SCIENTIFIC/CLINICAL ARTICLE

The Pollexograph®: a new device for palmar abduction measurements of the thumb

M. de Kraker, MD
R.W. Selles, PhD
Department of Plastic and Reconstructive Surgery, Erasmus Medical Center Rotterdam, The Netherlands
Department of Rehabilitation Medicine, Erasmus Medical Center Rotterdam, The Netherlands

T.A.R. Schreuders, PT, PhD
Department of Rehabilitation Medicine, Erasmus Medical Center Rotterdam, The Netherlands

S.E.R. Hovius, MD, PhD
Department of Plastic and Reconstructive Surgery, Erasmus Medical Center Rotterdam, The Netherlands

H.J. Stam, MD, PhD
Department of Rehabilitation Medicine, Erasmus Medical Center Rotterdam, The Netherlands

ABSTRACT:
Study Design: Clinical measurement, cross sectional.
Purpose: To introduce a new measurement device, the Pollexograph®, to easily measure palmar thumb abduction, and to compare its reliability with conventional goniometry.
Methods: Fourteen hand therapists measured palmar abduction of the same healthy subject with the Pollexograph and a conventional goniometer. In addition, intrarater reliability of the Pollexograph was studied in 21 patients with a hypoplastic thumb.
Results: Variance between measurements of the same subject measured by the hand therapist was 2–6 times smaller with the Pollexograph compared to conventional goniometry. Pollexograph intrarater reliability in hypoplastic thumb patients was excellent (intraclass correlation coefficient (ICC) = 0.98–0.99).
Conclusions: A new tool to measure palmar abduction in clinical care, the Pollexograph, has been introduced. The Pollexograph reduces variability between raters when measuring the same subject compared with conventional goniometry and excellent measurement reliability in hypoplastic thumb patients.
Level of evidence: Not applicable.

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For hand function, palmar thumb abduction thumb is essential, because it determines the width of a person's grip and ability to pinch with the thumb and oppose the other fingers of the hand.[1] Palmar abduction is traditionally defined as the angle between metacarpal 1 (MC1) and 2 (MC2) with the thumb maximally abducted and is conventionally measured with a goniometer (see, among others, Hartigan et al.,[2] Brand,[3] and Tubiana).[4] Because this angle is difficult to measure and, therefore, the measurement is generally considered to have poor reliability, a number of alternative measurements or definitions have been proposed. For example, the International Federation of Societies for Surgery of the Hand (IFSSH)[5] have defined palmar abduction as the movement in which the thumb metacarpal moves away from the index metacarpal, perpendicular to the plane of the palm. The American Society of Hand Therapists (ASHT)[6] measures the maximal distance from the distal palmar crease directly over the third metacarpophalangeal (MCP) joint to the tip of the thumb. The American Medical Association (AMA)[7] measures the maximal distance from the distal palmar crease directly over the third MCP joint to the interphalangeal (IP) joint.

Palmar abduction differs from radial abduction in which the thumb moves in the same plane as the palm of the hand. However, palmar abduction is an essential part of opposition, which is composed by projection, abduction, adduction, rotation, and finally opposition as described by Kapandji[8] and Tubiana.[4] Palmar abduction is obtained by a combination of extension, opposition, abduction, and rotation at the carpometacarpal joint (CMC joint) and can be diminished in a number of pathological conditions, such as in patients with CMC osteoarthritis, hypoplastic thumbs, nerve paralysis, spasticity, rheumatoid arthritis, fractures, dislocation of the thumb, and burns. A number of interventions are specifically aimed at increasing palmar abduction, such as splinting regimes, first web plasties, and tendon transfers. For efficacy evaluation of these procedures, reliable and valid measurement methods for palmar abduction are mandatory.

Correspondence and reprint requests to M. de Kraker, Erasmus MC, University Medical Center, Department of Plastic and Reconstructive Surgery, Dr. Molewaterplein 40, 3015 GD, Rotterdam, The Netherlands. Tel.: +31-10-7043291; fax: +31-10-7044685; e-mail: <m.dekraker@erasmusmc.nl>.

