

Retrospective Review of Microsurgical Repair of 222 Lingual Nerve Injuries

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Purpose: Injury to the lingual nerve (LN) is a known complication associated with several oral and maxillofacial surgical procedures. We have reviewed the demographics, timing, and outcome of microsurgical repair of the LN.

Materials and Methods: A retrospective chart review was completed of all patients who had undergone microsurgical repair of the LN by one of us (R.A.M.) from March 1986 through December 2005. A physical examination, including standardized neurosensory testing, was completed of each patient preoperatively. All patients were followed up periodically after surgery for at least 1 year, with neurosensory testing repeated at each visit. Sensory recovery was determined from the patient's final neurosensory testing results and evaluated using the guidelines established by the Medical Research Council Scale. The following data were collected and analyzed: patient age, gender, nerve injury etiology, chief sensory complaint (numbness or pain, or both), interval from injury to surgical intervention, intraoperative findings, surgical procedure, and neurosensory status at the final evaluation. The patients were classified according to whether they achieved "useful sensory recovery" or better, according to the Medical Research Council Scale, or had unsatisfactory or no improvement in sensation. Logistic regression methods and associated odds ratios (OR) were used to quantify the association between the risk factors and improvement. Receiver operating characteristic curve analysis was used to find the age threshold and duration that maximally separated the patient outcomes.

Results: A total of 222 patients (51 males and 171 females; average age 31.1 years, range 15 to 61) underwent LN repair and returned for at least 1 year of follow-up. The most common cause of LN injury was mandibular third molar removal (n = 191, 86%), followed by sagittal split mandibular ramus osteotomy (n = 14, 6.3%). Most patients complained preoperatively of numbness (n = 122, 55%) or numbness with pain (n = 94, 42.3%). The average interval from injury to surgery was 8.5 months (range 1.5 to 96). The most commonly performed operation was excision of a proximal stump neuroma with neuroorrhaphy (n = 154, 69%), followed by external decompression with internal neurolysis (n = 29, 13%). Nineteen patients (8.6%) underwent an autogenous nerve graft procedure (greater auricular or sural nerve) for reconstruction of a nerve gap. A collagen cuff was placed around the repair site in 8 patients (3.6%; external decompression with internal neurolysis in 2 and neuroorrhaphy in 6). Recovery from neurosensory dysfunction (defined by the Medical Research Council Scale as ranging from "useful sensory function" to a "complete return of sensation") was observed in 201 patients (90.5%; 146 patients with complete recovery and 55 patients with recovery to "useful sensory function"), and 21 patients (9.5%) had no or inadequate improvement. Using the logistic regression model, a shorter interval between nerve injury and repair resulted in greater odds of improvement (OR 0.942, $P = .0064$); with each month that passed, the odds of improvement decreased by 5.8%. The receiver operating characteristic analysis revealed that patients who waited more than 9 months for repair

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were at a significantly greater risk of nonimprovement. Statistical significance was observed between patient age and outcome (OR 0.945, $P = .0067$) representing a 5.5% decrease in the chance of recovery for every year of age in patients 45 years old and older. The odds of a return of acceptable neurosensory function were better when the patient's presenting symptom was pain and not numbness (OR 0.04, $P < .001$).

Conclusions: Microsurgical repair of LN injury has the best chance of successful restoration of acceptable neurosensory function if done within 9 months of the injury. The likelihood of recovery after nerve repair decreased progressively when the repair occurred more than 9 months after injury and with increasing patient age.

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Injury to the lingual nerve (LN), a peripheral branch of the trigeminal nerve, can result from a wide variety of oral and maxillofacial surgical procedures. The most common surgical procedure associated with LN injury is extraction of third molars; however, LN injury has also been reported after osteotomies, mandibular fractures, tumor removal, submandibular salivary gland excision for infection or a sialolith, dental implant placement, laryngoscopy, and general dental therapy, such as local anesthesia injection. The anatomic proximity of the LN places it at increased risk during procedures on adjacent structures in the oral and maxillofacial region.

