論文 / 著書情報
Article / Book Information

論題	
Title	Intrinsic Muscles of Human-like Robotic Hand using McKibben Actuators
著者	ｱﾊﾏﾄﾞ ｱﾃｨﾌ ﾓﾊﾏﾄﾞ ﾌｧｳｼﾞ, 鈴森康一, 大賀 淳一郎, 後藤 達彦
Author	Ahmad Athif Mohd Faudzi, Koichi Suzumori
掲載誌/書名	ロボティクス・メカトロニクス講演会2017 講演論文集, Vol. , No. 17-2, 2P1-L06(1-3)
Journal/Book name	Proceedings of the 2017 JSME Conference on Robotics and Mechatronics, Vol. , No. 17-2,　2P1-L06(1-3)
発行日 / Issue date	2017，5
URL	http://www.jsme.or.jp/publish/transact/index.html
権利情報 / Copyright	本著作物の著作権は日本機械学会に帰属します。
Note	このファイルは著者（最終）版です。 This file is author (final) version.

Intrinsic Muscles of Human-like Robotic Hand using McKibben Actuators

○ アハマドアティフモハマドファウジ (東工大, UTM)　正 鈴森康一 (東工大)
正　大賀　淳一郎（東芝）　後藤　達彦（東芝）

○ Ahmad Athif MOHD FAUDZI, Tokyo Institute of Technology and UTM, athif@utm.my
Koichi SUZUMORI, Tokyo Institute of Technology, suzumori@mes.titech.ac.jp
Junichiro OOGA, Toshiba Corporation, junichiro.ohga@toshiba.co.jp
Tatsuhiko GOTO, Toshiba Corporation, tatsuhiko.goto@toshiba.co.jp

This paper presents the intrinsic muscles of a Human-like Robotic Hand (HR-Hand), with a focus on dorsal interossei and palmar interossei muscles. Three links of palmar and four links of dorsal interossei muscles were fabricated according to human hand anatomy using 1.3 mm thin McKibben actuators. The experimental result using single index finger shows that the robotic hand could achieve palmar adduction and dorsal abduction and assist in flexion of fingers that imitate the actual function in the human hand.

Key Words: Intrinsic muscles, robotic hand, manipulation

1. Introduction

The hand has been a great tool for humans with the advantage of dexterous function and power to do daily activities [1]. The dexterous function of the hand enables humans to turn a doorknob, wear clothes, use a screwdriver and even catch balls. These dexterous hand motions are achieved due to biomechanics of hands and redundant mechanism of hand muscles. The contraction and extension of intrinsic and extrinsic muscles of hand make it possible for humans to perform these dexterous tasks. The intrinsic muscles of hands are muscles that fully contain its origin, insertion and muscle belly within the structure of hand (from wrist to carpal to finger phalanges) [2]. Extrinsic muscles, in contrast are muscles that arise outside of the hand having fleshy bellies located in the forearm, but acting on the hand structure [2].

Research on humanoid robots that imitate human drive mechanisms is currently being carried out worldwide. ACT hand is one of the early available researches that aims to replicate the human hand on anatomical level driven by DC motor [3]. The weight and size of the motor itself makes it difficult to install the intrinsic muscles at its original origin and insertion. Other developed hands that have been used include Anthropomorphic Prosthetic Hands (APH) [4], [5], while some are capable of demonstrating human levels of dexterity such as the dexterous robotic hand (DRH) for the task-based operations including KITECH hand [6] and Tachand [7], which neglect the intrinsic function of the hand.

In this paper, we propose a Human-like Robotic Hand (HR-Hand) by using McKibben actuators as in Fig. 1. The HR-Hand anatomically imitates the biomechanics of hand from the design and structure of the intrinsic and extrinsic muscles of hand to the bones, joint ligaments, tendon arrangement and the extensor hood mechanism. The development of the robotic hand is to further understand the human-hand mechanisms for possible use as an apparatus to guide in development of prosthetic and dexterous hand. The HR-Hand consists of 46 muscles with 11 intrinsic, 8 thenars and hypothenars muscles, 13 extensors and 14 flexors. In this paper, we present the palmar and dorsal interossei muscles, which are part of intrinsic muscles of hand.

