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Review Article

Surgical outcomes of the surgical techniques following management of iatrogenic trigeminal nerve injuries: A systematic review

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ABSTRACT

Objective: To investigate the effectiveness of the microsurgical treatment in restoring full sensory recovery following trigeminal nerve injuries caused by iatrogenic oral and maxillofacial surgical interventions.
Methods: A detailed search was conducted on the Cochrane central register of controlled trials, Medline and Embase. Clinical studies with at least twelve months of follow up were included and assessment of risks of bias was made using the Robbin I assessment tool.
Results: Six studies were identified in the searches which include 227 patients. The lingual nerve was the most common injured nerve, followed by the inferior alveolar nerve. Third molar removal was the most frequent cause of nerve injury, followed by root canal treatment, pathology excision, coronectomy, orthognathic surgery, dental implants and then local anaesthetic injections. Overall, surgical interventions for nerve injuries showed neurosensory improvement postoperatively in the majority of patients.
Conclusion: Direct neurorrhaphy is still the gold-standard technique when the tension at the surgical site is minimal. Promising results have been noted on conduit applications following traditional repair or grafting. Further research is needed on the efficacy of allografting and conduit applications in nerve repair.

1. Introduction

Trigeminal nerve injuries are considered one of the complications that may arise following dental or surgical procedures around the jaws or facial skeleton. However, the consequences of these injuries vary in their severity and significance (Tay and Zuniga, 2007). Despite the variability in pattern and causation of trigeminal nerve injuries, an understanding of the nature of these injuries began in the American Civil War when in 1864, Silas Weir Mitchell distinguished the clinical features of these injuries, which are still being used in the diagnosis and management of such injuries to this day (Gregg, 2013).

The trigeminal nerve has unique anatomical features, which emphasize the importance of this nerve (Aksoy et al., 2021). The trigeminal nerve is a mixed bilateral cranial nerve that has two roles. It is the fifth (V) of twelve cranial nerves that supply the head and neck region with sensory and motor function. The sensory component conveys pain, temperature, and touch sensations, while the motor component supplies the muscles of the mastication via the mandibular nerve, which include the masseter, temporalis, medial pterygoid, lateral pterygoid, mylohyoid, anterior digastric, tensor tympani, and tensor veli palatini muscles. All are conveyed within three main branches: the ophthalmic nerve (Vi), maxillary nerve (Vii), and mandibular nerve (Viii) (Norton, 2016).

Nerve injuries, in general, can be classified as direct and indirect injuries. Direct injuries can be caused by the use of various surgical instruments, while indirect injuries can be caused by local anesthesia, infection, hematoma formation of hemostatic agents (Alshadwi and Nadershah, 2016). Surgical extractions are a well-established major risk of nerve injury, especially in lower third molar surgery due to the anatomical proximity of the lingual nerve and inferior alveolar nerve (Valmaseda-Castellón, 2013). In terms of complicated surgical extractions, swelling and inflammation are expected to increase consequently due to the surgical trauma, and that may lead to nerve compressions, which will result in transient nerve injury, which can be limited by the use of *peri*-operative corticosteroids (Almeida et al., 2019). The management of patients with trigeminal nerve injuries is challenging as it

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relies on specific factors that can massively affect the approaches to management, such as the time since the injury, the mechanism of the injury, patient expectations, the subjective effect on the patient, and how the injury affects the patient's quality of life. The management can be broadly divided into medical and surgical management, depending on the elements that have been mentioned previously for each injury (Renton et al., 2013).

Medical (or therapeutic) treatment is usually offered in cases where surgical interventions are not indicated (or deemed to be of benefit) or in cases of chronic injuries that are associated with neuropathic pain (Renton et al., 2013). The decision to manage trigeminal nerve injuries with surgical intervention is a complicated matter as it requires a distinct diagnosis, especially when the evidence is not clear; also important is the criteria of the patient's selection. The concept of patient selection is often neglected once the patient meets the requirements for surgical intervention, including immediate nerve transaction during the procedure, pain due to a compress nerve, no improvement since the injury was reported > 3 months, hypoesthesia transformed into dysesthesia, direct contact of a foreign substance with the nerve, patient daily life activity affected, particularly protective reflexes, and injuries related to local anaesthetics, and that would dramatically affect the outcome as the surgeon may have promising results clinically and surgically following the intervention (Ziccardi and Steinberg, 2007).

The microsurgical techniques vary based on the site and the nature of the injury. Moreover, surgical magnification is recommended due to the delicacy of the procedure (Ziccardi and Steinberg, 2007). As mentioned previously, tension-free repair of the nerve is the aim, and in order to achieve that, a nerve graft may be used in cases where the nerve is massively disrupted. The grafts that have been used in nerve repair are either autogenous, such as sural and greater auricular nerves, used due to their localized area of innovation, which limits the postoperative morbidity, and also both have favorable surgical access. Compared to autogenous grafts (which involve multiple factors in the decision; for instance, the size of the graft should match that of the defect), a sural nerve graft is better for inferior alveolar nerve injuries, as the diameter for both ranges from 2.4 to 2.1 mm, respectively. In cases where the greater auricular nerve is considered, then the double grafting cable technique should be utilized to meet the size difference, as the greater auricular nerve diameter is approximately 1.5 mm and the lingual nerve is equal to 3.1 mm (Wolford and Rodrigues, 2013).

In recent decades, there has been an increase in demand for dental and surgical procedures, either for functional or aesthetic purposes, which may lead to an increase in the frequency of these morbidities. However, the primary issue that faces researchers and clinicians is the lack of valid or accurate records relating to these injuries, which has a negative impact on tackling the etiology, severity, and outcomes of any interventions for these injuries, which may result in inaccuracy, inconsistency, or controversy within the literature and ultimately weaken evidence-based practice (Bagheri and Meyer, 2013). Furthermore, the risk of injury to the inferior alveolar nerve was higher with oral surgery procedures, especially third molar removal, and the same study showed that the risk of injury was lower when general dental practitioners used an inferior alveolar nerve block for a restoration, which raises the question: is the injury caused by the local anesthesia or by the third molar extraction? Several studies in the literature have proposed different mechanisms regarding nerve injuries that are related to local anesthesia, which indicates a debatable dilemma as shown in Table 1 (Stacy and Hajjar, 1994; Pogrel et al., 1995; Maruyama, 1997; Pogrel and Maghen, 2001; Reina et al., 2003; Aps and Badr, 2020).

1.1. Aim and objective

The aim of this report was to investigate the effectiveness of the microsurgical treatment in restoring full sensory recovery following trigeminal nerve injuries caused by iatrogenic oral and maxillofacial surgical interventions.

This question - What are the surgical outcomes following microsurgical management of trigeminal nerve injuries that are induced by iatrogenic dental or oral surgery procedures? - was constructed in regard to the concept of participants, interventions, comparisons, and outcomes design (PICO), which was introduced by Moher et al. (2009).

2. Methodology

2.1. Study search

A comprehensive electronic search was performed on the following online databases: the Cochran Central Register of Controlled Trials (CENTRAL) (2013 –2021), MEDLINE and EMBASE via OVID (2013 –2021), and PubMed (2013 –2021). Furthermore, a detailed search was undertaken using controlled vocabulary, Mesh terms, and free text as recommended by the Cochrane Handbook for systematic review to locate the related studies (Cumpston et al., 2021). In addition, a broad search was created to identify studies that might be included in the references or bibliography.

