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Inferior alveolar neurosensory disturbance following unilateral mandibular fractures:

A pilot study comparing the visual analogue scale to a formal method of neurosensory testing and an assessment of surgical outcomes

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Abstract

Background and objectives: Neurosensory disturbance of the inferior alveolar (IAN) and mental nerves (MN) is common after mandibular trauma and operative management. This pilot study compared patients' subjective neurosensory disturbance following traumatic mandibular fractures with an objective measurement of their neurosensory function. We then investigated the impact of spaced versus non-spaced mini-plates, and the experience level of the primary operator on neurosensory outcomes.

Methods: This was a twelve-month prospective study of patients treated for unilateral mandibular fractures in the department of Oral and Maxillofacial Surgery in Auckland, New Zealand.

Patients completed a visual analogue scale (VAS) quantifying IAN neurosensory function on the fractured side of the mandible. The non-injured side was also measured. These measures were tested for correlation with the results of an objective neurosensory measurement. Mandible fractures were then treated via open reduction and internal fixation as indicated. Neurosensory testing via both methods was repeated day one post-operatively. The mean change in neurosensation (i.e., pre-op VAS minus post-op VAS) was compared between patients who underwent internal fixation of parasymphysis fractures with spaced and non-spaced miniplates, and between patients who underwent internal fixation of angle fractures by primary operators of varying experience levels.

Results: A total of fifty-five unilateral mandibular fractures were included. Post-operative patient rated neurosensory disturbance was strongly positively correlated with objective neurosensory examination findings (Spearman r = 0.72; 95% CI [0.55, 0.83]). There were no statistically significant differences between the mean change in VAS scores between patients undergoing internal fixation of parasymphysis fractures with spaced or non-spaced miniplates, or between patients undergoing internal fixation of angle fractures with operators of varying surgical experience.

Conclusions: This study suggests that the subjective VAS measurement of IAN neurosensation is strongly positively correlated with an objective neurosensory measurement among patients with unilateral mandible fractures. The VAS can therefore considered a reasonable measure of IAN neurosensory disturbance. Further studies are indicated to determine other peri-operative surgical factors that may influence IAN neurosensory disturbance, together with the predicted length of time for neurological recovery of the IAN and MN after open reduction and internal fixation of mandibular fractures.

Introduction

Mandibular fractures frequently result in neurosensory disturbance of the inferior alveolar nerve (IAN) or its distal mucocutaneous branch, the mental nerve (MN). Neurosensory disturbance may be a result of primary injury when the IAN lies in the line of a fracture, or as a secondary insult due to manipulation during fracture fixation (Iizuka and Lindqvist, 1991). Although the primary goal of trauma management is restoration of anatomical form and function, neurosensory deficits must also be considered (Thurmüller *et al*., 2001; Kulkarni *et al*., 2021). There is a paucity of literature investigating the incidence and outcomes of IAN injury associated with mandibular fractures. This may, in part, be due to confusion regarding multiple testing algorithms and classification systems reported in the literature, causing heterogeneity in protocol and miscommunication of results – so much so, that a recent study was aptly named "How many oral surgeons does it take to classify a nerve injury?" (Miloro *et al*., 2021). Inconsistencies can lead to a delay in timely referrals for micro-neurosurgical repair and variability in reported outcomes of neurosensory function.

Evaluation of nerve injuries can generally be split into objective and subjective measures (Meewis *et al*., 2021). Objective measures are considered the 'gold standard' and involve a group of standardized clinical neurosensory testing (CNST) manoeuvres designed to evaluate sensory function (Meyer and Bagheri, 2011). Results of CNST can then be used in algorithms to grade the severity of nerve injury. One such algorithm, developed by Zuniga and Essick, has been reported as the optimal chairside measure (Zuniga and Essick, 1992; Poort *et al*., 2009; Yadav *et al*., 2016; Chandan *et al*., 2021). Subjective measures generally involve asking the patient about their perception or to define their degree of nerve injury via words, questionnaire, or visual analogue scale (VAS). For measurement of IAN injuries, a VAS-

based questionnaire has been recommended alongside objective measures (Poort *et al*., 2009).

