AMERICAN ORTHOPAEDIC FOOT & ANKLE SOCIETY.

Foot & Ankle International
34(4) 587–592

DOI: 10.1177/1071100713477622
fai.sagepub.com

Biomechanical Analysis of Brostrom Versus Brostrom-Gould Lateral Ankle Instability Repairs

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Abstract

Background: The traditional Brostrom repair and the modified Brostrom-Gould repair are 2 historically reliable procedures used to address lateral ankle instability. The purpose of this study was to evaluate the biomechanical stability conferred by the Brostrom repair as compared to the Brostrom-Gould modification in an unstable cadaveric ankle model.
Methods: A total of 10 cadaveric specimens were placed in a Telos ankle stress apparatus in an anterior-posterior position and then in a lateral position, while a 170 N load was applied to simulate anterior drawer (AD) and talar tilt (TT) tests, respectively. In both circumstances, the ankle was held in 15 degrees of plantarflexion, neutral, and 15 degrees of dorsiflexion, while the movement of the sensors was measured using a video motion analysis system. Measurement of the translation between the talus and tibia in the AD test and the angle between the tibia and talus in the TT test were calculated for specimens in the (1) intact, (2) sectioned (division of the ATFL and CFL), (3) Brostrom repair and (4) Gould modification states.
Results: When compared to both the repaired states and the intact states, the sectioned state demonstrated increased inversion and translation at all ankle positions during TT and AD testing. Furthermore, no significant differences were found between the intact state and either of the repaired states. Finally, no difference in the biomechanical stability could be identified between the traditional Brostrom repair and the modified Brostrom-Gould procedure.
Conclusions: Our findings indicate that there is no significant biomechanical difference in initial ankle stability conferred by augmenting the traditional Brostrom repair with the Gould modification in this time-zero cadaveric model.
Clinical Relevance: These data suggest that the additional reinforcement of an ankle's lateral ligament complex repair of the ankle with the inferior extensor retinaculum may be marginal at the time of surgery.

Keywords: Brostrom, Brostrom-Gould, ankle sprain, ankle instability

In the United States, ankle sprains are the most common lower extremity injury presenting to an emergency department, as well as the most common athletic injury brought to the attention of the orthopedic surgeon.[7,9,12,15,22,27] Half of all ankle sprains are the result of injury suffered during sports participation.[30] The majority of these injuries involve the lateral ligament complex of the ankle. The lateral ligament complex of the ankle consists of the anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL), and posterior talofibular ligament (PTFL). The ATFL is the most common ligament to be disrupted. Combination disruption of the ATFL and CFL represents the second most common injury pattern.[8] Numerous biomechanical studies have demonstrated the contributions of these ligaments to lateral ankle stability.[21]

Although 80% to 90% of these injuries respond successfully to nonoperative management including short-term immobilization, progressive weight bearing, and physical therapy, the remaining cohort of patients may develop chronic symptoms leading to mechanical instability.[20] For those patients who fail nonoperative management, a multitude of operative procedures and modifications have been described.[4-6,10,13,29] The majority of these procedures can be classified as either anatomic repairs, anatomic reconstructions, or nonanatomic reconstructions.

To date, the Brostrom procedure with the Gould modification remains the favored procedure to address instability. It is a historically reliable anatomic repair of the lateral ligament

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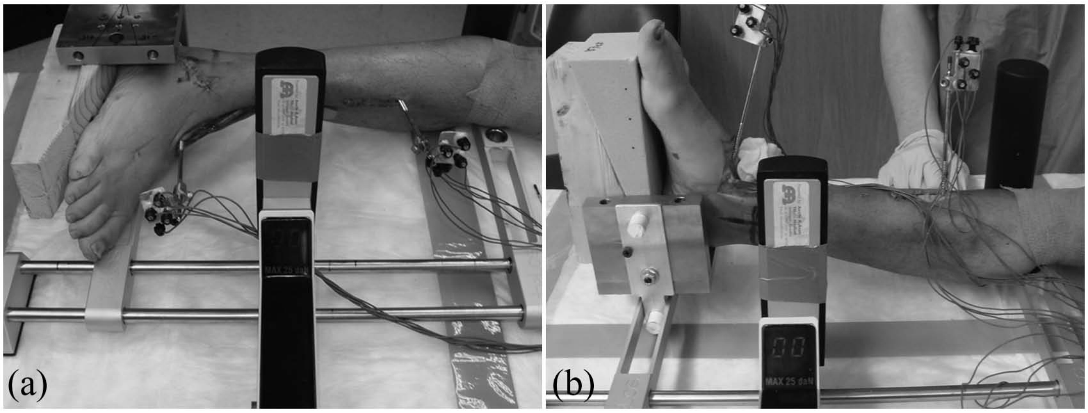

