

Original Research

Coronal Alignment in Revision Total Knee Arthroplasty: A Comparison of Cemented Vs Press-Fit Stems for Restoring Mechanical Axis

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ARTICLE INFO

Article history:

Received 13 April 2025

Received in revised form

25 August 2025

Accepted 28 August 2025

Available online xxx

Keywords:

Revision total knee arthroplasty

Coronal alignment

HKA

Cemented stem

Press-fit stem

ABSTRACT

Background: Restoring a neutral coronal alignment in revision total knee arthroplasty (rTKA) is paramount. Stem length and fixation type influence final limb alignment. This study compared overall limb alignment, measured by hip-knee-ankle (HKA) angle, in revisions using short-cemented (<75 mm), long-cemented (>75 mm), and press-fit stems. Secondary aims included evaluating coronal and sagittal alignment of tibial and femoral components and assessing canal fill ratio (CFR) in the press-fit group. **Methods:** A retrospective multicenter review of 124 rTKAs from January 2019 to January 2022 was conducted. Included cases had revision of both femoral and tibial components using stems, with postoperative weight-bearing radiographs. Patients were divided into 3 groups based on stem type. Radiographic assessments included HKA, mechanical lateral distal femoral angle (mLDFA), mechanical medial proximal tibial angle (mMPTA), and CFR. analysis of variance and chi-square tests were used for statistical analysis. **Results:** Data from 81 rTKAs were analyzed. Mean HKA was similar across all groups (group A: 178.9°, group B: 178.7°, group C: 178.7°; $P = .985$). No significant differences were found in mLDFA or mMPTA between groups. However, mLDFA showed more variability than mMPTA ($P = .021$), indicating greater femoral alignment deviation. CFR in press-fit stems averaged 77.3%, with no significant side-to-side differences. **Conclusions:** Short-cemented stems achieved alignment comparable to long-cemented and press-fit stems. Femoral alignment was more variable than tibial. Short-cemented stems provide a flexible option with reliable alignment outcomes.

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Introduction

Revision total knee arthroplasty (rTKA) is a significant burden on the healthcare system, largely due to the increasing number of primary total knee arthroplasty (TKA) procedures [1]. rTKA is a complex procedure which requires meticulous strategy and technique to restore proper alignment and knee function [2,3]. Surgeons face challenges related to surgical exposure, bone loss, soft tissue management, implant selection and fixation, to provide

long-term stability and regain function [2-4]. One of the most common causes of rTKA failure is loosening due to insufficient fixation, followed by infection and stiffness [5-9]. Proper implant fixation, accounting for bone loss and quality, is essential for implant longevity [10]. Morgan Jones [11] described “zonal” fixation in rTKA, considering zones: epiphysis, metaphysis, and diaphysis. Multizonal reconstruction with a combination of cemented and cementless parts is key for durable fixation [3,12]. Intramedullary stems, working with metaphyseal support, transfer load over a larger area, reducing strain at the bone-component interface and the risk of loosening [3,13]. Stems, bypassing deficient or damaged areas, provide diaphyseal fixation, protect the juxta-articular bone, and increase component stability and

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survivorship [13–15]. Literature supports the use of stems in rTKA, especially with highly constrained designs [16–18]. Based on length, stems are defined as metaphyseal-engaging stems or diaphyseal-engaging stems. Moreover, the stems' length is based on the patient's anatomy and the intended fixation, cemented or press-fit cortical contact. Cemented stems offer good initial stability, particularly in osteoporotic and difficult canals, but should be used cautiously in sclerotic canals [19]. Among the numerous variables to consider in rTKA, the choice of fixation type is of crucial importance and remains a topic of ongoing debate. Furthermore, the restoration of limb alignment is one of the most critical technical factors, as it directly impacts both implant survivorship and functional outcomes. Mechanical alignment (MA), aiming to achieve a neutral hip-knee-ankle (HKA) axis, is the dominant strategy in rTKA [4]. However, in primary TKA, dissatisfaction rates remain high after evidence suggests that rigid MA may not always optimize function. In TKA, kinematic alignment (KA), to restore or preserve the patient's prearthritic knee anatomy by resurfacing the native joint and maintaining the soft tissue envelope, is an alternative to MA to minimize these issues. KA has shown equivalent or better functional outcomes and survival rates in the mid-term than MA [20]. These concepts are gaining acceptance in revision surgery, where altered bony anatomy and loss of landmarks often complicate alignment decisions. The application of KA principles to rTKA has been reported by only a few authors, in selected patients [21,22]. However, given the challenges inherent to revision surgery, including bone loss, loss of landmarks, soft tissue management, and implants designed for MA, the MA technique remains the gold standard in rTKA [4,23].

