■ KNEE

No difference in long-term micromotion between fully cemented and hybrid fixation in revision total knee arthroplasty: a randomized controlled trial

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Aims

Both the femoral and tibial component are usually cemented at revision total knee arthroplasty (rTKA), while stems can be added with either cemented or press-fit (hybrid) fixation. The aim of this study was to compare the long-term stability of rTKA with cemented and press-fitted stems, using radiostereometric analysis (RSA).

Methods

This is a follow-up of a randomized controlled trial, initially involving 32 patients, of whom 19 (nine cemented, ten hybrid) were available for follow-up ten years postoperatively, when further RSA measurements were made. Micromotion of the femoral and tibial components was assessed using model-based RSA software (RSAcore). The clinical outcome was evaluated using the Knee Society Score (KSS), the Knee injury and Osteoarthritis Outcome Score (KOOS), and visual analogue scale (pain and satisfaction).

Results

The median total femoral translation and rotation at ten years were 0.39 mm (interquartile range (IQR) 0.20 to 0.54) and 0.59° (IQR 0.46° to 0.73°) for the cemented group and 0.70 mm (IQR 0.15 to 0.77) and 0.78° (IQR 0.47° to 1.43°) for the hybrid group. For the tibial components this was 0.38 mm (IQR 0.33 to 0.85) and 0.98° (IQR 0.38° to 1.34°) for the cemented group and 0.42 mm (IQR 0.30 to 0.52) and 0.72° (IQR 0.62° to 0.82°) for the hybrid group. None of these values were significantly different between the two groups and there were no significant differences between the clinical scores in the two groups at this time. There was only one re-revision, in the hybrid group, for infection and not for aseptic loosening.

Conclusion

These results show good long-term fixation with no difference in micromotion and clinical outcome between fully cemented and hybrid fixation in rTKA, which builds on earlier short- to mid-term results. The patients all had type I or II osseous defects, which may in part explain the good results.

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Introduction

As the average age of patients who undergo primary total knee arthroplasty (TKA) decreases, the importance of the stability of the components increases. When a primary TKA fails, a revision arthroplasty (rTKA) is usually required. Aseptic loosening is a common indication for a further revision,[1] therefore good fixation of a revision TKA is very important. As the components of a rTKA are introduced into damaged bone, fixation can be technically difficult. In order to enlarge the area of bony interface and decrease forces on the weakened bone, rTKAs with stems are often used. The stems can be fully cemented or a press-fit (hybrid).

Fully cemented rTKAs should be immediately stable, but the use of cement prolongs the operating time and makes the components more

