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Full Length Article

Inferior alveolar nerve bypass during tilted implant insertion: A 3-year retrospective cohort study

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ABSTRACT

Objective: Implant placement in atrophic mandibles can be challenging due to insufficient bone volume. To overcome this problem, bone grafts are often required to increase bone volume and provide a stable base for the implant. However, bone grafting procedures can be invasive, time-consuming, and costly. Tilted implants are a viable option to bypass the inferior alveolar nerve (IAN) and increase the contact surface and primary stability. The aim of this study was to evaluate the survival rate of tilted implants in posterior atrophic mandible and complications related to injury of the inferior alveolar nerve (IAN).

Methods: Accepted patients in this study were only those who suffered from teeth loss in the posterior atrophic mandible. The analysis of this study focused on tilted implants to investigate the survival rate following insertion and during the loading stage. Clinical assessment was conducted to analyze any occurrences of IAN injury.

Results: A total of 31 implants were placed in the posterior mandible of 26 patients with insufficient bone volume. Over a 36-month observation period, all implants exhibited a 100 % survival rate. Three patients experienced temporary neurosensory disturbances.

Conclusions: The use of tilted implants is a viable option for patients with atrophic edentulous mandible that lack the required alveolar height for traditional dental implants. Despite limited study observation time, bypassing the IAN during implant placement presents a predictable option for atrophic posterior mandible treatment.

1. Introduction

Before implant surgery, it is important to have an adequate implant bed for optimal implant positioning. Teeth loss leads to resorption of the alveolar bone, which can vary in its type and severity. Resorption can be reduced by treatment methods such as atraumatic tooth extraction and the use of tension-free sutures [1]. However, if the resorption of the alveolar ridge is progressive, implant surgery becomes more unfavorable [2]. In such cases, augmentation techniques can be used for bone reconstruction to enable successful oral rehabilitation [3]. Preparation for implant surgery on such resorbed bone volume includes additive (bone augmentation procedures) [4] and expansive (bone expansion and splitting) techniques [5]. Many cases become complicated as neither of the two options for bone grafting are viable due to patient-specific local or systemic conditions [6].

Smeets et al. (2022) conducted a systematic review of eight studies involving 276 procedures using various bone grafts for horizontal augmentation in the mandible. Their findings indicated an average horizontal bone width gain of 4.8 mm and a low overall bone graft failure rate of 4.4 % [7].

A systematic review by Elnayef et al. (2017) investigated various techniques for bone augmentation in the posterior mandible, including distraction osteogenesis, inlay block grafting, onlay block grafting, and guided bone regeneration. Their findings indicated that complication rates varied among the techniques, with guided bone regeneration exhibiting the lowest rate. Distraction osteogenesis and inlay block grafting demonstrated higher complication rates. Despite this, distraction osteogenesis achieved the greatest vertical bone gain with an average of 4.49 mm, surpassing the other techniques [8].

Bone grafting has its disadvantages, such as increased morbidity, treatment costs, and duration. To overcome these difficulties, some researchers have proposed unconventional alternatives like positioning implants buccally or lingually in relative to the inferior alveolar neurovascular bundle [9,10].

This method offers several benefits, including being minimally invasive, shorter treatment duration, and being appropriate for patients who can't undergo bone augmentation procedures because of relative or absolute contraindications [11]. Nevertheless, these unconventional

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and precisely executed procedures come with their own set of risks, with inferior alveolar nerve injury being a significant concern and most commonly injured (64.4 %) in oral surgery procedures followed by lingual nerve (28.8 %) [12].

Seddon proposed a three-category system for mechanical nerve injuries based on how long and how well the sensory function recovers [13]. He called these categories neuropraxia, axonotmesis and neurotmesis. LaBanc applied this system to trigeminal nerve injury cases [12].