The decision between cemented and cementless fixation is complex and may significantly impact the final outcome, particularly in terms of final limb alignment. Therefore, evaluating the effectiveness of achieving the targeted neutral MA with long press-fit stems, long-cemented stems, and short-cemented stems is crucial. The aim of this study was to assess differences in overall limb alignment, measured by HKA, between short-cemented (<75 mm), long-cemented (>75 mm), and press-fit stems, in rTKA using a single revision knee implant design. The secondary aims included comparing coronal and sagittal alignment of tibial and femoral components, mechanical medial proximal tibial angle (mMPTA), and mechanical lateral distal femoral angle (mLDFA), respectively, in order to investigate any variability among the 3 groups, as well as the canal fill ratio (CFR) in the press-fit stem group. We hypothesized that short-cemented stems allow restoration of alignment comparable to that achieved with longer cemented or press-fit stems, while offering greater flexibility for individualized alignment strategies in modern rTKA.

Material and methods

We conducted a multicenter analysis of all the rTKA surgeries performed on primary TKA between January 1, 2019, and January 1, 2022. This study was conducted under the ethical principles outlined in the Declaration of Helsinki. We retrospectively reviewed 124 knees (123 patients) who underwent rTKA surgery. Inclusion criteria were patients who underwent rTKA for all causes, revision of both the femoral and tibial components, implantation of stemmed implants (both sides), availability of both preoperative and postoperative full-length weight-bearing and standard antero-posterior (AP) and lateral radiographs, use of NexGen Legacy Constrained Condylar Knee (LCCK) semiconstrained implants (Zimmer Biomet, Warsaw, Indiana, USA), and minimum follow-up (FU) of 24 months. Partial revisions, patients who declined or died during the radiographic FU to date, cases with missing full-limb weight-bearing radiographs, and those treated

with implants other than Zimmer NexGen LCCK were excluded. Hospitals' medical records were recorded and analyzed using electronic software. The following information was collected: demographic data, cause of revision, size and length of stems, complications and failures (defined as any surgical reoperation on the rTKA, such as explant, amputation, polyethylene exchange, lysis of adhesions, fracture fixation, extensor mechanism reconstruction, and repeat rTKA). In accordance with the literature, stems shorter than 75 mm were regarded as metaphyseal-engaging stems, while stems longer than 75 mm were regarded as diaphyseal-engaging stems [15,19]. Hybrid fixation refers to diaphyseal fixation with long press-fit stem with cemented epiphyseal and metaphyseal areas [14]. According to stem type, the patients were divided into 3 groups: group A, long-cemented stems (>75mm); group B, short-cemented stems (<75mm); and group C, press-fit stems (hybrid fixation).

Surgical technique

All patients, whether revised for septic or aseptic indications, underwent a standardized preoperative assessment including long-leg radiographs and computed tomography scans in order to define the extent of bone loss. Digital preoperative planning was always performed. The decision for fully cemented (short or long) vs hybrid fixation was determined by the senior surgeons on a case-by-case basis. The instrumentation of NexGen LCCK revision provides a 90° coronal tibial component positioning with a 7° slope for the tibial component, and a 6° valgus angle for the femur. The combination of the femoral component with the LCCK insert limits rotation to 2° and the coronal tilt to 1.25°. The surgical aim was to restore a neutral MA, targeting 90° on the tibial side and 6° of valgus on the femoral cut according to the instrumentation. In the short-cemented stem group (<75 mm), intramedullary alignment guides were routinely employed for both tibial and femoral preparation. To increase accuracy, alignment was always cross-checked with extramedullary landmarks. On the tibial side, the rod was aligned with the space between the first and second metatarsals, while on the femoral side, the reference was approximately 2 cm medial to the anterior superior iliac spine. Cementation involved complete pressurization and filling of the metaphysis, following the placement of intramedullary plugs, sometimes in combination with trabecular metal cones in cases of bone loss. The advantage of this approach was the greater intraoperative freedom to orient the components independently of the diaphyseal canal, which allowed surgeons to correct deformities and restore a MA. The long-cemented stem group (>75 mm) relied primarily on intramedullary referencing, and these stems were fully cemented into the canal. They were particularly favored in situations with poor bone quality, extensive bone defects, or when diaphyseal support was required to achieve adequate fixation. The longer stems ensured robust mechanical stability by bypassing compromised metaphyseal bone. However, this increased stability came at the cost of reduced flexibility in positioning, since once the stem was cemented in the canal, the ability to fine-tune alignment was limited. The decision to use modular offsets was made case by case intraoperatively to center the femoral and tibial components and avoid malalignment. Finally, in the hybrid fixation group (long press-fit stems), stems were implanted with diaphyseal press-fit fixation and cementation limited to the epiphyseal and metaphyseal regions. Alignment was based on intramedullary guides, with the intraoperative target of achieving a CFR of at least 85% in both the AP and medio-lateral planes, as recommended by previous studies [24–26]. Because the fixation depended heavily on diaphyseal engagement, these stems imposed a rigid link to the intramedullary axis. As a consequence, the decision to use modular

