

# Profiling of Patients Presenting with Posttraumatic Neuropathy of the Trigeminal Nerve

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***Aims:** To describe the cause, clinical signs, and symptoms of patients presenting to a tertiary care center with iatrogenic lesions to the mandibular branches of the trigeminal nerve. **Methods:** Pain history, pain scores using the visual analog scale, and mechanosensory testing results were recorded from 93 patients with iatrogenic lingual nerve injuries (LNI) and 90 patients with iatrogenic inferior alveolar nerve injuries (IANI). Results were analyzed using the SPSS statistical software. Chi-square tests were applied for nonparametric testing of frequencies, where  $P \leq .05$  indicated statistical significance. Appropriate correlations were also carried out between certain data sets. **Results:** Significantly more females were referred than males ( $P < .05$ ). Overall, third molar surgery (TMS) caused 73% of LNI, followed by local anesthesia (LA) (17%). More diverse procedures caused IANI, including TMS (60%), LA (19%), implants (18%), and endodontics (8%). Approximately 70% of patients presented with neuropathic pain coincident with anesthesia and/or paresthesia. Neuropathy was demonstrable in all patients with varying degrees of loss of mechanosensory function, paresthesia, dysesthesia, allodynia, and hyperalgesia. Functionally, IANI and LNI patients mostly had problems with speech and eating, where speech was affected amongst significantly more patients with LNI ( $P < .001$ ). Sleep, brushing teeth, and drinking were significantly more problematic for IANI patients ( $P < .05$ ,  $P < .001$ , and  $P < .0001$ , respectively). **Conclusion:** Neuropathic pain, as well as anesthesia, frequently occurs following iatrogenic trigeminal nerve injury similar to other posttraumatic sensory nerve injuries. This must be acknowledged by clinicians as a relatively common problem and informed consent appropriately formulated for patients at risk of trigeminal nerve injuries in relation to dentistry requires revision. J OROFAC PAIN 2011;25:333-344*

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Iatrogenic injuries to the third division of the trigeminal nerve remain a common and complex clinical problem of significant research interest.<sup>1,2</sup> The exact incidence of painful trigeminal permanent sensory dysfunction is unclear due to the lack of clarity of working diagnostic criteria for trigeminal postsurgical or posttraumatic nerve injuries.<sup>3</sup> An approximate estimation, however, states that up to 5% of the patient population is affected with chronic pain, of which approximately 35% of these patients suffer from neuropathic pain (NP).<sup>4</sup> NP is characterized by a variety of sensory symptoms that differ significantly from those of other chronic pain states. Such symptoms of NP may include paresthesia (such as tingling and formication); ongoing burning pain; spontaneous shooting, electric shock-like pain; and evoked pain in the form of hyperalgesia and/or allodynia to thermal and possibly mechanical stimuli, which almost always occurs

within a specific area (apart from trigeminal neuralgia). Patients with NP also report maximum pain levels within the region that are often coextensive with the area of sensory deficit.

Persistent pain after endodontics was found to occur in 3% to 13% of patients<sup>5-7</sup> while surgical endodontics resulted in chronic NP in 5% of patients.<sup>8</sup> Significant factors associated with persistent postendodontic pain included prolonged preoperative pain, female gender, and previous chronic pain symptoms.<sup>7</sup> In 135 patients with inferior alveolar nerve injuries (IANIs) caused by dental treatment or malignancy, 22% presented with dysesthesia, which was significantly associated with the female gender.<sup>9</sup> In another study of 449 patients with trigeminal nerve injuries caused by dental treatment, paresthesia was the most prevalent neurogenic symptom (53.5%), but more incapacitating symptoms such as dysesthesia (17.1%) and allodynia (4.5%) accounted for a lot of suffering.<sup>1</sup>

Patients with trigeminal nerve injuries often complain that their symptoms of NP interfere significantly with daily function, such as speaking, eating, drinking, kissing, facial expression, make-up application, and shaving, since most social interactions involve this nerve. These interferences result in decreased quality of life and may ultimately lead to significant psychological problems.<sup>10</sup> These patients are often frustrated subsequent to surgery and this may result in increased complaints, litigation, and malpractice suits, as well as great embarrassment to the practitioner who caused the damage.<sup>1,9</sup>

While the presence of each of the characteristics described above aid in the diagnosis of NP, they are not universally present in NP or absolutely diagnostic of NP. Any sensory deficit towards noxious and thermal stimuli indicates damage to small-diameter afferent fibers or to central nociceptive pathways. Quantitative sensory thermal assessment objectively and specifically measures the activity of these small-diameter afferent fibers or pathways by testing the patients' thresholds to cold and heat pain.<sup>11</sup> Additional conventional mechanical tests, including two-point discrimination (TPD), light touch (LT), pin prick, and sharp-blunt discrimination (SBD) tests,<sup>12-14</sup> may also be carried out to assess their activity; however, these tests are subjective and, due to the variability in methodology and reporting, are of limited value for interstudy comparisons.

The results of any subjective (psychophysical) clinical test will depend on good communication between the patient and the clinician; ultimately, the outcome of the assessment will relate to the patient's perceived experience and their interpretation of how to report it. The results also bear little clinical

significance in relation to pain and functionality. Objective assessment may exclude the higher cognitive responses of the patient, relating accurately to neurophysiologic events but omitting the patient's perceived effects. Recently, several investigators have recommended the use of the patient's report alone,<sup>15,16</sup> in combination with subjective and objective neurosensory tests<sup>17,18</sup> or utilizing quality of life (Oral Health Impact Profile [OHIP]) questionnaires<sup>19</sup> for a more holistic approach for the assessment of patients with trigeminal nerve injury. Such assessments should be carried out over a period of time after the injury in order to provide accurate monitoring of sensory and functional recovery ideally with criteria for intervention where necessary.

The aims of this study were to describe the cause, clinical signs, and symptoms of patients presenting to a tertiary care center with iatrogenic lesions to the mandibular branches of the trigeminal nerve.

## Materials and Methods

### Subjects

A total of 254 patients with trigeminal nerve injuries were consulted over 3 years at the Dental Institute in King's College Hospital, London. Within this cohort of patients, 38 patients presented with trigeminal neuropathy caused by neurological disease, malignancy, multiple sclerosis, sickle cell disease, known alcoholism, injury caused by nondental trauma, orthognathic surgery, diabetes, HIV, postherpetic neuralgia, stroke, and chemotherapy. The etiology and functional status of the remaining 183 injuries to lingual (50.8%) or inferior alveolar nerves (49.2%) were evaluated and management documented in this report. All data presented in this report were part of routine clinical examination of patients with trigeminal nerve injuries at the authors' clinics.

