Institute of Medical & Biological Engineering

Characterisation of the Compressive Mechanical Properties of UHMWPE for the Use in Computational Models of Total Joint Replacements

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INTRODUCTION

- The mechanical properties of total joint replacement (TJR) bearing materials are important inputs to the computational models of TJRs.
- They significantly affect the wear and/or kinematic predictions of these models, and should therefore be measured under realistic compressive conditions.
- This study determined the elastic modulus and Poisson's ratio of conventional (GVF) and moderately cross-linked (XLK) ultra-high molecular weight polyethylene (UHMWPE) under compressive test conditions, similar to the operating conditions of TJRs.

MATERIALS & METHODS

Poisson's ratio (Figure 1):

- The contact area was measured experimentally using:
  - 12mm diameter cylindrical specimens of 10.2mm length.
  - 1mm compressive displacement.
  - 12 mm/min strain rate.
  - 10 minutes hold.
- Contact area-Poisson's ratio relationship was obtained from the computational simulation to the experimental test, assuming different Poisson's ratios.
- The experimental contact area was then used to determine the Poisson's ratio.
- GVF and XLK UHMWPE were tested.

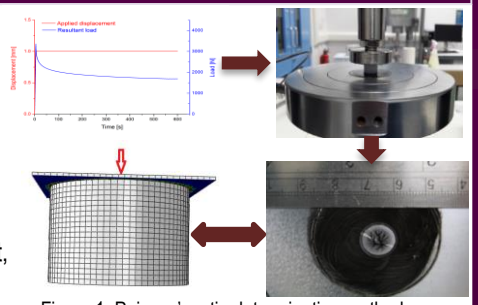

Figure 1: Poisson's ratio determination method.

Elastic modulus (Figure 2):

- Using a similar approach, the elastic modulus was determined using the contact area measured from:
  - 10mm flat specimens.
  - 63.5mm rigid ball.
  - 250N (average) dynamic sinusoidal load.
  - 6000 cycles (from the sensitivity study).

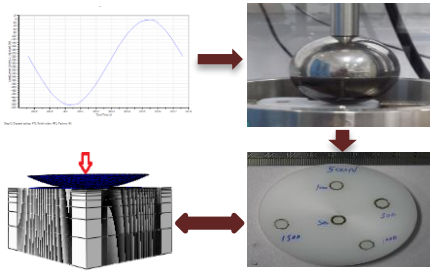

Figure 2: Elastic modulus determination method.

RESULTS

- The measured Poisson's ratio was 0.33±0.04 (n=5) and 0.32±0.08 (n=3) (mean ± 95% confidence interval) for GVF and XLK UHMWPE respectively.
- The corresponding values for the elastic modulus were 365±31 and 553±51 [MPa] (mean ± 95% confidence interval, n=3) respectively (Figure 3).

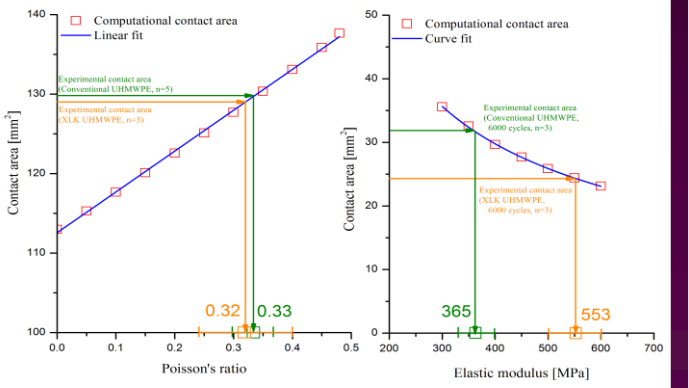

Figure 3: Poisson's ratio and elastic modulus for conventional and moderately cross-linked UHMWPE.

DISCUSSION

- A reverse engineering approach to characterise the mechanical properties TJRs bearing materials, under realistic compressive test conditions.
- 20% reduction in the measured Poisson's ratio and elastic modulus values, compared to those reported in the literature using tensile test conditions [1, 2].
- These material parameters will be inputs to future computational models of TJRs.

SIGNIFICANCE

- The measured mechanical properties, under compressive test conditions, were lower than those reported in the literature, under tensile loading conditions.
- Should therefore be adopted in future computational models of TJRs for a more realistic and robust virtual modelling platform.

References

[1] Bartel et al. CORR, 1995.

[2] Godest et al. J BioMech, 2002.

Acknowledgments

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