ISAKOS

International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine

9th Biennial ISAKOS Congress • May 12-16, 2013 • Toronto, Canada

Paper #50

In Vivo Kinematics of the Ankle During Gait Following Reconstruction for Chronic Ankle Instability

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Summary:
The purpose of this study was to determine the effectiveness of Brostrom-Gould (B-G) ligament reconstruction for restoring normal joint stability. 8 patients with unilateral chronic ankle instability who underwent a B-G procedure were examined using dynamic stereo x-ray imaging technique. Data acquired in 100Hz during level surface gait. Result supported the effectiveness of the Brostrom-Gould pro

Abstract:

INTRODUCTION

Lateral ankle ligament sprains are the most common ligamentous injury in sports. Chronic ankle ligament instability (CAI) occurs in up to 20% of all ankle sprains and may lead to degenerative joint disease. Surgical procedures such as the Brostrom-Gould (B-G) procedure or ligament reconstruction using grafts should be considered when conservative treatment fails to prevent instability episodes. These popular reconstructions have been shown to incompletely restore hindfoot biomechanics in vitro [1], but there are relatively little data examining the effect of surgery on the in vivo biomechanics. Numerous studies reported the kinematics of the ankle joint using skin markers to detect the movement of the bones that make up the ankle joint complex, but the relative motion between the skin and underlying bones, as well as the absence of external landmarks of the talus makes it difficult to assess the kinematics accurately. Dynamic stereo x-ray imaging provides direct, in vivo, dynamic tracking of multiple bones with sufficient sensitivity to detect the effect of the ligament reconstruction [2].

The purpose of this study was to determine the effectiveness of B-G procedure for restoring normal joint stability in subjects with chronic instability.

We hypothesized that the B-G procedure would restore hindfoot kinematics to match those of the contralateral, uninjured ankle (which will serve as a surrogate for the pre-injury state).

METHODS

Eight patients (23.3± 7.1years old ; 1 man, 7 women) with unilateral chronic ankle instability who underwent a B-G ligament reconstruction at least 3 months beforehand were recruited into this IRB-approved study. CAI was defined as a history of inversion injury and failure of physical therapy and bracing for more than 6 months. Anterior talofibular ligament and/or calcaneofibular ligament deficiency were identified through magnetic resonance imaging before surgery. Gait analysis was performed at least 3 months post-surgery. Subjects were excluded if they had symptoms of degenerative changes on X-ray or any other pathological history of lower extremity.

Biplane radiographic images of the ankle were obtained at 100Hz while the subjects walked on a level surface at a self-selected speed (Fig 1a). A model-based tracking technique was used to align 3D CT bone models to the radiographic image pairs, providing 6-DOF ankle kinematics. To match with the anatomical shape and main functional motion in ankle joint, we found the best match cylinder for every subject and defined the sagittal plane and the kinematic origin on talus (Fig 1b). Synchronized ground reaction force was collected via force plates (Bertec Corp. OH), together with optical motion measurement system (Vicon Corp. MX). These data served to determine the timing of heel contact (HC), foot flat (FF), heel rise (HR), and toe off (TO) of the stance phase of gait cycle (while the

studied foot is under loaded condition). Three trials were performed for each leg/foot for each subject and the averages of collected data were used for comparison of three-dimensional kinematics between their reconstructed (Affected) and contralateral, uninjured (Control) ankles. The maximum angle and distance of talus motion (as well as their timing in stance phase) were analyzed in Dorsal/Planter (D/P) Flexion, Internal/External (I/E) rotation, Abduction/Adduction (AB/AD) and Anterior/Posterior (A/P) translation with respective to the tibia. Paired t-test was used to compare the difference between the control and affected ankle.

RESULTS

The ranges of motion for the control and affected sides were 6.9±3.2°/ 7.5±3.2°(Control/Affected) of flexion, 4.8±1.1°/ 4.7±1.1°of rotation, and 2.4±1.0°/ 2.7±0.9°of AB/Adduction, and the talus translated 1.0±0.7mm / 0.7±0.2mm along with A/P direction (Figure2).

During the stance phase of the gait cycle, from HC (0%) to TO (100%), FF was observed at 21.9±5.1% / 22.5 ±6.3% and HO was observed at 48.3±12.7% / 47.6±16.8% on the control/affected sides.

A consistent pattern of D/P movement was found in sagittal plane. During the HS to FF phase, the talus initially planterflexed, then switched to flex dorsally (Fig3). Peak rotation was 5.3°/ 6.9°in planter flexion and 1.6° /1.6° in dorsal flexion. From HS to TO, internal rotation increased by 4.1±1.0°/ 4.0±1.9°. During stance phase, there was little AB/Adduction motion, ranging to 4.2 degrees. There was also very little A/P translation, averaging 0.7±0.7mm / 0.4±0.2mm for the control/affected sides.

No significant differences were identified for any of the measurement variables between control and affected ankles.

DISCUSSION

As hypothesized, there were no significant differences in pattern or range of motion in any plane of tibio-talar movement between reconstructed and contralateral, uninjured ankles. Kinematic patterns of sagittal-plane tibio-talar joint motion during stance phase were similar to those previously reported using skin marker motion tracking [3].

Another significant finding of this study was that the maximum values of the various measurement variables occurred at different times during the gait cycle (Fig 3). Thus, studies of serial, static positions may be inappropriate for evaluating ankle kinematics during gait [4].

There are several limitation in this study. First, walking speed was not strictly controlled. The walking speed may influence the kinematics of the ankle joint, but affects on the results should be small since the analysis focused on side-to-side differences within subjects. Second, there is a possibility that the tested activity was not demanding enough to detect instability on the ankle joint. Further study will required under the high-demand activity such as pivot movement or jump landing. Finally, the sample size may have been too small to detect some differences.

In conclusion, the current study found the Brostrom-Gould procedure re-establishes the ankle stability of the patient with chronic ankle instability.

Significance

This is the first study to evaluate the detailed dynamic kinematics of the ankle joint during the stance phase of the human gait, and revealed the effectiveness of the Brostrom-Gould procedure applied on chronic ankle instability cases.

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