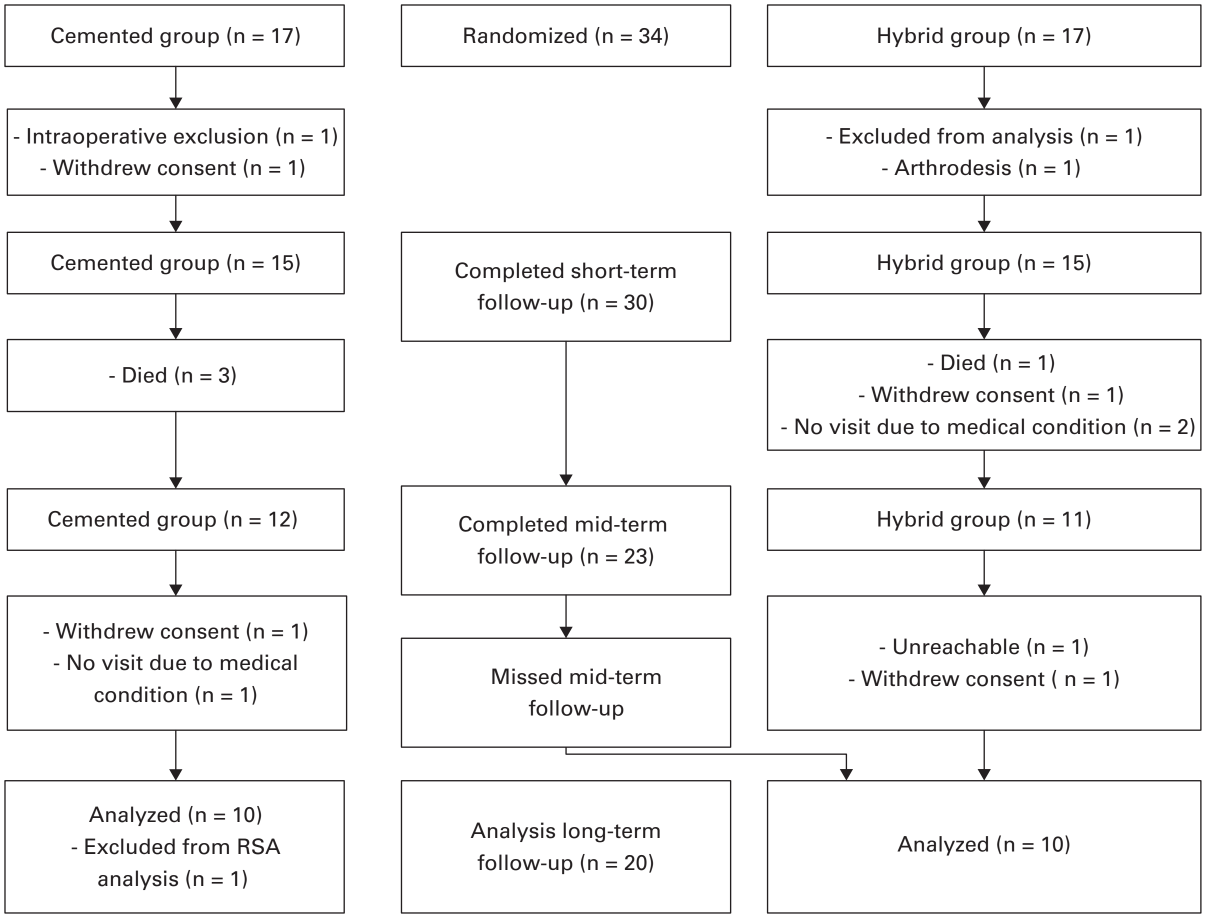

Fig. 1

Flow diagram of the enrolment of patients from short- to mid- and long-term follow-up. RSA, radiostereometric analysis.

difficult to remove if a further revision is required. Press-fitted stems, on the other hand, are easier to remove in case of a re-revision. However, patients have reported end-of-stem pain,[2] and the stability of these press-fitted stems in the long term remains unknown.[3]

Earlier papers presenting short-[4] and mid-term[5] radiostereometric analysis (RSA) of these patients have shown, on average, equal stability as reflected by micromotion for cemented and hybrid stems in rTKA. However, Heesterbeek et al[4] unexpectedly reported components in both groups with micromotion of > 1 mm or > 1°, although without clinical or radiological evidence of loosening, at a mean follow-up of two years. This highlighted the importance of longer follow-up. Subsequently, they reported two patterns of progressive femoral migration at a mean follow-up of 6.5 years.[5] A recent review evaluating the functional outcomes and implant survivorship with new generations of cementless TKAs has shown encouraging results for this type of fixation in primary TKA.[6] The authors also highlighted the importance of high-quality reporting of functional outcome and implant survivorship in the long term. To our knowledge, there are no other RSA studies with rTKAs, and therefore no data to act as reference when investigating the future effects of these patterns of migration. Thus, we thought it important to keep track of this group of patients. Although the implants with migration in the short- and mid-term might stabilize with the passage of time, those that were initially stable might start to migrate. Therefore, the aim of this study was to compare the migration patterns of both methods of fixation of the stems in this group of patients at ten years postoperatively. We also wished to report the clinical outcomes, adverse events, and re-revisions at this time.

Methods

This study was a long-term follow-up of a single-centre, patient-blinded, randomized controlled trial (RCT) (registered at Netherlands Trial Register: NTR1315) performed at the Sint Maartenskliniek between January 2008 and June 2020. All patients had an Anderson Orthopaedic Research Institute (AORI) type I or II bone defect,[7] were treated with a condylar Legion revision TKA (Smith & Nephew, USA) and were randomly allocated to undergo either fully cemented or hybrid fixation. The details of the original protocol and design can be found in the previously published paper.[4] All patients who completed the mid-term follow-up,[5] or who missed mid-term follow-up but were available for long-term follow-up, were

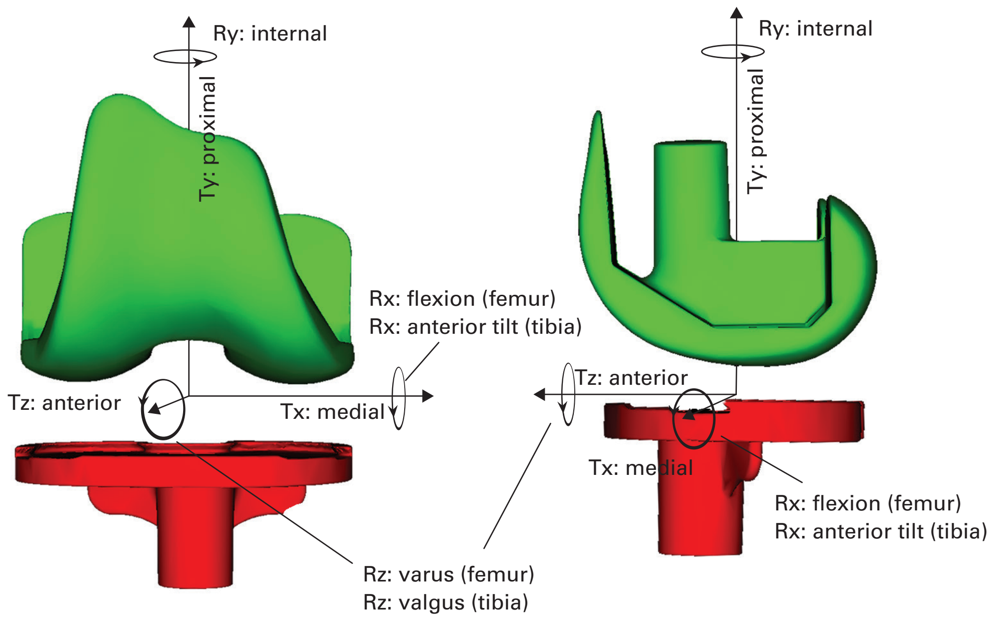

Fig. 2

Orientation of the longitudinal, transverse, and sagittal axes and the directions of positive translation (T) and rotation (R) for the femur and tibia.