In the event of the presence of missing data among the included studies, the authors were contacted via a proper channel to kindly give information regarding the missing data.

2.2. Inclusion and exclusion criteria

Participants were adult male or female patients diagnosed with trigeminal nerve injury due to iatrogenic dental or surgical interventions, medically fit and well participants, and those who underwent surgical intervention to address nerve injury. Intervention includes any surgical intervention with or without grafting or intubation, which includes nerve decompression, external neurolysis, neuroma removal, neurorrhaphy, and internal neurolysis. Studies included in the review were any clinical study that reported the surgical intervention with at least one participant and a minimum twelve months of follow-up, studies published in English with full text availability, studies published between 2013 and 2021, and human studies.

Any participant who had sustained a trigeminal nerve injury related to trauma or tumor resection, with an underlying medical condition disease that might compromise the overall healing outcomes, or who failed or did not have the capacity to fully report surgical outcomes were excluded. Excluded interventions were any medical intervention with or without the microsurgical treatment that had been used in treating

Table 1
Different suggested mechanisms of nerve injury by local anesthesia agents.

Nerve injury mechanism	Reference
▪ Direct needle penetration to the nerve during local anesthesia injections	(Stacy and Hajjar, 1994) (Maruyama, 1997) (Reina et al., 2003)
▪ Needle penetration into the tissues may cause bleeding which will result in creation of hematoma or scaring	(Pogrel et al., 1995) (Pogrel and Maghen, 2001)
▪ Neurotoxicity of local anesthesia solutions	(Hillerup and Jensen, 2006) (Hillerup et al., 2011) (Aps and Badr, 2020)

trigeminal nerve injuries. Studies that did not detail preoperative information regarding the type of the trigeminal nerve injury with less than twelve months of follow-up, which failed to measure the sensory recovery via the appropriate scales and studies that failed to detail surgical techniques used were excluded.

2.3. Outcomes measures

Primary outcomes include functional sensory recovery measured via a two-point discrimination test and the Medical Research Council Scale for Sensory Recovery shown in Table 2 (Dodson and Kaban, 1997). Secondary outcomes include the patient's quality of life and pain level.

2.4. Date collection and analysis

Relevant searched studies were stored in a reference software program, Endnote X9, to eliminate potential duplication that may result from journals and articles being indexed in different online databases. The studies were then screened via title and abstract to select the most relevant articles based on the inclusion and exclusion criteria and then screened further for evaluation of the full text. Data management and extraction were based on an approach utilized by the checklist introduced by the Cochrane Handbook for Systematic Reviews of Interventions, modified to serve the purpose of this review to include the following: study ID, study design, participants, surgical intervention, mechanism of the injury, time of the surgery, method of evaluation, follow-up and outcome (Liu et al., 2018). Cohen's kappa coefficient, particularly measured inter-rater reliability, was $k = 0.81$.

2.5. Assessment of the risk of bias within the studies

In order to assess the bias within the selected studies, the ROBINS I quality assessment tool for non-randomized studies was used to evaluate the included studies based on three categories: pre-intervention bias, intervention bias, and post-intervention bias. After evaluating the risk of bias in all the three domains, the overall risk of bias was classified into low, moderate, serious, critical, or no information (Sterne et al., 2016).

3. Results

The electronic search on the Cochrane central register of controlled trials, Medline and Embase via Ovid and PubMed revealed 1054 studies that were published between 2013 and 2021. One study was identified through a reference list search. Removing duplicated studies via the software referencing program Endnote x9 reduced the studies to 747. The remaining studies were further examined via title and abstract in accordance with inclusion and exclusion criteria which excluded 708 studies whilst 39 studies met the inclusion standard for this report. For all the remaining studies, full text articles were acquired in order to again assess their eligibility based on the inclusion and exclusion standard. Subsequently, 33 articles were excluded with explanations and 6 studies were included in this review. A flow chart diagram of the search strategies was formulated based on PRISMA guidelines as shown in Fig. 1 (Moher et al., 2009).

Table 2
Sensory recovery scale by the Medical Research Council (Dodson and Kaban, 1997).

Scale	Interpretation
S0	No response
S1	Response to painful stimulus
S2	Slight pain and touch sensation
S2+	Same as S2 but with more reaction
S3	Slight pain and touch sensation without overreaction and two point discrimination equal to > 15 mm
S3+	Same as S3 but with more accurate location of the stimulus and two point discrimination 7–15 mm
S4	Normal

3.1. Characteristic of the selected studies

As detailed previously, six studies Shown in Table 3 were deemed appropriate for inclusion in this review. The total numbers of participants in the studies were 227 patients. Five studies detailed the gender difference amongst the participants with a higher proportion of females accounting for 96 cases while men only accounted for 36 cases. One study with 95 patients failed to report the gender prevalence among the study group. Only one study noted the smoking status of patients. In all the studies, the lingual nerve was the most frequent nerve repaired (196), followed by the inferior alveolar nerve (49). In terms of the causation, the incidence of injury was as follows (cases): third molar extraction ranked (192) cases, endodontic treatment (34), dental pathology (5), orthognathic surgery (3), coronectomy (5), local anesthetics injury (1), apicectomy (1), and removal of operculum (1). With regrades to the surgical interventions, the frequency of surgical technique was direct neurorrhaphy (157), external neurolysis with allograft placement (33), grafting with sural nerve (26), and external neurolysis with conduit (29). One study did not report the distribution of the surgical interventions among patients. All of the studies had at least 12 months of follow up.

In terms of the criteria of neurosensory assessment, all studies used the Medical Research Council scale and two points discrimination tests along with other measurements such as the visual analogue scale for postoperative pain, contact threshold, pinprick sensation, sensitivity to cold and online questionnaires. In all the included studies, there was an improvement following the surgical interventions as the majority of the studies detailed achieving outcomes S3 postoperatively. One study highlighted that repair with an allograft showed successful results when the nerve gap was 70 mm or less. Another study also demonstrates the positive impact of direct neurorrhaphy in nerve repair regardless of the time since the injury, especially when patients suffered from pain.

3.2. Assessment of the bias in the included studies

As highlighted previously, the risk of bias within the studies were evaluated against the ROBINS I tool assessment criteria as shown in Table 4. All of the included studies showed "serious" bias in the overall assessment which was mainly due to confounding factors. However, as per the guidelines of ROBINS I, studies that scored at least serious in one domain considered "serious" in the overall evaluation (Sterne et al., 2016).

4. Discussion

Overall, the included studies in this review highlighted that surgical interventions following nerve injury were deemed to improve sensory response outcomes postoperatively based on the MRCS (Medical Research Council Scale). In the majority of cases, the lingual nerve was the most commonly repaired nerve. Furthermore, neurorrhaphy (direct apposition and sutures) was the predominant surgical technique used to treat the injured nerves. A further theme observed within the included studies related to the causation of injury, and this was primarily third molar extraction. In addition, of the 227 patients who underwent surgical treatment, 96 were female. Another important observation that appeared within the included studies related to the time of the surgery, which ranged from 3 to 67 months.