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Conventionally, palmar abduction is measured with a goniometer as the angle between metacarpal 1 and 2 with the thumb maximally abducted.[2–4] In addition to the conventional method, more complex and time-consuming methods have been developed. Three-dimensional video camera systems have been used to analyze motion of the thumb and fingers.[9–12] For this, a standardized setup with a minimum of 2 or more cameras and multiple markers are required as well as relatively time-consuming and complex data analysis. Besides motion analysis, a number of other devices have been developed to measure thumb abduction angles. For example, Harvey et al.[13] Designed a torque-controlled device to measure passive palmar abduction of the right hand. Shrinivasan[14] placed triangular pieces of wood with known angles into the thumb web to measure web angles. Similarly, Schwanholt and Ster[15] used cone-shaped models, and Bhattacharya[1] used dental compound molded into the web space to measure passive palmar abduction. Although some of these more complex methods may provide more detailed information than the conventional goniometer method, they seem impractical for use in daily clinical care.

To simplify measurements, several authors have proposed to measure distances between anatomical landmarks instead of angles to determine palmar abduction. For example, Buck-Gramcko[16] and the ASHT[6] proposed to measure the maximal distance between palm plane and tip of the thumb in full palmar abduction. Similarly, Murugkar et al.[17] measured the intermetacarpal distance (IMD) during maximum spread of the web space.

Most of these methods are associated with significant limitations. From our clinical experience, we were not convinced that measurements with the conventional method had sufficient reliability. However, to our knowledge, extensive reliability studies have not been performed. Only Murugkar et al.[17] performed a study comparing conventional goniometry with the IMD and found poor reliability for goniometry. However, although distance-based measurements may be reliable and appropriate for follow-up of individual adults, they may not be very comparable between subjects due to differences in hand size and in landmarks used for measuring the linear distance. This limitation is even more pronounced in children, where differences in length of the segments are large and change with time.

In this study, a new tool, the Pollexograph (Figure 1A), is introduced to measure active and passive palmar abduction as the angle between palm of the hand and tip of the thumb. The tool was designed in such a way that it is simple, affordable, applicable to left and right hands of varying sizes, and most importantly, valid and reliable. As a first test to determine applicability and interrater reliability, 14 occupational and physical therapists (in training for hand therapy) performed measurements on the same subject with a conventional goniometer and with the Pollexograph to assess interrater reliability. Additionally, Pollexograph intrarater reliability was assessed in 21 patients with a hypoplastic thumb (Blauth type II–IV) who had undergone surgical treatment in our medical center.

