Beyond Magnification: Biological, Technical, and Rehabilitation Determinants of Sensory Recovery After Primary Digital Nerve Repair

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Abstract

Background: Recovery after digital nerve repair is often treated as a technical consequence of coaptation. In practice, sensibility reflects injury biology, nerve-end quality, mechanics, axonal regeneration, target reinnervation, cortical adaptation, pain, and rehabilitation.

Aim: To synthesize determinants of functional sensory recovery and place magnification within a patient-centered outcome model.

Methods: PubMed/MEDLINE-indexed studies and reference lists were reviewed through August 2026. Systematic reviews, trials, cohorts, and mechanistic studies addressing prognosis, timing, tension, coaptation, adjuncts, sensory assessment, pain, cold intolerance, rehabilitation, and electrical stimulation were prioritized.

Results: Adult repair commonly restores protective sensation, but normal discriminative sensibility is less frequent. Younger age, short defects, sharp injury, viable ends, and tension-free repair are favorable. Tension and an adverse scar or vascular environment may impair regeneration regardless of optics. No reconstruction method is universally superior, and the NEON trial questions whether suturing benefits selected isolated injuries beyond careful alignment. Outcomes should combine sensory tests with pain, cold intolerance, hand function, and patient-reported measures. Prolonged immobilization has no established sensory advantage; education, graded sensory retraining, and selected brief electrical stimulation may support recovery.

Conclusion: Success cannot be reduced to loupe versus microscope. Magnification enables accurate surgery, but the meaningful endpoint is a mechanically sound, biologically permissive repair followed by standardized assessment and rehabilitation. Future research should use core outcomes and stratify by injury, tension, gap, and patient factors.

Keywords: *digital nerve repair; sensory recovery; nerve regeneration; rehabilitation; microsurgery*

Introduction

Digital nerves provide the dense sensory input required for precision grip, tactile exploration, safe tool use, and protection from thermal or mechanical injury. Their superficial course makes them vulnerable to glass, knives, machinery, and occupational trauma. A large population study confirmed that these injuries predominantly affect adults of working age and that sharp laceration is the most frequent mechanism, yet follow-up and rehabilitation practices vary substantially. This variation is clinically important because the effect of a technically successful coaptation may be diluted by delayed assessment, inconsistent therapy, pain, or unrecognized cold intolerance. [1]

Adult digital nerve repair frequently restores protective sensation, but recovery to normal or near-normal discriminative sensibility is much less predictable. A systematic review found that fewer than one quarter of repaired nerves achieved normal sensory grading, while a later meta-analysis of 66 studies and 2,446 cases reported satisfactory results across several techniques without identifying an absolute winner. These apparently different messages are compatible: most patients improve, but the level of recovery, measurement method, and definition of success vary widely. [2,3]

The persistent focus on loupe versus microscope risks narrowing a complex biological problem to one operative instrument. Magnification is necessary for controlled nerve handling, yet the image seen by the surgeon is only one link between injury and function. Age, mechanism, gap, delay, ischemia, scar, tension, suture trauma, axonal misdirection, Schwann-cell behavior, target-organ change, cortical interpretation, rehabilitation, and pain can each shape the result. A systematic review of prognostic factors found favorable recovery particularly in younger patients and shorter gaps, emphasizing that the optical platform cannot be evaluated independently from case mix. [4]

METHODS

A targeted narrative search of PubMed/MEDLINE and reference lists was performed through August 2026. Search terms combined digital nerve injury or repair with sensory recovery, prognostic factors, timing, tension, epineurial suture, fibrin glue, nerve wrap, nerve tape, sensory testing, cold intolerance, neuropathic pain, mobilization, sensory re-education, patient-reported outcome, and electrical stimulation. Systematic reviews and randomized trials were prioritized, followed by cohort and mechanistic studies that clarified clinically relevant pathways. Evidence from mixed upper-extremity nerves or animal models was used cautiously when direct digital-nerve data were unavailable. This was a narrative synthesis and not a systematic review or meta-analysis.

