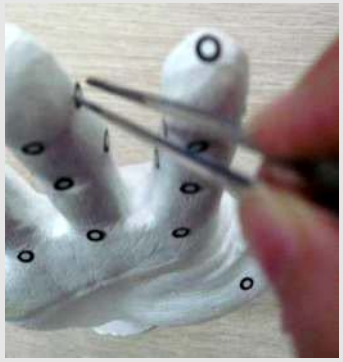
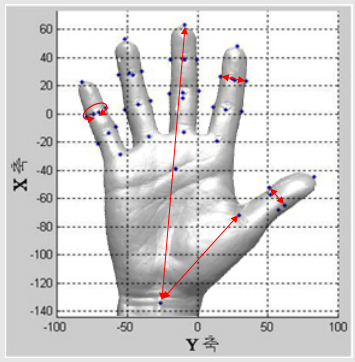
Development of a 3D Semi-Automatic Measurement Protocol (3D-SAMP) for Hand Anthropometric Measurement



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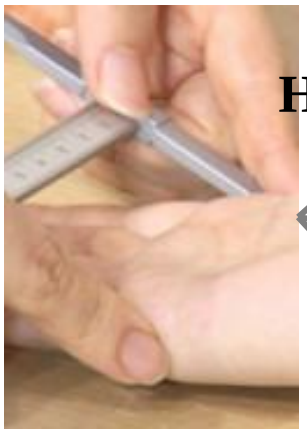
Hand Anthropometric Data in Ergonomic Design



Hand anthropometric measurements

Hand-operated devices

Wearable products

Applications

Shape of computer mouse

- Shape & size of control grip
- Location and orientation of buttons

Pattern of gloves

Benefits

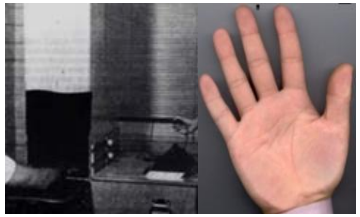
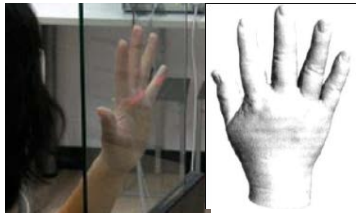
Comfortable grasp

Motion economy

Ease of control

Better grip fit

Hand Measurement Methods

Method	Measurement error		Reliability	Measurement capability	Price	Time	Ease of use	Post measurement availability
	By skin deformation	By equipment						
Direct measurement method (DMM) 	☹	☹	😐	😐 (Length, Width, Thickness, Circumference)	☺	☹	☺	☹
Photogrammetric method (PM) 	☹	😐	😐	☹ (L, W, T, ~~C~~)	😐	😐	😐	☺
3D scanning method (3D-SM) 	☹	😐	☺	☺ (L, W, T, C, Area, Volume, Shape)	☹	😐	😐	☺

Research Needs for 3D-SM

Limitations of existing studies

Improper 3D scan quality

caused by hand sway and/or use of a hand support

No evaluation of efficiency and subjective satisfaction

evaluated only accuracy and reliability

Needs

Improve 3D scan quality by minimizing hand sway and skin deformation

Evaluate not only **accuracy and reliability**, but also **time efficiency and ease of measurement**

Objectives of the Study

- **Develop a better 3D measurement protocol**
  - 3D semi-automatic measurement protocol (3D-SAMP)
  - Measurement of hand dimensions by capturing the digital image of a plaster hand

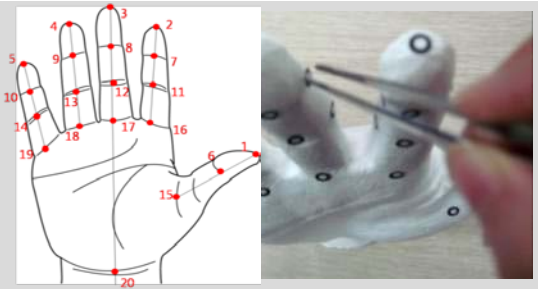
    ⇒ **better accuracy, reliability, efficiency, and usability**

- **Compare the 3D-SAMP with the conventional DMM**
  - Measurement difference
  - Intra- and inter-measurer reliabilities
  - Time efficiency
  - Subjective satisfaction