### Assessment

All patients were seen and assessed by a single clinician (TR) who initially obtained a detailed history that included the date and mode of injury and the patients' self-assessment of neurosensory function in terms of reduced function (hypoesthesia, anesthesia), and neurogenic discomfort (paresthesia, dysesthesia, allodynia, dysgeusia, ageusia, etc). The related interference with daily function was explored on a task basis. Psychological effects were also specifically identified, the details of which are described elsewhere.<sup>20</sup>

A series of standardized tests of neurosensory functions<sup>1</sup> was undertaken on all patients by the

same observer (TR) based on recommendations by Robinson et al<sup>21</sup> and previously used methods.<sup>14</sup> Examinations took place in a quiet room with the patients at ease, and they were urged to concentrate on the neurosensory test. Key factors assessed were size and extent of the neuropathic area, subjective function (SF), mechanosensory function, functional problems, and pain profiling.<sup>22</sup>

The percentage neuropathic area (percentage of extraoral and intraoral dermatome) within the mandibular (V3) division of the trigeminal nerve was mapped by running closed forceps gently over the surface from unaffected area to the injured zone, mapping points when the patient acknowledged a change in sensation. A neuropathic area of 100% within the extraoral dermatome indicated that the whole mandibular nerve extraoral skin area of the injured side was affected. Likewise, a neuropathic area of 100% within the intraoral mucosa indicated that the whole intraoral mucosa area of the injured side was affected.

The patients were then requested to assess their overall level of mechanosensory function of the affected nerve by using a SF scale ranging from 0 to 10 [0 = no perception of touch and 10 = normal perception].<sup>14</sup> If patients had hypersensitivity and possibly mechanical and/or thermal allodynia, they rated this on a further scale from 10 to 20. All assessments/ratings were based on a comparison with the uninjured side.

Specific mechanosensory tests were then carried out to further assess neurosensory qualities, such as LT, pin prick, SBD, moving-point discrimination (MPD), and TPD. All tests, apart from the MPD, were repeated five times. Pain was assessed at rest and after mechanical and cold stimulation by using a visual analog scale (VAS), where 0 was no pain and 10 was worst pain imaginable. The mechanical and cold stimuli were evoked by gently touching the neuropathic area with a dental probe and a piece of cotton wool sprayed with ethyl chloride (EC), respectively. All tests were limited to the V3 division of the trigeminal nerve; V1 and V2 divisions were not tested.

Patients with LNI were examined for the presence of a traumatic neuroma. An unpleasant, radiating sensation in the injured side of the tongue induced by digital pressure to the region of suspected injury at the medial aspect of the mandibular ramus was interpreted as caused by a traumatic neuroma. A further test carried out amongst only LNI patients included counting the fungiform papillae within the anterior two-thirds of the tongue. The injured side was compared with the contralateral uninjured side.

Following the assessment procedure, patients were informed of the diagnosis, the degree of injury, the likely cause, and permanency of the injury, followed by a discussion of the possible strategies to

manage their symptoms. Patients were seen on more than one occasion and were informed at each consultation of how their symptoms may relate to current understanding and explanations for NP (eg, cold allodynia).

## Statistical Analyses

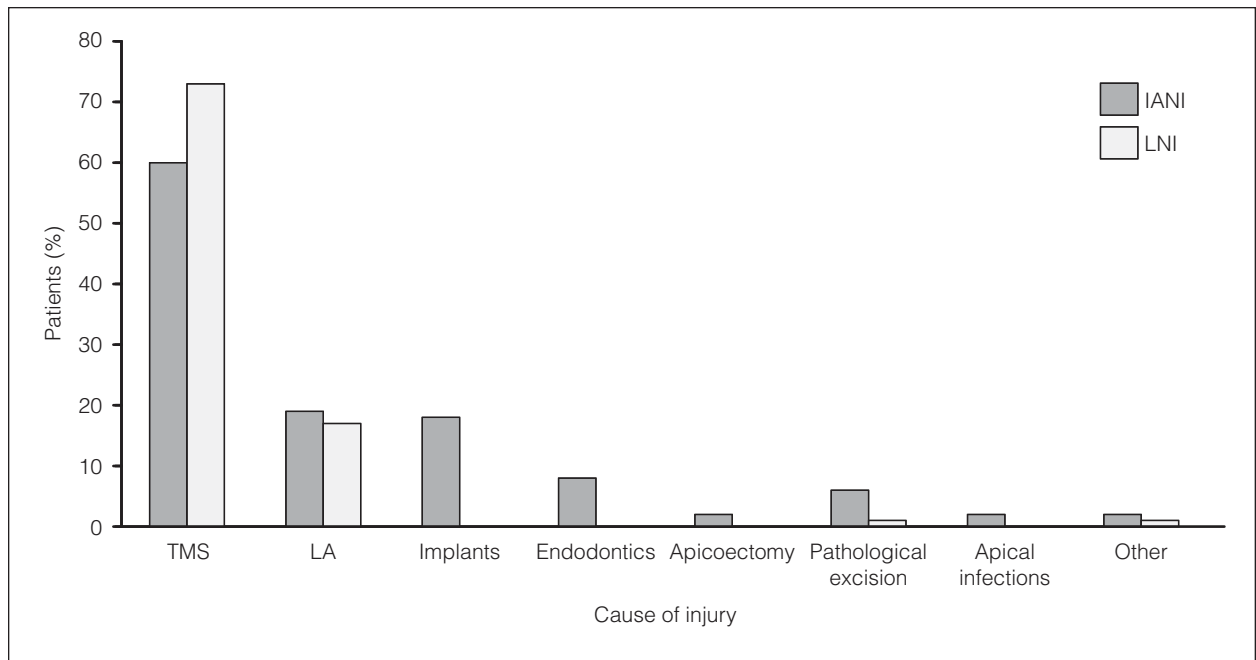
All data were analyzed using the SPSS statistical program (SPSS, IBM). Chi-square tests were applied for nonparametric testing of frequencies. Student *t* tests for the comparison of means were carried out where appropriate. The value of  $P \leq .05$  was chosen as the level of statistical significance. Appropriate correlations were also carried out between certain data sets.