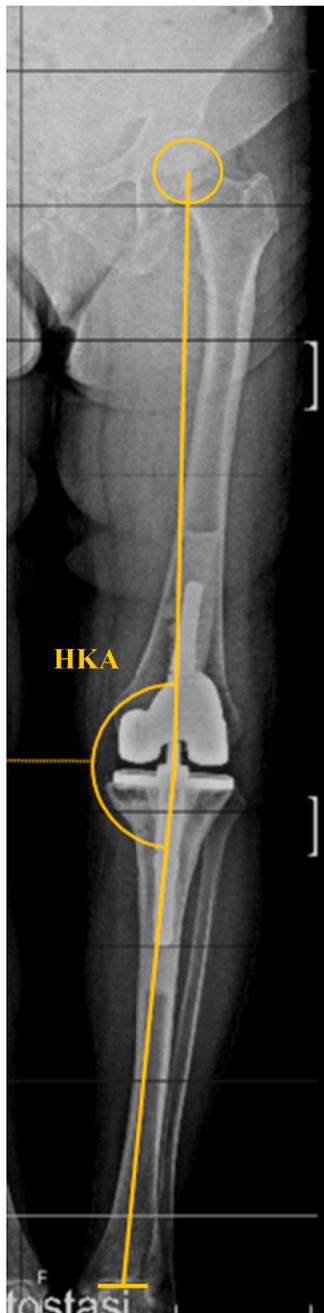


Figure 1. Radiographic assessment of postoperative measurements, HKAa hip-knee-ankle angle.

offsets was made case by case intraoperatively to center the femoral and tibial components and avoid malalignment. This technique provided strong axial stability, but at the expense of flexibility in restoring individualized alignment, as the orientation of the components was largely dictated by the patient's canal morphology.

Radiographic measurements

Standing short AP and lateral and full-length weight-bearing AP images were taken preoperatively, as well as 3 to 24 months postoperatively for all participants. Postoperative full-length weight-bearing radiographs were used to measure 3 angles: HKA defined as the angle formed by the mechanical femoral axis and



Figure 2. Radiographic assessment of postoperative measurements, mLDFA mechanical lateral distal femoral angle, mMPTA mechanical medial proximal tibial angle.

the mechanical tibial axis (Fig. 1), mLDFA defined as the lateral angle formed between the mechanical femoral axis and the knee joint line of the distal femur, and mMPTA defined as the medial angle formed between the mechanical tibial axis and the knee joint line of the proximal tibia Figure 2 [27-30]. Postoperative standard AP and lateral radiographs were used to measure the CFR defined as the percent of canal filled by tibial and femoral stem extensions and is calculated by dividing the width of the stem at its tip by the canal width at the same level, both on AP and lateral radiographs [24-26] Figure 3. The radiographic measurements were performed by 2 independent blinded orthopaedic surgeons on 2 occasions using the TraumaCad, version 2.0 system (BrainLab, Feldkirchen, Germany).

Statistical analysis

Statistical analysis was performed using SPSS (version 25.0; IBM, Armonk, NY, USA). The Shapiro-Wilk tests were used to assess for the normality of the distribution of continuous variables. Descriptive statistics (means, standard deviations, ranges, and medians as appropriate) were used to describe the patients' variables and radiological data. Categorical variables were assessed using chi-square or Fisher's exact tests for statistical significance. The continuous variables were compared with the use of one-way analysis of variance or the Kruskal-Wallis test depending on

