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Review Paper
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Managing iatrogenic trigeminal nerve injury: a case series and review of the literature

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Abstract. This study describes the management of 216 patients with post-traumatic iatrogenic lingual nerve injuries (LNIs; $n = 93$) and inferior alveolar nerve injuries (IANI; $n = 123$). At initial consultation, 6% IANI and 2% LNI patients had undergone significant resolution requiring no further reviews. Reassurance and counselling was adequate management for 51% IANI and 55% LNI patients. Systemic or topical medication was offered as pain relief to 5% of patients. Additional cognitive behaviour therapy (CBT) was offered to 8% of patients. Topical 5% lidocaine patches reduced pain and allodynia in 7% of IANI patients, most often used without any other form of management. A small percentage of IANI patients (4%) received a combination of therapies involving CBT, surgery, medication and 5% lidocaine patches. Exploratory surgery improved symptoms and reduced neuropathic area in 18 LNI and 15 IANI patients resulting in improved quality of life. In conclusion, the authors suggest a more diverse and perhaps holistic strategy for management of patients with iatrogenic trigeminal nerve injuries and recommend pragmatic assessment criteria for measurement of treatment success in these patients.

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The most problematic outcome of dental surgical procedures with major medico-legal implications is injury to the trigeminal nerve.[8] The prevalence of temporarily impaired lingual and inferior alveolar nerve function is thought to range between 0.5 and 2% for third molar surgery, whereas permanent injury caused by injection of local analgesics is much less frequent at 0.0001–0.01%.[15] Trigeminal nerve injury is complex because it is the largest peripheral sensory nerve in the human body, represented by over 40% of the sensory cortex. The trigeminal nerve or 'three twins' supplies the face, eyes, mouth and scalp with general sensation in three divisions (ophthalmic, maxillary and mandibular), and innervates the mastication muscles.

The most commonly injured trigeminal nerve branches, the inferior alveolar nerve (IAN) and lingual nerve (LN) are different entities. The LN sits loosely in soft tissue compared with the IAN that resides in a bony canal. Injury to the third division of the trigeminal may occur due to a variety of different treatment modalities, such as major maxillofacial and minor oral surgery.[4,12,16,19,44] Peripheral sensory nerve injuries are more likely to be persistent when the injury is severe, if the patient is older, there is increased duration between the injury and the review of the patient, and when the injury is more proximal to the cell body.

Subsequent to iatrogenic trigeminal nerve injury, the patient will experience reduced quality of life, psychological discomfort, social disabilities and handicap.[20] Patients often find it hard to cope with such negative outcomes of dental surgery since the procedure is often

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elective and the patient expects significant functional or aesthetic improvements.[18] Altered sensation and pain in the orofacial region may interfere with speaking, eating, kissing, shaving, applying make up, tooth brushing and drinking; in fact just about every social interaction.[47]

Current management of these nerve injuries is inadequate. The focus misguidedly remains on surgical correction or laser therapy of the nerve itself with little or no attention to the patient's complaints. A more holistic approach, such as medical or counselling intervention with consideration for the patients' psychological, functional or pain related complaints is required. The fault partly rests with how these patients are assessed. Assessment tends to show little regard for the functional or pain evaluation with the main focus remaining on basic mechanosensory evaluation, which is not necessarily reflective of the patients' difficulties. Oral surgery specialists assessing these injuries should follow guidelines from the World Health Organisation, which suggests that nerve injury outcomes should be assessed in terms of impairment, activity limitations, and participation restrictions.[21] Guidelines set out by the International Association for the Study of Pain and European Federation of Neurological Societies should also be heeded.[11] These recommendations involve assessment using quantitative thermosensory testing, pain profiling and quality of life questionnaires containing psychometric scales reflecting the important criteria by which the affectivity of interventions should be assessed. These recommendations, without exception, are holistic when compared with current reports evaluating the management of trigeminal nerve injuries.

Traumatic injuries to peripheral nerves pose complex challenges, and treatment of nerve injuries must consider all aspects of the inherent disability. A priority in managing these patients is reassurance and an honest opinion as to whether the nerve injury is permanent. This approach will give the patient a realistic platform from which to decide on future treatment and pain control and rehabilitation should be instituted as early as possible. Reparative surgery may be indicated when the patient complains of persistent problems related to the nerve injury, and is important for optimal physiological and functional recovery,[34] but there remains a significant deficiency in evidence base to support this practice.

