A novel method to analyze the mechanics of unloader braces for medial knee osteoarthritis

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Background

Bracing is a treatment option for medial knee osteoarthritis [1] that unloads the medial knee through the application of an external moment (brace moment) [2]. In theory, the brace moment is designed to reduce the total external adduction moment, as disease severity and external adduction moment are correlated [3]. The braces used in this study operate according to the principle of three-point bending [2] (Figure 1). A load is applied to the lateral knee (Figure 1, Fg), and two reaction forces are applied to the thigh and shank (Figure 1, Ft and Fs), generating the brace moment at the knee (Figure 1). According to this loading, brace moment is affected by the magnitude of the lateral load, and the distance from the lateral load to the thigh and shank reaction forces (Figure 1, dr and ds), called the thigh and shank lever arms. The magnitude of the lateral load can be controlled using adjustments, however the brace lever arms are defined by brace fit and design. Previous studies have quantified the brace moment using direct measurements [2] or using approximations [1,4], however no studies have considered the pressure distributions applied by the brace to the user. These are important as they can be used to better estimate the lever arm distances, and quantify the effect of design elements on brace moment. Therefore, the purpose of this study is to provide a novel means of analyzing brace mechanics, specifically by measuring the pressure distributions and lateral force applied at the knee between the brace and the user. Included in this objective is the comparison of two braces, to establish whether the proposed method is suitable to identify differences in the functionality of different brace designs.

Methods

This study consisted of a convenience sample of six healthy participants, one female and five males, with no known lower limb abnormalities, and ages ranging from 19 to 32. Two unloader knee braces were analyzed in this study: the DonJoy OA assist single hinge (H1), and the DonJoy OA adjuster 3 double-hinge (H2) brace ((DJO Global, Vista, California). The experimental setup used pressure mats under the thigh section of the brace, to estimate the thigh lever arm distance, motion capture markers placed on the brace to measure brace deflection, and a load cell placed between the user and brace on the lateral knee. Two 30 second walking trials were performed on an instrumented treadmill for each brace, and the last three strides of each trial were used to calculate the thigh lever arm, the force applied to the lateral knee, braced deflection, the brace moment as well as brace stiffness.

Results and Discussion

All results were relatively constant between the heel strike and toe off; therefore a mean value at mid stance was used to compare brace mechanics using a paired t-test (Table 1). This showed that the force applied to the lateral knee was greater for the dual-hinged brace compared to the single-hinged brace, which resulted in larger applied moments. However, as the dual hinged brace was less stiff, a larger adduction deflection was required to achieve this moment. There were no observed differences in the thigh lever arm between the braces, and these values were smaller than the total length of the thigh section for each brace. The pressure distributions on the lateral side showed a pressure point near the top portion of brace for H1 and H2. On the medial side however, the pressures for the dual-hinged brace were more distributed between the top of the brace and the knee, while a pressure point was observed under the lower strap for the single-hinged brace.

There are substantial differences in brace design that could explain the observed differences in brace mechanics. Specifically, the braces have different mechanisms to increase the force on the lateral knee, variable lateral beam construction, and differences in geometry (H2 being dual-hinged and H1 being single-hinged). The most important difference appears to be the tightening mechanism, which we believe contributed to both the higher lateral load and the lower stiffness for the dual-hinged brace.

Conclusion

This study used pressure distributions and the force applied to the lateral knee to examine the operation of two braces. The results indicate that differences in brace mechanics between designs can be isolated using this method, making it a reasonable non-invasive means of analyzing unloader braces. Further experiments include validation of these differences using a gold standard in brace moment measurement, such as the use of strain gauges embedded in the braces.

Table 1: Mean value, standard deviation and P value for H1 and H2

<table>
<thead>
<tr>
<th></th>
<th>H1</th>
<th>H2</th>
<th>P value</th>
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</thead>
<tbody>
<tr>
<td>Lateral Load (N)</td>
<td>13 (2)</td>
<td>13 (2)</td>
<td>&gt;0.05</td>
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<tr>
<td>Adduction Deflection (deg)</td>
<td>52 (10)</td>
<td>76 (11)</td>
<td>&lt;0.01</td>
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<tr>
<td>Brace Moment (Nm)</td>
<td>6.1 (1-1)</td>
<td>10.0 (2-1)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Brace Stiffness (Nm/deg)</td>
<td>3.8 (0.9)</td>
<td>4.5 (0.8)</td>
<td>0.03</td>
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</tbody>
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References
