



# A marker placement laser device for improving repeatability in 3D-foot motion analysis



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## ABSTRACT

**Background:** In 3D gait analysis, the repeated positioning of markers is associated with a high error rate, particularly when using a complex foot model with many markers. Therefore, a marker placement laser device was developed that ensures a reliable repositioning of markers. We report the development and reliability of this device for the foot at different tape conditions.

**Methods:** In 38 subjects, markers were placed at the foot according to the Heidelberg foot measurement method. Subjects were tested barefoot and barefoot with three different tape conditions. For all conditions, a static standing trial was captured. We analyzed differences in distances between markers and the intra-class correlation coefficients (ICC).

**Results:** Small differences between the conditions (0.03–3.28 mm) and excellent ICCs (0.91–0.97 mm) were found for all parameters.

**Conclusion:** The laser marker placement device appeared to be a reliable method to place markers on a tape at previously palpated positions and ensures an exact position. The device could find a wide application in different clinical research fields.

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## 1. Background

Marker-based 3D motion capture is applied in gait analysis also with 3D-foot models [1–3]. However, repeatability of foot marker placement is critically discussed [1,4]. Hence, improvement in marker placement and repeatability—possibly with additional devices—is highly desirable. For investigating additional footwear, orthoses or tapes, a method improving measurement repeatability across conditions would be helpful.

Noehren et al. [5] used a device with two arms to adjust to marker locations, which is not practical in multi-segment foot models. Henley [6] and Saraswat et al. [7] showed a good reliability by placing the feet into a plaster mold. However, this method could not be used with tapes. Telfer et al. [8] used pen marks on the skin to guide placement with a plastic wire with markers—reliable, but only applicable in barefoot conditions.

For monitoring the effects of taping to prevent ankle sprains, we developed a device which allows a good replacement of markers after tape application.

## 2. Material and methods

### 2.1. Participants

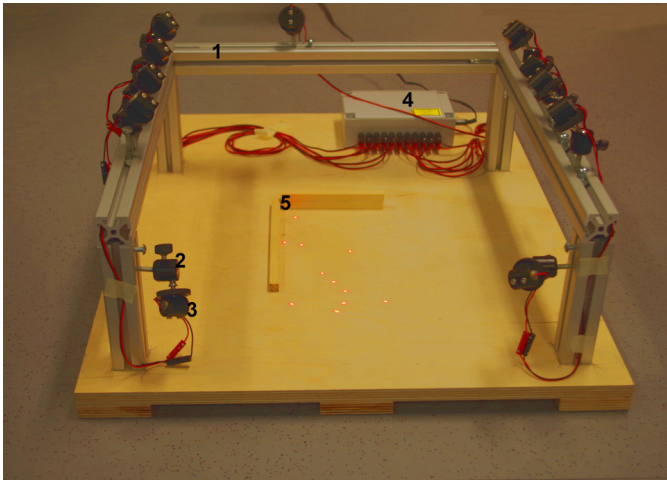
The Ethical Committee of the University of Heidelberg approved this study and all 38 participants (24 women, 14 men) gave informed consent prior to participation.

### 2.2. Design and construction of the marker placement laser device

On a wooden board, a rectangular design with aluminum profiles (ITEM, Solingen, Germany) had been fixed. Connection elements were movable within the profiles and could be anchored to any position by means of bolts. Laser pointers (red, 650 nm, 1mW, 3-12VDC, Picotronic, Koblenz, Germany; powered by a 3 V adapter) were fixed at ball heads of mini camera tripods (Somikon Ultra Flexible Camera Tripod with 3D Ball Head, pearl, Buggingen, Germany) on movable connection elements within the profiles to obtain a motion in all directions. Two pieces of wood (horizontal:

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**Fig. 1.** Marker placement laser device; 1 = aluminum profiles, 2 = connection elements, 3 = laser pointers fixed at ball heads of mini camera tripods, 4 = electrical power supply, 5 = pieces of wood for positioning the foot.

12 cm long/2 cm high, vertical: 18 cm long/1 cm high) were fixed at a 90 degree angle on the board to position the foot (Fig. 1).