Neuropraxia involves a conduction block without axon degeneration, often due to nerve manipulation, compression, or traction. Severe trauma to the endoneurial capillaries can cause intrafascicular edema, leading to temporary loss of sensation or function, which typically resolves within 1–2 days, with full recovery usually occurring within a week. This injury manifests as paresthesia. Axonotmesis results in axonal injury, degeneration, and regeneration, commonly due to traction or compression, potentially leading to severe ischemia and demyelination. Recovery may take 2–4 months, but full improvement can extend to 12 months. Neurotmesis is a severe injury that disrupts the connective tissue of the nerve trunk, compromising sensory and functional recovery. Causes include traction, compression, injection, chemical injury, laceration, and avulsion. The initial response to these injuries is anesthesia, followed by paresthesia, allodynia, hyperpathia, hyperalgesia, or chronic pain, with a poor prognosis for recovery [14].

The objective of this retrospective study was to evaluate the survival rate of tilted implants in the posterior atrophic mandible and assess the incidence of complications related to inferior alveolar nerve injury.

The author hypothesizes that tilted implants could provide a simpler and less invasive approach to restoring lost teeth without the need for additional procedures such as augmenting atrophic alveolar bone or performing more complex, uncommon techniques like bone distraction and inferior alveolar nerve lateralization.

The study aims specifically at.

1 Evaluating survival rate of loaded dental implants which bypass the IAN
2 Subjective evaluation of IAN damage by clinical examination

2. Material and methods

2.1. Study design and sample

The investigation was implemented in accordance with the Declaration of Helsinki as a retrospective study on a sample of 26 patients treated and then observed from January 2020 to February 2023 in Latakia, Syria. This study was approved by the Institutional Ethics Committee of Tishreen University Hospital no. 958/2023(April 19, 2023). Written consent was obtained from each participant.

The study has been reported in line with the STROCSS criteria [15].

This study is registered with the Research Registry by the identifying number: researchregistry8911 and the reference hyperlink is: https://www.researchregistry.com/browse-the-registry#home/

2.2. Participants

The study sample was composed of patients suffering teeth loss in the posterior mandible who presented for treatment in University Hospital in 2019. All selected patients for this study had atrophic posterior mandible (class 5 and 6 according to Cawood & Howell classification [16]) with difficulties of bone augmentation procedures due to local (insufficient soft tissue coverage, lack of adequate surrounding bone) or systemic (blood disorders) contraindications. All accepted patients in the study sample were of both genders over 18 years old and indicated for implant placement to restore one or more extracted teeth. Excluded patients from this study were patients who suffer endocrine diseases that affect bone metabolism, oncology patients who receive radiotherapy and/or chemotherapy, pregnant women, and smokers. All patients underwent treatment from the same surgeon N.S., who followed the same surgical protocol for each patient.

To evaluate the position of the inferior alveolar nerve and assess the residual bone volume before

treatment, a Cone Beam Computed Tomography (CBCT) was performed (CS9600 CBCT machine Carestream software for DICOM viewing). The implants used in this study are IBS Implant System® (IBS, Daejeon, South Korea).

2.3. Variables

The primary predictor variable was the treatment protocol included in this study, which is based mainly on placement of tilted implants to restore lost teeth in the atrophic posterior mandible.

Primary outcome variables include.

1 3-year survival rate of inserted implants
2 Clinical assessment of Neurosensory damage

Covariates include.

1 Bone density at the site of drilling

2.4. Surgical technique

All treated patients rinsed out their mouths preoperatively with chlorhexidine gluconate 0.12 % (Biofresh-K mouth rinse®). The skin around the mouth and lips were sterilized with povidone-iodine®. Antibiotic prophylaxis of 2gr amoxicillin with clavulanic acid was taken 1 h before the procedure (Augmentin 1000 mg tab®,Syria).

Buccal and lingual infiltrative local anesthesia was done using lidocaine 2 % with 1:100000 epinephrine (adrecaine®) to maintain sensorial feedback from the patient while drilling near the IAN.

