Institute of Medical & Biological Engineering

Coordinate Measuring Machine-Based Methodology for Wear and Creep Assessment of Polyethylene Tibial Knee Inserts

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INTRODUCTION

- Total knee replacement is a common surgical procedure in orthopedics. Wear of polyethylene bearing component is a major problem in total knee replacement, and studies have shown that about 16% of knees fail because of wear [1].
- Wear assessment of the polyethylene knee inserts has been an essential subject for improving the longevity [2]. Wear measurement methodologies become critically important if differentiations with respect to materials and design are sought when geometry change is small, which can consist of both wear and creep.
- The coordinate measuring machine (CMM) has been proved to be an accurate technique for volumetric assessment [3,4].

AIM

- The aim of this study was to develop a three dimensional (3-D) geometrical methodology to determine volumetric material loss of tibial knee inserts and validate its effectiveness on the basis of physical volume removal and theoretical creep deformation tests.

METHODS

- The surface coordinates of tibial knee inserts were acquired using CMM as pre-wear data for later validation, using a CAD model for accurate coordinate capture.
- A 2nd order polynomial curve surface fitting algorithm was used to generate the original 3-D surface based on this undeformed region, which was identified automatically using a MATLAB (V 7.11) program (Figure 1).
- A 24 mm diameter ball-ended cutter was used to remove physical materials on the left condyle of tibial knee inserts with maximum wear depths from 0.1 mm to 1 mm.
- Artificial creep deformation tests were simulated on the PFC Sigma total knee replacement under 2600 N load with 5 mm offset in the medial direction.

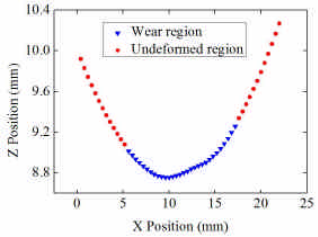

Figure 1 Schematic of wear and undeformed region

RESULTS

- With the increasing interval of the CMM scan, the volume difference increased while the time taken decreased (Figure 2).

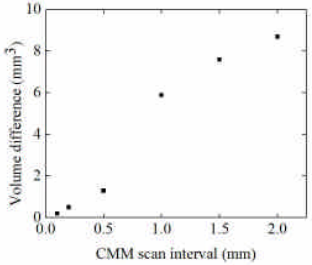

Figure 2 The influence of CMM scan interval

- The validation results of physical volume removal tests indicated that the methodology is accurate for volumetric assessment, with concordance correlations coefficients (CCC) of 0.9998 and 0.9960 with and without initial surface coordinates respectively (Figure 3).
- For the artificial creep tests, the CCC was 0.9940 and 0.8494 with and without initial surface geometry of the tibial knee inserts provided and the corresponding estimated creep volume ranged from 37.9 mm³ to 61.4 mm³ and 39.5 mm³ to 69.7 mm³ respectively (Figure 3).

RESULTS

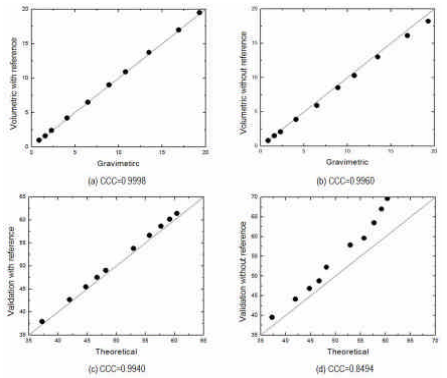

Figure 3 Validation of 3-D volumetric assessment methodology based on physical volume removal ((a), (b)) and creep deformation tests ((c), (d))

Discussion

- Further studies indicated that at least 50% undeformed region was required as reference for accurate volumetric assessment.
- The general high levels of agreement indicate that the present methodology is appropriate to measure clinically relevant levels of wear where no pre-wear data, CAD models or original design drawings are available.

References

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Acknowledgement

The research was supported by the EPSRC, the Centre of Excellence in Medical Engineering funded by the Wellcome and by the NIHR LMBRU Leeds Musculoskeletal Biomedical Research Unit. JF is an NIHR senior investigator.