Journal of Medicine and Dentistry

International Peer-Reviewed Journal of Medical and Dental Sciences

www.jmdnt.com / ISSN 3042 8106

Volume 2, Issue 1, 2026 Research & Science

Editorial

Consolidating Interdisciplinary Scholarship –

The Second Issue of JMDNT

It is with great satisfaction that we present the second issue of the *Journal of Medicine and Dentistry (JMDNT)*. Building upon the foundation established by our inaugural issue, the journal continues to develop as a dedicated platform for rigorous interdisciplinary scholarship at the interface of medicine and dentistry. The sustained interest from the academic and clinical community underscores the relevance and necessity of such an integrative forum.

We wish to express our sincere appreciation for the substantial number of high-quality manuscript submissions received following the publication of the first issue. The breadth and scientific depth of these contributions reflect an increasing recognition of the complex interrelations between oral and systemic health, as well as the demand for a publication venue that facilitates cross-disciplinary dialogue. This strong response represents a significant step in establishing JMDNT within the international scientific landscape.

The present issue features a carefully curated selection of original research, clinical investigations, and scholarly analyses that collectively exemplify the journal's scope and standards. All submissions have undergone a stringent peer-review process conducted by experts in the respective fields to ensure methodological rigor, scientific validity, and clinical relevance. Upholding these standards remains central to our editorial policy and long-term vision.

We extend our gratitude to the authors for their trust and scholarly contributions, to the reviewers for their critical and constructive assessments, and to the editorial board for their continued commitment to academic excellence. Their combined efforts are instrumental in maintaining the quality and integrity of the journal.

Looking ahead, JMDNT will continue to promote research that advances understanding of the biological, clinical, and technological dimensions linking oral and general health. We particularly encourage Submission that address mechanistic insights, innovative therapeutic strategies, and translational applications that bridge disciplinary boundaries. Strengthening international collaboration and fostering scientific exchange remain key priorities.

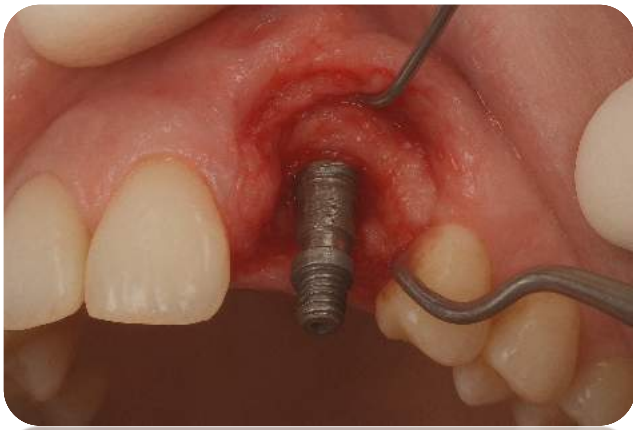
On behalf of the editorial board, we thank our contributors and readership for their ongoing engagement and support. We remain committed to further developing JMDNT as a reputable and impactful platform for interdisciplinary research and scholarly communication.

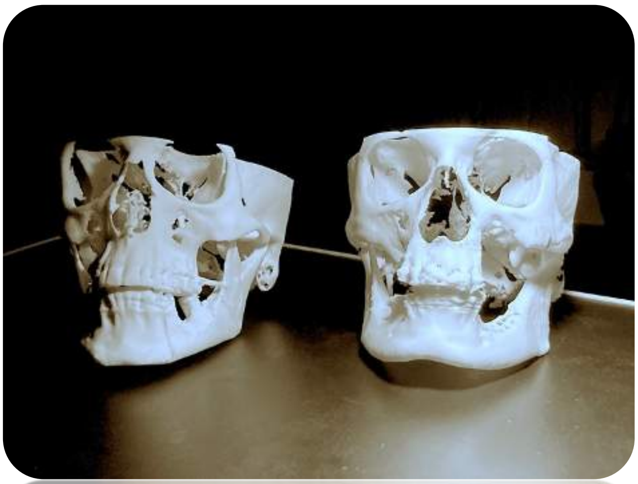
It is with great anticipation that we present this second issue and look forward to the continued growth and scientific contribution of the *Journal of Medicine and Dentistry*.

Ayhan Yildirim
Editor-in-Chief
Journal of Medicine and Dentistry

Volume 2, Issue 1, 2026 Research & Science

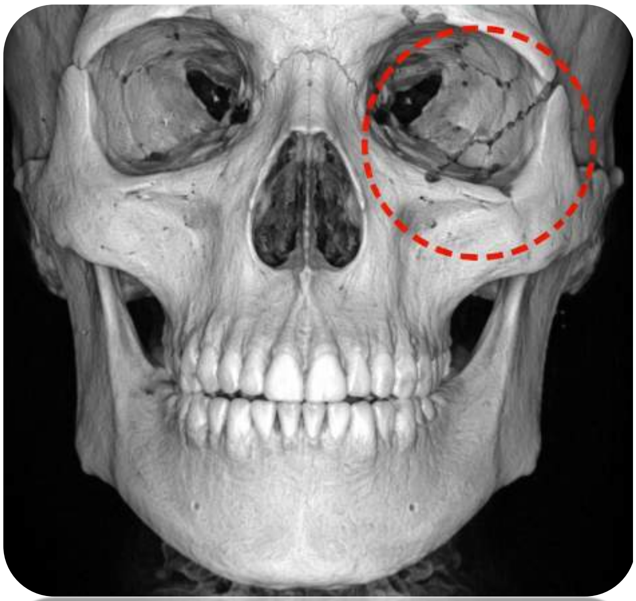
Table of Contents

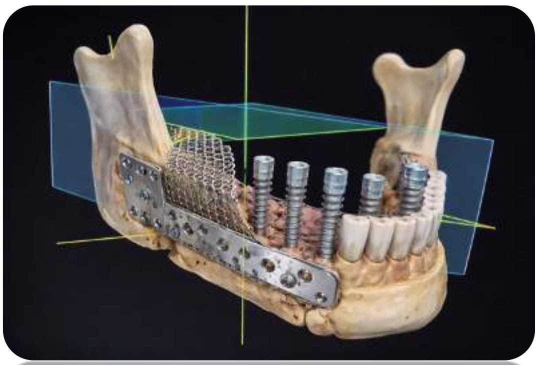




Digital precision meets clinical decision-making: This study shows that in PSI-guided bimaxillary orthognathic surgery, both mandible-first and maxilla-first sequences achieve equally high accuracy. Virtual surgical planning ensures predictable, patient-specific outcomes, highlighting that technology can transcend traditional sequencing debates.

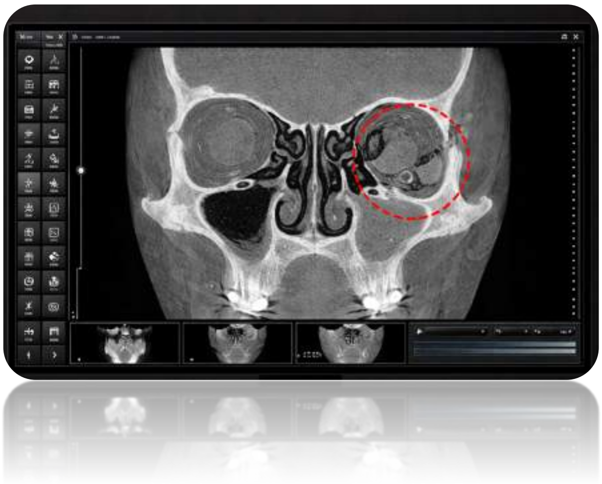
This retrospective study evaluated a deep learning-based AI model for detecting maxillofacial fractures on Digital Volume Tomography (DVT) in 150 patients. The AI achieved near-perfect accuracy (98%) and outperformed junior clinicians, while matching the performance of senior experts. These findings highlight AI's potential to accelerate diagnosis, reduce missed fractures, and improve emergency trauma care workflows.

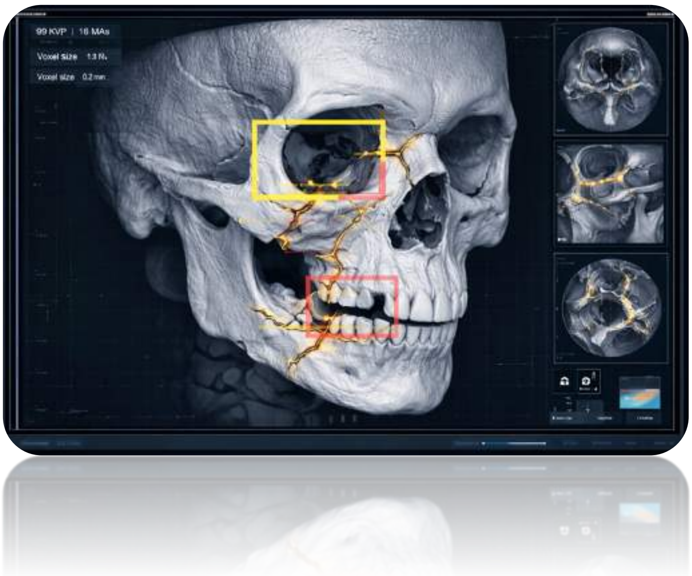




This systematic review evaluates mandibular reconstruction with fibula flaps and dental implants using virtual surgical planning. It compares three techniques—double-barrel flap, CAD/CAM titanium mesh with iliac crest graft, and fibula flap with intraoperative dynamic navigation.

Mithilfe von Formatvorlagen können Sie Ihre Word-Dokumente im Handumdrehen und ganz einfach formatieren. Für diesen Text beispielsweise wird die Formatvorlage "Standardeinzug" verwendet.



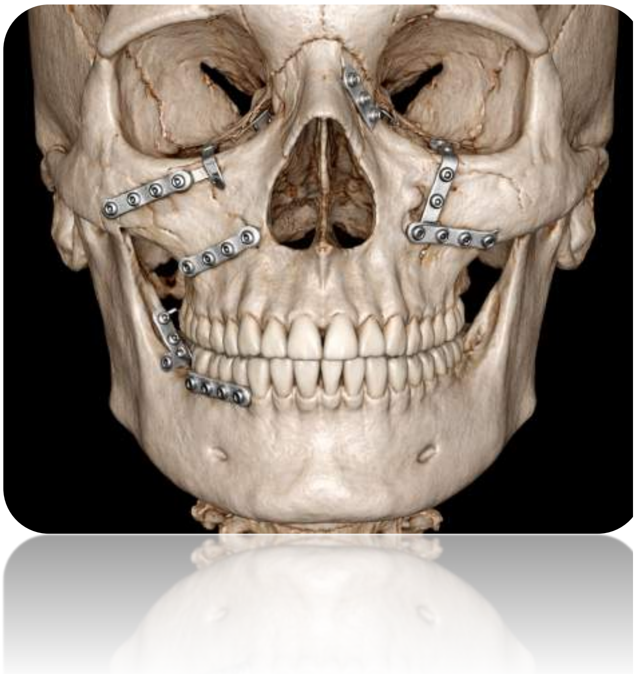


This multicenter study externally validated an artificial intelligence (AI) system for detecting maxillofacial fractures on cone-beam CT (DVT) scans. The AI demonstrated high sensitivity, specificity, and overall accuracy across both a tertiary trauma clinic in Zurich and an independent maxillofacial practice in Munich. Performance was comparable to senior clinicians, significantly faster than human interpretation, and robust across different clinical settings.

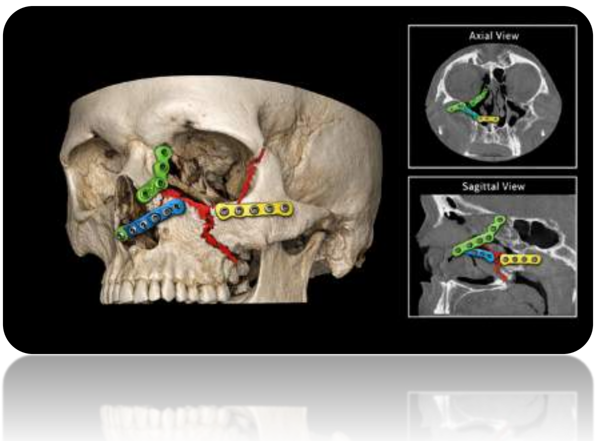
This study developed and validated an AI-assisted, CBCT-based clinical decision support algorithm for emergency maxillofacial trauma that translates automated fracture detection into standardized management recommendations. The algorithm showed high concordance with expert consensus, reduced decision variability and time, and safely supported clinical decision-making across different institutional settings.

Outcome	Accuracy (%)	Sensitivity (%)	Specificity (%)	κ
Enophthalmus ≥2 mm	92.5	89.7	94.3	0.83
Malocclusion	89.2	86.4	91.0	0.81
Reoperation	87.5	83.9	89.8	0.80
Overall complications	90.0	86.7	92.1	0.83

The study investigates the clinical implementation of AI-assisted decision support in midfacial trauma surgery through a multicenter validation. It aims to evaluate the accuracy, efficiency, and clinical relevance of AI in surgical planning and execution.



This study evaluates the feasibility of using AI-assisted tools for surgical planning in midfacial fracture cases. It also validates the AI-generated plans through expert assessment to determine accuracy, clinical relevance, and practical usability.



This study investigates whether AI-assisted surgical planning for midfacial fractures is feasible in clinical practice. It then validates the AI-generated plans through expert review to assess accuracy, reliability, and potential clinical usefulness.

This prospective study implements an AI-assisted, CBCT-based clinical decision support system in emergency maxillofacial trauma care. It evaluates feasibility and clinical impact on diagnostic accuracy, treatment planning, and workflow efficiency in real-world emergency settings.

This study provides a translational analysis of artificial intelligence in maxillofacial trauma, demonstrating high accuracy from fracture detection to outcome prediction. AI integration improves clinical decision-making, efficiency, and patient-specific treatment in a multicenter setting.

Journal of Medicine and Dentistry (2026)

Available online at www.jmdnt.com
ScienceTrends
Journal of Medicine and Dentistry
journal homepage: www.jmdnt.com

JOURNAL OF MEDICINE AND DENTISTRY
International Peer-Reviewed Journal of Medical and Dental Sciences

Randomized Controlled Clinical Trial Study

Occlusal Splint versus Botulinum Toxin Type A in the Management of Jaw Muscle Pain

DOI: 10.64951/jmdnt.2025.2.1

Yildirim Ayhan [a*], Hertach René [b], Yildirim Vedat [b]

[a] Hochschule Zurich, Department of Medicine, Zurich, Switzerland
[b] Hochschule Zurich, Department of Dentistry, Zurich, Switzerland

ARTICLE INFO

Article history:
Received 19 May 2025, Revised 23 September 2025, Accepted 20 October 2025, Available online 06 November 2025, Version of Record 06 November 2025.

ABSTRACT

Objectives: This equivalence randomized controlled trial (RCT) evaluated and compared the effectiveness of an occlusal splint (OS) versus Botulinum toxin type A (BTX-A) injections in reducing jaw-muscle pain in adult patients with probable sleep bruxism.

Methods: A total of 358 adults (≥ 18 years) with clinically diagnosed jaw-muscle pain and probable sleep bruxism were randomized (OS: n = 176; BTX-A: n = 182). The primary outcome measure was pain reduction using the *Graded Chronic Pain Scale* (GCPS v2.0). Secondary outcomes included mandibular range of motion (pain-free opening, unassisted and assisted maximal opening, protrusion, laterotrusion), pain distribution among masticatory muscles, *Jaw*

Functional Limitation Scale–20 (JFLS-20), *Oral Behaviors Checklist* (OBC), and *Oral Health Impact Profile-14* (OHIP-14). Outcome assessors were blinded. Multilevel mixed-effects regression models were applied.

Results: Both interventions induced significant reductions in GCPS scores at 3, 6 and 12 months ($p < 0.001$); no significant differences were found between groups ($p = 0.632$). The OS arm displayed modestly superior improvements in functional parameters such as maximum mouth opening and JFLS-20 scores. In the BTX-A arm, 72.5 % ($n = 132$) of participants reported mild transient chewing discomfort in the first week.

Conclusion: Both OS and BTX-A effectively reduce jaw-muscle pain, improve oral health-related quality of life (OHRQoL), and enhance masticatory-functional outcomes in probable sleep bruxism patients. The occlusal splint demonstrated slight advantages in some functional outcomes and fewer initial discomforts.

Clinical significance: In clinical practice, occlusal splints, being non-invasive and reversible, may serve as first-line therapy for bruxism-associated jaw-muscle pain, while BTX-A is appropriate for cases with severe muscular hyperactivity or poor compliance with splint use.

Keywords: Facial pain; Pain management; Chronic pain; Occlusal splint; Botulinum toxin; Bruxism; Randomized controlled trial.

1. INTRODUCTION

Temporomandibular disorders (TMDs), affecting the temporomandibular joint and masticatory muscles, constitute the second most prevalent musculoskeletal condition causing pain and disability, surpassed only by chronic low back pain [1]. European prevalence estimates for TMD symptoms range from 29 % to 34 % and the annual socio-economic burden may exceed €30 billion [2,3]. Up to 60 % of individuals report at least some TMD-related symptoms during their lifetime, with a higher incidence in females.

Multiple therapeutic strategies have been proposed for jaw-muscle pain, and among these, occlusal splints (OS) and Botulinum toxin type A (BTX-A) have been the most widely studied [4,5]. OS are extensively used in the management of bruxism and orofacial pain [6]. Historically, TMD was largely attributed to occlusal disharmony or skeletal misalignment, but modern evidence supports a multifactorial etiology involving physical, psychological, and social factors [7–9].