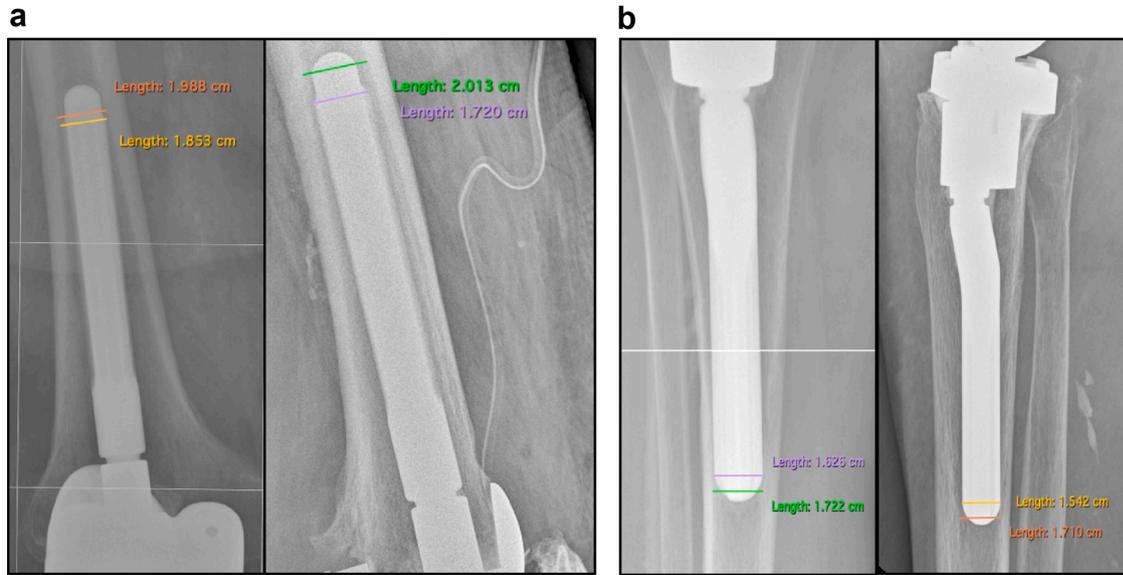


Figure 3. Radiographic assessment of postoperative measurements of the canal fill ratio, (a) Femoral stem AP and lateral views; (b) Tibial stem anteroposterior and lateral views.

parametric or nonparametric values, respectively. All tests were 2-tailed. A 2-sided *P* value of <0.05 was defined to be considered statistically significant. The intraclass correlation coefficients were used to quantify the interrater and intrarater reliability of all radiographic measurements. Intraclass correlation coefficient values greater than 0.90 indicated excellent reliability. This study was not powered a priori to detect small differences in radiographic parameters, as the retrospective design provided a fixed sample size. Post hoc considerations indicate that with approximately 40 patients per group, the minimum detectable difference for HKA and mLDFA/mMPTA was around 2°, assuming a standard deviation of 3°. Therefore, while no statistically significant

differences were observed, smaller but potentially clinically meaningful variations cannot be excluded.

Results

According to inclusion and exclusion criteria, 81 knees (80 patients) were included in the final analysis. Seven knees were lost to FU (5) or died (2), 8 had partial rTKA, in 26, a different implant other than LCCK was used, and 2 patients were not able to perform full-length radiographs **Figure 4**. Twenty-nine were men (36.3%) and 51 women (63.7%). The mean age at revision time was of 75.4 ± 8.5 years. Thirty-three were left knees and 48 right knees; only 1 patient had bilateral rTKA surgery. Indications were prosthetic joint infection (34/81, 42%) and aseptic loosening (47/81, 58%). The epidemiological data are shown in **Table 1**. The mean FU was 26 ± 4.5 months.

According to stem type, patients were divided in 3 groups:

- group A: long-cemented stems (>75mm): 24 knees;
- group B: short-cemented stems (<75mm): 27 knees;
- group C: press-fit stem (hybrid fixation): 30 knees.

In the entire cohort, offset adapters were used in 7 femoral stems (8.6%) and 29 tibial stems (35.8%), predominantly in cases with canal eccentricity or metaphyseal deformity in groups A and C (long-cemented stems and press-fit stems). No offsets were used in group B. Specifically, 17 offset adapters were used in tibial press-fit stems (56.7%) and 5 in femoral press-fit stems (16.7%). In addition, 12 offset adapters were used in tibial long-cemented stems (50%) and 2 in femoral long-cemented stems (8.3%), with no significant difference in distribution between groups A and C (*P* = .53).

HKA

The mean alignment reported as HKA in the cohort was 178.8° ± 3.0. The mean HKA in group A (long-cemented stems) was 178.9° ± 2.9° (range: 170.3°-187.4°), in group B (short-cemented stems) was 178.7° ± 2.51° (range: 174.6°-184.8°), and in group C (press-fit stems) was 178.7° ± 3.4° (range: 174.5°-188.8°) **Table 2**.

