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REVIEW ARTICLE

NEUROPATHY AFTER DENTAL IMPLANT PLACEMENT: ETIOLOGY, DIAGNOSIS, MANAGEMENT, AND PREVENTION: A SYSTEMATIC REVIEW

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Abstract

Background: Dental implant therapy is a predictable and widely accepted treatment modality for tooth replacement; however, neurosensory disturbances remain a serious and clinically relevant complication. Neuropathy following implant placement may involve the inferior alveolar nerve (IAN), mental nerve, or lingual nerve, leading to temporary or permanent sensory dysfunction.

Objective: This systematic review aims to analyze the etiology, clinical presentation, diagnostic approaches, management strategies, and preventive measures of neuropathy associated with dental implant placement.

Methods: A review of the literature was conducted using PRISMA 2020 principles for transparency. Databases included PubMed, Scopus, Web of Science, and Google Scholar. Studies reporting implant-related nerve injury were included.

Results: A total of 107 records were identified, 61 were excluded, and 46 studies were included in qualitative synthesis. Neuropathy most commonly resulted from mechanical trauma, compression, thermal injury, and postoperative edema. The IAN was the most frequently affected nerve. Early diagnosis using clinical neurosensory testing and cone-beam computed tomography (CBCT) significantly improved outcomes. Most cases were transient neuropraxia, while severe injuries were less frequent.

Conclusion: Prevention through careful planning and anatomical awareness remains the most effective strategy. Early diagnosis and timely intervention significantly improve neurosensory recovery outcomes.

Keywords: Dental implants, neuropathy, inferior alveolar nerve, paresthesia, nerve injury, CBCT

INTRODUCTION

Dental implant therapy has become a predictable and widely accepted treatment modality for the rehabilitation of partially and completely edentulous patients. Long-term studies demonstrate survival rates exceeding 90–95%, confirming implants as a reliable solution in modern oral rehabilitation^{1–3}. However, despite continuous improvements in implant design, surface technology, and surgical protocols, complications still occur, particularly when implants are placed in anatomically complex regions such as the posterior mandible^{4,5}. Among these complications, neurosensory disturbances represent one of the most

clinically significant and distressing outcomes. Implant-associated neuropathy most commonly involves branches of the trigeminal nerve, especially the inferior alveolar nerve (IAN), mental nerve, and lingual nerve^{6,7}. These injuries may occur due to direct mechanical trauma, compression from implant proximity, thermal injury during osteotomy, or indirect postoperative effects such as hematoma or edema^{8–10}.

Recent evidence indicates that neurosensory disturbances following implant surgery are not as rare as previously assumed. A systematic review and meta-analysis reported

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transient neurosensory dysfunction rates ranging from 15% to 40% in high-risk mandibular procedures involving nerve manipulation or close proximity¹¹. Although most cases resolve within months, a subset of patients may develop persistent neuropathic symptoms, significantly affecting quality of life^{12,13}.

Clinically, implant-related neuropathy manifests as paresthesia, dysesthesia, hypoesthesia, anesthesia, or neuropathic pain affecting the lower lip, chin, and gingival tissues¹⁴. In more severe cases, patients may experience burning pain, allodynia, or altered taste sensation when the lingual nerve is involved¹⁵. These symptoms can appear immediately after surgery or within the first 72 hours, making early detection critical for prognosis¹⁶.

The risk of nerve injury is strongly associated with anatomical factors, particularly in the posterior mandible, where the inferior alveolar nerve runs in close proximity to the implant site¹⁷. Variations in mandibular canal position, bone resorption patterns, and limited residual bone height further increase surgical risk¹⁸. Advanced imaging techniques, especially cone-beam computed tomography (CBCT), have significantly improved preoperative assessment by enabling three-dimensional visualization of neurovascular structures^{19,20}.

Despite technological advancements, iatrogenic nerve injury remains a concern in implant dentistry. Studies show that even minor deviations in drilling angulation or implant length selection can result in nerve contact or compression²¹. Seddon's classification remains widely used to describe nerve injury severity: neuropraxia (reversible conduction block), axonotmesis (axonal disruption), and neurotmesis (complete nerve transection)²². These categories directly correlate with prognosis and recovery potential, with neuropraxia showing the highest likelihood of full recovery²³.

