Study Implementation

Implant survival depends not only on implant design but also on several factors related to surgical technique. Hospitals in the province of Buenos Aires were therefore considered using uniform selection criteria.

During much of the study period, the OMICRON 2® prosthesis was supplied to 16 public hospitals in the province of Buenos Aires through the Comprehensive Medical Care Program (PAMI), allowing large-volume distribution. Hospitals from this group were selected according to the following criteria:

- Availability of clinical and radiographic records throughout follow-up.
- Use of the same surgical approach, implant, and instrumentation.
- Use of the same measured resection technique with balancing of the flexion and extension gaps in all cases.
- A standardized cementing technique aimed at optimizing preparation of the bone bed.
- Use of the transepicondylar axis to determine external rotation of the femoral component in all procedures.
- Tibial component rotation guided by the tibial tubercle.
- Use of the same brand of domestically manufactured bone cement.

Based on these criteria, a retrospective longitudinal observational study was conducted at three hospitals in the province of Buenos Aires: Hospital Municipal Central de San Isidro "Dr. Melchor Á. Posse," Hospital Zonal de Agudos "Dr. Carlos A. Bocalandro," and Hospital Municipal "Bernardo Houssay."

A total of 1,346 TKAs were performed between 2009 and 2024. Only 616 patients completed the clinical and radiographic assessment; the remaining patients were lost to follow-up or had died. Patients were classified as lost to follow-up when they missed follow-up visits and could not subsequently be contacted. Deaths that could be confirmed were documented through hospital records and telephone contact with relatives or acquaintances.

Patients who underwent primary TKA were included, and revision procedures were excluded. Implant survival was defined as retention of the implant in situ at the final follow-up visit.

Statistical Methods

Clinical and functional outcomes were recorded in a standardized manner at each hospital by multiple examiners who were blinded during the study. Assessments used questionnaires specifically intended for these patients, administered before and after surgery. The database was combined with a retrospective review of medical records to collect demographic data (age, sex, and body mass index) and surgical data.

A Kaplan–Meier curve was used to determine implant survival at 15 years after implantation. Patient function was assessed using the Knee Society Score (KSS) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC).

Permission to obtain patient data was requested from the ethics committee at each hospital.

In terms of implant survival, the success rate was 92.4% ($p = 0.924$) among the 616 patients followed in this study. The minimum required sample size was $n = 300$ patients, yielding a margin of error of 0.03%, a standard level of precision for clinical studies.

Patient Population

The mean age at implantation was 71.6 years; 67.2% of patients were women and 32.8% were men. Mean weight was 80.9 kg, and mean body mass index was 29.2 kg/m² (Table 1).

Table 1. Demographic data.

	n = 616
Mean age	71.6 years
Sex	Female 67.2% (414 patients)
	Male 32.8% (202 patients)
Mean weight	80.9 kg
Mean body mass index	29.2 kg/m ²
Implant laterality	Left knee 48.2% (297 patients)
	Right knee 51.8% (319 patients)
Malalignment	Varus 63.6% (392 patients)
	Valgus 36.4% (224 patients)

Surgery was performed on the left knee in 48.2% of cases and the right knee in 51.8%. Varus was the most common malalignment (71.1%), followed by valgus (28.9%). All patients had competent ligaments, allowing the use of primary knee prostheses.

The most common diagnosis leading to surgery was primary knee osteoarthritis (86%), followed by rheumatoid arthritis (6%), posttraumatic osteoarthritis (4%), sequelae of femoral osteonecrosis (2.5%), and osteoarthritis secondary to septic arthritis (2%) (Table 2).

Table 2. Indications for total knee replacement.

Preoperative diagnosis	Percentage	Number of implants n = 616
Primary knee osteoarthritis	86.2%	531
Rheumatoid arthritis	5.3%	33
Posttraumatic osteoarthritis	3.9%	24
Avascular necrosis	2.5%	16
Sequelae of septic arthritis	2.1%	12

The 730 patients without complete follow-up were slightly older than those who completed follow-up, with a mean age of 73.8 years. There were no statistically significant differences in sex distribution or body mass index ($p > 0.05$).