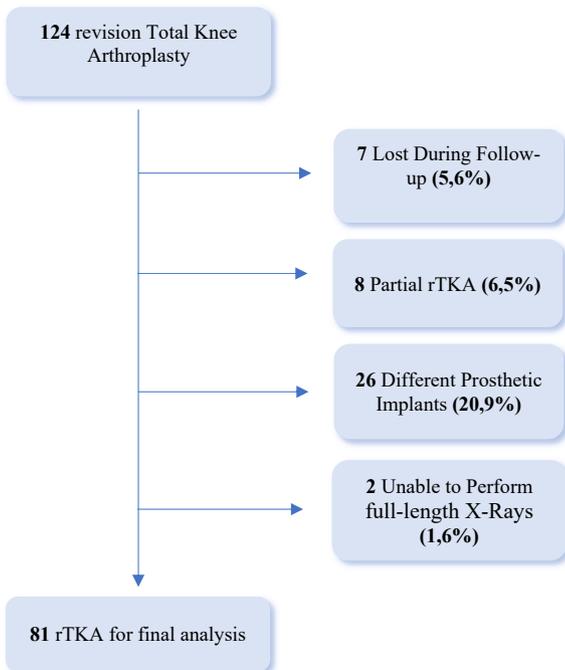


Figure 4. The flowchart of the patients who were included in the study.

Table 1
Cohort epidemiological and procedure-related data.

Baseline/Medical data	Global	Group A	Group B	Group C	P value
Sex					0.178
Women (knees)	52	19	15	18	
Men (knees)	29	5	12	12	
Age	76.28 ± 8.49	75.92 ± 7.67	73.98 ± 9.92	76.63 ± 7.69	0.539
Side					0.338
Right	48	15	13	20	
Left	33	9	14	10	
Body mass index	29.3 ± 5.6	29.2 ± 5.7	28.9 ± 5.6	29.4 ± 5.3	0.350
rTKA cause					0.06
Septic	34	16	11	7	
Aseptic	47	8	16	23	

Comparison of the three groups revealed not statistically significant difference (P value 0.985) (Fig. 5), even if group C exhibited greater variability in the results, as reported by the size of the boxplot and the standard deviation. There was not statistically significant difference (P value 0.285) in the proportion of outliers, defined as HKA angle $>3^\circ$ from neutral MA (6/24 in group A, 6/27 in group B, 12/30 in group C) between the 3 groups. Subgroup analysis did not show a difference in HKA between rTKA with and without offset adapters ($P > .05$).

mLDFA and mMPTA

The mean mLDFA of the population was $90.6^\circ \pm 2.3^\circ$ (range: 84.3° – 98°), with a higher proportion (58%, 47/81) of patients with varus alignment of the femoral component. The femoral component lays within $\pm 3^\circ$ of the MA in 80% of cases. The mean mLDFA was $90.9^\circ \pm 2.2^\circ$ (range: 86.2° – 95.4°) in group A, $90.5^\circ \pm 1.8^\circ$ (range: 86.8° – 94.7°) in group B, and $90.51^\circ \pm 2.9^\circ$ (range: 84.3° – 98°) in group C, respectively, as reported in Table 2. Not statistically significant difference resulted between the 3 groups (P value 0.573) (Fig. 6). The mean mMPTA of the cohort was $89.32^\circ \pm 1.64^\circ$ (range: 85° – 94.5°). Tibial alignment was within $\pm 3^\circ$ of neutral in 93% of cases, with a higher proportion of tibial component (74%, 60/81) in varus alignment. The mean mMPTA was $89.1^\circ \pm 1.1^\circ$ (range: 86.8° – 91.1°) in group A, $89.5^\circ \pm 2.0^\circ$ (range: 85° – 94.5°) in group B, and $89.3^\circ \pm 1.7^\circ$ (range 85.7° – 92.8°) in group C, respectively, as reported in Table 2. The difference was statistically not significant between the 3 groups (P value 0.704) (Fig. 7). However, in the entire cohort, the femoral component alignment resulted statistically significant more variable than the tibial side (SD: 2.37° vs 1.64°). A greater number of outliers (angle >3 degrees from neutral MA) in the femoral component than the tibial was reported, 16/81, 20% vs 6/81, 7%, respectively, (P value 0.021). Furthermore, no significant difference in mLDFA and mMPTA between the implants with and without offset stems ($P > .05$).

Canal filling ratio

In group C (press-fit stems), average CFR was $77.3\% \pm 8.6\%$ (range: 48%–92.2%). Average femoral CFR was $76.2\% \pm 9.2\%$ (range:

45%–92%) and average tibial CFR measured $78.4\% \pm 9.2\%$ (range: 51%–94%), as reported in Table 3. This difference was not statistically significant (P value 0.615). Greater numbers of outliers (CFR lower than 70%) were found on the tibial side (5/30) in comparison to the femoral side (2/30).