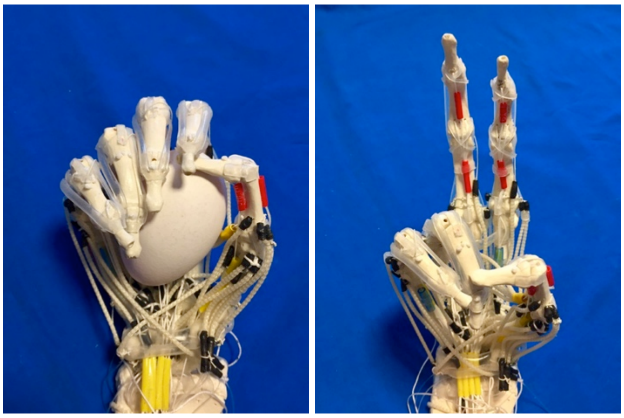

Fig. 1 HR-Hand

2. Intrinsic Muscles of HR-Hand

The intrinsic muscles shown can be divided into three groups, which are thenars eminence (groups of muscles that control little finger), hypothenar eminence (group of muscles that controls the thumb and intrinsic muscles). The intrinsic muscles consist of four lumbrical (LUM), three palmar interossei (PI) and four dorsal interossei (DI). Most of the muscles arise from the carpus or the metacarpus, and are contained in a confined space. The interossei (PI and DI) also control finger abduction and adduction, and flexion of the metacarpophalangeal (MP) joints.

All intrinsic muscles were fabricated using 1.3 mm diameter McKibben actuator. Table I displays all available intrinsic muscles and their function. Fig. 2 shows the fabricated intrinsic muscles on HR-Hand, which focused on the palmar and dorsal interossei.

Table 1: Intrinsic Muscles of HR-Hand

Group	***Abbreviation***	***Full Name***	***Function***
Thenars	OP	Opponens Policis	Flexion, abduction and medial rotation at the carpometacarpal joint
	APB	Abductor pollicis Brevis	Abduction at the carpometacarpal joint

	FPB	Flexor Pollicis Brevis	Flexion at the carpometacarpal joint
	AP	Adductor Pollicis	Adduction at the carpometacarpal joint
Hypothenars	PB	Palmaris Brevis	Protect the neurovascular pathway from compression
	ADM	Abductor Digiti Minimi	Abduction: carpometacarpal and MP joint Extension in the PIP and DIP joints
	FDM	Flexor Digiti Minimi	Flexion in the MP joint
	ODM	Opponens Digiti Minimi	Flexion, adduction and lateral rotation at the carpometacarpal joint
Intrinsics	**DI**	**Dorsal Interossei**	**First and second: radial abduction** **Third and fourth: ulnar abduction** **Together with PI: flexion in the MP joint** **Extension in the proximal and DIP joints**
	PI	**Palmar Interossei**	**Flexion, adduction and medial rotation at the carpometacarpal joint**
	LUM	Lumbricals	Abduction at the carpometacarpal joint