Patients' presenting complaints may include functional problems due to the reduced sensation, intolerable changed sensation or pain that is predominantly intransigent to surgery. Frequently, poorly expressed psychological problems relating to the iatrogenesis of the injury and chronic pain are overlooked.[17,36,37] Generally for lesions of the peripheral sensory nerves in humans, the gold standard is to repair the nerve as soon as possible after injury.[3] The relatively few series of trigeminal nerve repair in humans relate mainly to repairs undertaken at significantly more than 6 months after injury, which is unsatisfactory. This phenomenon is peculiar to dentistry and may be based on the misconception that the majority of trigeminal nerve injuries resolve, when in fact, it is only lingual nerve injuries related to lingual access surgery that resolve in 10 weeks in 88% of cases.[4,22]

It is evident from the literature review that there needs to be a cultural change in the choice of intervention, timing and outcome criteria when evaluating interventions for trigeminal nerve injuries. To date, there have been a very limited number of prospective randomized studies to evaluate the effect of treatment delay, and the surgical, medical or counselling outcomes for trigeminal nerve injuries in humans. This is probably due to the ethical difficulties of initiating such a study.

The aims of this study were to establish the main complaints of patients with iatrogenic trigeminal nerve injuries and determine how they are managed, with the aim of recommending improved criteria for assessing the outcomes of these interventions.

Materials and methods

Two hundred and fifty-four patients with trigeminal nerve injuries collected over 3 years were consulted at the authors' institution. Thirty-eight patients presented with trigeminal neuropathy caused by neurological disease, malignancy, multiple sclerosis, sickle cell disease, known alcoholism, injury caused by non dental trauma, orthognathic surgery, diabetes, HIV, post-herpetic neuralgia, stroke or chemotherapy. The aetiology and functional status of the remaining 216 injuries were evaluated and their management documented.

All patients were seen and assessed by a single clinician (TR) who obtained a detailed history. This included the date and mode of injury and the patients' self-assessment of neurosensory function in terms of reduced function (hypoaesthesia, anaesthesia), and neurogenic discomfort (paraesthesia, dysaesthesia, allodynia, dysgeusia, ageusia). The related interference with daily function was explored on a task basis, and psychological effects were specifically identified, the details of which are described elsewhere.[29]

A series of standardized tests of neurosensory functions[15] was undertaken on all patients by the same observer (TR) based on recommendations by Robinson et al.[35] Key factors assessed were size and extent of the neuropathic area, subjective function, mechanosensory function, functional problems and pain profiling.[29,30]

The percentage neuropathic area (percentage of extra-oral and intra-oral dermatomes) was mapped by running closed forceps gently over the surface from the unaffected area to the injured zone, mapping points when the patient acknowledged a change in sensation. A neuropathic area of 100% within the extra-oral dermatome indicated that the whole mandibular nerve extra-oral skin area of the injured side was affected. A neuropathic area of 100% within the intra-oral mucosa indicated that the whole intra-oral mucosa area of the injured side was affected. Pain scores were rated on a visual analogue scale, where 0 indicated no pain and 10 the worst pain imaginable. Mechanical allodynia was indicated by evoked pain in response to touch.

Following assessment, the patient was 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 and their expectations. The consultations usually lasted 30–40 min. Patients were seen on more than one occasion and were informed at each consultation of how their symptoms may relate to current understanding of neuroscience with explanations of neuropathic pain (for example cold allodynia). The patients were always offered the contact details of the clinician.

The strategy for selecting the mode and timing of intervention was based on the cause of the injury, the patient's symptoms, the extent and permanency of the injury and the patient's choice. The key management strategies included counselling and reassurance, medication and surgery (exploration with or without decompression or direct anastomosis). As time progressed, the service developed by providing liaison psychiatric and psychological support in the form of cognitive behavioural therapy (CBT). CBT was provided by initial screening by a consultant liaison psychiatrist and provided by a clinical psychologist and was based on both qualitative analysis and results from specific psychometric questionnaires, of

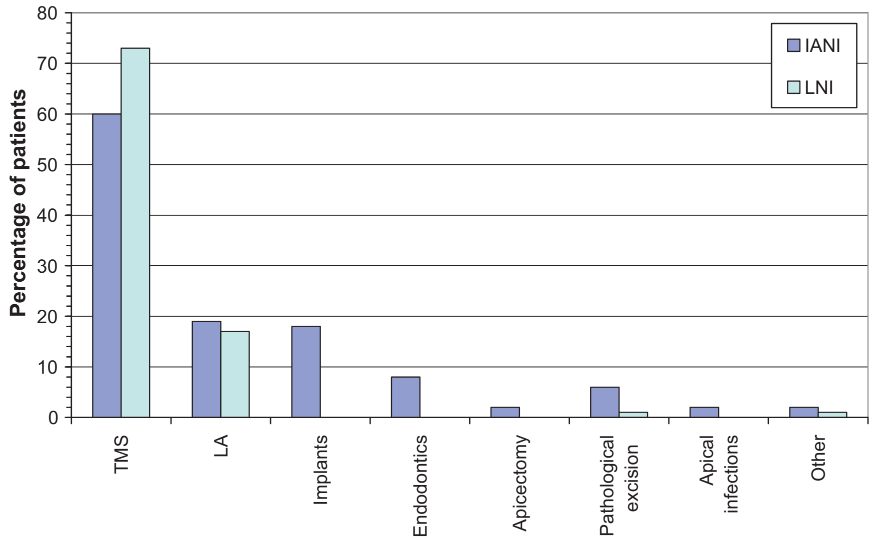

Fig. 1. Key causes of IANI and LNI. The majority were caused by third molar surgery, followed by local anaesthetic. Only IANI were caused by implants and endodontics.

which one was the PainDETECT questionnaire. Other novel strategies included topical 5% lidocaine patches, topical clonazepam and botulinum toxin type A (Botox) injections. More traditional pain management strategies included systemic pregabalin, oxcarbazepine, venlafaxine and nortriptyline for chronic pain. Outcomes assessed were pain relief, improved functionality and ability of the patient to cope with their iatrogenic post-traumatic neuropathy.