Figure 1. Ankle testing with Telos Stress Device and measurement with Optotrak position sensor of (a) anterior drawer and (b) talar tilt.

complex, which purports to have the advantage of restoration of normal anatomy and maintenance of ankle and subtalar motion over nonanatomic reconstruction.[9] The Brostrom procedure involves repair of the ruptured ATFL and CFL, whereas the Gould modification augments the repair with the inferior extensor retinaculum.[5,13] Published studies indicate success rates exceeding 90% and routine resumption of high-level sports in athletic populations.[3] Some authors have questioned the efficacy of this procedure in specific population groups, especially those with generalized ligamentous laxity or poor quality tissue who are considered less than ideal candidates for this procedure.[8] In practice, the Brostrom repair is effectively an imbrication of the lateral ligamentous and capsular tissues. Certainly, if there is severe attenuation or poor integrity of the tissue, one might reasonably surmise that simple imbrication may be insufficient to effectively stabilize the ankle. The Gould modification, however, seems to be frequently used to reinforce this tissue regardless of its overall capacity for repair. This retinacular tissue, though, is often thinner and more fragile than the lateral ligamentous structures themselves, an observation that has prompted us to delve further into the rationale behind this relative standard.

The purpose of this study was to quantify the additional stability offered by combining the Gould modification with the Brostrom procedure, using a standard clinical assessment method. We hypothesized that the extensor retinaculum used in the Gould modification would provide little additional stability to the Brostrom procedure.

Materials and Methods

A total of 10 lower extremity cadaver specimens (from the proximal tibia to the toes) were obtained from 10 cadavers (mean 40 ± 12 years). These samples were screened for gross anatomical defects and preexisting ankle laxity, and placed in a freezer at -20°C until 24 hours prior to testing.

A 5-mm Steinman pin was inserted into both the tibia and the talus in each specimen. Six infrared sensors were rigidly affixed to each of the wires to establish relative planes of movement using an Optotrak 3020 Computer Navigation System (NDI, Waterloo, Canada). The pins were oriented to avoid impingement on any adjacent anatomic structure. The tibial pin was inserted bicortically in an anterior to posterior direction and the talar pin inserted unicortically in an oblique direction along the longitudinal plane of the talar neck. To measure anterior drawer (AD) translation and talar tilt (TT) angle, specimens were placed in a Telos ankle stress apparatus (Telos, Hungen, Germany) in 3 different orientations: neutral, 15 degrees of plantarflexion, and 15 degrees of dorsiflexion. Measurements were recorded in the unloaded state, and then repeated after a 170 N load was applied, to simulate the AD and TT tests used clinically and as previously described by Langer et al (Figure 1).[16,23,26] The difference in translation between the talus and tibia in the loaded AD test as well as the angle between the tibia and talus in the loaded TT test were calculated. The location of each sensor in 3-dimensional space was tracked using the Optotrak camera system and First Principles software (NDI, Waterloo, Canada) in both the unloaded and loaded conditions, for both the AD and TT test.

Samples were initially tested in the intact state for both AD and TT. Then, a lateral incision was made along the fibula and the ATFL and CFL origins were identified. Both were sectioned along their origins on the fibula to simulate an unstable ankle, and the measurements were repeated. Following completion of this testing, the sectioned ligaments were repaired using 2 double-loaded size 3.5 mm diameter corkscrew suture anchors (Arthrex, Inc, Naples, FL) using the standard Brostrom open repair. Anchors were placed at the anatomic origins of both the ATFL and the CFL. The sutures were tied in a mattress, pants-over-vest type fashion with the ankle reduced via routine posterior