## Results

### Demographics

This study involved a total of 183 patients, of whom 50.8% presented with LNI and 49.2% with IANI. Patients were referred from all parts of the United Kingdom. Specialist practitioners in secondary care trusts referred 50% and 32% of LNI and IANI patients, respectively. General dental practitioners referred 40% of LNI and 51% of IANI patients. Ages of the patients ranged from 20 to 64 years, with a mean age of 38.4 among the LNI patients. IANI patients presented with a mean age 43.8 years (range 22 to 85 years). Significantly more females suffered from injured nerves (63% of LNI patients,  $P = .01$ ; 61% of IANI patients,  $P = .003$ ), but there was no significant difference in the severity of symptoms between females and males.

The majority of IANIs and LNIs (60% and 73%, respectively) were caused by third molar surgery (TMS) and local anesthesia (LA) (Fig 1). A more diverse range of procedures, including implant placement and endodontic treatment caused IANIs. Larger intraoral neuropathic areas (80%) were observed in those patients who received TMS under general anesthesia (GA) ( $P < .01$ ). Time from injury to examination followed a skewed distribution with an arithmetic mean of 17 months (standard deviation [SD] 42.2; median = 6 months; range 0.25 to 360 months). Injuries were regarded as being permanent if the patient had symptoms for more than 6 months. Many of the LNI and IANI patients had permanent injuries (63.4% and 54.8%, respectively) and females were more likely to suffer from permanent nerve injury ( $P < .001$ ). Temporary injury was indicated in 12.9% and 5.4% of the LNI and IANI cases, respectively, as their symptoms were resolving significantly or had resolved at their consultation appointment.



**Fig 1** Cause of the IANI and LNI. TMS caused the most cases of IANI and LNI. This was followed by LA. IANIs were also caused by implants, endodontics, and apicoectomies. A small number of IANIs and LNIs were caused by pathological excisions and other procedures.

**Table 1** Summary of the Neuropathic Area Affected and Subjective Function (SF) of the LNI and IANI patients.

	Neuropathic area (%)	SF	
		Minimum	Maximum
<b>IANI</b>			
Intraoral	57.7 (4–100)	2.0 (0–4)	8.0 (1–18)
Extraoral	55.5 (0.8–100)	4.3 (0–18)	7.6 (1–20)
<b>LNI</b>			
Lingual	47.9 (2–100)	3.0 (0–8)	5 (0–12)
Lingual gingivae	43.8 (6–100)	3.0 (0–8)	5 (0–12)

Hypersensitivity to touch indicated by SF values greater than 10, as a value of 10 indicated normal perception. A SF value of less than 10 indicates diminished SF, and 0 indicates no SF.

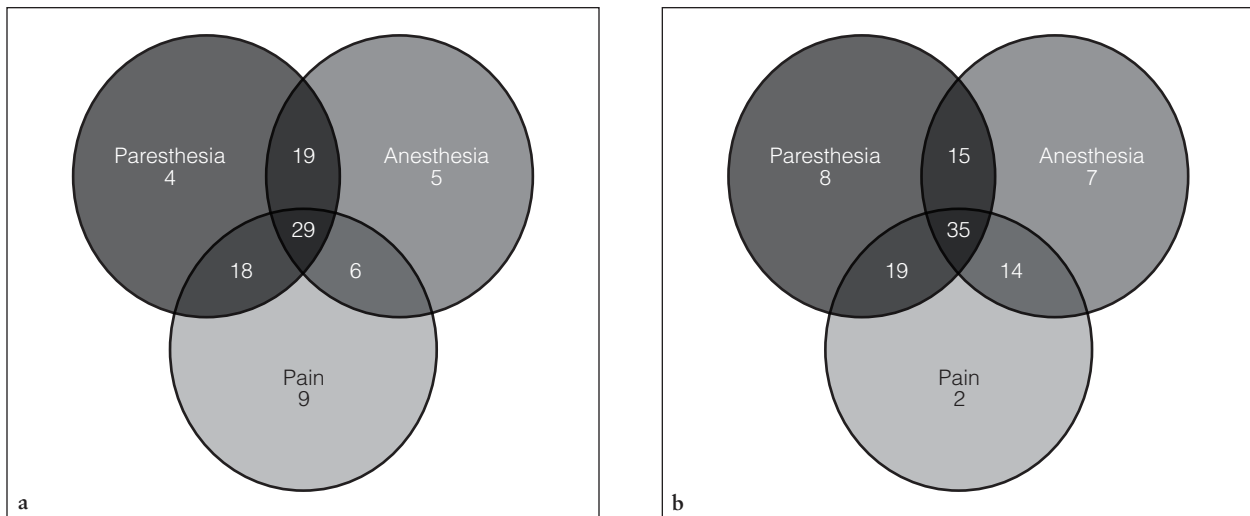
Both IANI and LNI patients reported moderate to severe pain at rest and at its worst. Mechanical allodynia was indicated when VAS scores increased immensely upon mechanical stimulation of the tongue and gingivae. IANI patients suffered from a slightly larger intraoral mean neuropathic area of 57.7% compared to 47.9% of the lingual dermatome amongst the LNI patients ( $P > .05$ ), and their mean SF value of 8.0 was larger than the mean score (5.0) of the LNI patients ( $P > .05$ , Table 1). SF values greater than 10 indicated that more IANI patients suffered from hypersensitivity and possibly

hyperalgesia/allodynia, particularly on the affected gingivae. The size of the extraoral and intraoral neuropathic area significantly correlated with the gender of only the IANI patients, where females had the larger areas ( $P < .001$  and  $P = .01$ , respectively).

