International Scholars Journals

International Journal of Anatomy and Physiology ISSN 2326-7275 Vol. 15 (11), pp. 001-006, November, 2026. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Author(s) retain the copyright of this article.

Full Length Research Paper

Electromyographic and Morphological Evaluation of the Palmaris Longus Muscle Variant and Its Association with Median Nerve Compression

R. E. Dubois, S. M. Patel, O. A. Sanusi*

Department of Anatomy, Faculty of Medicine, Sorbonne University, Paris, France.
Department of Radiology, All India Institute of Medical Sciences, New Delhi, India.
Department of Anatomy, Faculty of Basic Medical Sciences, College of Medicine, University of Ibadan, Ibadan, Nigeria.

Accepted November 05, 2026 • Received September 02, 2026 • Revised October 18, 2026 • Published November 26, 2026 • DOI: 10.46882/2026/IJAP/001028

ABSTRACT

The palmaris longus muscle is a superficial flexor of the forearm known for its high rate of evolutionary agenesis and structural variations, including duplicated, reversed, or hypertrophied muscle bellies. These muscular anomalies can reduce the available space within the proximal forearm and carpal tunnel, compressing the median nerve. This study combined cadaveric dissection and surface electromyography (sEMG) to examine the morphological variations of the palmaris longus and evaluate their functional association with median nerve compression. Dissection of 100 formalin-fixed upper limbs revealed palmaris longus variants in 6 extremities (6.0%). A reversed palmaris longus (muscle belly located distally near the wrist) was identified in 2 limbs (2.0%). In the clinical phase, eight symptomatic patients diagnosed with a reversed or hypertrophied palmaris longus via musculoskeletal ultrasound underwent sEMG and nerve conduction velocity (NCV) testing. The sEMG evaluation during sustained grip tasks demonstrated a high root-mean-square (RMS) voltage over the anomalous muscle distal belly, which correlated with a significant reduction in median nerve sensory conduction velocity across the wrist joint (38.5 ± 3.4 m/s vs. 54.2 ± 4.1 m/s in normal controls; $p < 0.01$). These anatomical and neurophysiological findings demonstrate that structural palmaris longus variants can cause mechanical median nerve entrapment, and should be considered in the differential diagnosis of atypical carpal tunnel syndrome.

Key words: *Palmaris longus muscle, Anatomical variant, Median nerve compression, Carpal tunnel syndrome, Electromyography.*

***Corresponding author.** Department of Anatomy, Faculty of Basic Medical Sciences, College of Medicine, University of Ibadan, Ibadan, Nigeria.

INTRODUCTION

The palmaris longus (PL) muscle is a slender, spindle-shaped muscle situated within the superficial flexor compartment of the anterior forearm. In its classical anatomical configuration, the muscle arises from the medial epicondyle of the humerus via the common flexor tendon, as well as from the adjacent intermuscular septa and the antebrachial fascia. It courses distally as a short, fusiform proximal muscle belly that transitions into a long, flattened tendon in the middle third of the forearm. This tendon passes superficial to the flexor retinaculum (transverse carpal ligament) at the wrist and inserts distally into the central apex of the palmar aponeurosis, with occasional fibrous slips extending toward the thenar and hypothenar fasciae. Innervated by the median nerve (C7, C8) and supplied primarily by branches of the anterior ulnar recurrent artery, the palmaris longus acts as a weak accessory flexor of the radiocarpal joint and contributes to tensing the palmar aponeurosis during manual grasping.

Phylogenetically, the palmaris longus is widely recognized as a retrogressive muscle undergoing evolutionary degeneration in primates and humans. In quadrupedal mammals, the muscle functions as an active flexor of the manus and plays a vital role in weight-bearing locomotion and claw retraction. As hominids transitioned to bipedalism and developed refined prehensile hand dexterity, the mechanical demand on the superficial palmar flexor diminished substantially, resulting in a progressive reduction in muscle belly length and a reciprocal elongation of its distal tendon. Because of its minimal functional contribution to grip strength and wrist flexion — and its superficial, easily accessible anatomical trajectory — the palmaris longus tendon is routinely harvested by reconstructive, orthopedic, and plastic surgeons as an autologous graft for tendon transfers, ligament reconstructions, ptosis correction, and facial reanimation procedures.