In Yampolsky et al. (2017), Miloro et al. (2015), and Erakat et al. (2013), and Atkins and Kyriakidou (2021) studies, the mean age of the patients ranged between 28.3 and 34 years old. In contrast, in other studies, including Sonneveld et al. (2021) and Byun et al. (2016), the mean age ranged from 36.4 to 48.6 years old, indicating a generally older population of patients. These observations may be explained by

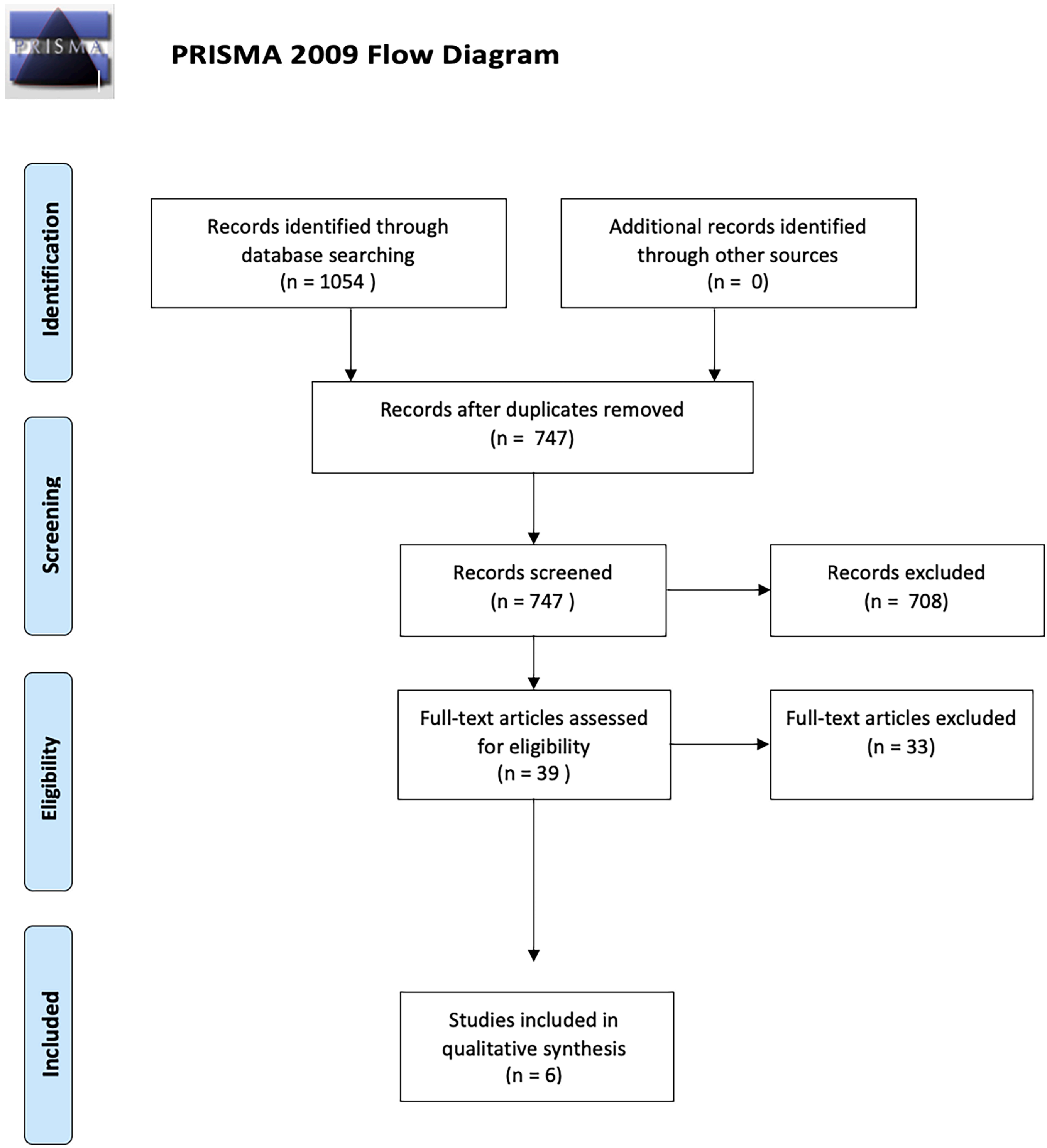

Fig. 1. Flow chart demonstrated the search and selection process based on PRISMA guidelines (Moher et al., 2009).

the fact that third molar extraction was the primary reason for injury in the former five studies, whereas root canal treatment was the cause of injury in the Byun et al. (2016) and Sonneveld et al. (2021) studies. Two systematic reviews also confirmed that third molar surgery was the most frequent procedure that induced iatrogenic nerve injuries (Kushnerev and Yates, 2015; Suhaym and Miloro, 2020). However, orthognathic surgery was the second most common cause in the Suhaym and Miloro (2020) review, which is differs from the current results. In terms of gender prevalence, females appeared more likely to experience iatrogenic nerve injury when compared to males. This finding mirrors the results of earlier studies that detailed that the female gender is considered a preoperative risk factor for nerve injuries (Hillerup, 2007; Pääsky et al., 2021). However, a recent systematic review and *meta*-analysis by Suhaym and Miloro (2020) debated these results, as they could be influenced by the fact that females are more willing to have treatment and thus report post-operative problems, which could explain the gender variation for such injuries.

The lingual nerve was the predominant nerve injured among the included studies, which confirms the strong relationship between lingual nerve injuries and third molar surgery and is in line with the

Table 3
Selected studies for review.

Study ID	Study design	Study title	participants	Surgical interventions	Causes of injury	Time of the surgery	Method of evaluation	Follow up	Outcomes
(Yampolsky et al., 2017)	Retrospective cohort	Efficacy of Acellular Nerve Allografts in Trigeminal Nerve Reconstruction	16) participants, 12 female and 4 male	External neurolysis and excision of the scar tissue nerve allograft	Third molar extraction (9) Second molar root canal (2) Posterior mandibular implants (2) Molar apicoectomy(1)	The mean time between the injury and surgery was (272 ± 249 days),	Medical research council scale and two point discrimination test	102–784 days	15 patients showed functional sensory recovery while one patient did not reach the recovery level.
(Sonneveld et al., 2021)	Retrospective cohort	Microsurgical Repair of Inferior Alveolar Nerve Injuries Associated With Endodontic Treatment: Results on Sensory Function and Relief of Pain	23) participants, 20 female and 3 male	Debridement with or without use conduit (7) Resection with direct neurorrhaphy (3) Resection with allograft reconstruction (13)	Endodontics treatments	The mean time between the injury and surgery was 10.9 months	Medical research council scale for sensory recovery and visual analog scale for postoperative pain	12 months	10 patients achieved full sensory recovery based on the Medical research council scale
(Miloro et al., 2015)	Retrospective cohort	Lingual Nerve Repair: To Graft or Not to Graft?	(43) participants, 25 female and 18 male	direct neurorrhaphy (19) Nerve grafting (28) (24 sural nerve autograft and 4 allograft)	Third molar surgery (34) Pathological excision (5) Orthognathic surgery (3) Dental implant (1)	The median time between the injury and surgery was 3.2 months	Medical research council scale	2 years	85 % of candidate who had direct neurorrhaphy and 89 % who received grafting achieved full sensory recovery
(Erakat et al., 2013)	Retrospective cohort	Interval between injury and lingual nerve repair as a prognostic factor for success using type i collagen conduit	(41) participants, 32 female and 9 male	External neurolysis External neurolysis and internal neurolysis, direct neurorrhaphy and neuroma excision and placement of type I collagen nerve conduit	Third molar surgery (40) Excision of operculum (1) Local anaesthesia (1)	Type I collagen conduit group, mean 5.18 + -1.44, Traditional repair surgery group, mean 7.75 + -5.64	Medical research council scale	range 3.5 to18 months	100 % success rate for type I collagen nerve conduit group. 17/20 patients have full sensory recovery S3 when without using for type I collagen nerve conduit
(Byun et al., 2016)	Retrospective cohort	Surgical management of damaged inferior alveolar nerve caused by endodontic overfilling of calcium hydroxide paste	(9) participants, 7 female and 2 male	Foreign body removal (endodontic materials) Decompression (6) Excision neuroma and direct neurorrhaphy (1) Excision and autogenous nerve graft(sural nerve) (2)	Endodontics treatments	The mean time was 61.6 days	Medical research council scale Contact threshold 2-point discrimination Pin prick Sensitivity to cold	128 to 1360 days	Seven patients achieved S3 to S4 based on MRCS.
(Atkins and Kyriakidou, 2021)	Case series	Clinical outcomes of lingual nerve repair	(95) participants, NO gender information	direct neurorrhaphy (114)	Third molar surgery (109) Coronectomy (5)	The mean time was 16.1 months	Visual analogue scales 2-point discrimination Pin prick Questionnaire	12 months	Direct neurorrhaphy is recommended for patients (suffered pain)