Surgical Technique

Preoperative planning included weight-bearing anteroposterior radiographs of both knees, a lateral view at 30° of flexion, and an axial patellar view to provide a comprehensive assessment of the affected joint.¹²

Standard prophylaxis included antibiotics 30 minutes before skin incision and antithrombotic prophylaxis in the immediate postoperative period.

All procedures were performed through a medial parapatellar approach.

The prostheses were implanted using a measured resection technique and standard instrumentation. The patella was everted and resurfaced at the surgeon's discretion, depending on the characteristics of the bone. As a general rule, resurfacing was performed in cases of extensive patellar cartilage destruction. It was contraindicated when patellar thickness was <20 mm because of the risk of fracture.¹³ The patella was resurfaced in 61.5% of patients.

All components were cemented, with particular attention to preparing a clean, dry cancellous bone bed to improve cement interdigitation. Cement was applied to both the bone surface and the implant, including the keel, which was cemented in all cases. }

RESULTS

Two independent surgeons at each hospital performed the radiographic assessments. Implant survival and stability were assessed by examining standardized zones around the components for signs of loosening.

The system described by Meneghini et al. and Kumar et al. was used to assess implant stability radiographically (Figure 4).^{9,14}

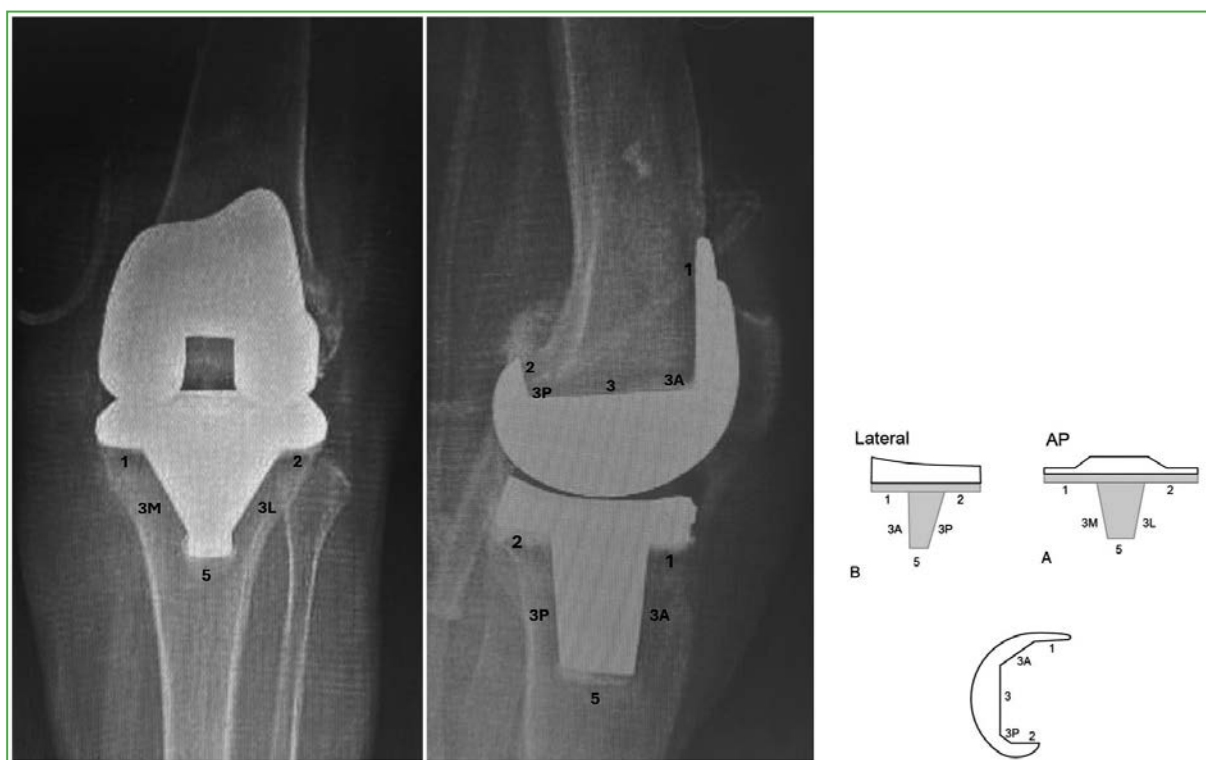


Figure 4. Meneghini radiographic zones.