Despite its surgical utility, the palmaris longus exhibits one of the highest rates of anatomical variability among all muscles in the human musculoskeletal system. The most extensively documented anomaly is complete agenesis, which demonstrates substantial ethnic and geographic variation. Unilateral or bilateral absence occurs in approximately 15% to 25% of Caucasian populations, whereas prevalence rates are markedly lower in East Asian, Sub-Saharan African, and Indigenous American cohorts, typically ranging between 2% and 10%. Beyond agenesis, structural and morphological

variants occur in roughly 5% to 9% of limbs and encompass a broad spectrum of architectural phenotypes. These include the reversed palmaris longus (palmaris longus inversus), in which a proximal tendon originates from the medial epicondyle and transitions into a muscular belly situated in the distal forearm; duplicated or biventer (digastric) muscles; central-belly variants featuring tendons at both ends; bifid or trifid distal tendons; accessory muscular slips; and the rare palmaris profundus, whose tendon courses deep to the flexor retinaculum alongside the median nerve within the carpal tunnel.

The clinical significance of structural palmaris longus variations lies in their intimate topographical relationship with the median and ulnar nerves at the distal forearm and wrist. In normal anatomy, the median nerve lies deep to the flexor digitorum superficialis in the forearm and emerges between the tendons of the flexor carpi radialis and palmaris longus approximately 3 to 5 cm proximal to the distal wrist crease before entering the carpal tunnel. When a structural anomaly — such as a reversed distal muscle belly, an accessory slip, or a hypertrophied muscle mass — occupies the restricted osteofibrous space of the distal antebrachium, it alters local compartmental biomechanics. During repetitive wrist flexion, grasping, or occupational manual labor, contraction and vascular engorgement of an ectopic muscle belly exert direct mechanical pressure against the underlying median nerve or compress the roof of the carpal tunnel.

Clinically, this dynamic mechanical compression frequently manifests as activity-induced median neuropathy, exerting symptoms that mimic idiopathic carpal tunnel syndrome (CTS). Patients typically present with volar wrist swelling, exertion-related aching in the distal forearm, and paresthesia or numbness along the palmar distribution of the lateral three and a half digits. However, because the compression is often dynamic and triggered by muscular contraction rather than static space-occupying pathology, standard resting electrodiagnostic assessments and classical provocative maneuvers — such as Phalen's test and Tinel's sign — frequently yield false-negative or equivocal results. Failure to recognize an underlying muscular variant prior to surgical intervention can result in incomplete decompression, persistent postoperative symptoms, or iatrogenic injury to the median nerve during routine carpal tunnel release.

While numerous isolated case reports and purely anatomical cadaveric surveys have described palmaris longus anomalies, few investigations have integrated macroscopic cadaveric morphometry with dynamic functional neurophysiology in living symptomatic subjects. Specifically, the quantitative relationship between the myoelectric recruitment of an anomalous distal muscle belly during sustained grip tasks and acute changes in median nerve conduction velocity remains underexplored. Therefore, the present study was designed with a dual objective: first, to determine the prevalence and precise morphometric characteristics of structural palmaris longus variants in a large sample of formalin-fixed cadaveric upper limbs; and second, to evaluate the functional neuromuscular activity of reversed and hypertrophied palmaris longus variants using surface electromyography (sEMG) and nerve conduction velocity (NCV) testing in symptomatic patients.

MATERIALS AND METHODS

Study design and ethical considerations

This investigation employed a two-phase, cross-sectional observational design integrating a descriptive cadaveric anatomical survey (Phase I) with a prospective clinical neurophysiological case-control evaluation (Phase II). All cadaveric procedures were conducted in accordance with institutional ethical guidelines governing anatomical donation and biomedical research, utilizing embalmed human specimens donated for medical education and scientific inquiry. For the clinical phase, ethical approval was obtained from the institutional human research ethics review boards prior to participant recruitment. All clinical participants and healthy control volunteers provided written informed consent after receiving a detailed explanation of the sonographic and electrodiagnostic protocols.

Phase I: Cadaveric dissection and morphometric protocol

A total of 100 formalin-fixed human upper extremities (50 right and 50 left limbs) obtained from 50 adult cadavers (28 males and 22 females; age at death ranging from 44 to 86 years, mean 67.4 ± 11.2 years) were examined across the participating anatomical laboratories. Specimens exhibiting gross traumatic deformities, previous surgical scars over the volar forearm or wrist, advanced degenerative contractures, or pathological soft-tissue lesions were excluded prior to dissection.

Each upper limb was positioned in full supination with the elbow extended and the wrist in a neutral anatomical alignment (0° flexion/extension). A longitudinal midline skin incision was made along the anterior aspect of the forearm extending from the medial epicondyle of the humerus to the central palm, supplemented by transverse incisions at the cubital fossa and the distal palmar crease. Following reflection of the skin and subcutaneous adipose tissue, the antebrachial fascia was carefully incised and reflected to expose the superficial flexor compartment.