Table I. Migration of the femoral component at all follow-up intervals for the cemented and hybrid groups until ten years postoperatively.

Femoral component	Follow-up timepoint						
	6 wks	3 mths	6 mths	1 yr	2 yrs	6.5 yrs	10 yrs
Cemented							
Median Tx, mm (IQR)	0.05 (0.00 to 0.10)	0.12 (0.02 to 0.17)	0.00 (-0.10 to 0.17)	0.06 (0.02 to 0.11)	0.09 (-0.03 to 0.16)	0.06 (0.02 to 0.15)	0.04 (0.01 to 0.11)
Median Ty, mm (IQR)	0.06 (0.01 to 0.08)	0.03 (0.00 to 0.07)	0.04 (-0.05 to 0.16)	0.02 (-0.03 to 0.03)	-0.01 (-0.04 to 0.07)	-0.00 (-0.07 to 0.02)	-0.03 (-0.08 to 0.03)
Median Tz, mm (IQR)	0.04 (-0.14 to 0.10)	0.02 (-0.01 to 0.08)	0.02 (-0.18 to 0.11)	0.12 (-0.02 to 0.26)	0.06 (0.00 to 0.29)	0.15 (-0.01 to 0.40)	0.12 (-0.11 to 0.44)
Median Rx, ° (IQR)	0.09 (-0.05 to 0.22)	0.17 (0.11 to 0.57)	0.16 (-0.15 to 0.55)	-0.08 (-0.25 to 0.21)	0.04 (-0.19 to 0.31)	-0.00 (-0.17 to 0.16)	-0.08 (-0.44 to 0.23)
Median Ry, ° (IQR)	-0.01 (-0.14 to 0.23)	-0.06 (-0.24 to 0.04)	0.09 (-0.11 to 0.31)	-0.01 (-0.25 to 0.23)	0.15 (-0.36 to 0.48)	-0.03 (-0.27 to 0.22)	-0.08 (-0.35 to 0.21)
Median Rz, ° (IQR)	0.02 (-0.04 to 0.08)	0.03 (-0.07 to 0.10)	0.08 (-0.09 to 0.17)	0.07 (-0.07 to 0.18)	0.05 (-0.08 to 0.26)	0.04 (-0.04 to 0.09)	-0.04 (-0.07 to 0.05)
Hybrid							
Median Tx, mm (IQR)	-0.02 (-0.14 to 0.06)	-0.08 (-0.15 to 0.07)	-0.10 (-0.17 to 0.02)	-0.04 (-0.12 to 0.09)	-0.01 (-0.25 to 0.14)	0.02 (-0.49 to 0.08)	-0.01 (-0.36 to 0.11)
Median Ty, mm (IQR)	-0.03 (-0.09 to 0.07)	-0.02 (-0.07 to 0.05)	0.04 (-0.08 to 0.17)	0.07 (-0.09 to 0.19)	-0.01 (-0.09 to 0.13)	0.01 (-0.10 to 0.12)	0.03 (-0.05 to 0.16)
Median Tz, mm (IQR)	0.07 (-0.20 to 0.28)	0.06 (-0.45 to 0.43)	-0.01 (-0.41 to 0.23)	-0.06 (-0.34 to 0.27)	0.13 (-0.40 to 0.49)	0.15 (-0.24 to 0.34)	0.05 (-0.12 to 0.23)
Median Rx, ° (IQR)	-0.10 (-0.33 to 0.28)	-0.15 (-0.59 to 0.54)	-0.09 (-0.25 to 0.63)	-0.04 (-0.33 to 0.78)	-0.13 (-0.61 to 0.49)	0.22 (-0.31 to 0.48)	0.17 (-0.36 to 0.47)
Median Ry, ° (IQR)	-0.01 (-0.25 to 0.20)	-0.09 (-0.35 to 0.17)	-0.00 (-0.30 to 0.31)	-0.05 (-0.24 to 0.25)	-0.11 (-0.37 to 0.17)	-0.12 (-0.25 to 0.11)	-0.17 (-0.39 to 0.27)
Median Rz, ° (IQR)	-0.23 (-0.30 to 0.00)	-0.21 (-0.25 to -0.01)	-0.14 (-0.28 to 0.02)	-0.08 (-0.28 to -0.05)	-0.17 (-0.21 to -0.02)	-0.12 (-0.23 to -0.06)	-0.14 (-0.17 to -0.04)

IQR, interquartile range; R, rotation; T, translation.

invited to participate. A total of 19 of the original 32 patients were available for long-term follow-up. The reasons for loss to follow-up are shown in Figure 1.

Approval for the study was obtained from the Medical Ethical Review Board of Slotervaart and Reade (amendment on dossier NL16352.091.07). It was conducted in accordance with the Declaration of Helsinki,[8] Consolidated Standards of Reporting Trials (CONSORT) guidelines,[9] and International Organization for Standardization (ISO) 16087:2013 for RSA and RSA guidelines.[10] All patients gave written informed consent.

Table II. Migration of the tibial component at all follow-up intervals for the cemented and hybrid groups until ten years postoperatively.