Data analysis

All data was analysed using SPSS and Excel. Student's *t*-tests were carried out for the analysis of the mean, where *P* values less than 0.05 were statistically significant.

Results

Two hundred and sixteen patients, referred from many parts of the UK, were involved in this study. One hundred and twenty-three patients had IAN injury (IANI, 57%) and 93 patients had LN injury (LNI, 43%). In this cohort, the authors present a more holistic assessment of patients with post-traumatic neuropathy with equal focus on mechanosensory results and the patients' experience of pain and altered sensations, and functional morbidity.

LNI patients presented with a mean age of 38.4 years (range 20–64 years) and IANI patients with a mean age of 44.0 years (range 22–85 years). The majority of these injuries were caused by third molar surgery carried out under local anaesthesia (Fig. 1). Time from injury to examination followed a skewed distribution with median of 6 months (arithmetic mean of 16.7 months; standard deviation (SD) 41.5 months; range 1 week to 360 months) for IANI patients, and a median of 5.5 months (arithmetic mean of 17.3 months; SD 43.3 months; range 1 week to 312 months) for LNI patients.

Nerve injuries were defined as permanent if caused by implant or endodontic procedure (>1 month), third molar surgery and other causes (>6 months). The majority of IANI (64%) and LNI (69%) patients had permanent injury, in comparison with only 7% and 14% with temporary IANI and LNI, respectively. Twenty-nine percent IANI patients and 17% LNI patients were under repeated review as their lesions continued to resolve with minimal pain or functional problems not requiring any specific intervention with the exception of the initial and subsequent consultations.

Approximately 70% of all patients presented with neuropathic pain, despite the additional presence of anaesthesia and hypoaesthesia, and other neuropathic symptoms, such as paraesthesia (Fig. 2). Neuropathy was demonstrable in all patients with varying degrees of loss of mechanosensory function, paraesthesia (74%), dysaesthesia in the form of burning pain (18%), mechanical allodynia (by pain

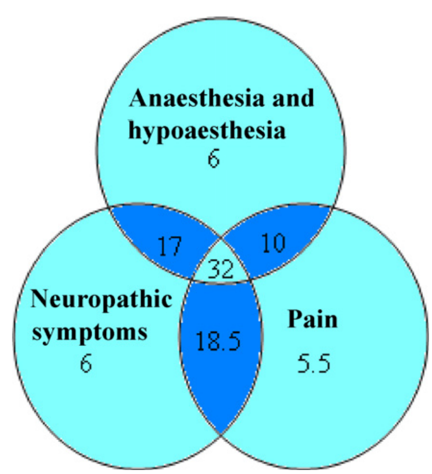

Fig. 2. Incidence of pain, anaesthesia and hypoaesthesia, and neuropathic symptoms (e.g. pins and needles, paraesthesia) in all patients. Although anaesthesia, pain and other neuropathic symptoms such as paraesthesia are different sensations, patients experienced a mixture of symptoms in different parts of the neuropathic area. For example, pain may occur in the chin area of a patient with IANI despite numbness of the lip. Thirty-two patients experienced anaesthesia, pain and other neuropathic symptoms in the form of paraesthesia.