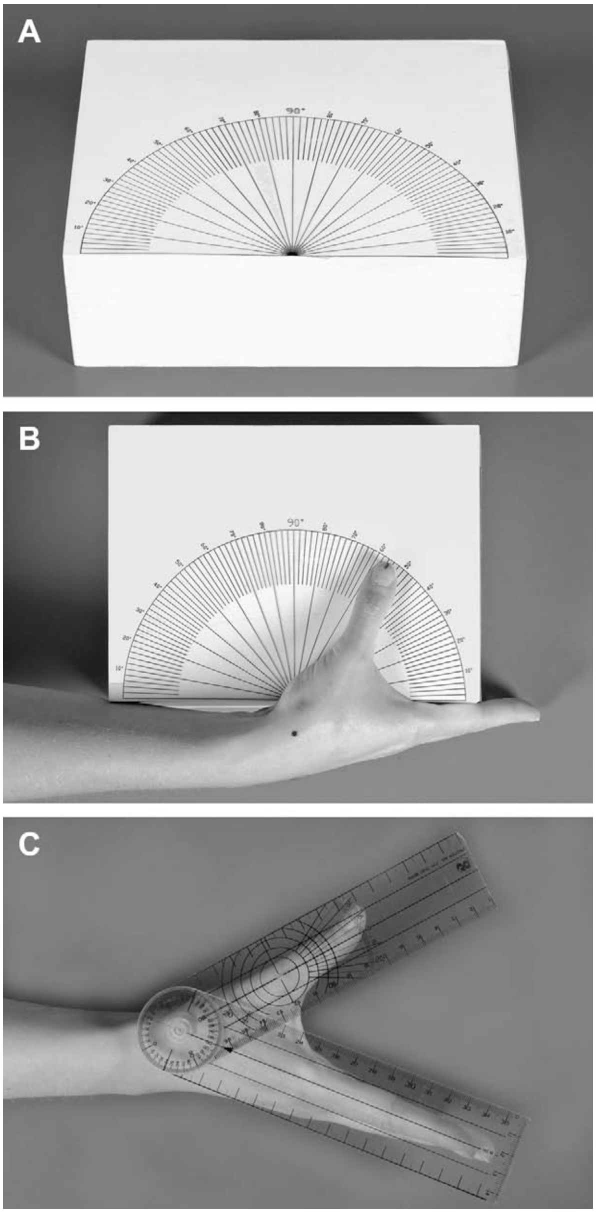

FIGURE 1. (A) The Pollexograph with a protractor on top. The Pollexograph has a length of 21 cm, height of 7 cm, width of 13.5 cm, and a radial protractor length of 13 cm. The protractor is divided into steps of 2°. (B) Positioning of hand and forearm with two landmarks (CMC joint and middle distal part of the nail) on the Pollexograph. (C) An active palmar abduction measurement with the goniometer placed over metacarpal 1 and metacarpal 2.

METHODS AND MATERIALS

Subjects

To obtain a first estimate of interrater reliability, 14 occupational and physical therapists in training for hand therapy, were asked to measure active and passive palmar abduction with the Pollexograph and a conventional goniometer of the right hand of a 25-year-old, right-handed, healthy female with no prior trauma to the upper extremity. The average age of the therapists was 38.8 years (range, 24–53 years), and the average years of experience were 5.1 years (range, 0–12 years). Eleven out of 14 therapists had experience with goniometry of the hand, and the average number of hand goniometry measurements they performed per week was 8 (range, 0–50). Four therapists had frequently performed palmar abduction goniometric measurements. Before measurements, all therapists watched an instruction video displaying the two measurement methods for palmar abduction (conventional goniometry and Pollexograph) for both active and passive measurements.

Additionally, Pollexograph test–retest measurements were performed by one of the authors on the hands of 21 patients with a hypoplastic thumb (Blauth type II–IV) who had previously received surgical treatment in our medical center. The patient group consisted of 14 males and 7 males with a mean age of 12.6 years (range, 4–30 years) who visited the outpatient clinic for a regular consultation after surgery. A retest was performed during the same consultation. Time between surgery and palmar abduction measurements was at least 1 year. This study was approved by the Medical Ethics Committee of our medical center, and written consent was obtained from all participating subjects or their parents.

Devices and measurements

Pollexograph design (Figure 1A) was based on the concept that hand position should be standardized to obtain repetitive and reliable measurements. Since palmar abduction is a motion in one plane, it should be assessed in this plane along a smooth surface. Thus, the Pollexograph measures the movement in which the thumb moves away from the index metacarpal, perpendicular to the plane of the palm.

A box shape (length = 21 cm, height = 7 cm, width = 13.5 cm) was chosen so that the thumb would be forced to move in the plane perpendicular to the hand. A protractor (radial length = 13 cm) on top was divided in steps of 2°, conforming to the scale of many conventional goniometers. The protractor runs from 0° to 90° from the left to the middle and from the right to the middle, making the Pollexograph applicable for left and right hands of all sizes. In addition, the examiner marked a number of anatomical points on the hand to optimally align the hand and to read the palmar abduction angle. First, to allow the thumb to move freely in the right plane, it was important to place the thenar crease exactly on the edge of the box. Therefore, the thenar crease was marked before placing the hand. In addition, since rotation during palmar abduction originates from the CMC joint, we chose to mark this joint so that it could be aligned with the 90° line on the protractor. Finally, the middle distal part of the nail was marked to facilitate angle readings.

