Knee Bracing May Restore Joint Stability in Response to a Valgus Torque in Medial Collateral Ligament Deficient Knees

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INTRODUCTION: The medial collateral ligament (MCL) is the most injured structure in the knee during sports such as American football and is generally treated nonoperatively with knee bracing [1-4]. Knee braces are hypothesized to protect the joint from further injury by compensating for decreased joint stability that occurs with MCL injury [5, 6]. Thus, the objective of the current study was to quantify the effects of knee bracing on valgus stiffness and rotatory joint laxity (i.e., amount of valgus rotation until load-displacement curve enters linear region) of the knee complex in response to a valgus torque in MCL deficient (MCLD) cadaveric knees. It was hypothesized that: 1) valgus stiffness will decrease, and rotatory joint laxity will increase in the MCLD knee compared to the Native knee and 2) knee bracing in the MCLD knee will restore valgus stiffness and rotatory joint laxity to magnitudes not significantly different from the Native knee.

METHODS: Seven fresh-frozen cadaveric knees (age range 37-77 years, all males due to specimen availability) were utilized for the current study. The femur and tibia were potted in an epoxy compound (Bondo; 3M, St Paul, MN) and secured within custom-made aluminum clamps for attachment to a 6 degree-of-freedom robotic testing system (MJT model FRS2010). The clamps were modified to allow brace attachment (DonJoy Playmaker II) and motion in the proximal-distal direction (with respect to the clamps, via linear rails and ball bearing carts). Thus, the attachment simulates real-world brace motion and will be referred to as a "realistic brace". The passive path of the knee was determined from full-extension to 90° of flexion and a 10Nm valgus torque was then applied three times and in four joint positions: 1) full-extension, 2) 30°, 3) 60° and 4) 90° of flexion. Six degree-of-freedom kinematics were quantified using the Grood and Suntay approach [7] and the procedure was performed in three knee states: 1) Native, 2) MCLD (complete transection of deep and superficial layers), and 3) MCLD Realistic Brace. For each joint position, the third loading cycle was isolated and utilized to quantify stiffness and rotatory joint laxity using the respective load-displacement curve. The stiffness of the complex was quantified as the slope of the linear region of the load-displacement curve (points removed until linear fit reached a r^2 value ≥0.99) [8,9]. Rotatory joint laxity was quantified as the amount of valgus rotation from the respective passive path position to the transition point (i.e., point load-displacement curve enters the linear region). Outcome parameters included the stiffness and rotatory joint laxity of the knee complex at each flexion angle in response to a 10 Nm valgus torque. Two-way repeated measure ANOVAs were utilized to determine the effect of knee state on the outcome parameters. If significant, Dunnett's post-hoc tests were utilized to compare each knee state with respect to the Native state. Significance was set at $p<0.05$.

RESULTS: Significant decreases in valgus stiffness were observed between the Native and MCLD state at full-extension, 60°, and 90° of flexion ($p<0.05$, Figure 1). Valgus stiffness decreased by 33.3%, 35.4%, and 37.9% at full-extension, 60°, and 90° of flexion in the MCLD state compared to the Native state, respectively. No differences were observed at any flexion angle between the Native and MCLD Realistic Brace states ($p>0.05$). Interestingly, the variability (standard deviation) in stiffness was less in the MCLD state compared to the MCLD Realistic Brace state from full-extension to 60° of flexion (full-extension 0.7 vs. 1.2Nm/deg, 30° 0.2 vs. 1.2 Nm/deg, 60° 0.5 vs. 1.5 Nm/deg). Significant increases in rotatory joint laxity were observed in the MCLD state compared to the Native state at 30° and 60° of flexion ($p<0.05$). Specifically, the MCLD state underwent 147.7% and 172.9% more valgus rotation compared to the Native state before entering the linear region of the load-displacement curve.

DISCUSSION: The major findings of the current study were: 1) valgus stiffness decreased in the MCLD state compared to the Native state, but no differences were observed between the Native and MCLD Realistic Brace states and 2) the MCLD state exhibited more rotatory joint laxity compared to the Native state, but no differences in rotatory joint laxity were observed between the Native state and MCLD Realistic Brace states. Thus, the proposed hypotheses were accepted. The implications of the findings are that complete injury to the MCL significantly increases instability of the knee complex in response to a valgus torque. Stability of the knee complex was restored to magnitudes not significantly different from the uninjured knee with realistic knee bracing, however variable changes were observed which may be due to factors such as bony morphology. Physiological levels of valgus loading during a sidestep run-to-cut maneuver were shown to be 8Nm in individuals with neutral valgus alignment of the tibiofemoral joint [10]. Thus, the external loading condition in the current study should be sufficiently larger than what is experienced during rehabilitation. Therefore, in athletes with MCL injuries, knee bracing may restore joint stability during rehabilitation activities. Future work will investigate the effects of bracing on tibiofemoral joint stability in female cadaveric knees to understand potential sex-based differences.

SIGNIFICANCE/CLINICAL RELEVANCE: In athletes with MCL injuries, knee bracing may be warranted during rehabilitation to restore valgus joint stability.

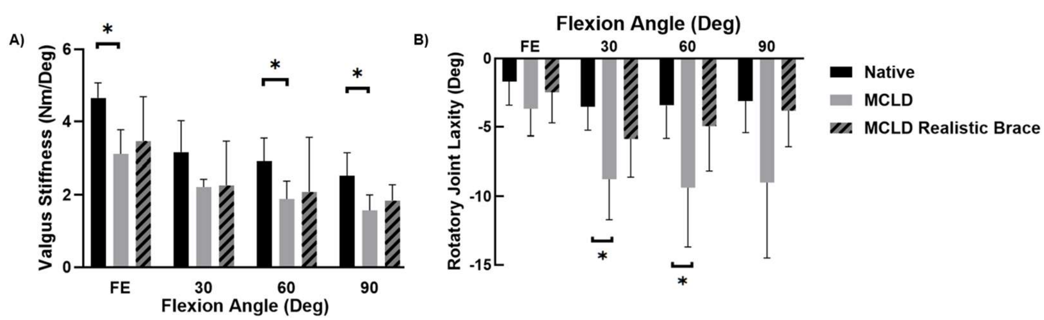

Figure 1: A) Valgus stiffness and B) rotatory joint laxity of the knee complex in response to a 10Nm valgus torque (mean ± standard deviation, * indicates significance at $p<0.05$).

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