KNEE

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

K. Mills,
A. B. Wymenga,
G. G. van
Hellemondt,
P. J. C. Heesterbeek

From Sint
Maartenskliniek,
Nijmegen, the
Netherlands

Correspondence should be
sent to K. Mills; email:
k.mills@maartenskliniek.nl

© 2022 Author(s) et al.
doi:10.1302/0301-620X.104B7.
BJJ-2021-1600.R1 $2.00

Bone Joint J
2022;104-B(7):875–883.

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.

Cite this article: Bone Joint J 2022;104-B(7):875–883.

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, 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
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, and the stability of these press-fitted stems in the long term remains unknown.

Earlier papers presenting short- and mid-term 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. 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. 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. 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, 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. All patients who completed the mid-term follow-up, or who missed mid-term follow-up but were available for long-term follow-up, were...
NO DIFFERENCE IN LONG-TERM MICROMOTION BETWEEN FULLY CEMENTED AND HYBRID FIXATION IN RTKA

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, Consolidated Standards of Reporting Trials (CONSORT) guidelines, and International Organization for Standardization (ISO) 16087:2013 for RSA and RSA guidelines. 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
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. 4**

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.

**Fig. 5**

(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

\[
\text{Total Translation (TT)} = \sqrt{(T_x^2 + T_y^2 + T_z^2)}
\]

and

\[
\text{Total Rotation (TR)} \approx \sqrt{(R_x^2 + R_y^2 + R_z^2)}.
\]

Clinical outcomes were evaluated using the Knee Society Score (KSS),\textsuperscript{11} Knee injury and Osteoarthritis Outcome Score (KOOS),\textsuperscript{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...
knee-related quality of life). The total KOOS score was used to compare the groups. In case of missing values in one or more of 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. 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.

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

**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      |

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.
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. Micro-motion 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, most conclude that both methods give good fixation in these patients. 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 reported a ten-year survival of 84% for cemented fixation and 94% for hybrid fixation. Fleischman et al 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. 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. This composite of stem length and width might be a reason for the low failure rate in these patients: as Fleischman et al 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.

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 investigating the migration patterns of tibial...
4. Heesterbeek PJC, Wymenga AB, van Hellemont G. No difference in implant micromotion between hybrid fixation and fully cemented revision total knee arthroplasty: a randomized controlled trial with radiostereometric analysis of patients with mild-to-moderate bone loss. J Bone Joint Surg Am. 2016;98-A(16):1359–1369.

5. Kossa NM, van Hellemont G, Wymenga AB. Heesterbeek PJC. Comparable stability of cemented vs press-fit placed stems in revision total knee arthroplasty with mild to moderate bone loss: 6.5-year results from a randomized controlled trial with radiostereometric analysis. J Arthroplasty. 2017;32(1):197–201.

6. Asokan A, Plaetow R, Kayani B, Radhakrishnan GT, Magan AA, Haddad FS. Cementless knee arthroplasty: a review of recent performance. Bone Jt Open. 2021;21(1):48–57.

7. Emgh GA, Ammeen DJ. Bone loss with revision total knee arthroplasty: defect classification and alternatives for reconstruction. Instr Course Lect. 1999;48:167–175.

8. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA. 2013;310(20):2191–2194.

9. Schulz KF, Altman DG, Moher D. CONSORT Group. CONSORT 2010 statement: updated guidelines for reporting parallel group randomized trials. Ann Intern Med. 2010;152(11):726–732.

10. Valstar ER, Gill R, Ryd L, Flivilik G, Börlin N, Kärholm J. Guidelines for standardization of radiostereometry (RSA) of implants. Acta Orthop. 2005;76(4):583–572.

11. Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res. 1989;248:13–14.

12. Roos EM, Lohmander LS. The Knee injury and Osteoarthritis Outcome Score (KOOS), from joint injury to osteoarthritis. Health Qual Life Outcomes. 2003;1:64.

13. Fehring TK, Odum S, Olekson C, Griffin WL, Mason JB, McCoy TH. Stem fixation in revision total knee arthroplasty: a comparative analysis. Clin Orthop Relat Res. 2003;416(217–224).

