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Contemporary cementless patellar resurfacing in total knee arthroplasty is associated with a low early complication rate across residual bone thicknesses

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Abstract

Purpose: The aim of this study was to evaluate early clinical and radiographic outcomes of primary total knee arthroplasty (TKA) with patellar resurfacing using contemporary cementless fixation, with emphasis on early complications, revision risk, residual patellar bone thickness, and its relationship to fracture risk.

Methods: A retrospective review was performed on 323 primary TKAs with cementless patellar resurfacing performed between 2021 and 2024. Patients with follow-up less than 12 months were excluded. Outcomes included fracture and revision rates, osteolysis, pre- and postoperative patellar thickness, and residual bone thickness. Paired t-tests with mean difference (MD) were used to compare patellar measurements. Interclass correlation coefficient for residual bone thickness was 0.92 ($p = 0.009$). Logistic regression was performed to assess the association between residual bone thickness and fracture risk.

Results: Mean follow-up was 36 months (range, 16–67 months). No patellar revisions were performed. Two fractures occurred (0.6%), both managed conservatively, and no aseptic loosening or implant migration was observed. Radiographic osteolysis was identified in 11 patients (3.4%), with 19 osteolytic patterns distributed across four anatomical regions, most commonly the lateral quadrant. Full patellar thickness showed a small postoperative reduction (MD −0.77 mm, $p < 0.001$). Mean postoperative residual bone thickness was 13.5 mm (range, 9–17.7 mm). Fracture cases had lower residual bone thickness compared with non-fracture cases (MD −1.4 mm, $p < 0.001$). There were no intraoperative fractures for the entire cohort.

Conclusion: Contemporary cementless patellar resurfacing demonstrates excellent early clinical and radiographic outcomes, with minimal complications and no revisions. No fractures occurred in patellae with residual thickness <12 mm; however, given the limited number of fracture events, no definitive conclusions can be drawn regarding a thickness threshold and fracture risk.

Abbreviations: BMI, body mass index; CI, confidence interval; CT, computed tomography; ICC, intraclass correlation coefficient; IQR, interquartile range; MD, mean difference; OR, odds ratio; SD, standard deviation; SPSS, Statistical Package for Social Sciences; TKA, total knee arthroplasty.

Level of Evidence: Level IV.

KEYWORDS

cementless patella, metal-backed patella, patellar components, polyethylene, resurfacing, total knee arthroplasty

INTRODUCTION

Patellar resurfacing is a successful procedure for treating end-stage osteoarthritis and is commonly performed as part of primary total knee arthroplasty (TKA) [29, 33]. While cementless TKA designs are gaining interest and national registry recorded numbers are increasing, there, historically, was a concern for early implant failure of cementless metal-backed patellar components due to multiple design flaws, including polyethylene fracture and wear, polyethylene dissociation from the metal backing, inadequate bone ingrowth, and component fracture [1, 3, 11, 15, 24]. Osteolysis was the most catastrophic complication, caused by metal-on-metal contact between the metal-back of the patella and the anterior femoral flange following even minimal maltracking [9, 22, 25, 28, 34]. As such, the widespread abandonment of cementless patellar components favoured cemented all-polyethylene alternatives [14, 21].

In recent years, significant advances in implant design have led to a renewed interest in cementless patellar resurfacing. Modern cementless metal-backed patellar components incorporate 3D additive porous surface techniques and improved polyethylene, enhancing fixation to promote rapid osseointegration while minimising the revision rate that plagued earlier designs [18, 31]. Recent large cohort studies have demonstrated favourable survivorship and complication rates of modern cementless metal-backed patellar components at mid-term follow-up [12, 13]. However, these studies have primarily focused on implant survival, leaving several clinically relevant aspects insufficiently explored.

Concerns persist regarding residual bone thickness, fracture risk, and osteolysis that may develop over time. In addition, comprehensive data on the clinical and radiographic outcomes of contemporary cementless patellar resurfacing are lacking, particularly with regard to the relationship between residual bone thickness and fracture risk and the rate and pattern of osteolysis. Therefore, the aim of this study was to provide a comprehensive evaluation of residual patellar bone thickness in a consecutive robotic-assisted cohort undergoing primary TKA with contemporary cementless patellar resurfacing, including its distribution, its relationship with early complications and quadrant-specific radiolucency patterns, and the internal validation of radiographic measurements.