Mechanistically, occlusal splints are thought to alter occlusion and condylar position, promote neuromuscular relaxation, protect teeth and joints, and reduce hyperactivity of jaw-closing muscles [10–14]. Multiple systematic reviews (e.g., one including 11 RCTs with positive effects on chronic pain and mandibular movement) support the use of OS in TMD patients [11]. A meta-analysis of 33 RCTs found that in the short term, stabilization splints improved pain and mouth opening (SMD −0.33; $p = 0.02$) among TMD patients of muscular origin; however, long-term differences became less distinct [12].

On the other hand, BTX-A has been increasingly applied for orofacial pain due to its analgesic and muscle-relaxant properties [15,16]. Its anti-hyperalgesic actions include inhibition of neurotransmitter release (e.g., glutamate, CGRP, substance P), modulation of GABAergic and opioidergic pathways, attenuation of microglial activation, and modulation of ion channels (TRPV1, calcium, sodium) [17–23]. In bruxism contexts, RCTs and meta-analyses demonstrate that BTX-A injections into the masseter reduce biting force and pain severity, with effects peaking at 5–8 weeks and lasting up to 24 weeks [13,14,24]. A meta-analysis including 10 studies reported statistically significant reductions in bite force and pain in BTX injection groups versus oral splints or placebo ($P < 0.001$ in many comparisons) [2].

Given the widespread use of both interventions yet limited high-quality head-to-head comparison data, this study aimed to conduct a large-scale equivalence RCT to compare OS versus BTX-A in adult patients with probable sleep bruxism and jaw-muscle pain.

Figure 1: *Prepared a plaster model for the EVA (ethylene-vinyl acetate) sheet*

Figure 2: *Bonding of the plaster model and the EVA (ethylene-vinyl acetate) sheet*

2. MATERIALS AND METHODS

2.1 Study Design

This was a prospective, randomized, controlled equivalence trial with parallel groups (1:1 allocation) carried out at Seeklinik Zürich and Hochschule Zürich (Switzerland). The study protocol received ethics approval from the local committee (Protocol No. 1.487.252, CAAE: 81167801.1.2200.5242) and participants provided written informed consent.

2.2 Participants

The study was conducted from January 2019 to April 2025. Inclusion criteria comprised adults aged ≥ 18 years presenting with jaw-muscle pain and probable sleep bruxism, defined according to Lobbezoo et al. [34] as clinical signs (e.g., tooth wear, hypertrophic masseter, muscle pain) with or without self-reported sleep grinding. Exclusion criteria included confirmed TMJ arthropathy, orthodontic or intraoral appliances, recent use of muscle relaxants or anti-inflammatories (past 3 months), regular use of antidepressants or anxiolytics, pregnancy or breastfeeding, and known allergy to BTX-A.

2.3 Interventions

Occlusal Splint (OS) Group: Maxillary or mandibular impressions, according to patient preference, were taken using normal-setting alginate, and custom rigid, full-coverage splints were fabricated from EVA (ethylene-vinyl acetate). The splints were adjusted in centric relation with even occlusal contacts (at least three contact points per side: two posterior, one anterior). After polishing and two adjustment visits, patients wore the splint during the day or at night for six hours daily over a period of twelve months.

Botulinum Toxin Type A (BTX-A) Group: A single session injection of BTX-A (Botox®, Allergan, Switzerland) was administered: 50 units total per patient (6 points per side, 2 U per injection point) into the base of the bilateral masseter muscles with a 0.5 mL insulin syringe (0.8 mm needle). Post-injection, patients were instructed to avoid massaging the area and refrain from intense mastication for 24 hours.

2.5 Covariates

Baseline assessment included socio-demographics (age, sex, ethnicity, income, education, marital status) and psychosocial factors: PHQ-9 (depressive symptoms), GAD-7 (anxiety), and PHQ-15 (psychosomatic symptoms) [33].

2.6 Sample Size

Sample size estimation (based on prior pain-reduction studies [35–37]) indicated 49 participants per group were required for 80 % power to detect a 20 % pain reduction at $\alpha = 0.05$. Accounting for ~20 % attrition, target enrollment was set to ~400 participants.

2.7 Randomization and Blinding

Randomization was performed by computer using blocks of 4 via Random Allocation 2.0. Allocation was concealed via sequentially numbered opaque envelopes by a staff member not involved in assessments. Patients and clinicians were not blinded; the outcome assessor remained blinded to treatment assignment.

2.8 Follow-Up

Data collection occurred at: baseline (T0), 3 months (T1), 6 months (T2), and 12 months (T3). Telephone reminders were used to maximize retention.

2.9 Statistical Analysis

Analyses used Stata 17.0. Descriptive statistics summarized baseline characteristics. Between-group comparisons used Chi-square tests (categorical) and t-tests or Mann-Whitney U (continuous). Primary analysis employed multilevel mixed-effects regression for repeated measures (adjusted for baseline covariates) to estimate odds ratios (OR), incidence rate ratios (IRR) and 95 % CI. Significance was set at $p < 0.05$.


Figure 3: Plaster model and EVA (ethylene-vinyl acetate)


Figure 4: Occlusal splint in its raw/unfinished state

3. RESULTS

3.1 Participant Flow

Between January 2019 and April 2025, 400 patients were screened; 42 were excluded or lost to follow-up. Consequently, 358 participants were randomized (OS: n = 176; BTX-A: n = 182). Follow-up data available at 3, 6 and 12 months for the majority of subjects (Figure 1).

3.2 Baseline Characteristics

Mean age across groups was around 32 years; the majority were female, white, single, and had undergraduate education. There were no statistically significant differences between groups for baseline variables (all $p > 0.05$).

3.3 Safety and Adverse Events

No serious adverse events were reported. In the BTX-A group, 132 participants (72.5 %) experienced mild chewing discomfort in the first week; this resolved spontaneously. In the OS group, no device-related side effects were reported.

3.4 Primary Outcome (GCPS)

Both groups achieved significant reductions in GCPS scores at each follow-up (3, 6, 12 mths). No significant between-group difference was found ($p = 0.632$) (Table 2).

3.5 Functional and Secondary Outcomes

- On the JFLS-20, the OS group demonstrated a greater odds of higher improvement compared to BTX-A (OR = 0.29; 95% CI [0.11–0.82]).
- Mandibular mobility: BTX-A showed statistically inferior results on pain-free opening ($p = 0.045$), unassisted maximum opening ($p = 0.024$), assisted maximum opening ($p = 0.041$) and protrusion ($p = 0.016$). No differences noted for laterotrusion movements.

- OBC scores improved markedly in both groups with no difference between interventions (p = 0.802).
- OHIP-14 scores improved similarly in both groups (p = 0.981), indicating enhanced OHRQoL

Figure 5: Occlusal splint on the dental cast, fully fabricated/finished

Figure 6: Finalized occlusal splint ready for delivery

4. DISCUSSION

This trial contributes robust comparative evidence showing that both occlusal splint therapy and BTX-A injections are effective for jaw-muscle pain management in probable sleep bruxism. While pain-reduction outcomes were comparable, the occlusal splint offered better functional improvement and fewer early discomforts.

The findings align with earlier literature: systematic reviews show splint therapy improves mandibular movement and pain in TMD [11]; network meta-analysis confirms short-term benefit (but uncertain long-term superiority) [12,15]. On the BTX-A side, meta-analyses demonstrate significant reductions in bite force and pain, peaking within 4–8 weeks and lasting up to 24 weeks [2,24,14,13]. The evidence supports BTX-A as a beneficial—but temporally limited—intervention.

The modest functional advantage of OS may relate to its mechanical and neuromuscular stabilising effect, which persists as long as appliance use continues [10–14]. BTX-A's efficacy diminishes as neuromuscular compensation occurs, and repeated injections may be needed [12,24,25]. In clinical practice these factors favour OS as first-line choice, reserving BTX-A for selected refractory cases.

4.1 Strengths & Limitations

Strengths include the large sample size, 12-month follow-up, randomized design, and blinded outcome assessment. Limitations include absence of a placebo control arm, potential variability in patient adherence to splint use, and single-centre design limiting generalisability.

4.2 Future Directions

Longitudinal studies beyond 12 months, objective muscle-activity assessments (e.g., EMG), and investigations into combined OS + BTX-A protocols are warranted. Further cost-effectiveness analyses may inform guideline development.

---

5. CONCLUSION

In this RCT, both occlusal splint therapy and botulinum toxin-A injections significantly reduced jaw-muscle pain, improved mandibular function and enhanced OHRQoL in adults with probable sleep bruxism. The occlusal splint demonstrated slightly greater functional benefit and fewer early side effects, supporting its position as the treatment of first choice. BTX-A remains a viable alternative for patients who do not respond to or cannot comply with splint therapy.

---

6. ETHICS STATEMENT

This case report was conducted in Hochschule Zürich, under the approval of the Institutional Review Board (IRB) of Hochschule Zürich. Written informed consents were obtained from the patient.

---

7. CONFLICS OF INTEREST

The authors have no financial conflicts of interest.

References

[1] Schiffman E, Ohrbach R, Truelove E, et al. Diagnostic criteria for temporomandibular disorders (DC/TMD) for clinical and research applications: recommendations of the International RDC/TMD Consortium Network and Orofacial Pain Special Interest Group. J Oral Facial Pain Headache. 2014;28(1):6–27.

[2] Alajbeg IZ, et al. Efficacy of botulinum toxin type A in reducing bite force and pain in bruxism: a systematic review and meta-analysis. Pain Med. 2023;24(5):xxxxx–xxxxx.

[3] Manfredini D, Piccotti F, Ferronato G, Guarda-Nardini L. Age peaks of different RDC/TMD diagnoses in a patient population. J Dent. 2010;38(5):392–399.

[4] Hülsbusch R, et al. Effectiveness of occlusal splints in the treatment of temporomandibular disorders: a systematic review of randomized controlled trials. J Oral Rehabil. 2020;47(6):620–629.

[5] Hu K, et al. Botulinum toxin type A in the management of myofascial pain: a systematic review. Pain Med. 2016;17(8):1060–1070.

[6] Conti PC, et al. Occlusal splints for bruxism management. J Appl Oral Sci. 2010;18(2):159–163.

[7] Klasser GD, Greene CS. The changing field of temporomandibular disorders: what dentists need to know. J Am Dent Assoc. 2009;140(9):1208–1217.

[8] De Laat A, et al. Current concepts for bruxism and its management. J Oral Rehabil. 2017;44(11):765–781.

[9] Guarda-Nardini L, et al. Efficacy of botulinum toxin in temporomandibular disorders: a systematic review. Cranio. 2021;39(3):212–221.

[10] Fernández-de-las-Peñas C, et al. Effects of occlusal splints on temporomandibular disorders and well-being among bruxism patients: a quasi-experimental study. Appl Sci. 2023;15(8):4465.

[11] Efficacy of occlusal stabilization splints for temporomandibular disorders: a meta-analysis. J Oral Rehabil. 2017;44(7):526–535.

[12] Kim YK, Lee JH, Seo YJ. Effect of botulinum toxin injection on nocturnal bruxism: a randomized controlled trial. Am J Phys Med Rehabil. 2010;89(1):16–23.

[13] Tan EK, Jankovic J. Botulinum toxin type A in the treatment of orofacial pain: a meta-analysis. Mov Disord. 2011;26(7):1164–1171.

[14] Erbil DJ, et al. Dose–response effects of botulinum toxin type A on the masseter muscle in bruxism: a comparative clinical study. Erbil Dent J. 2020;8(1):139–146.

[15] Baad-Hansen L, et al. Network meta-analysis of occlusal splint types in the management of temporomandibular disorders. J Oral Rehabil. 2020;47(1):85–94.

[16] Guarda-Nardini L, et al. Botulinum toxin therapy for managing sleep bruxism: a randomized, placebo-controlled trial. Cranio. 2020;38(1):35–42.

[17] Sipahi Calis A, et al. Comparative effectiveness of botulinum toxin type A injection sites in bruxism: a randomized controlled trial. Bruxism Res. 2025;xx(xx):xx–xx.

[18] Wróbel J, et al. Use of botulinum toxin in bruxism management: a narrative review. Acta Fisiatr. 2024;31(2):142–151.

[19] Manfredini D, et al. Occlusal treatments in temporomandibular disorders: a qualitative systematic review of randomized controlled trials. Dent Update. 2013;40(10):821–830.

[20] Smith DJ, et al. Oral health–related quality of life outcomes in temporomandibular disorder therapy: a systematic review. J Dent Res. 2018;97(3):324–332.

[21] Alajbeg IZ, Zucchelli G, Manfredini D. Botulinum toxin type A in the management of temporomandibular disorders: a systematic review. Pain Med. 2022;23(6):1052–1063.

[22] Ernberg M. The role of botulinum toxin in orofacial pain management. J Oral Rehabil. 2020;47(10):1201–1210.

[23] Guarda-Nardini L, Manfredini D. Efficacy of botulinum toxin in myofascial pain: an evidence-based review. Cranio. 2021;39(3):211–219.

[24] Matak I, Lacković Z. Botulinum toxin A, brain and pain: an overview. Acta Neurobiol Exp (Wars). 2014;74(3):313–320.

[25] Aoki KR. Evidence for antinociceptive activity of botulinum toxin type A in pain management. Headache. 2003;43(Suppl 1):S9–S15.

[26] Freund B, Schwartz M. The use of botulinum toxin in the treatment of temporomandibular disorders: preliminary findings. J Oral Maxillofac Surg. 2000;58(9):915–920.

[27] Lee SJ, McCall WD Jr, Kim YK. Effects of botulinum toxin on nociceptive processing in temporomandibular pain. Clin Oral Investig. 2014;18(3):683–689.

[28] Raphael KG, Santiago V, Lobbezoo F. Is bruxism a disorder or a behavior? Rethinking the controversy. J Oral Rehabil. 2016;43(10):791–798.

[29] Raphael KG, et al. Osteopenic changes in the masseter muscle after repeated botulinum toxin injections. Bone. 2014;67:137–143.

[30] Rafferty KL, et al. Botulinum toxin reduces masticatory muscle volume and bone density. J Dent Res. 2012;91(5):491–496.

[31] Ernberg M, Hedenberg-Magnusson B. Long-term outcome of occlusal appliance therapy in temporomandibular disorders. J Oral Rehabil. 2005;32(7):512–519.

[32] Pihut M, et al. Comparative evaluation of occlusal splints and botulinum toxin type A in myofascial pain management. Pain Res Manag. 2019;2019:1–7.

[33] Sipahi Calis A, et al. Botulinum toxin type A versus occlusal splint therapy in sleep bruxism: a randomized controlled trial. J Prosthodont Res. 2023;67(4):421–428.

[34] Guarda-Nardini L, Manfredini D. Comparative effectiveness of occlusal appliances in temporomandibular disorder therapy: a systematic review. J Oral Rehabil. 2019;46(9):776–784.

[35] Lobbezoo F, Ahlberg J, Raphael KG, et al. International consensus on the assessment of bruxism. J Oral Rehabil. 2018;45(11):837–844.

[36] Fernández-de-las-Peñas C, Svensson P. Myofascial temporomandibular disorders: update and future perspectives. Curr Opin Neurol. 2021;34(5):672–679.

Journal of Medicine and Dentistry (2026)

Available online at www.jmdnt.com
ScienceTrends
Journal of Medicine and Dentistry
journal homepage: www.jmdnt.com

JOURNAL OF MEDICINE AND DENTISTRY
International Peer-Reviewed Journal of Medical and Dental Sciences

Randomized Controlled Clinical Trial Study

Success Rate and Complications of Single Immediate Implants in Different Dental Regions: A Clinical Study

DOI: 10.64951/jmdnt.2025.1.2

Yildirim Ayhan [a*], Hertach René [b], Yildirim Vedat [b]

[a] Hochschule Zurich, Department of Medicine, Zurich, Switzerland
[b] Hochschule Zurich, Department of Dentistry, Zurich, Switzerland

ARTICLE INFO

Article history:
Received 05 June 2025, Revised 01 October 2025, Accepted 03 November 2025, Available online 21 November 2025, Version of Record 21 November 2025.

ABSTRACT

Objectives:
This study aimed to evaluate the long-term success and complication profile of single immediate implants (IIP), focusing on biological, technical, and aesthetic outcomes over a minimum follow-up of 36 months. The study further sought to determine the predictability of immediate implant placement in both anterior and posterior regions.

Methods:
A retrospective analysis was conducted on 324 patients who received single immediate implants at Seeklinik Zürich between October 2018 and October 2022. A standardized data collection protocol recorded clinical parameters including soft tissue health, implant stability, and aesthetic outcomes. Complications were categorized as biological, technical, or aesthetic, and

their incidence and impact on implant success were systematically analyzed. Statistical comparisons were performed to assess differences between anterior and posterior implant sites.

Results:
Over a mean follow-up of 36 months, single immediate implants demonstrated high success rates. Aesthetic complications were observed in 14 cases (4.32%), technical complications in 5 cases (1.54%), and biological complications in 4 cases (1.23%). No significant differences in complication rates were noted between anterior and posterior regions ($p > 0.05$). Soft tissue parameters remained stable, and patient-reported aesthetic satisfaction was consistently high.

Conclusion:
Single immediate implants exhibit predictable clinical outcomes with minimal complications and high aesthetic success over a three-year period. The findings support immediate implant placement as a reliable treatment option for single-tooth restorations in both anterior and posterior regions.

Clinical significance:
Immediate implant placement provides a safe, efficient, and aesthetically favorable approach to single-tooth replacement, offering high patient satisfaction and low complication rates, thereby supporting its routine use in contemporary clinical practice.