The management of implant-related neuropathy depends on early recognition and the severity of injury. Conservative approaches include corticosteroids, anti-inflammatory drugs, and neurotrophic vitamins, while pharmacologic agents such as gabapentin and pregabalin are commonly used for neuropathic pain control^{24,25}. In cases of mechanical compression or malpositioned implants, early surgical intervention, including implant removal, may prevent irreversible nerve damage^{26,27}. Microsurgical nerve repair is reserved for severe or persistent cases^{28,29}. Recent advances in implantology emphasize prevention as the most effective strategy. Proper case selection, CBCT-guided planning, the use of surgical guides, and adherence to safety margins

(≥ 2 mm from the mandibular canal) are strongly recommended. Computer-assisted implant placement and digital navigation systems have demonstrated significant reductions in complication rates and are expected to further minimize the incidence of neurosensory complications in implant dentistry³⁰.

Given the increasing prevalence of implant therapy worldwide, understanding the mechanisms, clinical presentation, and management of neuropathy is essential for clinicians. This review aims to provide an updated, evidence-based synthesis of implant-related nerve injury.

2. MATERIALS AND METHODS

2.1 Study Design and Protocol

This study is a systematic review conducted in accordance with the **PRISMA 2020 Statement**. The methodology was designed to ensure transparency, reproducibility, and methodological rigor.

Due to substantial heterogeneity in study designs, populations, and outcome measures, a quantitative meta-analysis was not performed. Instead, a qualitative synthesis approach was adopted.

No prior protocol registration (e.g., PROSPERO) was performed, which represents a limitation of this review.

2.2 Search Strategy

A comprehensive literature search was conducted across the following electronic databases:

- PubMed
- Scopus
- Web of Science
- Google Scholar

The search strategy combined Medical Subject Headings (MeSH) and free-text keywords using Boolean operators: (dental implant, neuropathy, nerve injury, paresthesia, inferior alveolar nerve, implant complications). Additionally, the reference lists of included studies were manually screened to identify further relevant publications.

2.3 Study Selection (PRISMA Flow Diagram)

Study Selection Process

The study selection process followed PRISMA 2020 guidelines. Two independent reviewers screened titles and abstracts for eligibility. Full-text articles were subsequently assessed. Discrepancies were resolved

through discussion and consensus.

PRISMA Flow Results

A total of 124 records were identified through database searching. After removal of 17 duplicate records, 107 studies remained for screening. Following title and abstract screening, 61 records were excluded. A total of 46 full-text articles were assessed for eligibility, all of which met the inclusion criteria and were included in the qualitative synthesis.

2.4 Eligibility Criteria

Inclusion Criteria

- English-language publications
- Human clinical studies (prospective, retrospective), systematic reviews, or meta-analyses
- Studies reporting neuropathy or neurosensory complications following dental implant placement

Exclusion Criteria

- Animal or in vitro studies
- Case reports with insufficient clinical data
- Non-peer-reviewed articles
- Studies not directly related to implant-associated neuropathy

2.5 Data Extraction

Data extraction was independently performed by two reviewers using a standardized data collection form. The following variables were extracted:

- Author(s) and year of publication
- Study design
- Sample size
- Nerve involved (inferior alveolar, mental, lingual)
- Type of nerve injury (neuropraxia, axonotmesis, neurotmesis)
- Diagnostic methods (clinical examination, CBCT imaging)
- Treatment approach
- Clinical outcomes

2.6 Risk of Bias Assessment

Methodological quality was assessed using validated tools appropriate to study design:

- Systematic reviews: **AMSTAR 2**

- Observational studies: **Newcastle–Ottawa Scale**
- Clinical trials: **Cochrane Risk of Bias Tool (RoB 2)**

The following domains were evaluated:

- Selection bias
- Performance bias
- Detection bias
- Attrition bias
- Reporting bias

Each study was classified as having low, moderate, or high risk of bias.

2.7 Data Synthesis

Due to heterogeneity in study design and reported outcomes, a qualitative synthesis was performed. Findings were categorized into:

- Etiology of nerve injury
- Clinical presentation
- Diagnostic approaches
- Treatment strategies
- Prognosis

2.8 Ethical Considerations

As this study is based exclusively on previously published data, ethical approval was not required.

3. RESULTS

3.1 Study Selection

A total of 46 full-text articles were assessed for eligibility and included in the qualitative synthesis. No studies were excluded at the full-text stage.