During Pollexograph measurements, subjects were seated at a table with the elbow in 90° flexion. The hand was placed on the Pollexograph with the thenar crease on the edge of the box and the CMC marking aligned with the 90° line of the protractor. The lower arm was positioned parallel to the box with the fingers pointed slightly ulnar (Figure 1B). During measurements, the other fingers were fixed against the box by the examiner. Fixation of the four fingers enables the examiner to survey hand and wrist position and thereby whether the subject performs the movement correctly. With the Pollexograph, measurements were performed both actively (subject moves the thumb in maximal palmar abduction) and passively (examiner places the thumb in maximal palmar abduction). For active measurements, the patient was instructed to move the thumb to maximum palmar abduction in a single fluent movement. For passive measurements, the researcher moved the thumb to maximal palmar abduction, while the subject was instructed to relax. In both measurements, the maximal palmar abduction was read from the position of the nail marking above the protractor.

For the conventional measurement method, a goniometer was used. We measured the angle between the first and second metacarpal with the thumb maximally abducted. For active palmar abduction, the subject was asked to hold the thumb in maximal abduction and the goniometer was placed over the first and second metacarpal (Figure 1C). For passive palmar abduction, the same measurement was performed while the examiner held the thumb in maximal palmar abduction.

Statistical analysis

To determine interrater reliability, we calculated means, standard deviations (SDs) and the 95% confidence interval (CI) (mean, $\pm 1.96 \times SD$) of the repeated measurements of the same subject. Mean values indicate systematic differences between measurement techniques. SDs indicate measurement differences between therapists when measuring the same subject. Therefore, a lower SD indicates better reliability.[18] The Paired Sample t-test was used to compare means of both methods. Levene's test was used to compare the equality of the variances. A p-value ≤0.05 was considered significant, and SPSS 14.0 was used for all analyses.

Intrarater reliability of the Pollexograph was calculated using intraclass correlation coefficients (ICC). The ICC is a measure of agreement between test and retest values found for each subject. It ranges from 0 to 1, where an ICC of 0 means no agreement between test and retest, whereas an ICC of 1 means perfect test–retest reliability.[19,20]

Additionally, two absolute reliability indices were calculated: standard error of measurement (SEM) and smallest detectable difference (SDD). The SEM was calculated with the estimated variance components, whereas the SEM is the square root of the error variance.[18,21] From the SEM, the SDD ($SDD = 1{,}96 \times \sqrt{2} \times SEM$) was determined. The SDD is specifically valuable for clinical use, since with this index, an examiner can distinguish between a measurement error and a real (treatment) change. Only a difference that exceeds the SDD can be considered a real (nonerror) change in an individual patient.[22] For example, an SDD of 5° indicates that a follow-up measurement should differ by at least 5° from a baseline measurement to be sure that there is a real (nonerror) change in abduction angle in an individual subject.

RESULTS

Repeated measurements on a healthy subject

Table 1 shows, standard deviations and the 95% confidence interval for active and passive measurements of both methods. The mean active and passive angles measured with conventional goniometry (64.5 and 69.1) were significantly larger ($p = 0.013$ and $p = 0.004$) than those with the Pollexograph (57.7 and 60.9).

Levene's test showed that active and passive Pollexograph measurement variance of the repeated measurements of the same subject (the SD in Table 1) was significantly smaller (2–6 times) than goniometer measurement variance ($p = 0.001$ for active palmar abduction and $p = 0.028$ for passive palmar abduction), suggesting that the Pollexograph is more reliable in measuring palmar abduction than a conventional goniometer.