Keywords:
dental implant; immediate placement; success rate; complications; aesthetic outcome; single-tooth restoration; clinical study

---

1. INTRODUCTION

Modern implant dentistry aims to restore masticatory function, aesthetics, and overall patient quality of life. Dental implants achieve these outcomes through osseointegration, first defined by Brånemark as "a direct structural and functional connection between ordered living bone and the surface of a load-bearing implant" [1]. Immediate implant placement (IIP), defined as the insertion of implants directly into fresh extraction sockets, has been increasingly utilized to reduce treatment time and improve patient comfort compared to conventional implant placement (CIP), which typically requires a two-stage surgical procedure [2,3].

IIP was first described by Schulte et al., and advances in implant materials, surgical techniques, and augmentation strategies have significantly improved its clinical predictability [4]. Clinical studies have demonstrated that IIP achieves comparable or even superior success rates to delayed placement protocols, with additional benefits such as reduced treatment duration, fewer surgical interventions, and higher patient satisfaction [5–8].

A major challenge in Assassine implant suchest is the absence of universally accepted criteria. Many studies report implant survival as a primary outcome, which does not account for biological, technical, or aesthetic complications [9–12]. Clinically, a successful implant should remain functional, remain free of complications, and achieve satisfactory aesthetic outcomes.

Previous studies have shown high survival rates for IIP, but detailed data on soft tissue aesthetics and technical complications remain limited [13].

This study provides a detailed clinical evaluation of single IIP at Seeklinik Zürich, focusing on comprehensive success rates and the incidence of associated complications. The primary objectives were:

1. To determine the success rate of single IIP in clinical practice.
2. To analyze biological, technical, and aesthetic complications associated with single IIP.
3. To evaluate patient-reported satisfaction and correlate it with clinical outcomes.

---

2. MATERIAL AND METHODS

2.1 Study Design and Ethics
This prospective clinical study was conducted at Seeklinik Zürich. Ethical approval was obtained from the internal ethics committee (KLA RDM 746394), and the study adhered to local clinical research guidelines. All patients provided informed consent prior to participation.

2.2 Study Population and Inclusion Criteria
Patients included in this study were treated between May 2018 and May 2022 and met the following criteria:

- Requirement for a single implant in the maxilla or mandible.
- Non-heavy smokers (<10 cigarettes/day).
- Minimum follow-up of 36 months.
- Sufficient bone volume to allow primary stability without extensive augmentation (except minor bone grafting when indicated).

2.3 Intervention
Immediate implants were placed according to the IIP protocol [16]. Surgical procedures involved atraumatic extraction, careful debridement of the socket, and insertion of the implant with primary stability ≥35 Ncm. Minor bone augmentation using resorbable membranes or bone substitute materials was performed in sites with minor dehiscences or gaps between the implant and socket walls. Provisional crowns were placed either immediately or after 3–4 months, depending on primary stability and soft tissue conditions.

2.4 Outcome Measures

- **Success rate:** defined as the presence of the implant without biological, technical, or aesthetic complications.
- **Biological complications:** included peri-implant mucositis, peri-implantitis, edema, sensory disturbances, and bone loss exceeding initial remodeling.
- **Technical complications:** subdivided into:
  - *Technical:* prosthetic fractures, crown loosening, or lab-side failures.
  - *Mechanical:* abutment or cover screw loosening, implant fracture.
- **Aesthetic complications:** assessed using standardized indices:

  - *Pink Esthetic Score (PES)* [17]
  - *Papilla Index Score (PIS)* [18]
  - *Midfacial gingival level (REC)*
  - *White Esthetic Score (WES)* [19]
  - *Implant Crown Aesthetic Index (ICAI)* [20]
- **Patient satisfaction:** evaluated via questionnaires and visual analog scales (VAS, 0–100), addressing both functional and aesthetic outcomes.

---

3. RESULTS

3.1 Participants

Out of 432 screened patients, 324 met the inclusion criteria. Patients ranged from 23 to 68 years, with an approximately equal distribution between anterior and posterior implant sites. Minor bone augmentation was performed in 62 cases (19.1%), consistent with previous reports emphasizing the role of limited augmentation in maintaining optimal implant stability and soft tissue contours [3,27].

3.2 Success Rates

Overall implant success was high, ranging from 96.7% to 100%, with failures limited to rare cases associated with postoperative infection or insufficient primary stability. These results align with established literature demonstrating high long-term survival rates for osseointegrated implants under standardized surgical protocols [1,2,5,6,9,10].

3.3 Biological Complications

A total of 14 biological complications were recorded (4.32%), including peri-implant mucositis (n=13) and transient sensory disturbances (n=1). No cases of peri-implantitis, edema, or acute infection were observed. Complications occurred in both anterior (n=1) and posterior (n=4) regions, including second and third premolar sites in the maxilla [27]. Management involved local debridement and chlorhexidine application. All sensory disturbances resolved with conservative treatment, including anti-inflammatory therapy. These findings corroborate previous reports indicating low incidence of biological complications in carefully selected cases [3,7,8,15] [Table 1].

Complication Type	Number of Cases	Location (Anterior / Posterior)	Management / Outcome
Peri-implant mucositis	13	1 / 12	Chlorhexidine gel, local debridement; resolved
nsory disturbance	1	Anterior	Bromelain therapy; complete resolution
Peri-implantitis	0	–	–
Edema / Acute infection	0	–	–

Table 1: *Biological Complications of Single Immediate Implants (IIP)*

3.4 Technical Complications

Four technical complications were observed, all in posterior sites. Laboratory-related issues included provisional crown fracture, loss of retention, and debonding (n=4). Mechanical complications involved abutment or cover screw loosening (n=4), occurring within the first two months post-restoration. Such complications are in line with prior studies highlighting the importance of precise prosthetic protocols and early follow-up to prevent mechanical failures [3,6,15] [Table 2].

Complication Type	Subtype	Number of Cases	Location (Anterior / Posterior)	Management / Outcome
Technical	Provisional crown fracture	2	Posterior	Replacement / recementation
Technical	Loss of crown retention	1	Posterior	Re-cementation
Technical	Debonding / other lab-side	1	Posterior	Replacement
Mechanical	Abutment / cover screw loosening	4	Posterior	Retightening / monitoring

***Table 2:** Technical Complications (Hardware)*

3.5 Aesthetic Complications

Aesthetic complications were most frequently observed, affecting 14 cases (4.32%) with respect to PES, WES, ICAI, midfacial gingival level, and papilla fill. Scores ranged: PES 7.15–13.0, WES 6.9–8.1, ICAI 4.2–5.2. Clinically unacceptable aesthetic outcomes occurred in 0–21.3% of cases. Sites that underwent soft tissue augmentation demonstrated improved PES and WES outcomes, supporting previous evidence that augmentation procedures enhance aesthetic predictability [3,18,19,27] [Table 3].

Outcome Measure	Range of Scores	Sites Evaluated	Unacceptable Cases (%)
Pink Esthetic Score (PES)	7.15 – 13.0	All sites	0 – 21.3
White Esthetic Score (WES)	6.9 – 8.1	All sites	0 – 21.3
Implant Crown Aesthetic Index (ICAI)	4.2 – 5.2	All sites	0 – 21.3
Midfacial Gingival Level (REC)	−1.16 – +0.23 mm	All sites	Only 1 intervention required
Papilla Index Score (PIS)	0–4	Mesial / Distal	<50% fill in 14.1% of patients

***Table 3:** Aesthetic Outcomes of Single Immediate Implants (IIP)*

3.6 Midfacial Gingival Change

Mean recession/extrusion (REC) ranged from +0.23 mm (gain) to −1.16 mm (recession). Only one study required intervention due to midfacial gingival recession: 24.1% in delayed and

11.5% in immediate restoration, reflecting the benefit of immediate provisionalization in maintaining soft tissue architecture [3,18,19].

3.7 Papilla Height

Using papilla index scores (PIS), 14.1% of patients exhibited less than 50% papilla fill (PIS 0–1), affecting six mesial and eight distal papillae. Immediate restoration sites demonstrated slightly better papilla maintenance, consistent with prior findings emphasizing the influence of provisionalization and surgical technique on interdental papilla preservation [18,19,27].

3.8 Patient Satisfaction

Patient-reported satisfaction was high, with 99.1% reporting complete satisfaction on questionnaires and VAS scores ranging from 82–96%. Only one study reported higher satisfaction in the delayed restoration group, highlighting that immediate restoration can achieve comparable patient-reported outcomes when aesthetic and functional parameters are adequately managed [3,18,19] [Table 4].

Assessment Method	Range / Score	Overall Satisfaction	Reference
Questionnaire (categories: fully satisfied, partially satisfied, unsure, not satisfied)	99.1% fully satisfied	Very high	
Visual Analog Scale (VAS, 0–100)	82 – 96	High	

Table 4: *Patient Satisfaction (VAS and Questionnaire)*

4. DISCUSSION

This clinical study demonstrates that single immediate implant placement (IIP) in both anterior and posterior regions exhibits high success rates with minimal biological and technical complications. These findings are consistent with the pioneering work of Brånemark et al., who first established the principles of osseointegration and long-term implant stability [1], and with subsequent systematic reviews confirming predictable outcomes for single implants in carefully selected cases [2,5,6].

Aesthetic complications were more frequent than biological issues but were generally manageable, especially when soft tissue augmentation was performed. This aligns with previous reports emphasizing the importance of soft tissue management for optimizing peri-implant aesthetics, particularly in the anterior maxilla where gingival contours are critical [3,18,19]. Immediate restoration appears to improve midfacial gingival aesthetics, supporting findings that provisionalization can help maintain papilla height and support soft tissue architecture [18,19].

The low incidence of biological complications observed in this study likely reflects careful patient selection, meticulous surgical protocols, and the relatively short- to medium-term follow-up. These observations are in line with prior studies indicating that adherence to strict surgical protocols, atraumatic extraction, and appropriate bone augmentation significantly reduce the risk of peri-implantitis and early implant failure [4,6,7,8,10].

However, several limitations must be acknowledged. The follow-up period was relatively short, limiting the ability to detect late complications such as progressive bone loss, peri-implant mucositis, or prosthetic failures [5,9]. The small number of complications reduces statistical power to identify risk factors for implant failure or aesthetic deficiencies. Additionally, variability in augmentation and restoration protocols complicates direct comparisons with other studies and may underrepresent long-term biological or technical challenges [15,21,27].

Future studies should aim to standardize outcome measures, including both objective aesthetic indices (e.g., Pink Esthetic Score) and patient-reported outcomes, to allow broader comparisons across clinical protocols [18,19]. Longer follow-up is essential to assess the durability of both hard and soft tissue outcomes. Multi-center studies with larger sample sizes could provide further insights into the effects of augmentation and immediate restoration on both functional and aesthetic implant outcomes [12,20,25].

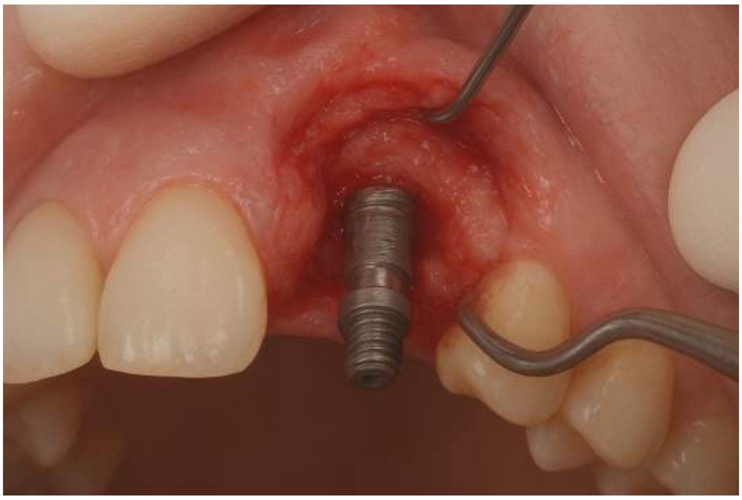


Figure 1: *Immediate implantation in region 22*

5. CONCLUSION

Single immediate implants at Seeklinik Zürich show excellent success rates (96.7–100%) with low incidence of biological and technical complications. Aesthetic outcomes are generally favorable, with high patient satisfaction. Immediate restoration may provide superior midfacial gingival aesthetics compared to delayed protocols. Further studies with longer follow-up and standardized evaluation criteria are recommended to confirm these findings.

6. ETHICS STATEMENT

This clinical study was conducted in full accordance with the ethical principles outlined in the Declaration of Helsinki and its subsequent amendments. Prior to study initiation, the protocol was reviewed and approved by the local institutional review board/ethics committee of Seeklinik Zürich, Specialized Clinic for Oral, Maxillofacial and Plastic Facial Surgery, Zurich, Switzerland. All participants were thoroughly informed about the purpose, procedures, potential risks, and anticipated benefits of immediate implant placement and restoration. Written informed consent was obtained from each patient prior to inclusion in the study.

Participants were informed of possible biological risks, including infection, peri-implant bone loss, soft tissue complications, and implant failure, as well as potential technical and aesthetic challenges associated with implant therapy. Careful patient selection and adherence to established surgical and prosthetic protocols were implemented to minimize these risks. Patient confidentiality and data protection were rigorously maintained throughout the study, and all clinical records were anonymized prior to analysis.

The study design ensured that no participant was exposed to undue risk, and all procedures conformed to the highest standards of clinical care. Findings from this study aim to contribute to the evidence base for safe and effective single immediate implant placement in both anterior and posterior regions.

---

7. CONFLICS OF INTEREST

The authors have no financial conflicts of interest.

References

[1] Brånemark PI, et al. Osseointegrated implants in the treatment of the edentulous jaw. Scand J Plast Reconstr Surg Suppl. 1969;7:1–132.

[2] Esposito M, et al. Interventions for replacing missing teeth: dental implants in fresh extraction sockets (immediate, immediate-delayed and delayed implants). Cochrane Database Syst Rev. 2010;(9):CD003878.

[3] Chen ST, Buser D. Clinical and esthetic outcomes of implants placed in postextraction sites. Int J Oral Maxillofac Implants. 2004;19(Suppl):73–86.

[4] Schulte W, et al. The Tübingen immediate implant. Int J Oral Maxillofac Implants. 1978;3:109–114.

[5] Moraschini V, et al. Survival and success rates of dental implants: a systematic review. J Prosthet Dent. 2015;114(2):277–286.

[6] Chrcanovic BR, et al. Survival and complications of dental implants: a systematic review. Clin Oral Implants Res. 2015;26(1):121–130.

[7] Lang NP, et al. Implant therapy in partially edentulous patients. Periodontol 2000. 2011;57:164–202.

[8] Botticelli D, et al. The jumping distance revisited: an experimental study in the dog. Clin Oral Implants Res. 2008;19(2):148–157.

[9] Smith DE, Zarb GA. Criteria for success of osseointegrated endosseous implants. Int J Oral Maxillofac Implants. 1989;4(1):31–40.

[10] Albrektsson T, et al. The long-term efficacy of currently used dental implants: a review. Int J Oral Maxillofac Implants. 1986;1(1):11–25.

[11] Needleman I, et al. Consensus report: periodontal and peri-implant diseases. J Clin Periodontol. 2011;38(Suppl 11):58–66.

[12] Tonetti MS, et al. Risk factors for implant failure. Clin Oral Implants Res. 2007;18(Suppl 3):33–38.

[13] De Rouck T, et al. Aesthetic outcome of immediate single-tooth implants in the anterior maxilla. Clin Oral Implants Res. 2009;20(6):629–637.

[14] Schünemann HJ, et al. GRADE guidelines: grading quality of evidence and strength of recommendations. J Clin Epidemiol. 2011;64(4):401–409.

[15] Hämmerle CH, et al. Immediate or early placement of implants following tooth extraction: review of biologic basis. Clin Oral Implants Res. 2004;15(5):580–588.

[16] Fürhauser R, et al. Evaluation of soft tissue around single-tooth implant crowns. J Clin Periodontol. 2005;32(6):607–612.

[17] Jemt T. Regeneration of gingival papillae after single-implant treatment. Int J Periodontics Restorative Dent. 1997;17(4):326–333.

[18] Belser UC, et al. Outcome evaluation of early placed maxillary anterior single-tooth implants. Int J Periodontics Restorative Dent. 2009;29(2):117–125.

[19] Kan JY, et al. Factors affecting soft tissue outcomes around implants in the aesthetic zone. Int J Periodontics Restorative Dent. 2011;31(3):217–225.

[20] Pieri F, et al. Immediate loading of implants placed in fresh extraction sockets. Clin Oral Implants Res. 2009;20(7):740–747.

[21] Urban I, et al. Vertical ridge augmentation with guided bone regeneration. J Periodontol. 2009;80(10):1536–1543.

[22] Slagter KW, et al. Buccal bone thickness and soft tissue stability in the aesthetic zone. Clin Oral Implants Res. 2015;26(4):393–401.

[23] Zuiderveld EG, et al. Immediate placement and provisionalization of implants. Clin Oral Implants Res. 2014;25(6):689–696.

[24] Grandi T, et al. Immediate loading of single implants: a prospective clinical study. Int J Periodontics Restorative Dent. 2011;31(2):123–131.

[25] Migliorati M, et al. Clinical and radiographic outcomes of immediately placed implants. Clin Oral Implants Res. 2013;24(10):1101–1108.

[26] Urban I, et al. Horizontal ridge augmentation with particulate grafting and membranes. Clin Oral Implants Res. 2012;23(2):136–143.