Complications and failures

Five postoperative complications were reported: 2 patients had postoperative anemia treated with transfusions, 2 cases of deep vein thrombosis treated with anticoagulant therapy, and 1 intra-operative fracture (partial detachment) of the tibial tubercle treated conservatively with suture and extension cast. Three cases of failure were registered: 2 knees due to reinfection and 1 due to aseptic failure. The 2 cases of septic failure were an 81-year-old man, previously revised for periprosthetic joint infection by methicillin-resistant *Staphylococcus aureus*, who failed due to reinfection and then converted to arthrodesis and an 82-year-old man, who suffered late reinfection by *Pseudomonas aeruginosa* who underwent chronic suppressive antibiotic therapy. Aseptic failure occurred in a 76-year-old woman who had undergone revision with long press-fit stems 3 years earlier for aseptic loosening, and who subsequently required further revision with a hinged implant due to aseptic femoral loosening.

Discussion

Proper alignment is a critical consideration in rTKA, as inadequate alignment has been consistently shown to be a major contributor to implant loosening in both primary and rTKA

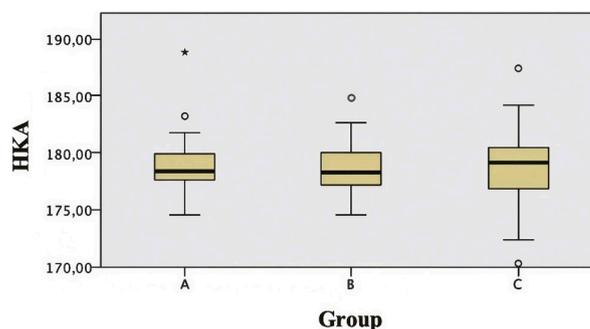


Figure 5. Analysis of correlation between serum HKA and groups according to stems type: a (long-cemented stems), b (short-cemented stems) (<75 mm), group c (press-fit stem). The box height represents the interquartile range (Q1–Q3), the line within the box is the HKA median value, and the lower and upper whiskers represent the lowest and the highest samples, respectively. The circles and stars in boxplots represent outlier samples (>1.5 IQR and >3 IQR, respectively).

Table 2
Radiographic postoperative HKA, mLDFA, and mMPTA Measurements.

Radiographic postoperative measurements	Global	Group A	Group B	Group C
HKA	178.8° ± 3.0°	178.9° ± 2.9°	178.7° ± 2.51°	178.7° ± 3.4°
mLDFA	90.6° ± 2.4°	90.9° ± 2.2°	90.5° ± 1.8°	90.5° ± 2.9°
mMPTA	89.3° ± 1.6°	89.1° ± 1.1°	89.5° ± 2.0°	89.3° ± 1.7°

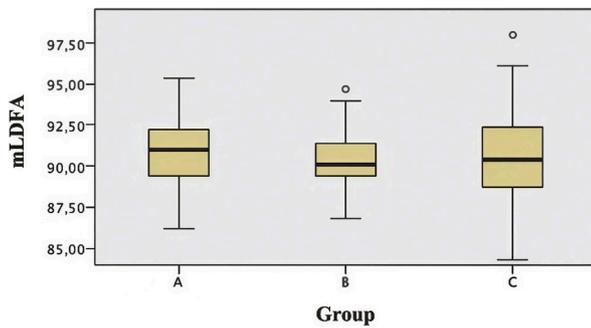


Figure 6. Analysis of correlation between serum mLDFA and groups according to stems type: a (long-cemented stems), b (short-cemented stems) (<75 mm), group c (press-fit stem). The box height represents the interquartile range (Q1-Q3), the line within the box is the mLDFA median value, and the lower and upper whiskers represent the lowest and the highest samples, respectively. The circles and stars in boxplots represent outlier samples (>1.5 IQR and >3 IQR, respectively).

procedures [4,26,31]. The primary focus of this study was to evaluate whether postoperative standing long-leg radiographs revealed any differences in final limb alignment among 3 groups: short-cemented, long-cemented, and long press-fit. Our findings demonstrated that short-cemented stems achieve comparable results in terms of final HKA alignment when compared to long-cemented and press-fit stems ($P = .285$), with no significant differences in alignment outliers between the groups. Furthermore, the entire cohort showed a greater variability and higher number of outliers of the femoral component positioning (P value 0.021) than tibial side.

Accordingly, the review by Patel concluded that the optimal stem length is the one that achieves a mechanically strong construct while preserving as much native bone as possible [15]. Comparable results in terms of outcome using short-cemented stems in rTKA are reported in literature. Jacquet showed that the use of a short-cemented tibial stem combined with a trabecular metal cone in rTKA offers identical survival rate with better functional outcome compared with the use of a long uncemented stem associated with trabecular metal cones or metallic augments at a minimum of 5 years of FU [32-35]. Furthermore, the use of cemented stem provides comparable or better results in terms of implant stability than press-fit stem as reported by Conlisk [36]. The authors, in a vitro study, showed that cemented stems reduce significantly the bone-implant micromotion and offer equivalent