3D-SAMP Development

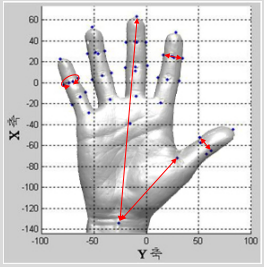
S1. Fabricating a plaster hand

S2. Landmarking the plaster hand



S3. Extracting landmarks

S4. Extracting hand measurements



3D-SAMP

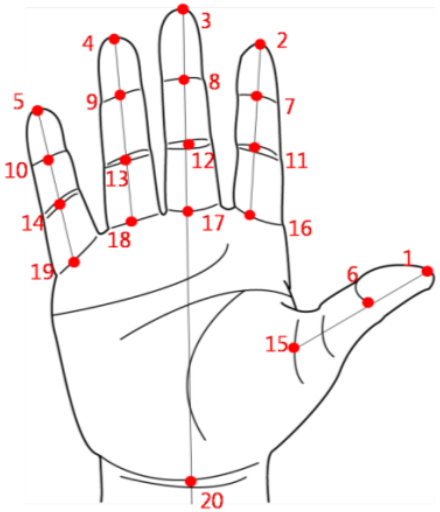
S1. Fabricating a plaster hand

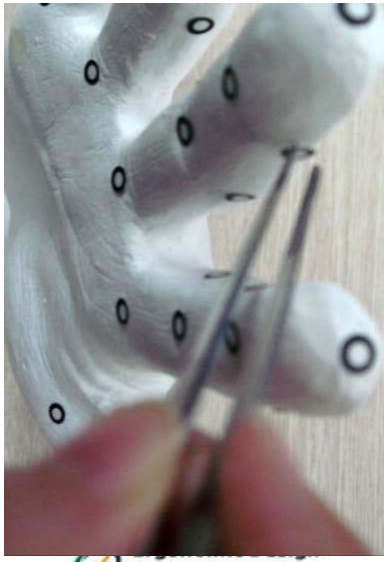
- Prevent errors due to a sway of the hand and skin deformation

⇒ Fabricate a plaster hand using alginate and plaster (< 10 min)

S2. Landmarking the plaster hand

- Attach landmark stickers on the plaster hand





3D-SAMP (cont'd)

S3. Extracting landmarks

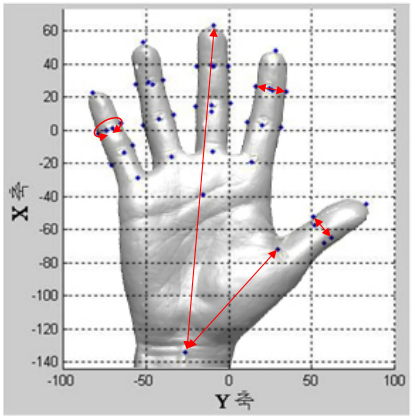
- Extract 3D landmarks automatically using a 3D scanning system (Rexcan 560 & ezScan)

S4. Extracting hand measurements

- Identify landmarks automatically and extract hand measurements using a program coded by Matlab