Reliability in hypoplastic thumb patients

Table 2 shows mean angles measured with the Pollexograph in 21 patients with a hypoplastic thumb. Mean Pollexograph angles were approximately 49°, ranging from 24° to 70°.

Intrarater reliability for Pollexograph in patients with a hypoplastic thumb is also shown in Table 2. For both active and passive Pollexograph measurements, we found excellent ICCs (0.98–0.99). In addition, SDDs were smaller than 5°, also indicating excellent reliability.

DISCUSSION

Although palmar abduction is essential for normal hand function, little is known about optimal range of motion of the thumb and how to measure this. Conventional methods (e.g., goniometry) are generally considered to have poor reliability.[17] We therefore developed a new tool, the Pollexograph, for measuring palmar abduction. To obtain a first estimate of its reliability, we compared variation between raters when assessing the same subject using the Pollexograph and conventional goniometry. Additionally, Pollexograph intrarater reliability was assessed in 21 patients with a hypoplastic thumb and showed excellent reliability. Overall, preliminary analysis showed that Pollexograph measurements were significantly more reliable than conventional goniometry measurements.

Tubiana,[4] Hartigan,[2] and Brand[3] applied the conventional method of measuring palmar abduction with a goniometer. The mean values in the healthy population ranged from 40° to 80° according to Tubiana, whereas Brand et al. quote the normal range of the web angle as being 40°–50°. Harvey et al.[13] found mean passive palmar abduction to be 56° in healthy subjects. In our study, in the healthy subject, mean active and passive palmar abduction values with conventional goniometer methods were 64.5° and 69.1°, which are in accordance with Tubiana's results. The large variation between different reports may also indicate poor interrater reliability, although, to our knowledge, this has never been thoroughly investigated.

***TABLE 1.* Means, SDs and 95% CI of the mean obtained from repeated measurement of the same healthy subject using conventional goniometry and the Pollexograph**

Method	*Active/Passive*	*Mean (°)*	*SD (°)*	*95% CI of Mean*
Goniometer	Active	64.5	8.5	(47.8–81.2)
Pollexograph	Active	57.7	1.4	(55.0–60.4)
Goniometer	Passive	69.1	7.2	(55.0–83.2)
Pollexograph	Passive	60.9	3.7	(53.6–68.2)

Abbreviations: CI = confidence interval; SD = standard deviations.

TABLE 2. **Mean angles, standard deviation, ranges, and reliability (SEM, SDD, and ICC) for palmar abduction measured with the Pollexograph in 21 patients with a hypoplastic thumb**

Method	*Active/Passive*	*Mean (°) ± SD*	*Range (°)*	*SEM*	*SDD*	*ICC*
Pollexograph	Active	47.5 ± 14.2	24–70	1.6	4.5	0.99
Pollexograph	Passive	50.2 ± 12.4	28–78	1.8	5.0	0.98

Abbreviations: SD = standard deviation; SEM = standard error of measurement; SDD = smallest detectable difference; ICC = intraclass correlation coefficient.

We found that mean palmar abduction in the patients (±49°) did not differ much from the mean measured in a healthy adult (±58°) and the data reported by Tubiana (40°–80°). However, more normative data measured with the more reliable Pollexograph are needed to conclude on differences between patients and controls. It is striking, however, that values in the patient group did show considerable variation (range 24°–78°) as could be expected based on clinical experience with hypoplastic thumb patients.

Pollexograph design was based on the concept that hand position should be standardized to obtain repetitive and reliable measurements. Since, palmar abduction is a motion in one plane, it should be possible to perform and accurately assess this along a smooth surface. We therefore decided to design a tool in the shape of a box with a protractor on top. It is important that the thumb can move freely, which is accomplished by marking and placing the thenar crease on the edge of the box. Since rotation during palmar abduction originates from the CMC joint, we chose to mark and align this joint. The middle distal part of the nail was then chosen as the last landmark to facilitate angle readings.