**Subjective Signs and Symptoms**

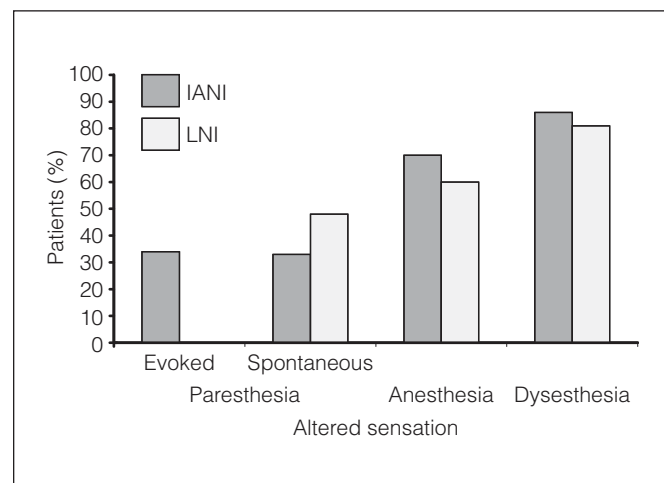
Approximately 70% of all patients presented with NP, despite the additional presence of anesthesia and/or paresthesia, as summarized in Fig 2. A significantly greater percentage of female patients in general complained of evoked and spontaneous pain, paresthesia, and anesthesia ( $P < .05$ ). Reports of evoked pain by IANI and LNI patients seemed to be greater if their nerve injury was more than 4 or 6 months duration. Conversely, reports of spontaneous paresthesia amongst the LNI patients significantly reduced if they had their symptoms for more than 6 months. The duration of the injury did not significantly affect the incidence of spontaneous pain. Patients who had their TMS carried out under LA were significantly more likely to complain of evoked pain, evoked and spontaneous paresthesia, and anesthesia in comparison to those patients who had their TMS carried out under GA. Age of the IANI and LNI patients did not correlate significantly with symptoms, neuropathic area, or permanency of the injury.

The majority of patients suffered from painful altered sensation (dysesthesia), followed by



**Fig 2** Summary diagrams showing the incidence of paresthesia, anesthesia, and pain amongst the (a) IANI and (b) LNI patients. The largest majority of IANI and LNI patients had a mixture of pain, paresthesia, and anesthesia. More IANI patients experienced pain alone. Paresthesia alone or with pain, and anesthesia alone or with pain were experienced by more LNI patients.

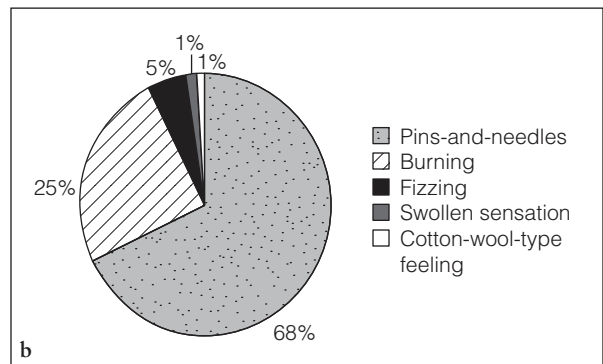
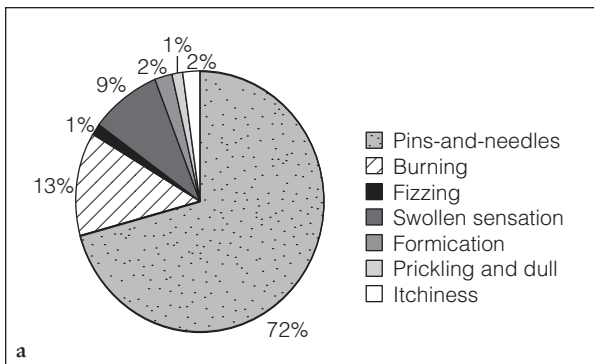
**Fig 3** Incidence of altered sensation amongst the IANI and LNI patients. IANI and LNI patients mostly complained of dysesthesia, followed by anesthesia and paresthesia ( $P > .05$ ). Evoked paresthesia was only seen amongst the IANI patients.



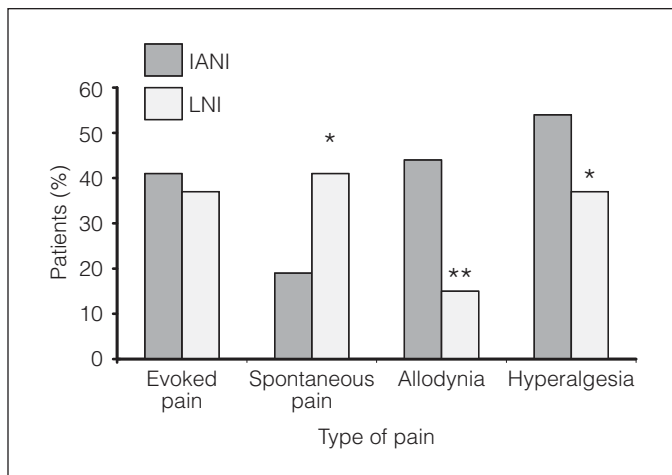
anesthesia, and spontaneous/evoked paresthesia (Fig 3). The most commonly reported character of paresthesia was pins-and-needles (Fig 4). Other altered sensations included burning, swollen and fizzing sensations, formication, and cotton-wool-type feeling in the mouth. IANI patients tended to suffer more from evoked pain, allodynia ( $P < .001$ ), and hyperalgesia ( $P < .05$ ) than spontaneous pain (Fig 5). Similar proportions of IANI and LNI patients had problems with evoked pain, but significantly more LNI patients suffered from spontaneous pain ( $P < .05$ ).

Patients with IANI suffered mostly from extraoral and intraoral mechanical allodynia, followed by cold allodynia (Fig 6). A lower percentage of LNI

patients complained of mechanical ( $P < .001$ ) and cold allodynia intraorally, and only LNI patients demonstrated intraoral heat allodynia, taste allodynia, and allodynia to spice. Other tastants that provoked symptoms amongst the LNI patients included salty food, red wine, ginger, mint, citrus flavor, and fizzy drinks/flavors. Despite the presence of taste allodynia among 5% of LNI patients, the number of fungiform papillae on the injured side of the tongue decreased in comparison to the contralateral, uninjured side. Fungiform papillae numbers had significantly reduced in the injured side of the tongue in comparison to the opposite uninjured side among 38% of LNI patients.