A full thickness mucoperiosteal flap was raised to obtain a complete visual of the alveolar bone. Accurate positioning of the pointer drill was evaluated according to the studied case by CBCT scan. Drilling started with the pointer drill just 2 mm to access through the cortical bone to the sponge bone. A maximum speed of 400 RPM with good cooling irrigation was critical for preventing potential thermal injury to the IAN. A pilot drill of 2.2 mm was then used to prepare the site of the implant until reaching the planned height. To ensure the correct angulation for implant insertion, the technique involved unguided drilling, positioning the drill either buccally or lingually based on the planned implant placement, while keeping the drill parallel to the buccal or lingual plate. In and out motions with light pressure during preparation of the implant site were helpful to pay attention to any pain reflexes from the patient. The sequential drills for the planned diameter were inserted carefully with the same axis of the pilot drill. Any pain sensed by the patients was carefully noticed during the drilling phase. Implant insertion was done manually, and the wound was sutured with 3/0 silk (Unify®) using simple interrupted suture technique. Patients were given a prescription for antibiotics (Augmentin 1000 mg tab, Syria —amoxicillin plus clavulanic acid 1 g/every 12 h) and one tablet of an anti-inflammatory drug (Ibuprofen 600 mg every 8 h) for the following 5 days. Chlorhexidine gluconate 0.12 % was prescribed for daily usage (3 times a day for 1 min). Sutures removal was done after 7 days. Patients' recall for clinical checkup was done on day 1 after procedure, day 7, 2 weeks, 4 weeks, and monthly until reaching the 39th month. Implants loading was done 3 months after the procedure.

Before the surgery, a CBCT scan (CS9600 CBCT machine –Carestream software for DICOM viewing) was performed to check the position of the IAN and measure bone density in the planned site.

To ensure the safety of implant placement, a minimum of 6 mm of bone width was required adjacent to the inferior alveolar nerve (IAN). A 2 mm safety margin was implemented during drilling to minimize the risk of nerve damage.

Another CBCT scan was done right after the implants were placed to evaluate the location of the tilted implants for each patient. Figs. 1 and 2.

All implants were loaded 3 months postoperatively.

2.5. Assessment of neurosensory impairment

Subjective evaluation is crucial for assessing neurosensory loss; a questionnaire based on a visual analog scale (VAS) was used as a standardized and quantifiable method as it contains questions with a continuous horizontal line and two descriptive ends where the patients mark it at a point that they feel it represents their status. The horizontal line is 100 mm in length and the score is calculated by the measurement of the millimeters from the left to the right [17]. The zero measurement means no sensation and the 100 measurement means full normal sensation without any disturbances.The targeted area which corresponds to the IAN anatomy is the lower lip and the chin. The questionnaire was administered on the first day post-surgery. Patients who had any changes in sensation levels filled out the questionnaire again on the seventh day, the fourteenth day, one month, two months, and so on until the twelfth month if sensation problems persisted. Sensation changes that lasted beyond 12 months after the procedure were