WHAT CONSTITUTES A SUCCESSFUL OUTCOME?

The traditional endpoint of digital nerve surgery is sensory recovery, but that phrase can refer to very different achievements. Protective sensation allows detection of potentially harmful pressure or heat. Tactile threshold reflects the minimum force perceived. Spatial discrimination tests the ability to distinguish closely separated stimuli. Functional sensibility integrates these signals with dexterity, object recognition, pain, and confidence in hand use. A patient may regain a measurable threshold while remaining troubled by cold, numbness, electric pain, or fear of reinjury. Conversely, modest two-point discrimination can coexist with acceptable daily function. [5]

Clinical reporting should therefore separate impairment from activity and patient experience. Static and moving two-point discrimination, Semmes–Weinstein monofilaments, temperature or quantitative sensory testing, pain scales, cold-intolerance scores, and validated hand-related patient-reported measures are complementary rather than interchangeable. Follow-up must be long enough for regeneration and cortical adaptation, but fixed time points are also necessary for comparison. The question should not be simply whether sensation returned; it should be what type of sensation returned, when, with what symptoms, and with what effect on use of the hand.

THE BIOLOGY BETWEEN COAPTATION AND SENSATION

After transection, the distal axon undergoes Wallerian degeneration, macrophages clear debris, and Schwann cells convert to a repair phenotype that organizes longitudinal bands and produces trophic support. Proximal axonal sprouts then cross the coaptation and advance through the distal endoneurial pathways. Accurate approximation reduces the distance and chaos at this interface, but it cannot ensure that each regenerating axon enters its original sensory territory. Misrouting and collateral sprouting contribute to imperfect localization and discrimination even when protective sensation returns. [6–8]

Schwann cells are central to this process. They dedifferentiate, proliferate, guide axons, and later remyelinate successful sprouts. Their supportive phenotype is time limited; chronic denervation and delayed repair reduce Schwann-cell effectiveness and alter the distal environment. Experimental work has shown deterioration in Schwann-cell function and target recovery with delayed nerve repair, supporting timely reconstruction while acknowledging that purely sensory recovery may remain possible after longer intervals than motor recovery. [9]

Neurotrophic signals regulate neuronal survival, axonal elongation, and target interaction, yet exogenous modulation has not translated into a simple clinical solution. The regenerative process is spatially and temporally coordinated, and adding one factor cannot correct an obstructive scar, excessive tension, ischemia, or misalignment. The surgeon's most reliable biological contribution remains preservation of viable tissue and creation of a permissive path rather than aggressive manipulation intended to perfect the appearance of the nerve ends. [10]

PATIENT AND INJURY DETERMINANTS

Age is among the most consistent predictors of sensory recovery. Younger patients have greater axonal regenerative capacity and cortical plasticity, while older age is associated with slower regeneration, comorbidity, microvascular change, and reduced adaptability. Age should inform counseling, not exclusion. An older adult may regain useful protective sensation even when normal two-point discrimination is unlikely, and patient priorities may favor pain prevention, border-digit protection, or occupational safety rather than a laboratory definition of normality. [4,5]

Mechanism and zone of injury determine the quality of the substrate. A clean sharp laceration usually creates a narrow zone with identifiable ends; crush, avulsion, contamination, thermal damage, and delayed scarring extend injury beyond what is immediately visible. Under-resection leaves nonviable tissue that blocks organized sprouting, while over-resection creates a gap and increases tension. The correct balance is conservative excision to healthy fascicular architecture, judged together with soft-tissue viability and perfusion. [3,6]

Gap length after debridement affects both treatment choice and prognosis. Direct repair is appropriate when the ends meet freely in a functional digit position. If approximation requires substantial traction, excessive joint flexion, or extensive mobilization, a graft or conduit may provide a more favorable mechanical environment despite adding interfaces. Reviews consistently associate shorter gaps with better sensory recovery and show that technique comparisons are strongly confounded by gap length, since more complex injuries are preferentially reconstructed rather than directly sutured. [3,4]