Tibial component	Follow-up timepoint						
	6 wks	3 mths	6 mths	1 yr	2 yrs	6.5 yrs	10 yrs
Cemented							
Median Tx, mm (IQR)	0.01 (-0.07 to 0.03)	0.02 (-0.08 to 0.13)	-0.00 (-0.06 to 0.28)	0.03 (-0.12 to 0.31)	-0.06 (-0.10 to 0.38)	-0.01 (-0.10 to 0.47)	0.01 (-0.12 to 0.47)
Median Ty, mm (IQR)	0.01 (-0.04 to 0.02)	0.02 (-0.04 to 0.03)	0.03 (-0.06 to 0.10)	0.06 (-0.07 to 0.14)	0.06 (-0.06 to 0.11)	0.07 (-0.08 to 0.16)	0.05 (-0.06 to 0.16)
Median Tz, mm (IQR)	-0.08 (-0.23 to 0.04)	-0.19 (-0.23 to 0.05)	-0.03 (-0.07 to 0.02)	-0.11 (-0.21 to -0.01)	-0.20 (-0.22 to 0.02)	-0.13 (-0.23 to -0.05)	-0.04 (-0.30 to 0.03)
Median Rx, ° (IQR)	0.13 (-0.23 to 0.20)	-0.03 (-0.26 to 0.25)	0.16 (0.06 to 0.43)	-0.10 (-0.15 to 0.40)	-0.24 (-0.40 to 0.25)	-0.07 (-0.10 to 0.34)	-0.03 (-0.30 to 0.48)
Median Ry, ° (IQR)	0.18 (0.03 to 0.26)	0.15 (0.03 to 0.43)	-0.09 (-0.36 to 0.22)	0.25 (-0.13 to 0.32)	0.17 (-0.18 to 0.41)	0.00 (-0.22 to 0.23)	-0.02 (-0.31 to 0.32)
Median Rz, ° (IQR)	-0.01 (-0.09 to 0.03)	0.02 (-0.15 to 0.09)	-0.04 (-0.27 to 0.04)	-0.04 (-0.43 to 0.12)	0.00 (-0.55 to 0.18)	-0.12 (-0.56 to 0.19)	-0.07 (-0.62 to 0.14)
Hybrid							
Median Tx, mm (IQR)	0.01 (-0.05 to 0.05)	0.05 (-0.13 to 0.16)	-0.00 (-0.11 to 0.08)	-0.05 (-0.11 to 0.12)	0.00 (-0.07 to 0.07)	-0.10 (-0.22 to 0.09)	-0.16 (-0.20 to -0.12)
Median Ty, mm (IQR)	0.01 (0.00 to 0.04)	0.02 (-0.05 to 0.07)	0.02 (-0.03 to 0.06)	-0.00 (-0.05 to 0.05)	0.04 (-0.04 to 0.07)	0.05 (0.05 to 0.11)	0.03 (-0.03 to 0.07)
Median Tz, mm (IQR)	0.10 (-0.01 to 0.18)	0.07 (-0.12 to 0.20)	0.02 (-0.18 to 0.16)	0.03 (-0.22 to 0.20)	0.01 (-0.19 to 0.22)	0.11 (-0.14 to 0.24)	-0.08 (-0.33 to 0.16)
Median Rx, ° (IQR)	0.16 (-0.04 to 0.28)	0.12 (-0.19 to 0.29)	0.05 (-0.11 to 0.14)	0.00 (-0.16 to 0.34)	0.12 (-0.11 to 0.41)	0.26 (-0.08 to 0.44)	-0.12 (-0.35 to 0.35)
Median Ry, ° (IQR)	-0.16 (-0.21 to 0.09)	-0.11 (-0.45 to -0.02)	-0.08 (-0.11 to 0.17)	-0.10 (-0.16 to 0.08)	-0.17 (-0.37 to 0.16)	-0.27 (-0.32 to 0.02)	0.03 (-0.28 to 0.26)
Median Rz, ° (IQR)	0.09 (0.05 to 0.15)	0.01 (-0.17 to 0.21)	0.12 (-0.05 to 0.21)	0.14 (-0.20 to 0.27)	0.11 (-0.10 to 0.22)	0.19 (0.05 to 0.39)	0.43 (0.14 to 0.57)

IQR, interquartile range; R, rotation; T, translation.