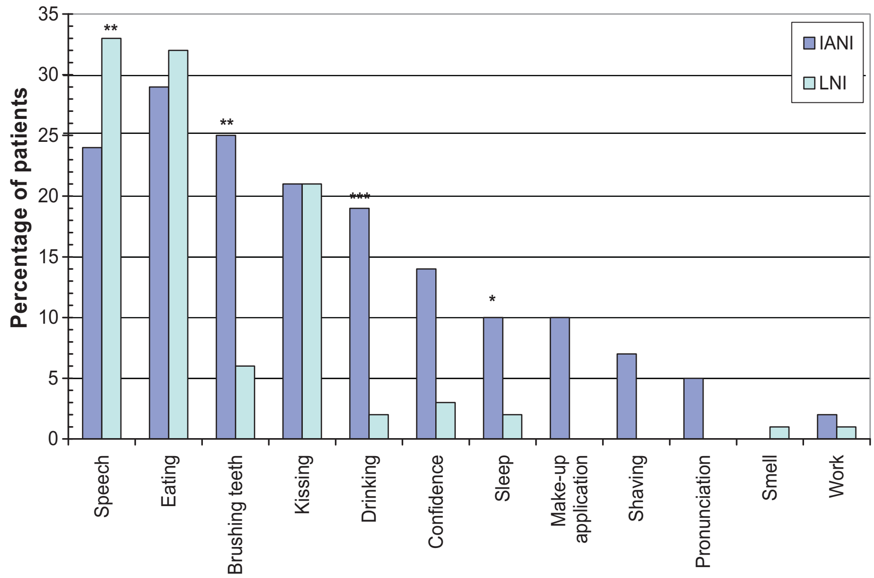

Fig. 3. Interference of symptoms with functionality of the patients. The majority of IANI and LNI patients had problems with speech and eating; speech significantly affected more LNI patients (**$P < 0.001$). Significantly more IANI patients had difficulties with brushing their teeth (**$P < 0.001$), drinking (***$P < 0.0001$) and sleep (*$P < 0.05$). Kissing was affected in equal percentages of IANI and LNI patients.

to light touch discrimination; 32%) and mechanical hyperalgesia (by pain to sharp-blunt discrimination; 46%). Although IANI patients suffered from a larger mean intra-oral and extra-oral neuropathic area (58% and 56%), their mean subjective function value of 8.0 was slightly better than the 5.0 of the LNI patients. Key functional problems experienced by this cohort are shown in Fig. 3.

All patients with permanent nerve injury were reassured that their injury will not worsen, while at the same time it will not improve, and that it will not predispose them to developing any pathology in the area. They were also offered an explanation of the physiology of nerve injuries and were told how difficult they are to treat. This was the only form of management for 63 IANI (51%) and 51 LNI (55%) patients, as there was no indication for medical, surgical or liaison psychiatric assistance in the form of CBT (Fig. 4). Seven IANI patients and two LNI patients who were only reassured, because medical, surgical or CBT treatment was not indicated, had recovered well from their injuries and were discharged from hospital. CBT alone was offered to 5% of all patients (seven IANI and four LNI patients), while 5% of IANI patients had CBT combined with another treatment method (Table 1). It is anticipated that these values will increase over time, as CBT sessions provided by a clinical psychologist had only just started to be offered in the authors' multi-disciplinary facial pain clinics.

Combined therapies were offered to nine patients, of whom all had IANI (Table 1). Such combinations included CBT with surgery ($n = 2$), CBT with medication ($n = 1$), CBT with 5% lidocaine patches ($n = 1$), CBT combined with surgery and topical 5% lidocaine patches ($n = 1$), and CBT in combination with medication and topical 5% lidocaine patches ($n = 1$). Other combinations included the use of topical 5% lidocaine patches with surgery ($n = 2$) and topical 5% lidocaine patches with medication

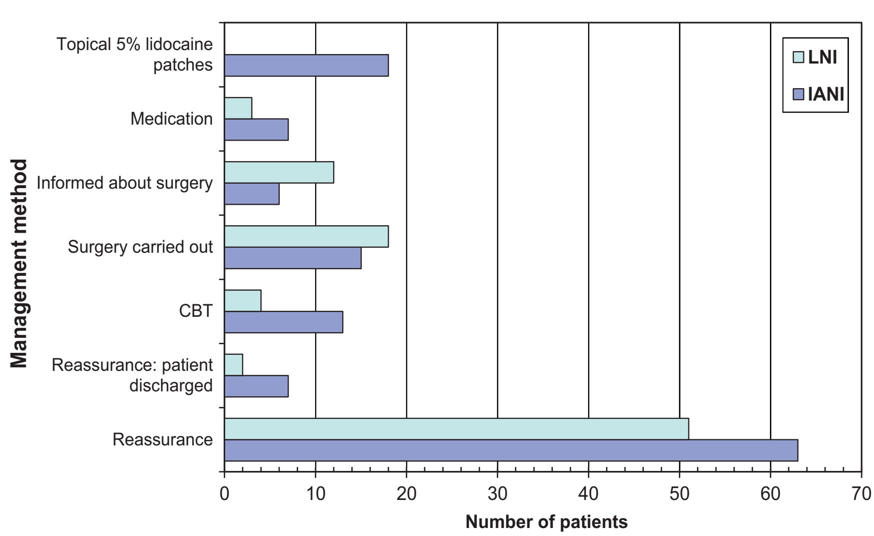

Fig. 4. Key management modes for patients with IANI and LNI.

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Table 1. Key methods used for managing patients with IANI and LNI.

