TKR WEAR SCAR FORMATION IS INFLUENCED BY THE HOST'S GAIT PATTERN

Introduction: Wear simulators have become a valuable tool for pre-clinical testing of new prostheses designs and materials. While the testing protocols of hip simulators can be regarded as clinically predictive, current knee simulator protocols are not equally validated and the kinematic and/or kinetic input parameters are debatable. This may be illustrated by a recent study of Harman et al. [1], where considerable differences in the wear scar formation between retrieved and simulator tested implants of the same type became obvious. In particular, the in vivo contact areas were considerably more variable and the extent of damage was much greater than predicted by the knee simulator.

It was hypothesized that the variability of in vivo wear scar formation is related to the variability of human gait after TKR. Therefore, the aim of the study was to investigate the relationship between tibial polyethylene damage and gait measures of their hosts.

Methods: Positive matches from our institute’s TKR retrieval data bank and the TKR gait data bank were investigated. Prostheses removed for loosening, instability, malposition, and those with a service life <12 months were excluded. In addition, implants with a secondary type of damage due to delamination, and/or extensive metal or cement debris, were ignored. Lastly, the analysis was limited to a single design, leaving five tibial polyethylene inserts from a PCL-retaining prosthesis (MG II, Zimmer Inc.) for detailed analysis. The inserts functioned successfully for 65±35.5 (range 16.5–99.5) months in five patients and were retrieved postmortem, and for pain, osteophytes (n=2), and bone fracture.

Wear Analysis: Using a video based measuring system (Smartscope®), the outlines of the overall wear scar were digitized for both the medial and lateral plateau. By means of AutoCad®, the contact area of the insert, the contact zone between the insert and the bone, and the antero-posterior extent of damage were calculated and normalized relative to the medium size MG II insert.

Gait Analysis: Two female and two male patients (one of them bilateral) were tested in the institute’s biomechanical laboratory during the years ‘91 to ‘93. By that time the patients were 55±9 years old, pain free, and had their implants between 3 and 16 (mean 11.5) months in situ. The studies were performed using a three-dimensional optoelectronic system for motion capture and a multi-component force plate for the measurement of ground reaction forces. For this study, a characteristic trial at the self-selected “normal” speed from each of the subjects was chosen to represent daily walking activity. All knee moments are reported normalized to a percentage of body weight and height (%BH), acting externally at the tibia.

Potential linear relationships between worn area and moment characteristics (in the sagittal, frontal, horizontal plane) were statistically analyzed with Pearson correlations. A significance level of p=0.05 was used.

Results: The wear analyses revealed a mean medial wear area of 484.5±252.0 mm², and a mean lateral wear area of 484.2±218.9 mm², illustrating a high variability (Figure 1). The gait data showed that, apart from one, all patients walked slightly flexed at heel strike (5.3º±3.4º) and without pronounced mid-stance flexion, which is a typical observation with TKR patients (Figure 2). Four out of the five knees showed incidence of quadriceps reduced gait, which is reflected by a diminished flexion moment at heel strike.

There was an inverse, linear relationship between AP wear scar extension and the product of knee flexion angle and flexion moment at heel strike for the medial and the lateral plateau (R²=0.892 re. R²=0.833, p<0.04). In addition, reduced quadriceps activity (indicated by a low extension moment following the flexion moment) may also play a role in the AP wear scar formation. There was a trend (p=0.1) that smaller peak-to-peak moment differences (Fig.2, d’) caused larger AP wear scars (R²=0.667 and R²=0.655 for the medial re. lateral plateau). The medial/lateral differences in wear scar size correlated with the maximum adduction moment: the higher the adduction moment, the larger the differences between medial wear scar circumference and lateral wear scar circumference (R²=0.793, p=0.05). However, the medial/lateral differences in AP wear scar spread were best explained by the internal rotation moment peak occurring during late stance: the higher the

Discussion: To the authors’ knowledge this is the first study which compared in vivo wear outcome with kinetic gait measures. Although the current sample size was limited to only five components, relationships between gait pattern and wear scar formation can be reported.

As expected, the frontal plane moment influenced medial/lateral wear differences. Thus, a higher adduction moment caused, compared with the lateral side, a larger wear area medially. The external flexion moment at heel strike is mostly balanced by the hamstring muscles [2]. If this moment peak occurs while the knee is flexed (and not fully extended), a horizontal force is generated which pulls the tibia backwards causing the often-reported “negative” femoral rollback in TKR patients. The anteriorly directed slip of the femoral condyle is even more pronounced, when additional quadriceps insufficiency prevents the forward pull at the tibia. The horizontal moment during late stance causes the tibia to rotate internally and thus pushes the medial condyle towards the anterior lip of the tibial component. This explains the externally rotated wear pattern, although the femoral condyles were implanted internally rotated.

In conclusion, most of the variability in worn contact area may be explained by gait abnormalities of TKR patients. These abnormalities cause larger wear areas contributing to possibly higher wear rates. Since most TKR patients walk with an abnormal gait pattern, knee simulator input parameters should be reconsidered.

References:

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