NOVEL US DEVICE FOR THE ESTIMATION OF PELVIC TILT

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INTRODUCTION

Tracking of the anterior pelvic plane is of interest for medical interventions such as total hip arthroplasty (THA), for which it is used as a reference for the positioning of the acetabular cup (Lewinneck 1978).

The measure of pelvic tilt has been investigated by a few research groups for the purpose of improving total hip arthroplasty planning. The means of measurement of the pelvic tilt can be sorted in invasive and non-invasive types. The invasive methods comprise conventional 2D X-ray (Ala Eddine 2001), 3D low dose X-ray (Humbert 2009) and computerized tomography (CT) (Lazennec 2004). The non-invasive methods include inclinometers with soft tissue compensation (Lembeck 2005) or without (Prushansky 2008), robotic digitizer arm (Mayr 2005) or navigated ultrasound (US) probes (Dardenne 2009).

We introduce and evaluate here a new portable US device for the instantaneous estimation of the pelvic tilt taking into account soft tissue thickness above the bony landmarks of interest. This device is small, autonomous and designed to be used during the pre-THA visit to measure the pelvic tilt in different positions of daily living (e.g. standing, sitting and supine) in order to improve and allow a patient specific planning.

MATERIAL AND METHODS

The US device (Figure 1) used for this study consists of two US probes (L12-5L60N, Telemed, Vilnius, Lithuania) operated simultaneously and articulated with respect to a main body using spheroidal joints. The translation between the two probes is also allowed thanks to a prismatic joint in the main body. The two probes, after being calibrated (Dardenne 2007), are used to locate the anterior superior iliac spine (IS) and the pubic symphysis (PS).

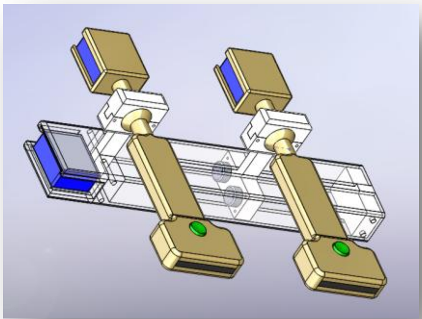
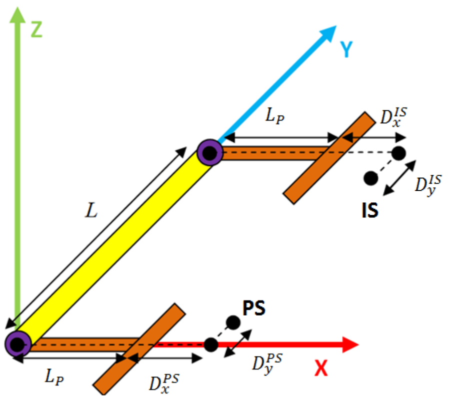


Figure 1 – The ultrasound device for the estimation of the pelvic tilt.

Besides the US probes, the sensors embedded in the device include 3 inertial sensors (LPMS-B, Omni Instruments, Dundee, Scotland), attached to each probe and the main body, respectively, and one distance sensor located on the prismatic joint, inside the main body.

When the user sees the bony landmarks on US images, he presses the freeze button and the data from all sensors are read and recorded in order to estimate the pelvic tilt. First, the bony landmarks are located on the US frames, then, the pelvic tilt is automatically computed using the sensors mentioned above and the formula illustrated on Figure 2.



$$Pelvic\ Tilt = \operatorname{acos}\left(\frac{(\overrightarrow{v_{PS-IS}})_z}{\sqrt{(\overrightarrow{v_{PS-IS}})_x^2 + (\overrightarrow{v_{PS-IS}})_y^2 + (\overrightarrow{v_{PS-IS}})_z^2}}\right)$$

$$\overrightarrow{v_{PS-IS}} = [0 \quad L \quad 0] \cdot R_M + [L_P + D_x^{IS} \quad D_y^{IS} \quad 0] \cdot R_S^{IS} - [L_P + D_x^{PS} \quad D_y^{PS} \quad 0] \cdot R_S^{PS}$$

Figure 2 – Computation of the pelvic tilt, with L the distance between the center of rotation of the probes, LP the length of the probes, D the position of the bony landmark (IS or PS) along the axis (x or y) of the US frame, R the rotation matrices (main body (M), IS probe or PS probe), given by the inertial sensors.

In order to assess the accuracy of our measurement system, simulations of acquisitions have been run using a custom made software using the estimated errors of the sensors: localization of bony landmarks in US frame (±3 mm), distance between US probes (±4 mm), inertial sensors (±2°). The simulation was run a hundred thousand times with an initial pelvic tilt of 4°, mimicking the standing position.

RESULTS

After being ran the simulation gave the following mean ± standard deviation [minimum; maximum]: 0.18° ± 0.96° [-3.85°; 4.33°]. A tolerance of 2.5° around the actual pelvic tilt was considered adequate; this led to an acceptance rate of 99.0% of the measures (207 below tolerance, 825 above).

DISCUSSION

Only few studies present measurement precision, Eckman et al. (2006) for instance reported an error of 0.004±1.38° [-4.0°,3.0°] (mean±SD [min,max]). Other studies present standard deviations on repeated measures from 0.6° to 1.2° (Dardenne 2009) and 1.8° (Nishihara 2003) or a precision based on SD between 0.8° and 1.4° (Humbert 2009).

Our device shows a similar level of accuracy to the one observed in the literature and compatible with the surgical constraints. Moreover, our device comes without the cost (compared to navigation stations) or the invasiveness (no X-ray or intracortical pins) of other methods and is user friendly.

This simulation study needs to be extended to seated and supine positions and will be performed in vitro in a first step and then on subjects and patients in order to assess its results in vivo.

ACKNOLEDGEMENT

This work was supported by the French national research agency (ANR) through the TECSAN 2012 Modulhips project.

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Tracking of the anterior pelvic plane is of interest for medical interventions such as total hip arthroplasty, for which it is used as a reference for the positioning of the acetabular cup.
We introduce and evaluate a new portable ultrasound device for the measure of the pelvic tilt in different positions of daily living. This device consists of two ultrasound probes articulated with respect to each other in order to visualize simultaneously the bony landmarks of interest that are one of the anterior superior iliac spine and the pubic symphysis. A series of sensors and the calibration of the ultrasound probes allow the measurement of the relative position of the landmarks with respect to a vertical line.
The accuracy of the device has been investigated through a simulation study and showed errors (mean ± standard deviation [minimum; maximum]) as 0.18° ± 0.96° [-3.85°; 4.33°], with 99% of measurements within a ± 2.5° with respect to the actual pelvic tilt.
This level of accuracy is similar to what can be found in the literature for the same purposes. Our device gathers advantages such as being portable and user friendly in order to be used during the pre-operative consultation. It is also non invasive and non irradiant. Further investigations will be run to assess this accuracy in vitro and in vivo.