Table 4
Assessment of the bias in the included studies using ROBINS I tool.

	Pre-intervention bias		At the intervention bias	Post-intervention bias			Overall risk of bias
Study ID	Confounding	Selection of participants	Classification of intervention	Missing data	Measurement of outcome	Reported results	
(Yampolsky *et al.*, 2017)	Serious	Moderate	Low	Low	Moderate	Moderate	Serious
(Sonneveld *et al.*, 2021)	Serious	Moderate	Serious	Serious	Moderate	Moderate	Serious
(Miloro *et al.*, 2015)	Serious	Moderate	Low	Moderate	Moderate	Moderate	Serious
(Erakat *et al.*, 2013)	Serious	Moderate	Low	Moderate	Moderate	Serious	Serious
(Byun *et al.*, 2016)	Serious	Moderate	Low	Low	Moderate	Moderate	Serious
(Atkins and Kyriakidou, 2021)	Serious	Moderate	Low	Moderate	Moderate	Moderate	Serious

current evidence in the literature (Cheung et al., 2010; Pippi, Spota and Santoro, 2017). The authors acknowledge that the unique anatomical characteristics of the lingual nerve may have implications for its vulnerability and susceptibility to injury (Maheshwari et al., 2007; Al-Amery et al., 2016).

With regrad to the primary outcome, Erakat et al. (2013) stated that the time between the injury and surgical intervention was statisiticly significant. Based on the data of 41 patients included in the study, each month of delay results in a 23 % drop in the likelihood of achieving a full sensory recovery. Wilson et al. (2017) reported that there was no difference in the FSR (full sensory recovery) between the study groups that had lingual nerve repair using type I collagen conduit or porcine small intestinal submucosal conduit based on the time since the injury. These results align Sonneveld et al. (2021) and Miloro et al. (2015) also reported the time between injury and treatment did not significantly affect the FSR when direct neurorrhaphy or allograft and autograft were used to repair the lingual nerve. Yampolsky et al. (2017) did not give details but Atkins and Kyriakidou (2021) reported an improvement in FSR outcomes following surgical intervention three years post-injury.

Zuniga (2015) reported on 10 out of 23 patients who underwent micro-surgical repair with allograft reconstruction less than three months after injury, all of whom demonstrated 100 % improvement in sensory response outcomes, while 13 out of 23 patients who had the same surgical intervention after three months showed 77 % neurosensory improvement. Recently, Suhaym and Miloro (2020) conducted a systematic review and *meta*-analysis in order to clarify the debate on this topic in the literature: does early repair of trigeminal nerve injuries have an effect on neurosensory recovery? The authors answered the question according to the *meta*-analysis of the data and detailed how both early and late intervention could improve neurosensory recovery up to 93 % and 78.5 %, respectively.

In the Sonneveld et al. (2021) study, three out of twenty-one patients had repair of the IAN by direct neurorrhaphy following endodontic-related injuries, and only ten out of twenty-one patients achieved FSR at 12 months based on the MRCS scale (S3 or more) but failed to demonstrate which interventions were associated with success or failure cases. In contrast, Miloro et al. (2015) and Erakat et al. (2013) reported that 85 % of the patients who had their lingual nerve repaired by direct neurorrhaphy scored S3 or greater based on the MRCS scale at 24 and 13 months, respectively. Based on the two-point discrimination test, the mean of the measurements prior to the surgery was 13.87 mm and postoperatively was 8.77 mm, which indicates a good outcome for FSR as this result is considered S3 + on the MRCS scale. A further point to mention is that all the patients included in this study received two courses of antibiotics prior to and after the surgery, along with a dose of dexamethasone. Yampolsky et al. (2017) demonstrated the usefulness of allograft in IAN and lingual nerve reconstruction. The authors reported that 93.75 % (15 out of 16) have achieved a recovery of S3 or more after being treated by Avence nerve allografts (Axogen) along with nerve graft protectors (Axogen or Neuragen). The gap size in reconstruction surgeries was 2 cm or less. In the Sonneveld et al. (2021) study, 11 out of 21 patients had their IAN repaired via axogen allograft, with only 6 patients reporting FSR. In contrast, Byun et al. (2016) demonstrated that 2 out of 9 patients had their IAN reconstructed with a sural nerve graft. One of the two cases did not report FSR, and the authors explained that the reason for the failure was due to the large degree of extrusion of endodontic material within the IAN canal.

With regards to secondary outcomes, pain levels have also been investigated by Atkins and Kyriakidou (2021) based on the visual analogue scale (VAS) (0 = no pain, 100 = worst pain impaginable). The authors found that the pain level has been significantly reduced following lingual nerve repair via direct neurorrhaphy, as pre-operative scores were more than 40 % and post-operatively dropped to 28 %. Similarly, Sonneveld et al. (2021) reported an improvement in the VAS of pain level at 12 months following inferior alveolar nerve repair caused by endodontics treatment. The mean preoperative VAS was 4.86, which has decreased to 2.76 postoperatively, which was a statistically significant result at $p = 0.001$. In terms of patient quality of life, only one study has reported that patient satisfaction (via VAS score) was higher following lingual nerve repair treated via grafting, 8.9 compared to direct neurorrhaphy 8.1, which was statistically significant at $p = 0.02$.