Associated injuries matter. Tendon laceration may impose a mobilization protocol different from that of an isolated nerve repair; fracture, digital artery injury, skin loss, infection, and scar can compromise perfusion or delay therapy. Vascular supply influences Schwann-cell and axonal metabolism, and experimental and translational literature increasingly recognizes blood flow as a component of nerve assessment and regeneration. Evidence from nerve grafting likewise suggests that vascularization is important, particularly as graft length and metabolic demand increase. [11,12]

TIMING AND THE CONDITION OF THE NERVE ENDS

Acute repair of a clean transection is attractive because the anatomy is fresh, dissection is limited, and the distal pathways have not undergone prolonged denervation. In practice, timing must be integrated with wound contamination, tissue viability, associated injuries, patient stability, and access to microsurgical expertise. A 2025 upper-extremity study developed a prediction model for the likelihood and size of a nerve defect, highlighting that retraction and the need for reconstruction are influenced by injury and patient features rather than time alone. [13]

Delay can increase retraction, fibrosis, and the difficulty of identifying healthy ends, but a rushed repair in an inadequately debrided or contaminated field may be equally harmful. The operative objective is not the earliest possible stitch at any cost; it is a timely repair in a clean, viable, well-vascularized bed with a strategy appropriate to the actual defect. Documentation should include injury-to-repair interval, gap after debridement, resting position used for measurement, and whether tension influenced the chosen method.

TENSION: THE MECHANICAL VARIABLE MAGNIFICATION CANNOT RESCUE

Tension-free coaptation is repeatedly stated as a principle, but it is often described qualitatively. Stretch can reduce intraneural blood flow, deform fascicles, increase inflammation, and promote fibrosis or dehiscence. A recent clinical review emphasized that direct repair success depends on recognizing the point at which approximation is no longer biologically acceptable. Magnification may make the ends look aligned while the nerve remains mechanically overloaded; visual neatness is therefore not a substitute for testing relaxation in the permitted range of motion. [14]

Biomechanical experiments show that neurorrhaphy strain changes with defect size, joint position, and the method of approximation. Gene-expression studies further suggest that tension alters molecular pathways involved in inflammation and repair. Although these models cannot define a single safe threshold for every digital nerve, they support a practical rule: if the coaptation requires persistent traction or deforms when the digit is positioned for postoperative function, reconstruction should be considered. [15,16]

TECHNICAL QUALITY OF PRIMARY REPAIR

Primary epineurial repair aims to restore continuity with minimal additional trauma. The ends should be sharply prepared, oriented without rotation, and approximated with the fewest sutures that maintain alignment. Fine monofilament sutures are placed through the epineurium, avoiding fascicular capture and excessive inversion. One or two properly positioned sutures may be sufficient for a small digital nerve; additional passes add foreign material and opportunities for injury without necessarily improving stability. Modern technical guidance accepts either high-powered loupes or a microscope when the image is adequate for these steps. [5]

The operating microscope provides adjustable magnification, coaxial light, and a stable shared image. High-quality loupes offer mobility, speed, and lower infrastructure demands. Comparative clinical evidence has not consistently shown better sensory recovery with the microscope, which reinforces the distinction between enabling technology and biological treatment. The correct standard is adequate resolution to recognize healthy tissue, place epineurial sutures precisely, and inspect the final coaptation. If the loupe image does not meet that standard, conversion to the microscope is indicated.