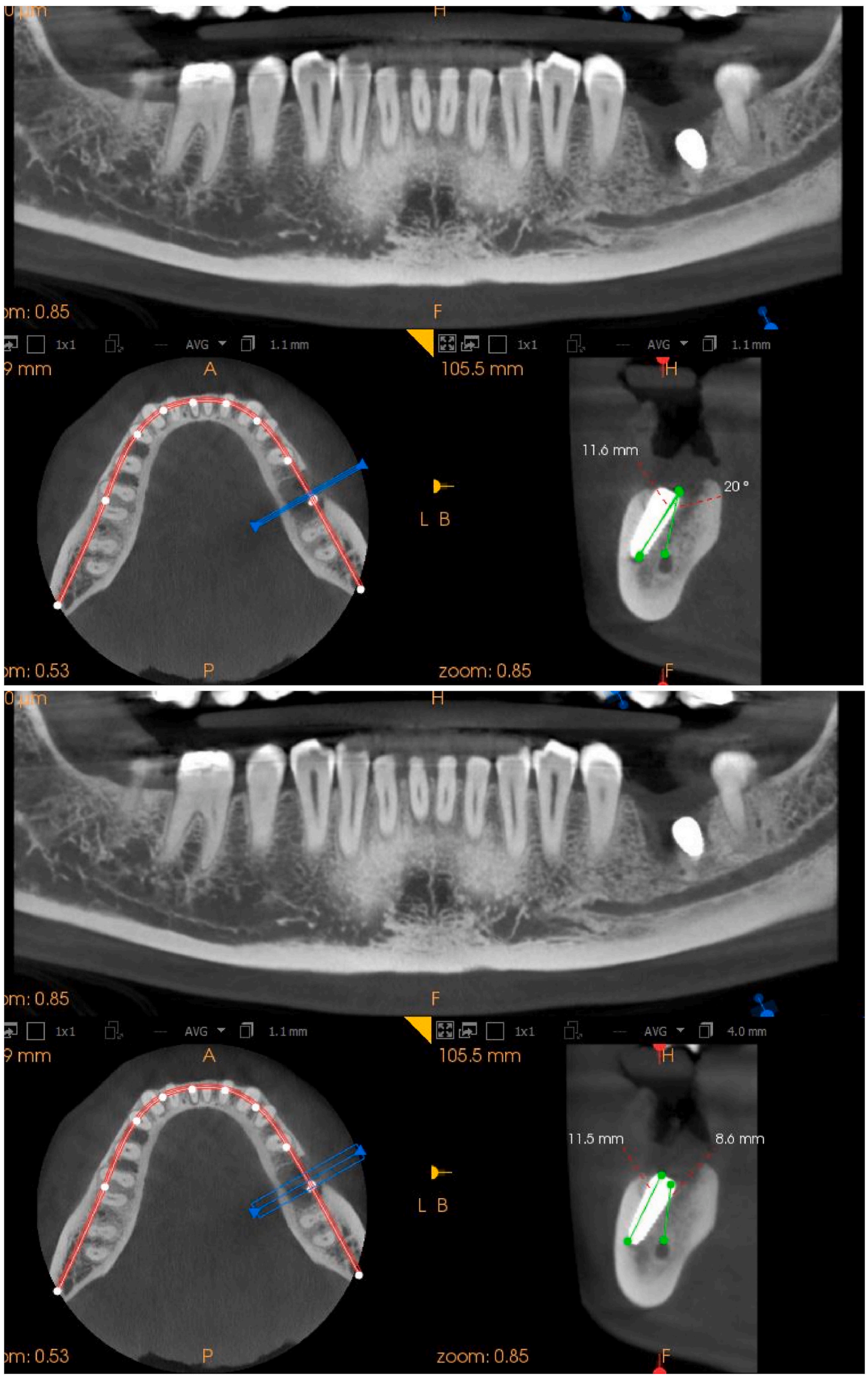

Fig. 1. Clinical case planning and checking after implant placement using CBCT scan.