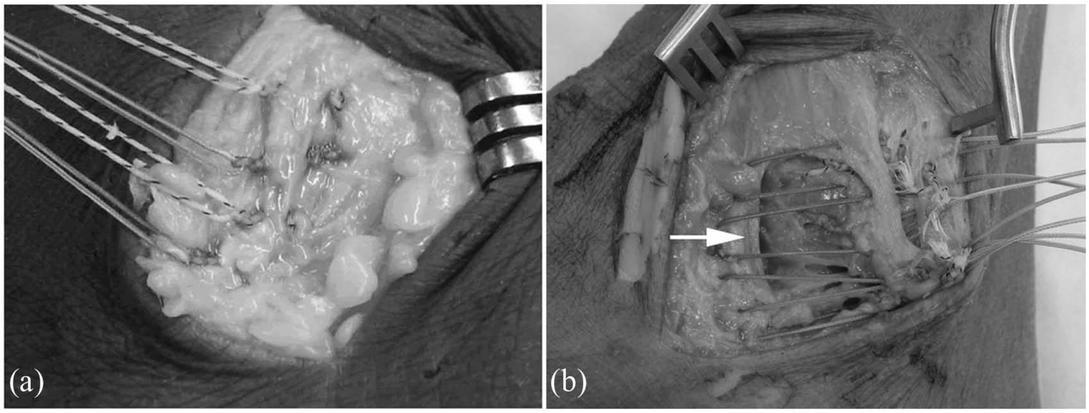

Figure 2. Cadaveric specimen following (a) Brostrom procedure and (b) Gould modification prior to tightening of extensor retinaculum sutures; white arrow: extensor retinaculum.

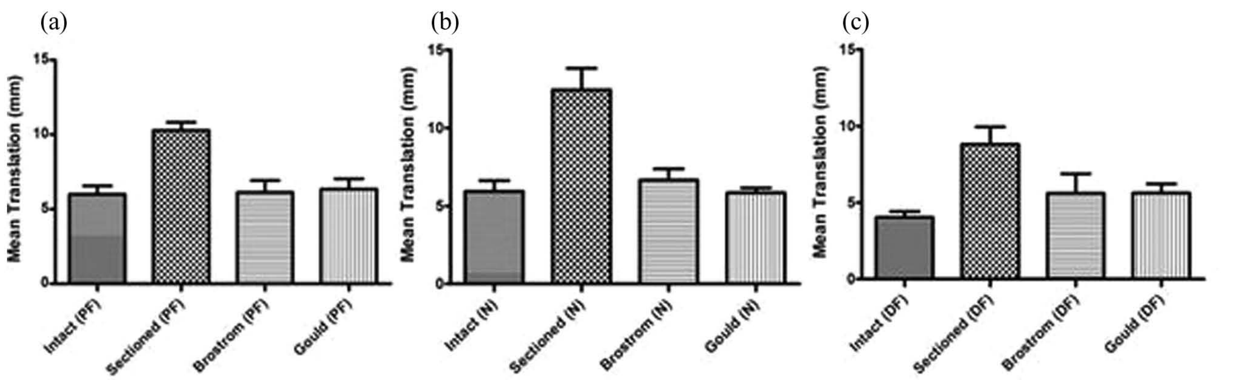

Figure 3. Magnitude of translation from anterior drawer testing in (a) plantarflexion, (b) neutral and (c) dorsiflexion.

translation and eversion (Figure 2a). Sutures were tied sequentially from inferior to superior. All ankles were then loaded and tested according to the aforementioned protocol. Following the Brostrom repair, the Gould modification was performed (Figure 2b) via oversewing the extensor retinaculum using 4 No. 2 Arthrex Fiberwire sutures to augment the repair. This was again performed in a mattress pants over vest type fashion. The specimens were then reloaded, and displacements and rotations were again recorded.

A 2-way repeated measures analysis of variance was used to determine statistical significance between treatment groups and ankle position. In all cases, statistical significance was set to $P \leq .05$ a priori.

Results

In all ankle positions during AD testing, the sectioned (injured) magnitude of translation was significantly higher when compared to the intact or either of the repaired states ($P < .014$). In no instance was there a significant difference in translation magnitude between the intact, Brostrom, or Gould treatment groups. The study was powered at $1\text{-}\beta = 1.0$ to detect differences between treatment groups and $1\text{-}\beta = 0.431$ to detect differences between foot position orientations. The study was underpowered to determine statistical differences between treatment groups at each foot position. Figure 3 reports the mean translation magnitude for the AD tests between treatment groups. No significant differences existed between treatment groups for translations in both the medial-lateral and superior-inferior directions. For anterior translation, the sectioned samples exhibited significantly more translation compared to the intact, Brostrom, and Gould treatment groups in plantarflexion and neutral ankle flexion ($P < .001$). In dorsiflexion, although the sectioned samples exhibited greater anterior translation than the intact group ($P < .001$), this difference with the Brostrom ($P = .062$) and Gould ($P = .079$) groups approached but did