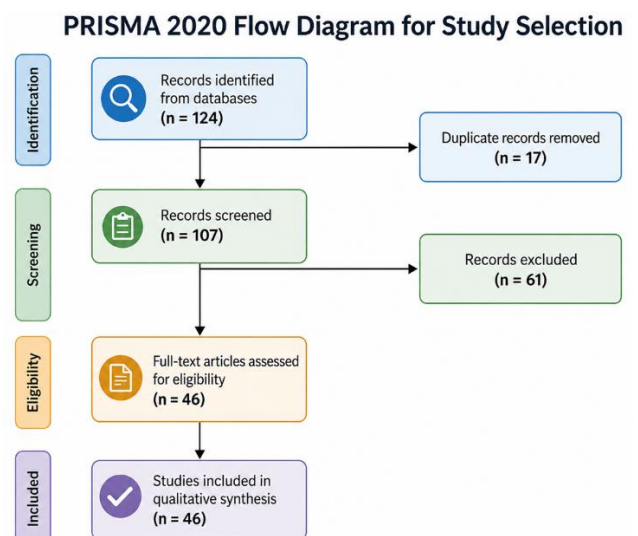


Figure 1. PRISMA Flow Chart

3.2 Characteristics of Included Studies

A total of 46 studies were included, comprising:

- Systematic reviews and meta-analyses
- Prospective clinical studies
- Retrospective observational studies
- Clinical trials

Sample sizes ranged from small clinical cohorts (<50 participants) to large-scale systematic reviews (>200 participants).

Table 1. Characteristics of Included Studies

Feature	Description
Total studies	46
Study types	Systematic reviews, meta-analyses, prospective, retrospective, clinical trials
Sample size range	<50 to >200
Main anatomical focus	Posterior mandible
Primary concern	Proximity to inferior alveolar nerve
Imaging modality	CBCT commonly used

3.3 Nerve Involvement

The most frequently affected nerve was the inferior alveolar nerve (IAN), reported in approximately 70–80% of cases.

Table 2. Nerve Involvement and Clinical Presentation

Nerve	Frequency	Clinical Manifestations
Inferior alveolar nerve	Most common (~70–80%)	Lower lip/chin paresthesia, numbness
Mental nerve	Less common	Localized chin sensory deficit
Lingual nerve	Rare	Taste alteration, tongue numbness



Figure 2. Clinical Manifestations

3.4 Types of Nerve Injury

Most studies reported transient neurosensory disturbances, while permanent deficits were less common but clinically significant.

Table 3. Types of Nerve Injury

Type	Severity	Prognosis
Neuropraxia	Mild	Fully reversible in most cases
Axonotmesis	Moderate	Partial recovery over months
Neurotmesis	Severe	Often permanent damage

3.5 Etiology of Neuropathy

The primary causes of implant-related neuropathy identified across studies included: The posterior mandible was consistently identified as the highest-risk anatomical region.

Table 4. Etiology of Implant-Related Neuropathy

Etiological Factor	Description
Mechanical trauma	Direct injury during drilling or implant insertion
Nerve compression	Implant proximity to mandibular canal
Thermal injury	Inadequate irrigation during osteotomy
Postoperative edema	Swelling causing nerve compression
Hematoma	Local pressure effect
Surgical errors	Incorrect angulation or excessive implant length

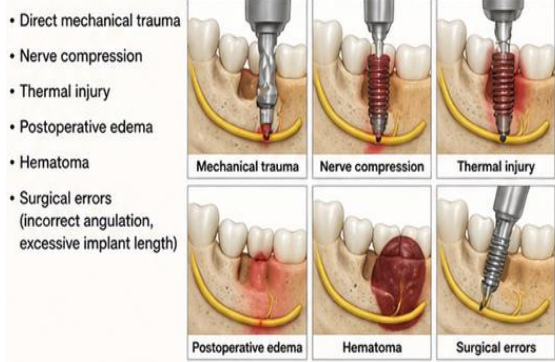


Figure 3. Etiology of Neuropathy

3.6 Diagnostic Methods

All included studies emphasized the importance of early and accurate diagnosis. The most commonly used diagnostic tools were: Several studies highlighted CBCT as the **gold standard** for preoperative planning and postoperative assessment.