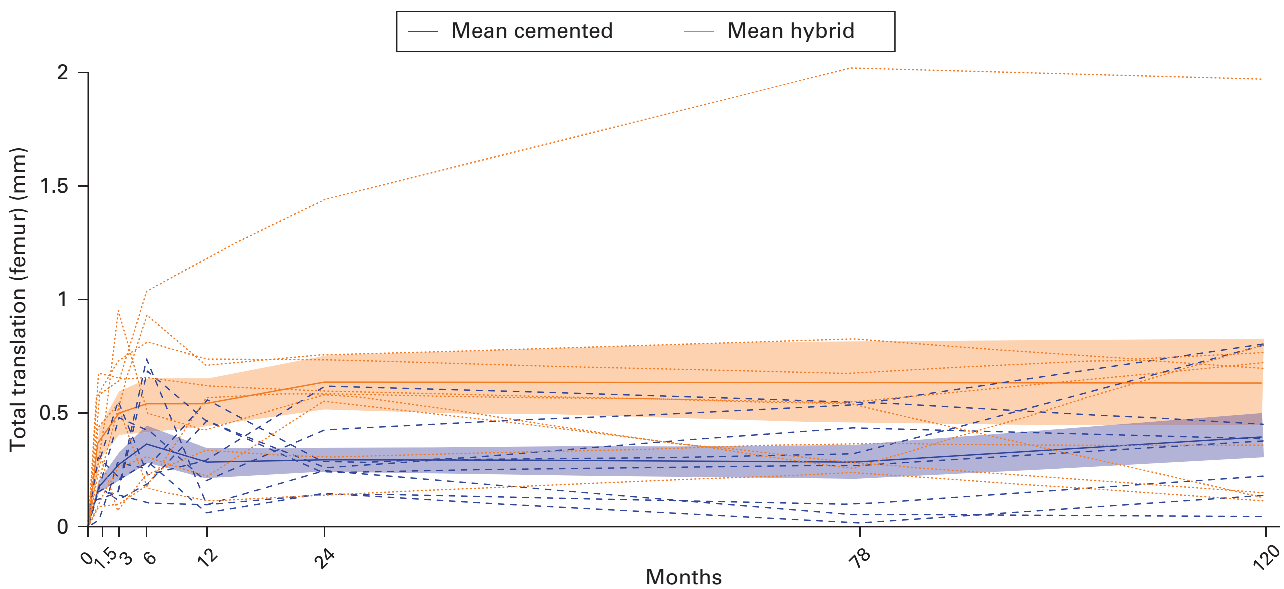

Fig. 3

Total translation of the femoral component with respect to the femoral bone, for the cemented and hybrid groups separately. The coloured bands around the means present the standard error, and the dotted lines are the migration patterns of the separate patients for each group.

RSA radiographs were taken ten years postoperatively, with the patients in a supine position. Micromotion of the femoral and tibial components was assessed using model-based RSA software (RSAcore, the Netherlands). According to the ISO guidelines, a maximum condition number of 120 and a mean error of rigid body fitting < 0.35 was defined as a reliable measurement of the stability and distribution of marker beads within a rigid body. The same RSA markers were activated for all follow-up times to create the bone reference model.

Migration was determined using previous radiographs as a reference, and was defined as the change in position and orientation of the components relative to the bone. Translation

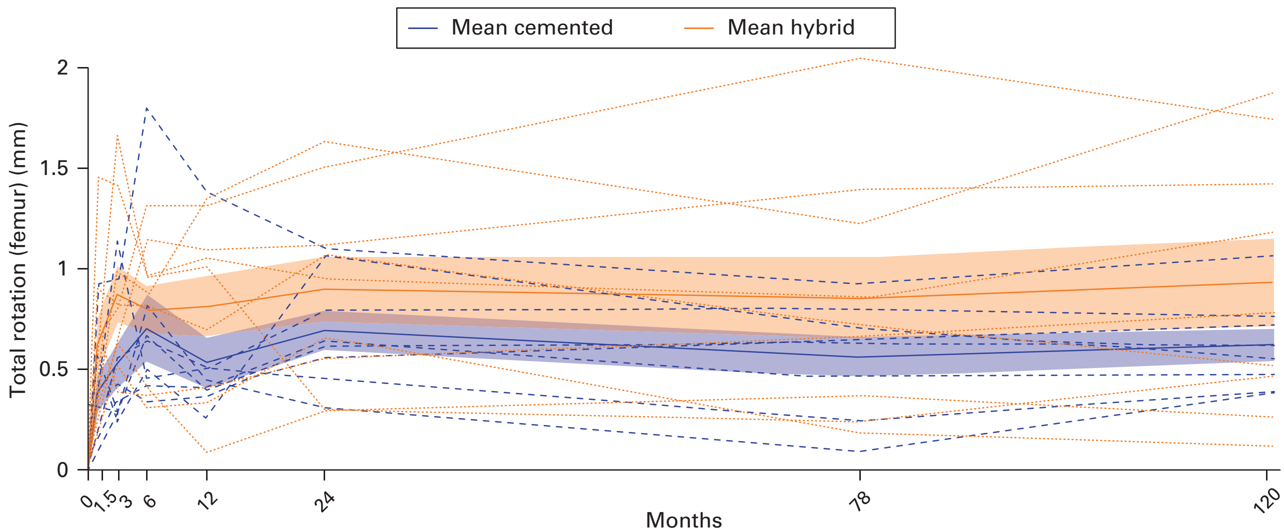

Fig. 4

Total rotation of the femoral component with respect to the femoral bone, for the cemented and hybrid groups. The coloured bands around the means present the standard error of the means, and the dotted lines are the migration patterns of the separate patients for each group.

