

DEVELOPMENT OF A CUSTOM, PATIENT-SPECIFIC FEMORAL COMPONENT FOR UNICOMPARTMENTAL KNEE REPLACEMENT

¹ Dawie van den Heever, ¹ Cornie Scheffer, ² Pieter Erasmus and ² Edwin Dillon

¹ Biomedical Engineering Research Group, Department of Mechanical and Mechatronic Engineering, Stellenbosch University,

² Mediclinic Stellenbosch; email: dawie@sun.ac.za, web: www.sun.ac.za/berg

INTRODUCTION

The knee sustains very high forces and is the biggest, most complicated and incongruent joint in the body [1]. The knee is susceptible to injury and chronic diseases of which osteoarthritis (OA) is most common [2-3].

This study describes the development of a novel, patient-specific unicompartmental knee prosthesis. The articulating surfaces of the medial and lateral condyles are represented by polynomials instead of the more commonly used circles of commercial prostheses. A patient specific femoral component is designed using the geometry of the patient's affected knee.

In commercially available prostheses the surface geometry in sagittal view is either of a specific single or multi-radius design which is predetermined by the manufacturer. This geometry does not necessarily present the true radius of a specific knee. The same applies to the mediolateral radius of both the medial and lateral condyles when viewed axially.

The curvatures of the individual condyles, as viewed in the anterior/posterior plane, are also ignored and in most designs there is no difference between the design for the medial and lateral condyles. In practice the curvature on the medial side is much more pronounced than on the lateral side.

METHODS

In this study the complex geometries of the condyles in both sagittal view as well as axial view are represented by polynomials. Polynomials are mathematical equations of the form

$$f = a_0x^n + a_1x^{n-1} + \dots + a_{n-1}x + a_n.$$

CT data of healthy knee joints were obtained with a slice thickness of 1 mm with a resolution of 512 x 512. The CT data were imported into MIMICS version 12.01 (Materialise, Leuven, Belgium). MIMICS is a software package used for editing and 3D reconstruction of CT data. Numerous points were placed along the articulating surfaces of the condyles in both the sagittal view and the axial view. The coordinates of the points describing the surface geometry were imported into Matlab version 7.0.1 (The MathWorks Inc). Polynomials were then fitted through the points using the polyfit function.

These polynomials are then used to create the articulating surfaces of a new prosthesis design. To further make the prosthesis more patient-specific, the patient's current knee surface is used as the inner surface of the design. This is done by creating a solid part using the polynomials and subtracting the affected knee geometry from the model using 3matic (Materialise, Leuven, Belgium). The

posterior/anterior curvature of the specific knee is also incorporated in the design.

RESULTS AND DISCUSSION

The results comparing the use of a single radius and a polynomial to represent the articulating surface of a condyle in axial view is shown in Figure 1.

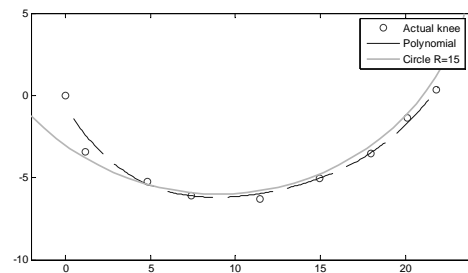


Figure 1: Comparison of the lateral condyle surface geometry in axial view.

Figure 2 shows the anterior/posterior curvature present when viewed from the bottom. Prostheses designs incorporating this curvature are also shown.

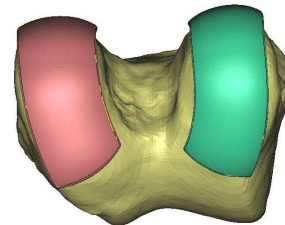


Figure 2: Anterior/posterior curvature of the knee.

It is clear that the polynomials possess the ability to closer approximate the complex geometry of the articulating surfaces of the femur than a circle. It is also clear that the anterior/posterior curvature is important and should be considered when designing a new prosthesis.

CONCLUSIONS

The knee is a very complicated joint and hence it is difficult to design prostheses that will be appropriate for everyone. It is shown that using polynomials to represent the articulating surfaces of the femoral condyles, a more accurate representation of the actual knee geometry is produced. This method together with the patient's affected knee geometry can be used to develop custom, patient specific prostheses which also consider the curvature in the anterior/posterior plane.

REFERENCES

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