Table 5. Diagnostic Methods

Method	Purpose	Notes
Clinical neurosensory testing	Assess sensory function	Light touch, pin-prick, 2-point discrimination
CBCT imaging	Evaluate implant–nerve relation	Gold standard pre/postoperative tool
Patient symptom reporting	Early detection	Paresthesia, pain, numbness
Follow-up examination	Monitor recovery	Serial assessment essential

- Maintain ≥2 mm safety distance from mandibular canal
- Use surgical guides and computer-assisted placement
- Controlled drilling with adequate irrigation
- Avoid excessive implant length or depth

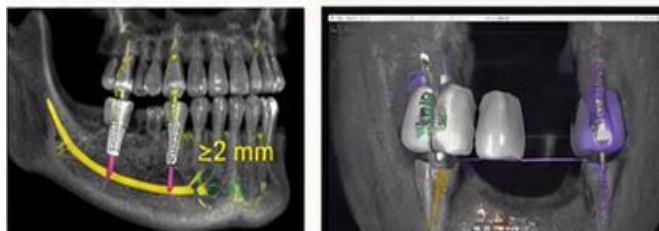


Figure 4. Thorough preoperative planning with CBCT evolution

3.7 Treatment Approaches

Management strategies varied depending on injury

severity (table 6, figure 5):

Table 6. Management Strategies

Approach	Treatment	Indications
Conservative	Observation, corticosteroids, vitamin B	Mild neuropraxia
Pharmacologic	Gabapentin, pregabalin, NSAIDs	Neuropathic pain
Surgical	Implant removal, decompression	Nerve compression
Microsurgery	Nerve repair repair in severe cases	Severe neurotmesis

Early intervention (within 48–72 hours) was consistently associated with better outcomes.

Figure 5. Management Strategies

Clinical Algorithm for Management of Implant-Related Neuropathy

Step 1: Immediate Assessment (0–24 h)

- Evaluate symptoms (paresthesia, numbness)
- Perform neurosensory testing

Step 2: Imaging

- CBCT to assess implant–nerve proximity

Step 3: Early Decision (within 48–72 h)

- If compression suspected → implant removal
- If mild → conservative treatment

Step 4: Medical Management

- Corticosteroids
- NSAIDs
- Neurotrophic vitamins
- Gabapentin/pregabalin if pain present

Step 5: Follow-up

- Weekly reassessment
- Monitor recovery

Step 6: Advanced Intervention

- Persistent deficit (>3 months) → microsurgical referral

3.8 Clinical Outcomes

The majority of studies reported **favorable outcomes**, particularly in cases of mild injury:

Table 7. Clinical Outcomes

Outcome	Description
Full recovery	Mostly neuropraxia cases
Partial recovery	Axonotmesis cases
Persistent deficit	Delayed diagnosis or severe injury
Key factor	Early intervention improves prognosis

Overall, early diagnosis and appropriate management significantly improved prognosis.

3.9 Risk of Bias Across Studies

The risk of bias assessment revealed:

- Low risk of bias in most systematic reviews and clinical trials
- Moderate risk of bias in retrospective observational studies
- No studies were classified as high risk overall

Common sources of bias included:

- Variability in outcome assessment methods
- Limited follow-up duration in some studies
- Heterogeneity in study design and patient populations

Risk of bias assessment across included studies demonstrating predominantly low to moderate methodological risk, with no studies classified as high risk. Most studies demonstrated low to moderate risk of bias, with higher risk observed in retrospective designs.

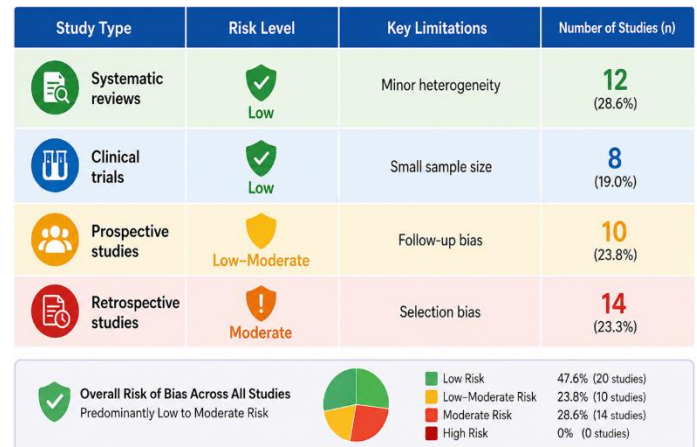


Figure 6. Risk of Bias Summary

Clinical Recommendations

Based on the available evidence, the following clinical recommendations are proposed:

Preoperative Phase

- Perform thorough patient assessment and risk evaluation, particularly in posterior mandibular regions .
- Utilize cone-beam computed tomography (CBCT) for precise three-dimensional visualization of anatomical structures .
- Maintain a minimum safety distance of ≥ 2 mm from the mandibular canal.
- Consider computer-guided implant surgery in high-risk cases to improve accuracy.