LN injuries are detrimental to patients because of their negative effects on speech, taste, swallowing, ability to maintain food and liquid competence, social interactions, the playing of wind musical instruments, and pain perception. Most of these injuries result in sensory changes that are temporary and recover spontaneously with time. The prognostic statistics reported for patients with LN injury because of third molar extraction have shown that the probability of spontaneous recovery is 60% at 3 months, 35% at 6 months, and less than 10% at 9 months or longer.¹ Although all nerves respond similarly to injury, genetic, hormonal, anatomic, physiologic, behavioral, or other factors might influence recovery.² Three factors are known to affect the rate and degree of peripheral sensory nerve recovery after injury that have been accepted to apply to all patients, regardless of patient age, injury location, or type of injury.³

Although estimates have varied, published reports have supported that a small number of patients who have sustained LN injury have permanent neurosensory dysfunction. Permanent injury to the LN from third molar surgery has ranged from 0.04% to 0.6%.⁴⁻⁸ Numerous reports have documented inferior alveolar nerve sensory changes after the sagittal split ramus osteotomy, but few have explored the incidence of temporary or permanent LN sensory alterations. The incidence of injury to the LN because of a sagittal split mandibular ramus osteotomy has been reported to range from 9% to 19.4%.⁹⁻¹⁶

A number of algorithms exist for the diagnosis, prognosis, and management of LN injuries that have aided the surgeon in identifying those patients who have a poor prognosis for full LN sensory recovery and might gain from microsurgical intervention.¹⁷⁻²¹ The algorithm followed for the patients in the present study was that proposed by Zuniga and Essick¹⁷ and verified by clinical application.²²

Microsurgical operative management might be the most effective approach for restoring the subset of patients in whom significant LN sensory dysfunction has failed to resolve spontaneously after a reasonable interval of clinical observation.²³ A number of outcome studies have explored the effects of LN microsurgical repair.^{18,24-32} The optimal timing of microsurgical repair of the LN remains a clinical dilemma and a source of controversy. Multiple studies have suggested no association between delayed repair and neurosensory outcome,^{18,19} and others have reported improved outcomes with early repair.^{13,17,20} This controversy has primarily resulted from data from small case series using nonstandardized methods to evaluate the outcomes, making comparison between studies problematic and their outcomes difficult to evaluate. Because neurosensory function cannot be assessed directly, indirect clinical measurements of sensation (eg, temperature discernment, vibration, pinprick, light touch, and 2-point discrimination) have been evaluated as a representation of neurosensory function, with varying methods of using these measurements.

A modified British Medical Research Council scale, originally developed for the upper extremities, to grade and monitor brachial plexus injuries was adapted to monitor functional sensory recovery (FSR) of trigeminal nerve injuries and make comparisons among studies possible.³³⁻³⁶ The Medical Research Council scoring scale provides a global assessment of neurosensory function, using a combination of measurements. It ranges from a score of S0 (no improvement) to S4 (complete recovery by objective testing). For peripheral nerve injuries, a score of S3 or greater has been defined as "useful sensory recovery (USR)." The advantages afforded by this scoring system are to provide objective criteria for the classification of results; to promote and develop common and accepted use of the scale in all

disciplines in which peripheral nerve surgery is performed (ie, hand surgery, plastic and reconstructive surgery, neurosurgery, oral and maxillofacial surgery); and to enable comparison among data in various published studies, even when the scale was not used by the study investigators.

The purpose of the present study was to evaluate the long-term outcome of LN repair using a standardized approach for the diagnosis,¹⁷ standardized criteria for offering microsurgical repair, and using FSR as determined by the Medical Research Council Scale, with USR the standard criterion of a successful outcome.

Materials and Methods

A retrospective chart review was completed of all patients who had undergone microsurgical repair of the LN by one of us (R.A.M.) from March 1986 through December 2005. A physical examination, including standardized neurosensory testing (NST), as described by Zuniga et al,²² was completed for each patient preoperatively. All patients were followed up periodically after surgery for at least 1 year, with NST repeated at each visit. Sensory recovery was determined by the patient's final NST results and evaluated using the guidelines established by the Medical Research Council scale³⁷ (Table 1). The following data were collected and analyzed: patient age, gender, nerve injury etiology, chief sensory complaint (numbness, pain, or both), time from injury to surgical intervention (duration in months), intraoperative findings, surgical procedure, and neurosensory status at final evaluation. In addition, patients were separated into 2 groups according to the interval from the injury to surgery to determine any statistical significance in NST results at 1 year. The first group included the patients who had undergone nerve repair "early" (defined as within 6 months of in-