The palmaris longus muscle was identified and meticulously traced from its proximal attachment at the medial epicondyle to its distal insertion into the palmar aponeurosis or adjacent wrist structures. When present, the anatomical morphology of each specimen was classified as: (1) Classical (Normal) Morphology: proximal fusiform muscle belly transitioning to a long distal tendon inserting into the palmar aponeurosis; (2) Agenesis: complete absence of both muscular and tendinous components; (3) Reversed Palmaris Longus (Inversus): proximal tendon arising from the medial epicondyle transitioning into a distal muscle belly located in the lower third of the forearm; (4) Duplicated or Biventer Variant: presence of two distinct muscle bellies (either parallel or arranged in series with an intermediate tendon); (5) Accessory or Bifid Tendon Variant: splitting of the distal tendon into multiple slips inserting into the flexor retinaculum, pisiform, scaphoid, or hypothenar fascia.

Using calibrated digital Vernier calipers (accuracy ±0.01 mm), the following morphometric parameters were recorded in triplicate by two independent anatomists and averaged: total musculotendinous length (from the medial epicondyle to the distal wrist crease), maximum length of the muscle belly, length of the proximal and/or distal tendinous segments, maximum transverse width and anteroposterior thickness of the muscle belly, and the perpendicular distance from the distal margin of the muscle belly to the proximal border of the flexor retinaculum. Furthermore, the precise topographical relationship between the palmaris longus variant and the underlying median nerve was documented, including the exact level at which the nerve crossed deep to the muscular or tendinous fibers.

Phase II: Clinical cohort and musculoskeletal ultrasound

In the clinical phase, eight symptomatic patients (5 females, 3 males; mean age 34.8 ± 7.6 years, range 24–47 years) presenting to outpatient orthopedic and neurology clinics with unilateral activity-induced volar wrist pain, distal forearm swelling, and intermittent paresthesia in the median nerve distribution were prospectively enrolled. Eight age- and sex-matched healthy volunteers (5 females, 3 males; mean age 33.9 ± 6.8 years) with normal classical palmaris longus anatomy and no history of upper extremity neuropathy, systemic

metabolic disease (e.g., diabetes mellitus, hypothyroidism), or cervical radiculopathy served as the control group.

Prior to electrodiagnostic testing, all symptomatic patients and control subjects underwent high-resolution musculoskeletal ultrasonography (MSK-US) of the anterior forearm and carpal tunnel using a linear-array transducer (12–18 MHz). Subjects were examined seated with the forearm supinated and resting comfortably on an examination table. Transverse and longitudinal sonograms were acquired from the proximal forearm to the distal carpal tunnel to confirm the presence, orientation, and cross-sectional area (CSA) of the palmaris longus muscle belly, as well as to evaluate the CSA of the median nerve at the carpal tunnel inlet (pisiform level). Dynamic sonographic scanning was performed during active wrist flexion and finger gripping to observe real-time mechanical displacement or flattening of the median nerve beneath the anomalous muscle belly.

Surface electromyography (sEMG) and nerve conduction velocity (NCV)

Neurophysiological assessments were performed in a temperature-controlled clinical laboratory (ambient temperature maintained at 24°C–25°C, with palmar skin temperature verified at ≥32°C prior to testing). To quantify the myoelectric recruitment of the palmaris longus muscle during functional loading, bipolar Ag/AgCl surface electrodes (10 mm diameter, 20 mm inter-electrode distance) were placed over the distal third of the anterior forearm directly overlying the sonographically mapped anomalous muscle belly in patients, and over the proximal muscle belly (and corresponding distal forearm surface landmark) in healthy controls. Skin impedance was reduced below 5 kΩ using gentle abrasion and isopropyl alcohol cleansing. A reference ground electrode was secured over the lateral epicondyle of the humerus.

Participants performed a standardized isometric sustained grip task using a calibrated handgrip dynamometer set at 50% of their predetermined maximum voluntary contraction (MVC) for three trials of 10 seconds each, separated by 60-second rest intervals to prevent neuromuscular fatigue. Raw sEMG signals were sampled at 2,000 Hz, band-pass filtered between 20 Hz and 450 Hz, and full-wave rectified. The root-mean-square (RMS) voltage amplitude (μV) was computed over the middle 5-second steady-state epoch of each sustained contraction and averaged across trials.

Standardized orthodromic and antidromic median nerve conduction studies were conducted immediately following the sustained grip protocol to capture post-exertional neurophysiological changes. Median sensory nerve conduction velocity (SNCV) across the wrist was measured antidromically by stimulating the median nerve 14 cm proximal to the active ring recording electrode placed over the proximal interphalangeal joint of the index finger (digit II), with the reference electrode positioned 3 cm distally. Median motor distal latency (MDL) and compound muscle action potential (CMAP) amplitude were recorded from the abductor pollicis brevis (APB) muscle following supramaximal stimulation at the wrist (8 cm proximal to the active electrode) and at the antecubital fossa. Ulnar sensory and motor conduction parameters were simultaneously evaluated to exclude generalized peripheral polyneuropathy.

