



A Novel Intraoral Mandibular Osteotomy For Set-Back Surgery In Complex Mandibular Anatomy

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Abstract

Objective Complex mandibular anatomy including rolled-out inferior mandibular border, thin rami with cortically adherent inferior alveolar nerve (IAN) complicate the application of the current mandibular osteotomies. This study aims to introduce an intraoral Inverted-L Ramus Osteotomy (ILRO) modified with IAN lateralization and intra-canal osteotomy for management of complex mandibular anatomical variations during mandibular setback surgery.

Patients and Methods This prospective study included 20 skeletal class III patients (mean age: 21.6 ± 3.3 years) with complex mandibular anatomy indicated for mandibular setback surgery (mean setback: 6.05 ± 1.1 mm). Preoperative CBCT imaging, digital planning, and fabrication of cutting / drilling guides were performed. Surgery involved mandibular setback through the application of the ILRO modified with nerve lateralization and intra-canal osteotomy. IAN function evaluated preoperatively at intervals up to one year postoperatively. Data on bad splits and surgical duration were also analyzed.

Results The mean surgical duration was 2.26 ± 0.21 h, with bilateral IAN exposure completed in 11 ± 3.2 min per side. All 40 osteotomy sites were separated without bad splits. Neurosensory deficits were observed in 90% of patients at two months, decreasing to 35% at six months and 5% at one year.

Conclusion The introduced osteotomy overcomes the limitations of the traditional mandibular osteotomies in dealing with mandibular complex anatomy with adequate IAN protection and split segments integrity during mandibular setback surgery.

Clinical relevance The introduced osteotomy provides a safe alternative to the current mandibular osteotomies utilized in mandibular setback surgery.

Keywords Orthognathic surgery · Angle class III · Inferior alveolar nerve injuries · Surgery, computer-assisted · Prognathism · Intraoperative complications

Introduction

Mandibular setback surgery is a complex process when challenged by anatomical variations such as rolled-out inferior mandibular border, thin rami with cortically adherent inferior alveolar nerve (IAN) and inferiorly seated IAN

canal [1]. Traditional jaw osteotomies, including Bilateral Sagittal Split Osteotomy (BSSO), Vertical Ramus Osteotomy (VRO) and the traditional Inverted-L Ramus Osteotomy (ILRO), have been widely used to correct mandibular deformities [2–4]. However, these techniques are limited in cases with complex anatomical variations, as they pose risks of unfavorable splits, increased nerve injury, and extensive distal interferences during setback movements [5–7].

BSSO is the workhorse for correction of different mandibular deformities owing to its versatility [2]. It also allows for rigid internal fixation with maximum bony contact. Nevertheless, Mandibular anatomical variations such as thin rami, low marrow to cortex ratio with cortically adherent IAN and rolled out inferior mandibular border are considered as major limitations for this osteotomy. These variations complicate the splitting procedure and increase the risk for bad split and IAN injury [1, 6]. VRO is an established method in

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the management of mandibular prognathism with minimal risk of bad splits and IAN injury. However, it doesn't allow for rigid fixation that necessitates prolonged maxilla-mandibular fixation. Moreover, the massive distal interferences in setback cases hinder its applicability [3].

The traditional ILRO is a competent alternative to the BSSO in terms of versatility and amenability to rigid fixation with a lower risk of bad splits and neurosensory disturbance. Despite its advantages, ILRO is performed via an extraoral approach, and it faces limitations in mandibular setback cases due to distal interferences and the need for IAN protection [4, 8, 9]. Subsequently, the C-osteotomy introduced by Caldwell et al. 1968, modified the traditional ILRO to be performed via an intraoral approach by extending the long descending arm anteriorly below the IAN canal, this anterior arm is usually thin and prone to unfavorable splits with neurosensory disturbances, especially in cases with inferiorly positioned IAN canals [8–10].

Recently, Senior et al. modified the C-osteotomy's anterior extension to be performed at the level of the inferior

border of the IAN canal while protecting the IAN upward to run as a sagittal split osteotomy instead of bicortical traditional anterior extension. This modification possesses the same limitations of the traditional BSSO [10]. These limitations highlight the need for an innovative technique that combines safety, versatility, and effectiveness in managing complex mandibular anatomical variations. Specially that the advances in digital planning and customized surgical approaches have offered solutions to some of these limitations. This study aims to introduce a modified intraoral ILRO involving IAN lateralization and intra-canal osteotomy for management of complex mandibular anatomical variations with IAN protection and preservation of split segments integrity during mandibular setback surgery.



Fig. 1 A CBCT coronal cut showing the thin mandibular rami, rolling out of the inferior mandibular border, and the IAN proximity to the buccal cortex