Radiographic findings at the final follow-up were retrieved from each hospital's digital database for the 616 patients in the study population. Radiographs for the remaining patients were unavailable because of loss to follow-up. Deaths during follow-up were identified through hospital records and confirmed by telephone contact with relatives.

At the final follow-up, 89.8% of implants showed no radiographic changes or signs of loosening. Changes suggestive of osteolysis measuring <1 mm were observed in zones 1 and 2 around the tibial component in 8.2% of implants. The remaining 2% showed minimal changes measuring <2 mm in zone 1 around the femoral component, without clear signs of loosening.

Functional outcomes were assessed using the KSS (Table 3). The total score (maximum, 100) improved significantly from a preoperative mean of 37.5 to 91.6 at 1 year ($p < 0.001$), 90.2 at 5 years ($p < 0.001$), 87.9 at 10 years ($p < 0.001$), and 85.1 at 15 years. Our findings are consistent with those reported in the current literature. The WOMAC score (worst possible score, 96) also improved, from a preoperative mean of 89.2 to 15.5 at the final follow-up.

Table 3. Functional outcomes assessed using the Knee Society Score.

<i>Knee Society Score</i> functional assessment	Score	p
Preoperative	37.5	
1-year follow-up	91.6	<0.001
5-year follow-up	90.2	<0.001
10-year follow-up	87.9	<0.001
15-year follow-up	85.1	<0.001

A key strength of our findings on KSS and WOMAC score improvements is that they are based on long-term clinical and radiographic follow-up.

The main limitation was the progressive loss of patients to follow-up. Although substantial, this loss is unsurprising and consistent with that reported in other long-term studies. Nevertheless, the 95% confidence interval for implant survival at 15 years was 90.31%–94.49%, indicating high statistical precision, with a margin of error of 2.09%, and supporting the robustness of the study.

The design features of the OMICRON 2® total knee replacement system have remained unchanged over the years. Its favorable functional outcomes and 15-year implant survival reflect the success of its design. The OMICRON 2® prosthesis therefore serves as the benchmark for comparing TKA systems at the participating institutions.

Complications

Complications are detailed in Table 4, although most were unrelated to the implants.

Twenty-three revision procedures were performed. Five were for septic loosening and were managed with two-stage revision.

Table 4. Complications.

Intraoperative	Systemic postoperative	Local postoperative	Revision surgery
Femoral condyle fracture (internal fixation): 3	Pneumonia: 4	Stiffness: 21	Septic loosening: 5
Patellar tendon rupture: 2	Ileus: 2	Hematoma: 2	Periprosthetic fracture: 3
Varus malalignment of the tibial component: 15	Deep vein thrombosis: 9	Quadriceps weakness: 1	Aseptic loosening: 4
Femoral component malrotation: 13	Urinary tract infection: 12	Delayed wound healing: 14	Instability: 3
		Early infection (debridement, antibiotics, and implant retention): 12	Persistent pain: 2

Three periprosthetic fractures involved substantial loss of bone stock and required revision to a more constrained prosthesis.

Aseptic loosening led to revision in 10 patients. The tibial component had been placed in varus in seven patients, and the femoral component was malrotated in three, resulting in osteolysis and early loosening.

Three patients required further surgery for instability and two for persistent anterior knee pain. Neither of the patients with anterior knee pain had undergone patellar resurfacing.

The infection rate was 2.7%, with chronic infections in five patients and acute infections in 12. The acute infections resolved with early debridement, antibiotics, and implant retention.

DISCUSSION

This study reports the long-term outcomes of a consecutive series of 616 patients treated between 2009 and 2024. Overall, the 15-year implant survival rate of 92.4% is favorable (Figure 5).