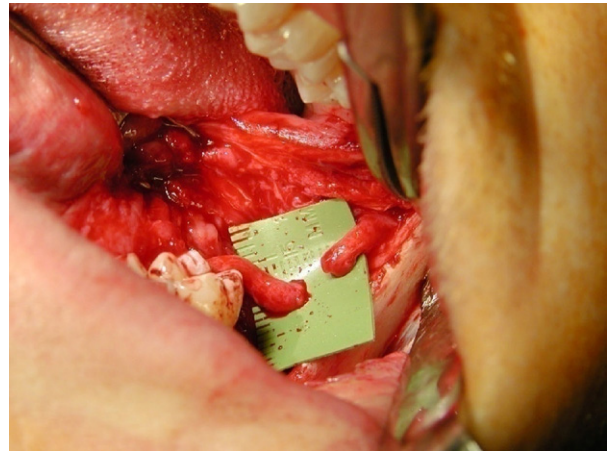


FIGURE 1. Exposure of distal and proximal LN stumps.

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jury), and the second group included patients who had undergone repair "late" (defined as more than 6 months since the injury). The patients were classified according to whether they exhibited USF. The surgical procedure included access by way of a lingual mucoperiosteal tissue flap, with the incision beginning in the gingival cuff of the mandibular canine tooth, extending posteriorly to the last tooth in the mandibular arch, and then postero-buccally across the retromolar pad. The buccal soft tissues were also retracted to allow for placement of self-retaining cheek retractors (Fig 1). The lingual periosteum was incised axially, and the LN was exposed. Next, one or more of the following procedures were performed with appropriate magnification using an operating microscope or loupes ($3.5\times$ to $5\times$), as indicated, until the operation was completed: external decompression, internal neurolysis, excision of the stump neuroma and intervening scar tissue, dissection for mobilization of the proximal and distal nerve stumps, neurorrhaphy without tension or reconstruction of the nerve gap with autogenous nerve graft (donor sural or great auricular; Figs 2, 3), and/or placement of a collagen nerve cuff (Figs 4-7). Logistic regression methods and associated odds ratios (ORs) were used to quantify the association between the risk factors and improvement. Receiver operating characteristic (ROC) curve analysis was used to determine the threshold of age and interval to surgery that maximally differentiated the patient outcomes.

Results

A total of 222 patients (51 males and 171 females; average age 31.1 years, range 15 to 61) underwent LN repair and returned for at least 1 year of follow-up.

Table 1. MEDICAL RESEARCH COUNCIL SCALE

Grade*	Description
S0	No sensation
S1	Deep cutaneous pain in autonomous zone
S2	Some superficial pain and touch
S2+	Superficial pain and touch plus hyperesthesia
S3	Superficial pain and touch without hyperesthesia; static 2-point discrimination >15 mm
S3+	Same as S3 with good stimulus localization and static 2-point discrimination of 7-15 mm
S4	Same as S3 and static 2-point discrimination of 2-6 mm

Data from Birch et al.³⁷

*Grades S3, S3+, and S4 indicate useful sensory recovery.

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FIGURE 2. Exposure of sural nerve before harvesting.

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The most common cause of LN injury was mandibular third molar removal (n = 191, 86%), followed by sagittal split mandibular ramus osteotomy (n = 14, 6.3%; **Table 2**). Most patients complained preoperatively of numbness (n = 122, 55%) or numbness with pain (n = 94, 42.3%; **Table 3**). The average interval from injury to surgery was 8.5 months (range 1.5 to 96). The most common intraoperative finding was a neuroma in continuity (n = 83, 38%; **Table 4**). The

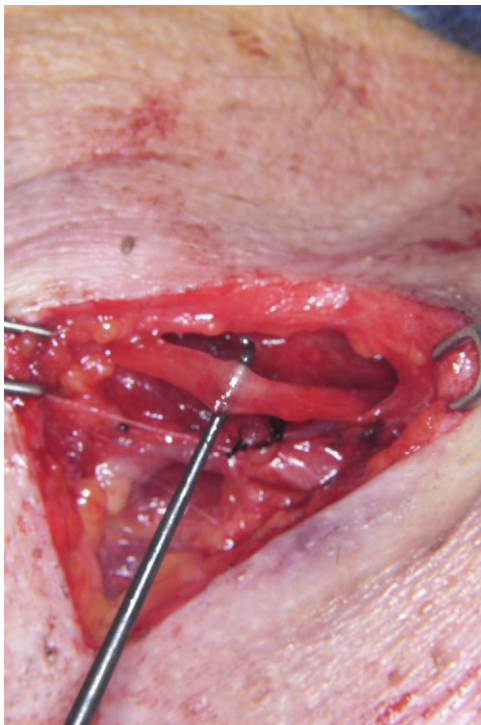


FIGURE 3. Exposure of great auricular nerve before harvesting.