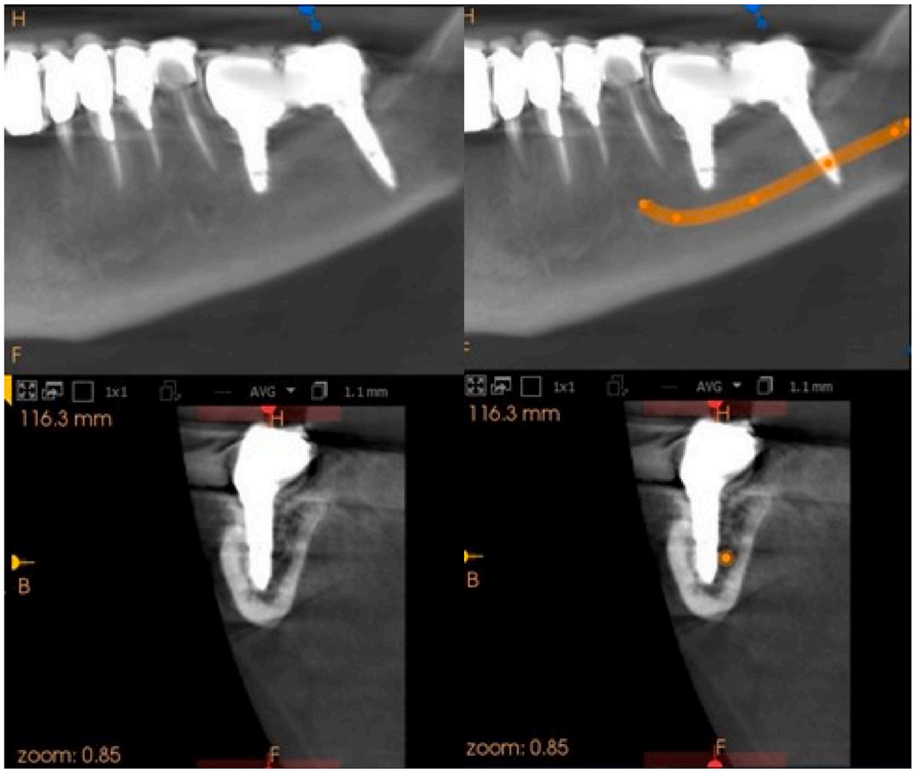

Fig. 2. An example of restored implants at 3 years post-insertion.

considered as permanent damage to the IAN.

The following treatment was given to patients with neurosensory disturbance (NSD).

1 Prednisolone (Predlone®) oral administration in a 5-day decreasing dose (50-40-30-20-10 mg).
2 B vitamins (Betatonic®) for a month, three times daily.

2.6. Data analysis

Statistical analysis was done using IBM SPSS 2020 version 27.0 software for Windows.The distribution of time-to-event (neurosensory disturbance, implant failure) was analyzed using Kaplan-Meier survival analysis to see if it differed based on factors such as implant tilting direction (buccal or lingual), implant diameter, implant length, or implant positioning (premolar, first and second molar). Censoring was considered when no event occurred during the observation period or if the patient dropped out of the study [18].

Log-rank tests were performed to decide if the distribution of complication/implant survival events varied based on factors such as implant tilting (buccal vs. lingual), implant dimensions, and implant positioning. Descriptive analysis for subjective evaluation of NSD was used.

Spearman correlation test was used to evaluate the relationship between bone density and NSD [19].

3. Results

Twenty-six participants were included in this study (aged 45.11 ± 8.05) of which 12 were men. Thirty-one implants were placed in the posterior atrophic mandible. Twenty-four implants were directed buccally (74.19 %) and 8 implants lingually (25.8 %). Positioning of implants varied between second premolars (25.8 %), first molars (38.7 %), and second molars (35.4 %).

No failure of any implant happened, and the survival rate of all inserted implants was 100 %. During the assessment period, none of the patients withdrew from the study. All data regarding patients' details including gender, age, implants dimensions, tilting, and average bone density is shown in Table 1.

The three-year survival analysis regarding implant tilting (buccal and lingual), dimensions, and positioning (second premolar, first, and second molar) was conducted using the Kaplan-Meier curve. This method graphically represents the survival rate, illustrating the likelihood that an implant will last beyond a specific time point. Fig. 3.

Statistical analysis concerning implants survival rate showed no significant differences when studying implants tilting (log rank $\chi^2 = 1.55$, p-value = 0.21, DF = 1), implants diameter (log rank $\chi^2 = 0.28$, p-value = 0.86, DF = 2), implants length (log rank $\chi^2 = 0.55$, p-value = 0.75, DF = 2), and implants positioning(log rank $\chi^2 = 2.83$, p-value = 0.24, DF = 2).

Three patients showed abnormal sensation (first patient: 75 % of normal sensation on VAS, second patient: 82 % of normal sensation on VAS, third patient: 70 % of normal sensation on VAS) on the day after the procedure. All patients' neurosensory disturbances were localized in the lower lip. Two patients showed normal sensation after 2 weeks. One patient showed normal sensation after 3 weeks.