MATERIALS AND METHODS

Study design and population

After obtaining informed consent, all patients who underwent primary robotic-assisted TKAs using the same asymmetric cementless Stryker Triathlon Tritanium Metal-Backed Patella (Stryker, Kalamazoo, MI, USA) performed at a single institution between January 2021 and December 2024 with a minimum follow-up of 12 months were included. We analysed the data on complications, patellar fractures, and revision rates, osteolysis, as well as pre- and post-operative patellar thickness and postoperative residual bone thickness. The study was conducted in accordance with the STROBE guidelines [4].

Surgical protocol

All procedures were performed using asymmetric Stryker Triathlon Tritanium Metal-Backed Patella (Stryker) during primary TKA using the MAKO® robotic-assisted system (Stryker) and restricted kinematic alignment. The tourniquet was routinely inflated during the TKA. TKAs were performed by two board certified orthopaedic surgeons. All patients underwent the same perioperative fast-track recovery, antibiotic, and anti-thromboembolic protocols.

Patellar thickness and residual bone thickness measurements

Patellar and residual bone thickness measurements were calculated on Merchant's view [17] X-rays and the Song et al. [30] method, with analysis performed using TraumaCad® software (Brainlab SE, Munich, Germany) integrated auto-calibration system (Figure 1).

Preoperative patellar thickness was defined as the maximum length of the thickest portion of the preoperative patellar bone. Postoperative patellar bone thickness was defined as the combined length of the thickest portion of the resected patellar bone plus the patellar button thickness of the implant as reported in the surgical report. Residual patellar bone thickness was defined as the height of the thickest portion of the resected patella following patellar osteotomy.

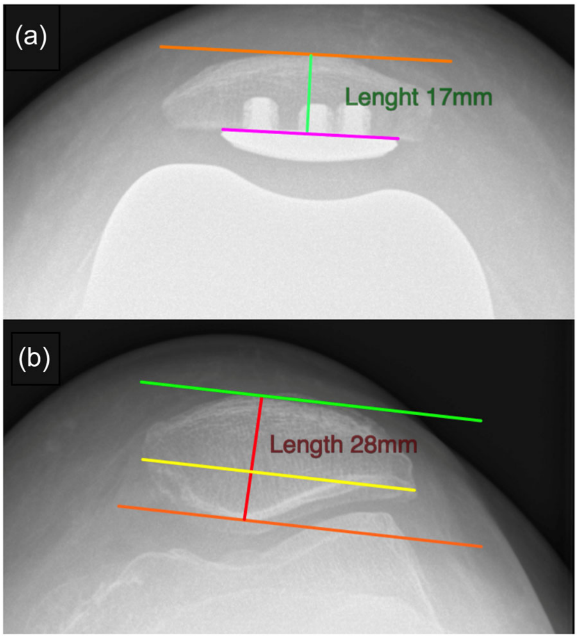

FIGURE 1 The image shows the methodology for assessing patellar measurements with the self-calipered software. (a) Residual bone thickness (green line) is calculated from the mid-base of the patellar button (magenta line) to the opposite cortex (orange line) in the axial view X-ray. (b) Preoperative full patellar thickness (red line) is measured from the innermost point to the opposite cortex (orange line), perpendicular to the patellar virtual resection line (yellow line) in the axial view X-ray.

Radiographic reliability and internal validation

To ensure methodological validity and reliability, we performed a post-hoc internal validation and inter-rater reliability assessment on a subset of 15 patients. Power analysis using G*Power Version 3.1.9.6 indicated that with 15 subjects, we achieved 84.7% power for two-method comparisons and 89.1% power for three-rater reliability studies to detect intraclass correlation coefficient (ICC) values ≥ 0.90 ($\alpha = 0.05$).

For internal validation, preoperative patellar thickness measurements obtained from Merchant's view X-rays were compared against axial CT scans (the same imaging data used for MAKO robotic planning protocol to generate 3D anatomical models), demonstrating excellent agreement (ICC = 0.94, 95% confidence interval [CI]: 0.86–0.98). Postoperative patellar thickness measurements were validated by comparing Merchant's view X-rays against lateral view X-rays, demonstrating excellent agreement (ICC = 0.91, 95% CI: 0.82–0.96).