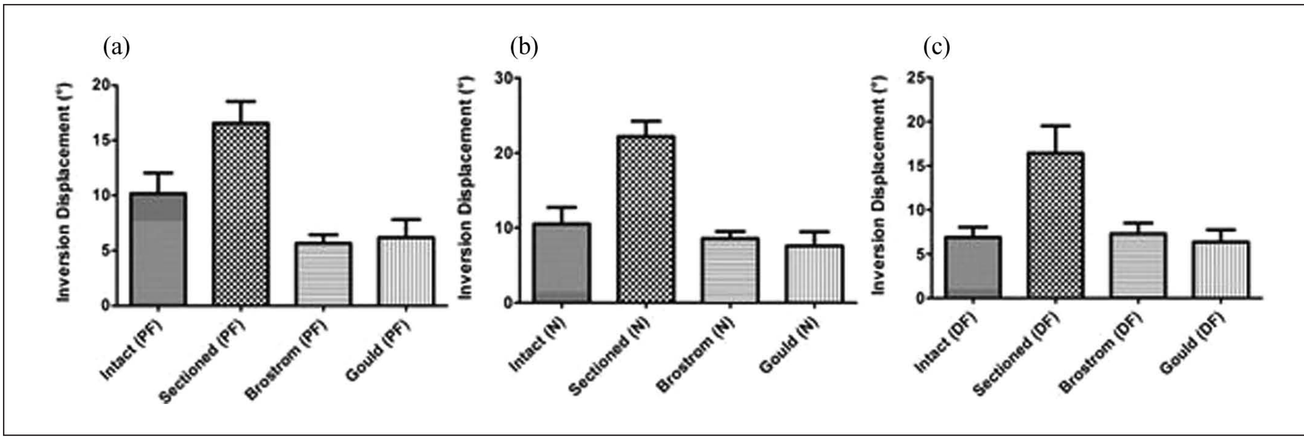

Figure 4. Rotation after talar tilt testing in (a) plantarflexion, (b) neutral and (c) dorsiflexion.

not achieve statistical significance. There was no statistically significant difference in anterior translation during AD testing among the intact, Brostrom, and Gould groups at any ankle position.

In all treatment conditions during TT testing, the sectioned (injured) inversion rotation was significantly higher than the intact or repaired states ($P < .001$). There was no significant difference in inversion rotation between the intact and either of the repaired states. In addition, there was no significant difference in inversion rotation at any ankle position between the Brostrom and Gould groups ($P > .950$). The study was powered at $1\text{-}\beta = 1.0$ to detect differences between treatment groups, $1\text{-}\beta = 0.8$ to detect differences between foot position orientations, and $1\text{-}\beta = 0.7$ to determine differences between treatment groups at each foot position. Figure 4 summarizes the results of the TT testing.

Discussion

The results of our study demonstrated that both the Brostrom procedure alone as well as the Brostrom-Gould modification effectively restored stability to the mechanically unstable ankle in a cadaveric model. These data also suggest that reinforcement of the lateral ligament complex of the ankle with the inferior extensor retinaculum does not confer a significant degree of additional stability. The results of this study support the notion that the additional initial reinforcement provided by the inferior extensor retinaculum may be only marginal. Such observations are corroborated not only by the often good quality collateral ligament tissue found during surgery but also by the often fragile and delicate nature of the extensor retinaculum tissue observed during these procedures.

A prior study by Lee et al tested the additional stability conferred by reconstruction of the CFL in addition to the ATFL in the Gould modification with a 150 N AD force and with a 150 N varus force applied, and found initial stability in both the single ligament (ATFL) and double ligament (ATFL + CFL) groups to be equivalent.[24] A number of other previous investigations have also evaluated the biomechanical properties of these lateral ankle complex repairs and reconstructions. Bahr et al demonstrated that under increasing anterior translation forces up to 50 N, and increasing supination torque up to 3.4N-m, the modified Brostrom procedure produced ligament force patterns that more closely resembled the normal ankle than the Watson-Jones procedure.[2] Fujii et al found that under a constant 1.7 N-m torque in inversion and internal rotation, the Evans procedure produced abnormal subtalar function; however, the modified Brostrom procedure improved stability without restricting subtalar motion.[11] Liu et al evaluated cadaveric ankles that had undergone the modified Brostrom, Watson-Jones, and Chrisman-Snook procedures using varus and AD forces of 60, 120, and 160 N. The results of this study indicated that, although each procedure conferred stability when compared with the incised ATFL/CFL group, the modified Brostrom procedure produced the most restraint with regard to TT and AD stress.[25] A recent study by Prisk et al used 4.5 Nm of inversion with a 200-N axial compressive load, and demonstrated increased restriction of hindfoot inversion with the Brostrom-Gould repair as compared to both their intact and Brostrom repair states.[28] Despite similarities to our study, it should be noted that this investigation utilized a different loading protocol, and sought to define hindfoot kinematics as opposed to the tibiotalar relationship that was studied here. Similarly, Aydogan et al reported increased inversion stiffness between 5 and 25 degrees in repairs with the Gould modification.[1] This experiment quantified stiffness of the entire ankle joint via a rotary transducer on the actuator of the test frame. Prior to performing the experimental measurements, viscoelastic effects were stabilized by applying 10 preconditioned loads. Torque and rotation values were extracted from the torque rotation curve from a single dynamic test of each condition, culminating in failure of the repairs. These techniques differed from our experiment of isolating tibiotalar motion by using an accepted clinical diagnostic method, rather than using increasing inversion loading to failure, and thus are not directly comparable.