NSD was related to drilling and inserting implants. Spearman correlation test showed that there was a statistically significant relationship between NSD and preparing implant bed in low bone density rs = −0.69436, p (2-tailed) = 0.00407.Out of the total number of implants, soft tissue impaction was observed in 7 cases (22.58 %), all of which occurred specifically at the site of the second molar where the inserted implants were tilted buccally.

4. Discussion

Posterior atrophic mandible rehabilitation with dental implants is a complex and multidisciplinary task that requires careful planning and execution. Several techniques have been proposed to overcome the limitations of bone quantity and quality, such as bone regeneration

Table 1
Descriptive data of patients, implants' dimensions, implants' positioning, implants' tilting direction, and the average of bone density in insertion site.

Patient No.	Gender	Age (years)	Implant placement position	Implant Diameter/Length (mm)	Tilting Direction (Buccally/ Lingually)	Average Bone density Hounsfield units (HU)
1	Female	44	37	3.5/13	Buccally	276.21
			45	3.5/11	Lingually	689.64
2	Female	49	45	3.5/9	Lingually	732.85
3	Female	42	36	3.5/11	Buccally	643.78
			47	3.5/11	Buccally	589.88
4	Male	50	46	3.5/11	Buccally	629.41
5	Female	39	37	3.5/11	Buccally	569.83
6	Male	45	47	4/9	Buccally	938.53
7	Male	56	35	3/13	Lingually	689.72
8	Female	52	46	3.5/11	Buccally	723.34
			37	3.5/13	Buccally	311.35
9	Female	40	35	3/11	Lingually	652.65
10	Male	32	46	3.5/11	Buccally	794.45
11	Male	38	45	3/13	Lingually	865.43
12	Male	47	47	3.5/11	Buccally	341.46
13	Female	32	36	3.5/11	Buccally	764.29
14	Female	37	47	3.5/13	Buccally	658.41
15	Male	28	36	3.5/13	Buccally	965.38
16	Female	41	46	3.5/13	Buccally	427.62
17	Female	56	37	3.5/13	Buccally	331.96
18	Male	39	36	3.5/13	Buccally	725.85
			46	3.5/13	Buccally	356.74
19	Female	52	46	3.5/13	Buccally	286.49
20	Male	46	35	3/13	Lingually	389.17
21	Male	58	37	3.5/13	Buccally	895.25
22	Female	47	35	3.5/13	Lingually	937.52
23	Female	45	46	3.5/13	Buccally	563.85
			37	3.5/13	Buccally	635.28
24	Male	56	45	3/11	Lingually	425.86
25	Female	49	46	3.5/13	Buccally	968.19
26	Male	53	37	3.5/11	Buccally	875.13

surgeries, nerve lateralization, distraction osteogenesis, and extra short implants. The choice of the most suitable technique depends on several factors, such as the degree of atrophy, the patient's general health, the cost-effectiveness, and the patient's preference. The use of extra short implants (≤6 mm) has been suggested as a minimally invasive and reliable option for restoring severely resorbed posterior mandibles. Several studies have reported high survival rates, stable marginal bone levels, and satisfactory prosthetic outcomes with this technique. However, some challenges and limitations still exist, such as the need for adequate primary stability, careful implant positioning, passive fit of the prosthetic components, and adequate occlusal loading [20].

Guided bone regeneration (GBR) and onlay bone grafting are a suggested solution for managing atrophic mandible. Nevertheless, bone augmentation in the mandible may increase the treatment time, cost, and morbidity for the patients [21].

This retrospective study was done to evaluate the difficulties and complications related to angulation of implants in order to bypass the inferior alveolar nerve, thus permitting restoring lost teeth in atrophic bone without the need for additional procedures. The main purpose of monitoring such cases is to assess NSD, which is of paramount importance for the quality of a patient's life.

The survival rate of inserted implants was not affected by implant tilting direction, implant dimensions, or implant placement site, so this study supports Filipov et al.'s findings [11].

Three cases of NSD were noticed during this study, and all of them recovered. This kind of complications are very common in procedures such as IAN lateralization [22] and distraction osteogenesis [23].

