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ORIGINAL ARTICLE

**C. Luring · L. Perlick · C. Trepte · O. Linhardt**
**C. Perlick · W. Plitz · J. Grifka**

# Micromotion in cemented rotating platform total knee arthroplasty: cemented tibial stem versus hybrid fixation

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**Abstract** *Introduction*: Improving the longevity and reliability of cemented total knee arthroplasty (TKA) remains a major step to achieve. It is still unclear, whether a cemented tibial stem reduces micromotion of the tibial tray and produces therefore a better initial stability or not. The higher conformity of rotating platform design and the possible rotary forces to the tibial platform may produce higher micromotion when the tibial stem remains cementless (hybrid fixation). *Materials and methods*: An in vitro study was performed using the PFC® mobile bearing tibial tray (DePuy®, Warswa, IN, USA) to test the hypothesis that the addition of cement surrounding the tibial stem reduces micromotion of the tibial tray in cemented TKA with mobile bearing design. Ten tibial trays with mobile design were implanted in sawbones with a 3-mm cement mantle beneath the baseplate of the tibial tray and with or without the cemented stem. Tibial trays were loaded additionally in the ventral, lateral, medial and posterior positions with 2,500 N using the Zwick Z010® instrumentation and HBM pick up Hottinger Baldwin®. *Results*: In this study, a significant increased mean maximum liftoff was found when only cementing the tibial baseplate (hybrid fixation), compared to the fully cemented tibial tray ($P < 0.02$). *Conclusion*: In conclusion, the stem of mobile bearing tibial components should be cemented to provide increased micromotion and earlier loosening.

**Keywords** Rotating platform · Total knee arthroplasty (TKA) · Cementing technique · Micromotion

C. Luring (✉) · L. Perlick · C. Trepte · O. Linhardt · J. Grifka
Department of Orthopaedic Surgery, University of Regensburg, Kaiser-Karl-V. Allee 3, 93077 Bad Abbach, Germany
E-mail: c_luering@yahoo.de
Tel.: +49-9405-184843
Fax: +49-9405-182926

C. Perlick
Department of Orthopaedics, Amtssygehus, Aalborg Sygehus, Aarhus Universitetshospital Hobrovej, Aalborg, Denmark

W. Plitz
Laboratory for Biomechanics and Experimental Orthopaedics, Ludwigs-Maximilians-University, Munich, Germany

## Introduction

Total knee arthroplasty (TKA) has become a standard operative procedure. Long-term results show only 10% aseptic loosening after 10 years [6, 17]. Aseptic loosening due to micromotion is one of the major problems connected to TKA.

After establishment of conventional total knee replacement (TKR), the rotating platform design attracted increasing scientific interest [7, 8, 11, 15, 16, 18]. The hypothesis that axial rotation and a greater articular conformity of polyethylene that reduce polyethylene wear, could be verified [12], but little is known about the initial stability in rotating platform of TKR with cemented tibial stem versus hybrid fixation.

It is commonly accepted that initial fixation of the tibial component is one cornerstone of longevity of prosthesis. Numerous studies have been performed showing that multiple factors influence this initial stability such as viscosity of cement, time of cementing, bony preparation (pulsile lavage versus manual syringe lavage) and design of tibial tray [4, 5, 9, 10, 13, 20, 21].

Still, the question whether to cement the tibial stem or not in the case of cemented TKA is discussed controversially [1, 19]. There are only few studies focussing on the effect on micromotion of the tibial tray in cemented versus cementless stems [2, 3, 14].

The current experimental in vitro study was performed to prove the hypothesis that a cemented stem in TKA with mobile bearing design will reduce micromotion of the tibial tray.

## Materials and methods

The tibial tray of the PFC Sigma® total knee prosthesis (DePuy) with rotating platform design was used in this experiment. Ten tibial trays were implanted in sawbone models (composite bones, Pacific Research Laboratories Inc.); five with cement mantle around the stem and five with cementless stem, all with 3 mm cement beneath the baseplate. CMW 2,000® cement was prepared using vacuum mixing. The sawbones were cut 10 cm beneath the tibial tray and were cemented in a special holding device (Fig. 1). This device was fixed in Zwick's machine which allows to load pressure on definite points of the tibial tray. Four inductive pick ups (HBM® pick up, WETA® measuring range 12 mV/V; 8 mV/V = 1 mm) were fixed in a special frame to pick up micromotion on the four 'edges' of the tibial tray (Fig. 2). This pick up frame was rigidly attached to the sawbone and the pick ups were gauged. Then, the tibial tray was subjected to four loading conditions: first to an anterior, second to a medial, third to a lateral and fourth to a posterior biased load of 2,500 N, which represents approximately three times the body weight of a 75-kg patient. The maximum liftoff was measured with the pick ups on the antero-medial and anterolateral side of the tray as well as dorsomedial and dorsolateral side (Fig. 3). Each loading was repeated three times and the mean maximum liftoff was averaged.