Inter-rater reliability was assessed by having three independent, blinded clinicians measure patellar thickness parameters on the same 15 patients using Merchant's view radiographs. Preoperative patellar bone thickness measurements (ICC = 0.93, 95% CI: 0.85–0.97), postoperative patellar bone thickness (ICC = 0.95, 95% CI: 0.89–0.98), and residual patellar bone thickness (ICC = 0.92, 95% CI: 0.84–0.96) demonstrated excellent inter-rater reliability.

Data collection and study endpoints

Data were collected including age, gender, side, patellar measurements, implant characteristics, and radiographic outcomes. Radiographic data were collected using lateral and Merchant's view X-rays for each patient. The presence of radiolucent lines and osteolysis was assessed on serial radiographs obtained at standard postoperative follow-up intervals (3, 6, 12, and ≥12 months). Radiographic osteolysis was defined as a focal area of cancellous bone resorption with loss of trabecular architecture visible on plain radiographs in axial medial, axial lateral, sagittal proximal, sagittal distal patellar quadrant, and follow-up. (Figure 2). Non-progressive radiolucent lines were defined as radiolucencies <2 mm that remained unchanged across available follow-up time points. Patient-reported outcome measures (PROMs) were collected at the latest follow-up (1 year) using the Forgotten Joint Score (FJS), the EQ-5D-5L index, the Oxford Knee Score (OKS) and the Knee injury and Osteoarthritis Outcome Score (KOOS).

The primary outcomes included failure rates, revision rates, radiographic osteolysis (per patient and per quadrant), and patellar fractures identified on radiographs.

The primary outcomes were failure rates, reason for failure rates, revision rates, reason for revision rates, osteolysis rates in at least one patellar quadrant per patient, and the overall osteolysis rates in each patellar quadrant, or fractures visible on X-rays. The secondary outcomes were the paired mean difference in preoperative and postoperative patellar thickness and the overall data distribution of residual bone thickness, the data distribution of residual bone thickness for each reason for failure, and the predictive association between residual bone thickness and fracture.

This study was conducted in accordance with the principles of the Declaration of Helsinki and reported in compliance with the STROBE guidelines. According to institutional policy and national regulations, formal Institutional Review Board approval was not required for this retrospective observational study based exclusively on anonymized clinical and radiographic data collected during routine care.

All patients provided written informed consent for the surgical procedure and for the use of their anonymized data for research purposes. No additional procedures or imaging were performed for research purposes. All data were de-identified prior to analysis to ensure patient confidentiality.