SUTURE, ADJUNCTS, AND THE QUESTION OF NECESSARY FIXATION

Fibrin glue has been studied as a way to reduce suture trauma and operative manipulation. A randomized clinical trial comparing autologous fibrin glue with microsuture in peripheral nerve reconstruction reported clinical feasibility, while systematic review evidence suggests shorter repair time but remains heterogeneous regarding strength and long-term functional outcomes. Glue alone may be vulnerable to early failure; a small number of sutures or a wrap can improve stability. [17,18]

A later systematic review and meta-analysis concluded that fibrin glue may achieve outcomes comparable to sutures in selected peripheral nerve repairs, but the evidence base contains varied nerves, injury models, and techniques. New sutureless devices, wraps, and nerve tape are designed to standardize alignment and distribute load. Early usability reports are promising, yet widespread adoption should await independent comparative studies that examine gapping, inflammation, neuroma, sensory recovery, cost, and ease of revision rather than operative convenience alone. [19,20]

The NEON multicenter randomized trial provides a more fundamental challenge. Adults with isolated digital nerve injury were assigned to microsurgical suture repair or careful nerve alignment without sutures. The trial closed before reaching its planned sample size and therefore cannot establish definitive equivalence, but it found no evidence of benefit from suturing for the primary patient-reported outcome. The appropriate response is not to abandon repair indiscriminately. Instead, the study compels clearer identification of which injuries require fixation, which may remain aligned within an intact tissue envelope, and which outcomes matter to patients. [21]

RECONSTRUCTION WHEN DIRECT REPAIR IS NOT APPROPRIATE

When a true gap prevents relaxed end-to-end coaptation, autograft, processed allograft, biological conduit, synthetic conduit, or selected autologous tissue conduits may be considered. Meta-analytic findings vary by outcome: one technique may appear best for static discrimination while another performs better for moving discrimination or monofilament grading. Such rankings are sensitive to study quality, gap length, follow-up, and selection bias. The clinically sound conclusion is that no single method dominates across all defects and that increasing gap length narrows the range of dependable options. [3]

For a short sensory gap, avoiding a high-tension direct repair is more important than preserving the label of primary neurorrhaphy. Autograft remains a reference option but causes donor morbidity. Processed allograft avoids donor injury but adds cost and depends on appropriate indication. Conduits can be useful in short gaps, although long or poorly vascularized segments are less favorable. The repair plan should be based on the measured post-debridement defect, wound bed, nerve caliber, patient factors, and available evidence rather than on material preference.

STANDARDIZED SENSORY ASSESSMENT

Static two-point discrimination is widely reported because it is familiar and clinically relevant to spatial acuity, but it is influenced by examiner technique and can have ceiling effects. Moving two-point discrimination may recover earlier. Semmes–Weinstein monofilaments provide graded pressure thresholds, while quantitative sensory testing can characterize thermal and nociceptive fibers. Numerical results should be reported for the injured and contralateral digit with a defined protocol, rather than being converted immediately into broad categories. [22,23]

Preoperative tests should not be treated as perfect evidence of transection. A 2026 diagnostic study of 60 patients found that static two-point discrimination at a 7-mm threshold was highly sensitive but poorly specific; adding warm detection threshold increased specificity while maintaining sensitivity. For postoperative research, direct surgical confirmation of injury type, complete documentation of the repair, blinded assessment when feasible, and repeated fixed time points are essential. [22]

Assessment validity also depends on the construct being measured. A systematic review of sensibility tests found variable evidence for reliability, validity, and responsiveness. Using several tests is defensible only when each addresses a prespecified domain; otherwise, multiple uncoordinated endpoints increase noise and selective reporting. A core set might include monofilament threshold, static two-point discrimination, pain, cold intolerance, a hand-specific patient-reported measure, and return to work or usual activity. [24]

PAIN, COLD INTOLERANCE, AND PATIENT EXPERIENCE

Pain may dominate function even when objective sensation improves. A study of upper-extremity nerve injury found that bodily pain accounted for a large proportion of disability variance, with older age and nerve level also contributing. Digital-nerve research should distinguish spontaneous neuropathic pain, stimulus-evoked pain, scar tenderness, neuroma symptoms, and hypersensitivity because these problems require different management. [25]