Management method	Number (%) of patients	
	IANI	LNI
Reassurance and counselling	63 (51.2)	51 (54.8)
Reassurance and counselling; patient discharged	7 (5.7)	2 (2.2)
CBT:		
- Alone	7 (5.7)	4 (4.3)
- With surgery	2 (1.6)	–
- With medication	1 (0.8)	–
- With topical 5% lidocaine patches	1 (0.8)	–
- With surgery and topical 5% lidocaine patches	1 (0.8)	–
- With medication and topical 5% lidocaine patches	1 (0.8)	–
Surgery:		
- Carried out alone	15 (12.2)	18 (19.3)
- Informed patient but refused surgery	6 (4.9)	12 (12.9)
Medication:		
- Alone	4 (3.3)	2 (2.2)
- Refused by patient, no surgery or CBT	1 (0.8)	1 (1.1)
- Medication and CBT refused by patient	2 (1.6)	–
- Medication finished 3 months prior to appointment	–	1 (1.1)
- Pregabalin and topical lidocaine intra-orally	–	1 (1.1)
Topical 5% lidocaine patches:		
- Alone	8 (6.5)	–
- Alone with positive results; discharged from clinic	2 (1.6)	–
- Alone but gave adverse reaction so patients given medication	2 (1.6)	–
- With surgery	2 (1.6)	–
- With medication	1 (0.8)	–
Alternative:		
- Chew chillies	–	1 (1.1)
- Speech therapy	–	1 (1.1)
- Pregabalin and tabasco sauce	–	1 (1.1)

($n = 1$). Four patients were managed with Botox injections and two responded well.

Topical 5% lidocaine patches were used alone by 12 patients with IANI (Table 1). A couple of these patients were very happy with the pain relief provided by the topical 5% lidocaine patches and were subsequently discharged from the clinic. Two IANI patients developed a rash when using the patches, preventing their use, and were prescribed oxcarbazepine as long-term medication.

Systemic medication was continued by only 3% of all patients (four IANI and two LNI patients), 28% of patients stopped using drugs due to their side effects. Medication regimes included pregabalin, lorazepam, nortriptyline and amitriptyline. Medication was refused by three IANI patients, two of whom also refused CBT. A low number of patients were prescribed medication because many of the patients with pain had previously tried multiple chronic pain medications prior to being referred without any success in reducing their pain.

The prescription of medication was also avoided due to the complex side effects caused by such medication which it was thought the patients would find hard to cope with in addition to their disabling side effects. In some cases, the level of pain was not significant enough to justify the use of daily medication with the attendant side effects.

Surgery with no other treatment was a management option for 51 (24%) patients, but 18 (35%) of these patients refused surgery (Table 1). Thirty-three of these patients (18 LNI and 15 IANI patients) elected to have exploratory surgery. Such surgery for patients with LNI ranged from exploration and decompression of the lingual nerve, release of scar tissue to excision of any neuroma and re-anastomosis of the nerve (Table 2). IANI patients also had similar exploration and decompression surgery but they tended to have surgery to remove retained roots in conjunction with nerve exploration (Table 3).

Three patients with implant-induced IANI experienced a reduction in symptoms and reduced neuropathic area following urgent surgery to remove the implant within 24 h. Fifteen percent of implant-related IANI patients who did not have urgent surgery did not see any improvements in their symptoms, highlighting the importance of removing the implant within 24 h of placement if symptoms of anaesthesia, paraesthesia and/or pain occur. Surgery was not indicated for many patients since these injuries resulted in partial neuropathy with no pain and reasonable function. Any further surgery may have made their situation worse.

Key improvements post-treatment

One of the key improvements detected at patient review appointments was the significant decrease in the size of the neuropathic area often indicating natural resolution of the sensory dermatome which was partial in most cases (Fig. 5). The greatest reduction in the mean neuropathic area from 100% to 35% ($P < 0.05$) occurred within the intra-oral IAN dermatome in three IANI patients, in comparison to a 37% reduction from 68% to 31% ($P < 0.001$) in the extra-oral IAN dermatome of 17 IANI patients. A 41% reduction in the percentage size of the neuropathic area from 65% to 21% ($P < 0.001$) was indicated in 25 LNI patients, a common pattern being the residual neuropathic area covering the lateral border of the tongue adjacent to the teeth.

IANI patients reported reduced mean levels of pain from 9.8 (range 7–15) to

Table 2. Key surgical procedures carried out for lingual nerve injury (LNI) patients.

Procedure	Number of patients
Exploration and decompression	11
Release of scar tissue, excision of neuroma and re-anastomosis of the nerve	7
Nerve appears normal	1

Table 3. Key surgical procedures carried out for patients with IANI.

Procedure	Number of patients
Exploration and debridement	1
Exploration and decompression	4
Exploration and removal of roots and decompression	6
Excision of neuroma and re-anastomosis of the nerve	3
Extraction of infected retained root and re-anastomosis of the nerve	1