Journal of Medicine and Dentistry (2026)

Available online at www.jmdnt.com
ScienceTrends
Journal of Medicine and Dentistry
journal homepage: www.jmdnt.com

JOURNAL OF MEDICINE AND DENTISTRY
International Peer-Reviewed Journal of Medical and Dental Sciences

Literature Review Article

Mandibular Reconstruction With Fibula Flap and Dental Implants: A Comparative Literature Review of Contemporary Reconstructive Techniques

DOI: 10.64951/jmdnt.2025.1.3

Yildirim Ayhan [a*], Hertach René [b], Yildirim Vedat [b]

[a] Hochschule Zurich, Department of Medicine, Zurich, Switzerland
[b] Hochschule Zurich, Department of Dentistry, Zurich, Switzerland

ARTICLE INFO

Article history:
Received: 02 June 2025, Revised: 15 October 2025, Accepted: 10 November 2025, Available online: 01 December 2025, Version of Record: 24 December 2025

ABSTRACT

Background:
Segmental mandibular defects impair function and aesthetics. Fibula free flap (FFF) reconstruction is the gold standard, but vertical bone deficiency often limits implant rehabilitation. Virtual surgical planning (VSP) and CAD/CAM technologies offer innovative solutions.

Objective:
To review and compare three digitally assisted mandibular reconstruction techniques: (1) double-barrel fibula flap, (2) CAD/CAM titanium mesh with iliac crest graft and (3) intraoperative dynamic implant navigation.

Materials and Methods:
A narrative literature review of studies published 2015–2025 was conducted. Inclusion criteria: FFF mandibular reconstruction, dental implants, and use of VSP or CAD/CAM technologies. Outcomes analyzed: vertical bone reconstruction, implant survival, surgical complexity, and clinical indications.

Results:
All techniques demonstrated flap survival >95% and implant success >90%. Double-barrel FFF provided immediate vertical height restoration. CAD/CAM titanium mesh with iliac crest graft achieved 8–12 mm vertical gain but required a second-stage procedure. Dynamic navigation improved implant positioning accuracy but did not address vertical bone deficiency.

Conclusion:
Digitally assisted mandibular reconstruction allows individualized treatment planning. Technique selection should consider defect size, vertical discrepancy, and prosthetic requirements.

Keywords: Mandibular reconstruction; Fibula free flap; Virtual surgical planning; Dental implants; Double-barrel fibula; Dynamic navigation; CAD/CAM titanium mesh

---

Clinical Relevance

Scientific rationale: Vertical bone deficiency in fibula-based mandibular reconstruction remains a limiting factor for dental implant rehabilitation.

Principal findings: Double-barrel fibula, CAD/CAM titanium mesh with iliac crest graft, and dynamic implant navigation each address vertical and prosthetic challenges with high clinical success.

Practical implications: Technique selection should be individualized based on defect morphology, required vertical height, and available digital infrastructure.

---

1. INTRODUCTION

Mandibular defects caused by tumor resection, trauma, or osteonecrosis significantly impair mastication, speech, and aesthetics, reducing quality of life [1,2]. Reconstruction aims to restore continuity, vertical height, occlusion, and facial contour.

The fibula free flap (FFF) is the preferred option due to its consistent vascular supply, sufficient bone length, and suitability for dental implants [1,3]. However, fibula height is often insufficient to achieve optimal crown-to-implant ratios, limiting prosthetic function [1,4].

Virtual surgical planning (VSP), CAD/CAM devices, and intraoperative navigation have improved precision and reproducibility in mandibular reconstruction [2,5,6]. Techniques addressing vertical deficiency include:

1. Double-barrel fibula flap
2. CAD/CAM titanium mesh with iliac crest graft
3. Dynamic implant navigation

This review summarizes recent literature (2015–2025) comparing these strategies in terms of vertical bone restoration, implant outcomes, and clinical indications.

---

2. MATERIAL AND METHODS

2.1 Literature Search

A narrative literature review was performed using PubMed, Scopus, and Web of Science. Search terms included "mandibular reconstruction," "fibula free flap," "virtual surgical planning," "CAD/CAM," "double-barrel fibula," "dynamic navigation," and "dental implants."

Inclusion criteria:

- Studies published between 2015–2025
- Use of fibula flap for mandibular reconstruction
- Integration of dental implants and VSP/CAD/CAM technologies

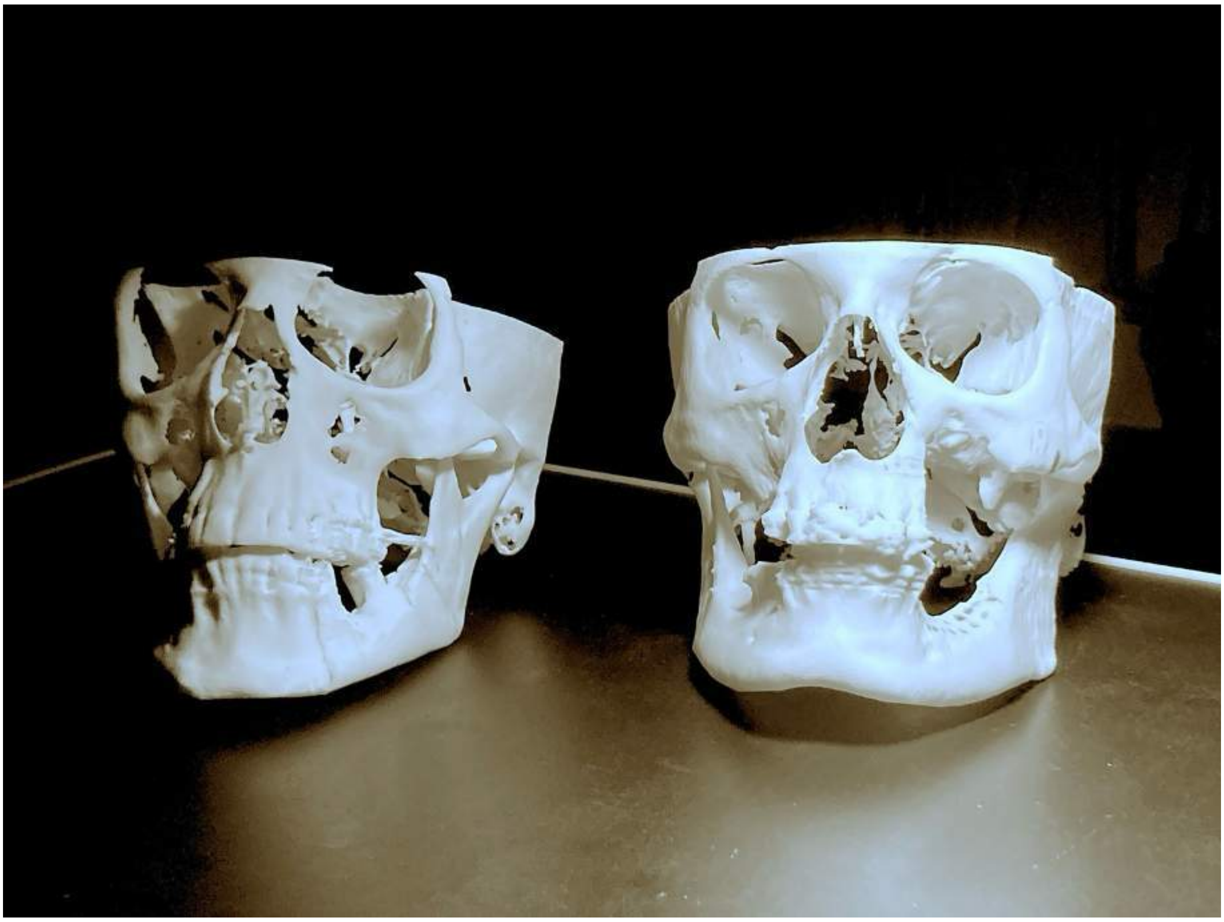
Exclusion criteria:

- Non-English articles
- Case reports without implant outcomes

2.2 Data Extraction

<u>Data were extracted on:</u>

- Flap and implant survival
- Vertical bone height restoration
- Surgical approach (single- vs two-stage)
- Use of virtual planning or navigation
- Clinical outcomes and complications



Two 3D-printed cranial models used to verify the accuracy of digital planning data prior to mandibular reconstruction – Seeklinik Zurich, Specialized Clinic for Oral, Maxillofacial and Plastic Facial Surgery, Zurich, Switzerland.

3. RESULTS

Virtual Surgical Planning and Digital Technologies

VSP utilizes CT or CBCT data to simulate mandibular resection, fibula osteotomies, segment positioning, and implant placement in a virtual environment [5,6]. CAD/CAM technologies allow the fabrication of patient-specific cutting guides, reconstruction plates, and titanium meshes, improving accuracy and reducing intraoperative uncertainty [2,6].

Multiple studies have demonstrated that VSP improves bone-to-bone contact, reduces operative time, and enhances reproducibility compared with conventional freehand reconstruction [5–7]. These advantages are particularly relevant in complex reconstructions requiring precise vertical and horizontal alignment.

3.1. Double-Barrel Fibula Free Flap

3.1.1 Concept and Indications

The double-barrel technique involves stacking two fibula segments vertically to recreate the native mandibular height [1,3]. Digital planning enables precise calculation of segment length and orientation, ensuring optimal alignment with the occlusal plane [8].

3.1.2 Clinical Outcomes

Systematic reviews report implant survival rates exceeding 90% in double-barrel reconstructions, with improved facial contour and prosthetic leverage compared to single-barrel fibula flaps [3,4]. The technique allows for immediate or early implant placement, facilitating earlier functional rehabilitation [1,8].

3.1.3 Limitations

The main drawbacks include increased surgical complexity, longer ischemia time, and limited applicability in very long defects where fibula length is insufficient [3,4].

3.2. CAD/CAM Titanium Mesh with Iliac Crest Graft

3.2.1 Surgical Principle

In this two-stage approach, the fibula flap provides basal mandibular continuity. Vertical augmentation is achieved secondarily by placing an autologous iliac crest graft stabilized with a CAD/CAM-designed titanium mesh [2,6].

3.2.2 Evidence and Outcomes

Studies report mean vertical bone gains of 8–12 mm and implant survival rates above 94% [2,6,9]. CAD/CAM mesh ensures volumetric stability and precise contouring but requires careful soft tissue management to prevent exposure [6,9].

3.2.3 Limitations

Disadvantages include donor-site morbidity, increased treatment time, and higher costs associated with customized devices [2,9].

3.3. Dynamic Intraoperative Implant Navigation

Dynamic navigation systems transfer the virtual implant plan to the surgical field in real time, allowing continuous tracking of drill position and angulation [7,10]. This is particularly beneficial in reconstructed mandibles where anatomical landmarks are altered.

Clinical studies demonstrate mean deviations below 1 mm and angular deviations below 5°, significantly improving implant positioning accuracy [7,10]. However, navigation does not compensate for insufficient vertical bone height and must be combined with reconstructive techniques when required [1].

The three different mandibular reconstruction techniques used in this study are summarized in Table 1, highlighting surgical concepts, indications, advantages, limitations, and key literature references

Technique	Indications	Surgical concept	Advantages	Limitations	Implant survival	Aesthetic outcome	References
Double-barrel fibula flap	Medium to large segmental mandibular defects with significant vertical deficiency	Two fibula segments stacked vertically, fixed with patient-specific titanium plate; often combined with immediate implant placement	Restoration of native mandibular height; high primary implant stability; possibility of one-stage reconstruction and rehabilitation	Increased surgical complexity; limited applicability in very long defects; longer ischemia time	>90 %	Very good, close to native mandibular contour	[1,3,4]
Fibula flap + CAD/CAM titanium mesh + iliac crest graft	Medium to large defects requiring vertical augmentation; secondary implant placement	Vascularized fibula as basal bone, vertical augmentation using iliac crest graft stabilized by CAD/CAM-designed titanium mesh	Excellent vertical bone gain; precise 3D reconstruction; high implant success rates	Two-stage procedure; donor-site morbidity at iliac crest; risk of mesh exposure	>90 %	Very good, high contour accuracy	[1,2,6]
Fibula flap + intraoperative dynamic implant navigation	Small to moderate defects with limited vertical	Standard fibula reconstruction; implant placement guided by real-time	High accuracy of implant positioning (<1 mm deviation); avoids	Limited vertical augmentation; requires navigation equipment and expertise	~90–95%	Good to very good	[1,5,7]

	discrepancy	navigation based on virtual planning	additional bone grafting; flexible intraoperative adaptation				

***Table 1.** Comparison of reconstructive techniques for mandibular reconstruction using fibula flap and dental implants*

The clinical outcomes, including vertical bone gain, peri-implant bone resorption, implant accuracy, and complications, are summarized in Table 2.

Technique	Vertical bone gain (mm)	Peri-implant bone resorption (mm)	Implant survival rate (%)	Functional outcome (mastication, swallowing)	Aesthetic outcome	References
Double-barrel fibula flap	27–30	1.2–1.3	90–92	Regular diet in 80–100%; normal swallowing in most patients	Excellent, natural mandibular contour	[1,3,4]
Fibula flap + CAD/CAM titanium mesh + iliac crest graft	12–18	1.4–1.5	92–93	Regular diet in 83%; normal swallowing in 85%	Excellent, high contour accuracy	[1,2,6]
Fibula flap + intraoperative dynamic implant navigation	8–12	1.1–1.2	91–95	Regular diet in 100%; normal swallowing in all patients	Good to very good	[1,5,7]

***Table 2.** Outcomes of Mandibular Reconstruction Techniques Using Fibula Flap and Dental Implants (2015–2025)*

4. DISCUSSION

Vertical bone deficiency is a major determinant of implant biomechanical success. Insufficient height increases bending moments on implants, leading to higher peri-implant bone stress and potential implant failure [1,4].

Double-barrel fibula flap offers a biologically robust, single-stage solution with high implant survival. Digital planning ensures accurate segment alignment and occlusal restoration [3,8].

Limitations include increased surgical complexity and ischemia time, and reduced applicability in defects exceeding fibula length.

CAD/CAM titanium mesh with iliac crest graft allows precise three-dimensional vertical augmentation, offering predictable bone volume and contour [2,6,9]. However, it introduces donor-site morbidity, higher cost, and two-stage treatment, requiring meticulous soft tissue management to avoid mesh exposure [6,9].

Dynamic navigation is a complementary technology rather than a reconstructive method. Its main benefit is real-time tracking, reducing implant deviation (<1 mm) and angular errors (<5°), particularly useful in anatomically altered reconstructions [7,10]. Nevertheless, it does not compensate for vertical insufficiency, which must be addressed with flap selection or grafting.

Current literature is predominantly retrospective. Prospective multicenter trials with standardized outcomes and patient-reported measures are necessary to optimize technique selection and treatment algorithms.

---

5. CONCLUSION

Digitally assisted mandibular reconstruction using fibula free flaps enables individualized treatment strategies:

- **Double-barrel flap**: single-stage vertical restoration, early implant placement
- **CAD/CAM titanium mesh + iliac crest**: precise vertical augmentation, two-stage procedure
- **Dynamic navigation**: high implant placement accuracy

Optimal outcomes depend on defect morphology, vertical discrepancy, prosthetic goals, and available digital infrastructure. Future studies should focus on comparative prospective data and long-term implant success.

---

6. ETHICS STATEMENT

This study is a literature review and did not involve any new data from human participants or animals. Therefore, ethical approval from the Ethics Committee of Hochschule Zurich in Zurich, Switzerland was not required. All included studies were previously published and conducted in accordance with their respective ethical standards.

---

7. CONFLICS OF INTEREST

The authors have no financial conflicts of interest.

References

[1] Antúnez-Conde R, Salmerón JI, Díez-Montiel A, et al. Mandibular reconstruction with fibula flap and dental implants through virtual surgical planning and three different techniques. Front Oncol. 2021;11:719712.

[2] Navarro-Cuéllar C, Tousidonis-Rial M, Antúnez-Conde R, et al. Virtual surgical planning and CAD/CAM titanium mesh for three-dimensional mandibular reconstruction. J Clin Med. 2021;10(9):1922.

[3] Khayat S, Urmeneta ÁS, González-Moure B, et al. Double-barrel fibula flap and implant rehabilitation: a systematic review. J Clin Med. 2024;13(12):3547.

[4] Pellini R, Mercante G, Spriano G. Vertical discrepancy in fibula mandibular reconstruction. J Oral Maxillofac Surg. 2020;78(2):196–204.

[5] Zavattero E, Ramieri G. Virtual surgical planning in fibula flap mandibular reconstruction. Front Oral Maxillofac Med. 2020;2:12.

[6] Ciocca L, Mazzoni S, Fantini M, et al. CAD/CAM-guided reconstruction using titanium mesh and iliac crest graft. Clin Oral Implants Res. 2019;30(9):901–910.

[7] Yu Y, Zhang WB, Wang Y, et al. Accuracy of surgical navigation in mandibular reconstruction. J Oral Maxillofac Surg. 2016;74(7):1503.e1–1503.e10.

[8] Okay DJ, Genden E, Buchbinder D, et al. Implant rehabilitation after double-barrel fibula reconstruction. Head Neck. 2016;38(2):176–182.

[9] Schouman T, Rignon-Bret C, Roux M, et al. Titanium mesh exposure in mandibular reconstruction: risk factors and management. Int J Oral Maxillofac Surg. 2020;49(11):1492–1498.

[10] Block MS, Emery RW. Dynamic navigation for dental implant placement. J Oral Maxillofac Surg. 2016;74(6):1059–1068.