Statistical analysis

Data were analyzed using SPSS statistical software (Version 28.0, IBM Corp., Armonk, NY, USA). Continuous morphometric and neurophysiological variables were tested for normality using the Shapiro-Wilk test and are expressed as mean ± standard deviation (SD). Categorical frequencies are presented as counts and percentages. Differences in sEMG RMS voltage, median nerve SNCV, MDL, and sonographic median nerve CSA between the symptomatic variant group and healthy controls were evaluated using independent-samples Student's t-tests (or Mann-Whitney U tests for non-parametric distributions). Pearson's correlation coefficient (r) was calculated to assess the linear relationship between distal sEMG RMS amplitude and median nerve sensory conduction velocity. A two-tailed p-value < 0.05 was established as the threshold for statistical significance, with $p < 0.01$ denoting high significance.

RESULTS

Cadaveric prevalence and morphological variants

Out of the 100 formalin-fixed upper extremities dissected in Phase I, the palmaris longus muscle was present in 91 limbs (91.0%) and completely absent (agenesis) in 9 limbs (9.0%). Among the limbs exhibiting agenesis, bilateral absence was observed in 3 cadavers (6 limbs, 6.0%), whereas unilateral absence occurred in 3 cadavers (3 limbs, 3.0%: 2 left, 1 right).

Of the 91 extremities possessing a palmaris longus muscle, classical anatomical architecture — characterized by a proximal muscular belly arising from the medial epicondyle and a slender distal tendon inserting into the palmar aponeurosis — was identified in 85 limbs (85.0% of total limbs; 93.4% of present muscles). Distinct structural variations of the palmaris longus were identified in 6 extremities (6.0% of all dissected limbs; 6.6% of present muscles). No statistically significant difference in variant prevalence was noted between right and left extremities (4 right vs. 2 left; $p = 0.41$) or between male and female specimens ($p = 0.68$).

1. Reversed Palmaris Longus (n = 2; 2.0%): Both specimens were unilateral and observed in right forearms. Each exhibited a slender proximal tendon measuring 114.2 ± 6.8 mm originating from the medial epicondyle, which transitioned in the middle third of the forearm into a robust, fusiform distal muscle belly measuring 128.6 ± 9.4 mm in length, 18.4 ± 1.7 mm in maximum width, and 8.9 ± 1.1 mm in thickness. The distal muscle belly terminated directly at the proximal border of the flexor retinaculum (mean distance 2.1 ± 0.8 mm proximal to the wrist crease), completely covering the median nerve prior to its entry into the carpal tunnel. In one specimen, the median nerve demonstrated visible macroscopic flattening directly beneath the widest portion of the reversed muscle belly.

2. Duplicated / Biventer Palmaris Longus (n = 2; 2.0%): One right and one left specimen displayed a parallel duplication featuring a normal primary palmaris longus alongside an accessory medial slip. The accessory belly originated from the antebrachial fascia in the mid-forearm, measured 94.5 ± 5.2 mm in length and 12.1 ± 1.4 mm in width, and inserted via a short tendon into the flexor retinaculum and pisiform bone. This accessory belly encroached directly upon the ulnar aspect of the median nerve within the distal forearm space.

3. Hypertrophied / Extended Belly (n = 1; 1.0%): A single right specimen demonstrated an unusually long and bulky muscle belly (length 218.0 mm, width 21.5 mm, thickness 10.4 mm) extending uninterrupted from the medial epicondyle to within 4.5 mm of the transverse carpal ligament, leaving only a 14.0 mm distal tendinous segment.

4. Bifid Distal Tendon (n = 1; 1.0%): A left specimen demonstrated a normal proximal muscle belly whose distal tendon bifurcated 38.0 mm proximal to the wrist crease into a radial slip inserting into the palmar aponeurosis and an ulnar slip merging with the flexor retinaculum.

Table 1. Distribution, laterality, and anatomical relationship to the median nerve (MN) of palmaris longus phenotypes across 100 dissected cadaveric upper limbs.

Morphological Classification	Number (n = 100)	%	Laterality (R / L)	Relationship to Median Nerve (MN)

Classical (Normal) Morphology	85	85.0%	42 / 43	Tendon crosses superficial to MN ~32 mm proximal to wrist crease
Complete Agenesis	9	9.0%	4 / 5	No muscular or tendinous structure present
Reversed Palmaris Longus	2	2.0%	2 / 0	Distal muscle belly directly overlies and compresses MN proximal to flexor retinaculum
Duplicated (Biventer) Variant	2	2.0%	1 / 1	Accessory distal belly lies immediately ulnar and anterior to MN at distal forearm
Hypertrophied / Extended Belly	1	1.0%	1 / 0	Muscle fibers extend distally to proximal margin of transverse carpal ligament
Bifid Distal Tendon	1	1.0%	0 / 1	Dual tendinous slips straddle the MN superficial to flexor retinaculum

Sonographic findings in the clinical cohort

High-resolution MSK-US successfully characterized the underlying muscular architecture in all eight symptomatic patients in Phase II. Six patients (75.0%) exhibited a unilateral reversed palmaris longus characterized by a hyperechoic proximal tendon and a prominent, hypoechoic striated muscle belly occupying the distal volar forearm immediately superficial to the median nerve. The remaining two patients (25.0%) presented with a markedly hypertrophied, distally extended palmaris longus muscle belly terminating at the carpal tunnel inlet.

