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DOES AN INDIVIDUAL DESIGN OF THE PATELLOFEMORAL GROOVE IN TKA ENHANCE THE BIOMECHANICAL PERFORMANCE REGARDING PATELLAR KINEMATICS AND PRESSURES?

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SUMMARY

The aim of this study was to analyze the influence of the patellofemoral groove design in TKA on patellar kinematics and pressures with a special regard to an individual design adaption. Five different designs of the patellofemoral groove were created based on the Genesis II prosthesis. Muscle loaded knee flexion was simulated on 10 human knee specimens while measuring the patellar kinematics and patellofemoral pressure distribution. For 3 specimens, additional individual implants were developed based on CT-scans.

The largest influence was found for the completely flat design, where increased medal shift and lateral tilt were measured after TKA compared to the native knee. The other designs only showed small differences. Therefore, a moderate groove should be sufficient to guarantee stable motion. Considering the patellofemoral peak pressure, on average the designs only had a small effect, although large individual differences were found. The individually adapted designs did not show an improvement, which might be attributed to the alteration of overall knee biomechanics during TKA. Therefore, an individual choice between different standard implants might be a good option.

INTRODUCTION

Despite continuous improvements and excellent clinical results in total knee arthroplasty (TKA), patella resurfacing remains a highly controversial issue. In-vitro studies have shown extremely high patellofemoral pressure [1] and a modified kinematics [2] after TKA with and without resurfacing which are accounted for many problems like persistent anterior knee pain, subluxation or dislocation of the patella as well as early aseptic loosening and increased polyethylene wear of the patella implant.

The design of the patellofemoral joint surfaces is attributed a large influence on the varying knee biomechanics after TKA. While for patients without patella resurfacing, the native patella is sliding on the standardized femoral component and therefore the possibility of a reduced surface matching is high, patella resurfacing has been shown to decrease the joint contact area and yield to increased patellofemoral pressure [1]. With regard to a further design optimization, the current study examined the biomechanics of the patellofemoral joint after TKA with and without resurfacing comparing 5 differently designed patellofemoral joint surfaces of the femoral implant. Additionally, 3 individually adapted implant designs were developed and analyzed with the intention of achieving an improved surface matching.

METHODS

The femoral implant of a Genesis II prosthesis (Smith & Nephew) was scanned and an adaptable CAD-model was built using CATIA. Five different designs of the patellofemoral groove were created:

1) original Genesis II
2) completely flat
3) laterally elevated (+2mm lat, -1mm med)
4) medially elevated (+2mm med, -1mm lat)
5) laterally & medially elevated (+3mm lat+med)

The tibiofemoral joint as well as patellofemoral groove path and radius remained unchanged. Rapid Prototyping was used to produce prototypes made of polyamide.

A dynamic muscle loaded knee squat was simulated on 10 fresh frozen knee specimens with a self-developed, upright knee simulator [3]. The patellofemoral pressure distribution was measured using a flexible, resistive force sensor (TEKSCAN) while tibiofemoral and patellofemoral kinematics were recorded with an ultrasonic motion tracking system (ZEBRIS). Measurements were taken on the native knee as well as after TKA and after additional patellar resurfacing with alternating femoral implant.

Furthermore, for 3 specimens, individually designed implants were developed and tested, adapting the patellofemoral groove to the native anatomy on the basis of CT-scans.

RESULTS AND DISCUSSION

Considering patellofemoral kinematics, the largest influence was found for the flat design where increased lateral tilt (up to 6°) and medial shift (up to 5mm) were measured after TKA compared to the native knee. The other designs only had a small effect on patellar kinematics (Figure 1). After additional patellar resurfacing, similar results were achieved regarding kinematics.