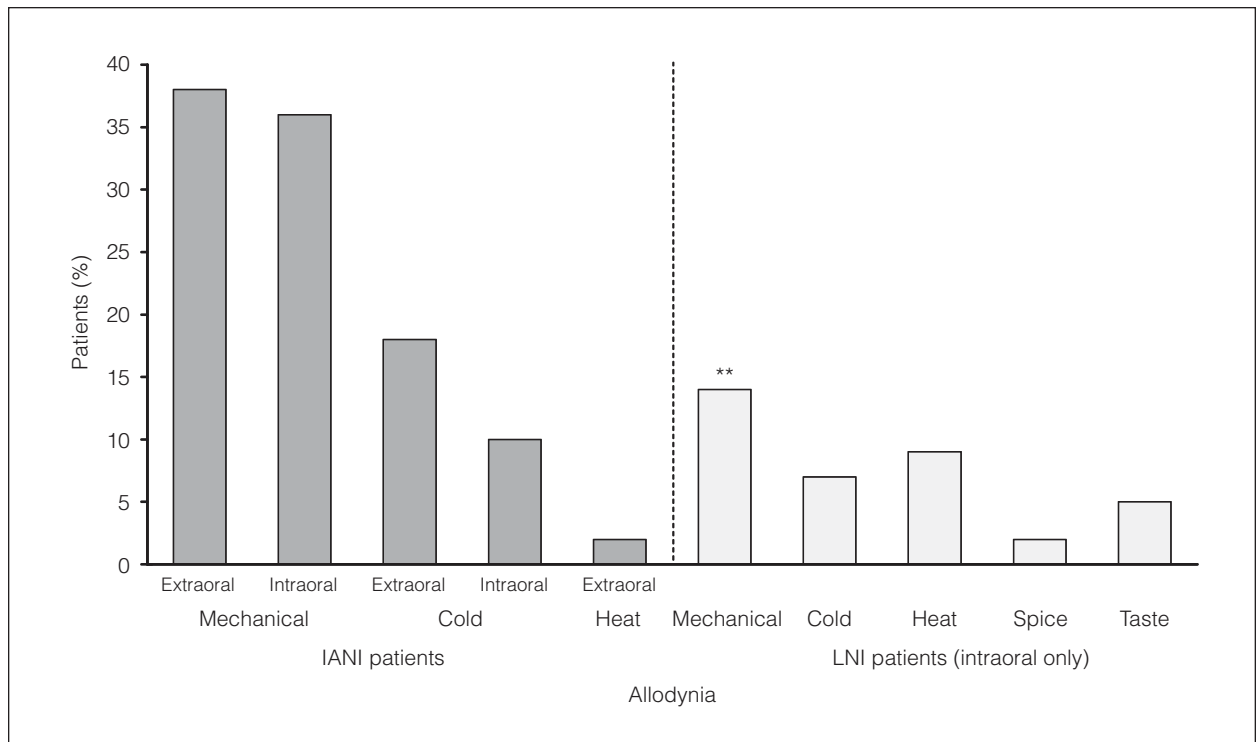


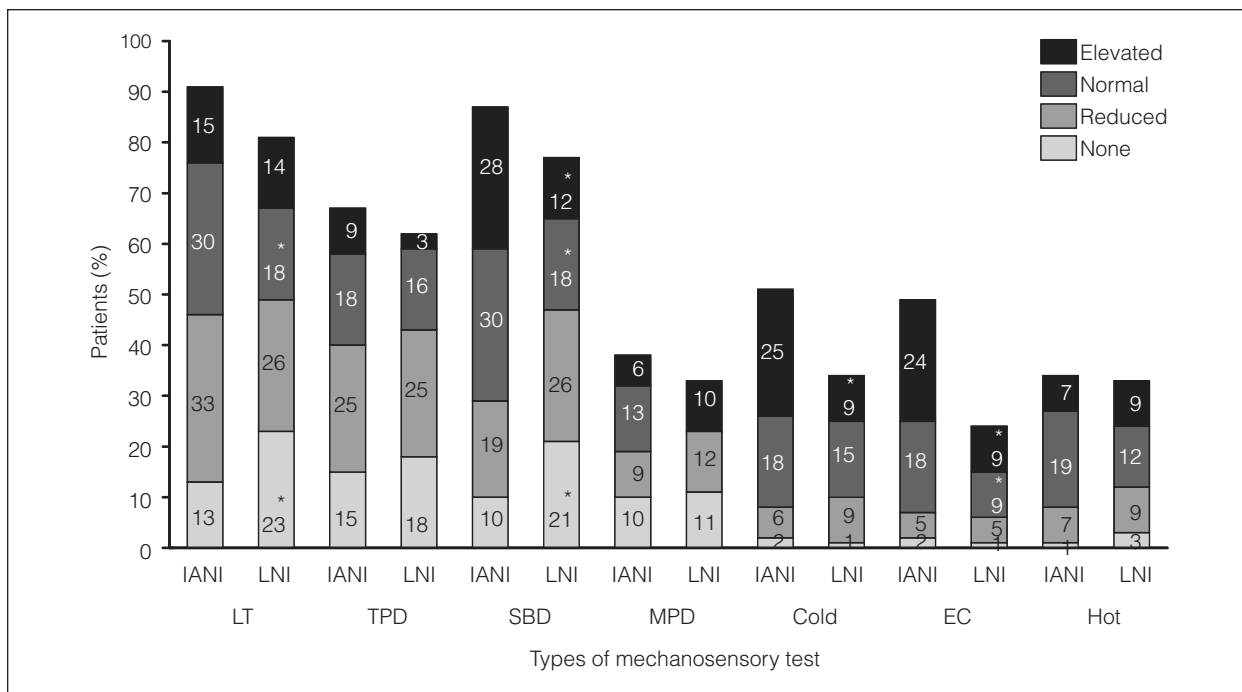
**Fig 4** Presentation descriptors of altered sensation for (a) IANI and (b) LNI patients. Most patients had complaints of pins-and-needles. The next key complaint was burning. Both IANI and LNI patients had complaints of fizzing and swollen sensations.



**Fig 5 (left)** Types of pain experienced by IANI and LNI patients. Although similar numbers of IANI and LNI patients experienced evoked pain, a significantly larger proportion of LNI patients experienced spontaneous pain ( $P < .05$ ). Significantly more IANI patients experienced allodynia ( $P < .001$ ) and hyperalgesia ( $P < .05$ ).

**Fig 6 (below)** Incidence and types of allodynia experienced by the IANI and LNI patients. Key types of allodynia experienced by the patients were mechanical, cold, and heat. A small percentage of LNI patients also experienced allodynia to spice and taste. A significantly larger percentage of IANI patients experienced intraoral mechanical allodynia ( $P < .001$ ).





**Fig 7** Mechanosensory results for IANI and LNI patients (\* $P < .05$  when IANI and LNI patients were compared for each type of mechanosensory test). A greater percentage of IANI patients had elevated responses to TPD, SBD, cold, and EC than the LNI patients, who showed decreased sensitivity to the mechanosensory tests. Significantly more LNI patients had no response to LT and SBD ( $P < .05$ ).