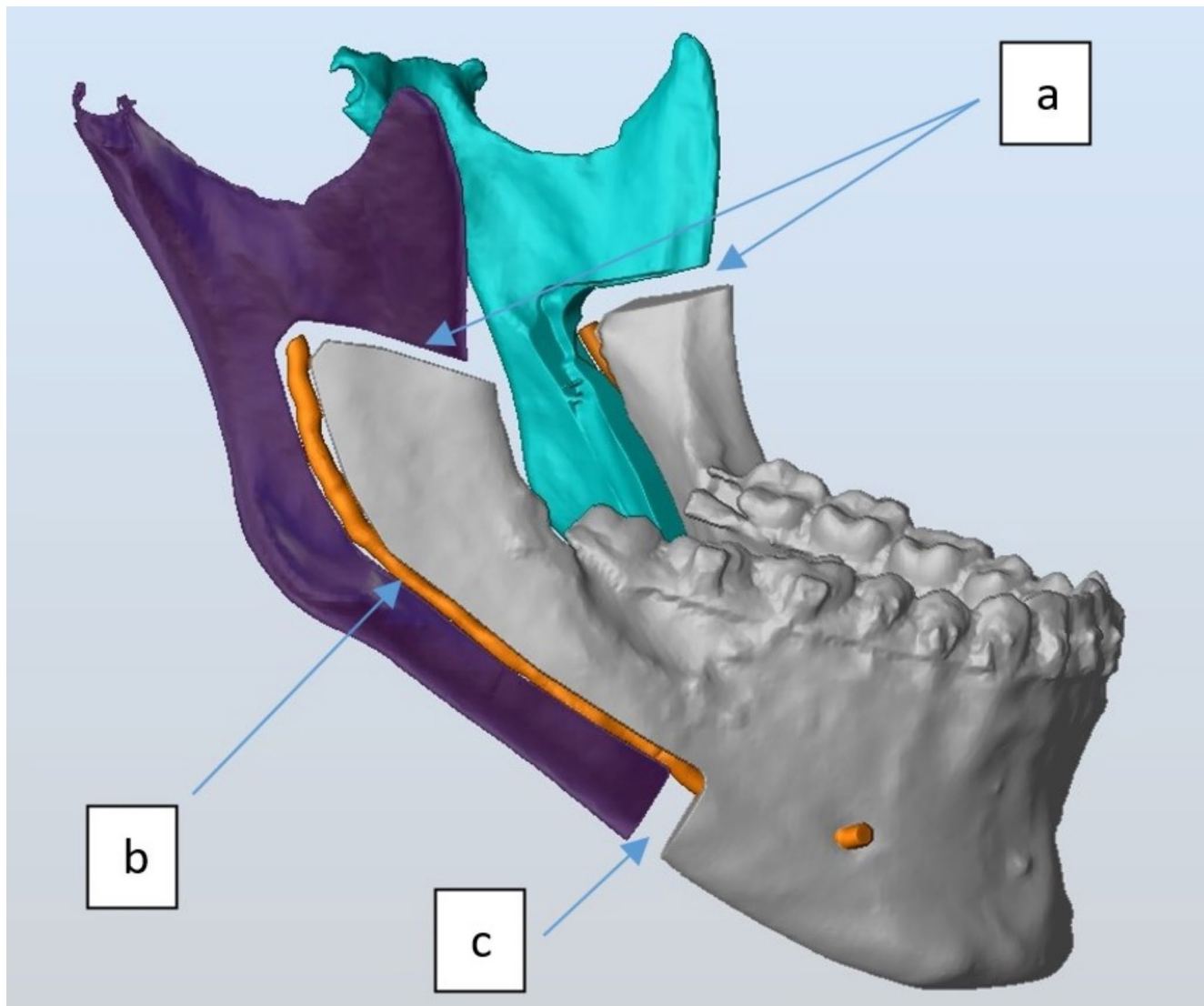


Fig. 2 A snapshot showing the current osteotomy design: **a**; The horizontal Ramal cut extending from the anterior border of the ramus above the level of the lingula and just posterior to it. **b**; A lateral intracanal osteotomy that starts from the most posterior end of the horizontal cut

and then curves down to path through the mandibular canal. **c**; The Two vertical cuts extend from the most anterior end of the intracanal osteotomy to the inferior border of the mandible

Patients and methods

The study was registered on ClinicalTrials.gov under the registry number NCT05397002. It adhered to the Declaration of Helsinki on medical research ethics and received approval from the Institutional Research Ethics Committee of the Faculty of Dentistry, Cairo University (IRB number: 151020). This prospective, single-center case series included 20 patients consecutively recruited from the outpatient clinic of the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Cairo University. Patient recruitment began in October 2020 and continued until April 2022. The intervention phase was conducted from December 2020 to April 2022, with follow-up extending

from December 2020 to April 2023. Data collection was carried out throughout the study duration, concluding in May 2023. Patients were selected according to the following inclusion criteria: (1) Adult patients complaining of skeletal class III malocclusion requiring mono-maxillary or bi-maxillary surgical intervention; (2) CBCT examination revealed anatomical hindrances that interfere with the application of BSSO indicating the application of the currently modified intraoral ILRO osteotomy (thin mandibular rami with minimal or no medullary bone, inferior alveolar nerve proximity to the buccal cortex along the length of the BSSO cuts, lateral bending of the inferior mandibular border at molar angle region, high mandibular foramen, inferiorly seated IAN canal and extensive distal interferences) (Fig. 1)

