Measured Flexion Following Total Knee Arthroplasty

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abstract

Postoperative flexion is an important factor in the outcome of total knee arthroplasty. Although normal activities of daily living require a minimum of 105° to 110° of flexion, patients from non-Western cultures often engage in activities such as kneeling and squatting that require higher flexion. The desire to achieve greater flexion serves as the driving force for prosthetic modifications, including high-flexion designs. Techniques used to measure knee flexion and knee position during measurement are not often described or are different depending on the examiner. The purpose of this study was to compare active (self) and passive (assisted) flexion after successful total knee arthroplasty for 5 prostheses (2 standard and 3 high-flexion) using clinical (goniometer) and radiographic (true lateral radiograph) measurement techniques by different independent examiners.

At a mean follow-up of 2.7 years (range, 1-5.6 years), a total of 108 patients (144 total knee arthroplasties) had completed the study. Mean postoperative active flexion was 111° clinically and 109° radiographically for the standard designs and 114° clinically and 117° radiographically for the high-flexion designs. Adding passive flexion increased flexion to 115° clinically and 117° radiographically for the standard designs and 119° clinically and 124° radiographically for the high-flexion designs. Flexion differences between the 2 measurement techniques (active vs passive and clinically vs radiographically) were statistically significant ($P < .05$). These findings demonstrate the importance of describing how flexion is measured in studies and understanding how the method of measurement can affect the findings.

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Total knee arthroplasty (TKA) restores function, corrects deformity, and reduces pain associated with end-stage arthritis. Postoperative flexion is an important factor in determining patient satisfaction after TKA. Postoperative flexion tends to stabilize by 12 months postoperatively, with little change beyond that point according to previous reports. Knee flexion is integral to functions in activities of daily living. Although normal activities of daily living require a minimum of $105^\circ$ to $110^\circ$ of flexion, patients of non-Western cultures often engage in activities such as kneeling and squatting that require higher flexion. The desire to achieve greater flexion serves as the driving force for prosthetic modifications, including high-flexion designs.

Techniques used to measure knee flexion and the position of the knee during measurement are not often described and are different depending on the examiner. Comparison of flexion among prostheses is difficult when methods of measurement are inconsistent, which may explain some of the discrepancy in postoperative flexion, ranging from $103^\circ$ to $139^\circ$, reported in the literature. With the advent of the high-flexion design knee prosthesis, the method of measurement becomes increasingly important.

The purpose of this study was to compare active (self) and passive (assisted) flexion after successful TKA for 5 prostheses using clinical (goniometer) and radiographic (true lateral radiograph) measuring techniques performed by 3 independent examiners (K.T.M., C.A.V., C.W.C.) who were blinded to the other examiners’ findings.

**Materials and Methods**

Five knee prostheses were evaluated. The prostheses included 2 standard designs, the Natural Knee (Zimmer, Warsaw, Indiana) (n=29) and the PFC Sigma (DePuy, Warsaw, Indiana) (n=40), as well as 3 high-flexion designs, the Genesis II (Smith & Nephew, Memphis, Tennessee) (n=29), the NRG (Stryker Howmedica Osteonics, Rutherford, New Jersey) (n=21), and the Triathlon (Stryker Howmedica Osteonics) (n=25).

Only nonweight-bearing flexion was measured in this study due to the relative ease of obtaining radiographic films in this position and the reproducibility of measurements among the examiners. Active flexion was measured with the patient lying supine and maximally bending his or her own knee, and passive flexion was measured with the patient’s operative knee bent maximally by the examiner until stopped by anterior discomfort or posterior soft tissue impingement (Figure). Clinical measurements were obtained with a long-armed goniometer (360 Degree Transparent Goniometer, 12.5”; Roylan Medical, Menomonee Falls, Wisconsin) using these 2 positions. True lateral digital radiographs were obtained with the operative knee in these same 2 positions. Radiographic flexion was measured using the Stentor PACS (Philips; Brisbane, California). Radiographic flexion was based on the angle subtended by the lines midway between the anterior and posterior cortices of the femur and the tibia. Radiographic flexion was then compared with clinical flexion. To improve reliability, postoperative clinical and radiographic measurements were performed independently by the 3 observers; values were compared and reported as mean flexion.

Statistical analysis was performed using SPSS version 13.0 software (SPSS, Inc, Chicago, Illinois). Independent sample t tests were used to assess differences in flexion and demographics (ie, age, height, weight, and body mass index) between the standard and high-flexion groups. Chi-square test was used to assess sex differences between groups. Independent sample t tests were used to compare gravity- and active-assisted postoperative flexion between the groups as measured clinically with a goniometer and radiographically with a true lateral radiograph. The average measurement of all 3 examiners was used for the t test. Pearson’s correlation coefficients were used to compare flexion measurements among the 3 examiners. All tests were 2-tailed, and an alpha level of 0.05 was used to determine statistical significance.

**Results**

At a mean follow-up of 2.7 years (range, 1-5.6 years), a total of 108 patients (144 TKAs) had completed the study. No statistically significant differences were observed in height, weight, or body mass index among the patients (Table 1). The proportion of men and women differed among the implant design groups, but this did not correlate with the flexion results. Although patients in the Genesis II group were significantly younger than the rest of the cohort, age did not correlate with flexion. Patients with bilateral TKAs were evenly distributed between the 2 groups.
Mean postoperative active flexion was 111° clinically and 114° radiographically for the standard designs compared with 114° clinically and 117° radiographically for the high-flexion designs. By adding passive flexion, mean postoperative flexion increased to 115° clinically and 117° radiographically for the standard designs compared with 119° clinically and 124° radiographically for the high-flexion designs (Table 2).