Patellofemoral peak pressures were significantly increased

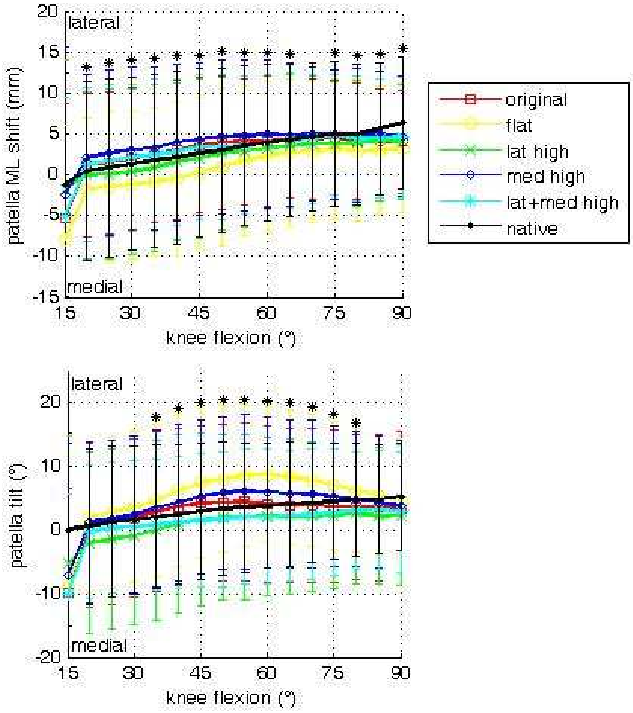

Figure 1: Mediolateral shift and tilt of the patella with respect to the femur after TKA with the 5 different designs – original Genesis II, completely flat, laterally elevated (lat high), medially elevated (med high) as well as laterally and medially elevated (lat+med high) – compared to the native knee.

(almost doubled) after patella resurfacing with all implants while it were only slightly enhanced after TKA without resurfacing compared to the native knee. Regarding the different designs, only a small influence on the mean maximal peak pressure was found (Figure 2). However, for the individual knee specimens, the pressure distribution and peak pressures varied clearly among the different designs.

Patellofemoral kinematics and pressures measured with the 3 individually designed implants did not differ noticeably from the results with the other implants.

The design of the patellofemoral groove mainly influences the mediolateral motion of the patella. Patella medial shift as well as lateral tilt were significantly enhanced with the flat implant. However, a moderate groove – as with the original Genesis II implant – seems to be sufficient to guarantee a stable motion of the patella during muscle loaded knee flexion.

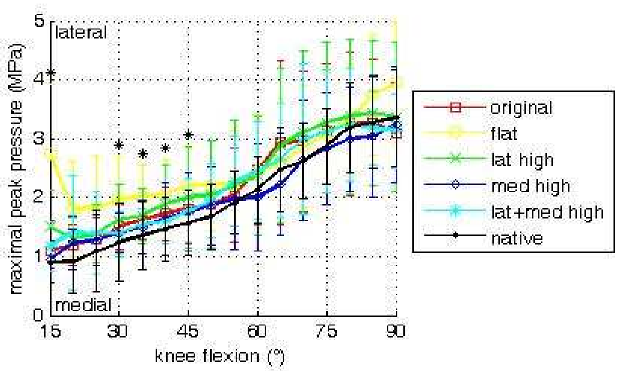

Figure 2: Maximal patellofemoral peak pressure after TKA with the 5 different designs compared to the native knee.

Considering patellofemoral peak pressures, no advantages of a special design or design criterion could be found. On average, there were only marginal differences. However, the optimal design – the design which led to the lowest peak pressures during knee flexion – varied among the different knee specimens. Therefore, regarding pressures, the optimal design seems to depend on the individual anatomy of each knee. However, this assumption could not be proven by the results of the 3 individually adapted implants. No improvements could be shown by an individual adaption of the implant design to native knee anatomy. A possible explanation for these results might be the fact that TKA alters the overall knee biomechanics. Modified tibiofemoral kinematics had been shown after TKA compared to the native knee [4,5]. Therefore, an individual adaption to native knee anatomy might not be the best possibility for an individual design of the patellofemoral groove. But – as only 3 knees have been tested yet – general conclusions have to be drawn carefully.

In contrast to other studies comparing different types of prosthesis [6,7], a selective analysis of the patellofemoral groove design influence on patellar biomechanics was possible in our study. Furthermore, as only the groove was modified, surgery could be performed with the same instruments for all designs including the individual ones. This facilitates the positioning procedure as well as quality control. However, an appropriate matching of the design and implant position, which had been shown to be important for the success of individually designed implants [8,9], remains challenging.

CONCLUSIONS

Increased mediolateral motion was found for the flat design compared to the others and the native knee concluding that a moderate groove is necessary but also sufficient to guarantee stable motion. For the maximal patellofemoral peak pressure, large individual differences between the designs were measured while the average influence was small. The individual designs did not show an improvement. Regarding the alterations of overall knee biomechanics after TKA, a copy of the native patellofemoral anatomy might not be the best possibility of implant individualization. Therefore, further concepts have to be tested. An individual choice between some standard implants might be an interesting option.

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