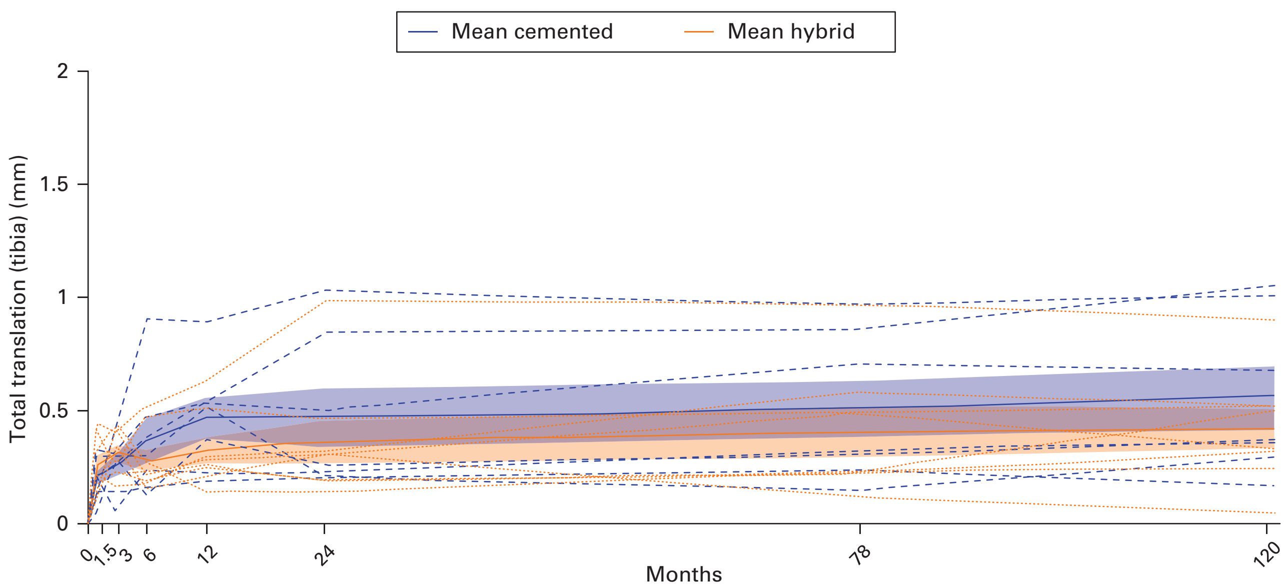

Fig. 5

Total translation of the tibial component with respect to the tibial bone, for the cemented and hybrid groups. The coloured bands around the means present the standard error of the means, and the dotted lines are the migration patterns of the separate patients for each group.

(T) in mm and rotation (R) in degrees is expressed along or around the medial-lateral (x), proximal-distal (y), and anterior-posterior (z) directions (Figure 2). Summarized micromotion of the femoral and tibial components was calculated as $Total\ Translation\ (TT) = \sqrt{(Tx^2 + Ty^2 + Tz^2)}$ and $Total\ Rotation\ (TR) \approx \sqrt{(Rx^2 + Ry^2 + Rz^2)}$.

Clinical outcomes were evaluated using the Knee Society Score (KSS),[11] Knee injury and Osteoarthritis Outcome Score (KOOS),[12] and visual analogue scale (VAS) for pain and satisfaction. The KSS was scored by a research nurse (see Acknowledgements), and is subdivided into clinical (maximum 100), functional (maximum 100), and total scores (clinical + functional). The KOOS consists of five subscales (symptoms, pain, activities of daily living, sports and recreational function, and

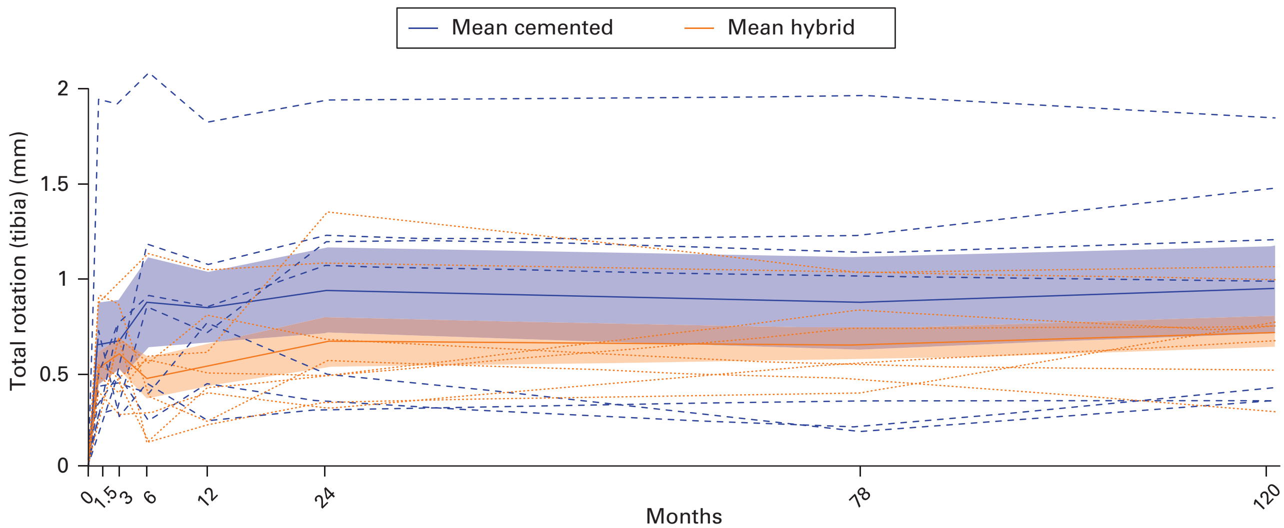

Fig. 6

Total rotation of the tibial component with respect to the tibial bone, for the cemented and hybrid groups. The coloured bands around the means present the standard error of the means, and the dotted lines are the migration patterns of the separate patients for each group.

knee-related quality of life). The total KOOS score was used to compare the groups.[12] In case of missing values in one or more or the subscales, the mean of the remaining scores was used to form the total score. All KOOS scores were calculated according to general instruction and transformed to a 0 to 100 scale (a percentage), with zero representing extreme symptoms and 100 representing no symptoms.[12] The VAS pain and satisfaction scores were scored on a scale from 0 to 100, with 0 representing no pain or lowest satisfaction, and 100 representing the worst imaginable pain or highest satisfaction.