On transverse sonograms at the distal forearm, the mean cross-sectional area of the anomalous distal muscle belly in patients was 1.84 ± 0.36 cm², whereas healthy controls demonstrated only a thin, hyperechoic fibrillar tendon (CSA 0.11 ± 0.03 cm²; $p < 0.001$) at the identical anatomical level. Furthermore, the median nerve CSA at the carpal tunnel inlet was significantly enlarged in symptomatic patients compared to controls (13.8 ± 1.9 mm² vs. 8.4 ± 1.1 mm²; $p < 0.001$), accompanied by localized hypoechoic neural edema proximal to the variant belly. Dynamic ultrasound imaging during active sustained gripping confirmed anterior-to-posterior bulging of the variant muscle belly, which produced measurable anteroposterior flattening of the underlying median nerve against the flexor digitorum superficialis tendons.

sEMG and NCV outcomes

During the 50% MVC sustained isometric grip task, surface electromyography revealed intense myoelectric recruitment over the distal volar forearm in all eight symptomatic patients. The mean sEMG root-mean-square (RMS) voltage recorded over the anomalous distal muscle belly was markedly elevated at 186.4 ± 24.8 µV, compared to a baseline minimal volume-conducted signal of 34.2 ± 8.6 µV over the distal tendinous region in healthy control subjects ($p < 0.001$). Notably, the distal RMS amplitude in symptomatic patients was comparable to the myoelectric activity recorded over the proximal muscle belly in healthy controls (179.8 ± 21.5 µV; $p = 0.56$), confirming active contractile engagement of the ectopic distal muscle fibers during sustained manual gripping.

Post-exertional nerve conduction studies demonstrated pronounced focal slowing of median nerve sensory conduction across the wrist joint in the variant group. The mean median sensory nerve conduction velocity (SNCV) in symptomatic patients was 38.5 ± 3.4 m/s, representing a statistically significant reduction compared to 54.2 ± 4.1 m/s in healthy controls ($p < 0.01$). Median motor distal latency (MDL) was also significantly prolonged in the patient cohort relative to controls (4.62 ± 0.48 ms vs. 3.38 ± 0.31 ms; $p < 0.01$), whereas compound muscle action potential (CMAP) amplitudes showed a modest, non-significant reduction (7.8 ± 1.6 mV vs. 9.2 ± 1.4 mV; $p = 0.08$). Ipsilateral ulnar sensory and motor conduction velocities remained entirely within normal physiological limits in both groups (ulnar SNCV: 56.1 ± 3.8 m/s vs. 57.0 ± 3.5 m/s; $p = 0.62$), ruling out diffuse peripheral neuropathy.

Correlation analysis across the symptomatic patient group revealed a strong, statistically significant inverse linear correlation between distal sEMG RMS voltage and median nerve sensory conduction velocity ($r = -0.82$, $p = 0.012$). Higher myoelectric recruitment of the anomalous distal muscle belly during sustained gripping corresponded directly to greater slowing of sensory impulse propagation across the wrist. Similarly, distal sEMG RMS amplitude correlated positively with median motor distal latency ($r = 0.74$, $p = 0.036$).

Table 2. Comparison of sEMG, NCV, and high-resolution ultrasound parameters between symptomatic patients with palmaris longus variants and healthy controls during/after sustained grip tasks. NS = Not statistically significant.

Parameter	Symptomatic Variant (n = 8)	Healthy Control (n = 8)	p-value
Distal Forearm sEMG RMS Voltage (µV)	186.4 ± 24.8	34.2 ± 8.6	$p < 0.001$
Median Sensory Conduction Velocity (m/s)	38.5 ± 3.4	54.2 ± 4.1	$p < 0.01$
Median Motor Distal Latency (ms)	4.62 ± 0.48	3.38 ± 0.31	$p < 0.01$
Median CMAP Amplitude (mV)	7.8 ± 1.6	9.2 ± 1.4	$p = 0.08$ (NS)
Ulnar Sensory Conduction Velocity (m/s)	56.1 ± 3.8	57.0 ± 3.5	$p = 0.62$ (NS)
Distal PL Sonographic CSA (cm²)	1.84 ± 0.36	0.11 ± 0.03	$p < 0.001$
Median Nerve CSA at Wrist Inlet (mm²)	13.8 ± 1.9	8.4 ± 1.1	$p < 0.001$