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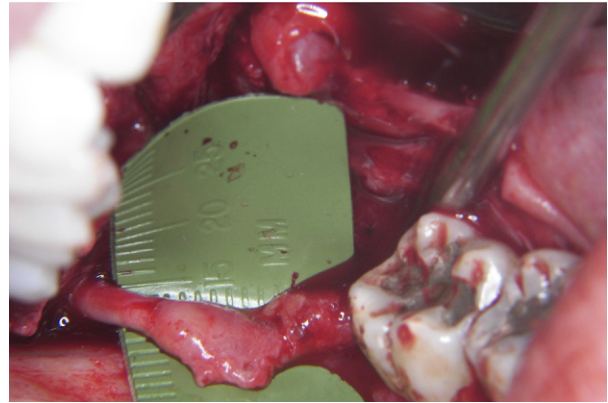


FIGURE 4. Exposed LN neuroma in continuity.

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most commonly performed operation was excision of a proximal stump neuroma with neuroorrhaphy (n = 154, 69%), followed by external decompression with internal neurolysis (n = 29, 13%; **Table 5**). Nineteen patients (8.6%) underwent an autogenous nerve graft procedure (greater auricular or sural nerve) for reconstruction of a nerve gap. A collagen cuff (Neuroflex; Collagen Matrix, Franklin Lakes, NJ) was placed around the repair site in 8 patients (3.6%; external decompres-

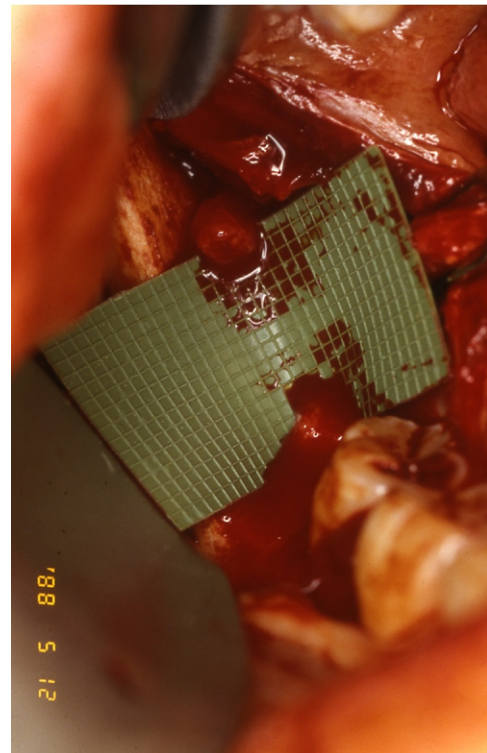


FIGURE 5. Excised neuroma showing distal and proximal nerve stumps.

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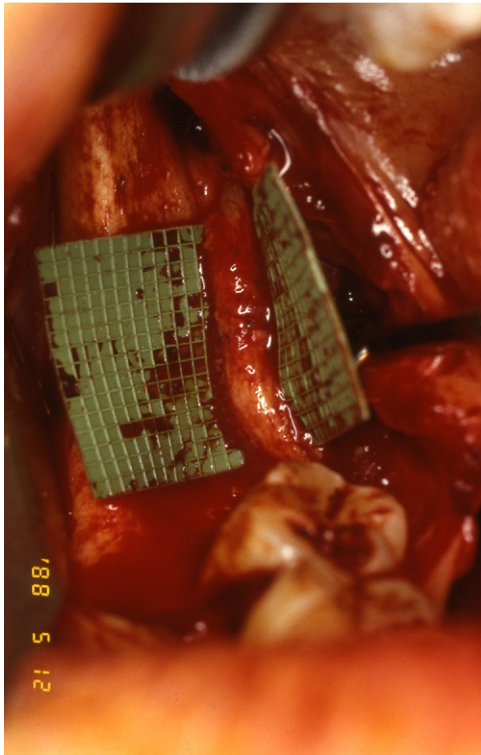


FIGURE 6. Neuroorrhaphy of LN with 8-0 nylon suture.

