In vivo trapeziometacarpal joint kinematics using an optoelectronic system: a data basis on healthy subjects

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Abstract— **Trapeziometacarpal joint is important concerning thumb function. However, this deep joint is clinically difficult to assess. The purpose of our study is to evaluate the range-of-motion of trapeziometacarpal joint with an *in vivo* kinematics protocol.**

One hundred and fifteen hands have been studied in 73 healthy subjects, (twenty-two females and fifty-one males). The mean age was 23.1 years old. (Range, 22 to 35 years). An optoelectronic device (Polaris®) was used to analyse thumb range-of-motion. Splints were used to evaluate the isolate trapeziometacarpal joint. Retroreflective markers were placed on the splints and thumb. Anatomical landmarks were pointed to localize bone segment. Three patterns of range-of-motion were assessed. Guides were used to improve movement repeatability.

The protocol has been feasible in all subjects. The mean measurement time was 15 minutes. Mean flexion-extension and abduction-adduction was respectively 53 and 42 degrees without guides, 68 and 48 degrees with guides. The mean axial rotation of the thumb was 27 degrees. The mean distance between axes of each movement was 7 millimetres.

We developed a data basis of trapeziometacarpal joint range-of-motion *in vivo* measures, to our knowledge, which have not been previously proposed. Comparison with literature shows range-of motion is similar to short *in vivo* series or *in vitro* studies. However, distance between axes of flexion-extension and abduction-adduction is more important in our study. Moreover, thumb axial rotation occurs in abduction-adduction movement, which has not been previously described.

I. INTRODUCTION

The trapeziometacarpal (TMC) joint is fundamental in thumb range-of-motion. It plays an important role in opposition and abduction of thumb movements [1]. However, the anatomy of TMC joint is complex. The shape of the trapezium and first metacarpal bones are described as a double saddle with concave and convex surfaces. Moreover, many ligaments have been described in TMC joint [2], however, the function of each structure is not still clearly known. Nevertheless, tendons and muscles action may modify the pattern of motion of TMC joint because of capsular laxity of the TMC joint.

Range-of–motion of this joint is clinically difficult to evaluate accurately. The kapandji score measures the entire thumb motion and gives no accurate data on TMC joint range-of-motion [1]. Measures made with a goniometer are very difficult because trapezium is a deep bone.

Many authors have studied *in vitro* kinematics of the TMC joint [3-12]. However, these analyses described a theorical model of TMC joint kinematics. As a matter of fact, active muscles and tendons are not considered in this kind of studies.

In vivo studies are currently developed. Analysis using X-rays may be considered dangerous for patients because of the radiation exposure [8]. IRM analysis allows static study in different position. Many systems have been developed to analyze *in vivo* kinematics: electromagnetic tracking device, optoelectronic systems. However, few publications have studied the TMC joint [13,14]. These studies validated a kinematics protocol, however, no publication, to our knowledge presented data basis of TMC joint range-of – motion in healthy subjects.

The purpose of our study was to collect data from TMC joint range-of–motion, in different specific patterns of movements, in order to obtain a panel of values for normal TMC joint.

II. MATERIALS AND METHODS

Seventy three subjects, 22 females and 51 males were evaluated. The mean age was 23.1 years old. (Range, 22 to 35 years). Both hands were studied for 71 subjects and only one hand for two subjects. One hundred and forty four hands were finally analyzed. All subjects underwent a medical query in order to select subject without any hand injury.

The hand was placed on a splint to immobilize the wrist. A small splint was placed to fix the PIP and MCP joint of the thumb in order to analyze the TMC joint only.

An optoelectronic system (Polaris®) was used to analyze the movements of the thumb. It was composed of two fixed infrared cameras and retroreflective markers. Retroreflective markers were placed on the two splints (fig.1). A pen with markers was used to localize bony landmarks of the first metacarpal. Infrared beam were send by the two cameras and captured after reflection on the markers. Coordinate of the markers were calculated by the system and range-of-motion of the thumb were calculated. Special devices were performed to guide the movements (abduction-adduction and flexion-extension) in order to improve the measure reliability. Measures were performed with and without these guides to compare reliability. This protocol is accurately described in part one.

Four patterns of movements were analyzed: abduction and adduction (ante-retroposition, flexion and extension, circumduction (three parameters: θa, θb and b described by Cheze et al. [13]) and abduction adduction in the palm plan. For these movements, ten parameters were analysed: for each movement: maximal range-of-motion were calculated. Distance and angles between the different axes of rotation (flexion-extension and abduction adduction) of the TMC joint were evaluated.