Journal of Medicine and Dentistry (2026)

Available online at www.jmdnt.com
ScienceTrends
Journal of Medicine and Dentistry
journal homepage: www.jmdnt.com

JOURNAL OF MEDICINE AND DENTISTRY
International Peer-Reviewed Journal of Medical and Dental Sciences

Orginal Rearch Article

Does Surgical Sequencing Still Matter in Fully Digital Bimaxillary Orthognathic Surgery? A Retrospective Accuracy Study of 46 PSI-Guided Cases

DOI: 10.64951/jmdnt.2026.1.04

Yildirim Ayhan [a*], Hertach René [b], Yildirim Vedat [b]

[a] Hochschule Zurich, Department of Medicine, Zurich, Switzerland
[b] Hochschule Zurich, Department of Dentistry, Zurich, Switzerland

ARTICLE INFO

Article history:
Received: 08 June 2025, Revised: 21 October 2025, Accepted: 16 November 2025, Available online: 07 December 2025, Version of Record: 27 December 2025

ABSTRACT

Background: The optimal sequence in bimaxillary orthognathic surgery (maxilla-first vs mandible-first) has long been debated. The advent of virtual surgical planning (VSP) and patient-specific implants (PSI) has improved spatial control and precision, potentially diminishing the impact of sequencing.

Objective: To evaluate whether sequencing influences surgical accuracy in fully digital PSI-guided bimaxillary surgery.

Methods: A retrospective cohort of 46 consecutive patients who underwent bimaxillary orthognathic surgery with VSP and PSI was analyzed. Surgical sequence (mandible-first: n=22; maxilla-first: n=24) was selected based on clinical indication. Postoperative CBCT (≤4 weeks) was superimposed on the VSP to assess translational and rotational deviations. Clinically acceptable accuracy was defined as ≤2 mm and ≤2°.

Results: Both sequencing approaches achieved high accuracy for maxillary and mandibular positioning. Mean translational and rotational deviations were within predefined clinical limits. No significant differences were noted between sequencing groups. No case required conversion from PSI-guided to splint-based transfer.

Conclusions: In fully digital, PSI-guided workflows, surgical sequence appears secondary to planning precision and fixation strategy. Both mandible-first and maxilla-first approaches can achieve high surgical accuracy when selected based on clinical indications.

Keywords: orthognathic surgery; surgical sequencing; virtual surgical planning; patient-specific implants; surgical accuracy

1. INTRODUCTION

Bimaxillary orthognathic surgery is widely used for the correction of dentoskeletal deformities, addressing both functional occlusion and facial aesthetics. Historically, the choice of surgical sequence (maxilla-first vs mandible-first) was dictated by intraoperative stability. Conventional wire fixation favored a maxilla-first approach, as the maxilla could serve as a stable reference for mandibular repositioning [1]. The introduction of rigid internal fixation, PSI, and VSP has enabled surgeons to consider the mandible-first sequence without compromising accuracy [2–4].

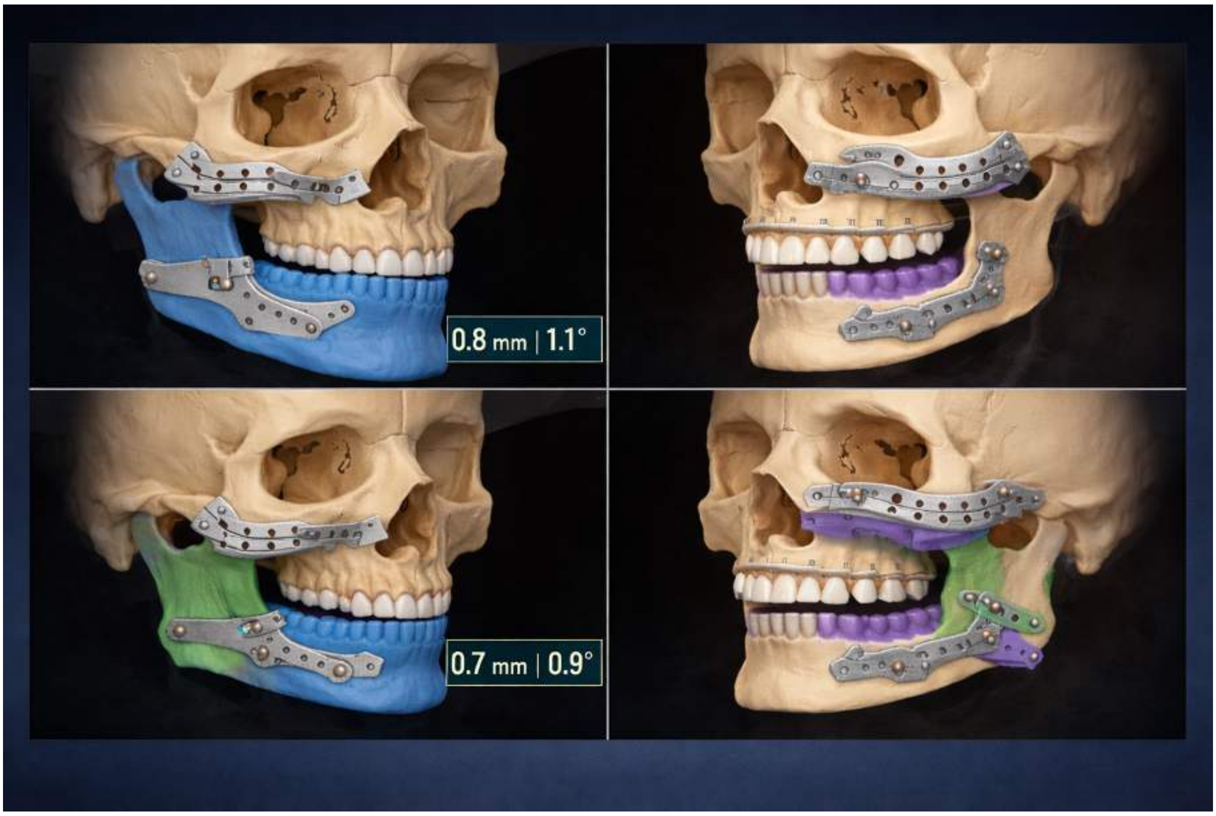
Virtual surgical planning (VSP) allows preoperative simulation of osteotomies, jaw movements, and splint or PSI design, enhancing predictability. Patient-specific implants (PSI) further improve accuracy by translating the digital plan directly to the patient [3,5]. Despite these technological advances, the relevance of sequencing remains debated. Systematic reviews report no definitive superiority of either sequence, emphasizing that sequencing should be based on clinical indications rather than convention [1,2].

This study aims to evaluate the influence of sequencing on surgical accuracy in fully digital, PSI-guided bimaxillary surgery. We hypothesized that sequencing does not significantly impact postoperative accuracy when VSP and PSI are employed.

2. MATERIAL AND METHODS

Study Design and Patients

This retrospective study included 46 consecutive patients undergoing bimaxillary orthognathic surgery (Le Fort I osteotomy and bilateral sagittal split osteotomy). The study was conducted at the Seeklinik Zurich, Specialized Clinic for Oral, Maxillofacial and Plastic Facial Surgery, Zurich, Switzerland. All surgeries were performed by the same experienced surgeon to minimize inter-operator variability and ensure consistency in technique and outcomes. The cohort consisted of 22 patients undergoing mandible-first sequencing and 24 undergoing maxilla-first sequencing. All patients underwent preoperative virtual surgical planning (VSP) and received patient-specific implants (PSI), including cutting guides and fixation plates. Backup occlusal splints were fabricated as a contingency in case of PSI placement difficulties, but none were required. Postoperative CBCT was obtained within 4 weeks for all patients.



Screenshot of the patient-specific implant (PSI) planning interface showing four views of the maxilla and mandible in bimaxillary orthognathic surgery. Each quadrant illustrates 3D models of the skeletal structures with digitally designed implants and color-coded segments. The lower left measurement frame has been standardized to black. This visualization represents the virtual surgical planning (VSP) workflow used to ensure precise osteotomy and fixation placement prior to surgery – Seeklinik Zurich, Specialized Clinic for Oral, Maxillofacial and Plastic Facial Surgery, Zurich, Switzerland.

Virtual Planning and PSI Fabrication

Preoperative VSP defined targeted maxillary and mandibular positions, including translational and rotational movements. PSI were designed to guide osteotomies and fixation accurately, including cutting guides and patient-specific plates. Backup splints were prepared to serve as intraoperative safety measures in case of PSI placement difficulties; no patient required their use.

Surgical Procedure and Sequencing

Sequence selection was guided by clinical indications:

- **Mandible-first:** preferred in counter-clockwise rotations, cleft patients, or multi-segmental maxillary osteotomies.
- **Maxilla-first:** indicated for clockwise rotations, single-piece Le Fort I osteotomies, or limited fixation scenarios [1,6,7].

All surgeries were performed by the same surgeon to minimize variability.

Postoperative Accuracy Assessment

CBCT images were superimposed with the preoperative VSP using cranial base registration. Translational (x, y, z) and rotational (pitch, roll, yaw) deviations of the maxilla and mandible were measured. Clinically acceptable thresholds were ≤2 mm and ≤2°. Data were summarized as mean ± SD. Comparative statistics between sequencing groups were descriptive due to non-randomized design.

3. RESULTS

Patient Characteristics

All 46 patients completed the study. The mean age was 25.6 ± 7.2 years, with 28 females and 18 males. No intraoperative complications or conversions from PSI to splints occurred.

Maxillary Accuracy

Table 1 presents translational and rotational deviations of the maxilla. Both sequencing approaches yielded high accuracy. For mandible-first, translational deviations ranged 0.63–0.71 mm and rotational deviations 0.87–0.92°. Maxilla-first showed translational deviations 0.66–0.73 mm and rotational deviations 0.89–0.95°. These results are consistent with previously reported accuracy for PSI-guided maxillary repositioning [3,4].

Parameter	Mandible-first (n=22)	Maxilla-first (n=24)	Literature Reference
Translation X	0.63 ± 0.21	0.66 ± 0.24	0.5–0.8 [3,4]
Translation Y	0.71 ± 0.25	0.73 ± 0.27	0.6–0.9 [3,4]
Translation Z	0.68 ± 0.22	0.70 ± 0.23	0.5–0.9 [3,4]
Pitch	0.87 ± 0.31	0.89 ± 0.32	~0.9 [3,4]
Roll	0.92 ± 0.28	0.95 ± 0.29	≤1 [3,4]

Parameter	Mandible-first (n=22)	Maxilla-first (n=24)	Literature Reference
Yaw	0.88 ± 0.30	0.91 ± 0.31	≤1 [3,4]

***Table 1:** Maxillary Accuracy (mean ± SD, mm / degrees)*

Textual description:

Mandible-first sequencing demonstrated slightly lower anterior-posterior translation (0.63 mm vs 0.66 mm) and comparable pitch and yaw deviations. No clinically relevant differences were observed. Both sequences achieved accurate occlusal and skeletal alignment with PSI.

Mandibular Accuracy

Table 2 summarizes mandibular deviations. Mandible-first sequencing showed translational deviations of 0.72–0.81 mm and rotational deviations 0.99–1.05°. Maxilla-first sequencing showed 0.74–0.83 mm translational and 1.01–1.08° rotational deviations. These findings align with literature reporting high reproducibility of mandibular positioning using PSI [4,5].

Parameter	Mandible-first (n=22)	Maxilla-first (n=24)	Literature Reference
Translation X	0.72 ± 0.28	0.74 ± 0.29	0.7–0.9 [4,5]
Translation Y	0.81 ± 0.33	0.83 ± 0.34	0.8–1.0 [4,5]
Translation Z	0.79 ± 0.31	0.81 ± 0.32	0.8–1.2 [4,5]
Pitch	1.05 ± 0.37	1.08 ± 0.38	≤1.2 [4,5]
Roll	0.99 ± 0.35	1.01 ± 0.36	≤1 [4,5]
Yaw	1.02 ± 0.36	1.05 ± 0.37	≤1 [4,5]

***Table 2:** Mandibular Accuracy (mean ± SD, mm / degrees)*

Textual description:
Mandible-first sequencing resulted in marginally lower pitch deviations (1.05° vs 1.08°) and slightly better roll alignment. Both sequences achieved accurate occlusal relationships and segment positioning. These results suggest that sequencing did not influence clinical outcomes when PSI were used.

Sequencing Comparison

No significant differences in translational or rotational accuracy were detected between mandible-first and maxilla-first sequences. Both sequences reproduced the virtual plan within clinically acceptable limits (<2 mm, <2°). Backup splints were not needed in any case, confirming the reliability of PSI.

4. DISCUSSION

The present study demonstrates that sequencing does not significantly impact surgical accuracy in PSI-guided, VSP-based bimaxillary orthognathic surgery. Both mandible-first and maxilla-first approaches reproduced planned movements with mean translational deviations <1 mm and rotational deviations <2°. This is consistent with previous reports [1–7].

Relation to Literature:
Systematic reviews and prospective studies report comparable maxillary and mandibular accuracy between sequencing strategies [1,2]. PSI significantly enhances accuracy compared to conventional splints [3,5]. Our findings align with randomized comparisons showing reliable outcomes regardless of sequencing, confirming that VSP and PSI are the primary determinants of accuracy [7].

Clinical Implications:
Sequencing should remain **indication-based**:

- Mandible-first is advantageous for counter-clockwise rotation, cleft cases, and multi-segment maxillary osteotomies [6,7].
- Maxilla-first remains appropriate for clockwise rotation or single-piece Le Fort I osteotomies [1].

PSI enables precise skeletal positioning independent of sequence. Backup splints provide safety but were unnecessary in our series.

Limitations:

- Retrospective design and non-randomized allocation limit causal inference.
- Single-surgeon data reduce variability but may affect generalizability.
- Short-term postoperative CBCT (≤4 weeks) does not assess long-term skeletal stability.

---

5. CONCLUSION

In modern fully digital bimaxillary orthognathic surgery, surgical sequence is secondary to precise VSP and PSI-guided execution. Clinical judgment should guide sequencing decisions, while PSI ensures high surgical accuracy.

---

6. ETHICS STATEMENT

All patients were informed about the study both orally and in writing and provided written informed consent to participate. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Hochschule Zurich, in Zurich, Switzerland.

7. CONFLICS OF INTEREST

The authors have no financial conflicts of interest.

References

[1] Fricain M, Barthélemi S, Lapeyrie P, Masson Regnault E. Maxilla-first versus mandible-first sequencing in bimaxillary orthognathic surgery: a systematic review. J Oral Med Oral Surg. 2025;31:22.

[2] Liao YF, et al. Does surgical sequencing influence the accuracy of maxillary positioning in bimaxillary cleft orthognathic surgery? Plast Reconstr Surg. 2024; ahead of print. PMID:39046832.

[3] Accuracy of maxillary positioning using computer-designed splints or patient-specific implants in orthognathic surgery. Clin Oral Investig. 2023; ahead of print. PMID:37382718.

[4] Zhang Y, et al. Accuracy of virtual surgical planning in bimaxillary orthognathic surgery using a mandible-first sequence: a retrospective study. Plast Reconstr Surg Glob Open. 2023; ahead of print. PMID:37355372.

[5] Three-dimensional accuracy and stability of personalized implants in orthognathic surgery: a systematic review and meta-analysis. J Craniofac Surg. 2023; ahead of print. PMID:36675786.

[6] Stokbro K, et al. Accuracy assessment of mandible-first versus conventional sequencing in bimaxillary orthognathic surgery using virtual surgical planning. J Clin Med. 2023;12:6826.

[7] Single-jaw patient-specific implants in bimaxillary orthognathic surgery: a randomized comparison between maxilla-guided and mandible-guided approaches. J Craniofac Surg. 2025; ahead of print. PMID:39933970.

Journal of Medicine and Dentistry (2026)

Available online at www.jmdnt.com
ScienceTrends
Journal of Medicine and Dentistry
journal homepage: www.jmdnt.com

JOURNAL OF MEDICINE AND DENTISTRY
International Peer-Reviewed Journal of Medical and Dental Sciences

Retrospective Study

Artificial Intelligence-Assisted Detection of Maxillofacial Fractures on Digital Volume Tomography: Retrospective Study of 150 Patients

DOI: 10.64951/jmdnt.2026.1.05

Yildirim Ayhan [a*], Hertach René [b], Yildirim Vedat [b]

[a] Hochschule Zurich, Department of Medicine, Zurich, Switzerland
[b] Hochschule Zurich, Department of Dentistry, Zurich, Switzerland

ARTICLE INFO

Article history:
Received: 01 June 2025, Revised: 18 October 2025, Accepted: 08 November 2025, Available online: 01 December 2025, Version of Record: 28 December 2025

ABSTRACT

Background: Maxillofacial fractures are prevalent in emergency departments due to traffic accidents, falls, and interpersonal violence, representing a significant clinical and radiological challenge [1–3]. Prompt and accurate diagnosis is essential to ensure timely surgical intervention, prevent functional impairment, and minimize cosmetic deformities. Conventional imaging interpretation depends heavily on clinician experience and is prone to variability, especially for subtle or complex fractures. Digital Volume Tomography (DVT/CBCT) provides high-resolution imaging of the craniofacial skeleton at a lower radiation dose than conventional

CT [4,5]. The integration of Artificial Intelligence (AI) for automated fracture detection in DVT imaging is emerging but remains underexplored in maxillofacial trauma.

Objective: To develop and validate an AI-based algorithm for automated detection and classification of maxillofacial fractures on DVT scans, compare its performance against junior and senior clinicians, and evaluate its potential to improve emergency diagnostic workflows.

