Distribution of Nerve Endings in Human Distal Interphalangeal Joint and Surrounding Structures

1, 2Chikenji, T; +1Berger, R A; 2Fujimiya, M; 2Suzuki, D; 2Tsubota, S; 2An, K N
+1Biomechanics Laboratory, Division of Orthopedic Research, Mayo Clinic, Rochester, MN, 2Sapporo Medical University, Sapporo, Japan
Berger.Richard@mayo.edu

INTRODUCTION

Encapsulated nerve endings called mechanoreceptors are end components of afferent inflows and react to mechanical stimuli. Mechanoreceptors in periarticular tissues have been classified into three types: Type 1, Ruffini-like endings; Type 2, Pacini-like endings; Type 3, Golgi-like endings. It is however not known which type of the mechanoreceptors in periarticular tissues contribute to proprioceptive sensibility and to modulation of protective muscle responses. In our previous study, the distribution of mechanoreceptors in the human proximal interphalangeal (PIP) joint and surrounding structures have been extensively examined. The results showed that the C1 pulley, accessory collateral ligament and volar plate might relate to sensory function of the finger.

In the human finger pulley system, annular pulleys are important to restrain bowstring of the flexor tendon and permit excursion of the tendon smoothly during finger flexion. The cruciate pulley has been believed unlikely to serve a major mechanical function.

The distal interphalangeal (DIP) joints and PIP joints have a similar anatomy and pulley system. Our objective was to quantitatively analyze the distribution of the mechanoreceptors in the human DIP joint and surrounding structures, in order to provide a new function of the cruciate pulley and better understanding of the well-integrated sensory-motor systems in the human fingers.

METHODS

We processed twelve right index finger DIP joints and surrounding structures from fresh frozen cadavers (mean 85yrs, range, 73-96) for immunohistochemistry of the anti-protein gene product 9.5 (PGP9.5) and silver staining to detect encapsulated nerve endings. Serial transverse sections were cut throughout the whole specimen and divided into three regions along the longitudinal axis: distal, middle and proximal (Fig. 1A). Each of the transverse sections was partitioned into dorsal capsule (DC), radial capsule (RC), ulnar capsule (UC), volar plate (VP), and radial and ulnar assemblage nuclei (RAN and UAN) (Fig. 1A and B); the RAN and UAN are located on both the radial and ulnar side of the VP. The C3 pulley contained the proximal region of the RAN and UAN, while the A5 pulley contained the middle and distal. The accessory collateral ligament contained all the regions of the RAN and UAN. Density of encapsulated nerve endings (numbers/μm²) were analyzed and compared between the 18 different regions with one-way ANOVA and Tukey post-hoc test (α=.05) to each longitudinal and transverse plane.

RESULTS

Type 1 (Fig. 2) and type 2 nerve endings (Fig. 3) were identified in the human DIP joint, but no type 3 endings were identified. The density of type 1 nerve endings was not statistically significant (Fig. 4A). The density of type 2 nerve endings in the proximal region of the RAN and UAN was significantly higher than that in the proximal region of the VP (p<.0005), RC (p<.0005), UC (p<.0005) and DC (p<.0005), and than that in the proximal region of the VP (p<.0005), UC (p<.0005) and DC (p<.0005), respectively (Fig. 4B).

DISCUSSION

In the present study, the type II nerve endings were notably distributed in both the proximal RAN and the UAN in the DIP joint and surrounding structures. The proximal RAN and UAN contained C3 pulley, radial and ulnar accessory collateral ligaments in the DIP joint and surrounding structures. Our results suggested that the C3 pulley, radial and ulnar accessory ligaments may act as a sensory generator that transmits a traction force to the radial and ulnar assemblage nuclei, because type II nerve endings were densely distributed in these regions.

In our previous study, the type II nerve endings in PIP joints have been substantially distributed in the proximal RAN and UAN which contained C1 pulley, radial and ulnar accessory collateral ligaments. Our present and previous study suggested that cruciate pulley might relate to a sensory function in the finger pulley system.

Fig. 1: A) Radial oblique view of the DIP joint. The DIP joint was divided into distal, middle and proximal regions along the longitudinal axis. C3, C3 pulley; VP, Volar plate; A5, A5 pulley; RACL, Radial accessory collateral ligament; RCL, Radial collateral ligament; MP, Middle phalanx; DP, Distal phalanx. B) Six regions of the transverse section. UAN, Ulnar assemblage nucleus; VP, Volar plate; RAN, Radial assemblage nucleus; RC, Radial capsule; UC, Ulnar capsule; DC, Dorsal capsule; FDP, Flexor digitorum profundus.

Fig. 2: A) PGP9.5-positive type 1 nerve endings was found in the VP. A') Higher magnification of the area enclosed by the rectangle in A.

Fig. 3: A) Silver-stained section (x5). A') Higher magnification of the area enclosed by the rectangle (RAN) in A. Aggregation of type 2 nerve endings in RAN. B) Silver-stained type 2 nerve ending.

Fig. 4: Comparison of the density of type 1 nerve endings (A, n=6) and the density of type 2 nerve endings (B, n=6). ** p < 0.01