Unfortunately, no measure is perfect. Objective measures are cumbersome, time-consuming, and difficult to reproduce between operators (Poort *et al*., 2009). On the other hand, subjective measures have been considered less physiological and more varied in comparison to objective measures, however, they remain an important tool to reveal paraesthesia not indicated by quantitative testing (Coghlan and Irvine, 1986; Shintani *et al*., 2019). Subjective measures of well-being have been correlated with post-traumatic trigeminal neurosensory function (Meewis *et al*., 2021), however to the best of the authors' knowledge, there are no reports that have tested the degree to which subjective and objective measures of IAN neurosensory function are correlated specifically among patients with acute mandible fractures.

There is a need to identify the most practical testing methods to detect IAN injury, grade its severity, and monitor its recovery. The aim of this study was to investigate patients' perceptions of the degree of numbness they had following isolated unilateral mandibular fracture and to compare this with an objective measurement of neurosensory function both pre- and post-operatively. This will determine the degree to which a subjective measure of IAN neurosensory function (VAS) correlates with an objective CNST in the setting of an acute mandible fracture. Doing so may provide the motivation for a large scale validation study that investigates the utility of VAS as a screening tool to detect neurological injury and identify patients who require formal neurological assessment.

Additionally, we sought to determine whether the length of four-hole fixation mini-plates (spaced vs non-spaced) affected neurosensory outcomes in the MN distribution among patients undergoing open reduction and internal fixation (ORIF) of unilateral parasymphysis fractures. Anecdotally, there are competing theories among surgeons regarding the optimum plate length when fixating fractures close to the MN. Proponents of spaced plates state there is lower risk of inadvertent retraction injury to the MN, as the space allows screws to be placed further away from the mental foramen, reducing the need for aggressive retraction. Those favouring non-spaced plates state there is lower risk of MN injury due to the smaller surgical incision and soft-tissue stretch required to place the smaller non-spaced plate in the desired position. However, there is a lack of evidence supporting either theory. Determining whether the use of spaced versus non-spaced mini-plate fixation around the exiting MN influences neurosensory outcomes may modify plate selection when treating fractures in this area.

Lastly, we sought to determine whether IAN neurosensory outcomes among patients undergoing ORIF of unilateral angle of mandible fractures were different depending on the surgical experience of the primary operator. Determining whether primary operator experience influences neurosensory outcomes is an important aspect of continual internal departmental audit. This feedback helps drive subsequent alterations to both surgical technique for junior staff, if required, and the supervision practices for senior staff, if poorer outcomes are seen to be associated with junior staff. If there is no difference seen in neurosensory outcomes across operator experience level, then it will reinforce both the surgical skill set of junior staff and the level of supervision that is being provided. It will also provide reassurance to both patients and clinicians that a high level of care is being delivered.

We had three hypotheses:

H_1: Among patients with isolated unilateral mandibular fractures, patient rated sensation of the IAN distribution via VAS is positively correlated with an objective CNST.

H_2: Patients undergoing ORIF of an isolated unilateral parasymphysis of mandible fracture have improved IAN neurosensory outcomes when non-spaced mini-plates are used for fracture fixation compared to spaced mini-plates.

H_3: Patients undergoing ORIF of an isolated unilateral angle of mandible fracture have improved IAN neurosensory outcomes as surgical experience of the primary operator increases.

Methods

This was a prospective observational cohort study composed of patients treated for mandibular fractures at Middlemore Hospital, Counties Manukau District Health Board (CMDHB). Locality and ethical approval was granted by the National Health and Disability Ethical Committee and the Ethical Board, CMDHB.

Patients were recruited into the study over a twelve-month period from February 2020 to February 2021. The fractures were classified according to their anatomical locations (Cornelius *et al*., 2014). Inclusion criteria were: patients with an isolated unilateral mandible fracture who could consent to the study. Exclusion criteria were: previous mandibular trauma, pathological fracture of the mandible, known neurological condition that may impair neurological examination, acute alcohol or drug intoxication, concurrent neuromodulating medication(s) and paediatric patients (≤16 years). Patients unable to consent for any reason, such as having a reduced level of consciousness (as determined by Glasgow Coma Scale <15) or apparent inability to engage in meaningful discussion about the study, were also excluded.

Neurosensory measurements were conducted by the first author. Initial assessment was conducted in the Emergency Department during patient admission. All post-operative neurosensory testing was conducted on day-1 post-operation – at least 18 hours after the procedure to allow for the effects of local anaesthetic used intra-operatively to have worn off.

To subjectively assess IAN neurosensory function, a VAS as per Poort *et al*. (2009) was used to enquire about the degree of numbness on the fractured (ipsilateral) and non-fractured (contralateral) sides. This test was conducted by using a gloved finger to lightly stroke the lip and chin at several points on both the ipsilateral and contralateral sides. The patient was then asked to place a mark on the linear scale of the

VAS, which corresponded to the degree of numbness they felt they had on the ipsilateral side compared to the contralateral. A value of 10/10 on the VAS indicated perceived completely normal sensation and a value of 1/10 indicated perceived total loss of sensation.

This test was then followed by an objective CNST, modelled from Zuniga and Essick (1992) of both ipsilateral and contralateral IAN's using mechanoreceptive (two-point discrimination, static light touch, brush-directional stroke) and nociceptive (pinprick) methods (Figure 2). In all tests, the ipsilateral side was compared to the contralateral side, which served as an internal control. All testing was conducted with the patients eyes closed and lips separated slightly at rest. Two out of three normal responses were required in order for the result to be considered to have intact sensation at that level of testing. A description of the CNST conducted is as follows:

Level A testing measured spatiotemporal sensory perception (brush direction and two-point discrimination): Brush testing was conducted using dental gauze via a brush-directional stroke at multiple one centimetre (cm) squared sites over the chin and lower lip. A stroke of 1 cm length was applied three times in each area of skin tested and the patient was asked to determine the direction of the stroke, either right-to-left or left-to-right.

The two-point discrimination test was then conducted by lightly applying Dental College forceps with closed tips to various points over the skin of the chin and lower lip region. The forceps were then progressively opened in 4 mm increments until the patient could reliably differentiate one point from two. The forceps used were measured at 16 mm when fully open. Normal measurements for two-point discrimination in the trigeminal nerve distribution vary across the face, but the chin and lower lip regions typically have a two-point discrimination of between 3-5 – 15.5 mm, and 3.5 – 11.5 mm respectively (Hung and Samman, 2009). Therefore, patients unable to determine two individual points with the forceps fully open (points 16 mm apart) were considered to have diminished response and were progressed on to level B testing. It is important to clarify that patients who felt that they had abnomal neurosensory function on the VAS, but subsequently had normal brush directional and two point sensation on objective CNST were graded as having a normal response. Patients with abnormal responses in either test were at least mildly impaired in their function, and automatically advanced onto level B testing

Level B testing measured contact detection (via static light touch): Static light touch was assessed using the same gauze as used in level A testing. Patients able to detect the presence of the gauze at the same points on the skin as previously used were deemed to have a normal light touch response and therefore graded as having a mild nerve injury. Patients unable to detect the presence of the gauze at these points were deemed to have at least moderate nerve injury and advanced to level C testing.

Level C testing measured pain threshold via pinprick: This test was conducted using the front (sharp) and back (blunt) aspects of a Dental Explorer applied with light pressure without indenting the skin. Patients were asked to discriminate sharp from blunt sensations. Before proceeding to testing the chin and lower lip, a calibration test was conducted in each patient using healthy sensate skin at various points on their forehead and cheek, until the patient could reliably discriminate sharp from blunt. Once the patient was calibrated, the Dental Explorer was repeatedly applied at the same previous points on the chin and lower lip bilaterally. A normal response was recorded if the patient could feel the sharp sensation of the probe without requiring enough pressure applied to indent the skin, equally across the various points on the skin, indicating a moderate nerve injury.

If, at any of the points, the patient required increased pressure with the probe (enough to indent the skin) before they could feel sharpness, or if they could feel sharpness but in a diminished capacity compared with the control points, then this was marked as an abnormal response and they were graded as having severe impairment. If, despite causing an indentation to the skin with the sharp end of the probe the patient still could not detect a sharp sensation at any point, then no response was recorded, and the nerve was graded as being anaesthetic.

Patient scores from the VAS and CNST were then tested for positive correlation (H_1) using Spearman's rank correlation coefficient at a 95% confidence limit.

To test for a difference in IAN neurosensory function between patients with an isolated unilateral parasymphysis fracture undergoing ORIF with either spaced or non-spaced miniplates (H_2), the change in patient rated sensation (via VAS) was measured by subtracting the pre-operative VAS score from the post-operative VAS score. The mean change in VAS of the ipsilateral side was compared between the two patient groups and tested for statistical significance using a two-tailed Mann-Whitney test.

To test for a difference in IAN neurosensory outcomes among patients undergoing ORIF of an isolated unilateral angle of mandible fracture across increasing experience levels of the primary operator (non-training, year 2, or year 3 oral and maxillofacial surgery (OMFS) registrar) the mean change in VAS was calculated as above for patient groups operated on by each of the three experience levels and tested for a statistically significant difference using a Kruskal-Wallis test.

Patients were managed either expectantly or surgically, and via open or closed methods as dicated by the attending consultant. Patients who underwent ORIF for angle fractures were treated using the DePuySynthes MatrixMANDIBLE™ 2.0 system, with one 1.25mm mini-plate placed at the upper lateral border of the mandible. This was done in standard transoral fashion with a transbuccal trocar. Those with parasymphyseal and symphyseal fractures were treated using the same system, wth two plates placed in accordance with Champy's principles via a transoral approach (Champy *et al*., 1978).

Statistical analyses were conducted in GraphPad PRISM 5.0. Statistical significance was accepted

when $P < 0.05$. Graphical representation of the data was conducted in GraphPad PRISM 5.0.

Results

A total of 55 patients were included in this study. Almost all patients (90.9%) were male. The mean age was 30 years (median = 25, minimum = 17, maximum = 88). Interpersonal violence was the reported mechanism of injury in 67.3% of patients in this sample. Injury during sport accounted for 18.2%, mechanical falls for 9.1%, and workplaces accidents, medical events resulting in a fall, and motor vehicle accidents each accounted for 1.8% respectively.

In terms of fracture types, 35 patients (63.6%) presented with angle fractures, 10 (18.2%) with parasymphysis fractures, four (7.3%) with body fractures, four (7.3%) with condyle fractures, and two (3.6%) with symphysis fractures.

With regards to the first hypothesis (H_1), patient rated pre-operative sensation via VAS is moderately positively correlated with the results of the objective CNST method (Spearman r = 0.56; 95% CI [0.34, 0.72]). In the day-1 post-operative setting, VAS is strongly positively correlated with the results of the objective CNST method (Spearman r = 0.72; 95% CI [0.55, 0.83]).

Regarding the second hypothesis (H_2), there were 10 patients in this study who had an isolated unilateral parasymphysis fracture. One patient underwent ORIF with a combination of spaced and non-spaced miniplates hence was excluded from this comparison. There was no statistically significant difference in patient rated sensation (via VAS) of the ipsilateral MN among patients who underwent ORIF of a parasymphysis fracture with spaced mini-plates (n = 3) compared to non-spaced mini-pates (n = 6) ($P = 0.19$) (Figure 2).

Regarding the third hypothesis (H_3), there was no statistically significant difference in the mean change in patient rated sensation (via VAS) of the ipsilateral MN among patients who underwent ORIF of a unilateral angle of mandible fracture by either a Non-training OMFS registrar (n = 3), an accredited Year 2 training registrar (n = 20), or an accredited Year 3 training registrar (n = 10) ($P = 0.89$) (Figure 3).

Discussion

Neurosensory disturbances in the face, oral and perioral regions are often intolerable in comparison to other parts of the body. Despite the large volume of literature on mandibular fractures, there is a comparatively small amount of data regarding incidence, management, and prognosis of IAN injury in this setting. This is, in part, due to inconsistencies in incidence and description arising from differing grading protocols and classifications (Poort *et al*., 2009).

The Zuniga and Essick. (1992) algorithm (Figure 1) has been described as the optimal objective chairside evaluation of neurosensation (Poort *et al*., 2009). The value of CNST in assessing neurosensory

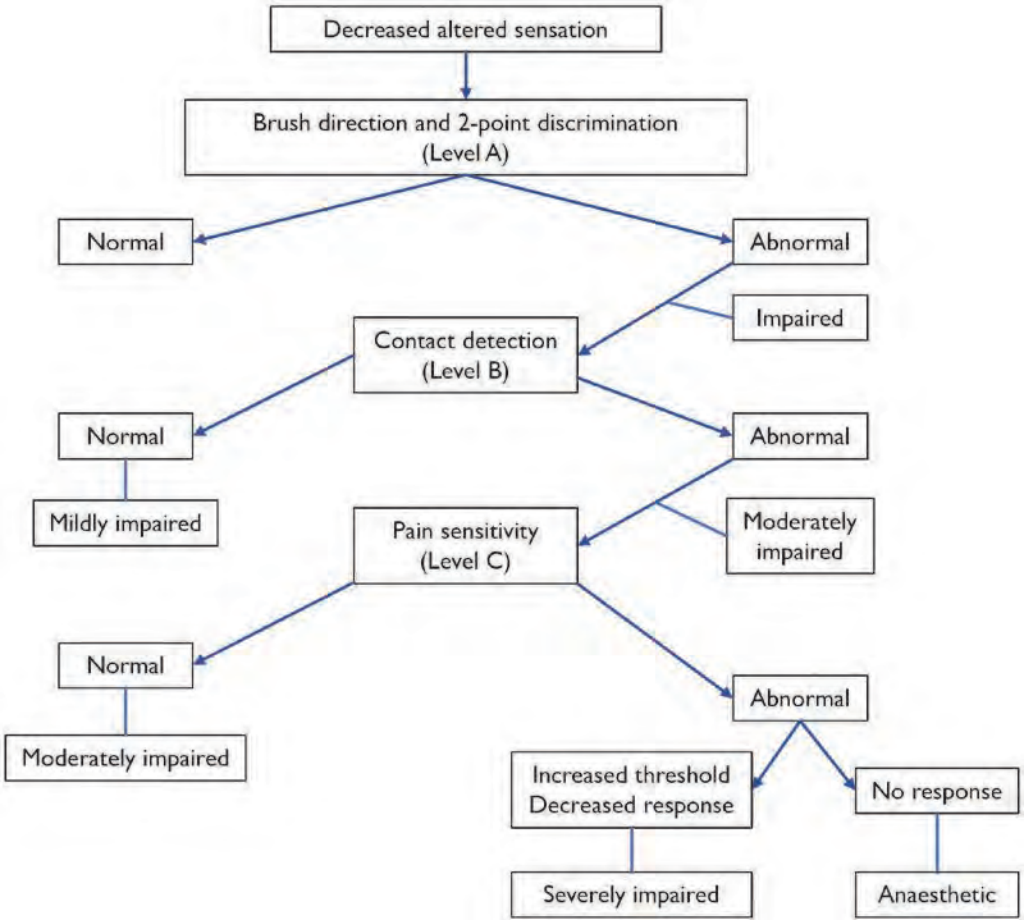

Figure 1. Grading algorithm to determine the objective neurosensory measure.

disturbance of the IAN is the ability to assess the presence of a major injury to expedite the option of timely nerve repair (Miloro *et al*., 2021; Tay *et al*., 2015). Identifying 'mild' or 'moderate' would logically exclude a major nerve injury and a large proportion of these patients will follow a natural course of recovery in three to six months post-injury (Cheung *et al*., 2010; Hillerup, 2008; Vieira *et al*., 2016). However, CNST is cumbersome and difficult to reproduce between operators (Poort *et* al., 2009).

This study demonstrates that patient-rated post-operative sensation measured by VAS correlates with objective CNST. The VAS may therefore be a reasonable method to efficiently assess IAN function among patients with unilateral mandibular fractures in the acute and day-1 post-operative setting. However, diagnostic accuracy testing, which was outside the scope of the present study, is required to validate the VAS as a test for excluding major nerve injury or identifying patients who likely require further micro-neurosurgical management. Furthermore, a validation study is required to assess the utility of the VAS in monitoring the entire course of IAN recovery, particularly where patients may report sensations of pain and burning as hyperaesthesia develops.

