The Metatarsophalangeal Joint Saline Load Test: An Accurate, Cost-effective Method for Evaluating Plantar Plate Integrity

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The Metatarsophalangeal Joint Saline Load Test: An Accurate, Cost-effective Method for Evaluating Plantar Plate Integrity

Presenter: Rufus Van Dyke MD

My disclosure in the Final AOFAS Mobile App. I have no potential conflicts with this presentation.
Introduction

- Plantar plate injuries are a common source of forefoot pain and diagnosing such injuries can be challenging. Several studies have looked at various diagnostic modalities, including arthrography, MRI, and ultrasound. These modalities have had varying degrees of success in diagnosis but also have deficiencies, most notably the latter two lacking specificity.

- Our study confirms previous studies in establishing a normal range of volume when giving an intra-articular injection into the MTP joint with an intact plantar plate.

- Secondly, we propose an MTP joint saline load test to determine the integrity of the plantar plate and validate it with a blinded randomized controlled trial.
Methods: Phase 1 Measuring MTP Joint Volume

• 9 pairs of fresh frozen cadaver feet without scars were obtained. The feet were dissected from the dorsal side and the MTP joints of the 2\textsuperscript{nd}, 3\textsuperscript{rd}, and 4\textsuperscript{th} toes exposed so that the joint capsule could be visualized.

• A solution of saline and blue food coloring was prepared and drawn up into a 3 mL syringe with 22-gauge needle.

• Each MTP joint was slowly injected with the blue solution under direct visualization just medial to the extensor tendon until ample resistance was met. Upon ample resistance, tension was removed from the plunger and it was allowed to drift in until the plunger rested in a tension free position. This volume was recorded as the volume of the MTP joint.

• Each of the toes was then dissected from a plantar approach to directly visualize the plantar plate and evaluate for any fluid extravasation from the joint indicating a possible plantar plate injury.
Methods: Phase 2 Blinded Randomized Saline Load Test

- 9 pairs of fresh frozen cadaver feet without surgical scars were obtained. Ultrasound was used to evaluate the plantar plates of the 2\textsuperscript{nd} and 3\textsuperscript{rd} MTP joints of each foot. Plantar plates were classified as either intact, partially torn, or completely torn. Complete and partially torn plantar plates were excluded.

- 16 plantar plates were diagnosed as intact with ultrasound and, using a random number generator, were randomized to receive an arthrotomy or sham plantar foot surgery.

- Each foot underwent a dorsal approach to the MTP joint of the 2\textsuperscript{nd} and 3\textsuperscript{rd} toes so that the joint capsule could be visualized. A plantar dissection was then performed to visualize the plantar plate on each toe.

- Using the plantar dissection, a scalpel was used to create an arthrotomy. The arthrotomy was created in a transverse orientation through the central portion of the designated plantar plates just proximal to its insertion on the proximal phalanx. The arthrotomy size was chosen to be 2.5 mm in length to mimic a grade 1 tear. No arthrotomy was performed in the sham group. The soft tissue and skin on the plantar aspect of both groups was closed in an identical fashion.

- A blinded physician had the Saline Load Test explained to them (see right margin). They then performed the test, injecting blue colored saline into each MTP joint through the dorsal approach under direct visualization. Their assessment of whether the plantar plate was intact or completely torn was recorded.

The Saline Load Test

1. Obtain a 3 mL syringe with a 22 gauge needle and fill it with saline to the 3 mL graduation.
2. Palpate the MTP joint and slightly plantar flex the toe.
3. Introduce the needle into the MTP joint from the dorsal side.
4. Slowly inject the saline intra-articularly until a dramatic increase in resistance gives the sensation of an endpoint.
5. Finally, cease applying any pressure to the plunger and allow it freely settle in a tension-free position.
6. Calculate the injected volume from the final position of the plunger and compare that volume with the experimentally determined standard volume for the given joint. If the injected volume is greater than 2 standard deviations above the standard volume, consider the test positive.*
7. If the entire syringe is injected into the joint without detecting an endpoint, this is a positive SLT and indicates there is a complete tear in the plantar plate.

*For extremely large feet, consider a volume within 3 standard deviations a negative result.
Pilot Study Results

- A firm tactile endpoint was obtained during injection in 57% of the MTP joints.

- Volume determination was unobtainable when the following adverse situations were present:
  - If the introduction of the needle into the capsule was at an angle that was “too oblique,” small tears formed at the entry site, allowing dyed saline to reflux back out of the joint around the needle before a tactile endpoint was sensed.
  - MTP joints requiring multiple attempts at injection experienced reflux through previous needles holes.

- Toes with no endpoint in the pilot study were not formally characterized to differentiate between technical error and plantar plate injury, but some of the plantar dissections showed dyed saline tracking proximally inside the flexor sheath.