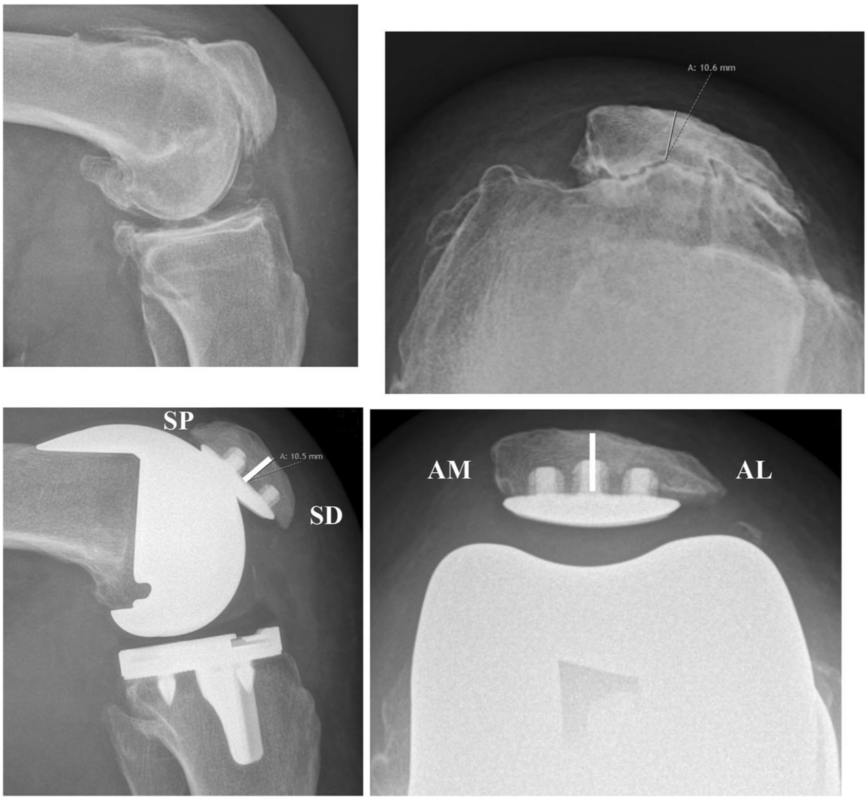

FIGURE 2 Example of a massively deformed osteoarthritic patella with significant bone loss. Osteolysis was assessed in four predefined patellar quadrants: axial medial, axial lateral, sagittal proximal and sagittal distal.

Data analyses

Data distribution was analysed using mean, median, range, and interquartile ranges for continuous variables and using frequencies and percentages for categorical variables. Chi-square tests were used to assess differences between categorical variables. Paired t-tests and mean differences were used to compare preoperative and postoperative patellar thickness measurements. Independent samples t-tests were used to compare the data distribution of residual bone thickness for each reason for failure.

Statistical analyses were performed using Statistical Package for Social Sciences (SPSS) version 29.0 (IBM SPSS Statistics for Windows; IBM Corp, Armonk, NY). Statistical significance was set at $p < 0.05$. All results were reported with 95% confidence intervals (95% Cis) with effect sizes and p-values.

RESULTS

Of 323 patellar resurfacings 18 cases were excluded due to incomplete data sets or less <12 month follow-up resulting in 305 cases for the final analysis. The mean follow-up was 36 months (range, 16–67 months). Baseline demographics are provided in Table 1.

TABLE 1 Patients characteristics.

	Mean (SD)	Range
Age (y)	68.5 (9.3)	42.1–92.8
Female gender [*n* (%)]	197	61
Right side [*n* (%)]	169	52.3
Button size 9 [*n* (%)]	3	0.9
Button size 10 [*n* (%)]	183	56.7
Button size 11 [*n* (%)]	122	37.8

Abbreviation: SD, standard deviation.

All cases showed no radiographic evidence of loosening, migration, or progressive radiolucencies at latest follow-up ($n = 305/305$; 100%), with no treatment failure cases (0%). There were two fractures (0.7%). Both fractures occurred after 12 months, which should be interpreted in the context of the relatively short follow-up. One fracture was caused by a fall on the knee during follow-up, and in the second case, there was no adequate trauma. The fractures healed with conservative treatment in both cases, needing no additional surgery. No failures following aseptic loosening were reported ($n = 0$; 0%). No revisions were reported ($n = 0$; 0%). Overall, evidence of radiographic osteolysis was reported for 11 patients (3.6%). All patients reporting radiographic evidence of osteolysis were asymptomatic; thus, no additional treatment or deviation from the standard follow-up protocol was implemented. The distribution of osteolysis by patellar anatomical quadrant is shown in Table 2. The axial lateral quadrant was the most frequently affected area, with 27 cases (8.9%) showing non-progressive radiolucency and 11 cases (3.7%) demonstrating osteolysis. No cases showed radiographic signs of loosening, migration or subsidence at latest follow-up, and no revisions for aseptic failure were recorded. Six patients (2.0%) showed multi-regional osteolysis. No significant associations were found between gender and fracture occurrence ($p = 0.67$), age and fracture occurrence ($p = 0.441$), or gender and osteolysis development ($p = 0.932$). At the latest follow-up, patient-reported outcomes were satisfactory. The mean Forgotten Joint Score was 65, the mean EQ-5D-5L index was 0.85, the mean Oxford Knee Score was 42, and the mean KOOS score was 80, indicating good joint awareness, knee function, and health-related quality of life.

Data distribution of preoperative and postoperative patellar thickness and residual patellar bone thickness is shown in Table 3. Full patellar thickness showed virtually no reduction postoperatively with a mean difference of 0.78 mm (95% CI: 0.56–1.00; t-test = 6.9; Cohen's $d = 0.359$; $p < 0.001$; $n = 305$; Table 3).

The mean postoperative residual bone thickness was 13.4 mm (range, 9.0–22.0 mm). Forty-eight patients (16%) had residual thickness below 12 mm, corresponding to the 25th percentile of the cohort distribution. Both fracture cases occurred at 12 mm. No fractures were observed among patients below the 25th percentile (<12 mm).