### 2.3. Marker set

17 reflective markers (6 mm in diameter) were attached to the skin on each leg according to the Heidelberg foot measurement method [2] (Fig. 2).

All markers were placed sitting with 90 degrees knee flexion. Kinematic data were collected at 120 Hz using a twelve-camera Vicon 612 system (Oxford Metrics, Oxford, United Kingdom).

### 2.4. Taping methods

The participants were tested under four conditions: barefoot, with kinesiotape (KINESIO SportsTexTape, Jovita Pharma, Ohlstadt, Germany) and two variations (“Sling” and “Classic”) with Leukotape (Leukotape® classic, BSN Medical GmbH & Co. KG, Hamburg, Germany) (Fig. 2), all placed by the same operator in a randomized order.

### 2.5. Protocol

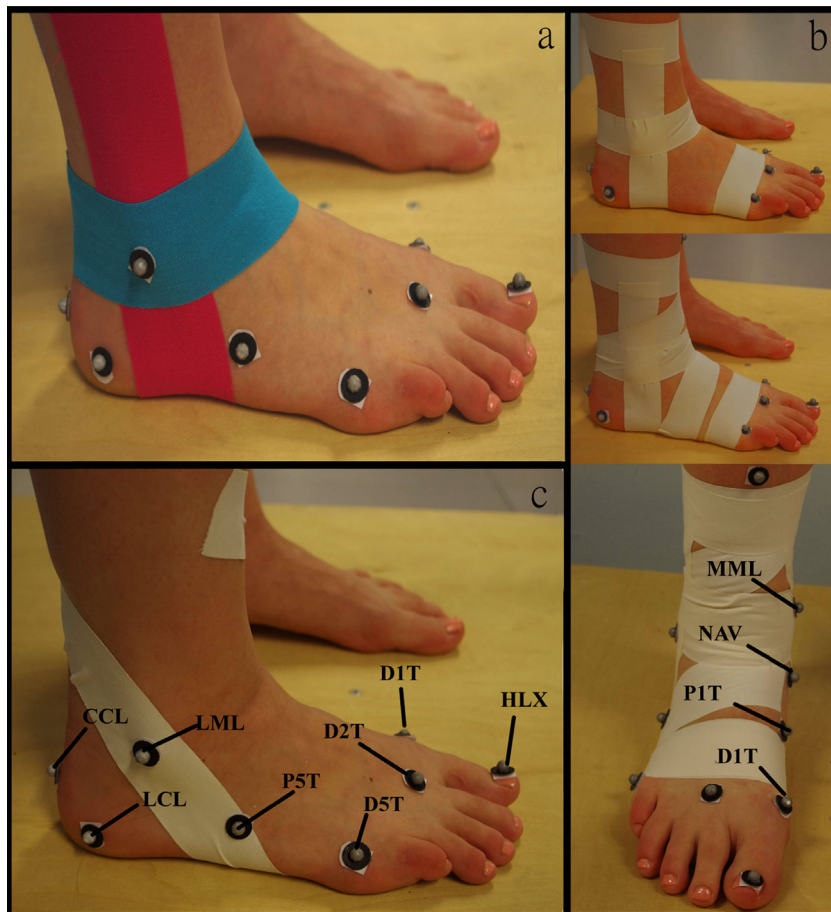
After the barefoot measurement in the neutral standing position, the subjects sat on a chair, with their arms placed on their thighs to minimize foot movement. The investigated foot stood in the device, the other foot stood outside the device on a wooden board to level height. The subjects had to rest steady while the investigator directed the laser pointers on the markers at the foot.

For the application of the different tapes, it was necessary to remove the following markers:

Sling: medial malleolus (MML) and 5th metatarsal (P5T)

Classic: medial and lateral malleolus (MML/LML), 1st (P1T) and 5th metatarsal (P5T), navicular (NAV)

Kinesiotape: medial and lateral malleolus (MML/LML) and depending on the size of the foot sometimes 5th metatarsal (P5T)



**Fig. 2.** Three different tape variations with markers. (a) Kinesiotape (lateral view). (b) Tape classic: step 1: anchor, stirrup and horseshoe strips (lateral view); step 2: heel lock (lateral view); step 3: repeated layers of tape (frontal view). (c) Sling (lateral view).

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