Avoiding the IAN in the posterior mandible during dental implant insertion is a delicate operation that requires careful planning; however, its results are very effective when it is carefully achieved with few complications. Despite measuring alveolar bone dimensions accurately, IAN can get damaged by drilling deeply (direct mechanical injury during surgery) because of the softness of the bone; this can cause the drill to slip even in skilled surgeons' hands [24].

The IAN can also get injured by an implant slippage into the canal. For instance, the posterior atrophic mandible is more of a spongy form and has larger spaces between the trabeculae which is a possible threat to the IAN [25].

Utilizing CAD/CAM surgical guide may be of paramount importance in dealing with tilted implants. This study did not utilize CAD/CAM guide and only good planning using the CBCT and hand skill were used. Although the surgical guide reduces patient's chair time, makes the surgical procedure more predictable and less stressful, there are some limitations that may cause harmful results especially when dealing with posterior mandible. Insufficient mouth opening, inadequate mouth opening depending on the guide and drilling system all factors that may cause inappropriate fixing of the surgical guide making the surgery unpredictable [26].

A significant correlation between NSD and low bone density was noticed during follow-up. Despite critical assessment of bony dimensions and thorough planning using CBCT, 3 patients showed subjective expression of NSD, and they were regarded throughout the follow-up period. The 3 patients showed a D4 bone density at the site of the inserted implants. This study agrees with Juodzbalys's literature review which stated that low bone density is related to NSD during implant surgery [27].

After the insertion of the healing cap, 7 patients experienced localized pain at the site of buccally tilted implants. This discomfort was attributed to the impaction of soft tissue. These patients were provided with lingually angulated abutments and appropriately designed crowns as a solution to fully solve the problem.

Many protocols were presented to evaluate IAN injury including NizamV. Ziccardi protocol [28]. However, NSD is subjective in clinical expression, so this study focused only on VAS in evaluating IAN injuries after surgical procedure.

This retrospective study showed an effective role of tilting implants to provide stability in minimal bone volume without the need for additional augmentation procedures. Thus, improving oral health and