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sion with internal neurolysis in 2 and neuroorrhaphy in 6). Recovery from neurosensory dysfunction (defined by the MRSC as ranging from “useful sensory recovery” to “complete return of sensation”) was observed in 201 patients (90.5%; 146 with complete return of sensation and 55 with USR), and 21 patients (9.5%) showed no or inadequate improvement.

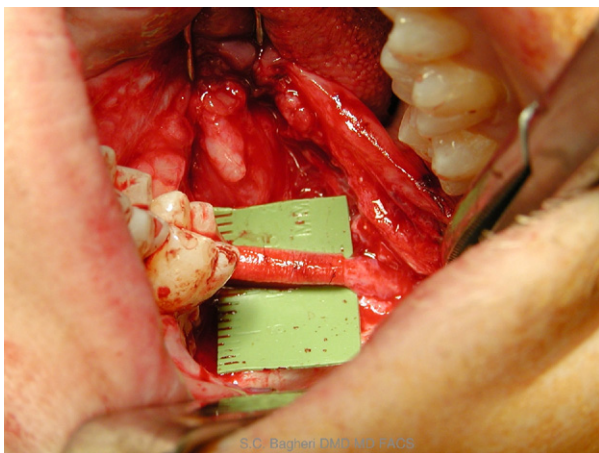


FIGURE 7. Placement of flexible collagen nerve cuff.

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Table 2. ETIOLOGY OF LINGUAL NERVE INJURY

Etiology	No. Patients
Third molar surgery	191 (86)
Sagittal split osteotomy	14 (6)
Local anesthetic	12 (5)
Gun shot wound	2 (1)
Second molar extraction	1 (0.5)
Tumor surgery	1 (0.5)
Mandible fracture	1 (0.5)

Data in parentheses are percentages.

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Using the logistic regression model, a shorter duration between nerve injury and repair resulted in greater odds of improvement (OR 0.942, $P = .0064$); thus, with each month that passed, the odds of improvement decreased by 5.8%. ROC curve analysis revealed that patients who waited more than 9 months for repair were at a significantly greater risk of nonimprovement. Statistical significance was observed between patient age and outcome (OR 0.945, $P = .0067$). ROC curve analysis revealed a 5.5% decrease in the likelihood of recovery for every year of age older than 45 years. The chance of a return of USR or complete return of sensation was greater when the patient’s main presenting symptom was pain and not numbness (OR 0.04, $P < .001$).

Of the 133 patients treated early (within 6 months), 125 (94%) demonstrated USR. Of the 89 patients treated late (after 6 months), 76 (85.4%) demonstrated improvement. This difference in improvement rates was statistically significant ($P = .032$) using a chi-square test. The odds of improvement for those who received early treatment was 2.67 times greater than the odds for those who received “late” treatment (OR 2.67, 95% confidence interval 1.06 to 6.75, $P = .037$).

Discussion

The purpose of the present investigation was to report the long-term outcomes of a large standardized patient group with LN injuries who had undergone

Table 3. CHIEF COMPLAINT

Complaint	No. Patients
Numbness	122 (55)
Numbness with pain	94 (42)
Pain	6 (3)

Data in parentheses are percentages.

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Table 4. INTRAOPERATIVE FINDINGS

Finding	No. Patients
Neuroma	83 (38)
Discontinuity	68 (30)
Partial severance	58 (26)
Compression	13 (6)

Data in parentheses are percentages.

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surgical repair and to review the demographics of this set of patients. The results of the study showed that most subjects (90.5%) achieved FSR as defined by the Medical Research Council Scale, ranging from S3 (“useful sensory recovery”) to S4 (“complete return of sensation”). Our results are comparable to those from Susarla et al,¹⁸ who presented the findings of a retrospective cohort study considering the results of LN repair in 64 subjects. They also used FSR to assess the outcomes of patients undergoing LN repair and found that more than 80% of their patients had achieved FSR at 1 year after surgery.