<table>
<thead>
<tr>
<th>Standardized Volumes via Saline Injection</th>
<th>2nd toe</th>
<th>3rd toe</th>
<th>4th toe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of toes tested</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Percentage of toes that provided readings</td>
<td>72.2</td>
<td>55.6</td>
<td>50.0</td>
</tr>
<tr>
<td>Mean volume (mL)</td>
<td>1.07 +/- 0.53</td>
<td>0.87 +/- 0.32</td>
<td>0.63 +/- 0.30</td>
</tr>
<tr>
<td>Range in volumes (mL)</td>
<td>0.6 - 2.5</td>
<td>0.7 - 1.7</td>
<td>0.2 - 1.3</td>
</tr>
</tbody>
</table>
Blinded Randomized Controlled Trial Results

- 12 of the 16 samples in the blinded trial were diagnosed correctly with the Saline Load Test
- 2 that were arthrotomized were incorrectly diagnosed as intact
- 1 that was intact was erroneously diagnosed as torn
- 1 test was found to be inconclusive

<table>
<thead>
<tr>
<th>Blinded RCT - 16 total samples</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct</td>
<td>12</td>
</tr>
<tr>
<td>Incorrect</td>
<td>3</td>
</tr>
<tr>
<td>Inconclusive</td>
<td>1</td>
</tr>
<tr>
<td>Accuracy</td>
<td>75%</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>75%</td>
</tr>
<tr>
<td>Specificity</td>
<td>75%</td>
</tr>
<tr>
<td>Inconclusive</td>
<td>6.30%</td>
</tr>
</tbody>
</table>

All statistical analyses performed in JMP version 11.0
Discussion: Blinded Randomized Saline Load Trial

• With an accuracy of 75%, the MTP joint saline load test has the potential to be a viable, inexpensive option for an in-office test.
  – The Saline Load Test’s specificity of 75% is much higher than the majority of published results for both ultrasound and MRI.

• The MTP joint saline load test is a quick test that can easily be performed in the office and potentially double as a therapeutic intervention.
  – While unable to localize a tear or differentiate between plantar plate tears graded 1 – 4, the saline load test could provide an immediate, more definitive piece of evidence that can be weighed in combination with physical exam to determine whether to proceed directly to surgery without an MRI or ultrasound.
  – A corticosteroid could also be added to the syringe’s contents. If the test showed an intact plate, the load from the test would still function as a steroid injection.
Discussion: Blinded Randomized Saline Load Trial

• Study Limitations
  – Cadaveric tissue integrity
    • We found this to be the most common reason for an incorrect test result.
      • In the 2 samples that were erroneously diagnosed as intact, the needle was tip was not completely in the joint, providing inconsistent feedback. This phenomenon was also noted in the Phase 1.
    • Cadaver capsular tissue lacks elasticity and tears easily. Only a single injection attempt could be made for each test because subsequent attempts would result in the saline refluxing through prior needle holes without distending the capsule or providing the solid tactile endpoint, indicating the capsule was intact and at capacity.
    • A patient’s capsular tissue may exhibit more elasticity and allow for multiple attempts at injection if necessary.
  – Extensive dorsal dissection
    • Our thorough exposure could also have contributed to the above phenomenon.
      • The overlying soft tissue surrounding dorsal capsule may provide enough resistance to keep the injected fluid in the joint and still allow for the tactile feedback of an endpoint after multiple sticks.
    • There will be no exposure or direct visualization when the test is actually performed in an office setting.
  – The SLT test does not detect grade 0 (attenuated) plantar plate injuries
    • Only complete tears allow for the injected fluid to spread into the flexor tendon sheath.
    • Very small complete tears that only allow fluid to leak from the capsule very slowly may still exhibit the “endpoint” phenomenon.
Discussion: Blinded Randomized Saline Load Trial

– Patient Discomfort
  • Though steroid injections into MTP joints are performed fairly routinely in the office, patient discomfort is an issue with the saline load test as it is with any intra-articular injection.

– Ensuring an intra-articular injection
  • Even when directly visualizing the dorsal capsule, at times there were still difficulties with confirming needle placement in the joint, particularly in grossly deformed toes.
  • Though some practitioners feel they can consistently inject these small joints, ultrasound guidance could be employed to confirm placement.
    – In such a circumstance, the saline load test could also be combined with a diagnostic ultrasound study, perhaps even with contrast, to increase the certainty of the diagnosis.
    – The saline load test may help reduce the number of false positives that can occur with ultrasound.

– Future studies
  • Further cadaver studies are needed to evaluate the reproducibility of our results
  • Translational studies are needed to validate the efficacy of this test in vivo.
Conclusion

• The Saline Load Test showed fairly high accuracy in preliminary testing as an in-office diagnostic tool to detect complete tears in the plantar plate.

• Further testing with larger sample sizes and ultrasound guidance to confirm intra-articular placement of the needle would be helpful to more clearly determine the level of accuracy.

• Correlation with intraoperative surgical findings would also provide a better “gold standard” reference with which to compare the results of the Saline Load Test.
References