3D scanning of a plaster hand with markers

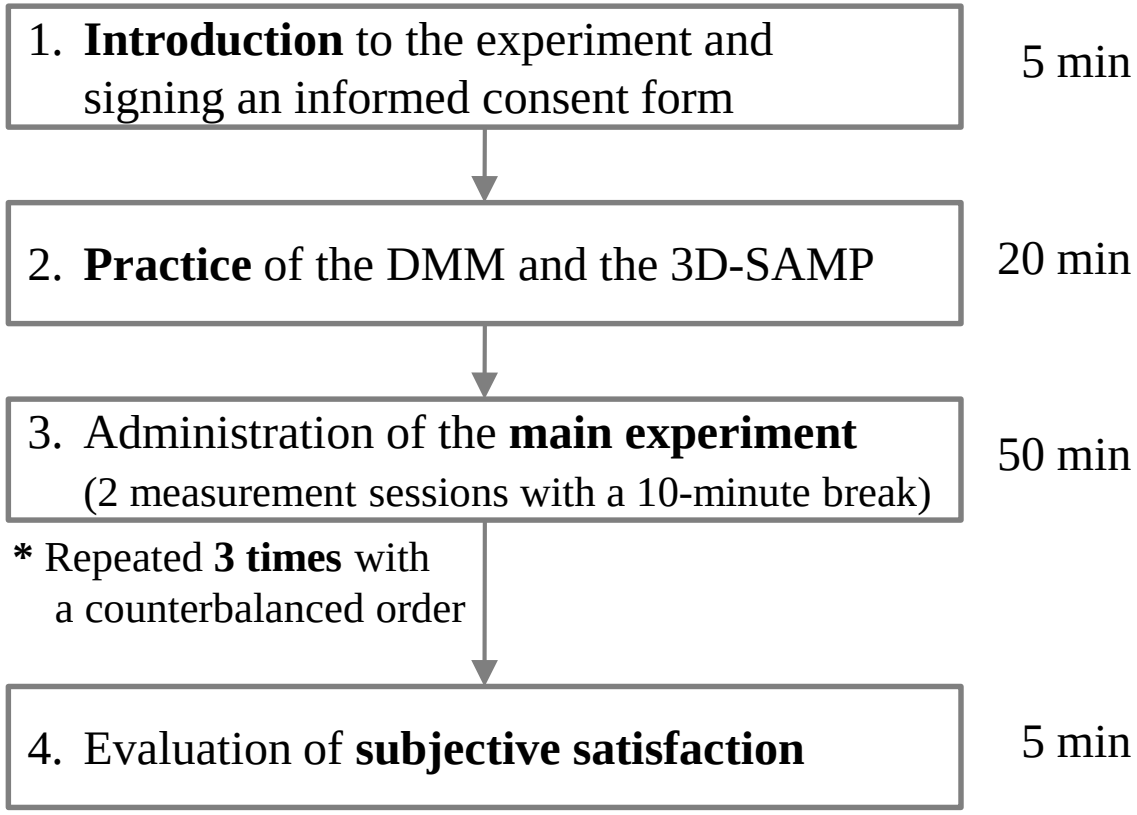
3D scanned hand data with landmarks



Automatic hand dimensions measurement

Evaluation of the 3D-SAMP

- **Participants**: 20 measurers (12 M & 8 F); age = 26 ± 2.2; no experience
- **Procedure**

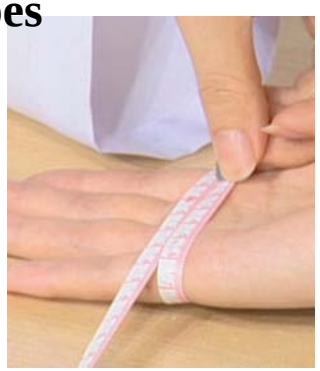


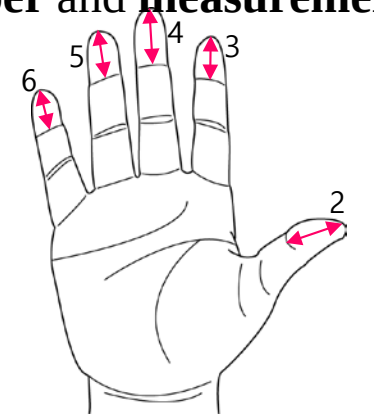
Experimental Task

- **Task**: Measurement of 52 hand dimensions using the DMM and the 3D-SAMP

DMM

Measurement of the hand dimensions using a **digital caliper** and **measurement tapes**