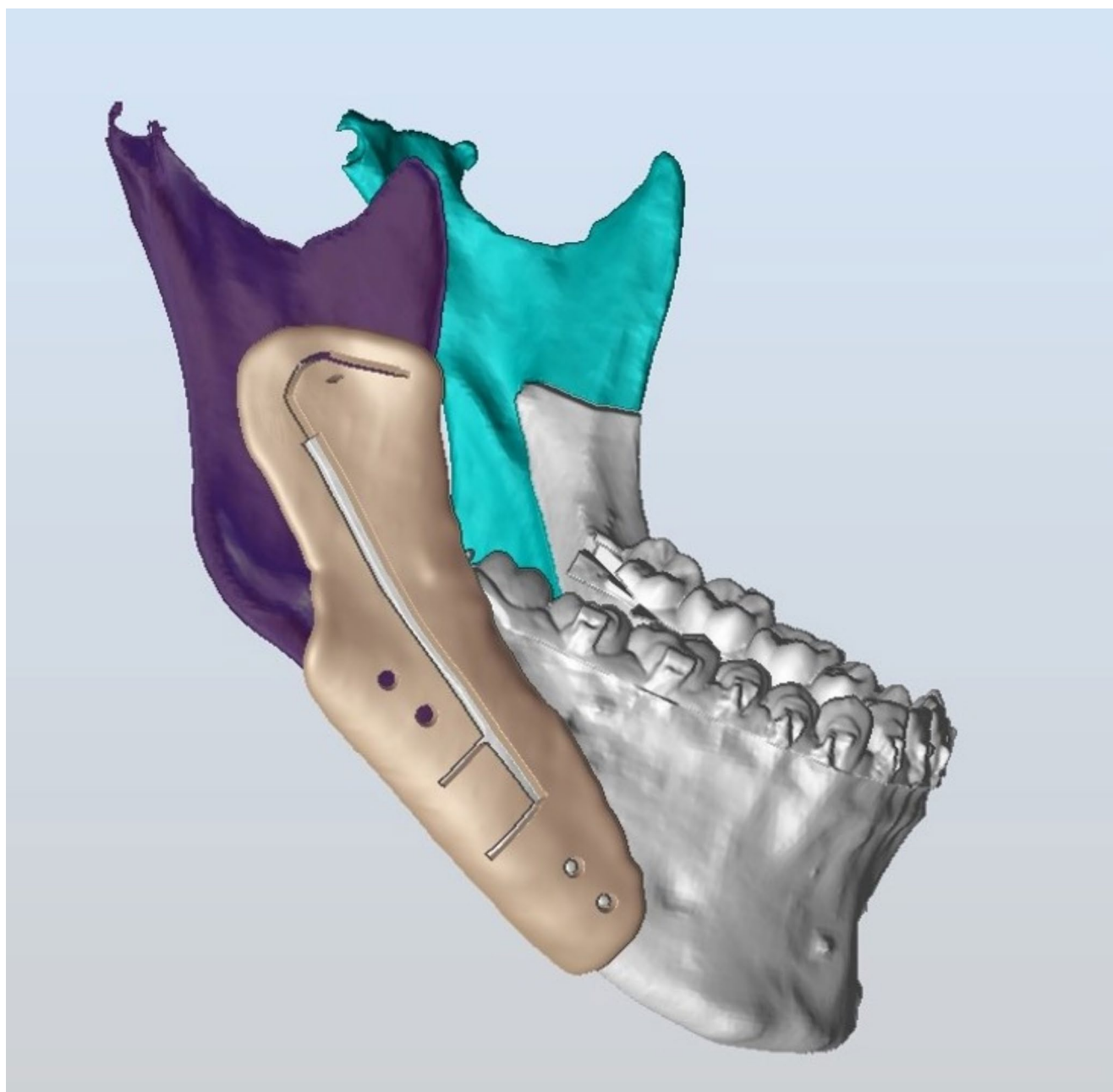


Fig. 3 A snapshot showing the 3D virtual design of the cutting and drilling guide

and (Fig. 2). Patients with previous extensive jaw surgery, mandibular pathological lesions, or temporomandibular joint dysfunction were excluded from the study.

Preoperative preparation and virtual planning

A thorough clinical examination was performed; preoperative photographs and plaster dental cast models were obtained for all enrolled patients. Selected patients were submitted to the orthodontic department for leveling, alignments, and decompensation of dental arches. After

orthodontic preparation upper and lower impressions were obtained to fabricate a stone model and generate a virtual model via optical scanning. Using CBCT machine (Scanora[®] 3D with AutoSwitchTM, Soredex, Helsinki, Finland - Exposure parameters were 85 kVp, 15 Ma, and 6 cm FOV) a full-skull CBCT image was captured in a natural head position with the patient slightly biting and with all the facial muscles at rest. The CBCT was used along with the virtual models to construct the virtual skull model for diagnosis, digital planning, guide designing, and manufacturing.