Recent literature suggests that current methodology for stability measurement calculation greatly exceeds the clinical practice of plane film measurement.[16] Thus, the investigators determined that this methodology was preferable to quasi-static loading to failure as this method is an accurate, repeatable, and clinically relevant technique for measuring tibiotalar stability.

The clinical success of both the Brostrom procedure and the Gould modification is well documented in the literature. In a series with 26-year follow-up, Bell et al demonstrated a greater than 90% good or excellent result in patients undergoing the Brostrom procedure.[3] In Brostrom's own series, 58 of 60 patients either had considerable improvement or were asymptomatic after their operations.[5] Hamilton et al reported a cohort of 28 patients who underwent the Gould modification of the Brostrom procedure, of whom 26 had excellent results at average 5-year followup.[14] In a prospective study comparing the Gould modification with an anatomic reconstruction described by Karlsson et al,[17,18] 83% of patients undergoing the Gould modification were found to have good or excellent results at 2 years.[19]

Our study suggests that there is no increase in stability between the Brostrom and Brostrom-Gould procedures when subject to TT or AD biomechanical testing. The improved clinical results with the Gould modification may simply be the result of the added suture used to repair the extra tissue, and the structural function of the extensor retinaculum in the native ankle is debatable. We found decreased inversion during the TT test in a plantarflexed foot after the Brostrom ($P = .074$) and the Brostrom-Gould ($P = .138$) procedures when compared to the intact ankles (Figure 4a). These results suggest that foot orientation when tying the suture greatly affects the repair construct. We postulate that the anchors were tied with the foot in slight eversion, which would place added tension on the ATFL construct. This would be most evident (reduced inversion motion when compared to intact) when the ankle was oriented in plantarflexion and inversion. Caution with regard to foot orientation when tightening sutures anchors may reduce the opportunity of over tensioning the ATFL construct.

Our data should not dissuade the addition of the Gould modification to stabilization surgery, and perhaps it is of greater use for subtalar joint pathology. This information does suggest, however, that the addition of this modification may add only marginal tissue strength, and biomechanical stability to the repair of the lateral tibiotalar joint ligaments. Moreover, if the quality of the lateral ligamentous tissue is exceptionally poor or part of a systemic elasticity that might also affect the extensor retinaculum, we believe one should not expect the retinaculum to compensate. In this case, consideration should be given to reconstruction with graft instead.

As with most cadaveric biomechanical studies, there are inherent limitations to this investigation. First, our findings are based strictly on a stress application method that is used clinically for diagnosing and assessing laxity, and mechanical challenges may not correlate with those that the repaired ligaments may be subjected to in the postoperative patient. The loads used in our study may not be large enough to distinguish performance differences between the 2 experimental groups. Second, our study addresses only the initial stability produced by the 2 repairs and does not account for any tissue healing that may play a more important role in the long-term success of the procedures. Furthermore, our instability model was based on sectioning of the lateral ligamentous structures, whereas in vivo instability is usually the result of attenuation of these structures, since gross detachments are uncommon. We also did not test the specimens to failure in this experiment to enable measuring of repair integrity under incrementally increasing loads. The study was underpowered with regard to detecting statistically significant differences in the AD test at the 3 different ankle orientations. For the TT test, a power value of 0.7 was slightly underpowered, yet the differences between the Brostrom and Gould groups in all ankle orientation were nominal ($P > .95$ in all cases). Thus, it would be reasonable to assume equivalence with regard to the Brostrom and Gould modification with respect to TT laxity. It is conceivable that a significant difference could have been achieved in this group with a greater number of specimens.

Conclusion

This biomechanical investigation compared the initial stability conferred to the unstable ankle by the Brostrom procedure versus the Brostrom-Gould modification, using a standard clinical assessment method. Both interventions restored stability, but significant differences between them were not observed with regard to TT or anterior displacement of the talus. These results suggest that the additional reinforcement of the repair of the lateral ligament complex of the ankle with the inferior extensor retinaculum may be marginal.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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