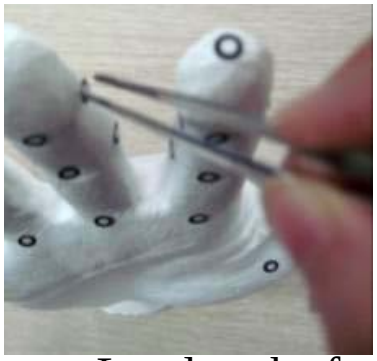


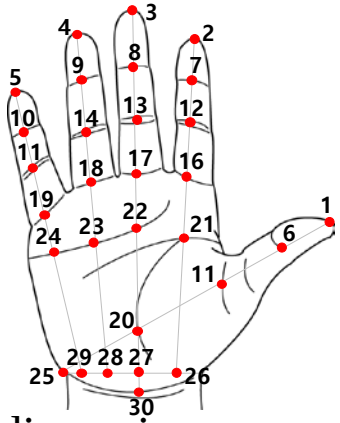


Hand dimensions

3D-SAMP

Attachment of **landmark sticker** on the plaster hand





Landmarks for dimensions

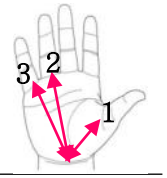
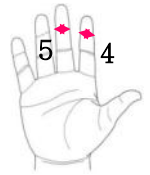
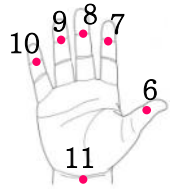
Dimension	# dimensions	# markers for 3D-SAMP
Length	27	24
Width	11	22
Thickness	7	14 (6 redundant)
Circumference	7	28 (28 redundant)
Total	52	54 (excluding redundant landmarks)

Evaluation Methods

Criteria	Metric	Test method
Measurement difference (MD)	3D-SAMP – DMM	▪ Paired *t*-test ▪ # dimensions of which |MD| > 2 mm
Reliability	Intra- and inter-measurer variabilities (SD & CV)	# dimensions of which exceed satisfactory criteria ▪ SD > 2 mm (Weinberg et al., 2005) ▪ CV > 5 % (Li et al., 2008)
Time efficiency	-	Paired *t*-test
Ease of measurement	7-point scale (1: very dissatisfied; 4: neutral; 7: very satisfied)	Paired *t*-test

Results: Measurement Difference

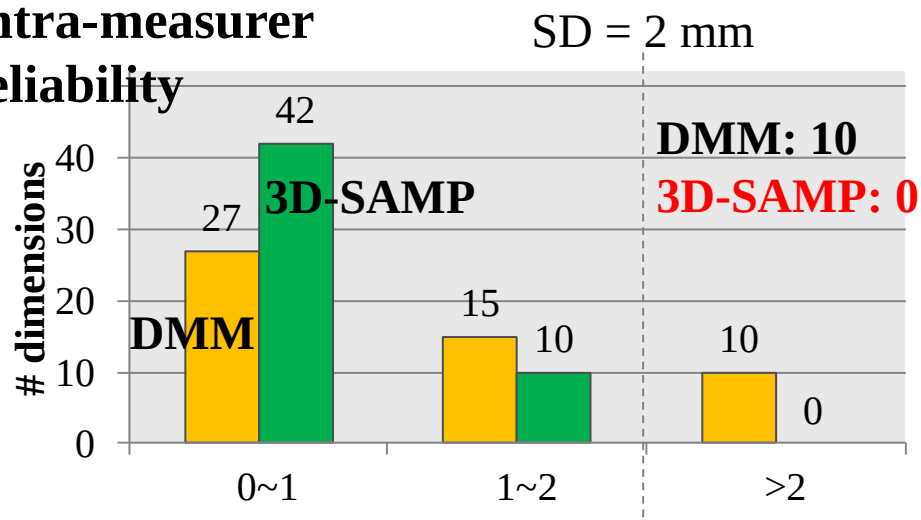
- Significantly different (α = 0.05) on 11 out of 52 hand dimensions