The timing of LN repair remains controversial. A consensus was formed, and their findings were reported in 1992 by Alling et al.³⁸ Although little scientific evidence is available to support these recommendations regarding nerve injury treatment,³⁹ the timing of nerve repair surgery was originally based on the extensive experience of Seddon^{40,41} during and after World War II. During the ensuing years, the extensive clinical experience of oral and maxillofacial surgeons has validated the concepts of timing that were previously merely speculative. On the basis of this experience, Meyer and Ruggiero²¹ proposed specific timing guidelines. Because it is impossible to develop valid prospective randomized clinical trials to compare early versus late repair, surgeons must rely on retrospective cohort studies. This makes it difficult to know whether patients who undergo early repair would have improved without surgical intervention. Meyer⁴² had an opportunity to follow-up 23 patients who had sustained closed (unobserved) inferior alveolar or LN injury and had presented initially with total anesthesia as determined by NST. None of these patients who refused surgical intervention and remained anesthetic at 12 weeks after injury progressed to any meaningful recovery of sensation during the ensuing 1 year of follow-up.⁴² The key point is that these were not anecdotal cases, but patients whose findings were documented by NST. Using the logistic regression model, a shorter duration (in months) between nerve injury and repair resulted in a greater chance of FSR in our study. With each month that passed from the time of injury, the odds of improvement decreased by

5.8%. ROC analysis revealed that patients who waited more than 9 months for repair had a significantly greater risk of nonimprovement. In addition, in our study, 94% of patients who had undergone “early” repair (less than 6 months since injury) had a statistically significant likelihood of FSR compared with 85% of the patients who had undergone “late” repair (more than 6 months since injury). These results are consistent with the report by Susarla et al,¹⁸ who found that 93% of subjects who underwent “early” repair (less than 90 days after injury) achieved FSR within 1 year compared with 62.9% of subjects who underwent “late” repair (more than 90 days after injury).

The finding that the patient whose primary complaint was pain rather than numbness had a better likelihood of recovery to USR or complete return of sensation than the patient who complained only of numbness was initially surprising. Gregg^{43,44} described the complexity of pain in the maxillofacial region and the difficulty of recovering from a nerve injury in which the principal symptom is pain. The inferior alveolar nerve lies within the protective confines of the inferior alveolar canal of the mandible. Pain from injury to the inferior alveolar nerve might or might not be stimulus related (principally from the mandibular teeth or labial mandibular gingiva). The LN, however, is totally surrounded by soft tissue, which offers little protection from the pressures of mastication and tooth brushing and the pull of the muscle activity involved in swallowing. The proximal stump “amputation” neuroma that often forms in response to LN severance is easily irritated by these activities and is the source of the “trigger area” elicited when the examining physician’s finger palpates the soft tissues on the lingual aspect of the mandible in the vicinity of the suspected area of nerve injury, adjacent to the site of the removed third molar tooth that was associated with the LN injury. Removal of this neuroma as a part of the LN repair often immediately and permanently relieves the patient’s pain symptoms, after which the patient begins to experience numbness until the new axonal growth traverses

Table 5. PROCEDURES

Procedure	No. Patients
Excision of neuroma with neuroorrhaphy	154 (69)
External decompression and neurolysis	29 (13)
Autogenous nerve graft	19 (9)
Neuroorrhaphy	15 (7)
External decompression	5 (2)

Data in parentheses are percentages.

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the nerve repair site and continues to its end plate in the mucosal surface, and sensation is restored. Why removal of an amputation neuroma from the proximal stump of the LN would be successful in relieving pain is not clear. However, Gregg⁴³ observed that the amputation neuroma was most often seen on the injured LN, but other types of neuromas were more likely to occur at the site of injuries to the inferior alveolar nerve. Perhaps the healing process and stimulus transmission differ in the neuroma-in-continuity, lateral exophytic neuroma, and lateral adhesive neuroma that develop more frequently in the injured inferior alveolar nerve.

Sunderland,⁴⁵ comparing the recovery rate after peripheral nerve suture in humans aged 11 to 42 years, observed no differences because of patient age. Other reports of LN injury and repair have also not shown age to be a significant factor in recovery.^{46,47} This was perhaps secondary to the small sample sizes of these studies that consisted mostly of patients who experienced LN injury during third molar extraction during adolescence or early adulthood. In the present study, ROC analysis revealed a statistically significant relationship between patient age and outcome (OR 0.945, $P = .0067$). We found a 5.5% decrease in the odds of recovery for every year of patient age older than 45 years.