We believe that this design and these landmarks contribute to the standardization of hand position and to the reliable measurements we found.

It might be argued that results for the conventional method were poor, because therapists were not highly experienced for this method. However, inspection of the data indicated that the four therapists with experience of palmar abduction goniometric measurement did not have more reliable measurements than those of therapists with no experience. However, during measurements we noticed that several therapists had difficulty applying the conventional goniometric method, especially during passive measurements. The largest difficulty was holding the goniometer over MC1 and MC2 and simultaneously spreading the thumb in maximal abduction. With the Pollexograph, they found it easier to measure both active and passive palmar abduction and were more confident that they performed the measurement correctly. Furthermore, it can be expected that measurement reliability will only increase when examiners become more experienced with the new method.

We believe that the various definitions for palmar abduction (''conventional palmar abduction,'' ''AMA definition,'' ''IFSSH definition,'' ''ASHT definition,'' and ''Pollexograph definition'') make it possible to answer different types of clinical questions concerning range of motion of the (whole) thumb. The different definitions offer examiners the possibility to choose the definition that is clinically most informative in a specific patient. Indeed, it should be noted that Pollexograph values cannot be directly compared with conventional goniometry measurements. One reason for this difference is that the conventional method measures the angle between MC1 and MC2, whereas the Pollexograph measures orientation of the thumb relative to the palm. Measuring the orientation of the thumb relative to the palm is more in line with the recommendation of the IFSSH, defining palmar abduction as the movement in which the thumb metacarpal moves away from the index metacarpal, perpendicular to the plane of the palm.[5] A second difference between conventional palmar abduction and the Pollexograph measurement is that possible laxity in the MCP and IP joint is included in the Pollexograph measurement. A third difference may be that the second metacarpal (MC2) does not run perfectly parallel to the edge of the box. However, we believe range of motion of the thumb as a whole to be of clinical relevance and, therefore, this method justifiable. For a future study, we could assess an alteration for the Pollexograph, allowing us to measure the same angle as the conventional method by placing a ruler over the first metacarpal, reading the angle from the ruler position above the protractor.

In this study, due to its design, we were not able to calculate ICCs for interrater reliability; therefore, it was not possible to compare our reliability results with other interrater reliability studies. For the intrarater reliability in the hypoplastic thumb patients, ICCs indicated excellent reliability. The high ICCs may partly be caused by the retest being performed during the same consultation. We choose to do the retest on the same day for practical reasons; the patients were measured as part of a large measurement protocol and visited us from a large region within the Netherlands. Therefore, we did not want to burden patients with a second visit to the outpatient clinic. Another explanation for the high ICCs could be found in the fact that the range within measured angles is quite large (24°–78°), resulting in higher ICCs.

We chose to assess Pollexograph intrarater reliability in patients with a hypoplastic thumb (Blauth type II—IV), because thumbs of these patients display a large spectrum of intrinsic, extrinsic, and web space abnormalities, thereby including a wide range of thumb deformities. Some of the patients we assessed showed MCP-joint laxity during manual testing. In our opinion, active range of motion is functionally most important in these patients, and we did not see any MCP laxity during active measurements with the Pollexograph. During passive measurements, we did find MCP laxity in several patients.

We did find that to properly position patients with abnormal anatomic features is more challenging than in ''normal healthy'' subjects. We experienced this in our patient group; however, reliability does not seem to be influenced much by this. Future studies should indicate the usefulness of the Pollexograph in other patient groups with different deformities, such as patients with severe spasticity or patients with flexion contractures of the IP and MCP joints. This way one may be able to assess reliability in a group where hand positioning may be troublesome in a different manner from that in the patient population we studied.

CONCLUSION

In conclusion, these preliminary results suggest that the Pollexograph is more reliable than a conventional goniometer for measuring palmar thumb abduction. Future studies should indicate whether reliability when measured in a large group of subjects with both impaired and unimpaired thumbs would provide the same results.

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