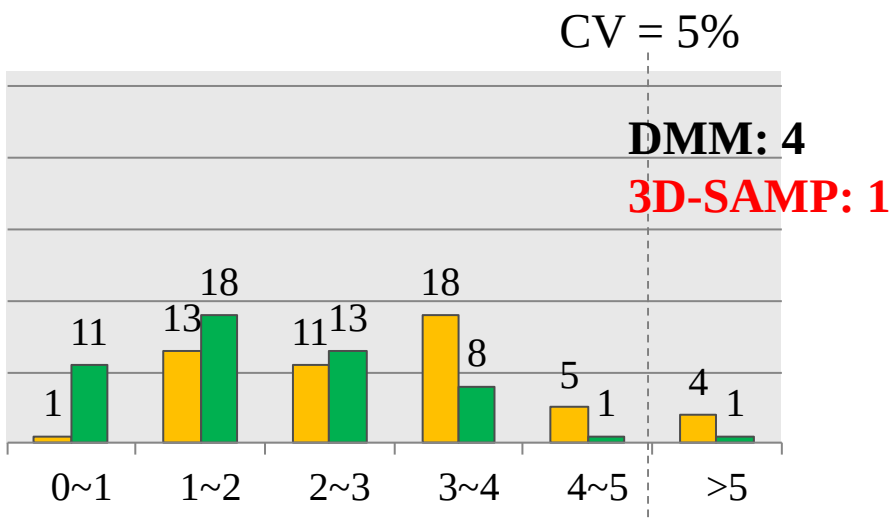
Category	# dimensions	# significantly different dimensions	No.	Dimension	Difference of Measured value (mm)	Figure
Length	27	3 (11%)	1	Base of digit 1 to wrist crease center	-2.1	
			2	Base of digit 4 to wrist crease center	-2.4	
			3	Base of digit 5 to wrist crease center	-3.5	
Width	11	2 (18%)	4	Digit 2 distal interphalangeal (DIP) joint width	2.5	
			5	Digit 3 DIP joint width	2.5	
Thickness	7	6 (86%)	6	Digit 1 DIP joint thickness	3.2	
			7	Digit 2 DIP joint thickness	2.1	
			8	Digit 3 DIP joint thickness	2.6	
			9	Digit 3 DIP joint thickness	3.1	
			10	Digit 3 DIP joint thickness	2.8	
			11	Wrist thickness	4.4	
Circumference	7	0	-	-	-	-
Total	52	11 (21%)	-	-	-	-

Results: Reliability

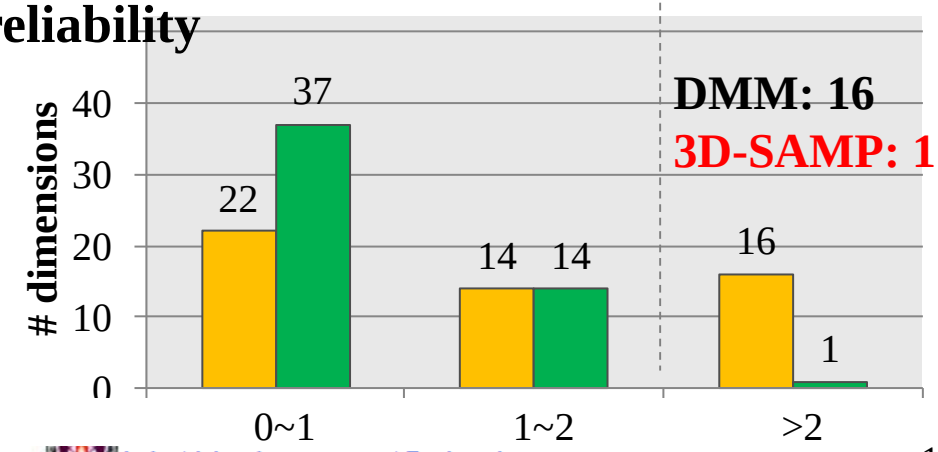
- Intra- and inter-measurer variabilities: DMM >> 3D-SAMP