Patients with fractures had a mean residual bone thickness of 12.0 mm compared to 13.42 mm in patients without fractures ($p < 0.001$; Table 4). However, logistic regression analysis showed no significant predictive association between residual bone thickness and fracture risk (odds ratio [OR] = 0.57; 95% CI: 0.215–1.336; Z-value = −1.15; $p = 0.248$). Among the 48 patients (16%) in the lower 25th percentile group for residual bone thickness (<12 mm), no fractures were reported.

DISCUSSION

The most relevant finding of this study was the low rate of early complications and absence of revision at short-term follow-up in a consecutive series of contemporary cementless patellar resurfacings. In addition, fractures showed no association with residual bone thickness with the data available in this cohort. These results suggested that contemporary asymmetric cementless metal-backed patellar resurfacing is a safe and effective procedure in the early term.

In the current series, we observed no revisions and all cases showed sufficient primary stability during surgery, so that no cement augmentations were utilised. No cases demonstrated progressive radiographic loosening, migration, or need for revision at latest follow-up. A recent meta-analysis demonstrated that the incidence of revision surgery for patellar complications occurred at a rate of 1 per 1000 person-years and a revision rate for aseptic loosening at a rate of 0.2 per 1,000 patient-years [6], confirming our findings. Similarly, Baker et al demonstrated excellent implant survivorship, with 99.9% of 707 patellar components remaining free from aseptic loosening-related revision at 7-year average follow-up [2]. Complementary evidence was provided by Jouflas et al., who reported 99.3% survivorship without aseptic loosening in 136 knees over a mean 10-year of follow-up [13].

The historical concerns associated with first-generation metal-backed implants have been effectively addressed in the current implant design, which conceals the metal component inside the polyethylene, avoiding possible metal-on-metal contact with the femoral flange and enabling fixation of the additive, highly porous Titanium matrix ingrowth surface. Additionally, multi-peg metal-back configurations provide superior primary stability and create multiple sites for bone ingrowth, resulting in enhanced osteointegration outcomes [13]. Enlarged-diameter fixation pegs also maximise the surface area available for bone ingrowth while distributing mechanical loads more effectively to reduce shear stress concentrations and potentially reduce early postoperative pain when osteointegration has not yet occurred [10, 12, 19, 23, 26]. One investigation previously reported weight-bearing pain levels throughout the first 3 months following cementless

TABLE 2 Osteolysis distribution by patellar anatomical quadrant.

Patellar quadrant	No Involvement n (%)	Non-progressive lucencies n (%)	Osteolysis n (%)
Axial medial	285 (93.4)	15 (4.9)	5 (1.6)
Axial lateral	267 (87.5)	27 (8.9)	11 (3.6)
Sagittal proximal	298 (97.7)	6 (2.0)	1 (0.3)
Sagittal distal	297 (97.4)	6 (2.0)	2 (0.7)

TABLE 3 Preoperative and postoperative patellar bone thicknesses measurements.

Measurement	*n*	Mean ± SD (mm)	Median (IQR) (mm)	Min–max (mm)
Preoperative patellar thickness	305	23.04 ± 2.33	23.0 (21.1–24.5)	16.5–30.3
Postoperative patellar thickness	305	23.83 ± 1.94	23.7 (22.6–25.0)	18.1–32.0
Residual patellar bone thickness	305	13.40 ± 1.86	13.1 (12.0–14.5)	9.0–22.0

Abbreviations: IQR, interquartile range; SD, standard deviation.

TABLE 4 Residual bone thickness by patellar fracture status.

Fracture status	*n*	Mean ± SD (mm)	Median (mm)	Min–Max (mm)
No fracture	303	13.42 ± 1.86	13.2	9.0–22.0
Fracture	2	12.00 ± 0.00	12.0	12.0–12.0

Abbreviation: SD, standard deviation.

patellar resurfacing, showing similar levels both at rest and during walking [32].

The patellar fracture rate of 0.7% in the current series was comparable to contemporary literature reporting periprosthetic fracture rates of 0.2%–0.5% in large-scale studies comparing cemented versus cementless TKA, with no significant difference between fixation methods (OR 1.22–1.30, $p > 0.05$) [7]. No fractures occurred intraoperatively or in the immediate postoperative period, meaning to us that the pressfit is not a problem. Additional to this, we were not able to find any correlation of increased fracture risk and patella with residual bone thickness below 12 mm, that is often referred to the minimal bone thickness. Possibly this is the effect of the biological bond and osteoinductive potential of cementless patella designs. Potentially, this data might influence current clinical practice, that cementless patella are of special interest for deformed and thin patella with preoperative bone loss.