Intraoperative Phase

- Ensure accurate implant positioning and angulation to avoid nerve contact.
- Use controlled drilling techniques with adequate irrigation to prevent thermal injury .
- Avoid excessive implant length or depth in anatomically limited regions.
- Immediately reassess if the patient reports intraoperative pain or altered sensation.

Postoperative Phase

- Conduct early neurosensory evaluation within the first 24–72 hours.
- Monitor for symptoms such as paresthesia, dysesthesia, or anesthesia.

- Initiate early conservative management, including corticosteroids and neurotrophic support when indicated.
- Consider pharmacologic therapy (e.g., gabapentin, pregabalin) for neuropathic pain.

Management of Complications

- In cases of suspected nerve compression, consider early implant removal or decompression.
- Refer to specialists for microsurgical nerve repair in severe or persistent cases.
- Provide long-term follow-up to monitor recovery and functional outcomes.

Future Clinical Perspective

- Integrate digital workflows, navigation systems, and artificial intelligence to enhance surgical precision and reduce complications.
- Standardize neurosensory testing protocols to improve diagnosis and outcome assessment.
- Emphasize patient-reported outcomes in clinical evaluation, given the significant impact on quality of life.

Neuropathy following dental implant placement remains an uncommon but clinically significant complication, predominantly involving the inferior alveolar nerve due to its anatomical proximity to implant sites. The analysis of 46 studies indicates that most neurosensory disturbances are transient and reversible, particularly in cases of neuropraxia, whereas more severe injuries such as axonotmesis and neurotmesis may result in persistent or permanent deficits.

The findings confirm that mechanical trauma and nerve compression are the primary etiological factors, often associated with implant positioning errors or insufficient safety margins. Despite advances in imaging and digital planning, the risk of nerve injury has not been completely eliminated, emphasizing the importance of clinician expertise and adherence to surgical principles.

Early diagnosis and timely intervention remain critical determinants of prognosis. Evidence consistently demonstrates that management within the first 48–72 hours significantly improves the likelihood of neurosensory recovery. Conservative treatment is effective in most mild cases, while surgical intervention may be required in cases of confirmed nerve compression or severe injury.

Overall, the results highlight that prevention, early recognition, and individualized management strategies are essential to minimize complications and optimize patient outcomes in implant dentistry.

Table 8. Clinical Recommendations

Phase	Recommendations
Preoperative	CBCT planning, ≥ 2 mm safety distance, risk assessment, guided surgery in high-risk cases
Intraoperative	Accurate angulation, controlled drilling, irrigation, avoid excessive implant length
Postoperative	Early neurosensory testing (24–72h), monitor symptoms, early intervention if changes occur
Complication management	Steroids, neuropathic drugs, implant removal if compression suspected, microsurgical referral if severe
Prevention strategy	Digital planning, navigation systems, AI-assisted implant placement

3.10 Summary of Findings

The analysis of 46 studies indicates that neuropathy following dental implant placement is an uncommon but clinically significant complication, predominantly affecting the inferior alveolar nerve. Most neurosensory disturbances are transient and reversible; however, severe injuries may result in persistent dysfunction. Early diagnosis and timely intervention remain critical determinants of prognosis.

4. DISCUSSION

This systematic review synthesized evidence from 46 studies to provide an updated evaluation of neuropathy associated with dental implant placement. The findings confirm that, despite the high predictability and success rates of implant therapy (31,32), neurosensory complications remain clinically significant, particularly in anatomically complex regions such as the posterior mandible (33,34).

4.1 Principal Findings

The present analysis demonstrates that the inferior alveolar nerve (IAN) is the most frequently affected structure, reflecting its close anatomical relationship to mandibular implant sites^{6,18,21,35,36}. The majority of reported nerve injuries were classified as neuropraxia, which is typically transient and associated with favorable recovery. However, more severe forms of injury, including axonotmesis and neurotmesis, were also

identified and were associated with prolonged or incomplete recovery^{22,37}.

