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Research Article



# Accuracy Of Ultrasound Versus Landmark-Guided First Metatarsophalangeal Joint Injections: A Cadaveric Study Comparing Novice and Experienced Providers

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## Abstract

**Objective:** To compare the accuracy of ultrasound-guided (US) versus landmark-guided (LM) first metatarsophalangeal (MTP) joint injections and assess the influence of injector experience. Prior foot/ankle studies-including MTP-specific cadaveric work-suggest that US guidance can achieve high placement accuracy, but comparative evidence in the first MTP joint remains mixed [1-5].

**Design:** Cadaveric comparative study.

**Methods:** Using 19 formalin-embalmed cadavers, one experienced sports-medicine physician (>20 years) and two fourth-year medical students each performed 12 first MTP joint injections (6 US, 6 LM), dorsal approach. A handheld high-frequency linear probe (Butterfly Network Inc., circa 2022) and a 25-gauge, 1.5-inch needle were used for US and LM procedures, respectively. Order of US vs LM injections was mixed across specimens. Each injector injected 1mL of a distinct dye color; accuracy was defined as dye coating the inside of the synovial membrane on blinded anatomical dissection. Fisher's exact tests compared proportions; binomial exact (Clopper–Pearson) 95% CIs were calculated.

**Results:** Accuracy (%) US vs LM: expert 83.3 vs 83.3 (p=1.000); student 1 50.0 vs 33.3 (p=1.000); student 2 66.7 vs 83.3 (p=1.000). Pooled across injectors, US 66.7% (12/18; 95% CI 41.0-86.7) vs LM 66.7% (12/18; 95% CI 41.0-86.7), p=1.000. Between-provider comparisons within technique showed no significant differences (all p≥0.242).

**Conclusion:** In this cadaveric model, US and LM guidance produced comparable accuracy for first MTP injections across experience levels. Although not superior for accuracy in this dataset, ultrasound may retain practical advantages (e.g., real-time visualization, anatomic variant recognition, educational value) in selected patients and training contexts [1-4, 6-9].

## Introduction

The first MTP joint is a common site of pain and disability (e.g., hallux rigidus/osteoarthritis, gout, inflammatory arthropathies), where diagnostic and therapeutic injections are routinely considered. While many clinicians perform palpation-guided injections, accuracy can vary due to small target size, osteophytes, sesamoid position, and deformity. Comparative studies across the

foot and ankle suggest that ultrasound guidance can deliver high accuracy in multiple sites, yet MTP-specific evidence-particularly head-to-head vs landmark-remains limited [1-5].

Cadaveric and clinical reports indicate that ultrasound can improve injection precision, visualize needle trajectory, and reduce collateral tissue trauma, with technique descriptions for the first MTP (e.g., long-axis in-plane) showing reproducible intra-articular placement [1, 3, 4, 6-9] At the same time, some literature across small joints shows equivocal accuracy differences between US and LM, underscoring the importance of joint-specific data [10-12]. We aimed to compare US- versus LM-guided first MTP injections in novices versus an experienced provider using a cadaveric model with dissection-based confirmation.

## Methods

### Study design and setting

Cadaveric study conducted in 2022-2023 using the Geisel School of Medicine (Dartmouth) anatomical donation program.

### Ethical Statement

Institutional review board review was waived due to the cadaveric nature, with adherence to ethical guidelines for anatomical research. Patients and the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

### Cadavers

Nineteen formalin-embalmed cadavers (mean height 162.6 cm; mean age at death 90 years; predominantly Caucasian; most deaths of natural causes). Both right and left first MTP joints were used, as suitability allowed.

### Participants

One experienced sports-medicine physician (family-medicine trained, sports-medicine fellowship, >20 years in practice) and two fourth-year medical students without prior injection experience.

### Injection protocol

Each injector performed 12 injections: 6 ultrasound-guided and 6 landmark-guided (36 total injections). A dorsal approach was used for all injections. Each provider was permitted only one attempt for each injection (eg once dye was injected, needle could not be repositioned). Ultrasound guidance employed a handheld high-frequency linear probe (Butterfly Network Inc., ~2022 model) with an in-plane technique and a 25-gauge, 1.5-inch needle; landmark injections used palpation of the first MTP joint line with the same needle. Medical students were educated by the experienced provider prior to the experiment on how to perform the injections. Injectate was diluted acrylic paint (~1 mL); to address occasional injection resistance, additional dilution with water was used as needed. The order of US vs LM injections was mixed across cadavers. Each provider used a distinct dye color to aid attribution on dissection.

### Accuracy assessment

After each injection, the joint was dissected by an experienced anatomist blinded to injection method. An injection was deemed accurate if the dye coated the inside of the synovial membrane (i.e., outlined the joint cavity). This aligns with prior cadaveric MTP studies using contrast or dye to confirm intra-articular placement [1, 3, 4].