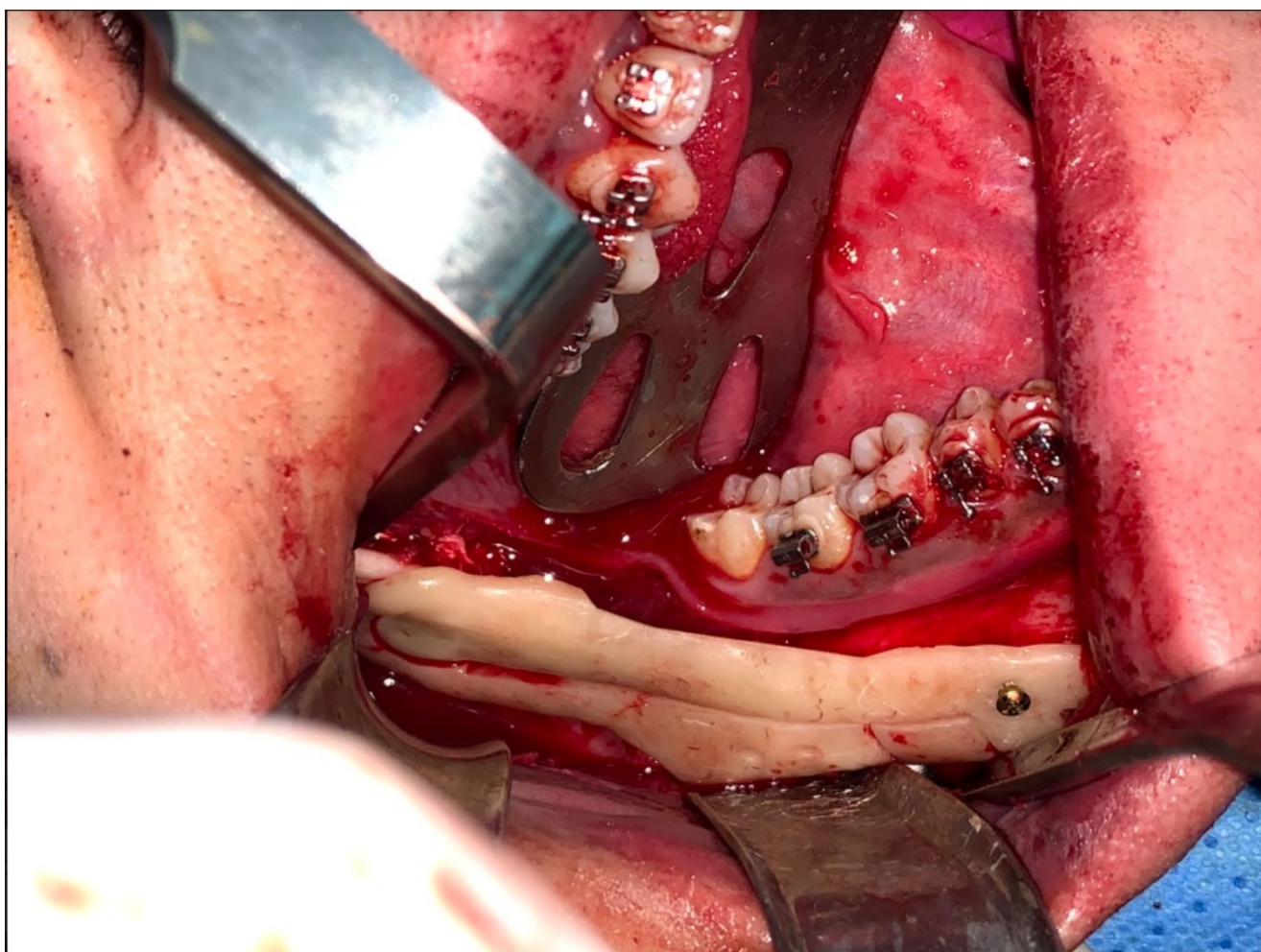


Fig. 4 Intraoperative photograph showing the guide seated in place

DICOM files were imported to the planning software ProPlan CMF software (Materialise, Belgium). Using the software, mandibular bone morphology was 3D analyzed to assure their correspondence with eligibility criteria. IAN was segmented, traced, and marked along the lateral surface of the mandibular canal. Osteotomy lines were planned to consist of Four cuts: (1) A horizontal ramal cut extending from the anterior border of the ramus above the level of the lingula and just posterior to it. (2) A lateral intra-canal osteotomy that starts from the most posterior end of the horizontal cut and then curves down to path through the mandibular canal. (3) Two vertical cuts extend from the most distal end of the intra-canal osteotomy to the inferior border of the mandible. The created bone segment between the two vertical cuts represents the amount of mandibular setback (Fig. 2). A corrected 3D model was fabricated to bend the plates and identify the screw holes. Then the model with the identified screw holes was scanned, and the cutting and drilling guides were fabricated using a PLA resin and a DLP 3D printer [11]. The guide was designed with a slit,

holes, and central trough to landmark the osteotomy lines, screw holes' position, and nerve path respectively (Fig. 3). Post-printing guides processing, and cold sterilization was performed.

Surgical procedures

Based on the preoperative clinical and radiographic assessment and virtual planning enrolled skeletal class III patients were categorized in to patients requiring mono-maxillary or bimaxillary surgical intervention. The surgical procedure was performed under general anesthesia. In Bi-maxillary cases, the maxillary surgery was performed first, segment was mobilized and positioned using a cutting and drilling surgical guide associated with pre-bent plates osteosynthesis, then the mandibular surgery was performed. The mandibular surgery starts with bilateral intraoral mandibular incisions. The surgical guide was placed in position (Fig. 4). Screw holes and osteotomy lines were performed. A reference marking points were performed using a surgical fissure