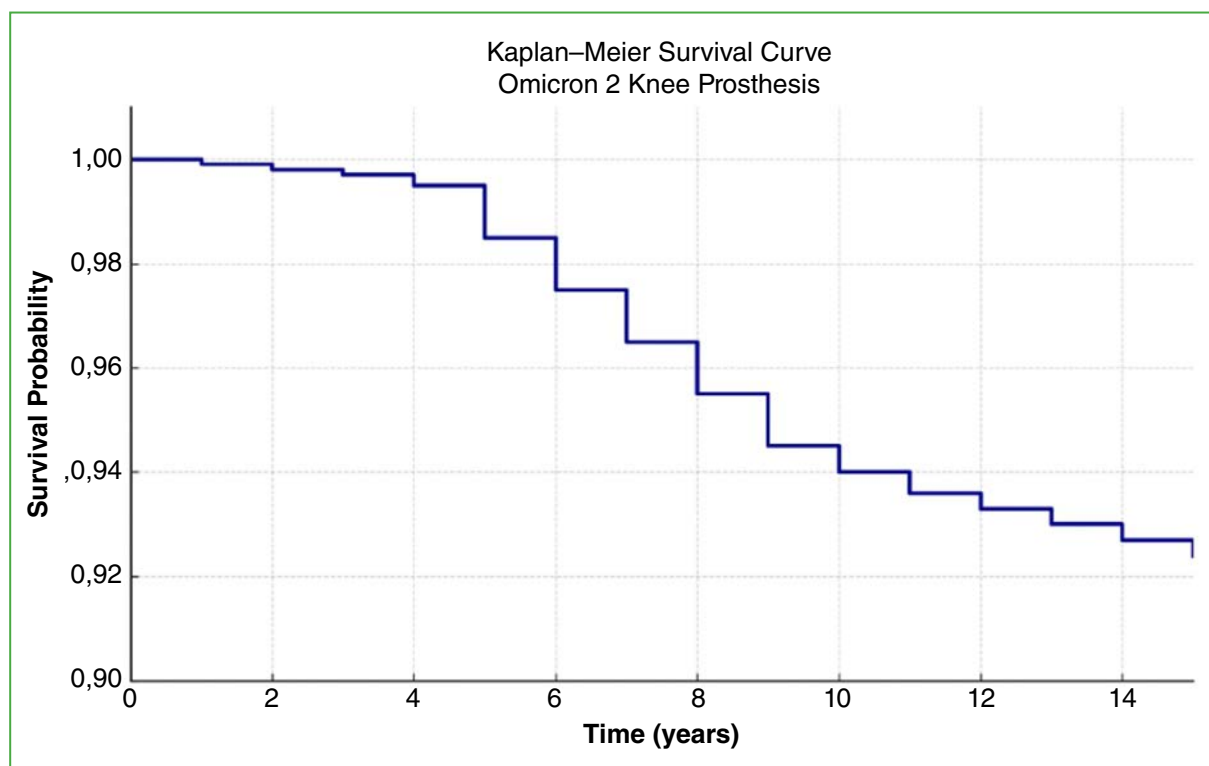


Figure 5. Kaplan-Meier survival curve.

Plain radiographs are the most widely used imaging modality for assessing component alignment, although three-dimensional computed tomography is the reference standard.^{15,16} We used the Knee Society TKA roentgenographic evaluation and scoring system,¹⁷ an accepted tool for radiographic assessment.^{18,19}

We believe that restoring alignment plays an important role in improving implant survival²⁰ and functional outcomes.^{21,22} Patient age may also influence implant survival. Some series of cemented knee replacements in young patients with rheumatoid arthritis have reported excellent long-term survival rates.^{23,24} However, these favorable results may be influenced by the lower activity levels of patients with inflammatory arthritis.

Younger patients generally have greater physical demands and a longer life expectancy, placing greater mechanical stress on the implants.

Roberts et al. found that implant survival was significantly higher in women and older patients.²⁵ Julin et al. reported 5-year survival rates of 92% and 95% in patients aged <55 years and 56–65 years, respectively, compared with 97% in those aged >65 years.²⁶ Younger patients had higher revision rates for noninfectious reasons. Keenan et al. reported 10-year survival after cemented TKA in patients aged <55 years at surgery and compared their functional outcomes with those of patients aged >55 years.²⁷

The original cohort of 1,346 patients decreased over the study period. By 12–15 years, 106 patients had died and 624 had been lost to follow-up. Those lost to follow-up were older than 85 years at the time of assessment, so it is reasonable to assume that many had died.