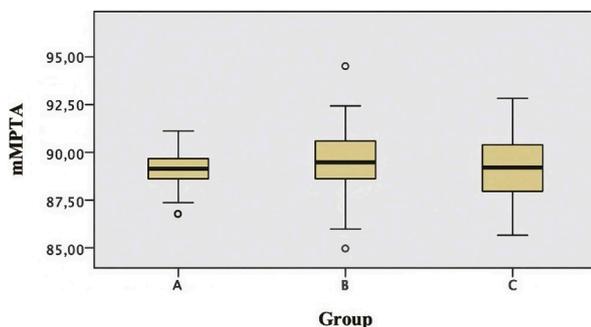


Figure 7. Analysis of correlation between serum mMPTA and groups according to stems type: a (long-cemented stems), b (short-cemented stems) (<75 mm), group c (press-fit stem). The box height represents the interquartile range (Q1-Q3), the line within the box is the mMPTA median value, and the lower and upper whiskers represent the lowest and the highest samples, respectively. The circles and stars in boxplots represent outlier samples (>1.5 IQR and >3 IQR, respectively).

Table 3
Radiographic postoperative canal filling ratio measurements.

Radiographic postoperative canal fill ratio	Global	Femur	Tibia
Mean CFR	77.3% ± 8.6%	76.2% ± 9.2%	78.4% ± 9.2%
Standard deviation of mean		1681	1684
Outliers	7/30	2/30	5/30

biomechanical properties and stability than longer press-fit stems [36]. The cumulative incidence of subsequent revision for aseptic loosening and instability was very low at 5 years with this fixed-bearing Varus-valgus constrained implant in rTKAs. Routine use of cemented and stemmed components with targeted use of metaphyseal cones likely contributed to this low rate of aseptic loosening [37]. However, the hybrid technique has some advantages over the fully cemented method, including relative ease of removal and preservation of bone stock if additional revision is required [38]. At the same time, press-fit stems need strong diaphyseal cortical contact, with risk of iatrogenic fracture. Uncemented stems that extend only to the metaphyseal region usually do not achieve a press-fit over a major endosteal area and have been associated with higher loosening rates and end-of-stem pain [4,39,40].

Contrary to our analysis, Parsley reported that the ability to achieve tibial alignment in the AP plane was more predictable and reliable when canal-filling cementless stems were used [26]. Accordingly, Nakasone [23] and Fleischman [24] suggested that uncemented diaphyseal engaging press-fit modular stems facilitate accurate alignment for both femoral and tibial components in revision surgery because of the engagement of the anatomic axis of the diaphysis. In clinical practice, short-cemented stems are somehow stigmatized due to the lack of strong diaphyseal referencing and the implicit risk of mispositioning, but our study rejected this theory, demonstrating similar results in terms of final coronal alignment between the 3 types of stems analyzed, with a slightly greater variability in terms of final HKA in the press-fit stems group. Our preference, thus supported by the result of our analysis, is to use preferably short-cemented stems that may achieve stability even when only engaging the metaphysis, which can be completely filled with cement and, preferably, cones. These results are supported by recent studies [41,42]. With fewer anatomical constraints, these implants offer surgeons greater versatility, particularly in revision surgeries involving osteoporotic bone or challenging canals. They typically eliminate the need for offset stems, which can pose difficulties during removal in the event of re-revision. Canal preparation is often simpler compared to press-fit stems; however, it is crucial to ensure that the alignment achieved during the trial phase is preserved throughout the implantation process, especially when the canal is not utilized as a point of support. Shorter cemented stems do not need to violate the diaphysis, and even if their removal is pretty hard, it's often easier than longer cemented ones.

Our study found no significant difference between the 3 types of stems regarding the positioning of individual components, both tibial and femoral, in terms of mLDFA and mMPTA, with comparable tibial and femoral alignment regardless of the type of stem implanted. However, the entire cohort showed a greater variability and a higher number of outliers of the femoral component positioning (P value 0.021) than the tibial side. The greater variability in femoral component positioning found in our study may be explained by the reduced intraoperative femoral reference in comparison to the tibia, by the limited modularity of the femoral implants and by the massive enlarged femoral canal frequently encountered in the revision setting. Greater attention must