Statistical analysis. The characteristics were reported descriptively. Differences between the groups for micromotion (TT and TR) and clinical outcomes were compared using Mann-Whitney U tests. All data were analyzed using STATA 13.1 (StataCorp, USA). A p-value < 0.05 was considered significant.

Results

In total, 19 of the 23 patients who completed mid-term follow-up, and one who completed short-term follow-up but missed the mid-term appointment, visited the clinic between March 2018 and June 2020 for the ten-year follow-up. The cemented group included five male and five female patients, and five left and five right TKAs, with a mean age at ten-year follow-up of 74.9 years (standard deviation (SD) 6.7). The hybrid group included one male and nine female patients, three left and seven right TKAs, with a mean age of 72.2 years (SD 11.7). The number of types of AORI bone defect (I, IIA and IIB) for the cemented and hybrid groups, respectively, were 3/5/2 and 4/4/2 for the femoral component, and 7/2/0 (1 missing) and 7/2/1 for the tibial component. A detailed description of the original patients and the indications for surgery can be found in the paper by Heesterbeek et al.[4] Figure 1 shows a flowchart for patients in this study.

One femoral and two tibial measurements were excluded from the analysis of micromotion in both groups because there were too few markers in the bone, or because the mean condition number exceeded the threshold of 120.

Table III. Type and number of device-related adverse events reported between 6.5 and ten years postoperatively.

Adverse event	Cemented	Hybrid
Persistent pain	5	3
Instability	2	1
Arthrofibrosis	0	1
Fall resulting in pain	1	0

The median TT femur and TR femur at ten years was 0.39 mm (interquartile range (IQR) 0.20 to 0.54) and 0.59° (IQR 0.46° to 0.73°) for the cemented group and 0.70 mm (IQR 0.15 to 0.77 m) and 0.78° (IQR 0.47° to 1.43°) for the hybrid group, with no significant difference between the groups (p = 0.630 for TT femur and p = 0.441 for TR femur). The median TT tibia and TR tibia was 0.38 mm (IQR 0.33 to 0.85) and 0.98° (IQR 0.38° to 1.34°) for the cemented group and 0.42 mm (IQR 0.30 to 0.52) and 0.72° (IQR 0.62° to 0.82°) for the hybrid group. Again, there was no significant difference between the groups (p = 0.488 for TT tibia and p = 0.563 for TR tibia).

Tables I and II show the median translations and rotations in x, y, and z directions for all follow-up intervals until ten years postoperatively.

Figures 3 to 6 show the mean total translations and rotations of the femoral and tibial components and their corresponding standard error range. The patterns of migration of both components were very stable from two years up until ten years postoperatively. One patient in the hybrid group showed progressive translation of the femoral component until 6.5 years postoperatively, with stabilization ten years postoperatively.

All device-related adverse events that occurred between 6.5 years and ten years postoperatively are shown in Table III. Two patients in the cemented group (one neuroma) and one in the

Table IV. Clinical ten-year postoperative outcome scores.

Outcome	Cemented	Hybrid	p-value*
Median KSS points (IQR), n			
Clinical (max 100)	91 (78 to 96), 8	90 (90 to 95), 10	0.964
Functional (max 100)	50 (40 to 80), 9	55 (40 to 80), 10	0.804
Total (max 200)	139.5 (123 to 176), 8	150 (130 to 172), 10	0.929
Median VAS points (IQR), n			
Pain (0 to 100)	48.5 (20 to 78), 10	17 (4 to 47), 10	0.082
Satisfaction (0 to 100)	71.5 (23 to 84), 10	92 (67 to 100), 10	0.095
Median KOOS percentage (IQR), n			
Pain	54.2 (33.3 to 80.6), 10	70.8 (38.9 to 80.6), 10	0.569
Other symptoms	66.1 (32.1 to 78.6), 10	71.4 (57.1 to 85.7), 10	0.472
Activities of daily living	52.9 (30.9 to 78.1), 10	75 (33.3 to 80.9), 9	0.513
Sports and recreation function	0 (0 to 20), 9	7.5 (0 to 52.5), 8	0.252
Knee-related quality of life	37.5 (18.8 to 50), 10	53.1 (18.8 to 75), 10	0.424
Total	45.4 (25.2 to 60.4), 10	67.5 (28.0 to 74.3)	0.257

*Mann-Whitney U test.
IQR, interquartile range; KOOS, Knee injury and Osteoarthritis Outcome Score; KSS, Knee Society Score; VAS, visual analogue scale.

hybrid group had treatment for persistent pain. One patient in the cemented group had physiotherapy and used a walking stick, and one in the hybrid group used a knee brace, both due to instability. Comparing these device-related events in the short- and mid-term follow-up, there were five patients (four with pain and one with instability) in the cemented group and two with pain in the hybrid group who did not have any device-related events until 6.5 years postoperatively. All other adverse events shown in Table III are subsequent events.