Cold intolerance is common after digital nerve injury and can interfere with outdoor work and daily activity. It should be measured with a validated symptom score rather than recorded as present or absent. Recent multicenter data found severe or extremely severe cold intolerance in a substantial minority after digital nerve-gap reconstruction and showed an association between cold symptoms and sensory function. These symptoms may evolve over a year, so early absence does not guarantee a symptom-free long-term result. [26]

MOBILIZATION, SENSORY RE-EDUCATION, AND CORTICAL ADAPTATION

Postoperative management must protect the coaptation without imposing unnecessary stiffness. A systematic review comparing immobilization, protected mobilization, and free mobilization found no clear sensory superiority of one regimen after isolated digital nerve repair; splinting may delay return to work and increase stiffness. The protocol should therefore be driven by the entire injury. A concomitant tendon repair, fracture, skin graft, or vascular repair may require restrictions that an isolated neurorrhaphy does not. [27]

Sensory re-education aims to help the brain interpret altered input as axons reinnervate the digit. Early programs may use visualization, mirror strategies, protection education, and exposure to graded textures before clear reinnervation. Later programs emphasize localization, discrimination, object recognition, and functional integration. A comparative study did not demonstrate a clear advantage from a particular immobilization duration or formal sensory re-education program, but the evidence is limited and therapy remains reasonable when individualized, goal directed, and linked to measurable deficits. [28]

Patient education is not a minor adjunct. Before protective sensation returns, the digit is vulnerable to burns and cuts. Patients should be taught skin inspection, temperature testing with the uninjured hand, scar care, edema control, and graded use. As sensation returns, desensitization should be progressive rather than painful. Recovery expectations should be framed over months, with explicit discussion that normal sensibility is not assured and that pain or cold intolerance deserves treatment rather than being dismissed as a failed sensory score.

ELECTRICAL STIMULATION AND EMERGING ADJUNCTS

Brief electrical stimulation applied around the time of repair is intended to accelerate axonal outgrowth across the repair site. A randomized trial in upper-extremity sensory nerve repair found greater improvement across sensory modalities by five to six months after one hour of stimulation. The result is promising, but implementation requires appropriate equipment, electrode placement, stimulation parameters, safety standards, and confirmation in larger digital-nerve cohorts. Electrical stimulation should currently be considered an adjunct, not a remedy for tension, devitalized ends, or poor alignment. [29]

Other emerging approaches include engineered conduits, growth-factor delivery, aligned scaffolds, pharmacological modulation, and enhanced imaging of nerve perfusion. Translation should be judged by durable patient-centered benefit rather than histological improvement alone. Interventions that accelerate early threshold recovery but do not reduce pain, cold intolerance, disability, or reoperation may have limited clinical value. Future trials should also account for the rehabilitation dose, because biological and behavioral treatments interact.

A CLINICAL MODEL FOR DECISION-MAKING

The preoperative phase should establish mechanism, time, level, affected sensory territory, associated injuries, occupation, hand dominance, smoking and comorbidity, baseline pain, and objective sensory findings. The patient should understand the uncertainty of normal recovery. Exploration should confirm complete versus partial injury, define the zone of damage, and assess the soft-tissue and vascular bed.

During repair, the surgeon should debride only nonviable tissue, measure the relaxed defect, choose direct repair only when approximation is free of meaningful tension, and use the optical platform that permits confident epineurial handling. The final coaptation should be inspected for rotation, gapping, constriction, and stability within the permitted joint position. If these conditions cannot be achieved, escalation to the microscope or conversion to reconstruction is preferable to forcing a technically convenient repair.

Follow-up should use scheduled clinical and patient-reported assessment, document therapy and return to activity, and screen specifically for pain and cold intolerance. Lack of early discriminative sensation is not necessarily failure, while persistent pain, an advancing Tinel sign that stops progressing, or a focal symptomatic mass may justify further evaluation.

The same framework should be used in research so that differences attributed to magnification or material are not actually differences in injury severity, tension, rehabilitation, or measurement.