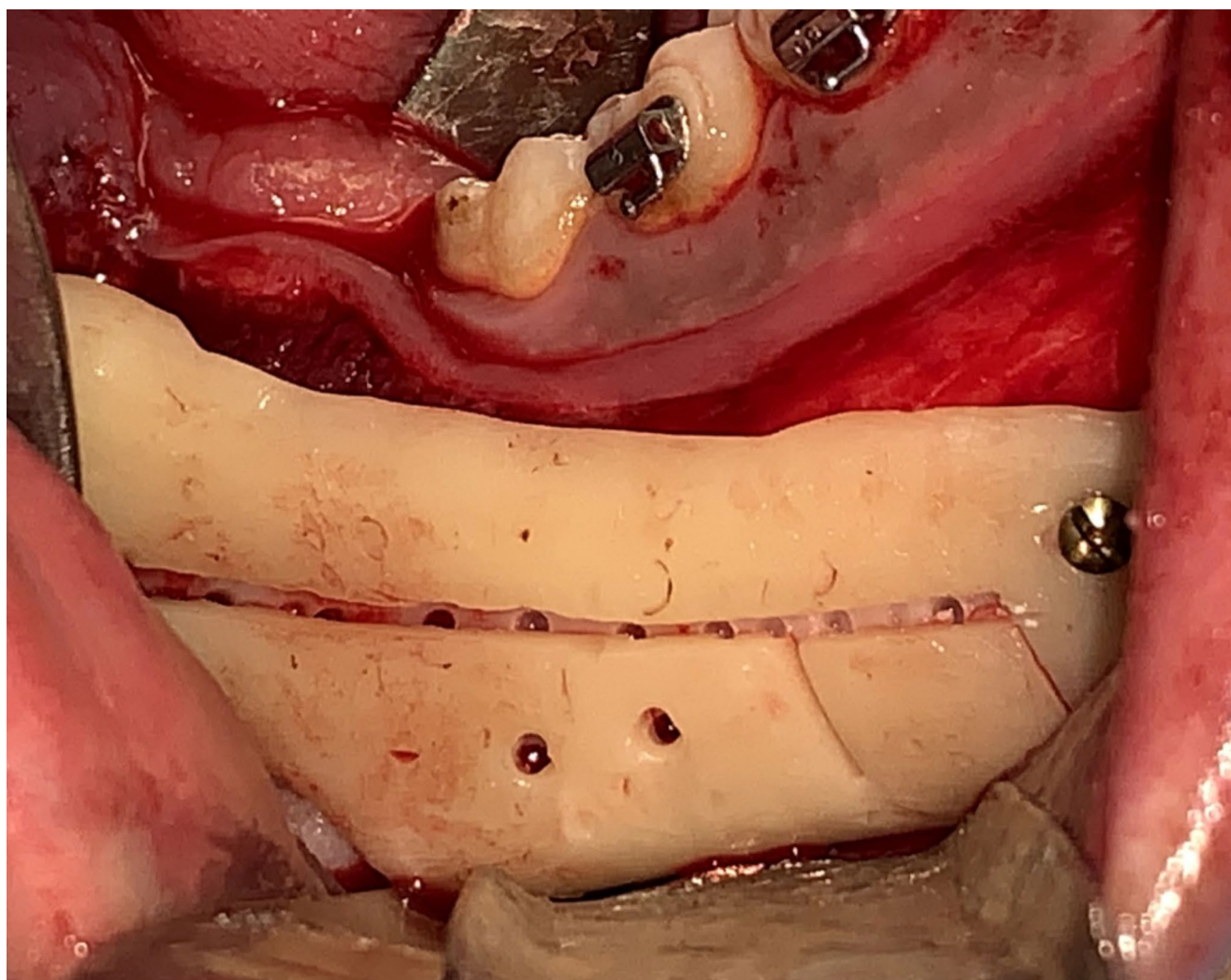


Fig. 5 Intraoperative photograph showing the marking holes for IAN course tracing

bur through the nerve tracing central trough of the surgical guide to mark the nerve pathway (Fig. 5). The device was removed, and the marked pathway was followed using a sinus lifting round stone to uncover the lateral cortical bone overlying the nerve. The nerve was then carefully repositioned in a lateral and upward direction using a nerve hook (Fig. 6). The intracanal osteotomy was completed through the uncovered mandibular canal using a reciprocating saw to connect the upward horizontal ramus cut with the two vertical inferior border cuts. The osteotomy lines were confirmed using spatula chisels then the proximal and distal segments were successfully separated. The distal interferences were removed while the IAN was safely lateralized, and the mandibular segments were repositioned guided with the pre-bent plates and screw holes (Fig. 7).

Neurosensory test procedure

The IAN function was examined preoperatively, one week, two months, six months, and one year postoperatively. A light brush technique and two-point discrimination were used at each follow-up consultation. Anesthesia was evaluated using the pin-prick test. The altered sensation was categorized as either hypoesthesia or as “positive” sensory phenomena such as hyperesthesia, dysesthesia, or paresthesia. The location of the sensory impairment was categorized as the left lower lip, and right lower lip.

Statistical analysis

It was performed using SPSS (Statistical package for the social sciences- IBM® SPSS® Statistics Version 20 for Windows, IBM Corp., Armonk, NY, USA). Quantitative data



Fig. 6 Intraoperative photograph showing the application of the designed osteotomy lines and drill holes: Inferior alveolar nerve lateralization and intracanal osteotomy through the lateral osteotomy, two

vertical osteotomy markings revealed the amount of setback and the drill holes' location for pre-bent plate guidance

were represented as mean \pm standard deviation. Qualitative data were represented as percentage or frequency.

Results

This case series included 20 patients (mean age: 21.6 ± 3.3 years; 13 females, 7 males) with skeletal class III malocclusion requiring mandibular setback surgery. 14 patients (70%) underwent bimaxillary surgery, while 6 patients (30%) underwent mono-maxillary surgery. The mean magnitude of the mandibular setback was 6.05 ± 1.1 mm. The average duration of the mandibular procedure, from the initial incision to suturing, was 2.26 ± 0.21 h. Inferior Alveolar Nerve (IAN) exposure was successfully achieved bilaterally within 11 ± 3.2 min per side (Table 1).

