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Original research

Immediate effect of valgus bracing on knee joint moments in meniscectomised patients: An exploratory study

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ABSTRACT

Objectives: Patients undergoing medial arthroscopic partial meniscectomy are at increased risk of developing and/or progressing knee osteoarthritis, with increased medial compartment load being a potential contributor. The aim of this study was to evaluate the immediate effect of a valgus unloader knee brace on knee joint moments in patients following medial arthroscopic partial meniscectomy.
Design: Within-participant design.
Methods: Twenty-two patients (age 35–55 years) who had undergone medial arthroscopic partial meniscectomy within the previous 8–15 months completed three-dimensional analysis of gait, forward lunge and one-leg rise during two conditions: with and without a valgus unloader knee brace. Outcome measures included the peak and impulse of the knee adduction moment and the peak knee flexion moment.
Results: The peak knee flexion moment increased during brace condition for forward lunge (mean difference [95% CI]) 0.54 [0.27–0.82] (Nm/(BW × HT)%), $p < 0.001$ and one-leg rise (mean difference 0.45 [95% CI 0.08–0.82] (Nm/(BW × HT)%), $p = 0.022$). No other significant differences were found between conditions in any of the included tasks.
Conclusions: A significant effect of the knee brace was detected in terms of an increase in peak knee flexion moment during the more demanding tasks such as forward lunge and one-leg rise. This increase implies enhanced stability of the knee provided by the brace, which may induce increased knee function and knee-related confidence during strenuous tasks. Future research is required to explore the structural implications.

1. Introduction

Osteoarthritis (OA) in the tibiofemoral and patellofemoral compartment is common in patients following arthroscopic partial meniscectomy (APM).[1] Despite strong evidence questioning the efficacy of APM to manage symptomatic meniscal tears,[2] a large volume of these procedures are performed.[3] Thus, investigation into treatments aiming to prevent or delay the development or progression of early OA in this patient population is warranted.

The external knee adduction moment (KAM) is an indicator of mediolateral knee joint load distribution where the peak KAM has been positively associated with structural joint change in patients following medial APM.[4] Studies from patients with established knee OA also report an association between higher KAM and structural degeneration during gait.[5,6] The KAM is predominantly determined by the product of the ground reaction force (GRF) vector and the perpendicular distance of this force to the centre of the joint (i.e. the frontal plane lever arm).[7] Increased varus malalignment is thought to increase the frontal plane lever arm and consequently increase the KAM.[7] Varus malalignment has been shown to progress over time in patients following medial APM[8] and partially account for the increase in KAM during gait.[9] Thus, varus malalignment is a potential target for treatments to address in patients following medial APM.

Valgus unloader knee braces are a non-surgical treatment strategy for patients with medial compartment knee OA.[10] Theoretically, the brace applies an external valgus moment, which plausibly reduces load in the medial tibiofemoral compartment[10] and retard structural disease progression.[11] According to a recent systematic review, valgus knee bracing can reduce the KAM during walking, with moderate-to-large effects in patients with established medial knee OA.[10] A similar effect of valgus bracing could potentially exist in patients following medial APM, although to our knowledge this has not yet been investigated.

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In addition to the KAM, the external knee flexion moment (KFM) is of interest. Patients following medial APM reportedly have a higher peak KFM[12,13] that appears to increase over time.[13] These results are of potential significance as there is an association between higher peak KFM during gait and patellar cartilage volume loss over 2 years in this population.[4] Although the mechanisms by which a valgus unloader knee brace would alter the KFM are unclear, it is important to evaluate the immediate effects of bracing on the KFM.

Given the association between knee joint moments during gait and structural change, reducing knee joint moments during gait is considered desirable. In addition to gait, we considered more physically demanding tasks appropriate to middle-aged APM patients. The purpose of this study was to test the hypothesis that wearing a valgus unloader knee brace would reduce the peak KAM during gait in middle-aged individuals following APM at high risk of developing or progressing early knee OA. The secondary exploratory aims of this study was to assess the immediate effect of the valgus unloader brace on KAM impulse and the peak KFM during gait, and all three moment parameters (peak KAM, KAM impulse and peak KFM) during a forward lunge and one-leg rise.

2. Methods

Participants aged 35–55 years who had undergone an isolated medial APM were recruited from the existing cohort study "Knee Arthroscopy Cohort Southern Denmark" (KACS).[14] Exclusion criteria were: major cartilage damage defined as deep visible clefts or bone observed at arthroscopy; co-morbidities affecting lower extremity function; current self-reported back problems; very low activity level (i.e. gait function restricted to indoor walking only); unable to read or understand Danish. Assessment was conducted in the Movement Laboratory at the University of Southern Denmark. Ethical approval was granted from the Regional Scientific Ethics Committee of Southern Denmark. All included participants provided written informed consent.