Declining patient numbers are common in long-term joint replacement studies, reducing the usefulness of functional scores as a discriminating measure.^{28,29} Some studies report that 82% of TKAs last approximately 25 years.³⁰ Callaghan et al. reported on the 26 surviving patients from an initial cohort of 86. Despite an excellent KSS of 89, the function score had declined to 67.³¹ Reports with a minimum follow-up of 15 years after TKA are scarce, and several concern implants that are no longer commonly used. Van Loon et al. followed 102 cemented kinematic TKAs for 10–15 years and reported a survival rate of 62% at 14 years. The main reasons for revision were deep infection and wear.³² Buechel reported a survival rate of 83% at 16 years.³³ Ito et al. examined 36 knees in 25 patients with rheumatoid arthritis and reported a 15-year survival rate of 93.7%.³⁴

Our results are therefore comparable with those reported in the international literature. However, we could not compare them with findings from Argentina, as no long-term studies of domestically manufactured prosthetic implants have been reported.

This study has several strengths and limitations that should be considered when interpreting its findings. A major strength is the length of follow-up, which allows assessment of the implant's long-term durability, with implant survival serving as a key indicator of clinical success. The observational design provides information on how the prosthesis performs under routine clinical conditions, encompassing a diverse population and reflecting everyday surgical practice. Finally, the sample size and availability of longitudinal data allow reliable statistical analyses.

Nevertheless, the study has limitations inherent to its design. The main limitations are the absence of a control group and the high rate of loss to follow-up, which may introduce bias, particularly selection and information bias. Reliance on retrospective clinical records also poses a risk of bias because these records may contain inaccurate data.

Changes or errors in the surgical techniques used during the study period may also have influenced the outcomes. For example, the five cases of aseptic loosening were associated with surgical errors involving incorrect component orientation.

These factors should be considered when assessing the validity and applicability of the findings. Although the retrospective design provides valuable insight into the prosthesis's performance in routine clinical practice, studies with more controlled designs are needed to support its conclusions and confirm the findings.

CONCLUSIONS

We report a favorable implant survival rate of 92.4% in a series of 616 TKAs using the OMICRON 2® system after 15 years of follow-up.

The system's distinctive design features have remained unchanged throughout its relatively long clinical history. In other systems, these features are often modified before long-term results are published.

The OMICRON 2® system continues to show favorable long-term implant survival at a mean follow-up of 15 years.

Conflicts of interest: Drs. Carlos Vega and Favio Moruno are paid medical consultants for IMECO S.A. The rest of the authors declare no conflicts of interest.