Surgical outcomes

All 40 mandibular osteotomies and setback procedures were successfully completed without any instances of bad splits. Complete nerve exposure and precise osteotomies were achieved and no reports of permanent anesthesia in the lower lip or chin, and no intraoperative complications related to nerve handling.

Neurosensory outcomes

Postoperative nerve function recovery was assessed at four intervals: one week, two months, six months, and one year. At one week, all patients (100%) experienced neurosensory disturbances (NSD), including hyperesthesia and hypoesthesia. At two months, NSD decreased to 18 patients (90%). At six months, NSD decreased to 7 patients (35%). At one year, NSD decreased to 1 patient (5%).

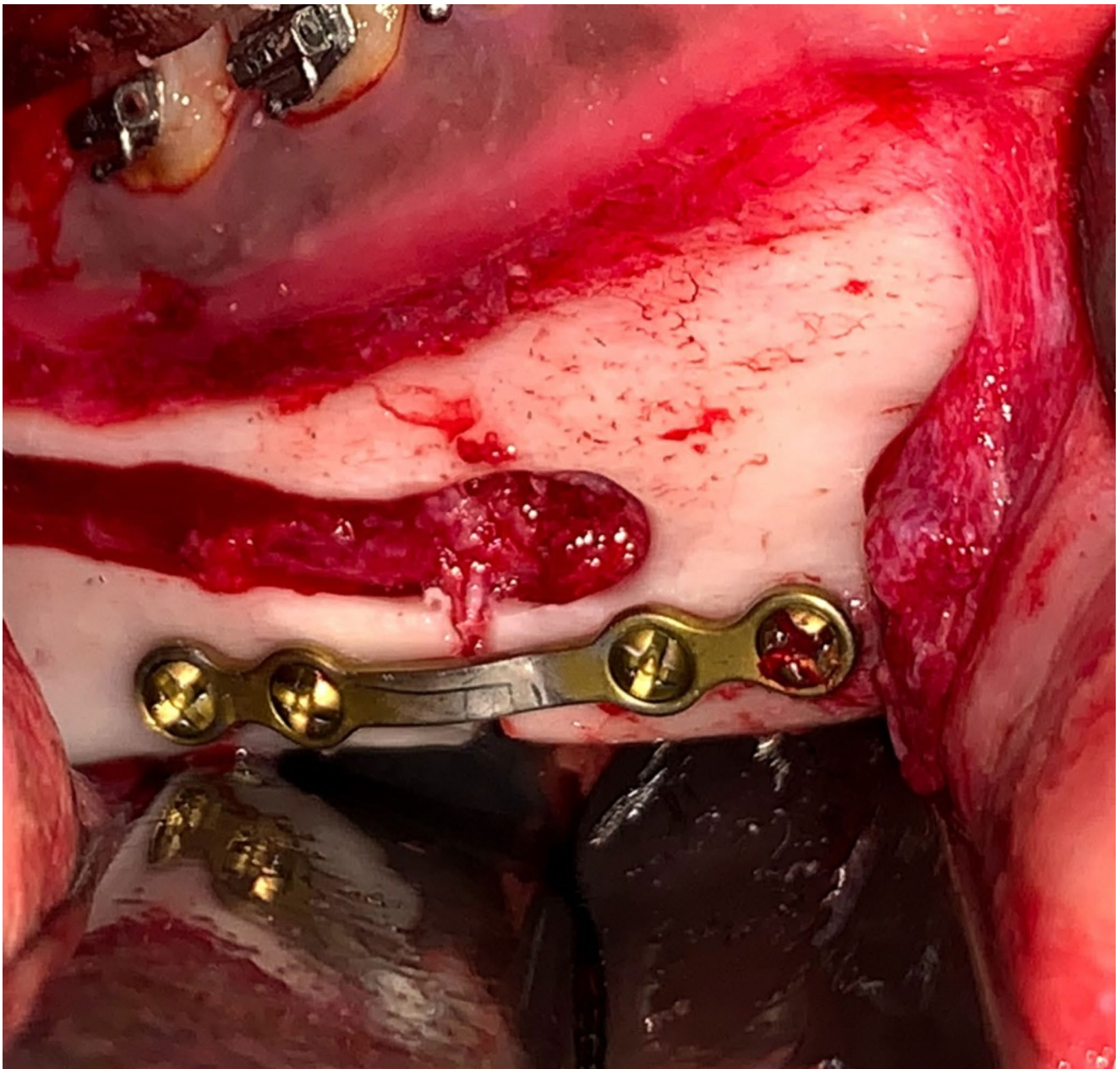


Fig. 7 Intraoperative photograph showing: Mandibular setback and pre-bent plate osteosynthesis

Hyperesthesia of the Inferior Alveolar Nerve (IAN) showed a progressive decline over the follow-up period. On the right side, hyperesthesia was reported in 15 patients (75%) at one week postoperatively and resolving entirely by one year. On the left side, hyperesthesia was reported in 14 patients (70%) at one week, declining to only one patient (5%) by one year. Similarly, hypoesthesia exhibited a similar recovery pattern. Right IAN hypoesthesia was observed in 5 patients (25%) at one week and resolving completely by six months. Left IAN hypoesthesia was reported in 6 patients (30%) at one week and resolving entirely by one year. (Table 2), (Fig. 8).