Statistics analysis: The Shapiro test was used on the parameters to check the normality of the data. In case of normality, the interval of the mean ± two standard deviations represents ninety five percent of the population.

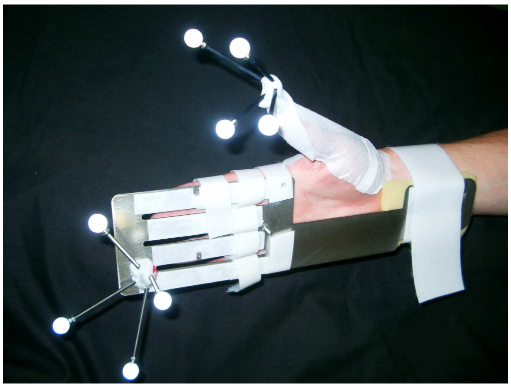

Figure 1: Splint with retroreflective markers to immobilize all joints except TMC joint

III. RESULTS

With guides (table 1):

The mean abduction-adduction range-of-motion was 68 degrees (range, 40 to 93). The mean flexion-extension range-of-motion was 48 degrees (range, 30 to 71). The mean parameters of circumduction θa, θb, and b were respectively 52 (range, 32 to 72), 65 (range, 41 to 89) and 57 (range, 47 to 67) millimetres.

The mean angle of axial rotation of the thumb was 21 (range, 6 to 33). The mean value of the angle between the axis of flexion-extension and abduction-adduction was 91 degrees (range, 104 to 88). The mean distance between the tow axes flexion-extension and abduction-adduction was four millimetres (range, 1 to 7)

Without guides (table 1)

The mean abduction-adduction range-of-motion was 53 degrees (range, 34 to 69). The mean flexion-extension range-of-motion was 42 degrees (range, 30 to 72). The mean parameters of circumduction θa, θb, and b were respectively 51 degrees (range, 24 to 63), 57 degrees (range, 40 to 84) and 57 (range, 45to 66) millimetres.

The mean angle of axial rotation of the thumb was 27 (range, 9 to 43). The mean value of the angle between the axis of flexion-extension and abduction-adduction was 92 degrees (range, 64 to 125). The mean distance between the two axes of flexion-extension and abduction-adduction was four millimetres (range, 0 to 14)

IV. DISCUSSION

Clinical assessment of the TMC joint is difficult. Therefore, *in vivo* kinematics of the thumb is important to develop a precise measurement protocol of TMC joint. *In vitro* studies do not evaluate the exact range-of-motion with muscle and tendon actions. They only quantify the theorical mobility of bone and ligament segments [1].

A few studies have developed *in vivo* kinematics studies using X-rays [3,15]. These accurate protocols provide skin and bone movements. However, because of radiation exposure, it cannot be routinely used in clinical practice. Moreover, axial rotation of the thumb is not easily calculated [15].

Non invasive procedures are currently used to analyze joint kinematics. Regarding TMC joint, Kuo used electromagnetic tracking device to measure thumb movement, placing skin markers [14]. The correlation between skin markers and bone segment has been previously verified [15]. *In vitro* study allowed range-of-motion of circumduction with a mathematical model from the first metacarpal length to be calculated. The thumb range-of-motion was represented with a spherical area. However, no distance between rotation axes can be calculated with this method.

Cheze et al. proposed an *in vivo* protocol with an optoelectronic device. The wrist was immobilized on a splint and markers were placed on the thumb [13]. abduction–adduction, flexion-extension and circumduction were studied: results of range-of-motion were similar to our study (table II). However, only 24 hands were studied. Distance between axes was different according the different articles. Cheze et al. found less than 1 millimetre, in comparison to 3 millimetres in the current study. This difference should be explained by the movement patterns. We used two movements with perpendicular axes described by Kapandji [1]. Cheze et al. used a global movement which includes abduction and flexion. Coert proposed a method to quantify the thumb circumduction with an electronic device [16]. However, interphalangeal and metacarpophalangeal joint were not stabilized. Therefore in this study TMC joint range-of-motion cannot be precisely calculated. To the author's knowledge, no publications have presented a data basis of TMC joint range-of-motion. The data basis of our study will permit to compare patients with arthritis thumb or healthy subjects. Moreover, thumb range-of-motion should be compared before and after operation for trapezectomy or TMC arthroplasty.

Aknowledgement: The authors wish to thank L. Cessey and J..Etchard for their assistance in this study.

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