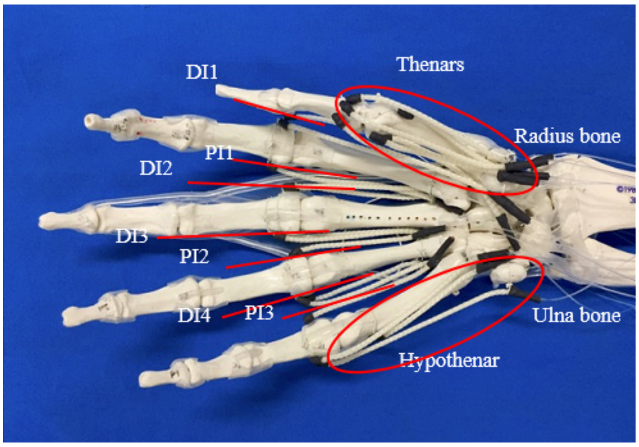

Fig. 2 Insertion and origin of dorsal and palmar interossei

Fig. 2 shows the insertion and origin of dorsal and palmar interossei for right hand. The dorsal interossei, DI1 to DI4, are originated from adjacent sides of two metacarpal bones. They are inserted at radial side of index finger, D1 radial side of middle finger, D2, ulnar side of middle finger, D3 and Ulnar side of ring finger. D1 and D2 will perform radial abduction while D3 and D4 will perform ulnar abduction. Palmar interossei originated from ulnar side of index finger, P1, radial side of ring finger, P2, and radial side of little finger, P3. Palmar interossei are inserted at dorsal aponeurosis (extensor hood) and at the base of proximal phalanx of their respective finger. The middle finger does not connect to the palmar interossei. Note that dorsal interossei is a bipennate muscle, therefore each DI1-DI4 link consists of 2 parallel muscles actuated from the same valves.

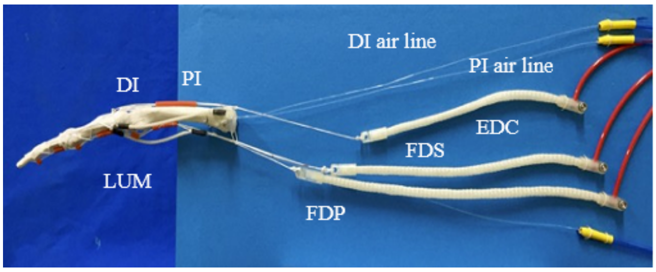

Fig. 3 Experimental setup of index finger

3. Experiment and discussion

The experiment for testing the function of the palmar and dorsal interossei muscle was conducted on an index finger. Two experiments were conducted; the first experiment is to observe the angle of abduction (ulnar deviation) and adduction (radial deviation) and the second experiment is to see the function of both interossei muscles in assisting flexion of the metacapal joint. Fig. 3 shows the experimental setup for the index finger where 6 muscles were connected with 3 intrinsic muscles, DI, PI and LUM and 3 extrinsic muscles extensor digiorium communis (EDC) for extension in metacarpal joint, flexor digitorium profundus (FDP) and flexor digitorium superficialis (FDS) for flexion in metacarpal joint.

3.1 Ulnar and radial deviation

Ulnar and radial deviation are terms that represent motion of single finger in direction towards ulnar and radial bone. On the index finger, DI1 is located on radial side whereas PI1 is located at ulnar side, which will perform radial and ulnar deviation respectively. PI is assosciated with finger adduction (motion of finger towards centre) represented by motion of PI1 in ulnar deviation, while DI1 does the abduction (motion of finger away from the centre). Fig. 4 shows the ulnar and radial deviation of the index finger. From the figure, we can see that, the angle of maximum radial deviation is larger than the ulnar deviation with 23^{o} and 16.4^{o} respectively. This follows the property of the DI1, which can abduct with bigger angle, as the space between the thumbs is larger compared to adduction, which will collide with the middle finger.

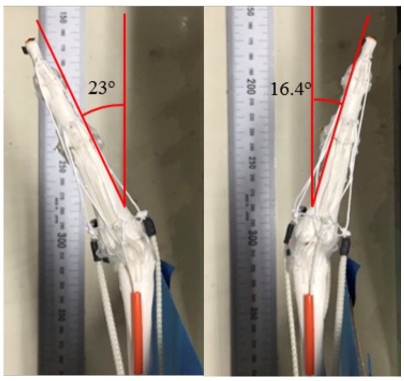

Fig. 4 Radial and ulnar deviation of index finger

3.2 Flexion of Metacarpophalangeal (MP) Joint

We conduct an experiment to identify the roles of palmar and dorsal interossei for flexion motion using the experimental setup as in Fig. 5. Each muscle was activated for the extension of the finger at the MP joint from -30^o (negative indicates extension motion) until 90^o pressure. The activated muscle pressures were recorded as in Fig. 6. From the figure, we identify that from t=5s to 10s, both PI and DI were activated to assist for norwal sweep of the hand flexion. Both PI and DI muscles extend the PIP joint while flexing the MP joint making the flexion motion moves smoother. The flexion motion is completed with the activation of FDP and FDS muscles to obtain maximum grip (complete flexion). In the case of direct activation of FDS and FDP directly after activation of EDC, the finger will exhibit claw deformity, which reduces the range of motion of the finger flexion.