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REFERENCES

1. Jauregui JJ, Cherian JJ, Pierce TP, Beaver WB, Issa K, Mont MA. Long-term survivorship and clinical outcomes following total knee arthroplasty. *J Arthroplasty* 2015;30(12):2164-6. <https://doi.org/10.1016/j.arth.2015.05.052>
2. Argenson JN, Boisgard S, Parratte S, Descamps S, Bercovy M, Bonneville P, et al. Survival analysis of total knee arthroplasty at a minimum 10 years follow-up: A multicenter French nationwide study including 846 cases. *Orthop Traumatol Surg Res* 2013;99(4):385-90. <https://doi.org/10.1016/j.otsr.2013.03.014>
3. Parratte S, Pagnano MW, Trousdale RT, Berry DJ. Effect of postoperative mechanical axis alignment on the fifteen-year survival of modern, cemented total knee replacements. *J Bone Joint Surg Am* 2010;92(12):2143-9. <https://doi.org/10.2106/JBJS.I.01398>
4. Aujla RS, Esler C. Total knee arthroplasty for osteoarthritis in patients <55 years of age: A systematic review, *J Arthroplasty* 2017;32(8):2598-2603.e1. <https://doi.org/10.1016/j.arth.2017.02.069>
5. Longo UG, Ciuffreda M, Mannering N, D'Andrea V, Locher J, Salvatore G, et al. Outcomes of posterior-stabilized compared with cruciate-retaining total knee arthroplasty *J Knee Surg* 2018;31(04):321-40. <https://doi.org/10.1055/s-0037-1603902>
6. Benazzo F, Ghiara M, Rossi SMP, Pruneri E, Tiwari T, Perelli S. Clinical and radiological analysis of a personalized total knee arthroplasty system design. *Int Orthop* 2019;43(5):1113-21. <https://doi.org/10.1007/s00264-018-4095-4>
7. Callaghan JJ, Martin CT, Gao Y, Andrew J, Pugely AJ, Liu SS, et al. What can be learned from minimum 20-year followup studies of knee arthroplasty? *Clin Orthop Relat Res* 2015;473(1):94-100. <https://doi.org/10.1007/s11999-014-3744-1>
8. Becker R, Doring C, Denecke A, Brosz M. Expectation, satisfaction and clinical outcome of patients after total knee arthroplasty *Knee Surg Sports Traumatol Arthrosc* 2011;19(9):1433-41. <https://doi.org/10.1007/s00167-011-1621-y>
9. Meneghini RM, Mont MA, Backstein DB, Bourne RB, Dennis DA, Scuderi GR. Development of a modern knee Society Radiographic Evaluation System and Methodology for total knee arthroplasty. *J Arthroplasty* 2015;30(12):2311-4. <https://doi.org/10.1016/j.arth.2015.05.049>
10. Baek JH, Lee SC, Choi K, Ahn HS, Nam CH. Long-term survivorship of total knee arthroplasty with a single-radius, high-flexion posterior stabilized prosthesis. *Knee* 2021;30(12):275-82. <https://doi.org/10.1016/j.knee.2021.04.017>
11. Fernandez-Fernandez R, Rodriguez-Merchan EC. Better survival of total knee replacement in patients older than 70 years: a prospective study with 8 to 12 years follow-up. *Arch Bone Jt Surg* 2015;3(1):22-8. PMID: 25692165
12. Cherian JJ, Kapadia BK, Banerjee S, Jauregui JJ, Issa K, Mont MA. Mechanical, anatomical, and kinematic axis in TKA: Concepts and practical applications. *Curr Rev Musculoskelet Med* 2014;7(2):89-95. <https://doi.org/10.1007/s12178-014-9218-y>
13. Migliorini F, Eschweiler J, Niewiera M, El Mansy Y, Tingart M, Rath B. Better outcomes with patellar resurfacing during primary total knee arthroplasty: a meta-analysis study. *Arch Orthop Trauma Surg* 2019;139(10):1445-54. <https://doi.org/10.1007/s00402-019-03246-z>
14. Kumar N, Yadav C, Raj R, Anand S. How to interpret postoperative X-rays after total knee arthroplasty. *Orthop Surg* 2014;6(3):179-86. <https://doi.org/10.1111/os.12123>
15. Hirschmann MT, Konala P, Amsler F, Iranpour F, Friederich NF, Cobb JP. The position and orientation of total knee replacement components: a comparison of conventional radiographs, transverse 2D-CT slices and 3D-CT reconstruction. *J Bone Joint Surg Br* 2011;3(5):629-33. <https://doi.org/10.1302/0301-620X.93B5.25893>
16. Sarmah SS, Patel S, Hossain FS, Haddad FS. The radiological assessment of total and unicompartmental knee replacements. *J Bone Joint Surg Br* 2012;94(10):1321-9. <https://doi.org/10.1302/0301-620X.94B10.29411>
17. Ewald FC. The Knee Society total knee arthroplasty roentgenographic evaluation and scoring system. *Clin Orthop Relat Res* 1989;(248):9-12. PMID: 2805502
18. Bach CM, Steingruber IE, Peer S, Nogler M, Wimmer C, Ogon M. Radiographic assessment in total knee arthroplasty. *Clin Orthop Relat Res* 2001;(385):144-50. <https://doi.org/10.1097/00003086-200104000-00022>
19. Ritter MA, Davis KE, Meding JB, Pierson FL, Berend ME, Malinzak RA. The effect of alignment and BMI on failure of total knee replacement. *J Bone Joint Surg Am* 2011;93(17):1588-96. <https://doi.org/10.2106/JBJS.J.00772>
20. Choong PF, Dowsey MM, Stoney JD. Does accurate anatomical alignment result in better function and quality of life? Comparing conventional and computer-assisted total knee arthroplasty. *J Arthroplasty* 2009;24(4):560-9. <https://doi.org/10.1016/j.arth.2008.02.018>
21. Longstaff LM, Sloan K, Stamp N, Scaddan M, Beaver R. Good alignment after total knee arthroplasty leads to faster rehabilitation and better function. *J Arthroplasty* 2009;24(4):570-8. <https://doi.org/10.1016/j.arth.2008.03.002>