Clinical correlations ranged from 0.78 to 0.90 among the 3 observers, whereas radiographic correlations were the strongest (Pearson $r=0.90-0.97$).

**DISCUSSION**

With patients maximally bending their own knees, nonweight-bearing postoperative active flexion was 111° and 114° clinically for the standard and high-flexion cohorts, respectively, similar to that reported in the literature. However, when examiners pushed on the patients’ knees (active flexion), flexion improved to 115° and 119° clinically in the standard and high-flexion cohorts, respectively. In addition, the results obtained with the clinical and radiographic measurement techniques varied significantly.

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**Table 1**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Standard Implants</th>
<th>High-flexion Implants</th>
<th>Combined Mean SD</th>
<th>Combined Mean SD</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Natural Kneea</td>
<td>PFC Sigmac</td>
<td>Combined Cohort</td>
<td>Genesis IIc</td>
<td>NRGd</td>
</tr>
<tr>
<td>No. of patients</td>
<td>29</td>
<td>40</td>
<td>69</td>
<td>29</td>
<td>21</td>
</tr>
<tr>
<td>Women, %</td>
<td>66</td>
<td>40</td>
<td>51</td>
<td>76</td>
<td>62</td>
</tr>
<tr>
<td>Mean age, y</td>
<td>72</td>
<td>72</td>
<td>72±7.1</td>
<td>66</td>
<td>70</td>
</tr>
<tr>
<td>Mean height, in</td>
<td>68</td>
<td>67</td>
<td>67±3.7</td>
<td>66</td>
<td>66</td>
</tr>
<tr>
<td>Mean weight, lb</td>
<td>188</td>
<td>186</td>
<td>187±41.6</td>
<td>187</td>
<td>177</td>
</tr>
<tr>
<td>Mean BMI</td>
<td>29</td>
<td>29</td>
<td>29±6.1</td>
<td>30</td>
<td>28</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index.
aZimmer, Warsaw, Indiana.
bDePuy, Warsaw, Indiana.
cSmith & Nephew, Memphis, Tennessee.
dStryker Howmedica Osteonics, Rutherford, New Jersey.

**Table 2**

<table>
<thead>
<tr>
<th>Postoperative Flexion</th>
<th>Standard Implants</th>
<th>High-flexion Implants</th>
<th>Combined Mean SD</th>
<th>Combined Mean SD</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Natural Kneea</td>
<td>PFC Sigmac</td>
<td>Combined Cohort</td>
<td>Genesis IIc</td>
<td>NRGd</td>
</tr>
<tr>
<td>Clinical, $^g$ deg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>107</td>
<td>114</td>
<td>111±9.7</td>
<td>115</td>
<td>113</td>
</tr>
<tr>
<td>Passive</td>
<td>111</td>
<td>119</td>
<td>115±10.0</td>
<td>119</td>
<td>118</td>
</tr>
<tr>
<td>Radiographic, $^h$ deg</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>105</td>
<td>112</td>
<td>109±12.0</td>
<td>118</td>
<td>111</td>
</tr>
<tr>
<td>Passive</td>
<td>113</td>
<td>121</td>
<td>117±11.7</td>
<td>125</td>
<td>122</td>
</tr>
</tbody>
</table>

Abbreviation: deg, degrees.
aPostoperative flexion represents the mean of measurements obtained by all 3 examiners.
bZimmer, Warsaw, Indiana.
cDePuy, Warsaw, Indiana.
dSmith & Nephew, Memphis, Tennessee.
eStryker Howmedica Osteonics, Rutherford, New Jersey.
f$P$ based on t test of flexion of combined mean of standard implants compared with flexion of combined mean of high-flexion implants.
gFlexion measured by goniometer.
hFlexion determined by digital lateral radiographs.
Studies comparing the flexion of standard knee prostheses with high-flexion designs have reached conflicting conclusions as to whether the design changes were beneficial.\textsuperscript{14,19-26} In addition, techniques used to measure flexion and the position of the knee during measurement are not often described. Comparison of flexion among prostheses is difficult when methods of measurement are inconsistent, which may explain some of the discrepancies reported in the literature for postoperative flexion, ranging from 139\textdegree{} to 141-17.

Although the average clinical collective postoperative nonweight-bearing flexion for these 3 high-flexion prostheses of 114\textdegree{} was statistically different from the 111\textdegree{} flexion for the standard design without specific high-flexion features, the difference was not clinically important. This 3\textdegree{} difference was similar to that found by Mehin et al,\textsuperscript{21} which they reported was not clinically important.

The limitations of the current study include a small sample size for each prosthetic group. A larger cohort may reveal further differences in flexion among these types of implants. The current study also only examined postoperative flexion associated with these specific prostheses; it did not examine prostheses that are no longer in widespread clinical use.

**Conclusion**

Although the correlation between measurements was moderately high to high among the 3 independent examiners, the differences in flexion between the 2 measurement techniques (active vs passive and clinically vs radiographically) were statistically significant ($P<.05$). These findings point to the importance of describing how flexion is measured in studies and understanding how the method of measurement can affect the findings.

**References**