LIMITATIONS AND FUTURE DIRECTIONS

The literature remains dominated by heterogeneous observational series. Studies vary in injury definition, gap, repair technique, age, follow-up, rehabilitation, and outcome classification. Mechanistic evidence often comes from mixed nerves or animal models and must be translated cautiously to small human sensory nerves. The NEON trial improved the level of evidence but was under-recruited, and several newer devices lack independent long-term comparative data.

Future work should establish a minimum reporting set: mechanism, nerve and digit, injury level, completeness, zone of damage, defect after debridement, tension assessment, optical system and power, number and material of sutures, adjuncts, associated repairs, therapy, complications, and reoperations. Outcomes should be collected at consistent intervals and include numerical sensibility, cold intolerance, pain phenotype, hand function, patient-reported recovery, work participation, time, and cost. Stratification by age and gap is essential, and equivalence claims should be supported by prospectively defined margins rather than nonsignificant P values.

CONCLUSION

Sensory recovery after digital nerve repair is the product of a biological and behavioral pathway, not a single microsurgical moment. Magnification enables precise handling, but it cannot overcome devitalized tissue, excessive tension, ischemia, adverse scarring, axonal misdirection, pain, or inconsistent rehabilitation. The most defensible approach is to create a healthy and mechanically relaxed repair, measure several meaningful domains of recovery, and support the patient through protection, mobilization, sensory retraining, and symptom management. Research that treats these elements as one integrated pathway will be more clinically useful than another isolated comparison of optical devices. [30]

References

1. Evertsson L, Carlsson C, Turesson C, Ezer MS, Arner M, Navarro CM. Incidence, demographics and rehabilitation after digital nerve injury: a population-based study of 1004 adult patients in Sweden. PLoS One. 2023;18(4):e0283907.

2. Dunlop RLE, Wormald JCR, Jain A. Outcome of surgical repair of adult digital nerve injury: a systematic review. BMJ Open. 2019;9(3):e025443.

3. Zhang Y, Hou N, Zhang J, Xie B, Liang J, Chang X, et al. Treatment options for digital nerve injury: a systematic review and meta-analysis. J Orthop Surg Res. 2023;18(1):183.

4. Kim JS, Bonsu NY, Leland HA, Carey JN, Patel KM, Seruya M. A systematic review of prognostic factors for sensory recovery after digital nerve reconstruction. Ann Plast Surg. 2018;80(5S Suppl 5):S311-S316.

5. Jain A, Dunlop R, Hems T, Tang JB. Outcomes of surgical repair of a single digital nerve in adults. J Hand Surg Eur Vol. 2019;44(6):560-565.

6. Lee SK, Wolfe SW. Peripheral nerve injury and repair. J Am Acad Orthop Surg. 2000;8(4):243-252.

7. Jessen KR, Mirsky R. The repair Schwann cell and its function in regenerating nerves. J Physiol. 2016;594(13):3521-3531.

8. Fu SY, Gordon T. The cellular and molecular basis of peripheral nerve regeneration. Mol Neurobiol. 1997;14(1-2):67-116.

9. Jonsson S, Wiberg R, McGrath AM, Novikov LN, Wiberg M, Novikova LN, et al. Effect of delayed peripheral nerve repair on nerve regeneration, Schwann cell function and target muscle recovery. PLoS One. 2013;8(2):e56484.

10. Gordon T. The role of neurotrophic factors in nerve regeneration. Neurosurg Focus. 2009;26(2):E3.

11. Yeoh S, Warner WS, Merchant S, Hsu E, Agoston DV, Mahan MA. Incorporating blood flow in nerve injury and regeneration assessment. Front Surg. 2022;9:862478.

12. Saffari T, Bedar M, Hundepool CA, Bishop AT, Shin AY. The role of vascularization in nerve regeneration of nerve graft. Neural Regen Res. 2020;15(9):1573-1579.