Participants completed the Knee Injury Osteoarthritis Outcome Score (KOOS) prior to testing, to evaluate knee pain and function. The KOOS is a valid and reliable self-reported outcome measure for use in, patients with meniscus injury and cartilage damage.[15] Knee pain (for the study knee) was additionally assessed using Numerical Rating Scale (NRS)[16] immediately before and after testing, to evaluate if pain changed during the testing session. Furthermore, participants registered the comfort of the brace by a NRS while wearing it during the movement tasks (0 indicate "most comfortable" and 10 indicate "least comfortable"). Static frontal plane knee alignment of the study knee was assessed using an inclinometer as participants stood comfortably upright. This method is reliable (ICC = 0.94) and valid compared to mechanical axis from full-length radiographs ($r = 0.80$).[17]

The valgus knee brace tested was the Rebound® Cartilage knee brace (Össur, Reykjavik, Iceland). The brace is a prefabricated based on a 3-point pressure system where a single axis joint on the medial side of the leg connects the thigh and shank segments. Prior to assessment, each participant had the brace fitted on the APM leg by the same physiotherapist (MT). The brace was fitted to each patient by adjusting straps and dials in order to produce a valgus torque without any perceived discomfort. The magnitude of torque applied by the brace was not assessed and unlikely uniform across all participants.

Kinematic data were acquired using a Vicon MX motion analysis system (Vicon, Oxford, UK) consisting of 16 cameras operating at 200 Hz. Kinetic data were captured in synchrony at 3000 Hz using two force plates (Advanced Mechanical Technology, Watertown, MA, USA) embedded in the floor. Similar to previous studies, the University of Western Australia seven-segment model was used.[18] Reflective markers were attached to the 10th thoracic vertebra, 7th cervical vertebra, manubrium and bilaterally to the anterior superior iliac spines, posterior superior iliac spines, lateral epicondyles, lateral malleoli, first and fifth metatarsal head, fifth metatarsal base and calcaneus; 3-marker triads were attached to each thigh and shin. To determine relative positioning of the knee and ankle joint centres, additional markers were placed at the medial femoral condyles and medial malleoli for a single static trial. The brace did not interfere with marker placement. Hip joint centres were estimated based on the Harrington approach.[19] Marker trajectories and GRF were low pass-filtered at 6 Hz. Moments of the lower limb joints were estimated using inverse dynamics BodyBuilder model (Vicon, Oxford, UK).

Following standardised instructions and familiarisation, participant performed three tasks, including: (i) gait, (ii) forward lunge and (iii) one-leg rise under two conditions: with a brace and without a brace on the previously meniscectomised knee. The sequence of tasks and conditions were randomised for each participant and an adaption period of at least 5 min was incorporated between conditions. Participants were instructed to perform all tasks at comfortable, self-selected pace while barefoot.

Participants performed six gait trials for each condition and were asked to adjust their walking speed if the self-selected walking speed was greater than ±5% different between conditions. For the forward lunge, participants were instructed to stand with feet shoulder width apart and leading with the APM leg step forward onto the force plate until the knee reached 90° flexion. Participants were asked to maintain their trunk in an upright position, with hands on their hips and maintain floor contact with contralateral foot throughout the duration of the movement. Participants then returned to the starting position by pushing backwards through extending the knee. The forward lunge distance was standardised between conditions according to leg length. Three forward lunge trials were recorded. For the one-leg rise task, using the APM limb only, participants were instructed to rise from the seat until standing upright and return to the seated position, in a controlled smooth motion. Meanwhile, the non-weight bearing leg was held off the ground by flexing the knee while arms were held across the chest. Seat position was standardised between conditions by marking seat depth and foot placement. Stance phase for the one-leg rise was defined from the period when the GRF reached 100 N to the point when the GRF dropped below 100 N. Three one-leg rise trials were recorded.

The moments of interest in the current study were: (1) peak KAM during the first half of stance as the primary outcome, (2) positive KAM impulse during the stance phase as a secondary outcome, (3) peak KFM throughout stance as a secondary outcome. Moments were averaged across trials and expressed as external moments normalised by the product of body weight (N) times body height (m).

For this exploratory study, an a priori sample size calculation estimated that 20 participants were required to detect a 7% change in peak KAM during gait with 80% statistical power. The estimation was based upon the smallest detectable (SDC) change $SDC/\sqrt{n}$ (using a SDC of 0.80 Nm/(BW × HT)% based on test–retest data from our laboratory and data from a knee OA sample).[20] However, due to equipment failure only 17 participants were available for gait analysis. A subsequent post hoc power analysis confirmed that 17 participants adequately detected a large effect size of 0.8 with 80% statistical power. The difference between conditions was calculated by subtracting the no brace condition-scores from the brace condition-scores. For NRS-pain, the difference was estimated by subtracting the "pre-session" score from the "post-session" score. Student's paired *t*-test (parametric test) and Wilcoxon signed rank test (non-parametric test) were used to compare biomechanical variables of interest between conditions, in addition to NRS-pain