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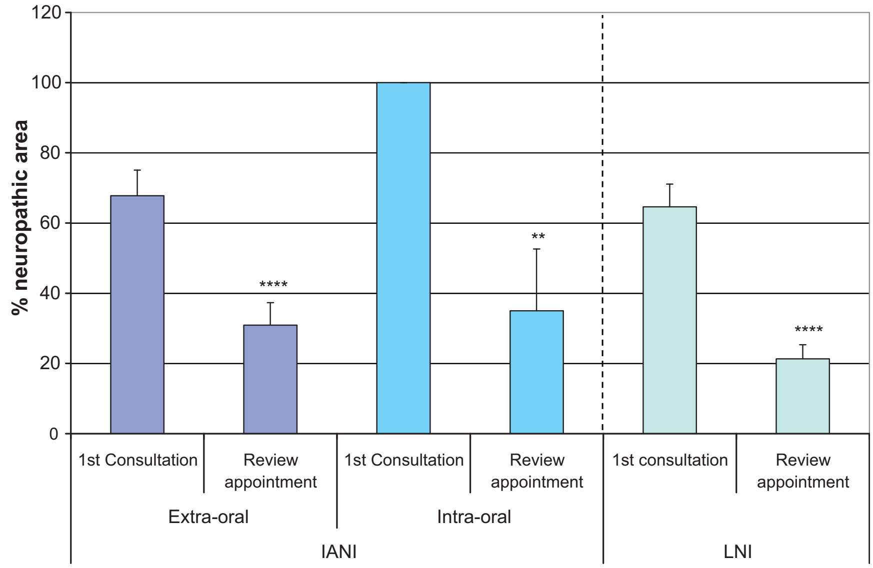

Fig. 5. Improvements in neuropathic area at review appointment (**$P < 0.05$; ****$P < 0.001$).

4.7 (3.5–10) on using the topical 5% lidocaine patches. The level of pain also significantly reduced from 15/10 to 4/10 in a patient with IANI who was taking carbamazepine and amitriptyline. Another IANI patient reported a reduction in pain levels with gabapentin combined with right IAN exploration and repair or even no pain. Complaints of paraesthesia also diminished with significantly better mechanosensory function again occurring due to natural resolution. Consequently, subjective function significantly improved from a mean of 2/10 at the consultation appointment to 7/10 ($P < 0.001$) in the IANI patients, and from 3/10 to 8.5/10 ($P < 0.001$) in the LNI patients. These improvements ultimately resulted in an overall improved quality of life.

Discussion

Patients with nerve injury often complain of disability associated with altered sensation, severe discomfort, pain and/or numbness, a large neuropathic area and interference with daily functions, such as eating and drinking. Many patients find accepting or coping with even minimal iatrogenic nerve injuries very difficult. This may be due to the unexpected nature of the injury, poor informed consent, poor postoperative management of the patient and lack of information.

This study reports on the key management strategies used to treat patients with iatrogenic LNI and IANI. It is likely that patients with persistent neuropathic pain following surgical nerve injury will persist in seeking care and advice and this may not be the case for similar patients with anaesthesia. This cohort of patients was self-selected, as it was confined to patients seeking tertiary care.

Similarly to previous studies,[28,42] there were more female than male patients, further highlighting the tendency of more females to present to a referral centre. Patients in this study were older, probably because although the key cause of the injuries was third molar surgery carried out under local anaesthesia, other causes of injury included chemical injury from the local anaesthetic itself, implant surgery and endodontics.

Neuropathic pain, which was present in approximately 70% of patients, was higher than figures in another study on a similar cohort of patients, where a 45% incidence of dysaesthesia was reported.[32] This was possibly due to patients being referred to the authors' specialist unit due to their pain. Neuropathy was evident in all patients with varying degrees of loss of mechanosensory function, paraesthesia, dysaesthesia, allodynia and hyperalgesia.

These results are discussed in greater detail in the authors' previous paper.[30] Patients with chronic neuropathy were treated by one or more of the following three key modalities: counselling, medical intervention usually for pain (anti-epileptics or anti-depressants), the application of topical 5% lidocaine patches, and/or surgery (Table 1).

Treatment regimes were planned and chosen so the concerns of the patients were considered appropriately. This initially involved a thorough assessment of the patient by the clinician prior to deciding what they were trying to treat the patient for; was it poor mechanosensory function or more pertinently, was it what the patient was complaining of?

The aims of treatment included the reduction of pain and discomfort, improvement in being able to cope with the pain psychologically and ultimately provide improved function. Improving the psychological state of patients with iatrogenic post-traumatic neuropathy of the trigeminal nerve is important, as many of these patients have to face a future of chronic pain afflicting their orofacial region with the attendant severe compromised daily function, and have to come to terms with the fact it has been caused by someone they trusted. This often results in the patients becoming fearsome of dental or medical visits.

Non-surgical interventions

Empirically, many patients seen in the authors' specialist clinics could manage their pain but could not cope with the consequences of their nerve injury and had associated functional difficulties that significantly impacted their social life or work. Management of these patients was successful through counselling and CBT, without any additional topical analgesia, medical or surgical intervention.

Such counselling involved the clinician (TR) consulting the patient in depth, providing realistic expectations by reaffirming the nerve injury was permanent if the patient had their symptoms for more than 3 months, and providing reassurance that their injuries will not predispose them to cancer and will never worsen. It was stressed that treatment may not completely restore function, such as eating, drinking, speaking, sleeping, neither would any treatment restore normal sensation in the neuropathic area, general sensory (i.e. mechanosensory function) or special sensory function (i.e. taste). Patients suffering with speech problems due to their nerve injury also benefited from access to speech therapy.