22. Duffy GP, Trousdale RT, Stuart MJ. Total knee arthroplasty in patients 55 years old or younger. *Clin Orthop Relat Res* 1998;(356):22-7. <https://doi.org/10.1097/00003086-199811000-00005>
23. Stuart MJ, Rand JA. Total knee arthroplasty in young adults who have rheumatoid arthritis. *J Bone Joint Surg Am* 1988;70(1):84-7. PMID: 3335576
24. Keenan AC, Wood AM, Arthur CA, Jenkins PJ, Brenkel IJ, Walmsley PJ. Ten-year survival of cemented total knee replacement in patients aged less than 55 years. *J Bone Joint Surg Br* 2012;94(7):928-31. <https://doi.org/10.1302/0301-620X.94B7.27031>
25. Roberts VI, Esler CN, Harper WM. A 15-year follow-up study of 4606 primary total knee replacements. *J Bone Joint Surg Br* 2007;89(11):1452-6. <https://doi.org/10.1302/0301-620X.89B11.19783>
26. Julin J, Jämsen E, Puolakka T, Kontinen YT, Moilanen T. Younger age increases the risk of early prosthesis failure following primary total knee replacement for osteoarthritis. A follow-up study of 32,019 total knee replacements in the Finnish Arthroplasty Register. *Acta Orthop* 2010;81(4):413-9. <https://doi.org/10.3109/17453674.2010.501747>
27. Ritter MA. The Anatomical Graduated Component total knee replacement. A long-term evaluation with 20-year survival analysis. *Bone Joint Surg Br* 2009;91-B(6):745-9. <https://doi.org/10.1302/0301-620X.91B6.21854>
28. Collier MB, Engh CA, McAuley JP, Ginn SD, Engh GA. Osteolysis after total knee arthroplasty: Influence of tibial baseplate surface finish and sterilization of polyethylene insert. *J Bone Joint Surg Am* 2005; 87(12):2702-8. <https://doi.org/10.2106/JBJS.E.00074>
29. Reay E, Wu J, Holland J, Deehan D. Premature failure of the Kinemax plus total knee replacements. *J Bone Joint Surg Br* 2009;91(5):604-11. <https://doi.org/10.1302/0301-620X.91B5.21525>
30. Evans JT, Walker RW, Evans JP, Blom AW, Sayers A, Whitehouse MR. How long does a knee replacement last? A systematic review and meta-analysis of case series and national registry reports with more than 15 years of follow-up. *Lancet* 2019;393(10172):655-3. [https://doi.org/10.1016/S0140-6736\(18\)32531-5](https://doi.org/10.1016/S0140-6736(18)32531-5)
31. Callaghan JJ. Mobile-bearing knee replacement: Clinical results: A review of the literature. *Clin Orthop Relat Res* 2001;(392):221-5. <https://doi.org/10.1097/00003086-200111000-00027>
32. Van Loon C, Wisse M, de Waal Malefijt M, Jansen RH, Veth RP. The kinematic total knee arthroplasty. *Arch Orthop Traumatol Surg* 2000;120(1-2):48-52. <https://doi.org/10.1007/PL00021215>
33. Buechel FF Sr. Long-term follow up after mobile-bearing total knee replacement. *Clin Orthop Relat Res* 2002;(404):40-50. <https://doi.org/10.1097/00003086-200211000-00008>
34. Ito J, Koshino T, Okamoto R, Saito T. 15-year follow-up study of total knee arthroplasty in patients with rheumatoid arthritis. *J Arthroplasty* 2003;(8):984-2. [https://doi.org/10.1016/S08835403\(03\)00262-6](https://doi.org/10.1016/S08835403(03)00262-6)