Discussion

Mandibular anatomical variations as rolled-out inferior mandibular border, thin rami with cortically adherent IAN and inferiorly seated IAN canal are considered a critical diagnostic finding which obligates the orthognathic surgeon to select a mandibular osteotomy over another [1]. Conventional mandibular osteotomies introduced in the literature, such as BSSO, ILRO, and C-osteotomy, are utilized for mandibular setback surgery but have notable limitations which direct the authors to find an alternative solution for management of such limitations aiming to reduce the incidence of

Table 1 Demographic and Surgical characteristics of patients undergoing mandibular setback surgery

Case no.	Age	Gender	Type of the operation	Magnitude of mandibular setback (mm)	Time for mandibular operation (hrs.)
1	19	Male	Bimaxillary	6	2.4
2	25	Female	Monomaxillary	5	2.2
3	21	Female	Bimaxillary	7	2
4	18	Female	Bimaxillary	5	2
5	20	Female	Bimaxillary	8	2.4
6	23	Male	Bimaxillary	6	2.5
7	22	Female	Monomaxillary	4	2
8	19	Male	Bimaxillary	7	2.4
9	18	Male	Monomaxillary	5	2
10	21	Female	Bimaxillary	6	2.5
11	25	Female	Bimaxillary	7	2.4
12	30	Male	Monomaxillary	8	2
13	27	Female	Bimaxillary	5	2.3
14	26	Female	Bimaxillary	6	2.4
15	19	Female	Monomaxillary	7	1.9
16	20	Male	Bimaxillary	5	2.3
17	19	Male	Monomaxillary	5	2.1
18	19	Female	Bimaxillary	6	2.4
19	20	Female	Bimaxillary	7	2.5
20	21	Female	Bimaxillary	6	2.4

neurosensory disorders and bad splits along with adequate mandibular setback without distal interferences [2–10].

Based on the literature, BSSO is associated with a variable incidence of bad splits, ranging from 0.2 to 14.6%, influenced by anatomical factors such as thin cortices and impacted molars [12, 13]. Moreover, it induces long-term neurosensory disturbances (NSD) which persist in 10–15% of patients at one year [14]. ILRO reduces the risk of nerve injury compared to BSSO but distal interferences limit its application in setback procedures [4]. To address these challenges, Senior et al. introduced a C-osteotomy modification with an intraoral sagittal split below the IAN canal which enhances bone contact, but it remains prone to bad

splits and nerve injury in patients with thin buccal cortices (<7–10 mm), inferiorly positioned IAN or rolled out mandibular border [10]. This directed the authors to designate this new modification for the intraoral ILRO to incorporate nerve lateralization with intra-canal osteotomy.

The incorporation of nerve lateralization ensured safe application of the intra-canal osteotomy and removal of distal interferences with non-blind nerve protection, while the intra-canal osteotomy enhanced the structural integrity of the anterior arm of the proximal segment with 0% incidence of bad splits and adequate rigid intraoral fixation through placement of 4-holes titanium mini-plate.

The fixation method used in this study differs from conventional approaches owing to the novel osteotomy design. Typically, two miniplates with monocortical screws are placed in mandibular body fractures or osteotomies, one in the traction zone and another in the compression zone to enhance stability [15]. However, in the current modified intraoral inverted-L ramus osteotomy, the anterior vertical osteotomy extends from the inferior border and terminates at the level of the inferior alveolar canal, meaning no osteotomy is present at the usual location for the superior plate typically applied in mandibular body osteotomies or fractures. Additionally, the current osteotomy follows a bicortical design, distinct from the traditional BSSO, which may result in different load transmission characteristics [16]. Given these factors, the use of a single miniplate for fixation was deemed appropriate within the scope of this study.

The nerve lateralization of the current osteotomy prompted an evaluation of its NSD risks that relied on subjective assessments such as Shintani Y. et al. who emphasized that subjective evaluations reflect the patient's experience and provide a more representative outcome compared to objective assessments of neural damage [17]. Abayev et al. reported transient NSD in 99.47% of cases within 1 to 6 months, with permanent NSD in only 0.53% of procedures. Similarly, this study observed transient NSD in 90% of cases, with progressive recovery to 5% at one year [18]. These findings surpass those reported for both BSSO and ILRO, where NSD recovery is slower and incomplete in a significant number of cases [19]. Roychoudhury et al. reported 13.3% NSD for BSSO using subjective assessments after one year follow-up [14]. Moreover, Kobayashi et al. found that NSD rates over one year after ILRO were consistently lower than those for BSSO, with 9.5% vs. 15.2% of cases respectively [20]. In comparison, the current study's osteotomy achieved only 5% NSD at one year.