4.1. *Strenghs and limitiation*

The inclusion and exclusion criteria in this review were constructed in more detail in order to represent the closest theme to the surgical outcome of microsurgical techniques used in trigeminal nerve injury repair. A key strength of the present review was the surgical outcome scale, which included two-point discrimination and MRCS. The search was limited to eight years (2013–2021) in order to investigate the most

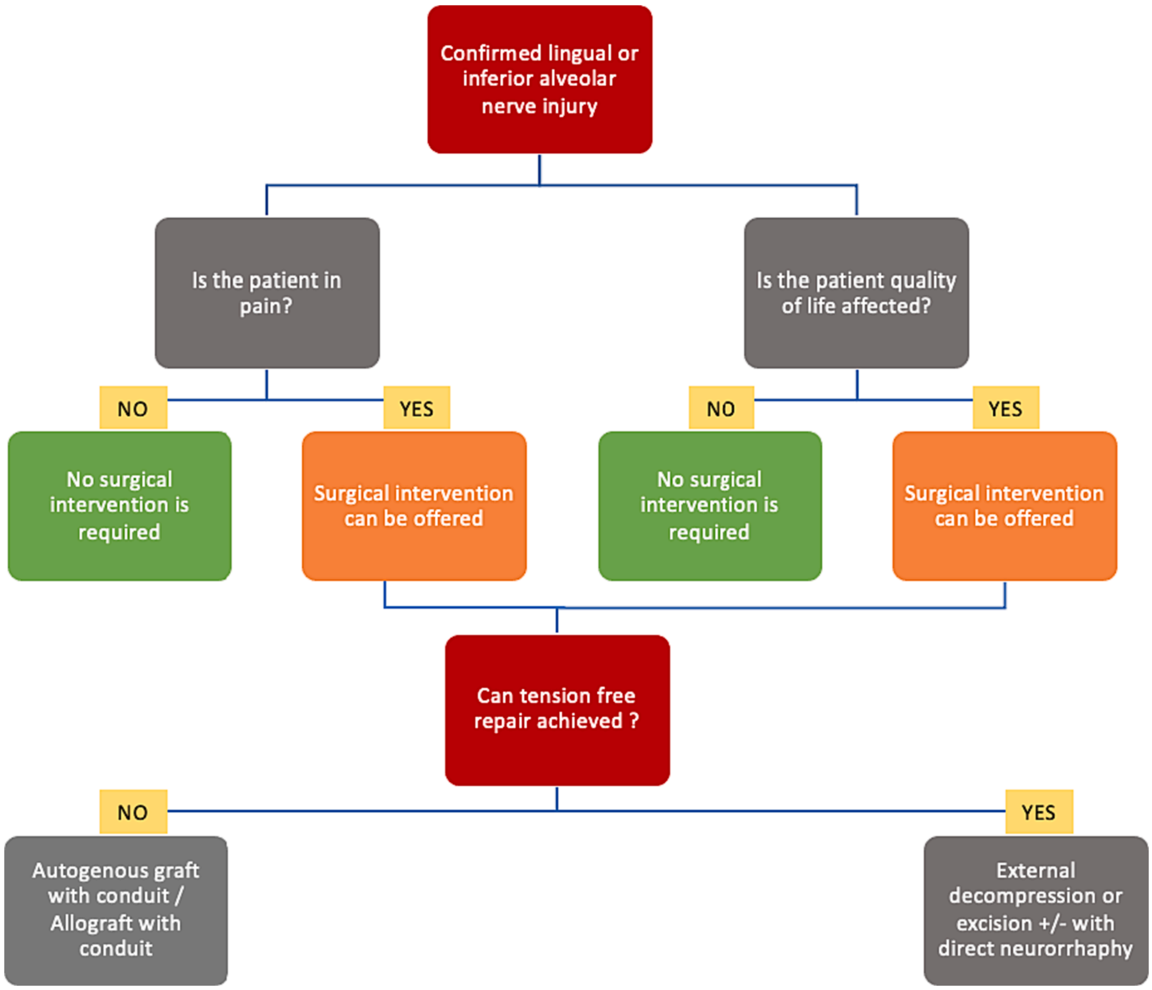

Fig. 2. Management pathway for trigeminal nerve injuries based on the current surgical outcomes.

recent grafting methods and how these techniques could improve the surgical outcome in comparison with traditional direct suturing nerve repair.

Regarding limitations, several biases have been identified in the pre-intervention, at-intervention and post-intervention domains within the included studies. Secondly, the subjective neurosensory measurement for the primary outcome, such as a pinprick, light touch, and VAS scale, was not included in this review as these measurements did not have standardized scales to interpret. Also, false positive and false negative responses are commonly linked with these tests, which makes it difficult to rely on them to draw a conclusion. Finally, the sample size within the included studies was low, which could affect the interpretation of the results.

5. Conclusion

The results of this review are in alignment with the current literature in terms of the age group, which was 30 years or more, the gender prevalence, which was female, and the primary cause of injury, which was third molar extraction. The timing of the surgery fluctuated between 3 months and 5 years in the studies reviewed. External decompressions were a successful microsurgical technique in nerve repair when the injury was caused by endodontic materials. Direct neurorrhaphy was the preferred technique used in lingual nerve repair when a tension-free repair was achievable. MRCS and two-point discrimination tests are very close to being objective scales and give a better understanding of surgical intervention effectiveness. Conduit applications showed outstanding results when applied over nerve grafts or direct neurorrhaphy. However, more research is necessary to establish a deeper understanding of the advantages and disadvantages of allograft nerve repair. In terms of autogenous grafts, a sural nerve graft is still the preferred approach, with fewer morbidities being reported in this review. The authors suggest a management pathway for trigeminal nerve injuries based on the current surgical outcomes (Fig. 2).

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Excluded studies and the reasons for exclusion

Study	Justification
(Zuniga et al., 2017)	Reconstruction surgery for the mandible
(Akbari and Miloro, 2019)	Survey study
(Ducic and Yoon, 2019)	Literature review
(Kim et al., 2017)	No full text, abstract only
(Kogan et al., 2021)	Systematic review
(Kushnerev and Yates, 2015)	Systematic review
(Lee et al., 2016)	No surgical intervention
(McLeod and Bowe, 2016)	Literature review
(Miloro and Zuniga, 2020)	Pediatric Participants
(Monaco et al., 2019)	No surgical intervention
(Patel et al., 2018)	Cross sectional survey study
(Suhaym and Miloro, 2020)	Systematic review and *meta*-analysis
(Susarla et al., 2020)	No surgical interventions
(Yadav et al., 2014)	No surgical interventions
(Yang et al., 2018)	No surgical interventions
(Maezawa et al., 2016)	Outcome measured by different scale
(Biglioli et al., 2017)	Outcome measured by different scale
(Morgan and Zuniga, 2020)	Reconstruction surgery for the mandible
(Pamula et al., 2019)	Reconstruction surgery for the mandible
(Salomon et al., 2016)	Reconstruction surgery for the mandible
(Tanaka et al., 2016)	Reconstruction surgery for the mandible
(Bianchi et al., 2017)	Outcome measured by different scale
(Zuniga et al., 2016)	Reconstruction surgery for the mandible
(Zuniga, 2013)	Reconstruction surgery for the mandible
(Yampolsky et al., 2017)	Reconstruction surgery for the mandible
(Wolford and Rodrigues, 2013)	Book chapter
(Wilson et al., 2017)	Did not mentioned the reason of injury
(Shimizu et al., 2015)	Reconstruction surgery for the mandible
(Ruckman et al., 2014)	Poster paper
(Zuniga, 2015)	Some of the Participants had underlying medical problems
(Bianchi et al., 2017)	Outcome measured by different scale
(Lampert et al., 2016)	No full text
(Wilson et al., 2017)	Did not mentioned the cause of the injury

Appendix B. Sensory recovery scale by the Medical Research Council (Dodson and Kaban, 1997).

Scale	Interpretation
S0	No response
S1	Response to painful stimulus
S2	Slight pain and touch sensation
S2+	Same as S2 but with more reaction
S3	Slight pain and touch sensation without overreaction and two point discrimination equal to > 15 mm
S3+	Same as S3 but with more accurate location of the stimulus and two point discrimination 7–15 mm
S4	Normal

References

Akbari, M. & Miloro, M. (2019). 'The inferior alveolar nerve: To graft or not to graft in ablative mandibular resection?' *J Oral Maxillofac Surg*, 77 (6), pp. 1280-1285. DOI: 10.1016/j.joms.2019.01.008 Available at: https://www.joms.org/article/S0278-2391(19)30011-4/fulltext.

