Single radius of curvature implant design enhances patient lower limb power output following total knee arthroplasty

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Introduction

End-stage osteoarthritis is characterised by pain and reduced physical function, for which total knee arthroplasty (TKA) is recognised to be a highly effective treatment.

Most knee implants are multi radius in design, incorporating a shifting centre of rotation of the knee as it moves through flexion. Recent advances in kinematic theory however suggest a single axis of flexion/extension is located in the distal femur. A recently launched TKA implant (Triathlon, Stryker US®), is based on this theory, adopting a single radius of curvature femoral component. It is suggested that this design allows superior patient function post-operatively, and specifically, that it results in enhanced efficiency of the quadriceps muscle group through a longer patello-femoral moment arm.

Adequate extensor mechanism function is considered a prerequisite for participation in many activities of daily living and in promoting a positive clinical outcome, while quadriceps muscle weakness is often present in patients receiving a TKA and has a substantial impact on movement patterns and performance during functional tasks. Laboratory cadaver experiments have demonstrated enhanced quadriceps efficiency with a single radius knee design; however this has not been assessed in patient studies.

Methods

To determine if any differences in the function of the patient’s extensor mechanism can be attributed to differing implant design, change in lower limb power output was compared between single and multi radius implants as part of a larger ongoing randomised controlled trial to benchmark the new implant.

101 patients receiving a single radius implant (Triathlon) and 82 patients with a traditional multi-radius implant (Kinemax, Stryker US®) were assessed pre-operatively and then at 6, 26 and 52 weeks post arthroplasty in a local clinical testing facility. The same researcher conducted all assessments blinded to the implant design. All patients were diagnosed with osteoarthritis, and drawn from a single centre. All procedures were carried out by a select group of surgeons with substantial experience in the use of both implants. Surgery was conducted in the same manner using standard hospital protocol and instrumentation for each system.

Patients lower limb power output was assessed by use of a Leg Extensor Power Rig (LEP) (Queens Medical Centre, Nottingham, NG7 2UH) which has been well validated for use with this population group. Output was reported as maximal wattage (W) generated in a single leg extension, and expressed as a proportion of the contralateral lower limb power output to act as an internal control.

Data were analysed using SPSS (Version 14, IBM Chicago, USA). Two way analysis of variance (ANOVA) was employed to assess the variation in output between the groups. Post hoc tests were performed using independent samples t-tests.

Results

Progressive improvement in lower limb power output was seen in both groups at each subsequent assessment, though larger percentage improvements were evident in the single radius group. This was particularly evident at both early post-operative assessment (30% improvement in maximal wattage generated in the single radius group compared to 7% in the multi-radius group) and at 1 year (106% compared to 85% in the respective groups). Expressed as a proportion of the contralateral limb, the power output of the single radius group was consistently superior to that of the multi radius group. The mean power output results are shown in Table 1.

Repeated measures ANOVA demonstrated a significant overall effect of TKA on the quadriceps power output, F = 249.09, p = 0.001 and also a significant interaction of the implant group on the output F = 11.33, p = 0.001.

Independent samples t-tests of between group differences at the four assessment periods highlighted greater improvement in the single radius TKA group at all post-operative assessments (p < 0.03), see table.

<table>
<thead>
<tr>
<th>Radii</th>
<th>Power (Watts)</th>
<th>Power (% cont limb)</th>
<th>Significance</th>
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<tbody>
<tr>
<td></td>
<td>Single</td>
<td>Multi</td>
<td>Single</td>
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<tr>
<td>Pre-op</td>
<td>42.2</td>
<td>47.1</td>
<td>50.4</td>
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<td></td>
<td>(37.8)</td>
<td>(44.3)</td>
<td>(32.0)</td>
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<td>6 weeks</td>
<td>54.9</td>
<td>50.1</td>
<td>68.9</td>
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<td></td>
<td>(38.5)</td>
<td>(32.5)</td>
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<td>6 months</td>
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<td>77.8</td>
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<td>(48.1)</td>
<td>(46.0)</td>
<td>(35.6)</td>
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</tbody>
</table>

Conclusion

Single radius total knee replacement implant design are suggested to confer superior patient outcome through a theoretical enhanced quadriceps muscle efficiency as a result of a longer patello-femoral moment arm.

This is the first study to assess this theory directly in a large prospective patient cohort. Both patient groups demonstrated substantial physical improvements as a result of the surgical intervention; however a significant implant effect was also apparent in outcome. The patient’s lower limb power output was significantly greater at all post-operative assessments in the single radius implant group compared to the multi radius group (both in maximal wattage achieved and as a proportion of the output of the contralateral limb). This difference was particularly relevant at early 6 week assessment and at 1 year review.

Lower limb power output is known to link positively to functional ability following total knee replacement. These results support the hypothesis that knee implants with a single radius design femoral components confer enhanced functional outcome compared to traditional multi-radius designs.

Significance

Development in prosthetic design seeks to improve patient functional outcome following TKA. This study suggests that implants based on single radius femoral design may achieve superior functional results through enhanced quadriceps efficiency.

References