13. Gray KM, Burkat AJ, Arney LA, Peterman NJ, Mandala SR, Capito AE. Timing and predictors of upper extremity peripheral nerve reconstruction. JPRAS Open. 2025;44:308-315.

14. McQuillan TJ, Zelenski NA, Ghareeb PA. The role of nerve tension on nerve repair success. J Hand Surg Glob Online. 2024;6(5):691-693.

15. Smetana BS, Cao J, Merrell G, Greenberg JA. Testing of direct neurorrhaphy strain. J Hand Surg Am. 2019;44(7):615.e1-615.e6.

16. Wood K, Fonseca MA, Gunderson KA, Nkana ZH, Dingle A, Israel JS, et al. The effect of tension on gene expression in primary nerve repair via the epineural suture technique. J Surg Res. 2022;277:211-223.

17. Sallam A, Eldeeb M, Kamel N. Autologous fibrin glue versus microsuture in the surgical reconstruction of peripheral nerves: a randomized clinical trial. J Hand Surg Am. 2022;47(1):89.e1-89.e11.

18. Sameem M, Wood TJ, Bain JR. A systematic review on the use of fibrin glue for peripheral nerve repair. Plast Reconstr Surg. 2011;127(6):2381-2390.

19. Koopman JE, Duraku LS, de Jong T, de Vries RBM, Zuidam JM, Hundepool CA. A systematic review and meta-analysis on the use of fibrin glue in peripheral nerve repair: can we just glue it? J Plast Reconstr Aesthet Surg. 2022;75(3):1018-1033.

20. Eberlin KR, Safa B, Buntic R, Rekant M, Richard MJ, Styron J, et al. Usability of nerve tape: a novel sutureless nerve coaptation device. J Hand Surg Am. 2024;49(4):346-353.

21. Wormald JCR, Gardiner MD, Jerosch-Herold C, Cook J, Pinedo-Villanueva R, O'Hanlon C, et al. The NEON (Nerve rEpair Or Not) trial: a randomized controlled trial of microsurgical repair versus nerve alignment for digital nerve injury. Br J Surg. 2025;112(9):znaf174.

22. Wong JN, Saini J, Curran MWT, Olson JL, Morhart MJ, Chan KM. Assessment of sensitivity and specificity of common sensory tests in diagnosing digital nerve lacerations. Muscle Nerve. 2026;73(4):559-565.

23. Hooper G, Ruettermann M. Reporting numerical values for sensory testing. J Hand Surg Eur Vol. 2022;47(11):1178-1180.
24. Jerosch-Herold C. Assessment of sensibility after nerve injury and repair: a systematic review of evidence for validity, reliability and responsiveness of tests. J Hand Surg Br. 2005;30(3):252-264.
25. Novak CB, Anastakis DJ, Beaton DE, Katz J. Patient-reported outcome after peripheral nerve injury. J Hand Surg Am. 2009;34(2):281-287.
26. Ilyas AM, Kirby DJ, Kasper A, et al. Cold intolerance following digital nerve injury: a multicenter prospective randomized comparison of decellularized nerve allograft versus nerve conduits. Hand (N Y). 2026;21(2):186-193.
27. Jabir S, Iwuagwu FC. Postoperative mobilization regimens following digital nerve repair: a systematic review. Eplasty. 2014;14:e5.
28. Manoli T, Schiefer JL, Schulz L, Fuchsberger T, Schaller HE. Influence of immobilization and sensory re-education on the sensory recovery after reconstruction of digital nerves with direct suture or muscle-in-vein conduits. Neural Regen Res. 2016;11(2):338-344.
29. Wong JN, Olson JL, Morhart MJ, Chan KM. Electrical stimulation enhances sensory recovery: a randomized controlled trial. Ann Neurol. 2015;77(6):996-1006.
30. Montgomery EK, Rask DMG, Wilson DJ, Plucknette BF, Sabbag CM. Microsurgical techniques for digital nerve injuries and vascular injuries. JBJS Essent Surg Tech. 2024;14(3):e23.00033.