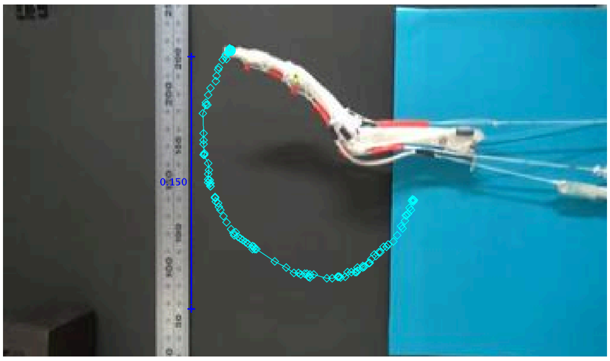

Fig. 5 Motion of index finger extension and flexion

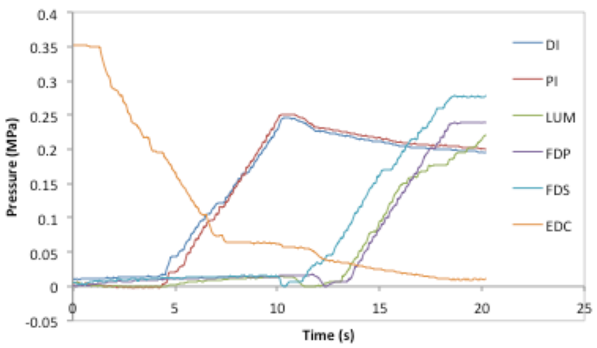

Fig. 6 Pressure reading for the muscles during normal extension and flexion

4. Conclusion

In this paper, a new "HR-Hand" applying thin McKibben actuators as intrinsic and extrinsic muscles were presented, representing a new approach in applying all actuators (muscles) of hand on the hand itself while maintaining its function. The functions of palmar and dorsal interossei, which assist in MP joint flexion and abduction-adduction motion, are highlighted with experimental evaluations. It is hoped that the development of the HR-Hand could further our understanding of the human-hand mechanisms for possible use as a medical apparatus in the future.

REFERENCES

[1] Z. Xu, Y. Matsuoka, and A. D. Deshpande, "Crocheted artificial tendons and ligaments for the anatomically correct testbed (ACT) hand," *2015 IEEE Int. Conf. Robot. Biomimetics, IEEE-ROBIO 2015*, pp. 2449–2453, 2016.

[2] "Farlex Partner Medical Dictionary," 2012. [Online]. Available: http://medical-dictionary.thefreedictionary.com/intrinsic+muscles.

[3] A. D. Deshpande, Z. Xu, M. J. Vande Weghe, B. H. Brown, J. Ko, L. Y. Chang, D. D. Wilkinson, S. M. Bidic, and Y. Matsuoka, "Mechanisms of the Anatomically Correct Testbed (ACT) Hand," *IEEE/ASME Trans. Mechatronics*, vol. 18, no. 1, pp. 1–12, 2013.

[4] I. N. A. M. Nordin, M. R. M. Razif, A. 'Athif M. Faudzi, E. Natarajan, K. Iwata, K. Suzumori, and IEEE, "3-D Finite-Element Analysis of Fiber-reinforced Soft Bending Actuator for Finger Flexion," *2013 IEEE/ASME Int. Conf. Adv. Intel. Mechatronics,*2013.

[5] C. J. Nycz, T. Bützer, O. Lambercy, J. Arata, G. S. Fischer, and R. Gassert, "Design and Characterization of a Lightweight and Fully Portable Remote Actuation System for Use With a Hand Exoskeleton," vol. 1, no. 2, pp. 976–983, 2016.

[6] D. Lee, J. Park, S. Park, M. Baeg, and J. Bae, "KITECH-Hand : A Highly Dexterous and Modularized Robotic Hand," vol. 4435, no. c, pp. 1–11, 2016.

[7] M. Ludersdorfer, "TacHand : A Tactile Robotic Hand with In-Hand Manipulation Capabilities," 2014.