Despite the added steps of nerve lateralization and intra-canal osteotomy, the mean surgical duration (2.26 ± 0.21 h) was comparable to traditional methods. The quick nerve exposure time (11 ± 3.2 min per side) and absence of intra-operative complications, such as nerve transection or major

Table 2 Neurosensory outcomes of the Inferior Alveolar nerve (IAN) at different postoperative intervals

Postoperative follow-up intervals	One week (n=20) No. (%)	Two months (n=20) No. (%)	Six months (n=20) No. (%)	One year (n=20) No. (%)
Total number of patients reported NSD	20 (100)	18 (90)	7 (35)	1 (5)
Right side Hyperesthesia	15 (75)	7 (35)	2 (10)	0 (0)
Left side hyperesthesia	14 (70)	11 (55)	6 (30)	1 (5)
Right side hypoesthesia	5 (25)	2 (10)	0 (0)	0 (0)
Left side Hypoesthesia	6 (30)	3 (15)	1 (5)	0 (0)

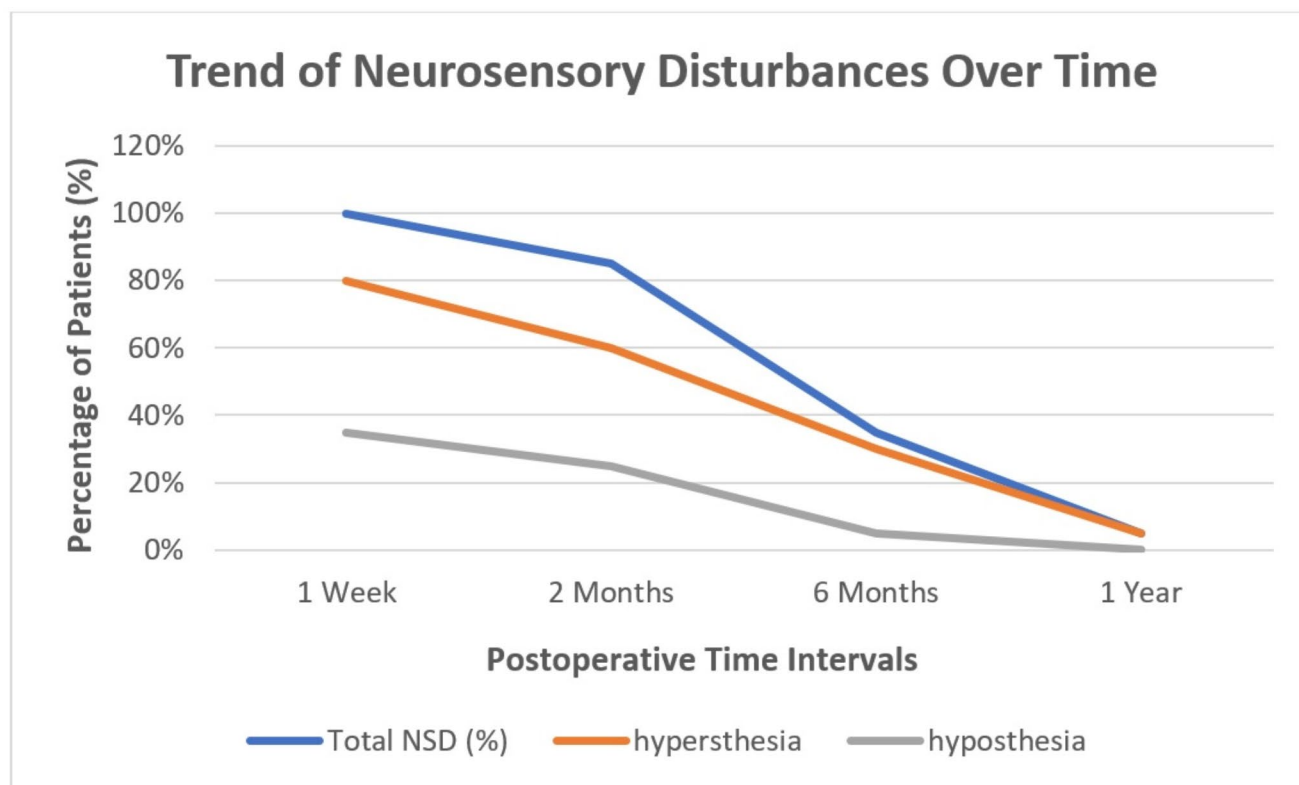


Fig. 8 A line graph demonstrating the neurosensory results over time

bleeding, highlight the technique's feasibility [21]. Additionally, the use of patient-specific guides through utilizing CBCT imaging and digital planning ensured precise segment separation without unfavorable splits. This is consistent with several studies, that reported improved outcomes with digital integration in orthognathic surgery [11, 22].

The combination of preoperative planning and intraoperative guidance minimizes human error and ensures better preservation of anatomical structures [23]. While the study demonstrates promising outcomes, its limitations include a single-center design. Future multicenter studies are necessary to validate these findings. Additionally, comparing this technique directly with other modifications, such as the C-osteotomy or variations of BSSO, would provide more robust evidence of its advantages. Future studies also should compare different fixation techniques to validate optimal fixation methods in relation to this novel osteotomy design and assess its long-term stability.

Conclusion

The introduced osteotomy overcomes the limitations of the traditional mandibular osteotomies in dealing with mandibular complex anatomy with adequate IAN protection and split segments integrity during mandibular setback surgery.

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Author contributions All authors (MO, SA, YS and NS) contributed to conception and study designing, Acquisition of data, analysis and interpretation of the collected data. The manuscript was written and revised by all authors (MO, SA, YS and NS). "All authors have read and approved the manuscript".

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Data availability No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate This study is performed in line with the principles of the Declaration of Helsinki on medical research and take a post-conduction clarification letter from the research ethics committee (IRB number: 151020). Written informed consent was obtained from all individual participants included in the study.

Consent for publication The authors affirm that human research participants provided informed consent for the publication of the images.

Competing interests The authors declare no competing interests.

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