DISCUSSION

The cadaveric findings of the present study corroborate the well-established evolutionary plasticity of the palmaris longus muscle while highlighting specific structural phenotypes capable of inducing neurovascular compromise. Our observed agenesis rate of 9.0% aligns closely with previous anatomical surveys conducted across mixed international and African-European cohorts, falling squarely between the lower frequencies reported in East Asian and Sub-Saharan populations (2%–6%) and the higher frequencies characteristic of Northern European cohorts (15%–25%). More importantly, our identification of structural palmaris longus variations in 6.0% of dissected extremities — specifically reversed (2.0%), duplicated/biventer (2.0%), hypertrophied/extended (1.0%), and bifid tendon (1.0%) morphologies — mirrors the 5% to 9% structural variation range documented in classical and contemporary anatomical literature.

From a morphometric standpoint, the critical factor governing clinical pathogenicity is not merely the presence of an anatomical variant, but the spatial translocation of contractile muscle mass from the capacious proximal forearm into the confined distal antebrachial compartment. In classical anatomy, the distal third of the anterior forearm contains compact, low-volume tendons surrounded by loose areolar connective tissue, allowing ample room for the median nerve as it approaches the carpal tunnel. In contrast, our morphometric measurements of reversed palmaris longus specimens demonstrated a bulky distal muscle belly averaging 18.4 mm in width and 8.9 mm in thickness terminating just 2.1 mm proximal to the flexor retinaculum. At this anatomical level, the antebrachial fascia thickens to become continuous with the transverse carpal ligament, creating a rigid, non-compliant osteofibrous roof. The interposition of a dense muscular belly directly between this unyielding fascial layer and the underlying flexor digitorum superficialis tendons drastically reduces the cross-sectional compliance of the distal forearm, predisposing the interposed median nerve to mechanical compression.

A central contribution of this investigation is the integration of dynamic sEMG and post-exertional NCV testing to elucidate the functional mechanism of nerve entrapment. Historically, idiopathic carpal tunnel syndrome is attributed to chronic, static increases in intracarpal canal pressure resulting from flexor tenosynovitis, synovial hypertrophy, or systemic fluid retention. Conversely, entrapment secondary to a reversed or hypertrophied palmaris longus operates primarily through a dynamic, activity-dependent biomechanical mechanism.

During sustained manual grasping or repetitive wrist flexion, neural drive from the motor cortex recruits motor units within the palmaris longus to stabilize the palmar aponeurosis. In patients harboring a reversed or distally extended variant, this recruitment occurs directly over the distal wrist crease, as evidenced by the high sEMG RMS voltage (186.4 ± 24.8 μV) recorded over the distal forearm in our clinical cohort. Isometric contraction of skeletal muscle generates a substantial increase in intramuscular cross-sectional thickness due to fiber shortening and radial expansion, compounded by exercise-induced hyperemia and vascular engorgement. Because the deep antebrachial fascia restricts outward expansion, the contracting muscle belly expands posteriorly, exerting direct compressive force against the underlying median nerve.

The strong inverse correlation observed between sEMG RMS voltage and median sensory conduction velocity ($r = -0.82$, $p = 0.012$) provides direct neurophysiological confirmation of this pressure-dependent conduction block. Acute mechanical compression of the median nerve impairs intraneural microvascular perfusion within the vasa nervorum, inducing transient segmental ischemia and focal demyelination of large-diameter, heavily myelinated sensory afferent fibers. Because large sensory fibers exhibit the highest metabolic demand and greatest vulnerability to mechanical deformation, sensory conduction velocity across the wrist drops precipitously (38.5 ± 3.4 m/s vs. 54.2 ± 4.1 m/s in controls) before substantial axonal loss occurs in motor fibers — a pattern reflected by the preserved CMAP amplitudes alongside prolonged motor distal latencies in our cohort.

In routine clinical practice, median nerve entrapment caused by palmaris longus variants is frequently misdiagnosed or overlooked, leading to delayed or inappropriate treatment. Standard clinical provocative maneuvers — such as Phalen's wrist-flexion test and Tinel's percussion sign — rely on passive positioning or static neural irritability and often yield false-negative results when the offending agent is a contractile muscle belly that only compresses the nerve during active loading. Similarly, conventional nerve conduction studies performed exclusively while the patient is completely at rest may appear borderline or normal in early-stage dynamic entrapment, particularly if baseline ischemic changes resolve rapidly upon cessation of hand use.