14. Edwards PK, Fehring TK, Hamilton WG, Perricelli B, Beaver WB, Odum SM. Are cementless stems more durable than cemented stems in two-stage revisions of infected total knee arthroplasties? Clin Orthop Relat Res. 2014;472(1):206–211.

15. Gómez-Velarde J, Albareda-Albareda J, Seral-Garcia B, Blanco-Ruizo N, Ezquerra-Herrando L. Revision total knee arthroplasty: hybrid vs standard cemented fixation. J Orthop Trauma. 2018;19(1):9.

16. Gilliland JM, Gaffney CJ, Odum SM, Fehring TK, Peters CL, Beaver WB. Clinical & radiographic outcomes of cemented vs. diaphyseal engaging cementless stems in aseptic revision TKA. J Arthroplasty. 2014;29(9 Suppl):224–228.

17. Fleischman AN, Azboy I, Fueray M, Restrepo C, Shao H, Parviszi J. Effect of stem size and fixation method on mechanical failure after revision total knee arthroplasty. J Arthroplasty. 2017;32(9S):S202–S208.

18. Laschiewicz PF, O’Dell JA. Is there a difference between cemented and uncemented femoral stem extensions in revision knee arthroplasty? J Knee Surg. 2020;33(1):64–65.

19. Wang C, Pietzner T, von Roth P, Mayr HO, Sostheim M, Hube R. Fixation of stem in revision of total knee arthroplasty: cemented versus cementless - a meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2016;24(10):3200–3211.

20. Bae DK, Song SJ, Heo DB, Lee SH, Song WJ. Long-term survival rate of implants and modes of failure after revision total knee arthroplasty by a single surgeon. J Arthroplasty. 2013;28(7):1130–1134.

21. Pijs BG, Plevier JWM, Nelissen R. RSA migration of total knee replacements. Acta Orthop. 2018;89(3):320–326.

22. Jacquiet C, Ros F, Guy S, Parratte S, Ollivier M, Argenson JN. Trabecular metal cones combined with short cemented stem allow favorable outcomes in aseptic revision total knee arthroplasty. J Arthroplasty. 2021;36(2):657–663.

23. Xie S, Conilk N, Hamilton D, Scott C, Burnett R, Pankaj P. Metaphyseal cones in revision total knee arthroplasty: The role of stems. Bone Joint Res. 2020;9(4):162–172.
NO DIFFERENCE IN LONG-TERM MICROMOTION BETWEEN FULLY CEMENTED AND HYBRID FIXATION IN RTKA

A. B. Wymenga: Conceptualization, Methodology, Writing – review & editing.
G. G. van Hellemondt: Conceptualization, Funding acquisition, Methodology, Writing – review & editing.
P. J. C. Heesterbeek: Conceptualization, Funding acquisition, Investigation, Methodology, Formal analysis, Supervision, Writing – review & editing.

Funding statement:
The authors disclose receipt of the following financial or material support for the research, authorship, and/or publication of this article: financial support and material support from Smith & Nephew. Smith & Nephew had no involvement in the present study design, data collection, analysis and interpretation, writing of the paper, or the decision to submit the work for publication.

ICMJE COI statement:
P. Heesterbeek is an unpaid board member of the International RSA Society and Dutch Orthopaedic Science Collaboration. G. van Hellemondt reports royalties and speaker payments from Smith & Nephew, and consulting fees from Zimmer Biomet and Bodycad, unrelated to this study. A. B. Wymenga reports royalties from Smith & Nephew, unrelated to this study.

Acknowledgements:
The authors wish to thank Saskia Susan for patient recruitment, clinical outcome scoring and study management, and Nienke Kosse for her contribution to this study.

Ethical review statement:
Ethical approval for this study was obtained from Medisch-ethische Toetsingcommissie voor het Slotervaartziekenhuis en Reade (amendment on dossier NL16352.091.07) and all patients provided written informed consent.

Open access funding:
The authors confirm that the open access fee was covered by their study budget.

Open access statement:
This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (CC BY-NC-ND 4.0) licence, which permits the copying and redistribution of the work only, and provided the original author and source are credited. See https://creativecommons.org/licenses/by-nc-nd/4.0/

This article was primary edited by J. Scott.