Aksoy, S., Sayın Şakul, A., Görür, D.İ., Şakul, B.U., Orhan, K., 2021. Evaluation of Anatomoradiological Findings on Trigeminal Neuralgia Patients Using Computed Tomography and Cone-Beam Computed Tomography. Diagnostics 12 (1), 73. https://doi.org/10.3390/diagnostics12010073.

Al-Amery, S.M., Nambiar, P., Naidu, M., Ngeow, W.C., 2016. Variation in Lingual Nerve Course: A Human Cadaveric Study. PLoS One 11 (9), e0162773.

Alshadwi, A., Nadershah, M., 2016. Surgical Repair of Trigeminal Nerve Injuries. [online] www.intechopen.com. Available at: https://www.intechopen.com/chapters/51195 [Accessed 30 Oct. 2023].

Aps, J., Badr, N., 2020. Narrative review: the evidence for neurotoxicity of dental local anesthetics. J. Dental Anesthesia Pain Med. 20(2), p.63. 10.17245/jdapm.2020.20.2.63.

Atkins, S., Kyriakidou, E., 2021. Clinical outcomes of lingual nerve repair. Br. J. Oral Maxillofacial Surgery 59 (1), 39–45. https://doi.org/10.1016/j.bjoms.2020.07.005.

Bagheri, S.C., Meyer, R.A., 2013. Dental Implant-Related Injuries of the Trigeminal Nerve. Trigeminal Nerve Injuries. https://doi.org/10.1007/978-3-642-35539-4_6.

Bianchi, B., et al., 2017. Microsurgical decompression of inferior alveolar nerve after endodontic treatment complications. J Craniofac Surg 28 (5), 1365–1368. https://doi.org/10.1097/scs.0000000000003672.

Biglioli, F., et al., 2017. Surgical treatment of painful inferior alveolar nerve injuries following endodontic treatment: A consecutive case series of seven patients. Oral Maxillofac Surg 21 (4), 461–466. https://doi.org/10.1007/s10006-017-0656-8.

Byun, S.-H., Kim, S.-S., Chung, H.-J., Lim, H.-K., Hei, W.-H., Woo, J.-M., Kim, S.-M., Lee, J.-H., 2016. Surgical management of damaged inferior alveolar nerve caused by endodontic overfilling of calcium hydroxide paste. Int. Endodontic J. 49 (11), 1020–1029. https://doi.org/10.1111/iej.12560.

Cheung, L.K., Leung, Y.Y., Chow, L.K., Wong, M.C.M., Chan, E.K.K., Fok, Y.H., 2010. Incidence of neurosensory deficits and recovery after lower third molar surgery: a prospective clinical study of 4338 cases. Int. J. Oral Maxillofac. Surg. 39 (4), 320–326. https://doi.org/10.1016/j.ijom.2009.11.010.

Cumpston, M., Li, T., Page, M.J., Chandler, J., Welch, V.A., Higgins, J.P., Thomas, J., 2021. Updated guidance for trusted systematic reviews: a new edition of the Cochrane Handbook for Systematic Reviews of Interventions. Cochrane Database System. Rev. 10.1002/14651858.ed000142.

Almeida, R. de A.C., Lemos, C.A.A., de Moraes, S.L.D., Pellizzer, E.P., Vasconcelos, B.C., 2019. Efficacy of corticosteroids versus placebo in impacted third molar surgery: systematic review and meta-analysis of randomized controlled trials. Int. J. Oral Maxillofac. Surg. 48(1), 118–131. 10.1016/j.ijom.2018.05.023.

Dodson, T.B., Kaban, L.B., 1997. Recommendations for management of trigeminal nerve defects based on a critical appraisal of the literature. J. Oral Maxillofac. Surg. 55 (12), 1380–1386. https://doi.org/10.1016/s0278-2391(97)90632-7.

Ducic, I., Yoon, J., 2019. Reconstructive options for inferior alveolar and lingual nerve injuries after dental and oral surgery: An evidence-based review. Ann Plast Surg 82 (6), 653–660. https://doi.org/10.1097/sap.0000000000001783.