Our findings underscore the diagnostic superiority of a combined dynamic sonographic and post-exertional electrodiagnostic protocol. High-resolution musculoskeletal ultrasound offers rapid, non-invasive, real-time visualization of the distal forearm soft tissues, allowing clinicians to immediately distinguish a reversed or hypertrophied muscle belly from ganglion cysts, lipomas, schwannomas, or flexor tenosynovitis. Furthermore, dynamic ultrasound scanning during active fist clenching demonstrates real-time indentation and flattening of the median nerve beneath the contracting belly, while transverse measurements confirm secondary neural swelling (mean CSA 13.8 mm^2) proximal to the entrapment site. Pairing ultrasound with sEMG and post-grip NCV testing bridges the gap between structural anatomy and functional pathology, objectively quantifying both the aberrant muscular recruitment and its immediate neurophysiological impact on median nerve conduction.

Recognizing structural palmaris longus variants carries critical implications for both conservative management and surgical planning. In patients with mild, intermittent activity-induced symptoms, conservative measures — including ergonomic modification, avoidance of repetitive forceful gripping, targeted physical therapy, and activity-specific wrist splinting — may alleviate transient neurogenic ischemia. However, in individuals with persistent paresthesia, nocturnal symptoms, or objective electrodiagnostic slowing, surgical intervention is typically warranted.

Crucially, performing a standard limited-incision or endoscopic carpal tunnel release without addressing an overlying reversed or hypertrophied palmaris longus frequently results in surgical failure and recurrent median neuropathy. Because the primary site of mechanical compression lies immediately proximal to or at the proximal margin of the flexor retinaculum, decompression requires an extended proximal volar approach to fully visualize the distal antebrachial compartment. Excision (myomectomy) of the anomalous distal muscle belly — combined with open release of the transverse carpal ligament when intracarpal compression coexists — permanently eliminates the dynamic space-occupying lesion. Because the palmaris longus is functionally expendable, complete resection of the variant belly achieves reliable, lasting resolution of neuropathic symptoms without compromising wrist flexion strength or hand dexterity. Additionally, preoperative ultrasound screening of the palmaris longus is advisable prior to harvesting the tendon for reconstructive grafting, ensuring that an unexpected reversed or duplicated architecture does not complicate graft retrieval.

Several limitations of the present study merit consideration. First, while the cadaveric sample size (n = 100 limbs) provided robust prevalence estimates for common variants, rare phenotypes such as palmaris profundus or triple-headed variants were not encountered, reflecting their extremely low population incidence (<0.5%). Second, the clinical cohort was relatively small (n = 8 symptomatic patients), owing to the rarity of clinically symptomatic palmaris longus variants presenting to tertiary centers. Third, surface electromyography over the anterior forearm is inherently susceptible to minor electrical crosstalk from adjacent superficial flexors, notably the flexor carpi radialis and flexor digitorum superficialis. Although high-resolution ultrasound guidance was used to precisely center the electrodes over the superficial variant belly and minimize crosstalk, future studies utilizing fine-wire intramuscular electromyography could isolate single-muscle motor unit action potentials with even greater spatial specificity.

Conclusion

This integrated anatomical and neurophysiological investigation demonstrates that structural variants of the

palmaris longus muscle — present in 6.0% of dissected upper limbs, with reversed morphology accounting for 2.0% — can serve as direct mechanical agents of median nerve compression. In symptomatic patients, active recruitment of an anomalous distal muscle belly during sustained grip tasks generates elevated localized myoelectric activity (sEMG RMS voltage) that correlates significantly with focal slowing of median nerve sensory conduction velocity across the wrist joint. Clinicians, radiologists, and hand surgeons should routinely include reversed and hypertrophied palmaris longus variants in the differential diagnosis of atypical, exertion-induced carpal tunnel syndrome. Incorporating high-resolution dynamic musculoskeletal ultrasound alongside post-exertional electrodiagnostic testing enables accurate preoperative identification, guiding targeted surgical excision of the anomalous muscle belly and ensuring optimal patient outcomes.

REFERENCES

[1] Reimann AF, Daseler EH, Anson BJ, Beaton LE. The palmaris longus muscle and tendon: a study of 1600 extremities. Anatomical Record. 1944;89(4):495–505.

[2] Olewnik Ł, Wysiadecki G, Polguj M, Podgórski M, Jezierski H, Topol M. Anatomical variations of the palmaris longus muscle including its relation to the median nerve: a proposal for a new classification. BMC Musculoskeletal Disorders. 2017;18(1):539.

[3] Georgiev GP, Iliev AA, Dimitrova IN, Kotov GN, Malinova LG, Landzhov BV. Palmaris longus muscle variations: clinical significance and proposal of new classifications. Folia Medica. 2017;59(3):289–297.

[4] Schuurman AH, van Gils AP. Reversed palmaris longus muscle on MRI: report of four cases. European Radiology. 2000;10(8):1242–1244.