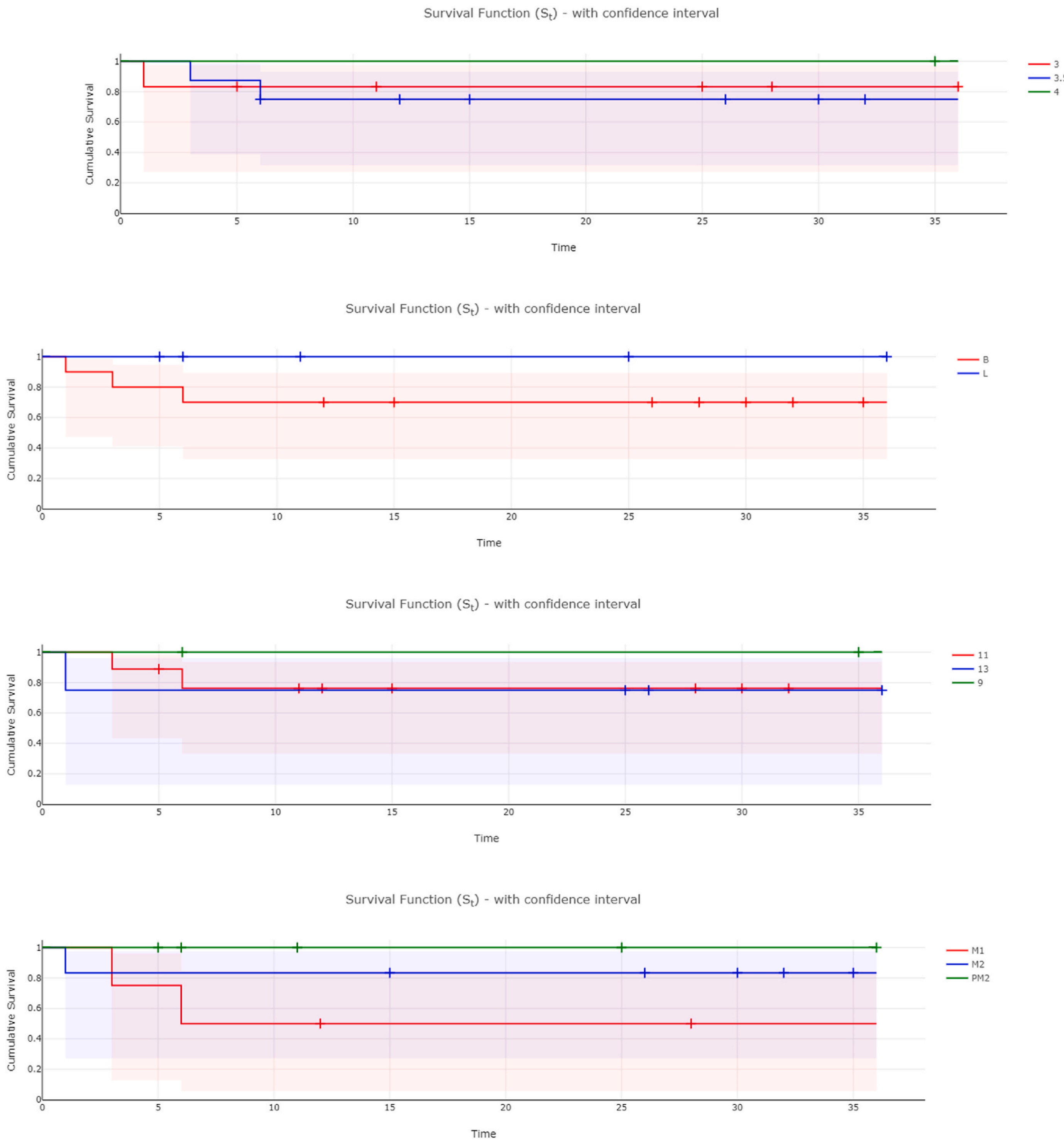

Fig. 3. Cumulative survival rate regarding implant tilting direction, implant diameter, implant length, and implant position. Buccal placement of implants demonstrated a 100 % chance of functioning for more than 36 months, while lingual placement showed a 70 % chance for the same duration. An implant diameter of 4 mm indicated a 100 % chance of functioning longer than 36 months, whereas diameters of 3 mm and 3.5 mm had over a 70 % chance. For implant lengths, a 9 mm length had a 100 % chance of lasting beyond 36 months, while lengths of 11 mm and 13 mm had over a 70 % chance. Implants placed in the second premolar region showed a 100 % chance of functioning longer than 36 months, whereas those in the second molar region had over an 80 % chance, and those in the first molar region had a 50 % chance.

the quality of life. On the other hand, some limitations faced this study, including the low number of participants, the absence of a control group, and a limited follow-up period. The surgical technique is complex and may benefit from the use of digital planning for improved predictability. Future research could explore marginal bone loss and the proficiency of surgeons using this technique.

5. Conclusion

Injuring the inferior alveolar nerve during dental implant surgery can be a serious problem. Practitioners should identify and eliminate factors that can cause nerve damage such as proper planning before surgery, and skillful hands during the operation. Although injury of IAN could be unsatisfying for the patient, good explanation of possible complications, and appropriate prescription when injury occurs could be very helpful. Despite the low number of participants in this study, a new concept of rehabilitating atrophic posterior mandible is a reality and achievable when CBCT is used and studied effectively before the surgical procedure.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Ethical approval

Board Name: Scientific Research Board Resolution- Tishreen University, Latakia, Syria. Board Status: Approved Approval no. 958/2023 (April 19, 2023)

Consent

Written informed consent was obtained from the patients for publication of this study and accompanying images, a copy of the written consent is available for review by the Editor-in-Chief of Advances in Oral and Maxillofacial Surgery Journal.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author did not use AI technologies in the writing process.

Financial disclosure

None reported.

Conflict of interest

None reported.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.adoms.2024.100502.

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