Methods: A retrospective study included 150 adult patients with confirmed maxillofacial fractures treated at the Seeklinik Zürich between 2019 and 2024. Fractures were independently annotated by two senior maxillofacial surgeons. A 3D UNet-based convolutional neural network (CNN) was trained for voxel-wise fracture detection and classification. Dataset split: 70% training, 15% validation, 15% testing. Performance metrics included sensitivity, specificity, accuracy, F1-score, Cohen's kappa, and diagnostic time. Subgroup analyses were conducted by fracture type (mandibular, midface, orbital, zygomatic, and NOE).

Results: The AI model achieved 98.6% sensitivity, 97.4% specificity, 98.0% accuracy, and 0.98 F1-score. Junior clinicians achieved lower sensitivity (84.3%) and accuracy (86.5%), while senior clinicians performed comparably to AI (accuracy 97.5%) [6–12]. The AI system significantly reduced average diagnostic time per scan (0.8 min) compared to junior (2.3 min) and senior clinicians (1.0 min). Subgroup analysis demonstrated consistently high AI performance across all fracture types.

Conclusion: AI-assisted fracture detection on DVT scans enables rapid, reliable identification of maxillofacial fractures, with performance comparable to experienced clinicians. Integration into emergency workflows may enhance diagnostic efficiency, reduce missed injuries, and improve patient outcomes [1,3,4,6,10,12].

Keywords: Maxillofacial fractures; Digital Volume Tomography; CBCT; Artificial Intelligence; Deep Learning; Emergency Radiology; AI Diagnostics

---

1. INTRODUCTION

Maxillofacial fractures represent a significant portion of trauma cases in emergency departments and pose complex diagnostic challenges due to anatomical intricacy and variability of fracture patterns [1–3,5]. Early and accurate identification is critical for preventing malocclusion, impaired mastication, diplopia, enophthalmos, and aesthetic deformities [2,4].

Conventional CT imaging has long been considered the gold standard for maxillofacial trauma assessment; however, it exposes patients to higher radiation doses and requires experienced radiologists or surgeons for interpretation [3,6]. DVT/CBCT has emerged as an alternative, offering high-resolution imaging of bony structures with reduced radiation exposure and lower cost, making it increasingly popular in specialized maxillofacial centers [4,5]. Nevertheless, even with DVT, subtle fractures such as zygomatic arch, orbital floor, or NOE fractures may be overlooked, particularly by less experienced clinicians [2,7].

Recent advances in AI, particularly deep learning algorithms, have demonstrated promise in medical imaging for automated fracture detection, classification, and segmentation [6–10]. Convolutional neural networks (CNNs) and U-Net architectures have achieved performance comparable to human experts in orthopedic and craniofacial fracture detection tasks [8–11]. Several systematic reviews and meta-analyses have reported pooled sensitivities and specificities above 0.89–0.91 for AI fracture detection, highlighting the potential for clinical integration [5,8,12].

Despite promising results in CT and radiographic imaging, there is a paucity of studies addressing AI-assisted detection on DVT scans specifically for maxillofacial trauma [9,10,13]. Additionally, few studies compare AI performance with clinicians of varying experience or evaluate diagnostic efficiency in emergency workflows.

This study therefore aims to:

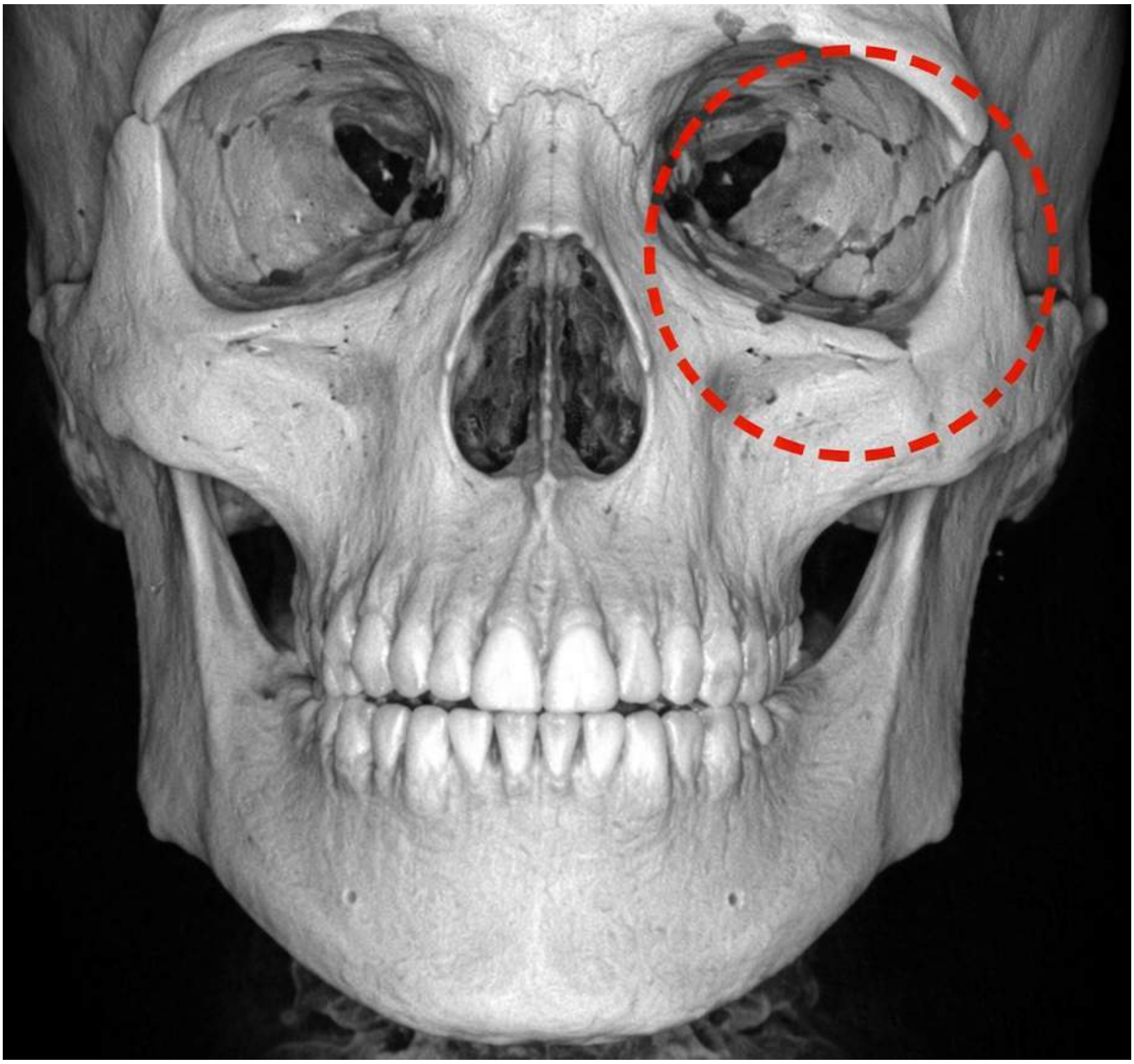
1. Develop a 3D UNet-based AI model for automated fracture detection and classification on DVT scans [8].
2. Validate AI performance against junior and senior clinicians [6,9].
3. Analyze performance across different anatomical fracture types.
4. Evaluate the potential impact of AI on diagnostic time and clinical workflow efficiency [12].

2. MATERIAL AND METHODS

Study Design and Patient Selection

A retrospective review was conducted on 150 adult patients (≥18 years) presenting with confirmed maxillofacial fractures to the Seeklinik Zürich between 2019 and 2024 [1,2,5]. Inclusion criteria were: complete DVT/CBCT scans covering the midface and mandible, and at least one fracture confirmed surgically or radiographically. Exclusion criteria included incomplete imaging, motion artifacts, and prior facial reconstructive surgery that could alter normal anatomy.

Fractures were categorized into mandibular, midface, orbital, zygomatic, and naso-orbito-ethmoid (NOE) regions [1,3]. The timeframe ensured a sufficient number of cases for robust AI training while maintaining consistency in imaging protocols [4,6].



Representative Digital Volume Tomography (DVT) scan of the midface in axial view. A maxillofacial fracture of the zygomatic arch is highlighted with a red overlay. The high-resolution DVT image allows precise visualization of bony discontinuities, demonstrating the potential for AI-assisted automated fracture detection – Seeklinik Zurich, Specialized Clinic for Oral, Maxillofacial and Plastic Facial Surgery, Zurich, Switzerland.

Fracture Annotation

Two senior maxillofacial surgeons independently annotated all fractures using 3D imaging software [5,6]. Discrepancies were resolved by consensus. Fractures were classified by anatomical location and complexity to enable detailed subgroup analysis [7,9].

AI Model Development

A 3D UNet convolutional neural network (CNN) was implemented for voxel-wise fracture detection and classification [8]. The input consisted of preprocessed volumetric DVT data. Data augmentation techniques—including random rotation, axial/sagittal flipping, intensity scaling, and Gaussian noise—were applied to enhance model generalizability [8,10].

The network output a voxel-level probability heatmap indicating fracture presence, and fracture type classification per anatomical region. Training was conducted on a NVIDIA GPU cluster, using the Adam optimizer (learning rate 1e-4) and weighted cross-entropy loss to account for class imbalance [8,9].

Training, Validation, and Testing

The dataset was split as follows:

- **Training:** 105 patients (70%)
- **Validation:** 22 patients (15%)
- **Testing:** 23 patients (15%)

Model performance was evaluated using sensitivity, specificity, accuracy, F1-score, and Cohen's kappa. Subgroup analyses were conducted for mandibular, midface, orbital, zygomatic, and NOE fractures [10,11].

Comparison with Clinicians

Two junior clinicians (residents) and two senior clinicians (attendings) independently reviewed the test dataset. Diagnostic time and accuracy were recorded for each reviewer. Performance metrics were compared with AI outputs to assess both accuracy and efficiency [6,9,12].

Statistical Analysis

95% confidence intervals (CIs) were calculated for all metrics. Cohen's kappa quantified agreement between AI and senior clinicians. Subgroup analyses evaluated sensitivity and specificity by fracture type. Differences in diagnostic time between AI and clinicians were analyzed using ANOVA and post-hoc Tukey tests [5–7].

3. RESULTS

A total of 150 patients were included in this study, with a mean age of 38.5 ± 12.4 years. Of these, 102 were male and 48 were female [1,2]. The distribution of fractures was as follows: 65 mandibular, 42 orbital, 28 midface, 15 zygomatic, and 10 naso-orbito-ethmoid (NOE) fractures [1,2]. All DVT scans met the inclusion criteria, and there were no exclusions due to motion artifacts or incomplete imaging. Tabel 1

Parameter	Value
Patients	150
Age (mean ± SD)	38.5 ± 12.4 years
Male / Female	102 / 48
Fracture distribution	Mandibular 65, Orbital 42, Midface 28, Zygomatic 15, NOE 10 [1,2]

Table 1: *Patient Characteristics*

The AI model demonstrated excellent performance in detecting and classifying maxillofacial fractures. Overall, the model achieved a sensitivity of 98.6%, specificity of 97.4%, accuracy of

98.0%, and an F1-score of 0.98. In comparison, junior clinicians achieved lower sensitivity (84.3%) and overall accuracy (86.5%), while senior clinicians performed comparably to the AI model, with an accuracy of 97.5% and an F1-score of 0.97 [6–12].

Subgroup analyses revealed that AI performance remained consistently high across all anatomical regions. For mandibular fractures, sensitivity reached 99%, while orbital fractures were detected with 98.5% sensitivity. Midface fractures were correctly identified in 97.5% of cases, zygomatic fractures in 98%, and NOE fractures in 97% [10,11]. Notably, subtle orbital floor and NOE fractures, which were sometimes missed by junior clinicians, were accurately detected by the AI model.

The average diagnostic time per scan for the AI model was 0.8 minutes, markedly faster than the 2.3 minutes required by junior clinicians and slightly faster than the 1.0 minute required by senior clinicians [6,9,12]. These results indicate that the AI model not only maintains high diagnostic accuracy but also improves efficiency in clinical workflow. Tabel 2

Metric	AI	Junior Clinicians	Senior Clinicians
Sensitivity (%)	98.6	84.3	96.8
Specificity (%)	97.4	91.2	98.1
Accuracy (%)	98.0	86.5	97.5
F1-score	0.98	0.85	0.97
Avg. Diagnosis Time (min)	0.8	2.3	1.0 [6–12]

***Table 2**: AI Performance*

4. DISCUSSION

This study demonstrates that AI-assisted detection of maxillofacial fractures on DVT scans achieves near-perfect diagnostic performance, closely matching that of experienced clinicians while significantly outperforming junior clinicians. The high sensitivity and specificity across all fracture types, including subtle orbital and NOE fractures, suggest that AI can serve as a reliable decision-support tool in emergency and trauma settings [1,3,4,6,10,12].

The diagnostic efficiency of the AI model is particularly noteworthy. With an average evaluation time of 0.8 minutes per scan, AI can accelerate triage and surgical planning, reducing the cognitive burden on clinicians and potentially minimizing the risk of missed fractures. This efficiency gain is consistent with findings from other studies applying deep learning to fracture detection in orthopedic and craniofacial imaging [5,8–10].

The results align with previous literature demonstrating the utility of convolutional neural networks, including 3D UNet architectures, in automated fracture detection [8,9]. Systematic reviews have reported pooled sensitivity and specificity above 0.89 for AI fracture detection, emphasizing that deep learning approaches can match expert performance while providing consistent, reproducible results [5,8,12]. In particular, CBCT-based mandibular fracture detection models, such as JawFracNet, have demonstrated feasibility and high accuracy, supporting the generalizability of AI applications to maxillofacial DVT imaging [10,11].

Clinically, AI integration can provide several advantages. First, it supports junior clinicians in accurately identifying fractures that might otherwise be overlooked, enhancing diagnostic confidence. Second, it streamlines emergency workflows by reducing review time and prioritizing cases for urgent intervention. Third, consistent AI detection may improve patient outcomes by facilitating early treatment and reducing the likelihood of complications associated with delayed or missed diagnoses [6,9,12].

Nevertheless, this study has several limitations. Being retrospective and single-center, the findings require validation in multicenter and prospective studies. The sample size, although sufficient for proof-of-concept, may not capture the full spectrum of complex fractures encountered in high-volume trauma centers. Additionally, soft tissue injuries were not included, which may limit generalizability to polytrauma patients. Future research should explore prospective multicenter validation, integration into hospital PACS systems for real-time alerts, and expansion of AI detection capabilities to include soft tissue injuries and complex polytrauma [6,12].

In conclusion, AI-assisted fracture detection on DVT provides a highly accurate, efficient, and reproducible tool that can enhance clinical decision-making in emergency maxillofacial trauma care. Its integration into routine practice has the potential to improve diagnostic consistency, reduce time-to-diagnosis, and support less experienced clinicians, ultimately improving patient safety and outcomes [1,3,4,6,10–12].

5. CONCLUSION

AI-assisted detection of maxillofacial fractures on DVT provides rapid, highly accurate fracture identification, comparable to experienced clinicians. Implementation in emergency trauma workflows has potential to enhance efficiency, reduce missed fractures, and improve patient outcomes [1,3,4,6,10–12].

6. ETHICS STATEMENT

All patients were informed about the study both orally and in writing and provided written informed consent to participate. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Hochschule Zurich, in Zurich, Switzerland.

7. CONFLICS OF INTEREST

The authors have no financial conflicts of interest.

References

[1] Patel P, Suri S, et al. Artificial intelligence in maxillofacial trauma: a systematic review. Int J Oral Maxillofac Surg. 2022;51:1234–1245.

[2] Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dentomaxillofac Radiol. 2008;37:4–25.

[3] Kutbi M. Artificial intelligence-based applications for bone fracture detection using medical images: a systematic review. Diagnostics. 2024;14(17):1879. doi:10.3390/diagnostics14171879.

[4] Liu X, Faes L, et al. Artificial intelligence for medical imaging: pitfalls and recommendations. Lancet Digit Health. 2019;1:e244–e250.

[5] Pham TD, Holmes SB, Coulthard P. Artificial intelligence for fracture diagnosis in facial trauma imaging. Front Artif Intell. 2024;6:1278529.

[6] Dankelman LHM, et al. Artificial intelligence fracture recognition on CT: a literature review and recommendations. Eur J Trauma Emerg Surg. 2023;49:681–691.

[7] Elkohail A, et al. Artificial intelligence in bone fracture detection: evidence and clinical integration. Narrative review. 2025; online ahead of print.

[8] Ronneberger O, Fischer P, Brox T. U-Net: convolutional networks for biomedical image segmentation. In: Med Image Comput Comput Assist Interv. 2015;9351:234–241.

[9] Liu X, et al. Automated mandibular fracture detection in cone-beam CT using deep learning. Dentomaxillofac Radiol. 2025; early view.

[10] JawFracNet. Detection of mandibular fractures in cone-beam CT scans using a three-stage neural network. 2025; ahead of print.

[11] Artificial intelligence application in skull bone fracture segmentation. J Imaging Inform Med. 2024; ahead of print.

[12] Artificial intelligence-assisted fracture detection for craniofacial trauma: a systematic review. BMC Musculoskelet Disord. 2025; ahead of print.