therefore be paid to femoral preparation and implantation, to reach the desired alignment and at the same time the necessary external rotation, and we believe that shorter cemented stems, with adequate technique, can be preferable to longer ones due to their lower link with the intramedullary canal and consequent greater versatility. Furthermore, our study showed less than ideal canal filling ratio values (average CFR $77.3\% \pm 8.6\%$) in press-fit stem group, with a higher number of outliers on the tibial side compared to Parsley [26], who introduced the concept of CFR. More recent studies found protective factors for prosthesis survival values of CFR >0.85 or CFR >0.7 and canal filling length (CFL) > 2 cm for the femoral component, and CFR >0.85 or CFR >0.7 and CFL >4 cm for the tibial component [25,43]. Obtain an ideal CFR with press-fit stems is not easy in revision settings, as shown by our study, due to extra-articular deformity, canal bowing (both tibial and femoral), and limited flexibility in stem positioning. The subgroup analysis showed that, in our cohort, the use of offsets in the long stem group was more than 10% on the femoral side and over 50% on the tibial side, which is consistent with the literature [4,19]. The lower number of offsets in the long-cemented stems, although not statistically significant, might be explained by the slightly greater variability related to stem diameter and the cement mantle. However, in the short stem group, offset adapters were not used, as these stems do not require cortical contact and can adequately address alignment issues when properly implanted. Moreover, surgical canal preparation with short stems is less risky and less time-consuming. This highlights the advantage of modularity in this type of stem for alignment, benefiting from the greater space available in the tibial and femoral metaphysis. Beyond these technical considerations, it is important to recognize that alignment strategies in revision TKA are evolving in parallel with those in primary TKA. While MA has long been considered the benchmark, emerging evidence suggests that individualized approaches such as KA and restricted KA may improve functional outcomes and patient satisfaction [20]. Even though the MA is still the gold standard alignment in the rTKA, the application of KA principles to revision surgery is gaining attention in the literature, although it has been reported only in selected cohorts. Carlson et al described conversion of a well-fixed MA TKA to KA rTKA in a patient without bone loss or soft tissue compromise [22], and Kostretzis et al reported favorable mid-term outcomes using restricted KA with short-cemented stems in 43 patients with early, non-wear-related MA failures [21]. Nevertheless, MA remains the most widely used and safest strategy, particularly when managing bone loss, soft tissue challenges, or the loss of anatomical landmarks in rTKA [4]. Stem choice is critical in this context. Long press-fit stems and hybrid fixation provide stability, but constrain alignment to the diaphyseal axis, limiting restoration of native anatomy. Short-cemented stems, by contrast, offer greater flexibility in achieving individualized alignment, which likely accounts for their growing use in contemporary revision practice. Based on the optimistic results of this study supporting the use of cemented short stems, it opens promising prospects for the future application of robotic systems designed to control alignment during surgery [44-46]. This would enable achieving the most precise MA possible while reducing potential alignment errors in the femur associated with the use of cemented short stems or use in selected patients, different concepts of alignment. Consequently, this could further expand the indications for the use of cemented short stems. This study has several limitations. The short-medium term FU (>2 years) may have reduced the cases of failures, although most cases of aseptic loosening occur within the first 3 years after implantation [47]. The interpretation of the data presented in this study is limited by the fact that it is unclear what the optimal coronal alignment of a revised TKA should be, although neutral MA

is usually recommended. Data that state that varus alignment is better tolerated than valgus alignment are extrapolated from the primary TKA literature and applied to the revised TKA [14,29]. Another limitation is the relatively low CFR value found in the press-fit stem group (group C), lower than the value of 0.85 proposed by Parsley [26]. The fact that globally the press-fit stems were slightly undersized might have altered the reached HKA, deviating it from neutral. Another potential limitation of this study is the uncontrolled use of porous metal cones and offset on both the tibia and femur, which were used on a case-by-case basis.

Conclusions

Stem length and fixation method do not significantly influence overall limb alignment in rTKA when using the LCCK design. These results challenge the traditional hesitation surrounding short-cemented stems due to presumed alignment risks. Given their versatility and comparable outcomes, short-cemented stems can be confidently incorporated into revision strategies, especially when combined with metaphyseal augmentation techniques like cones.

Ethical statement

The authors certify that all investigations were conducted in conformity with ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments. All patients have given their informed consent for participation and there is no financial interest to report.

CRediT authorship contribution statement

Niccolò Giabbani: Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Matteo Innocenti:** Writing – review & editing, Supervision, Software, Investigation, Formal analysis, Data curation, Conceptualization. **Rudy Sangaletti:** Validation, Supervision, Software, Formal analysis, Data curation, Conceptualization. **Fabrizio Mattassi:** Writing – review & editing, Validation, Supervision, Data curation, Conceptualization. **Francesco Benazzo:** Visualization, Validation, Supervision. **Roberto Civinini:** Visualization, Validation, Supervision. **Marco Mugnaini:** Visualization, Validation, Supervision. **Luigi Zanna:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization.

Data availability

The data supporting the findings of this study can be obtained upon request from the corresponding author, MI. These data are not publicly accessible due to restrictions related to compromising the privacy of research participants.

Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to <https://doi.org/10.1016/j.artd.2025.101863>.

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