[5] Backhouse KM, Churchill-Davidson D. Anomalous palmaris longus muscle producing carpal tunnel-like compression. The Hand. 1975;7(1):22–24.

[6] Schlafly B, Lister G. Median nerve compression secondary to bifid reversed palmaris longus. Journal of Hand Surgery (American Volume). 1987;12(3):371–373.

[7] Depuydt KH, Schuurman AH, Kon M. Reversed palmaris longus muscle causing effort-related median nerve compression. Journal of Hand Surgery (British and European Volume). 1998;23(1):117–119.

[8] Giunta R, Brunner U, Wilhelm K. Bilateral reversed palmaris longus muscle: a rare cause of peripheral median nerve compression syndrome. Der Chirurg. 1993;64(11):963–965.

[9] Meyer FN, Pflaum BC. Median nerve compression at the wrist caused by a reversed palmaris longus muscle. Journal of Hand Surgery (American Volume). 1987;12(3):369–371.

[10] Natsis K, Levva S, Totlis T, Anastasopoulos N, Paraskevas G. Three-headed reversed palmaris longus muscle and its clinical significance. Annals of Anatomy. 2007;189(1):97–101.

[11] Yildiz M, Sener M, Aynaci O. Three-headed reversed palmaris longus muscle: a case report and review of the literature. Surgical and Radiologic Anatomy. 2000;22(3–4):217–219.

[12] Acikel C, Ulkur E, Karagoz H, Celikoz B. Effort-related compression of median and ulnar nerves as a result of reversed three-headed and hypertrophied palmaris longus muscle with extension of Guyon's canal. Scandinavian Journal of Plastic and Reconstructive Surgery and Hand Surgery. 2007;41(1):45–47.

[13] Salama H, Stanley D, Kane P. Reversed palmaris longus muscle: anatomical variant — case report and literature review. Open Orthopaedics Journal. 2013;7:644–646.

[14] Guler F, Kose O, Turan A, Baz AB, Akalin S. Reversed palmaris longus muscle: a rare cause of median nerve compression. Journal of Hand Surgery (European Volume). 2013;38(3):331–332.

[15] Keese GR, Wongworawat MD, Frykman G. The clinical significance of the palmaris longus tendon in the pathophysiology of carpal tunnel syndrome. Journal of Hand Surgery (American Volume). 2006;31(4):657–660.

[16] Sebastin SJ, Lim AY, Bee WH, Wong TC, Methil BV. Does the absence of the palmaris longus affect grip and pinch strength? Journal of Hand Surgery (British and European Volume). 2005;30(4):406–408.

[17] Ioannis D, Anastasios K, Konstantinos N, Lazaros K, Georgios N. Palmaris longus muscle's prevalence in different nations and interesting anatomical variations: review of the literature. Journal of Clinical Medicine Research. 2015;7(11):825–830.

[18] Park MJ, Namdari S, Yao J. Anatomic variations of the palmaris longus muscle. American Journal of Orthopedics. 2010;39(2):89–94.

[19] Karabay N, Toros T, Hurel C. Ultrasonographic evaluation in idiopathic carpal tunnel syndrome: can it replace electrophysiological study? Clinical Radiology. 2007;62(7):680–685.

[20] Bianchi S, Martinoli C, de Gautard R, Gaignot C. Ultrasound of the digital nerves and carpal tunnel. Seminars in Musculoskeletal Radiology. 2007;11(2):127–136.

[21] American Association of Electrodiagnostic Medicine (AAEM), American Academy of Neurology, American Academy of Physical Medicine and Rehabilitation. Practice parameter for electrodiagnostic studies in carpal tunnel syndrome: summary statement. Muscle & Nerve. 2002;25(6):918–922.

[22] Benzon HT, Benzon HA, Iqbal M. Median nerve entrapment due to accessory palmaris longus muscle: a case report and dynamic ultrasound evaluation. PM&R. 2018;10(5):548–551.

[23] Koyuncu E, Özgüner G, Öztürk K, Bilkay Ç, Dursun A, Sulak O. The morphological features and clinical importance of the palmaris longus muscle in human fetuses. Surgical and Radiologic Anatomy. 2018;40(11):1287–1294.

[24] Fakoya AOJ, Tarzian M, Sabater EL, Burgos DM, Maldonado Marty GI. Clinical significance of a duplicated palmaris longus muscle with one reversed muscle: case report and literature review. Open Access Macedonian Journal of Medical Sciences. 2020;8(C):177–180.

[25] Gürses İA, Coşkun O, Gayretli Ö, Kale A, Öztürk A. Reversed palmaris longus muscle with median nerve compression: a case report and systematic review of the literature. Turkish Neurosurgery. 2021;31(2):294–300.