For statistical analysis, the paired Student's *t*-test was performed to test the hypothesis that cementing the stem reduces significantly the liftoff of tibial tray with rotating-platform design.

**Fig. 1** Tibial tray cemented in sawbone model with 3 mm cement under the tibial baseplate fixed in the holding device for Zwick's machine

## Results

For all test conditions, statistically significant increased maximum liftoff for the hybrid fixation in contrast to the cemented version ($P < 0.01$; Table 1) was found.

### Anterior loading

For the anterior loading test condition, the maximum liftoff was seen on the dorsomedial side of the tibial tray with a mean of 10.6 µm (SD 4.5) for the cemented stem and 28.5 µm (SD 4.7) for the hybrid fixation ($P = 0.003$).

### Lateral loading

When loading on the lateral side of the tibial tray the highest liftoff was measured on the ventromedial side of the tibial tray. Mean values were 2.7 µm (SD 1.1) for the cemented stem and 15.5 µm (SD 6.5) for the hybrid fixation ($P = 0.01$).

### Medial loading

For the test condition with medial loading of 2,500 N, maximum liftoff was seen on the ventrolateral side of the tibial tray. A mean maximum liftoff with 3.7 µm (SD 1.6) for the cemented stem and 18.6 µm (SD 0.6) for the hybrid fixation ($P > 0.0001$) were found.

### Posterior loading

For the posterior loading, the mean maximum liftoff was evaluated on the ventromedial side of the tibial tray with 7.7 µm (SD 1.5) for the cemented stem and 17.4 µm (SD 5.1) for the hybrid fixation ($P = 0.02$).

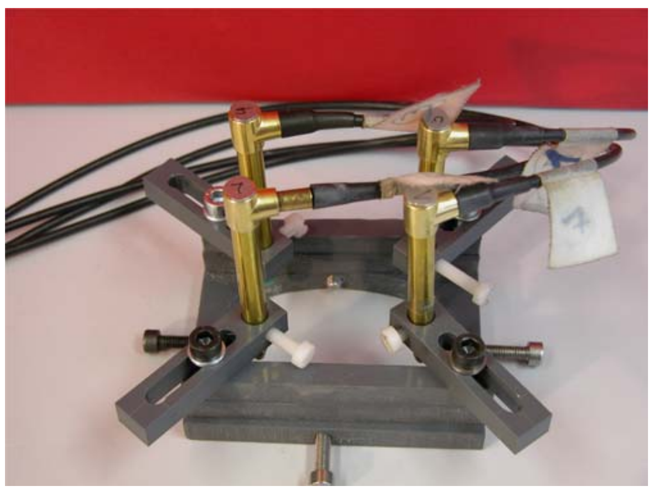

**Fig. 2** Pick ups in the holding device to be fixed on the sawbone with special screws

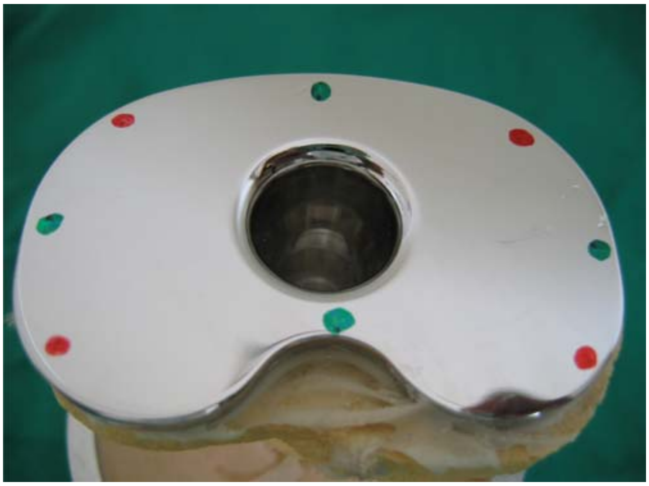

**Fig. 3** The tibial tray with the points of loading (*green*) and the points of measuring the liftoff (*red*)

## Discussion

One major step in achieving longevity of TKA is a good initial fixation of the tibial component [4, 5, 9, 10, 13, 20, 21]. The hypothesis of TKA with mobile bearing is that the unconstrained mobility of these implants reduces stresses and strains across fixation interfaces [12]. This resulted in the hypothesis that some surgeons did not cement the tibial stem to reduce bone loss in a possible revision situation. In current literature, the fixating technique of the tibial stem is still discussed controversially [1, 19]. Therefore the differences in micromotion in cemented rotating TKA with cemented and cementless stem were tested.