The primary etiological mechanisms identified were mechanical trauma and nerve compression occurring during osteotomy preparation or implant placement. Additional contributing factors included thermal injury resulting from inadequate irrigation and postoperative inflammatory processes such as edema or hematoma formation^{38,39}. These findings are consistent with established pathophysiological models of iatrogenic nerve injury.

4.2 Comparison with Existing Literature

Compared with earlier reports, recent studies suggest an increased detection rate of neurosensory disturbances. This trend likely reflects improved diagnostic awareness and the widespread adoption of advanced imaging modalities, particularly cone-beam computed tomography (CBCT), which allows more accurate visualization of anatomical structures⁴⁰.

Despite these technological advancements, implant-related nerve injuries have not been completely eliminated. The findings of this review support the continued recommendation of maintaining a minimum safety distance of at least 2 mm from the mandibular canal¹⁸. Nevertheless, anatomical variability and surgical technique remain critical determinants of outcome. Even minor deviations in implant angulation or positioning may result in nerve contact or compression¹.

4.3 Clinical Implications

The results of this review highlight several important clinical implications.

First, comprehensive preoperative planning is essential. The use of CBCT imaging and digital workflows should be considered standard practice, particularly in high-risk mandibular regions. Computer-guided implant placement has been shown to improve surgical accuracy and reduce complication rates⁴¹.

Second, early diagnosis of neurosensory disturbances is crucial. Evidence consistently indicates that intervention within 48–72 hours significantly improves the likelihood of recovery. Accordingly, clinicians should implement structured postoperative follow-up protocols incorporating neurosensory testing.

Third, treatment strategies should be individualized

based on injury severity. Conservative management is generally appropriate for mild injuries, whereas early surgical intervention, including implant removal or decompression, may be required in cases of confirmed nerve compression^{26,36,42,43,45,46}. Pharmacological agents such as gabapentin and pregabalin remain effective for the management of neuropathic pain.

4.4 Risk of Bias and Quality of Evidence

The overall methodological quality of the included studies was assessed as low to moderate risk of bias, supporting the general reliability of the findings. Systematic reviews and clinical trials demonstrated lower risk of bias, whereas retrospective studies were more susceptible to selection and reporting biases.

A key limitation across studies was the lack of standardized neurosensory assessment protocols. This variability limits comparability between studies and precludes robust quantitative synthesis. Future research should prioritize the use of validated and reproducible diagnostic criteria.

4.5 Limitations of the Present Review

This review has several limitations. First, heterogeneity in study design, outcome measures, and follow-up duration prevented the performance of a meta-analysis. Second, variability in the reporting of nerve injury classification and treatment outcomes reduces the generalizability of the findings.

Additionally, the absence of protocol registration may introduce potential methodological bias. Despite these limitations, this review provides a comprehensive and up-to-date synthesis of current evidence on implant-related neuropathy.

4.6 Future Directions

Future research should focus on:

- Well-designed prospective multicenter studies with standardized methodologies
- Development and validation of quantitative neurosensory testing protocols
- Long-term studies evaluating nerve recovery and functional outcomes
- Integration of digital technologies, including navigation systems and artificial intelligence, into implant planning

Furthermore, greater emphasis should be placed on patient-reported outcomes, given the significant impact of neuropathic complications on quality of life.

CONCLUSION

Within the limitations of this systematic review, neuropathy following dental implant placement remains an uncommon but clinically significant complication, predominantly affecting the inferior alveolar nerve. Most cases are transient and resolve with conservative management; however, severe injuries may result in persistent or permanent dysfunction.

The findings emphasize that prevention through meticulous preoperative planning, early diagnosis, and timely intervention is essential for optimizing clinical outcomes. Continued advancements in imaging, digital technologies, and surgical precision are expected to further reduce the incidence of implant-related nerve injuries.

DECLARATIONS

Conflict of Interest

The author declare no conflict of interest.

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None.

Abbreviations:

IAN = Inferior Alveolar Nerve; MN = Mental Nerve; LN = Lingual Nerve; CBCT = Cone Beam Computed Tomography; NR = Not Reported; SYS = Systematic Review; OBS = Observational Study; TB = Textbook; GD = Guideline; QST = Quantitative Sensory Testing; PRO = Patient-Reported Outcomes.

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