Younger individuals have better functional recovery after peripheral nerve injury than do adults. Although observations in humans have been limited, clinical experience has indicated that the efficiency of regeneration is less in later life. Aging influences several features of the peripheral nervous system. The results of experimental studies in animals, although sometimes variable, have indicated a decline in regenerative capacity by age 34 years. Morphologic studies have found that aging is associated with a loss of myelinated and unmyelinated nerve fibers, demyelination of myelinated fibers, decreased expression of the major myelin proteins, axonal atrophy, and reduced expression and impaired axonal transport of cytoskeletal proteins in the peripheral nerve.⁴⁶ The effect of age on angiogenesis could also play a role in peripheral trigeminal nerve recovery. In a mouse model, Pola et al⁴⁷ found that the peripheral nerves of old and senescence-accelerated animals were unable to locally upregulate vascular endothelial growth factor, a prototypical angiogenic cytokine, after injury and exhibited substantial deficits in mounting an appropriate intraneural angiogenic response during nerve regeneration. Therefore, the ability of an injured nerve to recover to the level of USF is probably dependent, in part, on the patient's age and general state of health, because these directly affect tissue healing.

Neuropsychological factors also influence the ability of the older patient to recover successfully from a peripheral nerve injury after its surgical repair. It is necessary for new axonal connections to occur, with referral of sensory input to different areas of the central nervous system. Early in the recovery process, new axons are sparsely myelinated, resulting in a slower conduction time. This makes interpretation more difficult for the central nervous system until accommodations can be achieved, a situation analogous to a baseball batter having to adjust to a "change-up" (dramatically slower speed) pitch. Although the older patient is slower to adapt to these changes imposed by recovery from a peripheral nerve injury, neuroplasticity (the concept that the brain has the capacity to adapt) is still viable even into advanced age. The concept of "sensory re-education" was first developed by Birch et al³⁷ and Wynn-Parry and Salter⁴⁸ for rehabilitation of hand and upper extremity injuries. This concept has been adapted to the maxillofacial regions and shown to be successful in improving sensory function once the responses to pain and static light touch have returned, especially the ability to localize the origin of a sensation and restore graphesthesia.³⁵ Sensory re-education undoubtedly plays a role in the nerve-injured patient's ability to improve the maximal level of sensory function over and above the USR level (from S3 to S3+ or S4).³⁵

Our study was subject to certain biases of which we are aware. The retrospective nature of the study introduced selection bias, and the heterogeneity of the LN injury etiology (third molar extraction, sagittal split mandibular ramus osteotomy, local anesthetic, gunshot wound, tumor removal, or mandible fracture) resulted in different patient mind sets and expectations from treatment and recovery and different types of injuries. The methods used to treat these nerve injuries also varied and were entirely dependent on the clinical status of the nerve at microsurgical exposure and the clinical judgment of the surgeon. The operation consisted of either excision of a proximal stump neuroma with neurolysis with or without the use of an autogenous nerve graft procedure or external decompression with internal neurolysis. Only 19 of the 222 LN injuries required reconstruction of a nerve gap with an autogenous nerve graft. Most of these were done early in the surgeon's (R.A.M.) experience. As more LN dissections were done, we realized that the LN, especially that portion distal to the usual site of injury adjacent to the mandibular third molar, has a rather tortuous course into the floor of the mouth. By dissecting away scar or connective tissue, the nerve could be extensively mobilized and, by taking advantage of the extra length achieved by straight-

ening the tortuous nerve, brought into approximation without tension, negating the need for a nerve graft in most patients.^{42,49,50}

The results of our study have demonstrated that microsurgical repair of LN injuries can result in sensory and functional improvement for patients who have surgical indications as determined by history and standardized NST. Most operated patients do regain acceptable sensation and associated function as classified by the Medical Research Council Scale. The relief of pain is also frequently a welcome benefit of surgical treatment. Microsurgical repair of the injured LN is a valid treatment method for many of these patients. In our study, the likelihood of recovery after nerve repair decreased progressively with the interval from the injury to surgery and with increasing patient age.

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