INTRODUCTION:
The performance of total knee replacement is dependent on a number of factors, such as the pre-operative range of motion and post-operative kinematics of the joint. The kinematics of total knee replacement are mainly determined by the design of the implant, particularly the geometry of the articulating surfaces [1]. The traditional knee implant is designed with several axes of rotation, the so called J-curved designs. In most cases of multi radius designs the motion of the knee is guided by the shape of the articulating surfaces. Alternatively single axis or single radius designs have been introduced on the market allowing the soft tissue to guide the motion of the knee on the articulating surfaces. For mobile bearing variants of this single radius design it has been assumed to provide even more freedom of motion preventing kinematic conflicts during the range of motion thereby reducing contact stresses and polyethylene wear.

The hypothesis was that the soft tissue surrounding a single radius knee implant provides mobility and stability during the functional arc of flexion.

METHODS:
For the multi radius group 10 fixed bearing Duracon TKP (Stryker, USA) were included. Two single radius groups consisted of both 10 fixed bearing (FB) Triathlon total knee prostheses (TKP), and 10 mobile bearing (MB) Triathlon TKP. The local MEC approved the study.

During a step up task without the use of holding bars, the kinematics by means of fluoroscopy (joint kinematics and movement of the polyethylene bearing) and EMG signals (muscle function and co-contraction) were assessed. A flat panel fluoroscopic system was used to analyze the in vivo kinematics of the knee joints including the movement of the marked polyethylene bearing in the MB group [2]. The step-up platform was centered between the image intensifier and the focus of the fluoroscope, so that the subject’s knee is positioned in front of the image intensifier. At the start of the step-up motion, the leg with the total knee prosthesis is positioned on top of the riser. The step-up motion is finished when the contra-lateral leg is on top of the riser.

During the fluoroscopic measurements synchronized EMG data was collected. Bipolar surface EMG data from the following muscles were collected: M. Rectus Femoris, M. Vastus Lateralis, M. Vastus Medialis, M. Biceps Femoris, M. Semitendinosus, M. Gastrocnemius Medialis. Electrode placement was according to the recommendations of the Seniam project (www.seniam.org). The recorded EMG signals were filtered, smoothed and rectified during post-processing. The EMG signals were normalized per muscle to their maximal measured value (100%).

RESULTS:
The fluoroscopic results show that all groups have approximately the same axial rotation of the femoral component with respect to the tibial component (Figure 1). For the MB single radius group, the polyethylene insert follows the femoral component during its axial rotation during extension. This indicates that there is minimal sliding of the femoral component over the polyethylene.

Looking at the muscle activation patterns, there seems to be an activation and timing difference between the multi radius group on the one hand and the single radius groups on the other hand.

The extensor muscles of the multi radius group show a much clearer on/off pattern than the extensor muscles of the single radius groups (Figure 2). Timing of extension activation seems different between both groups. The multi radius group has a peak EMG much later in the task (±60%) compared to the single radius groups (±30%). The multi radius group also has a small peak around 15% of the task. In this group these peaks are also more or less visible in the patterns of the flexor muscles. The flexor muscles of the single radius groups are continuously active in that way they provide stability to the knee (Figure 3).

DISCUSSION:
All total knees showed about the same axial rotation of the femoral component with respect to the tibial component. The MB variant of the single radius design did not add additional mobility to the knee joint supposedly not necessary during this functional arc of flexion. Since the polyethylene insert followed the motion of the femoral component, theoretically contact stresses and wear are limited. A RSA study assessing the effect of prosthesis-bone interface stresses on the micromotion of the components and a retrieval study showing wear patterns and particles (sizes) should further clarify the theoretical benefits of the mobile bearing. One might question the added value of a mobile bearing in general taking into account the added costs and complexity for implantation when a new generation of double or triple cross linked polyethylene inlays are available for fixed bearing total knees. These materials will limit wear that occurs during sliding of the femur on the tibial articulating surface.

The fixed bearing single radius design showed the same axial rotation as the MB variant showing the freedom to move on the articulating surface and allowing the soft tissue to guide the motion of the knee using higher flexor muscle activation patterns. Early activation of the muscles in the single radius group indicates an anticipatory stabilization of the knee joint. The muscles function as a secondary constraint to the collaterals stabilizing the knee.

This study showed that a single radius design provides mobility of the femoral component with respect to the tibial component during the functional arc of motion while maintaining stability by active stabilization of the muscles.

REFERENCES: