Neurosensory changes in the infraorbital nerve following zygomatic fractures

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Objective. To document the neurosensory changes in the infraorbital nerve following zygomatic fractures managed in various ways.

Study design. Twenty-five patients were included in the study. Neurosensory function was assessed with calibrated nylon monofilaments, electrical stimulation, heat detection thresholds and response to pin prick in the infraorbital, supraorbital, and mental nerve regions. Patients were seen immediately post-trauma, then 1 and 6 months following surgery.

Results. Nine fractures were caused by traffic accidents (TAs), 8 by falls, and 8 by a local blow in a physical dispute. The fractures consisted of 15 displaced and 10 minimally or nondisplaced zygomatic complex fractures, and were left surgically untreated in 7 cases (None group), reduced but not fixed in 8 cases (Reduction group), and fixed with plates in 10 cases (Plates group). Plates were employed significantly more often in displaced fractures (chi-squared \( P = .0006 \)). At 6 months significantly improved infraorbital nerve function was found in the Plate and None groups relative to the Reduction group (ANOVA \( P = .006 \)). Only 1 case of chronic neuropathic pain was found.

Conclusions. This study concurs with previous studies in finding that plate fixation allows for significantly better restoration of infraorbital nerve function. Chronic neuropathic pain following zygomatic fractures is rare.


Zygomatico-orbital fractures are one of the most common facial injuries1-3 and have been estimated to occur in 10.4 per 100,000 inhabitants.4 In most cases fracture lines involve the infraorbital (IO) foramen, canal, or fissure. Therefore, fractures of the zygomatic complex are characterized by sensory neuropathy (specifically hypoesthesia) in the area of innervation of the IO nerve both as a presenting symptom and as a postoperative complication.5-7 Some studies5,8 have shown that persistent disturbances in IO nerve function were present in nearly half their cases, while others have observed a lower rate of about 10% at 1 year follow-up. When these fractures are not treated promptly or are inadequately managed, IO nerve dysfunction is extremely common and has been reported in 47% of cases presenting for reoperation owing to residual esthetic and functional problems.9 In spite of the relatively common occurrence of zygomatic fractures the incidence of clinically relevant residual sensory loss is reportedly low and there are few cases of post-traumatic neuropathic-type pain reported.

The aims of the present study were to investigate sensory changes in the IO nerve following zygomatic fractures employing advanced qualitative and quantitative sensory testing (thermal, electrical, and mechanical thresholds), over a 6-month period. These parameters were correlated to the fracture severity and the treatment modality. The advantage of multimodal testing is the ability to differentiate between largely mechanosensitive neurons (Aβ fibers) by employing electrical stimuli and fine nylon filaments, and pinprick and thermal stimuli selectively activate nociceptors (Aδ and C fibers). In addition, we assessed the presence of chronic orofacial neuropathic pain at 6 months.
MATERIAL AND METHODS

Patient population

Patients admitted to the Department of Oral and Maxillofacial Surgery, Hadassah, Jerusalem with an isolated, unilateral fracture of the zygomatic arch, zygomaticomaxillary complex, or IO rim were the subjects of our study. Patients with multiple facial fractures were excluded. The patients were examined in the Department of Oral Medicine as soon as possible following the injury (from 3 to 12 hours), then at 1 and 6 months after surgery. Following the initial assessment, the patients underwent surgical management in the Department of Oral and Maxillofacial Surgery within 5 days. The evaluator was blinded as to the surgical management of the patient, and the surgeon was not allowed access to the results of the sensory assessment.

Fractures were diagnosed clinically and radiographically. Routine radiographs included a Water’s view, an submental vertex (SMV), and a true posterior-anterior view. In cases where there was diplopia or a displaced fracture, computed tomography (CT) is usually performed with or without plain radiographs. Indications for reduction of fractures are well documented and formed with or without plain radiographs. Indications for fracture, computed tomography (CT) is usually performed.

Following the initial assessment, the patients underwent surgical management in the Department of Oral and Maxillofacial Surgery within 5 days. The evaluator was blinded as to the surgical management of the patient, and the surgeon was not allowed access to the results of the sensory assessment.

Sensory threshold was quantified for each of the modalities bilaterally in the supraorbital (SO), IO, and mental (MNT) nerve regions.

Mechanical detection threshold

The orofacial region is very sensitive to mechanical stimulation, and standard sets (eg, nylon monofilaments) are unsuitable for assessing sensory function in the facial region. We developed sets of sensitive disposable mechanical stimulators similar to that described previously. We employed Proline 7-0 monofilaments (Ethicon, Somerville, NJ) suture thread precut to lengths that exerted clinically relevant forces for sensory testing in the face. To ensure standardization between monofilaments we tested the force applied by different lengths of monofilaments 8 times in 5 filaments of each length. For each measurement, a filament was grasped at one end by forceps and the other end was positioned perpendicular to a laboratory balance, applying enough force to induce slight bending of the filament. Results showed high and consistent correlation between filament length and force.

Mechanical detection was assessed in the patients by administering the series of filaments 2 times each in ascending order. With eyes closed, patients indicated each time a filament touch was detected in the MNT, IO, and SO areas of distribution. The lowest force resulting in a consistently positive response was defined as the detection threshold. Detection thresholds are expressed as ratios between the lengths of Proline filaments on the injured side divided by the control side. In a normal situation the ratio would not be expected to be different from a value of 1. Because the longer lengths of Proline induce a smaller bending force, decreased ratios indicate hypoesthesia of the injured side.

Heat detection threshold

Detection thresholds for heat stimuli were evaluated by a 5 × 5 mm water-cooled Peltier probe (TSA 2001; Medoc Advanced Medical Systems Ltd, Ramat Yishai, Israel) using a staircase paradigm in which stimulus intensity (temperature) was alternately increased on successive trials until a sensation was evoked, and decreased until no sensation was perceived. After each change in direction, the amount of stimulus change from each trial was reduced by 50%, and the ascending and descending trials were repeated until this increment was reduced to 0.1°C. In this series the starting temperature was 32°C and the starting increment was 3.0°C. Heat detection thresholds are consistent between patients with a mean of 32.5°C; data are therefore expressed as raw values.

Electrical detection threshold

For electrical detection threshold, continuous trains of constant-current electrical stimuli were delivered to the skin through 8-mm-diameter spherical gold-plated electrodes spaced 20 mm apart. Stimulus frequency was 200 Hz with a 50% duty cycle. Polarity of the electrodes was randomized. Detection thresholds were assessed by an ascending method of limits. Stimulating current was increased at a fixed rate until the subject indicated detection. Three detection thresholds were evaluated for each location and the mean calculated and used for data analysis. Results are expressed as ratios between the injured side and the control side. In a normal situation the ratio would not be expected to be different from a value of 1; higher ratios therefore indicate relative
hypoesthesia of the injured side and lower ratios indicate hyperesthesia.

Reaction to pinprick

The tip of a 0.2-mm-diameter blunted acupuncture needle (Needle No. 3; Seirin Kasei Co Ltd, Shizuoka, Japan) was pushed against the patient’s skin until the needle slightly bends (the skin was dimpled but not penetrated). Under these conditions the bended needle exerts a mean force of 10.5 \( \pm 0.036 \) grams as measured on a laboratory scale. The patient graded the sensation on a 100-mm visual analog scale (VAS) where 0 represented no sensation and 10 represented the strongest pain imaginable. Results were recorded as the difference in VAS values between the control and injured sides. In a normal situation the difference would not be expected to be different from a value of 0. Thus, positive values indicate relative hypoalgesia and negative values indicate relative hyperalgesia of the injured side.

RESULTS

Prior to patient exclusion (see below) a total of 30 patients were examined in the study with a mean age of 33.1 \( \pm \) 16.4 years (range 11-78 years). Of these, 25 were males with a mean age of 31.2 \( \pm \) 14.9 years (range 16-78 yrs) and 5 were females with a mean age of 42.6 \( \pm \) 22 years (range 11-71 years). Fractures occurred with a similar frequency on both sides of the face (16 left, 14 right) and were the result of road traffic accidents (RTA, 11 cases), physical disputes with local blows to the IO region (11 cases), and falls (8 cases).

Classification of fractures and treatment modalities

A simplified fracture classification was employed:

1. Isolated zygomatic arch
2. Zygomatic complex fractures
   a. Minimal or no displacement
   b. Displaced
3. Isolated IO rim fracture

Out of the 30 cases, 5 were preoperatively assessed by plain radiographs, 14 by both CT and plain radiography, and 11 by CT only. Sixteen cases were zygomatic complex fractures with displacement, 10 were ZC fractures with minimal or no displacement, 2 were isolated arch fractures, and 2 were IO rim fractures. Because only 2 cases each of IO rim and isolated arch fractures were obtained these have been excluded from analyses.

Treatment modalities included reduction (8 cases: 5 via Gillie’s approach, 3 with traction hook), reduction and frontomaxillary wiring (1 case), open reduction and fixation with miniplates (10 cases), and no treatment (11 cases). Because only 1 case of wiring was performed we have excluded the data from all statistical analyses. One of 3 senior members of staff in the Department of Oral and Maxillofacial Surgery were responsible for the surgical procedures in all cases.

In total, we analyzed 25 cases, with a mean age of 32.4 \( \pm \) 17.3 years (range 11-78 years). Of these, 21 were males with a mean age of 30.2 \( \pm \) 15.2 years (range 16-78 yrs) and 4 were females with a mean age of 43.5 \( \pm \) 25.5 years (range 11-71 years).

In these 25 cases, 9 fractures were caused by RTA, 8 by falls, and 8 by a local blow in a physical dispute. The fractures consisted of 15 displaced and 10 minimally or nondisplaced zygomatic complex fractures and were left surgically untreated in 7 cases (None group), reduced but not fixed in 8 cases (Reduction group), and fixed with plates in 10 cases (Plate group). The data are summarized in Tables I and II. None of the cases in this study needed reoperation over the period studied (6 months).

Statistical analyses

Data was tabulated and analyzed with a commercial software package (StatView; SAS Institute Inc, Cary, NC) with alpha for significance set at .05. Differences between treatment modalities or trauma types were analyzed with a factorial analysis of variance (ANOVA) and differences between fracture severity with an unpaired \( t \) test. ANOVAs were followed by Scheffe’s post-hoc (pairwise) comparisons. Comparisons of group means to an expected or documented mean were performed with a 1-group \( t \) test. Data are expressed as mean \( \pm \) standard deviation, but all graphs show mean \( \pm \) standard error of the mean for the purpose of clarity.
Fracture diagnosis and treatment modality

An extended use of miniplates in displaced fractures is clearly present while nondisplaced or minimally displaced fractures are more often followed up with no surgical intervention (Table I). Analysis of the 2×3 contingency table (Table I) between fracture and treatment modality with the chi-squared test showed a significant level of correlation (df = 2, chi-squared = 15, chi-squared P = .0006). Table II shows the relationship between the type of injury (RTA, blow, fall) and the resultant fracture severity with no significant trend becoming apparent (chi-squared P > .05).

Sensory changes

The values obtained immediately postinjury were not significantly different between the groups of treatment modalities or fracture classification (ANOVA, P > .05). Therefore, the data at this time point has been analyzed as one group. Of the 25 patients seen initially, 14 returned for the 1-month recall and 20 for the 6-month recall.

For the sensory modalities other than heat we had no previous absolute figures to use as standards. Analysis of the ratios obtained for tests performed in the supraorbital and mental nerve regions (control areas) revealed that there was consistency within patients. For example, at the immediate time point the mental nerve ratios for electrical and mechanical stimuli were 1.04 ± 0.77 and 1.01 ± 0.05 respectively, the temperature threshold was 32.4 ± 0.22°C, and the pinprick difference score was 0.48 ± 0.89. Owing to several patients suffering from ecchymoses that extended around the eye and possibly affected the supraorbital measurements, the mental nerve data has served as control and is shown in the graphs. Based on these control data, we defined a deviation of ≥±20% from the expected ratio of 1 as abnormal for electrical and mechanical stimuli and a difference score of ≥±2 for the pinprick data as indicating significant sensory deficit or abnormal response.

Examining the general trends in all 25 patients, we observed that following trauma there were abnormal threshold ratios (between injured and uninjured sides) to electrical stimuli in 58.3% (8.3% hyper, 50% hypo) of patients, and at 6 months the incidence was 78.8% (15.8% hyper, 63% hypo). Abnormal response to fine mechanical stimuli at the immediate time point was found in 55% (all hypoesthetic) of cases, and at 6 months 30% (all hypoesthetic) still exhibited deviations in fine mechanical threshold ratios.

Pinprick difference scores were greater than ±2 in 29% (all hypoesthetic responses) of cases at the posttrauma time point and in 18.8% (6.3% hyper, 12.5% hypo) at the 6-month recall. For the heat threshold data, the values obtained for the control and uninjured side at the immediate time point confirmed our previous study’s finding of a mean close to 32.5°C (present mean 32.58°C, 95% confidence interval [CI] 32.3-32.8°C). At the immediate time point, 50% of the whole group demonstrated values of thermal detection thresholds on the injured side that lay outside the 95% CI (10% hyper, 40% hypo). At the 6-month time point 24% of all patients demonstrated threshold values that lay outside the 95% CI (all hypo).

Although the data showed some heterogeneity, with some patients demonstrating hyperalgesic responses and others hypoalgesic responses, the prominent and most common feature is hypoalgesic reactions. In all cases there was excellent correlation between the patient’s clinical report and the results of sensory testing, ie, all patients complaining of “numbness” or other sensory alteration showed abnormal test results and vice versa. We employed no scale to measure how much the sensory disturbance was unpleasant for the patient.

Light mechanical detection thresholds (Fig 1)

In Fig 1, A, the effect of treatment modality on light mechanical threshold ratio is shown. Immediately following injury there was a significantly decreased ratio, indicating IO hypoesthesia on the injured side for the group as a whole (mean ± standard deviation = 0.799 ± 0.21, 1-sample t test for a mean of 1, df = 21, t = −4.57, P = .0002).

At 1 month postoperative, the results seem to indicate an improvement in the ratios for the Plate (0.88 ± 0.15) and the None (0.93 ± 0.13) groups but no change in the Reduction group (0.75 ± 0.13); however these differences were not statistically significant (ANOVA; F2,11 = 1.882, P = .198).

At 6 months postoperatively mean ratios for the group treated by Reduction (0.78 ± 0.12) were significantly lower than those for the None (1.01 ± 0.15) and the Plate (0.95 ± 0.08) groups, (ANOVA; F2,17 = 6.921, P = .006. Sch; Reduction versus None or Plate P < .05). The ratio for the group treated by Reduction (0.78 ± 0.12) was significantly different from the expected ratio of 1, indicating substantial hypoesthesia (1-sample t test for a mean of 1, df = 7, t = −5.124, P = .0014).

In Fig 1, B and C, the effects of fracture type and trauma type, respectively, on mechanical threshold ratio are shown. No significant effect is present at the 6-month time point of fracture severity on residual hypoesthesia. A significant overall effect is present at the 6-month time point between the types of trauma and residual hypoesthesia (ANOVA; F2,17 = 4.497, P = .0271). Specifically, a local blow was more likely
to cause significant hypoesthesia than an RTA or a fall (Sch; blow versus RTA or fall $P < .05$).

**Heat detection threshold (Fig 2)**

Immediate postinjury the group as a whole demonstrated heat hypoalgesia (34.03 ± 3.46°C), but this was not statistically significantly different to the control value of 32.5 ± 0.36°C ($t$ test, $df = 19$, $t = 1.971$, $P = .0634$). By the 6-month time point heat threshold had returned to normal, with the whole group demonstrating a mean of 32.58 ± 0.36°C.

**Electrical detection threshold (Fig 3)**

Overall, at the immediate time point the prominent pattern was electrical hypoesthesia (elevated ratios) in the Plate (3.03 ± 3.5), None (3.06 ± 2.8), and Reduction (0.95 ± 0.65) groups, but there was no overall significant differences at this time point (ANOVA; $F_{2,21} = 1.429$, $P = .262$).

At the 1-month time point, 50% of patients had electrical hyperesthesia with no significant differences between fracture severity (Fig 2) or treatment modality (not shown).

At the 6-month time point, 31.6% of patients had electrical hyperesthesia. The Reduction group had significantly elevated ratios (2.96 ± 1.6) relative to both the Plate (0.998 ± 0.43) and the None (1.286 ± 0.34) groups (ANOVA; $F_{2,16} = 7.117$, $P = .006$, Sch; Reduction versus Plate or None $P < .05$). Moreover at
the 6-month time point the mean ratio for the Reduction group was significantly different from an expected value of 1 (1-sample \( t \) test; \( df = 6 \), \( t = 3.223 \), \( P = .018 \)), indicating substantial electrical hypoesthesia.

Analysis of the effect of trauma type or fracture severity on sensory changes revealed no significant differences (ANOVA; \( P > .05 \), data not shown).

**Reaction to pinprick (Fig 4)**

The immediate time point is characterized by a relatively reduced reaction to pinprick in all treatment groups (Reduction: 0.85 ± 1.3, Plate: 3.03 ± 2.8, None: 0.33 ± 1.99) with no statistically significant differences between them (ANOVA; \( P > .05 \)). There were no significant effects of fracture severity or trauma type on reaction to pinprick at any of the time points (data not shown).

**Chronic pain**

Of the total 30 cases only 1 case developed chronic neuropathic pain. The patient was a 71-year-old female.
changes. Thermal and painful stimuli are thought to be transduced by thin unmyelinated (C) and thin myelinated (Aδ) fibers. Mechanical and electrical stimuli (at the settings we employed) selectively activate thick myelinated fibers (Aβ). Our findings indicate that the thin nociceptive fibers recover to a larger extent than the mechanoreceptors; 78% and 30% of patients exhibited altered electrical and fine mechanical threshold ratios, respectively, whereas 18.8% exhibited pinprick hyper/hypoalgesia and 24% showed significant altered heat threshold at the 6-month recall. In experimental models of nerve injury, Aβ fibers have been shown to be more susceptible to damage than C or Aδ fibers.26 Furthermore, axotomy of the IO nerve of the rat resulted in a relatively rapid return of response to pinprick (30 days) but no response to mechanical stimuli over the study period (51 days).27 In previous clinical and animal studies we have shown that hyperalgesic responses to electrical stimuli are caused by inflammation and hypoalgesia and anesthesia by nerve damage.12,13,28–31 Our patients mainly exhibited hypoalgesic responses consistent with nerve damage, although some cases presented with hyperalgesic responses, suggesting that inflammation may play an important role. The nature of the nerve-injury in zygomatic fractures is, however, unclear and may involve traction, pressure, ischemia, inflammation, and physical damage.

Of all the sensory modalities tested one would expect light mechanical threshold and temperature to be the most clinically relevant. The patient’s face is constantly barraged by light mechanical (eg, wind, touch, eating) and thermal stimuli (eg, washing face, sunshine). Based on our figures for abnormal thermal and light mechanical thresholds, we estimate that 24%-30% of our cases sustained nerve injury that would be clinically significant (6-month recall). Electrical threshold and pinprick responses are useful tools, but we are limited in extrapolating findings into everyday significance for our patients.

In our study a local blow was more likely to result in residual hypoesthesia as measured by fine mechanical stimuli, suggesting that the nature of the injury may have a significant effect. This effect was not observed in the electrical testing and in any of the other sensory modalities and is therefore of questionable significance. It should be borne in mind that a plexus of sensory nerves has been reported about 22 mm below the infraorbital foramen, and this may be particularly vulnerable to external local injury. Moreover, in a previous study33 we found that local blows were more likely to induce chronic neuropathic pain states, and therefore the possible connection between trauma character and persistent IO nerve damage merits further investigation.

The need for fracture reduction in zygomatic complex (ZC) fractures has been found in other studies to be between 77%-94% of cases.2,34 This study found that 19 of the original 30 cases (ie, 63%) needed reduction that is a similar figure considering the difference in number of cases between studies. The superiority of reduction and the use of miniplates for the fixation of ZC fractures relative to reduction alone in preventing sensory deficit of the IO nerves is supported by our findings. Similar findings have been reported by other groups15,19,22,35 that have also shown miniplate fixation to be better than fixation with intraosseous wiring. We are unable to compare these latter modalities because only 1 case in our series was treated by wire fixation and was excluded. The changing pattern of increasing use of plates rather than wiring for fixation has been previously noted.36,37 Indeed the routine use of miniplates for midface and mandibular fractures has resulted in low levels of residual sensory nerve dysfunction14 and has been recommended as the treatment of choice for fixation.19,38 Intraoperative stability of reduced ZC fractures does not ensure long-term stability; 20% of cases that were reduced with a traction hook and were stable at operation needed reoperating after 1 week owing to clinically detectable instability.39 Fortunately, we did not need to reoperate on any of our cases. The routine use of plates even in cases where reduction alone seems to be stable has been advocated19 and is supported by the findings in this study. The 3-dimensional stability obtained with miniplates at the zygomaticofrontal suture probably underlies this finding. Additionally the rigid fixation is believed to allow indirect decompression of the IO nerve, facilitating repair and recovery.21,22 Interestingly, our study showed a significant effect for treatment modality and not for fracture displacement on IO nerve recovery. This occurred despite the statistically significant trend of increased use of plates within the group of displaced fractures. This clearly lends further support to the importance of rigid fixation irrespective of fracture displacement. Although some investigators have found no significant relationship between treatment mode and residual nerve dysfunction,4,17 many have noted that treatment mode is paramount,7,15,18,19,25 at times, as in our study, independently of fracture type.18 The group not surgically treated showed recovery rates similar to that with rigid fixation, reflecting spontaneous recovery as has been observed in other studies.19 Our results clearly show that reduction and rigid fixation is superior to reduction alone but the question arises as to why the no-treatment group recovers so well. Assuming that the patients left untreated were those with the least fracture displacement, and therefore the least esthetic and functional impairments,
then this is a preselected population with relatively mild nerve injury. The lack of early nerve injury from fracture movement seems therefore to have a significantly positive clinical outcome even if the effect of fracture severity is not reflected in the statistical analyses.

Finally, only 1 case of the total 30 cases developed chronic neuropathic pain (3.3%). This is surprising in view of the clear nerve injury sustained as evidenced by the changes in sensory threshold in most patients. However, as stated, the trauma induced to the infraorbital nerve is variable and ranges from mild to severe with variable physical (eg, cutting, stretching, crushing) and chemical (eg, inflammation) components. Indeed one factor may induce a cascade involving some or all of the other factors. For example, an inflammatory process along the IO nerve trunk will lead to pressure and in closed areas such as the bony canal may lead to ischemia and nerve damage; we have previously demonstrated this process in experimental rats. Following fractures of the arm, the incidence of chronic neuropathic pain was 5.5%, a similar albeit higher figure. The different reaction of the trigeminal nerve to physical insults relative to spinal nerves has been documented experimentally. It may be that the trigeminal system is resistant to trauma-induced neuropathic pain and indeed even 1 case out of 30 was surprising, and no etiologic or epidemiologic conclusions can be drawn from this single case.

In conclusion, most cases of IO nerve dysfunction following zygomatic fractures will recover by 6 months. The incidence of residual sensory dysfunction varies with the testing modality and was most commonly detected with electrical stimuli. A highly significant beneficial effect on nerve function was noted when plates were used to stabilize fractures relative to fractures that were reduced but not fixed. Chronic pain is a rare complication and was found in 1 case of the 30 subjects in our study.

REFERENCES


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