There were no significant differences in the clinical outcome scores between the cemented and hybrid groups at ten years postoperatively (Table IV). However, the hybrid group had lower pain and higher satisfaction scores compared with the cemented group.

Discussion

In this study, we investigated the long-term stability of fully cemented and hybridly fixed rTKA using RSA measurements, as a follow-up of two previously published studies.[4,5] Micromotion appeared to be similar for both cemented and hybrid fixation of the stems in rTKA in patients with AORI Type I or II bone loss. The fixation was very stable in both groups at long-term follow-up. The improvements in clinical outcome scores were also similar in both groups with no significant differences in the KSS, KOOS, and VAS scores.

No previous studies have compared the long-term migration of rTKAs with cemented and hybrid stem fixation using RSA. Studies that have compared these methods of fixation have shown variable results. Although some favour one method over the other,[13–15] most conclude that both methods give good fixation in these patients.[16–19] To our knowledge, this is the first long-term RCT comparing micromotion of cemented and hybrid fixation in patients undergoing rTKAs. Strict inclusion and exclusion criteria which were used at the start of this study allowed an objective comparison of these two methods of fixation. However, it may also have compromised the generalizability of the results. Most importantly, all patients in the study had Type I or II osseous defects (in similar proportions), so that these results cannot be applied to patients with more severe bone loss.

What is remarkable in this study, compared with previous studies, is the low number of re-revisions in both groups. Only one hybrid rTKA of 17 was revised before two years' follow-up, because of infection, resulting in a rate of survival of 100% for cemented fixation and 94% for hybrid fixation for all revisions, and 84% for both groups (15 of 17) when including minor revisions such as changes of insert. In comparison, a recent study by Gómez-Vallejo et al[15] reported a ten-year survival of 84% for cemented fixation and 94% for hybrid fixation. Fleischman et al[17] reported ten-year rates of survival of 83% and 77% for cemented and hybrid fixation, respectively. Another study reported an overall rate of survival at ten years of 86% for modular rTKAs implanted by a single surgeon.[20] An explanation for the relatively high survival rates in the current study could be that all patients underwent revision for the first time and had relatively low bone loss with Type I, IIA, or IIB defects. Thus the findings cannot be generalized to patients with greater bone loss.

The total length of the reconstruction in this study was 150 or 160 mm for the femur and 120 or 130 mm for the tibia, depending on the use of an offset coupler as a shorter length of stem was chosen if an offset couple was used. Diaphyseal fixation was obtained using a canal-filling stem, with a patient-specific thickness of stem.[4] This composite of stem length and width might be a reason for the low failure rate in these patients: as Fleischman et al[17] reported, intramedullary canal filling was the strongest predictor of failure with hybrid stems, reducing the risk of a further revision by 41.2% for each 10% extra filling of the canal. Patients undergoing revision for periprosthetic joint infection (PJI) were also excluded. Previous authors have reported that the risk of mechanical failure was higher after initial revision for aseptic loosening or PJI.[17]

What we are aiming at with RSA research is to obtain a reference value for micromotion after rTKAs that can be used to predict the risk of loosening at an early stage. A meta-analysis by Pijls et al,[21] investigating the migration patterns of tibial components in primary TKAs, reported that most migrations occurred in the first six months after surgery. They therefore suggested a benchmark at six months postoperatively of 0.5 mm/degree of micromotion (maximum total point motion (MTPM)) for acceptable migration, with a higher amount indicating that the component is at risk of loosening. However, in the current study we investigated rTKAs, for which there is not yet a reference value. A total of 40% (four cemented, two hybrid) of tibial components available at ten-year follow-up had micromotion of > 0.5 mm/degree at six months postoperatively, without evidence of aseptic loosening. Pijls et al[21] also reported different migration patterns for cemented and uncemented components, highlighting the importance of mapping the patterns for different types of fixation separately. We cannot yet recommend a reference value based on our findings, as there were no re-revisions for aseptic loosening. Thus, further studies using RSA in these patients with large sample sizes and long-term follow-up will be required.

This study has limitations. First, only 20 patients were left at long-term follow-up, ten in each group, so the study is underpowered. Patients failed to visit the clinic due to unrelated medical conditions or died before ten-year follow-up. This should be accounted for when determining the sample size for future long-term studies after rTKA. The original plan was to perform RSA until two years postoperatively. Second, as mentioned, the results can only apply to patients with mild to moderate bony defects.

Last, metaphyseal porous cones or sleeves can now be used to manage bone loss in these patients to increase the surface area of the interface between the bone and the implant. The length of the stems might be reduced when these cones or sleeves are used.[22] A recent study, which investigated the use of cones with and without stems, reported slightly lower micromotion amounts when using stems in combination with a cone, but the levels of stress in the bone surrounding the stem, and at the end of the stem, were higher.[23] These techniques were not available at the start of this study.

In conclusion, our findings show long-term stability in both cemented and hybrid fixation after rTKA, in patients with mild to moderate bone loss. The long-term clinical outcome was also similar in both groups.

Take home message

- Both fixation methods show very little migration up until ten years postoperatively and no re-revision due to aseptic loosening, which indicates that both revision total knee arthroplasty constructs are valid options for patients with type I-II osseous defects.

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