This study also tested for a difference in neurosensory outcomes among patients undergoing ORIF of parasymphyseal fractures using either spaced or non-spaced mini-plates. There are competing theories amongst surgeons regarding the use of spaced versus non-spaced miniplates close to the MN. Proponents of using non-spaced miniplates state that the greater stretch on the soft tissue flap required to gain access to the most proximal screw holes in non-spaced mini-plates places the MN under undue tension, increasing the risk of nerve damage. Proponents of using spaced miniplates argue that having a space beneath the mental foramen, with the screws placed further proximally and distally confers less risk of MN injury, either by surgical manipulation to protect it while placing screws nearby or by direct trauma from the screw itself. We hypothesised that ORIF using non-spaced miniplates would confer improved neurosensory outcomes. The results showed no significant difference in neurosensory outcomes in the day-1 post-operative setting between spaced and non-spaced miniplates. However, this analysis included very low patient numbers, hence was likely underpowered. This therefore remains an area for further research.

To our knowledge this is first study to investigate the degree of IAN neurosensory function following mandibular fixation stratified by the degree of surgical experience of the OMFS registrar who assumed the primary operator role. Within Australasia, surgical training in the OMFS specialty takes four years. Operators are considered senior registrars if they are in the last two years of their training. We found no statistically significant difference in the change in IAN neurosensory function following ORIF by OMFS registrars of varying surgical experience levels. However, the number of patients in this analysis was also low and a larger study is required to confirm our initial findings. Such a study should also consider the degree of fracture displacement and the extent of surgical manipulation required to reduce the fracture as likely confounders.

The original intent of this study was to compare neurosensory deficits across all facial fracture types classified by anatomical location. Unfortunately, the number of patients and fractures were too few to make meaningful comparisons by fracture location.

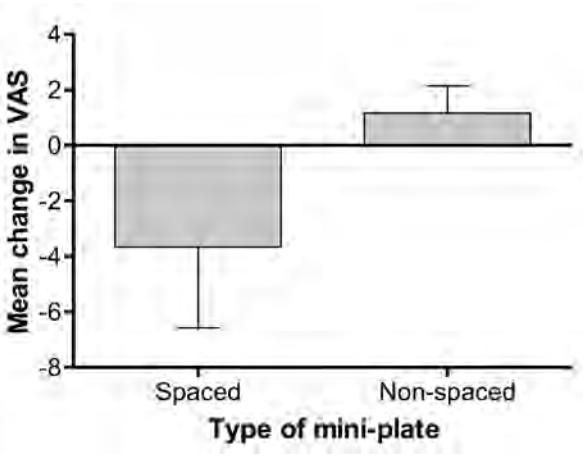

Figure 2. Mean change in patient rated sensation (via VAS) of the ipsilateral MN among patients who underwent ORIF of a unilateral parasymphysis fracture with spaced mini-plates compared to non-spaced mini-plates. No statistically significant difference was found (P = 0.19). Error bars represent ± standard error of the mean.

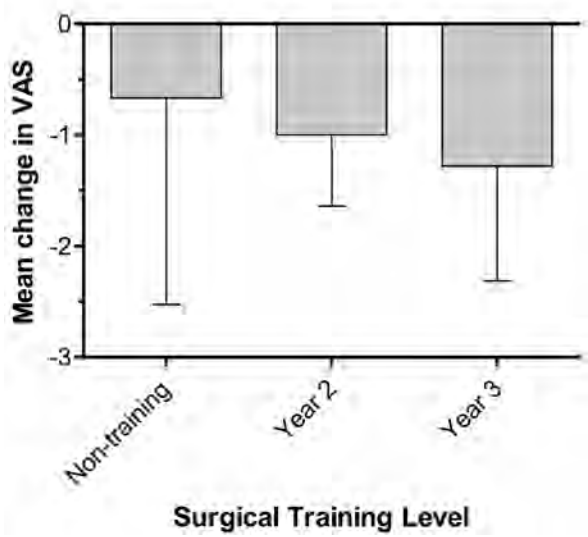

Figure 3. Mean change in patient rated sensation (via VAS) of the ipsilateral MN among patients who underwent ORIF of a unilateral angle of mandible fracture by either a Non-training OMFS registrar, an accredited Year 2 training registrar, or an accredited Year 3 training registrar as the primary operator. No statistically significant difference was found (P = 0.89). Error bars represent ± standard error of the mean.