## Sensory Impairment

IANI and LNI patients suffered significantly from reduced mechanosensory function (Fig 7). Significantly more patients with LNI had no LT perception and no SBD in comparison to the patients with IANI ( $P < .05$ ). Significantly greater proportions of IANI patients with hypersensitivity to cold and touch, as indicated by elevated responses to cold, EC, TPD, and SBD ( $P < .05$ , Fig 7) correlated positively with increased incidence of cold and mechanical allodynia amongst IANI patients.

IANI and LNI patients reported moderate to severe pain at rest and at its worst. An unpleasant, radiating sensation in the injured side of the tongue upon palpating the region of suspected injury at the medial aspect of the mandibular ramus suggested the presence of a traumatic neuroma in 19% of LNI patients.

## Functionality

A significantly greater percentage of LNI patients had problems with speech in comparison to IANI patients ( $P < .001$ ; Fig 8). Similar numbers of patients, however, complained of problems with eating. Significantly more patients with IANI had problems with brushing teeth ( $P < .001$ ), drinking ( $P < .0001$ ),

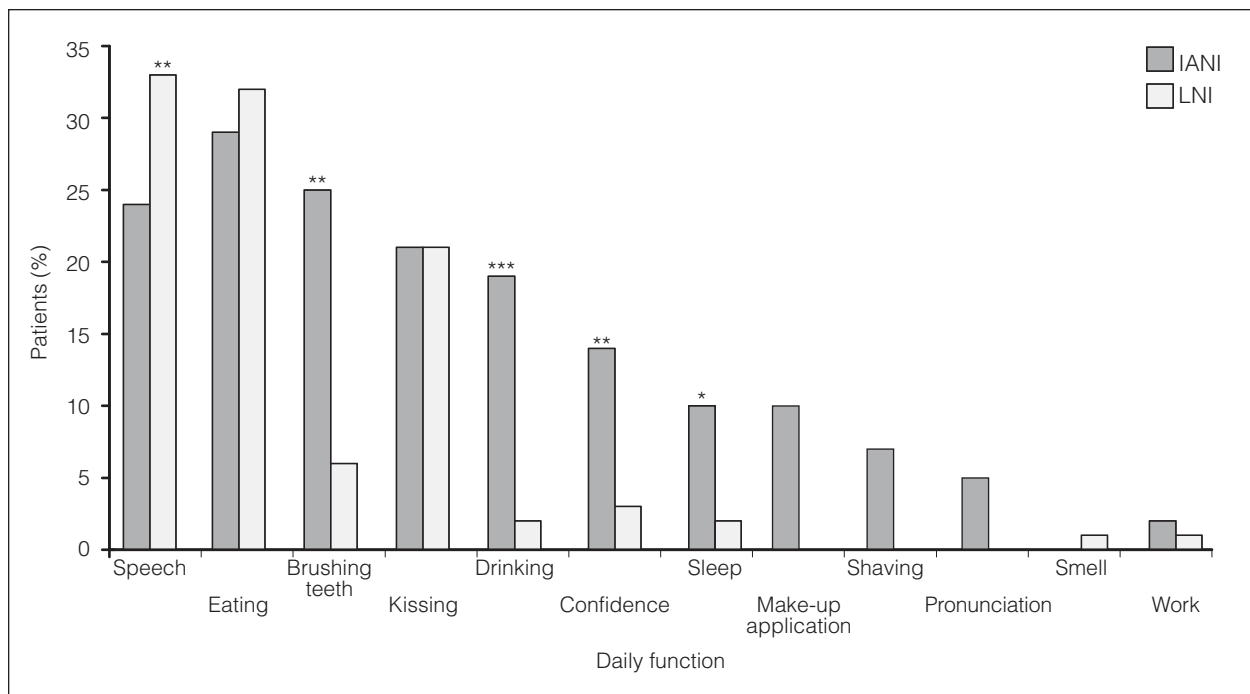
confidence ( $P < .001$ ), and sleep ( $P < .05$ ). Kissing was affected in equal percentages of IANI and LNI patients. Other problems experienced by patients with IANI included interference with make-up application, shaving, and pronunciation. A very small number of patients also had problems with work.

## Discussion

Iatrogenic trigeminal nerve injury in relation to dentistry remains a significant research interest to clinicians.<sup>1,2</sup> The present study describes the signs and symptoms experienced by patients with post-traumatic IANI and LNI.

## Cause of Injury

Results of this study add to the previous reports that injury to the third division of the trigeminal nerve may occur due to a variety of different dental treatments including TMS,<sup>12</sup> implant treatment,<sup>23,24</sup> dental LA injections,<sup>25</sup> and endodontic treatment.<sup>26</sup> The range of causes of LNI and IANI exist most likely because of the location of these nerves. The LN sits in soft tissue and is more likely to be prone to compression mechanical type injuries, particularly



**Fig 8** Interference of symptoms with functionality of the IANI and LNI patients. The majority of IANI and LNI patients had problems with speech and eating, where speech significantly affected more LNI patients than IANI patients (\*\* $P < .001$ ). Significantly more IANI patients had difficulties with brushing their teeth (\*\* $P < .001$ ), drinking (\*\* $P < .0001$ ), confidence (\*\* $P < .001$ ), and sleep (\* $P < .05$ ).

related to TMS involving lingual access. The IAN sits in a bony canal making it more likely to be exposed to mechanical or hemorrhagic compression and chemical endodontic injuries.

In accordance with previous reports, it was not surprising that TMS caused the highest incidence of LNIs and IANIs.<sup>1,2,27</sup> The significantly larger neuropathic areas (80%) caused by TMS carried out under GA in comparison to TMS carried out under LA may reflect the increased difficulty of the surgical procedures being selected for GA.<sup>28</sup> The IAN neuropathy related to TMS or IAN block injections is usually temporary but can persist and become permanent.<sup>1</sup>

LA-related injury to the trigeminal nerve was the second most common cause of IANI and LNI in this study at 19% and 17%, respectively. Nerve injury due to LA is complex. The nerve injury may be physical (needle, compression due to epineural or perineural hemorrhage) or chemical (hemorrhage or LA contents). The problem with these injuries is that the nerve will remain grossly intact and therefore one cannot identify the injured region, making it inappropriate to carry out surgery. Therefore, the most suitable management indicated is for symptomatic pain relief.<sup>29</sup> Several epidemiological reports have highlighted the increased incidence of persistent nerve injury related to IAN blocks with the introduction of

high LA concentration, eg, Prilocaine and Articaine, both at 4%.<sup>25,30</sup> These injuries have been shown to be associated with a 34%<sup>31</sup> and 70%<sup>29</sup> incidence of NP, which is high when compared with other causes of peripheral nerve injury.