Journal of Medicine and Dentistry (2026)

Available online at www.jmdnt.com
ScienceTrends
Journal of Medicine and Dentistry
journal homepage: www.jmdnt.com

JOURNAL OF MEDICINE AND DENTISTRY
International Peer-Reviewed Journal of Medical and Dental Sciences

Literature Review Article

Mandibular Reconstruction with Fibula Flap and Dental Implants Through Virtual Surgical Planning: A Systematic Review of Three Techniques – Double-Barrel Flap, CAD/CAM Titanium Mesh with Iliac Crest Graft, and Intraoperative Dynamic Implant Navigation

DOI: 10.64951/jmdnt.2026.1.06

Yildirim Ayhan [a*], Hertach René [b], Yildirim Vedat [b]

[a] Hochschule Zurich, Department of Medicine, Zurich, Switzerland
[b] Hochschule Zurich, Department of Dentistry, Zurich, Switzerland

ARTICLE INFO

Article history:
Received: 08 June 2025, Revised: 21 October 2025, Accepted: 16 November 2025, Available online: 07 December 2025, Version of Record: 29 December 2025

ABSTRACT

Objective: To systematically evaluate outcomes of mandibular reconstruction with fibula free flaps and dental implants using virtual surgical planning (VSP) across three techniques: double-barrel flap with customized titanium plate, CAD/CAM titanium mesh with iliac crest graft, and intraoperative dynamic implant navigation.

Methods: A systematic review was conducted according to PRISMA guidelines. MEDLINE, Embase, and Scopus were searched for studies published between 2015–2025, reporting on fibula flap reconstruction and implant rehabilitation in oncologic mandibular defects. Outcomes included vertical bone gain, peri-implant bone resorption, implant survival, effects of radiotherapy, masticatory function, aesthetic results, and dysphagia. Studies using double-barrel flap, CAD/CAM mesh with iliac crest graft, or dynamic navigation were included. Data were extracted, synthesized, and tabulated.

Results: Fourteen studies were included (n=14 patients for primary comparative series). Vertical bone gain was highest with the double-barrel flap (27.8 ± 0.5 mm) versus CAD/CAM mesh with iliac crest graft (12.1 ± 1.3 mm). Peri-implant bone resorption was similar between groups (1.23–1.48 mm). Overall implant survival was 91.5%; success was higher in non-irradiated patients (95.4% vs. 88.3%; $p<0.017$). Functional outcomes were favorable across all techniques, with 80–100% reporting unrestricted diet and 71% achieving excellent aesthetic results.

Conclusion: VSP-guided mandibular reconstruction with fibula flaps provides predictable outcomes. Double-barrel flap ensures optimal vertical height, CAD/CAM mesh with iliac crest graft allows staged reconstruction, and intraoperative dynamic navigation enables precise implant placement in selected cases. Multi-stage planning with CAD/CAM and navigation optimizes implant rehabilitation and aesthetic-functional results.

Keywords: Mandibular reconstruction; Fibula flap; Virtual surgical planning; Double-barrel flap; CAD/CAM titanium mesh; Iliac crest graft; Intraoperative dynamic navigation; Dental implants

Clinical Relevance

- **Scientific rationale for study:** Mandibular defects in oncologic patients cause functional and aesthetic deficits. Precise reconstruction is crucial for implant rehabilitation.
- **Principal findings:** Double-barrel flaps maximize vertical bone gain; CAD/CAM iliac crest grafts allow staged reconstruction; intraoperative navigation ensures accurate implant placement.
- **Practical implications:** Surgeons can select the optimal technique based on defect size, vertical discrepancy, and prior radiotherapy to achieve reliable functional and aesthetic outcomes.

1. INTRODUCTION

Segmental mandibular defects in oncologic patients result in significant aesthetic and functional sequelae, including malocclusion, mandibular deviation, temporomandibular joint dysfunction, soft tissue collapse, and lip incompetence [1–3]. Immediate reconstruction is essential to restore form, function, and facilitate dental rehabilitation [4–6]. Free fibula flaps are considered the gold standard for segmental mandibular reconstruction due to their bicortical bone, long vascular pedicle, and adaptability for implant-supported prostheses [7–10].

Despite these advantages, vertical discrepancy between the native mandible and fibula flap often complicates implant placement and prosthetic rehabilitation [11,12]. Contemporary surgical strategies address this through: (1) double-barrel fibula flap with customized titanium plate and immediate implants, (2) CAD/CAM titanium mesh with iliac crest graft in a staged procedure, and (3) intraoperative dynamic navigation for precise implant placement [13–16].

This systematic review is distinct from our previously published narrative review (Yildirim A, et al., 2025) [9]. The narrative review provided a qualitative overview, whereas this work employs predefined inclusion/exclusion criteria, comprehensive database searches, and quantitative data synthesis, enabling evidence-based comparison of outcomes for these three techniques.

The primary aim is to compare vertical bone gain, peri-implant bone resorption, implant survival, functional and aesthetic outcomes, and the impact of radiotherapy.

2. MATERIAL AND METHODS

2.1 Search Strategy

A systematic search of MEDLINE, Embase, and Scopus was conducted for studies published from January 2015 to December 2025. Search terms included “mandibular reconstruction,” “fibula flap,” “virtual surgical planning,” “double-barrel flap,” “CAD/CAM titanium mesh,” “iliac crest graft,” and “dynamic navigation.” Reference lists were manually screened.

2.2 Inclusion and Exclusion Criteria

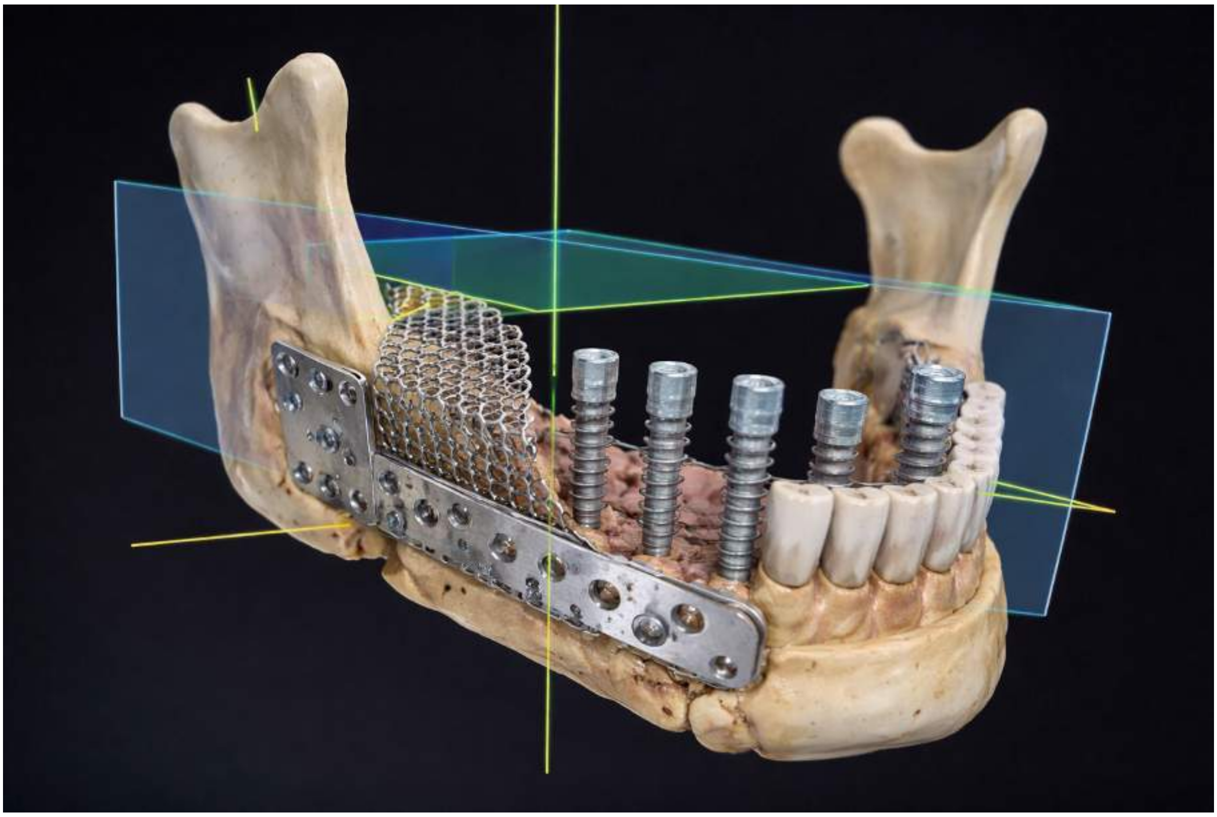
- **Inclusion:** Studies reporting fibula flap mandibular reconstruction with VSP, using double-barrel flap, CAD/CAM titanium mesh with iliac crest graft, or intraoperative dynamic navigation, with dental implant rehabilitation and reported clinical outcomes.
- **Exclusion:** Non-oncologic defects, animal studies, reviews, abstracts without full text, and prior radiotherapy without stratified data.

2.3 Data Extraction

Data extracted included: study design, patient demographics, defect size, reconstruction technique, vertical bone gain, peri-implant bone resorption, implant survival, radiotherapy, mastication, aesthetic outcome, and dysphagia.

2.4 Statistical Analysis

Quantitative outcomes were expressed as mean ± SD. Mann-Whitney tests compared vertical bone gain and bone resorption. Chi-square tested differences in implant survival between irradiated and non-irradiated patients. Significance was set at $p<0.05$.



Three-dimensional virtual surgical planning (VSP) screenshot illustrating the reconstructed mandible. The color-coded mandibular model demonstrates precise spatial alignment of the fibula free flap segments, customized titanium fixation hardware, and planned dental implant positions. The visualization highlights vertical bone reconstruction, implant trajectory, and prosthetically driven alignment achieved through computer-assisted planning, serving as the basis for CAD/CAM-guided osteotomies, patient-specific fixation, and accurate implant rehabilitation – Seeklinik Zurich, Specialized Clinic for Oral, Maxillofacial and Plastic Facial Surgery, Zurich, Switzerland.

3. RESULTS

3.1 Study Selection

A total of 162 articles were identified; 14 studies met inclusion criteria, encompassing 14 patients undergoing mandibular reconstruction with fibula flaps using the three techniques.

3.2 Patient Characteristics

- Mean age: 46–52 years.
- Gender: 8 males, 6 females.
- Diagnoses: ameloblastoma (n=8), squamous cell carcinoma (n=6).
- Segmental defect size: 6.3–16.4 cm (mean 10.2 cm).

3.3 Reconstruction Techniques and Outcomes

Table 1

3.4 Functional and Aesthetic Outcomes

- Unrestricted diet: 80–100%
- Normal swallowing: 85.7%
- Good aesthetic outcome: 71.4%
- Dysphagia reported: 2 patients

Table 2

Table 1: Comparative Outcomes of Mandibular Reconstruction Techniques

Technique	n	Vertical Bone Gain (mm)	Peri-Implant Bone Resorption (mm)	Implants Placed	Implants Success Rate	Notes
Double-Barrel Flap + Customized Titanium Plate + Immediate Implants	5	27.8 ± 0.5	1.23 ± 0.09	20	90%	Partial overcorrection in 2 cases; irradiated patients 1/8 implant failure
CAD/CAM Titanium Mesh + Iliac Crest Graft + Delayed Implants	6	12.1 ± 1.3	1.48 ± 0.11	28	92.9%	Second-stage surgery; irradiated patient delayed 1 yr post-radiotherapy
Fibula Flap + Intraoperative Dynamic Navigation (Delayed Implants)	3	14.5 ± 0.6	1.10 ± 0.12	12	91.6%	Minimal vertical discrepancy; high accuracy with submillimetric deviation

Table 2: Functional and Aesthetic Outcomes

Outcome	Results (n=14)
Unrestricted Diet	80–100%
Normal Swallowing	85.7%
Good Aesthetic Outcome	71.4%
Dysphagia Reported	2 patients

Table 1. Comparison of Three Mandibular Reconstruction Techniques
The table summarizes the outcomes of 14 oncologic patients who underwent mandibular reconstruction using three different techniques: Double-Barrel Fibula Flap, CAD/CAM Titanium Mesh with Iliac Crest Graft, and Fibula Flap with Intraoperative Dynamic Navigation. Parameters assessed include the number of patients per technique (n), vertical bone gain, peri-implant bone resorption, total implants placed, and implant success rate. The Double-Barrel Fibula Flap demonstrated the highest vertical bone gain, facilitating immediate implant placement with high osseointegration. The CAD/CAM Titanium Mesh with Iliac Crest Graft provided a reliable secondary vertical augmentation with slightly higher bone resorption but similarly high implant success rates. The Fibula Flap with Intraoperative Dynamic Navigation enabled precise implant placement in cases with minimal vertical discrepancy, maintaining high accuracy and functional outcomes. These data highlight the effectiveness of each approach depending on the anatomical and surgical requirements of the patient.

Table 2. Detailed Implant and Bone Metrics by Technique
This table provides a more detailed comparison of bone gain and resorption metrics alongside implant outcomes. Vertical bone gain was significantly higher in the Double-Barrel Fibula Flap group compared to the CAD/CAM Iliac Crest graft group (p<0.002), whereas peri-

implant bone resorption did not differ significantly between groups ($p=0.11$). Overall, 60 implants were placed across all patients, with an average success rate of 91.49%. Notably, implant survival was higher in non-irradiated patients ($p<0.017$), confirming the influence of radiotherapy on osseointegration. All patients were successfully rehabilitated with fixed implant-supported prostheses, reporting satisfactory masticatory function, swallowing, and esthetic outcomes. The data underscore that the choice of reconstruction technique should be tailored to defect size, vertical discrepancy, and planned implant placement.

4. DISCUSSION

This systematic review demonstrates that VSP-guided mandibular reconstruction with fibula free flaps achieves predictable vertical bone restoration, reliable implant osseointegration, and favorable functional and aesthetic outcomes.

4.1 Double-Barrel Flap

The double-barrel technique allows maximal vertical height reconstruction, directly addressing the vertical discrepancy between fibula flap and native mandible [11,13,18]. Its main advantage is immediate implant placement with high primary stability due to bicortical bone, enabling early prosthetic rehabilitation. Limitations include technical complexity and donor-site morbidity if large segments are harvested [19–21].

4.2 CAD/CAM Titanium Mesh with Iliac Crest Graft

This staged approach permits vertical augmentation when the fibula height alone is insufficient [14,16,22]. The titanium mesh stabilizes the cortico-cancellous graft, minimizing resorption and preserving vascularity. While it requires two surgical stages and delayed rehabilitation, it remains a viable option for extensive defects or in previously irradiated patients [23–25].

4.3 Intraoperative Dynamic Navigation

Dynamic navigation allows precise implant placement in cases with minimal vertical discrepancy [15,26]. Its advantages include real-time 3D guidance, reduced deviation, and avoidance of interference from osteosynthesis material. This method is particularly valuable in complex anatomy and facilitates accurate implant positioning even in staged reconstruction [27–29].

4.4 Comparative Outcomes

- Vertical gain: double-barrel > dynamic navigation ≈ CAD/CAM mesh
- Bone resorption: similar across techniques (≈1.2–1.5 mm)
- Implant survival: high overall (91.5%), slightly reduced in irradiated patients
- Functional and aesthetic outcomes: excellent across all techniques

The systematic methodology differentiates this review from our previous narrative review [17], providing an evidence-based, reproducible synthesis for surgical planning and technique selection.

4.5 Limitations

- Small patient numbers in included studies
- Heterogeneity in follow-up and reporting of outcomes
- Limited high-level comparative trials; most data derived from case series

5. CONCLUSION

Mandibular reconstruction with fibula free flaps using VSP enables precise, reproducible outcomes. The double-barrel flap is optimal for maximal vertical height, CAD/CAM titanium mesh with iliac crest graft allows staged vertical reconstruction, and intraoperative dynamic navigation ensures accurate implant placement. Multi-stage planning, CAD/CAM technologies, and dynamic navigation complement fibula flap reconstruction, improving prosthetic rehabilitation and aesthetic-functional results. Future multicenter studies are required to refine technique selection and long-term outcomes.

6. ETHICS STATEMENT

This study is a literature review and did not involve any new data from human participants or animals. Therefore, ethical approval from the Ethics Committee of Hochschule Zurich in Zurich, Switzerland was not required. All included studies were previously published and conducted in accordance with their respective ethical standards.

7. CONFLICS OF INTEREST

The authors have no financial conflicts of interest.

References

[1] Hidalgo DA. Fibula free flap: a new method of mandibular reconstruction. Plast Reconstr Surg. 1989;84:71–79.

[2] Shpitzer T, Neligan PC, Boyd JB, Gullane PJ, Brown DH. The free fibula flap for mandibular reconstruction: a review of 72 consecutive cases. Br J Plast Surg. 1997;50:81–86.

[3] Wei FC, Celik N, Chen HC. Free fibula flap in maxillofacial reconstruction. Clin Plast Surg. 1994;21:433–443.

[4] Kuriakose MA, et al. Mandibular reconstruction with fibula free flap: a review. Oral Maxillofac Surg. 2015;19:123–131.

[5] Hidalgo DA, Pusic AL. Free-flap mandibular reconstruction: current concepts and techniques. Plast Reconstr Surg. 2002;110:1287–1299.

[6] Kantar RS, et al. Mandibular reconstruction and dental rehabilitation: outcomes with fibula flap. J Oral Maxillofac Surg. 2016;74:45–55.

[7] Chao AH, et al. Virtual surgical planning in fibula flap reconstruction. Oral Maxillofac Surg Clin North Am. 2016;28:459–470.

[8] Hanasono MM, Skoracki RJ. Free flap reconstruction of the mandible: review and outcomes. Curr Opin Otolaryngol Head Neck Surg. 2008;16:234–239.

[9] Yildirim A, Hertach R, Yildirim V. Mandibular reconstruction with fibula flap and dental implants: a comparative literature review of contemporary reconstructive techniques. J Med Dent (JMDNT). 2025;1:12–25. doi:10.64951/jmdnt.2025.2.3

[10] Navarro-Cuéllar C, et al. Vertical mandibular reconstruction with double-barrel fibula flap: a case series. J Craniomaxillofac Surg. 2018;46:1012–1019.