Erakat, M.S., Chuang, S.-K., Shanti, R.M., Ziccardi, V.B., 2013. Interval between injury and lingual nerve repair as a prognostic factor for success using type I collagen conduit. J. Oral Maxillofac. Surg.: Off. J. Am. Assoc. Oral Maxillofac. Surgeons 71 (5), 833–838. https://doi.org/10.1016/j.joms.2011.11.026.
Gregg, J.M., 2013. Historical Perspectives on Trigeminal Nerve Injuries. [online] Pocket Dentistry. Available at: https://pocketdentistry.com/historical-perspectives-on-trigeminal-nerve-injuries/ [Accessed 30 Oct. 2023].
Hillerup, S., 2007. Iatrogenic injury to oral branches of the trigeminal nerve: records of 449 cases. Clin. Oral Invest. 11 (2), 133–142. https://doi.org/10.1007/s00784-006-0089-5.
Kim, I. H., Kim, S. M., Kim, M. J. & Lee, J. H. (2017). 'Assessment of clinical effectiveness of inferior alveolar nerve repair with nerve sliding technique' *International Journal of Oral and Maxillofacial Surgery*, 46 (Supplement 1) p. 276. DOI: http://dx.doi.org/10.1016/j.ijom.2017.02.932 Available at: https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emed18&AN=616680474http://man-fe.hosted.exlibrisgroup.com/openurl/44MAN/44MAN_services_page?sid=OVID:embase&iddoi: 10.1016%2Fj.ijom.2017.02.932&issn=1399-0020&isbn=&volume=46&issue=Supplement+1&spage=276&pages=276&date=2017&title=International+Journal+of+Oral+and+Maxillofacial+Surgery&atitle=Assessment+of+clinical+effectiveness+of+inferior+alveolar+nerve+repair+with+nerve+sliding+technique&aulast=Kim.
Kogan, M., Lee, K.C., Chuang, S.K., Ziccardi, V.B., 2021. Outcomes of direct lingual nerve repair after an injury: A systematic review. J Oral Maxillofac Surg 79 (3), 697–703. https://doi.org/10.1016/j.joms.2020.07.001.
Kushnerev, E., Yates, J.M., 2015. Evidence-based outcomes following inferior alveolar and lingual nerve injury and repair: a systematic review. J. Oral Rehabil. 42 (10), 786–802. https://doi.org/10.1111/joor.12313.
Lampert, R. C., Nesbitt, T. R., Chuang, S. K., Ziccardi, V. B., 2016. Management of endodontic injuries to the inferior alveolar nerve. Quintessence Int 47 (7), 581–7. doi:10.3290/j.qi.a36176.
Lee, C.H., et al., 2016. Recovery of inferior alveolar nerve injury after bilateral sagittal split ramus osteotomy (bssro): A retrospective study. Maxillofac Plast Reconstr Surg 38 (1), 25. https://doi.org/10.1186/s40902-016-0068-y.
Liu, J., Hua, C., Pan, J., Han, B., Tang, X., 2018. Piezosurgery vs conventional rotary instrument in the third molar surgery: A systematic review and meta-analysis of randomized controlled trials. J. Dental Sci. 13 (4), 342–349. https://doi.org/10.1016/j.jds.2016.09.006.
Maezawa, H., Tojyo, I., Yoshida, K. & Fujita, S. (2016). 'Recovery of impaired somatosensory evoked fields after improvement of tongue sensory deficits with neurosurgical reconstruction' J Oral Maxillofac Surg,74 (7), pp. 1473-82. DOI: 10.1016/j.joms.2016.01.011.
Maheshwari, B., Hemanth, H.R., Lalitha, R.M., Prasad, K., Ranganath, K., Kulkarni, R., 2007. Anatomic position of lingual nerve in third molar region—a cadaveric study. Int. J. Oral Maxillofac. Surg. 36 (11), 1025. https://doi.org/10.1016/j.ijom.2007.08.216.
Maruyama, M., 1997. Long-tapered double needle used to reduce needle stick nerve injury2. Regional Anesthesia Pain Med. 22 (2), 157–160. https://doi.org/10.1016/s1098-7339(06)80035-0.
McLeod, N. M. H. & Bowe, D. C. (2016). 'Nerve injury associated with orthognathic surgery. Part 3: Lingual, infraorbital, and optic nerves' *British Journal of Oral and Maxillofacial Surgery*, 54 (4), pp. 372-375. DOI: https://doi.org/10.1016/j.bjoms.2016.01.028 Available at: http://www.sciencedirect.com/science/article/pii/S0266435616000516.
Miloro, M., Ruckman, P., Kolokythas, A., 2015. Lingual Nerve Repair: To Graft or Not to Graft? J. Oral Maxillofac. Surg.: Off. J. Am. Assoc. Oral Maxillofac. Surgeons 73 (9), 1844–1850. https://doi.org/10.1016/j.joms.2015.03.018.
Miloro, M., Zuniga, J.R., 2020. Does immediate inferior alveolar nerve allograft reconstruction result in functional sensory recovery in pediatric patients? J Oral Maxillofac Surg 78 (11), 2073–2079. https://doi.org/10.1016/j.joms.2020.06.033.
Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., The PRISMA Group, 2009. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: the PRISMA Statement. PLoS Med. 6(7). 10.1371/journal.pmed.1000097.
Monaco, G., et al. (2019). 'Coronectomy: A surgical option for impacted third molars in close proximity to the inferior alveolar nerve—a 5-year follow-up study' *Journal of Oral and Maxillofacial Surgery*, 77 (6), pp. 1116-1124. DOI: https://doi.org/10.1016/j.joms.2018.12.017 Available at: https://www.sciencedirect.com/science/article/pii/S0278239118313879.
Morgan, S.D., Zuniga, J.R., 2020. Nerve grafting in head and neck reconstruction. Facial Plast Surg 36 (6), 737–745. https://doi.org/10.1055/s-0040-1721106.
Norton, N.S., 2016. Netter's Head and Neck Anatomy for Dentistry - 3rd Edition. [online] shop.elsevier.com. Available at: https://shop.elsevier.com/books/netters-head-and-neck-anatomy-for-dentistry/norton/978-0-323-39228-0 [Accessed 30 Oct. 2023].
Pääsky, E., Suomalainen, A., Ventä, I., 2021. Are women more susceptible than men to iatrogenic inferior alveolar nerve injury in dental implant surgery? Int. J. Oral Maxillofac. Surg. 51 (2) https://doi.org/10.1016/j.ijom.2021.05.008.
Pamula, P., Miloro, M. & Markiewicz, M. (2019). 'Functional sensory recovery following mandibular resection with immediate, long-span allograft reconstruction of the inferior alveolar nerve' *Journal of Oral and Maxillofacial Surgery*,77 (9 Supplement) pp. e85-e86. DOI: http://dx.doi.org/10.1016/j.joms.2019.06.116 Available at: https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emexa&AN=2002578675http://man-fe.hosted.exlibrisgroup.com/openurl/44MAN/44MAN_services_page?sid=OVID:embase&id=doi:10.1016%2Fj.joms.2019.06.116&issn=0278-2391&isbn=&volume=77&issue=9+Supplement&spage=e85&pages=e85-e86&date=2019&title=Journal+of+Oral+and+Maxillofacial+Surgery&atitle=Functional+Sensory+Recovery+Following+Mandibular+Resection+with+Immediate%2C+Long-Span+Allograft+Reconstruction+of+the+Inferior+Alveolar+Nerve&aulast=Pamula.
Patel, N., Ali, S. & Yates, J. M. (2018). 'Quality of life following injury to the inferior dental or lingual nerve – a cross-sectional mixed-methods study' *Oral Surgery*, 11 (1), pp. 9-16. DOI: 10.1111/ors.12259 Available at: https://doi.org/10.1111/ors.12259 (Accessed: 2020/09/27).
Pippi, R., Spota, A., Santoro, M., 2017. Prevention of Lingual Nerve Injury in Third Molar Surgery: Literature Review. J. Oral Maxillofac. Surg. 75 (5), 890–900. https://doi.org/10.1016/j.joms.2016.12.040.
Pogrel, M.A., Bryan, J., Regezi, J., 1995. Nerve damage associated: with inferior alveolar nerve blocks. J. Am. Dental Assoc. 126(8), 1150–1155. 10.14219/jada.archive.1995.0336.
Pogrel, M.A., Maghen, A., 2001. The use of autogenous vein grafts for inferior alveolar and lingual nerve reconstruction. J. Oral Maxillofac. Surg. 59 (9), 985–988. https://doi.org/10.1053/joms.2001.25821.
Reina, M.A., López, A., De Andrés, J.A., Machés, F., 2003. [Possibility of nerve lesions related to peripheral nerve blocks. A study of the human sciatic nerve using different needles]. Revista Espanola De Anestesiologia Y Reanimacion, [online] 50(6), pp.274–283. Available at: https://pubmed.ncbi.nlm.nih.gov/12940217/ [Accessed 30 Oct. 2023].
Renton, T., Janjua, H., Gallagher, J.E., Dalgleish, M., Yilmaz, Z., 2013. UK dentists' experience of iatrogenic trigeminal nerve injuries in relation to routine dental procedures: why, when and how often? Br. Dent. J. 214 (12), 633–642. https://doi.org/10.1038/sj.bdj.2013.583.
Ruckman, I. P. N., Miloro, M. & Kolokythas, A. (2014). 'Long-term outcomes of trigeminal nerve repair' *Journal of Oral and Maxillofacial Surgery*, 72 (9), p. e122. DOI: http://dx.doi.org/10.1016/j.joms.2014.06.216 Available at: https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emed15&AN=71597209http://man-fe.hosted.exlibrisgroup.com/openurl/44MAN/44MAN_services_page?sid=OVID:embase&id=doi:10.1016%2Fj.joms.2014.06.216&issn=0278-2391&isbn=&volume=72&issue=9+SUPPL.+1&spage=e122&pages=e122&date=2014&title=Journal+of+Oral+and+Maxillofacial+Surgery&atitle=Long-term+outcomes+of+trigeminal+nerve+repair&aulast=Ruckman+III.
Salomon, D. & Miloro, M. (2016). 'Outcome of immediate allograft reconstruction of long span defects of the inferior alveolar nerve' *Journal of Oral and Maxillofacial Surgery*, 74 (9 Supplement 1) p. e64. Available at: https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emed17&AN=620211915http://man-fe.hosted.exlibrisgroup.com/openurl/44MAN/44MAN_services_page?sid=OVID:embase&id=doi:&issn=1531-5053&isbn=&volume=74&issue=9+Supplement+1&spage=e64&pages=e64&date=2016&title=Journal+of+Oral+and+Maxillofacial+Surgery&atitle=Outcome+of+immediate+allograft+reconstruction+of+long+span+defects+of+the+inferior+alveolar+nerve&aulast=Salomon.
Shimizu, F., et al., 2015. Effect of concurrent mental nerve reconstruction at the same time as mandibular reconstruction using a fibula osteoseptocutaneous flap. J Plast Reconstr Aesthet Surg 68 (9), 1228–34. doi:10.1016/j.bjps.2015.05.010.
Sonneveld, K.A., Hasstedt, K.L., Meyer, R.A., Bagheri, S.C., 2021. Microsurgical Repair of Inferior Alveolar Nerve Injuries Associated With Endodontic Treatment: Results on Sensory Function and Relief of Pain. J. Oral Maxillofac. Surg. 79 (7), 1434–1446. https://doi.org/10.1016/j.joms.2021.01.037.
Stacy, G.C., Hajjar, G., 1994. Barbed needle and inexplicable paresthesias and trismus after dental regional anesthesia. Oral Surg., Oral Med., Oral Pathol. 77 (6), 585–588. https://doi.org/10.1016/0030-4220(94)90315-8.
Sterne, J.A., Hernán, M.A., Reeves, B.C., Savović, J., Berkman, N.D., Viswanathan, M., Henry, D., Altman, D.G., Ansari, M.T., Boutron, I., Carpenter, J.R., Chan, A.-W., Churchill, R., Deeks, J.J., Hróbjartsson, A., Kirkham, J., Jüni, P., Loke, Y.K., Pigott, T.D., Ramsay, C.R., 2016. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ 355 (355), i4919. https://doi.org/10.1136/bmj.i4919.
Suhaym, O., Miloro, M., 2020. Does early repair of trigeminal nerve injuries influence neurosensory recovery? A systematic review and meta-analysis. Int. J. Oral Maxillofac. Surg. https://doi.org/10.1016/j.ijom.2020.10.002.
Susarla, S.M., Ettinger, R.E., Dodson, T.B., 2020. Is it necessary to free the inferior alveolar nerve from the proximal segment in the sagittal split osteotomy? J Oral Maxillofac Surg 78 (8), 1382–1388. https://doi.org/10.1016/j.joms.2020.03.008.
Tanaka, K., et al., 2016. Bilateral inferior alveolar nerve reconstruction with a vascularized sural nerve graft included in a free fibular osteocutaneous flap after segmental mandibulectomy. Head Neck 38 (5), E111–E114. https://doi.org/10.1002/hed.24326.
Tay, A.B.G., Zuniga, J.R., 2007. Clinical characteristics of trigeminal nerve injury referrals to a university centre. Int. J. Oral Maxillofac. Surg. 36 (10), 922–927. https://doi.org/10.1016/j.ijom.2007.03.012.
Valmaseda-Castellón, E., 2013. Risk of lingual nerve damage: lingual split vs ostectomy with burs. Oral Surg. Oral. Med. Oral Pathol. Oral Radiol. 116 (5), 658. https://doi.org/10.1016/j.oooo.2013.04.022.
Wilson, M.T., Chuang, S.-K., Ziccardi, V.B., 2017. Lingual Nerve Microsurgery Outcomes Using 2 Different Conduits: A Retrospective Cohort Study. J. Oral Maxillofac. Surg.: Off. J. Am. Assoc. Oral Maxillofac. Surg. 75 (3), 609–615. https://doi.org/10.1016/j.joms.2016.09.022.
Wolford, L.M., Rodrigues, D.B., 2013. Nerve Grafts and Conduits. Springer eBooks 16 (12), 271–290. https://doi.org/10.1007/978-3-642-35539-4_16.
Yadav, S., Verma, A. & Sachdeva, A. (2014). 'Assessment of lingual nerve injury using different surgical variables for mandibular third molar surgery: A clinical study' *International Journal of Oral and Maxillofacial Surgery*, 43 (7), pp. 889-893. DOI: htt