Early indications suggested that CBT carried out by a specialist liaison psychiatrist in the department helped patients in this study to cope with their pain rather than reduce the perceived pain levels. A specialist clinical psychologist provided the CBT since there are multi-disciplinary facial pain clinics in the authors' department. The CBT was based on qualitative analysis and validated psychometric questionnaires. The aim of applying CBT to this patient group was not to reduce pain levels but provide better coping strategies to enable the patient to live as normal a life as possible. The overall psychological analysis of this cohort of patients will be presented in a separate paper with the aim of developing a tailored CBT programme for this patient group. The positive responses to CBT so far add to the increasing evidence for the successful use of CBT to treat chronic pain. Other chronic conditions where CBT has been beneficial include arthritis, chronic low back pain, headache, and chronic temporomandibular pain.[7,25]

Although only a limited number of patients were treated with individualized CBT in this study, early signs of fear and avoidance of attending their general dental practitioner indicate that this group may be suffering from a form of post-traumatic stress disorder. This situation is often compounded by lack of prior informed consent and poor postoperative management by the practitioner subsequent to the nerve injury. There is a need for research into the psychological effects of these iatrogenic injuries and the benefits of non-surgical interventions for these patients.

Topical analgesia

A small proportion of IANI patients in this study received significant pain relief by applying topical 5% lidocaine patches to the area where they were experiencing neuropathic pain. Combined application of topical 5% lidocaine patches with surgical nerve exploration and/or repair also proved to be beneficial for managing two patients with permanent IANI. These patches also successfully reduce the pain experienced by patients with post-herpetic neuralgia, painful diabetic neuropathy and low back pain.[1,23] Clinicians prescribing these topical patches should warn the patients to stop using the patches if they develop a rash.

Systemic analgesia

Low dose anti-depressants (amitriptyline, nortriptyline), and anti-epileptics (carbamazepine, oxcarbamazepine, gabapentin, pregabalin) can be used to manage pain experienced by patients with post-traumatic neuropathy.[10,14] Such systemic medication can cause a multitude of side effects that the patients would find hard to cope with in addition to their other symptoms. Owing to this, only a small group of patients in this study were prescribed medication, which included pregabalin, lorazepam and amitriptyline. Many patients in this study were reluctant to take medication because they had previously tried multiple chronic pain medications prior to being referred with no success in reducing their pain. In some cases, the level of pain was not significant enough to justify the use of medication.

Combined administration of systemic medications with the use of topical 5% lidocaine patches proved beneficial for one IANI patient in the study. Combination therapy involving both routes of administration allowed a therapeutic effect to be achieved faster, and a reduction in adverse drug reactions, drug tolerance or addiction.[14] Other topical agents that may be used include clonazepam, and benzocaine lozenges or gel (with or without stent). The benefit of botulinum toxin type A (Botox) in managing pain experienced by patients with iatrogenic trigeminal nerve injuries deserves investigation, as two out of four patients in this study saw some benefit and a recent study showed that Botox injections into the trigger zone reduced pain in trigeminal neuralgia.[26]

Surgery

Surgical treatment (Tables 2 and 3) alone resulted in significant decreases in the neuropathic area, reduced pain, and improved mechanosensory and subjective function in 15 IANI and 18 LNI patients. These findings will be presented in a separate report on the surgical intervention for post-traumatic neuropathy. The surgical intervention rate of 15% may be higher than other units but this may reflect the high rate of pain and associated morbidity in this patient cohort seeking tertiary care.

Despite the significant improvements experienced by patients who had surgical intervention, surgery should be the last option. The authors recommend only considering exploration within 3–6 months following the injury with/without repair if there is minimal or no resolution with large neuropathic area, poor mechanosensory function, and poor daily function with moderate to severe pain. Escalating a patient from intermittent pain to persistent pain would be a negative outcome as would causing a patient to have discomfort or pain when previously they only had anaesthesia. Patients must therefore be warned of the potential risk of escalating their neuropathic symptoms, which in this study resulted in 33% patients declining the reparative surgery offered.

All nerve injuries should be identified within 24 h of the surgery to maximize the chances of recovery. Lingual nerve injuries caused by third molar surgery should be reviewed regularly for up to 3 months. Many authors recommend referral of injuries before 4 months[13] but this may be too late for many peripheral sensory nerve injuries. Permanent central and peripheral changes occur within the nervous system 3 months subsequent to injury that are unlikely to respond to surgical intervention.[41,46] Based on cellular and biochemical events, the ideal time for nerve repair is 2–3 weeks after the injury in order to maximize the resolution of sensory function, minimize neuronal cell death and central changes, and optimize functional restoration.[48]