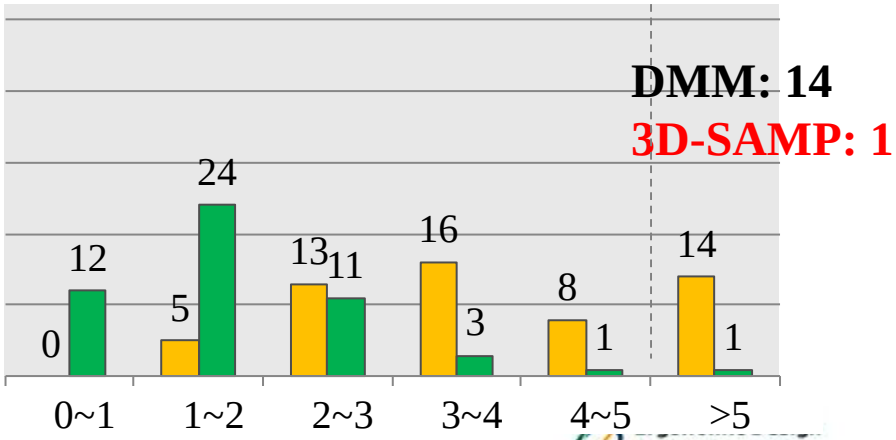
Intra-measurer reliability





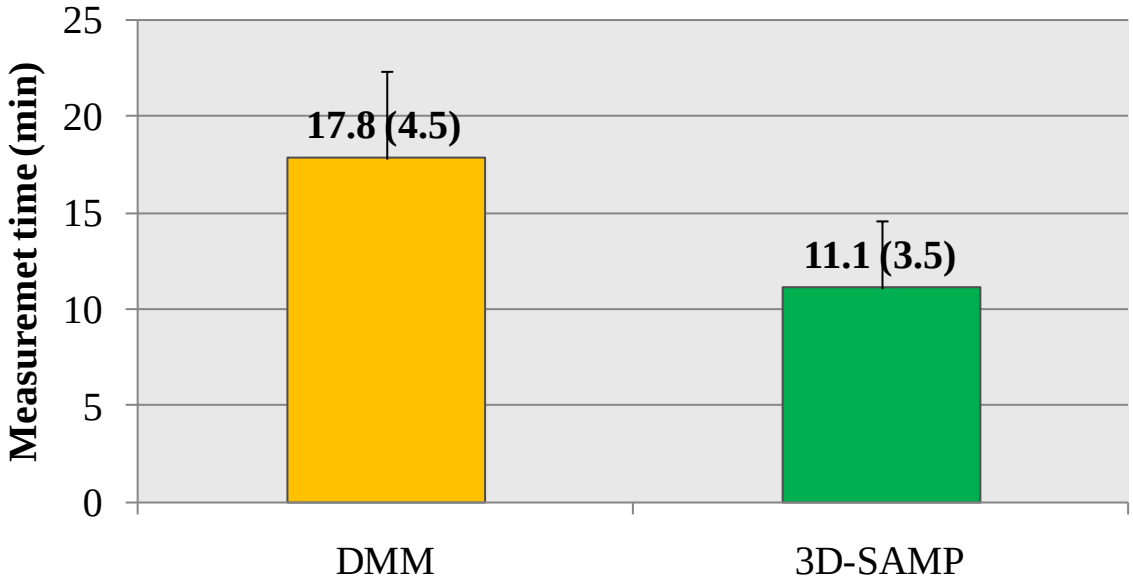
Inter-measurer reliability





Results: Time Efficiency

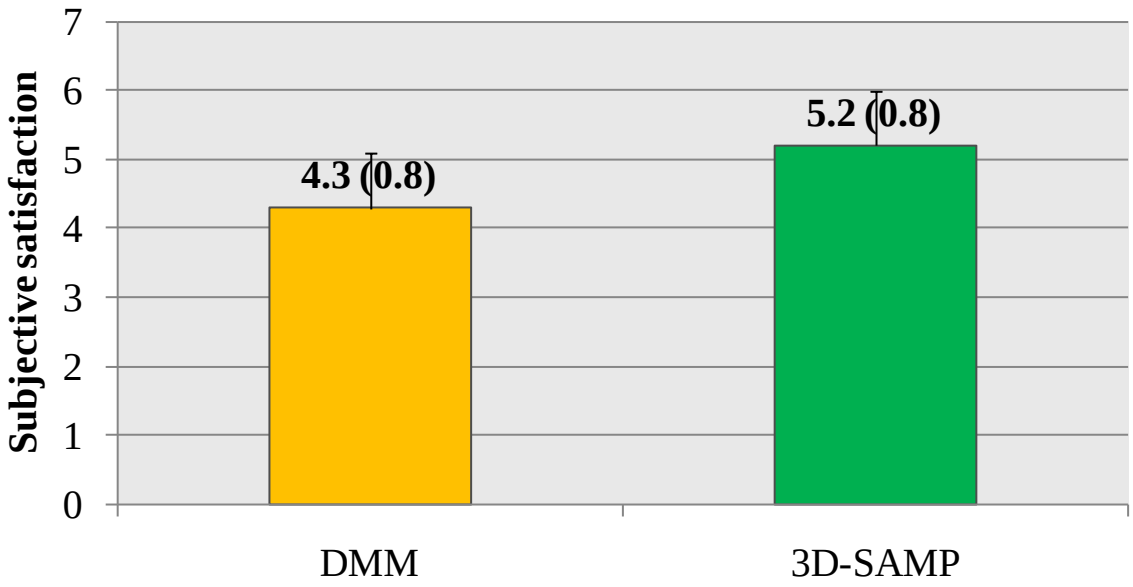
- DMM > 3D-SAMP ($t(59) = 13.23$, $p < 0.001$)