In this study, significant lesser amount of micromotion and maximum liftoff were found statistically in the group of prosthesis with cement mantle around the stem compared to the hybrid fixation after loading additionally the anterior, the lateral, the medial and the posterior side of the tibial tray with 2,500 N. It became clear that the tibial trays without cemented stems showed a higher micromotion than those with the cemented stems. Mean maximum liftoff was found dorsomedial when loading ventral, ventromedial when loading lateral, ventrolateral when loading medial and ventromedial when loading posterior (Table 1). These results indicate that if the stem of the tibial platform with rotating platform design is cemented, excellent initial fixation can be achieved. As long as the stem remains without a cement mantle, the initial fixation is of minor quality. Due to the results in this experiment, a cemented stem with deep penetration of the cement into the spongiosa has to be demanded.

It is hard to explain the pattern of loading and resulting micromotion as there are many factors which influence this. But, as the results demonstrate, the lowest micromotion becomes the outcome when loading the tibial plateau laterally. This may be due to the fact, that the anatomical lateral tibial plateau is smaller than medial and therefore lesser forces can be transmitted.

In current literature, there are only few studies dealing with this matter, which are very inhomogeneous. Therefore, a comparison is possible to a limited extend only.

Bert and McShane [2] demonstrated in a previous study, that only if the cement mantle beneath the tibial baseplate is less than 3 mm and the stem cementless, increased micromotion and liftoff can be verified. They did not see differences between the groups with cemented stem of 1- and 3-mm cement mantle beneath the tibial baseplate. They conclude that if the tibial stem remains uncemented, the cement mantle beneath the baseplate should be at least 3 mm. They found best fixation results in tibial trays with cemented stem of 3-mm cement mantle beneath the baseplate [2]. It is quite interesting that the results of Bert and McShane are contrary to those of authors who performed clinical outcome studies. Chon et al. performed a retrospective clinical and radiographic study comparing hybrid and cemented fixation. They investigated 115 revisions of TKR (75 tibial hybrid fixation, 24 fully cemented and 13 hybrid femur hand cemented tibia). Their 2–8-year follow-up demonstrates a lower, but not statistically significant failure rate in the hybrid group in TKR with fixed platform design [3]. An opinion that this might be due to the distribution of the patients was inferred.

Peters et al. [14] performed a cadaver study with conventional tibial trays and did not find differences between full versus surface cementing technique after 6,000 loading cycles with three times body weight as was done in this case. In contrast to this study, they used cadaver bones. It is not quite clear why they did not find differences. But there are two possibilities: the first idea is that the biomechanics of the cadaver bone differs from

**Table 1** Mean maximum liftoff (*italics*) (μm) when loading anterior, lateral, medial, posterior, standard deviation (SD) and *P* value within all different test conditions

| | Anterior loading | | Lateral loading | | Medial loading | | Posterior loading | |
|---|---|---|---|---|---|---|---|---|
| | *Dorsomedial* | | *Ventromedial* | | *Ventrolateral* | | *Ventromedial* | |
| | Cemented | Cementless | Cemented | Cementless | Cemented | Cementless | Cemented | Cementless |
| Median (μm) | 10.6 | 28.5 | 2.7 | 15.5 | 3.7 | 18.6 | 7.7 | 17.4 |
| SD | 4.5 | 4.7 | 1.1 | 6.5 | 1.6 | 0.6 | 1.5 | 5.1 |
| *P* value | 0.003 | | 0.01 | | 0.0001 | | 0.02 | |

the sawbone used and that the penetration of the cement is better in cadaver bones than in sawbones. Therefore Peters finds no differences. The other possibility is that different designs of tibial trays were used in this case. But, it is hard to say whether the design of the tray, the stem, respectively, has any influence on the initial stability. To clarify this question, comparative studies of different designs are needed.

One criticism of this study is, that sawbones were used for this testing that is comparable to the cited studies. Therefore, all experimental set-ups are limited to a similar extent and may differ from the clinical situation. The clinical outcome study is quite inhomogeneous according to the patients and thus the statement is therefore limited as well.

As stated, the current data and literature is quite inhomogeneous and indicates that initial fixation of the prosthetic components may be related to the depth of cement penetration. Nevertheless, up to now, it is believed that a better initial fixation is achieved with cemented stem, with deep penetration of the cement. Further studies comparing different designs with the same experimental set-up are necessary to find out about the influence of different types of tibial trays.

## Conclusion

In this experimental in vitro study, the hypothesis that the addition of cement surrounding the tibial stem reduces micromotion of the tibial tray in cemented TKA with mobile design was tested. It could be verified that unless the stem is cemented, higher micromotion of the tibial tray cannot be seen. Therefore it is concluded that the tibial tray should be fully cemented, especially in TKA with rotating platform.

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