Previous studies have also used radiographical displacement of fracture segments as a surrogate marker for likelihood of damage to the IAN (Yadav *et al*., 2016). However, the numbers in this study were too low to stratify the analysis by degree of radiographical fracture displacement. In addition to this, the use of plain film radiography in this context introduces multiple variables that can be difficult to control for, such as patient positioning within the machine and inter-operator variation in image quality. Plain films may be unreliable as the maximum displacement of fracture segments created at injury may not reflect the fracture displacement that is visualised radiographically (Tay *et al*., 2015). Volumetric imaging in the form of post-operative computed tomography (CT) would be more reliable in this regard, however the use of post-operative CT would be a deviation from standard practice in this unit.

It has previously been reported that IAN neurosensory disturbance is worse when the associated third molar is extracted at the time of ORIF compared to when it is left *in situ* (McNamara *et al*., 2016), however it is not clear whether these findings can be extrapolated to patient populations served by other OMFS units. The authors had planned to investigate the influence of concurrent third molar extraction on IAN neurosensory outcomes among patients with unilateral mandibular angle fractures. However, interestingly, there were no patients in this sample who had a unilateral mandibular angle fracture with an associated lower third molar that did not get extracted at the time of ORIF. This may represent local custom among surgical staff at Middlemore Hospital, or it may be that all studied patients who had an involved third molar also had absolute indications necessitating its removal.

There are a number of limitations to this study which ultimately required its conversion from a comprehensive prospective cohort study into a pilot study. This was predominantly due to lower than expected patient recruitment into the study which resulted in under-powering of our analyses. The Coronavirus pandemic has had significant impact on the delivery of services in Auckland, as it has elsewhere around the world, and this has had several flow-on effects. In the five year period just prior to the pandemic, our unit typically saw 250 to 300 mandible fractures per year that required operative management. This is in stark contrast to the 55 patients that were able to be recruited into the present study over the 12-month period, even after accounting for the various inclusion and exclusion criteria. Also, at various times during community outbreaks and heightened alert levels the OMFS department had policies imposed upon in it in terms of advocating non-surgical or closed management of fractures where possible, having the most senior staff available operating when surgery was necessary and conversion from face-to-face follow up appointments to telehealth consults where possible. The first two points above fortunately bore no impact on our findings, however a sharp drop off in face-to-face appointments rendered any form of neurosensory testing impossible. Unnecessary patient contact and neurosensory examinations for the purposes of research only could not be condoned during heightened alert levels. Additionally, even under normal circumstances clinical review appointments are often not accessible to the patients served by CMDHB. When combined with the relative hesitancy of patients to return for routine follow-up appointments during heightened alert levels, this made longitudinal assessment of neurosensory recovery difficult, which was one of the initial aims for the study. Multiple level four lockdowns throughout the study period with no traffic on the roads, minimal interpersonal socializing, reduced alcohol consumption and the cancelation of all weekend sporting activities caused a definite reduction in our usual trauma workload. This represents one of the many difficulties with conducting prospective research involving patient contact during a global pandemic.

Conclusion

This study found a strong positive correlation between a subjective measure of IAN neurosensory function (VAS) and the objective CNST method of Zuniga and Essick (1992) in patients with isolated acute unilateral mandible fractures. Thus, the VAS is a reasonable measure of neurosensory disturbance and may be useful in excluding major neurosensory impairment.

An expansion of this pilot study is planned to further investigate factors that may influence IAN neurosensory dysfunction during management of mandibular fractures, such as the removal of associated third molars in angle fractures and the use of spaced versus non-spaced mini-plates in parasymphyseal fractures. Ongoing follow-up of these patients will allow longitudinal assessment of their neurological function. It is hoped that results from this larger study will allow OMF surgeons to provide patients with an accurate prognosis of neurosensory disturbance following mandibular fracture and repair.

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Author contributions

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