* Excluded the times of plaster hand fabrication, scanning, and post processing in the 3D-SAMP

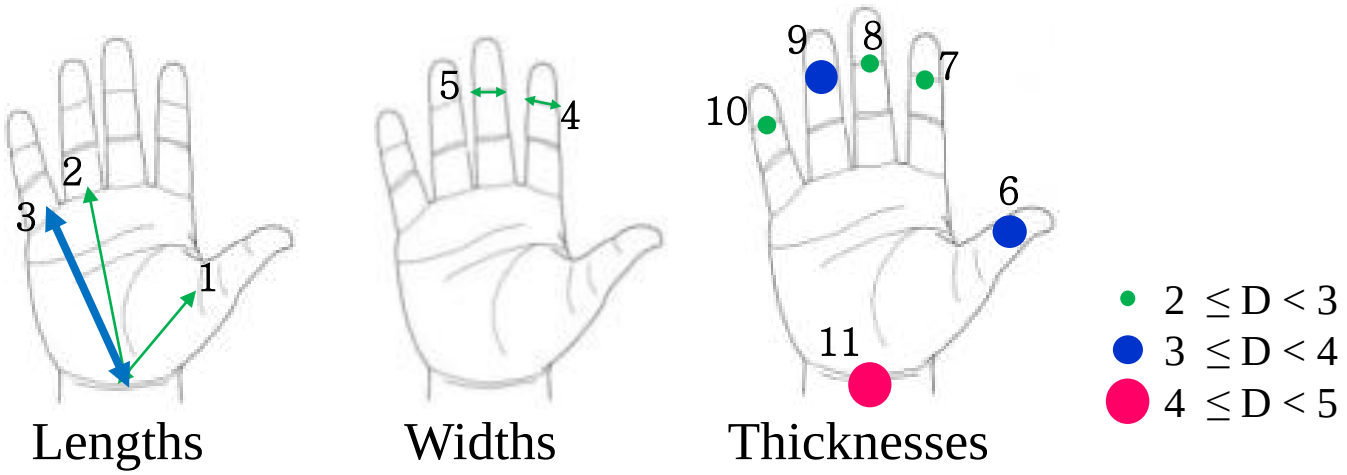
Results: Ease of measurement

- DMM < 3D-SAMP ($t(19) = 2.85$, $p = 0.01$)



Discussion

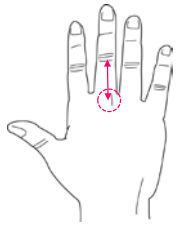
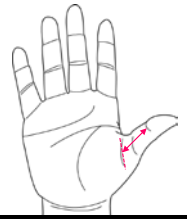
- **Measurement differences** between the DMM and 3D-SAMP were significant on 11 out of 52 dimensions
  - Cause: skin deformation in the DMM
  - **Limitation:** accuracy cannot be evaluated because the true values are unknown



Lengths Widths Thicknesses

Discussion (cont'd)

- Developed a 3D-SAMP which is **more reliable, efficient, and satisfactory** than the DMM and previous 3D measurement protocols
  - **Reliability**: out of 52 dimensions, 2 in 3D-SAMP & 24 in DMM exceeded satisfactory criteria (SD $\leq$ 2 mm, CV $\leq$ 5 %)

No.	Dimension	Figure	Cause
1	digit 3 proximal phalanx link length of dorsal		A difficulty of locating landmark on the **middle of the digit 3 knuckle**
2	digit 1 proximal phalanx link length		A difficulty of locating landmark on the **middle of the digit 1 first crease**

  - **Time**: 3D-SAMP (11.1 min) < DMM (17.8 min)
  - **Ease of measurement**: 3D-SAMP (5.2) > DMM (4.3)

Q & A

Thank you for your attention…