ps://doi.org/10.1016/j.ijom.2014.01.013 Available at: http://www.sciencedirect.com/science/article/pii/S0901502714000551.

Yampolsky, A., Ziccardi, V., Chuang, S.-K., 2017. Efficacy of Acellular Nerve Allografts in Trigeminal Nerve Reconstruction. J. Oral Maxillofac. Surg. 75 (10), 2230–2234. https://doi.org/10.1016/j.joms.2017.02.015.

Yang, Y.L., Wen-Ching Ko, E., Chen, Y.R., Huang, C.S., 2018. Does sensory retraining improve subjective rating of sensory impairment after bilateral sagittal split osteotomy? Plast Reconstr Surg Glob Open 6 (5), e1769. https://doi.org/10.1097/gox.0000000000001769.

Ziccardi, V.B., Steinberg, M.J., 2007. Timing of Trigeminal Nerve Microsurgery: A Review of the Literature. J. Oral Maxillofac. Surg. 65 (7), 1341–1345. https://doi.org/10.1016/j.joms.2005.11.090.

Zuniga, J. (2013). 'Trigeminal sensory recovery using processed nerve allografts for large continuity defects' *International Journal of Oral and Maxillofacial Surgery*, 42 (10) p. 1179. DOI: http://dx.doi.org/10.1016/j.ijom.2013.07.044 Available at: https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emed14&AN=71230352http://man-fe.hosted.exlibrisgroup.com/openurl/44MAN/44MAN_services_page?sid=OVID:embase&id=doi:10.1016%2Fj.ijom.2013.07.044&issn=0901-5027&isbn=&volume=42&issue=10&spage=1179&pages=1179&date=2013&title=International+Journal+of+Oral+and+Maxillofacial+Surgery&atitle=Trigeminal+sensory+recovery+using+processed+nerve+allografts+for+large+continuity+defects&aulast=Zuniga.

Zuniga, J.R., 2015. Sensory Outcomes After Reconstruction of Lingual and Inferior Alveolar Nerve Discontinuities Using Processed Nerve Allograft—A Case Series. J. Oral Maxillofac. Surg. 73 (4), 734–744. https://doi.org/10.1016/j.joms.2014.10.030.

Zuniga, J. R., Williams, F. C. & Petrisor, D. (2016). 'Immediate nerve allograft reconstruction with ablation of mandible for benign pathology' *Journal of Oral and Maxillofacial Surgery*, 74 (9 Supplement 1) pp. e37-e38. Available at: https://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emed17&AN=620211658http://man-fe.hosted.exlibrisgroup.com/openurl/44MAN/44MAN_services_page?sid=OVID:embase&id=doi:&issn=1531-5053&isbn=&volume=74&issue=9+Supplement+1&spage=e37&pages=e37-e38&date=2016&title=Journal+of+Oral+and+Maxillofacial+Surgery&atitle=Immediate+nerve+allograft+reconstruction+with+ablation+of+mandible+for+benign+pathology&aulast=Zuniga.

Zuniga, J.R., Williams, F., Petrisor, D., 2017. A case-and-control, multisite, positive controlled, prospective study of the safety and effectiveness of immediate inferior alveolar nerve processed nerve allograft reconstruction with ablation of the mandible for benign pathology. J Oral Maxillofac Surg 75 (12), 2669–2681. https://doi.org/10.1016/j.joms.2017.04.002.