Implants caused 18% of the IANIs, most likely due to the close anatomical location of lower third molars to the IAN.<sup>32,33</sup> An IANI may be avoided by carrying out a coronectomy, which is a procedure that involves removal of the crown of the wisdom tooth and leaving behind the roots.<sup>34,35</sup> Unfortunately, where this procedure may have been appropriate, none of the patients seen in this study with TMS-related IAN injury were offered a coronectomy procedure. This technique should also be routinely taught to future oral surgeons. In comparison to IANIs, LNIs more likely occurred due to lingual access surgery, which involves raising a lingual flap in addition to a buccal flap and carrying out specific lingual retraction to protect the LN and improve visibility and access to the third molar region.<sup>36</sup> The authors hope that with formalized oral surgery training, this high-risk surgical approach for mandibular TMS will phase out.

The small percentage of patients with IANIs in this study (8%) support the idea that serious mechanical and chemical damage may also occur from



endodontic procedures.<sup>26</sup> Any tooth requiring endodontic therapy that is in close proximity to the IAN canal should require special attention. If the canal is overprepared and the apex opened, chemical nerve injuries from irrigation of canal medicaments is possible as well as physical injury precipitated by overfilling using pressurized thermal filling techniques.<sup>37</sup> Postoperative root canal treatment reviews must be arranged on the day of completion and identification of any treatment product in the IAN canal should be treated within 48 hours.<sup>26</sup>

### Referral of Patients and Persistence of Injury

Most patients were seen within a year after the injury, and injuries were more frequently regarded as being permanent. The majority of IANIs caused by TMS were referred from general dental practitioners who may have had inadequate specialist training in oral surgery and inexperience of TMS. TMS under GA was more likely to result in IANI with a larger neuropathic area, possibly because of increased complexity of the cases. LNI patients, however, were mainly referred from secondary care clinics. These results indicate that both general practitioners and specialist oral surgeons need to take more care when carrying out such procedures.

Full recovery of nerve function following injury is less likely after a severe injury, when the patient is seen a long time after the injury, and when the injury is in close proximity to the cell body.<sup>38</sup> Faster referral of cases to specialist oral surgeons within 3 months after TMS injury, as well as management of implant- or endodontic-related injuries within 24 hours of the injury, may help maximize the resolution of neuropathy by interrupting and possibly reversing the cascade of events that occur after nerve injury.<sup>19,39,40</sup> There will, however, be the unfortunate cases where the nerve injury caused by LA, delayed referral of implant, or endodontic injuries that cannot be treated surgically. These patients should be reassured about their condition, referred for counseling if required, and medically managed for the associated pain.

### Patient Age and Gender

Age ranges were similar to previous reports of patient cohort with iatrogenic nerve injury.<sup>1,2</sup> Significantly more females had IANI and LNI, showing similarities to previous studies.<sup>1,41</sup> Females may appear to be more at risk of iatrogenic trigeminal nerve injuries because they are more likely to visit the doctor in general than males and are more likely to seek advice regarding pain. Significantly greater numbers of female patients reporting evoked and spontaneous pain, paresthesia,

and anesthesia support previous studies.<sup>7,41</sup> These increased reports of pain among females may be possibly due to their lower pain thresholds<sup>42</sup> or related to their increased tendency to communicate their problems. Reasons explaining why female patients with IANI suffered from significantly greater areas of neuropathy within the extraoral and intraoral dermatomes deserve further analysis.

### Neurosensory Assessment

*Pain and Altered Sensation.* A large proportion (70%) of patients with posttraumatic trigeminal nerve injury in the present study had NP with/without additional neurogenic discomfort, such as anesthesia and/or paresthesia. In a previous report, only 10 patients (14%) presented without neurogenic discomfort in patients undergoing LN repair.<sup>1</sup> However, 30% of LNI patients reported pain that was reduced to 26% after surgical intervention.<sup>43</sup> Several authors<sup>43,44</sup> separated out these symptoms, implying that the patients only experience one or the other; however, this study illustrates that pain can occur in addition to anesthesia and paresthesia. These troublesome symptoms inevitably resulted in a severe reduction of their overall quality of life, and the functional difficulties and associated psychological distress experienced by these patients are discussed in greater detail elsewhere.<sup>20</sup>

The majority of patients with IANIs or LNIs in this study suffered from painful altered sensation (dysesthesia). The prevalence of spontaneous paresthesia amongst LNI patients was consistent with the previously stated incidence of 50% to 80%.<sup>45</sup> Only IANI patients demonstrated spontaneous and evoked paresthesia. The most commonly reported character of paresthesia was pins-and-needles followed by burning sensations in both groups. Fizzing and swollen sensations were also experienced by both groups. However, only the IANI patients complained of “ants-crawling-across-the-area”-type sensations, otherwise known as formication. Itchiness and prickling, dull sensations were also experienced only by the IANI patients. A LNI patient also reported a cotton-wool type sensation within the mouth. The variation in reported symptoms probably reflects the difficulty patients have in describing their sensations and association of them with specific factors.

A greater number of IANI and LNI patients reported evoked pain if their nerve injury was more than 4 or 6 months in duration. However, the duration of the injury did not significantly affect the incidence of spontaneous pain, which may indicate that these symptoms remain stable. Patients who had

their TMS carried out under LA were significantly more likely to complain of evoked pain, evoked and spontaneous paresthesia, and anesthesia in comparison to those patients who had their TMS carried out under GA, indicating a possible role for the chemical within the LA in the development of these symptoms. Age of the IANI and LNI patients did not correlate significantly with symptoms, neuropathic area, or permanency of the injury. There was also a significant reduction in the number of LNI patients reporting spontaneous paresthesia if they had their symptoms for more than 6 months.