### Statistical analysis

The primary endpoint was accuracy (accurate vs inaccurate). Given small sample size, we used Fisher's exact tests for all pairwise comparisons (two-sided $\alpha$=0.05). We reported binomial exact (Clopper-Pearson) 95% confidence intervals (CIs) for accuracy proportions. Prespecified comparisons included: (1) US vs LM pooled across injectors; (2) US vs LM within each injector; (3) between-injector comparisons for US and for LM; and (4) an exploratory experience-level comparison (expert vs students combined, overall).

## Results

### Accuracy by injector and technique

- Experienced provider: US 83.3% (5/6) vs LM 83.3% (5/6); p=1.000.
- Medical student 1: US 50.0% (3/6) vs LM 33.3% (2/6); p=1.000.
- Medical student 2: US 66.7% (4/6) vs LM 83.3% (5/6); p=1.000.

Pooled across all injectors, US was 66.7% (12/18; 95% CI 41.0–86.7) and LM was 66.7% (12/18; 95% CI 41.0–86.7); p=1.000.

### Between-injector comparisons (within technique)

- Ultrasound only: Expert vs student 1 p=0.545; expert vs student 2 p=1.000; student 1 vs student 2 p=1.000.
- Landmark only: Expert vs student 1 p=0.242; expert vs student 2 p=1.000; student 1 vs student 2 p=0.242.

### Experience-level comparison (overall, technique-agnostic)

Expert (10/12) vs students combined (14/24): p=0.260; expert vs student 1 (5/12): p=0.089; expert vs student 2 (9/12): p=1.000. Results are summarized in Table 1.

## Discussion

In this cadaveric study of first MTP joint injections, US and LM guidance yielded comparable accuracy across injectors. Within each provider, no US-vs-LM difference reached significance; between-provider differences within technique were also non-significant. Collectively, these findings suggest that-under controlled conditions with a dorsal approach-landmark techniques can achieve accuracy comparable to ultrasound for first MTP injection.

**Table 1:** Accuracy by Practitioner (with 95% CIs).

| Injector | Method | Accurate/Total | Accuracy (%) | 95% CI |
|---|---|---|---|---|
| Experienced | Ultrasound | 5/6 | 83.33 | 35.88-99.58 |
| Experienced | Landmark | 5/6 | 83.33 | 35.88-99.58 |
| Medical Student 1 | Ultrasound | 3/6 | 50.00 | 11.81-88.19 |
| Medical Student 1 | Landmark | 2/6 | 33.33 | 4.33-77.72 |
| Medical Student 2 | Ultrasound | 4/6 | 66.67 | 22.28-95.67 |
| Medical Student 2 | Landmark | 5/6 | 83.33 | 35.88-99.58 |

## Context within the Literature

Our findings align with a nuanced literature base. Cadaveric MTP studies describe high US accuracy using in-plane approaches (often with standoff gel) and careful trajectory control, supporting the technical feasibility and reproducibility of US-guided MTP injection [3, 4, 6, 8, 9]. At the same time, palpation-guided first MTP injections can succeed in cadavers but may show variable placement and extravasation, as highlighted by Reilly et al., underscoring the potential for error in small joints [1].

Broader foot/ankle literature (ankle, subtalar, tendon sheaths) also documents high US accuracy, and contemporary reviews detail technique pearls (probe selection, needle orientation, structures to avoid) that are transferable to first MTP injections [2, 5-7, 9, 13]. Meanwhile, comparative reviews across small joints remind us that not all joints show large accuracy gaps between US and LM; thus, joint-specific data (as presented here for MTP) are valuable [10-12].

## Clinical Implications

Although ultrasound did not outperform landmark guidance for accuracy in this dataset, US may still be preferable in specific scenarios:

- Variant anatomy or deformity (e.g., severe hallux valgus, osteophytes) where palpation landmarks are distorted [2, 5, 7].
- Real-time visualization to reduce collateral tissue injury and confirm intra-articular spread (useful for trainees or infrequent injectors) [3, 4, 6, 8].
- Concurrent diagnostic value (effusion/synovitis, tophi), and procedural teaching [2, 5-7].

## Limitations

This was a cadaveric study using formalin-embalmed specimens; tissue turgor and joint distensibility differ from living patients. The sample size per injector was small (n=6), limiting power. We did not collect procedural timing, so efficiency comparisons cannot be made. Our accuracy endpoint (dye on synovial lining) matches accepted cadaveric standards but does not capture clinical outcomes (pain relief, function). Finally, while injection order was mixed, we did not pre-specify a randomized sequence stratified by side, which could influence subtle learning/fatigue effects.

## Future Directions

Prospective in-clinic studies measuring procedure time, patient-reported outcomes, and cost-effectiveness-with stratification by deformity/severity-would better define when US adds the most value for first MTP injections.

## Conclusion

In a cadaveric first MTP model, ultrasound- and landmark-guided injections demonstrated similar accuracy across novice and experienced injectors. Ultrasound retains practical advantages in select scenarios (anatomic variation, training, visualization) and should be considered within individualized clinical and educational contexts.

## Patient and Public Involvement

Patients and the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

## Acknowledgement

None.

## Conflict of Interest

No conflict of interest.

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