THE YOUNG'S MODULUS OF CANCELLOUS BONE IN THE RHEUMATOID AND NORMAL HAND

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INTRODUCTION

Rheumatoid arthritis is a common, debilitating disease. The joints most commonly affected are the metacarpo-phalangeal joints [Fleming et al, 1976]. Prosthetic replacement of these joints is effective in improving function, relieving pain and correcting deformity, however there is a high premature failure rate (over 20% in some series) in even the most commonly used implant, the Swanson silastic prosthesis, yet the reasons for these failures are poorly understood [Williams, 1999]. Finite element modelling promises an improved understanding of the reasons for such premature failure, and offers a method of improving prosthesis selection, evaluation and design without risk to patients. This will lead to future clinical trials subjects and patients having fewer problems with implanted prostheses.

Accurate finite element modelling of the behaviour of metacarpo-phalangeal joints for use in rheumatoid arthritis requires knowledge of the Young's modulus of cancellous bone in the rheumatoid hand. This data has not been previously determined.

The aim of this work was to determine the Young's modulus of cancellous bone in the rheumatoid hand in order to facilitate accurate finite element modelling of metacarpo-phalangeal joint prostheses for use in rheumatoid arthritis.

METHODS

Metacarpal heads, which are normally discarded during metacarpo-phalangeal joint replacement, were retained and stored. A three-point bending test was selected to optimize specimen numbers and accuracy, to facilitate identification of macroscopic bony defects and as bending tests are simple, robust methods for testing bone.

A no-contact, optical displacement gauge was developed, consisting of an inexpensive monochrome CCD video camera board and an inexpensive custom lens. The gauge resolution was determined to be better than 5 microns.

A jig was devised which allowed three point loading of specimens of varying size. Each specimen was progressively loaded on the jig whilst displacement was measured. Regression analysis of the linear portion of a load/displacement curve, corresponding to the region of elastic deformation of the specimen, allowed calculation of the Young's modulus for each specimen.

The jig and optical displacement gauge were validated using Perpex, aluminium and Delrin specimens.

Metacarpal heads were water cooled whilst being cut using a diamond sintered bandsaw, to provide the bone specimens which were then tested.

RESULTS AND DISCUSSION

92 specimens from 35 metacarpal heads in 11 patients with rheumatoid arthritis (of whom three had had bilateral surgery) were tested successfully. The mean value of Young's modulus for cancellous bone in the rheumatoid metacarpal was found to be 97MPa, standard deviation 103MPa, range 10-541MPa, 95% confidence interval 76.4-118.6MPa..

No correlations were found between Young's modulus and specimen thickness, cross-sectional area, shape or patient age. No significant difference was found between the values of Young's modulus for male and female specimens or between different digits.

SUMMARY

To facilitate accurate finite element modelling of metacarpo-phalangeal joint replacements for use in rheumatoid arthritis, the Young's modulus of cancellous bone in the rheumatoid hand has been determined, using a three-point bending technique, to be 97MPa (95% confidence interval 76.4-118.6MPa).

In addition, values for psoriatic arthritic and normal cancellous metacarpal bone have been determined and a displacement measuring gauge using an inexpensive lens and video camera with a resolution of better than 5 microns has been developed.

REFERENCES

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