While lingual nerve repair has been shown to be optimal at various delays (6–26 months) prior to repair, for example primary, early secondary and late secondary repair,[33,36] other studies on animals suggest that early repair of the nerve is favourable when compared with delayed repair of peripheral sensory nerves.[5,6,24,39] Results from the present study support studies that showed lingual nerve repair to be optimal at various delays and that benefits can be achieved in both early and late surgery. Surgery resolved symptoms experienced by a LNI patient who had had their symptoms for almost 2 years, and a LNI patient who had had their symptoms for 1 month. Resolution of symptoms also occurred in IANI patients who had their reparative/explorative operation a minimum of 2 months to a maximum of almost 2 years after injury. Despite these positive outcomes at almost 2 years (22 months) for an IANI patients and a LNI patient, caution needs to be taken when making a decision to opt for surgery. In most cases, patients should be treated therapeutically if they have had their injury for more than 6 months. Early referral of patients is favourable, as this minimizes the patient's

Table 4. Suggested management strategy for iatrogenic trigeminal nerve injuries.

Mechanism	Duration	Treatment
Known or suspected nerve section		Immediate exploration
Third molar surgery IANI – retained roots	<30 h	Immediate exploration
Implant	<30 h	Remove implant
Implant	>30 h	Treat patient therapeutically
Endodontic	<30 h	Remove tooth/overfill
Endodontic	>30 h	Treat patient therapeutically
Third molar surgery IANI – large neuropathic area, pain and disability	<3 months	Consider exploration
Third molar surgery LNI – large neuropathic area, pain and disability	<3 months	Consider exploration
Third molar surgery IANI	>6 months	Treat patient therapeutically
Third molar surgery LNI	>6 months	Treat patient therapeutically
Local anaesthesia, fracture, orthognathic, other surgery		Treat patient therapeutically

suffering and may improve the chances of their symptoms resolving.

Implant/endodontic injuries, as highlighted by this study, should be managed within 30 h to optimize resolution. If of longer duration, these injuries must be managed conservatively; similar to the previous recommendations of Pogrel.[27] Local anaesthesia, traumatic and orthognathic nerve injuries must also be managed conservatively. Third molar surgery IANI should be assessed immediately. If a retained root is present or compression of the IAN canal is observed on plane film, immediate exploration with/without repair should be advocated. If there is no root or other indication for immediate surgery, the patient should be reviewed every 2–3 weeks for up to 3 months. If there is minimal, or no, resolution with a large neuropathic area, poor mechanosensory function, and poor daily function with moderate to severe pain exploration with/without repair should be considered. If sensation has not improved by 2 months, especially if daily function is severely affected by a large neuropathic area (>40% dermatome), associated neuropathic pain, hypersensitivity or discomfort, a severe nerve injury is present and the prognosis for recovery is poor. These symptoms may not be best treated using surgical intervention, but the patient's inability to cope with disability is often the driving factor for the patient seeking treatment.

Improved management of these injuries

Commonly the patient's anger and frustration about receiving an iatrogenic injury is compounded by poor immediate management by the clinician involved. After causing the injury, many patients complain that the treating clinician refuses to communicate with them or remains in denial about the injury. Particularly in secondary care, the patients are reviewed for many months or even years, by consecutive junior staff, providing them with unrealistic false hope and reassurance that their nerve injury will resolve. Prevention is preferable to the present inadequate treatment modalities used to treat post-traumatic neuropathy. If damage occurs, earlier recognition and referral of trigeminal injuries are fundamental to improving the treatment of these patients. The authors have made a suggested strategy for managing these patients, summarized in Table 4.

Is prevention possible?

Prevention is better than cure, because once permanent (>3 months) nerve injury has occurred the patient is unlikely to regain normal sensation despite various interventions. Many injuries can be prevented through better patient selection, planning and execution of procedures. Patient management can often be improved by informed consent based on risk assessment and improved postoperative care with early referral for nerve injuries.[43,45] Early referral is essential for patients with complex regional pain syndrome,[31] peripheral nerve injuries caused by regional anaesthesia,[40] and in infant brachial plexus injuries[38] and spinal accessory nerve injuries.[9] Corticosteroids, such as dexamethasone, may be used intra-operatively in order to reduce swelling, pain and trismus after third molar surgery. According to recent research by Barron et al.,[2] dexamethasone and dipyrone administration may minimize post-extraction hypersensitivity.

In conclusion, this paper highlights several strategies that can be used to assist the practitioner in managing trigeminal nerve injuries while reaffirming that there is no 'silver bullet' for treating these patients. The frequent incidence of pain indicates that consent should highlight the likelihood of hyperaesthesia and pain in addition to numbness. Inadequate consent, poor management and the experience of pain and associated functional difficulties ultimately result in psychological distress. Attention should also be drawn to the fact that patients with IANI often require more urgent management, particularly with regard to implants and endodontics. This opportunity is often missed in this patient cohort. The authors recommend prospective randomized studies to evaluate the different management strategies for patients with post-traumatic trigeminal neuropathies, based on mechanism and duration of the nerve injury. This would improve the prevention and care of patients with post-traumatic neuropathies.

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