

# THE INFLUENCE OF SHAPE AND SLIDING DISTANCE OF MOVEMENT LOCI OF THE FEMORAL HEAD ON THE WEAR OF THE ACETABULAR CUP

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## INTRODUCTION

Wear and the generation of ultra high molecular weight polyethylene (UHMWPE) particles is now considered the most important cause of long term failure in total arthroplasty. The importance of multidirectional motion in the wear process of the components used as bearing surfaces in total hip and knee arthroplasties has recently been emphasised (Wang et al., (1997), Bragdon et al., (1996)). This study determines the trajectory of specified points on the femoral head of a total hip replacement (THR) for individual THR patients and the distances traversed by these points. The shape and distance traversed by these trajectories were correlated with radiographic wear measurements.

## METHODS

Twenty points were selected on the surface of the femoral head of a right custom hip implant. A computer program was designed to utilise gait data from THR patients to simulate the motion of these points. Gait analysis was performed on 19 THR patients at a period of 5 years post-operation. Gait analysis was performed using a 6 camera VICON 370 motion analysis system (Oxford Metrics, Oxford, England).

Angular motions of the points were determined by a program written specifically for this project (MATLAB, Mathworks Inc., Natick, MA). The loci

of the points were plotted on the developed surface of the femoral head. The shape of the loci were quantified by determining the aspect ratio (length/width =  $L/F$  in Figures 1 and 2) of each.

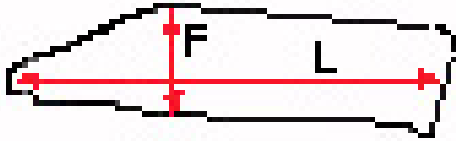
Wear measurements were made of serial radiographs using a development of Livermore's technique of concentric circles (Livermore et al., 1990).

## RESULTS AND DISCUSSION

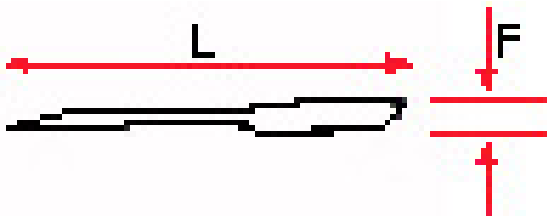
The size, shape and direction of the loci of the points differed widely between subjects and included oblong, quasi-elliptical, figure-8 and longitudinal paths. The largest average sliding distance traversed by the 20 points for a THR patient was 140% greater than the lowest average distance traversed. The average sliding distance of the points for THR patients was 18.06mm (ranging from 10.08 to 24.41mm).

The average aspect ratio of the loci varied between subjects from 2.49 to 9.21. Lower aspect ratios signified wider loci, while higher aspect ratios signified thinner loci. Figure 1 shows the locus of a point for Subject A, which was wider than that for Subject B (Figure 2), which tended to be longitudinal in shape. Thin, longitudinal wear paths closely resemble those paths produced under conditions of unidirectional motion (Barbour et al. (1999)). Conversely, wider paths resemble those wear paths produced under conditions of multidirectional motion at the hip joint.

Furthermore as a wider locus will cross more paths than a slender one, this would suggest that the wider path will also cause more wear on a molecular level.



**Figure 1.** Locus of point for Subject A.



**Figure 2.** Locus of point for Subject B.

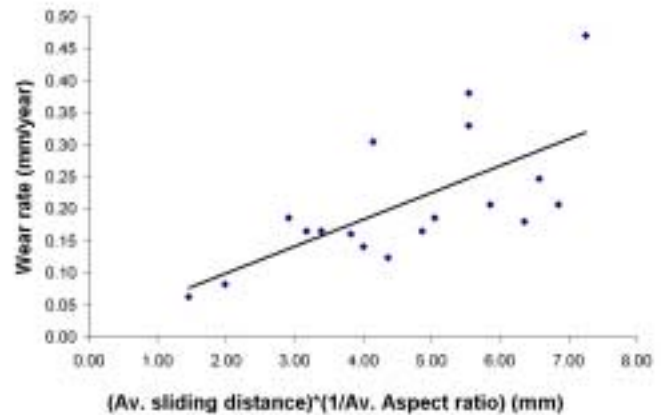
UHMWPE under unidirectional wear conditions experiences orientation hardening and displays higher wear resistance. Wear tests have shown the wear rate of UHMWPE to be significantly greater for conditions of multidirectional wear than for conditions of unidirectional wear (Wang et al., (1997), Endo et al., (1999)).

The average wear rate of the acetabular cup was 0.21mm/year (range: 0.06-0.47 mm/year). Individual wear rates showed positive correlation with the average sliding distance for the twenty points and improved positive correlation with the product of sliding distance and inverted aspect ratio (Figure 3).

## SUMMARY

An understanding of the paths taken by points on the femoral head may inform studies of wear mechanisms and shear forces acting on the polymer. Shorter,

longitudinal paths tend to cause less wear than larger, wider paths.



**Figure 3.** Plot of Wear rate against the product of the average sliding distance and the inverse of the average aspect ratio of the loci.

## REFERENCES

- Barbour P. S. M. et al., (1999). *Proc. Institute Mechanical Engineers., Part H: J. Engineering in Medicine*, **213**, 455-467.
- Bragdon C. R., et al. (1996). *Proc. Institute Mechanical Engineers., Part H: J. Engineering in Medicine*, **210**, 157-166.
- Endo M. M. et al. (1999). *Bio-Medical Materials and Engineering*, **9**, 13-20.
- Livermore J., (1990). *J. Bone and Joint Surgery*, **72-A**, 518-528.
- Wang, A. et al. (1997). *Wear*, **203-204**, 230-241.