Polyethylene damage in total knee implants is partly controlled by kinematics. In vitro tests provide a fairly good picture of causes and modes of wear when compared to retrievals, but do not give a complete clinical representation of actual in vivo kinematics. Usually restricted to simulating level gait, these tests do not incorporate activities of daily living, such as stair ascent and decent, kneeling, and rising from a chair, which contribute to increased wear and altered wear patterns. Though current studies have attempted to incorporate more rigorous testing, in vivo data have generally not been used as input for tibial insert testing. To begin to address this limitation, we performed tests aimed at characterizing wear patterns of tibial inserts produced by more physiologic in vitro testing, comprised of normal gait and clinically acquired stair climbing kinematics, with the premise that this would produce wear patterns more representative of in vivo kinematics and those observed in retrieved implant components. We used two types of knee implants, which differed in their articular surface designs, to determine the influence of contact geometry on the wear results.

**MATERIALS AND METHODS**

Four NexGen Cruciate Retaining Augmentable (CR) and four NexGen Legacy Posterior Stabilized (LPS) tibial inserts (Zimmer, Warsaw, IN), all of size E and 9 cm thickness, were used. The CR inserts were machined from 1050 compression molded sheet UHMWPE and the LPS inserts were directly molded from 1900 resin. All were gamma irradiated in nitrogen to 25 kGy. Six additional inserts, 3 per design, were kept unloaded in a 37°C deionized water bath as soak controls. All inserts were pre-soaked for 30 days prior to testing. Corresponding NexGen CR and LPS femoral components and metallic tibial trays were used.

Knee simulation was conducted on a 4-station Instron/Stanmore KCI knee simulator with AP springs pre-compressed (no gap, spring constant 14.48N/mm). Two test conditions were run. The first used the ISO Standard for normal gait, providing a baseline for the study. Axial loads were applied from 0 to 40° of flexion, and the max load was 2279N run at a frequency of 1.4Hz. The second incorporated two protocols: the ISO Standard and stair climbing. The stair climbing protocol was acquired from a previous gait study of 22 patients, who had received the Genesis II total knee system (Smith & Nephew, Memphis, TN) and were asked to walk, ascend and descend stairs, and rise from a chair while twisting. While performing these tasks, patients were monitored with a 3D motion analysis system in conjunction with a force plate and fluoroscopy. Nine test subjects (69 yrs, 5 males/4 females, ht = 174 ± 8 cm, wt = 85 ± 10 kg) had stair climbing data available for computations of the inputs (Fig. 1).

Quadriceps forces were calculated using a model described by Smidt, et al. The stair climbing input was incorporated at a ratio of 70:1 to the ISO conditions. The stair climbing input was incorporated at a ratio of 70:1 to the ISO conditions, is essential to preclinical testing of implants. The damage modes of both insert types were burnishing, pitting, and scratching. The wear rates from test condition 2 were 3.9±0.4 mg/Mc and 10.4±2.9 mg/Mc for the CR and LPS inserts, respectively, after 1 Mc of testing. The damage area was 28% for the CR insert and 24% for the LPS. The posts of the LPS inserts showed only slight posterior damage and no medial or lateral damage. Stair climbing resulted in similar AP displacements and greater IE rotations than normal gait: CR: 5.0mm, 9°, LPS: 6.0mm, 8.25° for gait; CR: 4.5mm, 16.25°, LPS: 6.5mm, 19° for stairs.

**RESULTS**

Gravimetric wear measurements were acquired, corrected for moisture absorption, and plotted versus total cycles. Wear rate (mg/Mc) was determined from linear regression, and the wear rates from the two conditions (normal gait) were compared with those from the second (normal gait with incorporated stair climbing cycles).

**DISCUSSION**

An understanding of wear patterns and their causes can be gained by in vitro testing, but only if that testing includes loads and kinematics that simulate in vivo conditions. Our results demonstrate that the addition of bouts of stair climbing kinematics into a simulation of normal gait markedly increased the wear damage area but did not affect the wear rate as compared to when no stair climbing was included in the tests. Stair climbing resulted in a 35% increase in damage area for the CR inserts and 28% increase for the LPS inserts compared to normal gait. The dominant damage mode was burning. By 1 Mc, the damage area of CR inserts increased 72% and PS inserts 53%. Wear and damage modes were not affected, but longer duration tests could show otherwise. In comparing designs, the CR femoral component had flatter condyles and resulted in larger contact areas in the ML direction. The LPS component was slightly more conforming in the AP direction and resulted in larger AP displacements.


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**Figure 1. ISO gait kinematics (black); stair ascent kinematics (gray)**

All inserts were assessed for evidence of wear, the presence of damage modes, and the percent contact surface area that showed wear damage.

**Table 1. Damage Area (mm²)**

<table>
<thead>
<tr>
<th>Test</th>
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<th>PS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mc</td>
<td>635</td>
<td>624</td>
</tr>
<tr>
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<td>891</td>
</tr>
<tr>
<td>1 Mc</td>
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**B. Damage Maps**