Also, no polyethylene dissociation occurred in our series. Previous metal-backed patellar failures also resulted from polyethylene dissociation due to inadequate heat-pressed locking mechanisms [5, 16, 27, 34]. The current implant design utilises compression-moulding techniques to bond polyethylene into highly porous surfaces, avoiding heat-pressed technology and improving interlocking strength.

A novelty of the current study was the inclusion of radiographic osteolysis and radiolucencies as outcome measures. Fricka et al. [8] found that cementless TKA demonstrated a greater incidence of radiolucent lines on postoperative radiographs, but overall survivorship at 2 years was equivalent between cemented and cementless TKA [33]. While prior radiostereometric studies documented early superior migration of approximately 3.5 mm in 10% of patients within the first 6 postoperative weeks, our cohort achieved 100% osseointegration without any evidence of loosening-related complications throughout the 22-month mean follow-up period, despite not specifically assessing component migration [31].

The excellent safety profile demonstrated in this study at least in the early phase may encourage surgeons to reconsider cementless patellar resurfacing as a viable alternative to all-polyethylene components, potentially especially for hardly worn out patella with significant bone loss. With the growing interest in cementless TKA components, particularly in high-demand patients such as active individuals, younger patients, or those with a high BMI, metal-back patella resurfacing may offer benefits in terms of long-term implant survival, greater intraoperative efficiency, and better use of resources [20, 32].

Several limitations should be acknowledged when interpreting these results. The retrospective design inherently limits our ability to control for confounding variables and introduces potential selection bias. In addition, this this study presents short-term follow-up and may not capture long-term complications such as late aseptic loosening, fractures, and dissociation of the patella-component. Furthermore, the study lacks a control group comparing outcomes with cemented all-polyethylene patellar components, limiting our ability to make direct comparative statements about superiority. Even though, we are presenting one of the largest consecutive series of modern cementless patella resurfacings, the overall number of complications and especially fractures are low. That might limit the power of the study, especially with regard to the residual bone thickness dependency to fracture risk. Furthermore, only patients undergoing patellar resurfacing were included in this study, and no comparison with non-resurfaced patellae was performed, which may limit the generalisability of the findings.

CONCLUSION

Contemporary cementless patellar resurfacing was associated with a low rate of early complications and no revisions at short-term follow-up in this consecutive series. Residual patellar bone thickness showed a broad distribution, and fracture events were rare.

AUTHOR CONTRIBUTIONS

Rudy Sangaletti: Conceptualisation and study design; surgical procedures; data acquisition; data analysis and interpretation; drafting of the manuscript; critical revision for important intellectual content. **Nils Meissner**: Study design; data acquisition; surgical contribution; critical revision of the manuscript. **Marco Pungitore**: Data acquisition; surgical contribution; data interpretation; critical revision of the manuscript. **Angelo V. Vasiliadis**: Methodology; data interpretation; critical revision of the manuscript for intellectual content. **Carlo Theus-Steinmann**: Data acquisition; surgical contribution; manuscript review. **Tilman Calliess**: Supervision; methodological support; data interpretation; critical revision of the manuscript. **Filippo Leggieri**: Data acquisition; statistical support; manuscript review. **Matteo Innocenti**: Senior supervision; conceptual oversight; final approval of the manuscript.

CONFLICT OF INTEREST STATEMENT

T.C. is a paid consultant for Stryker and Medacta International. N.M. has received research funding from the German Innovation Fund, the German Society for Orthopaedics and Trauma and Aesculap AG.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to ethical and privacy restrictions related to patient confidentiality.

ETHICS STATEMENT

This study includes retrospective analysis of the institutional database on primary total knee arthroplasies with radiographic evaluation of available postOP follow-up examinations. All patients included in the study gave their informed consent in the collection and scientific analysis of their data. To the institutional rules no extra IRB review is needed in such retrospective, anonymized data analysis. All patients included in the study gave their informed consent in the collection and scientific analysis of their data.

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