Both IANI and LNI patients reported moderate to severe pain at rest and at its worst. Mechanical allodynia was indicated when VAS scores increased immensely upon mechanical stimulation of the tongue and gingivae. This indicated altered activity of the A $\beta$ -fibers normally involved in mechanical sensation. In addition to this, the presence of cold allodynia extraorally and intraorally, and heat allodynia indicated altered activity of the smaller myelinated A $\delta$ - and unmyelinated C-fibers and/or their central pathways normally involved in thermal and pain perception.<sup>46</sup>

Long-term alteration of taste sensation following LNI has been previously reported.<sup>41</sup> In this study, the authors considered that altered activity of the chorda tympani was manifested by “tastant allodynia,” ie, pain elicited with specific flavors, despite the decreased number of fungiform papillae on the injured side of the tongue. This is the first study to report such a phenomenon in iatrogenic nerve injuries, whereby such patients also reported significant problems with eating. A decrease in the number and quality of fungiform papillae following LN section supports previous studies<sup>45,47,48</sup> and possibly explains the lack of trophism to the fungiform papillae due to damage to the chorda tympani nerve. Tastant allodynia may be due to specific up-regulation in neural receptors that respond to these adjuvants, including transient receptor-potential Vanilloid (TRPV) receptors and sodium channels (Na<sub>v</sub> 1.7 and 1.8), which have been shown to be up-regulated in other trigeminal pain conditions.<sup>49,50</sup>

Peripheral nerve injuries are also known to cause increased neuroimmune interactions, such as microglia within the spinal cord and brainstem and altered gene expression, that result in changes in the function of neurons. Such changes therefore result in disturbed sensory inflow to the central nervous system.<sup>51</sup> In addition to these alterations, changes in functional topography have been shown to occur within the cortex, and cortical gray matter is lost. Alterations in reciprocal connections can also occur, in particular between the spinal cord, brainstem, and higher brain centers,

which include an increase in descending facilitatory influences and a decrease in inhibitory influences.

Surgically induced injury resulting in chronic NP is now well-established, and the incidence is much higher than most surgeons anticipate. Approximate estimated incidences of chronic NP after various procedures include 60% following leg amputation, 50% following a thoracotomy, 30% after breast surgery, from 10% to 20% after cholecystectomy, and 10% to 15% after an inguinal herniorrhaphy.<sup>52-55</sup> One would expect the incidence of postsurgical NP relating to dentistry to be similar to other surgical procedures, however, this study highlights that the incidence of pain, dysesthesia, and hyperesthesia in postsurgical trigeminal nerve injuries was high compared with other postsurgical NP incidences.<sup>53,54</sup> A possible reason for such a high incidence of NP could be that most dental surgery is undertaken on an outpatient basis and patients are not kept in hospital, thus allowing better monitoring of postoperative persistent pain. The patient cohort was also self-selected, whereby patients had to persist or even demand referrals for their complex and painful symptoms. It is likely that patients with anesthesia perhaps are not so debilitated, thus not seeking secondary or tertiary referrals. Patients with pain are more likely to have severe functional and psychological difficulties even without due consideration to the additional damaging effects of the iatrogenic nature of the injury.

Chronic postoperative pain is generally more likely to occur amongst patients with preoperative pain, psychological vulnerability, anxiety, depression, and/or neuroticism, if the patient is going to benefit from workers compensation, if a surgical approach with risk of nerve damage is carried out, if the surgery is repeated, upon the occurrence of moderate or severe acute postoperative pain, and possibly if the patient is undergoing radiation therapy and/or neurotoxic chemotherapy.<sup>56</sup>

*Mechanosensory Impairment.* Although there have been numerous studies evaluating trigeminal neurosensory disturbance due to oral surgery, there seems to be no consensus as to the ideal choice of methods with which to measure such impairments. While such methods should be precise enough to match the requirements of modern science, they should also be pragmatic enough to be used in an outpatient setting. Elevated responses to more than one of the tests carried out frequently correlated positively with an increased incidence of cold and mechanical allodynia amongst IANI patients in the present study. Many patients also suffered significantly from reduced mechanosensory function, such as LT, TPD, SBD, and MPD. A report by Hillerup and

Stoltze<sup>57</sup> showed similar findings to this patient cohort, whereby patients showed decreased TPD of > 20 mm on the injured side in comparison to 6.3 mm (SD 2.3) on the noninjured side.

The presence of a traumatic neuroma was indicated when an unpleasant, radiating sensation in the injured side of the tongue occurred upon palpating the region of suspected injury at the medial aspect of the mandibular ramus. A traumatic neuroma was suggested in 19% of LNI patients, which is less than a previous study<sup>57</sup> that reported 53% of patients displayed this positive sign. This interestingly did not improve after reparative surgery.

## Recommendations

There is need for a consensus and standardization of IANI and LNI assessment in order to identify injury, while also simultaneously differentiating temporary from permanent injuries in the early postoperative period in order to expedite the appropriate selection of candidates for appropriate interventions. The authors recommend that a holistic approach would be beneficial to all clinicians and patients to recognize the incidence of pain, the related effect on functionality, and psychological implications.

It is imperative that for all patients undergoing procedures that place the trigeminal nerve at risk, surgical methods must be modified to minimize risk to the nerve and, if injury occurs, it must be recognized early on and appropriately referred to a specialist. Consent procedures should be instituted to ensure that patients are alerted to the possibility of chronic NP and be provided with realistic expectations as to the risks and consequences of trigeminal nerve injury. Assessment of risk must be undertaken in order to appropriately advise the patient with regard to alternative treatment plans and include this possibility in the consent forms.<sup>58</sup> The information should be explicit with ensuring that the patient is aware that nerve injury may cause altered sensation (anesthesia, pain, and/or troublesome altered sensation) that may be intermittent or constant, temporary or permanent. The patient must also be warned that the neuropathic area may affect all or part of the IAN dermatome, extra- and intraorally (whole of skin and vermilion of lip and chin on each side and all lower quadrant teeth and associated buccal gingivae), or LN dermatome (whole side of tongue and lingual gingivae).

Many authors recommend referral of injuries before 4 months<sup>59</sup> but this may be too late for many peripheral sensory nerve injuries. More recently, the authors have recommended early removal of implants as a strategy to optimize neuropathy resolution.<sup>40</sup>

It is now understood that after 3 months, permanent central and peripheral changes occur within the nervous system subsequent to injury that are unlikely to respond to surgical intervention.<sup>51</sup>

## Conclusions

Pain as well as anesthesia and/or paresthesia may occur following posttraumatic trigeminal nerve injury, and the functional problems and psychological morbidity are significant in this group. Based on these findings, the authors recommend the best practice for informed consent for patients at risk of iatrogenic nerve injury in relation to dental procedures.

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