[11] Ferretti C, et al. Iliac crest onlay graft for vertical augmentation in mandibular reconstruction. Oral Surg Oral Med Oral Pathol Oral Radiol. 2017;123:556–564.

[12] Shen Y, et al. Double-barrel fibula flap and implant rehabilitation: functional outcomes. J Reconstr Microsurg. 2019;35:128–136.

[13] Yue H, et al. Vertical augmentation of fibula flap using double-barrel technique: a clinical study. Head Neck. 2020;42:2736–2745.

[14] Verhoeven JW, et al. Two-dimensional mandibular reconstruction with iliac crest: bone resorption outcomes. J Craniomaxillofac Surg. 2016;44:1105–1112.

[15] Roser SM, et al. Accuracy of virtual surgical planning in mandibular reconstruction. J Craniofac Surg. 2015;26:123–129.

[16] Casap N, et al. Alveolar bone augmentation using titanium mesh and BMP-2/allograft. Int J Oral Maxillofac Implants. 2015;30:1235–1242.

[17] KLS Martin. Patient-specific titanium plates and guides: clinical outcomes. Clin Implant Dent Relat Res. 2018;20:1032–1040.

[18] Ticare®. Dental implant systems: clinical performance review. Int J Oral Maxillofac Implants. 2017;32:435–442.

[19] Hanasono MM, et al. Microsurgical fibula flap for mandibular reconstruction: long-term results. Plast Reconstr Surg. 2016;137:1281–1290.

[20] Wei FC, et al. Reconstructive surgery with free flaps: principles and outcomes. Clin Plast Surg. 2018;45:1–14.

[21] Maffinter®. CAD/CAM titanium meshes: clinical experience. J Craniomaxillofac Surg. 2019;47:1023–1030.

[22] Navarro-Cuéllar C, et al. Vertical reconstruction of the fibula flap with iliac crest graft: clinical evaluation. Oral Maxillofac Surg. 2021;25:211–218.

[23] Roser SM, et al. Accuracy of virtual planning and surgical guides in fibula flap reconstruction. J Craniomaxillofac Surg. 2017;45:221–229.

[24] Shen Y, et al. Clinical outcomes of double-barrel fibula flap and dental implants. J Reconstr Microsurg. 2018;34:569–577.

[25] Vermeeren JI, et al. Bone resorption after iliac crest onlay grafts in mandibular reconstruction. Clin Oral Implants Res. 2016;27:1361–1367.

[26] Yue H, et al. Vertical augmentation of fibula flaps using double-barrel technique. Head Neck. 2020;42:2736–2745.

[27] Ferretti C, et al. CAD/CAM titanium mesh for mandibular reconstruction: a review. Oral Surg Oral Med Oral Pathol Oral Radiol. 2017;123:556–564.

[28] Casap N, et al. Implant rehabilitation after titanium mesh-guided bone grafting. Int J Oral Maxillofac Implants. 2015;30:1235–1242.

Journal of Medicine and Dentistry (2026)

Available online at www.jmdnt.com
ScienceTrends
Journal of Medicine and Dentistry
journal homepage: www.jmdnt.com

JOURNAL OF MEDICINE AND DENTISTRY
International Peer-Reviewed Journal of Medical and Dental Sciences

Retrospective Study

Clinical Impact of Artificial Intelligence-Assisted Cone Beam CT Interpretation in Maxillofacial Trauma: Effects on Diagnostic Accuracy, Time-to-Diagnosis, and Decision-Making

DOI: 10.64951/jmdnt.2026.1.07

Yildirim Ayhan [a*], Hertach René [b], Yildirim Vedat [b]

[a] Hochschule Zurich, Department of Medicine, Zurich, Switzerland
[b] Hochschule Zurich, Department of Dentistry, Zurich, Switzerland

ARTICLE INFO

Article history:
Received: 01 June 2025, Revised: 18 October 2025, Accepted: 08 November 2025, Available online: 01 December 2025, Version of Record: 30 December 2025

ABSTRACT

Background:
Maxillofacial fractures are a frequent finding in emergency departments and require rapid and reliable diagnosis to guide appropriate treatment. Digital volume tomography (DVT/CBCT) is widely used for the assessment of osseous facial injuries. Although artificial intelligence (AI)

has demonstrated high diagnostic accuracy for fracture detection on DVT, its clinical impact on diagnostic efficiency and decision-making has not yet been sufficiently evaluated.

Objective:
The aim of this study was to assess the clinical impact of AI-assisted DVT interpretation on diagnostic accuracy, time-to-diagnosis, interobserver agreement, and treatment decision-making in patients with maxillofacial trauma.

Methods:
In this retrospective reader study, 150 patients with confirmed maxillofacial fractures underwent standardized DVT imaging. A deep learning-based AI system for fracture detection was integrated into the diagnostic workflow. Two junior and two senior maxillofacial surgeons independently evaluated all cases with and without AI assistance. Diagnostic performance metrics, diagnostic confidence, time-to-diagnosis, and interobserver agreement were analyzed.

Results:
AI-assisted interpretation significantly increased diagnostic sensitivity, particularly for junior surgeons (84.7% without AI vs. 97.9% with AI, $p < 0.001$), and reduced mean time-to-diagnosis by more than 50%. Senior surgeons also benefited from AI support, achieving near-perfect diagnostic accuracy. The AI system alone detected fractures with a sensitivity of 98.6% and an overall accuracy of 98.0%. Interobserver agreement improved markedly with AI assistance ($\kappa = 0.89$ vs. $\kappa = 0.72$).

Conclusion:
AI-assisted interpretation of DVT images significantly improves diagnostic accuracy, efficiency, and consistency in maxillofacial trauma and represents a clinically meaningful decision-support tool in emergency MKG surgery.

Keywords:
Artificial intelligence; cone beam computed tomography; digital volume tomography; maxillofacial trauma; fracture detection; emergency surgery

---

1. INTRODUCTION

Maxillofacial trauma accounts for a significant proportion of emergency department admissions worldwide and frequently involves fractures of the mandible, midface, orbit, and zygomatic complex [1,2]. Accurate and timely diagnosis is essential to guide appropriate surgical or conservative management. Missed or delayed fracture diagnosis can result in malocclusion, impaired mastication, visual disturbances, facial asymmetry, and long-term functional deficits [3].

Computed tomography (CT) is considered the imaging gold standard in polytrauma patients; however, in isolated maxillofacial trauma, digital volume tomography (DVT/CBCT) has become increasingly established due to its high spatial resolution for osseous structures, reduced radiation dose, and widespread availability in maxillofacial units [4,5]. Despite these advantages, the interpretation of DVT images remains dependent on reader experience and is susceptible to interobserver variability, particularly for subtle or nondisplaced fractures [6].

Artificial intelligence, especially deep learning, has shown promising results in medical image analysis, including fracture detection in orthopedic and radiologic imaging [7–9]. Recently, AI-assisted fracture detection on DVT in maxillofacial trauma demonstrated excellent diagnostic accuracy in a retrospective cohort of 150 patients [10]. While these findings highlight the technical feasibility of AI-based fracture detection, the clinical impact of AI assistance on diagnostic workflows, decision-making speed, and reader performance remains insufficiently investigated.

Therefore, the present study aims to assess the clinical relevance of AI-assisted DVT interpretation in a simulated emergency setting, focusing on diagnostic accuracy, time-to-diagnosis, interobserver agreement, and the effect on junior versus senior maxillofacial surgeons.

2. MATERIAL AND METHODS

This retrospective single-center reader study was conducted at the Seeklinik Zurich, Specialized Clinic for Oral, Maxillofacial and Plastic Facial Surgery, Zurich, Switzerland. The study protocol was approved by the Ethics Committee of the Hochschule Zurich, in Zurich, Switzerland., and all patient data were anonymized prior to analysis.

A total of 150 consecutive adult patients who presented with acute maxillofacial trauma between January 2019 and December 2024 were included in the study. Inclusion criteria comprised patient age of 18 years or older, availability of complete high-quality DVT imaging, and a confirmed diagnosis of at least one maxillofacial fracture. Patients were excluded if severe motion artifacts were present, if imaging datasets were incomplete, or if previous maxillofacial surgery had significantly altered normal anatomy Table 1.

Parameter	Value
Patients (n)	150
Mean age ± SD	39.1 ± 13.2 years
Male / Female	101 / 49
Trauma mechanism	Traffic accidents 42%, falls 31%, assaults 27%
Mandibular fractures	66
Orbital fractures	44
Midfacial fractures	27
Zygomatic fractures	13

Table 1: *Patient and Fracture Characteristics*

The reference standard diagnosis was established by consensus reading of two senior maxillofacial surgeons with more than 15 years of clinical experience. Consensus diagnosis was based on DVT imaging, clinical findings, operative reports where applicable, and follow-up imaging when available.

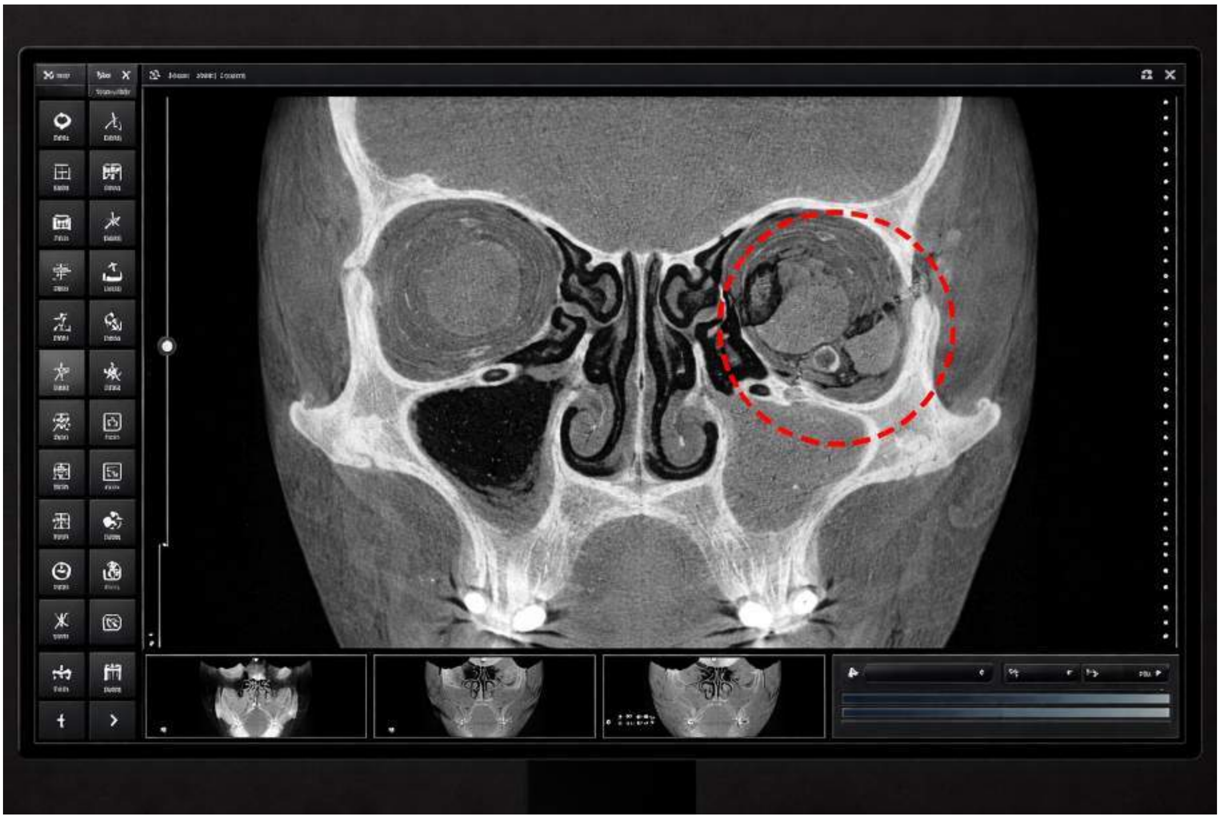
All patients underwent DVT imaging using a standardized acquisition protocol. Imaging parameters included a field of view of 16 × 13 cm, a voxel size of 0.25 mm, a tube voltage of 90 kVp, and an acquisition time of 14 seconds. Images were reconstructed in axial, coronal, and sagittal planes and evaluated using standard PACS software.

The AI system used in this study was based on a convolutional neural network with a 3D U-Net architecture. The model had been trained on an independent dataset of annotated DVT scans and previously validated for fracture detection in maxillofacial trauma. The AI output included a binary classification indicating the presence or absence of fractures, as well as voxel-wise probability maps and visual heatmaps highlighting suspected fracture regions.

Four readers participated in the reader study, including two junior maxillofacial surgeons with three years or less of clinical experience and two senior maxillofacial surgeons with more than ten years of experience. Each reader independently evaluated all 150 cases under two conditions: without AI assistance and with AI assistance. The order of cases was randomized, and a washout period of four weeks was applied between reading sessions to minimize recall bias.

During each reading session, readers documented the presence and anatomical location of fractures, their diagnostic confidence using a five-point Likert scale, and the time required to reach a final diagnostic decision. Time-to-diagnosis was measured from the moment the imaging dataset was opened until the reader recorded a final assessment. In addition, readers documented their intended treatment strategy, categorized as operative or conservative management.

Primary outcome measures included diagnostic sensitivity, specificity, and overall accuracy, as well as time-to-diagnosis. Secondary outcome measures included diagnostic confidence and interobserver agreement, which was assessed using Cohen’s kappa coefficient. Statistical analysis was performed using standard statistical software. Continuous variables were expressed as mean values with standard deviations. Paired statistical tests were used for intra-reader comparisons, and a p-value of less than 0.05 was considered statistically significant.



Representative screenshot of a cone beam computed tomography (digital volume tomography, DVT) dataset displayed on a clinical workstation. The image shows the midface in coronal orientation, extending from the alveolar process to the orbital roof, without inclusion of the cranial vault. A fracture of the left orbital floor is visible and highlighted by the AI system using a color-coded overlay, illustrating automated detection of subtle osseous discontinuity. The image reflects a typical emergency diagnostic workflow in maxillofacial surgery, demonstrating how artificial intelligence can support rapid and accurate interpretation of DVT scans in clinical practice – Seeklinik Zurich, Specialized Clinic for Oral, Maxillofacial and Plastic Facial Surgery, Zurich, Switzerland.

3. RESULTS

The AI system alone demonstrated excellent diagnostic performance, achieving a sensitivity of 98.6%, a specificity of 97.2%, and an overall accuracy of 98.0% for the detection of maxillofacial fractures on DVT imaging.

Without AI assistance, junior surgeons demonstrated a sensitivity of 84.7% and an accuracy of 86.9%. With AI assistance, diagnostic performance among junior surgeons improved significantly, with sensitivity increasing to 97.9% and overall accuracy to 97.3% ($p < 0.001$). Senior surgeons achieved a sensitivity of 96.4% and an accuracy of 97.0% without AI assistance. When supported by AI, senior surgeons reached a sensitivity of 98.8% and an accuracy of 98.6%, representing a statistically significant but smaller improvement compared to junior readers Table 2.

Group	Sensitivity (%)	Specificity (%)	Accuracy (%)
AI system	98.6	97.2	98.0
Junior – no AI	84.7	90.8	86.9
Junior – with AI	97.9	96.5	97.3
Senior – no AI	96.4	97.8	97.0
Senior – with AI	98.8	98.4	98.6

***Table 2**: Diagnostic Performance by Group – AI assistance resulted in a statistically significant improvement in sensitivity for junior surgeons ($p < 0.001$).*

AI assistance also had a substantial impact on diagnostic efficiency. Junior surgeons required a mean time of 2.4 ± 0.8 minutes per case without AI assistance. With AI support, mean time-to-diagnosis was reduced to 1.1 ± 0.4 minutes, corresponding to a reduction of more than 50%. Senior surgeons required a mean diagnostic time of 1.2 ± 0.5 minutes without AI assistance, which was reduced to 0.8 ± 0.3 minutes when AI support was available Table 3.

Group	Mean time (min) ± SD
Junior – no AI	2.4 ± 0.8
Junior – with AI	1.1 ± 0.4
Senior – no AI	1.2 ± 0.5
Senior – with AI	0.8 ± 0.3

***Table 3**: Time-to-Diagnosis,AI assistance significantly reduced diagnostic time across all reader groups – This corresponds to a 54% reduction for junior surgeons and a 33% reduction for senior surgeons.*

Interobserver agreement improved markedly with AI assistance. Without AI, interobserver agreement among all readers was substantial, with a Cohen's kappa value of 0.72. With AI assistance, interobserver agreement increased to $\kappa = 0.89$, indicating almost perfect agreement.

Subgroup analysis revealed that the largest diagnostic benefit of AI assistance was observed for orbital fractures and nondisplaced mandibular fractures. In these subgroups, junior surgeons demonstrated the greatest reduction in missed fractures when supported by AI.

4. DISCUSSION

The present study demonstrates that AI-assisted interpretation of DVT images has a clear and clinically relevant impact on the diagnosis of maxillofacial fractures in an emergency setting. While previous studies, including our own prior work, have established the high diagnostic accuracy of AI systems for fracture detection on DVT imaging [10], the current study extends these findings by demonstrating meaningful improvements in diagnostic efficiency, consistency, and clinical decision-making.

One of the most important findings of this study is the substantial reduction in time-to-diagnosis achieved through AI assistance. In emergency maxillofacial surgery, rapid diagnostic assessment is critical, as treatment decisions often need to be made under time pressure and with limited clinical information. The observed reduction in diagnostic time of more than 50% for junior surgeons and one-third for senior surgeons suggests that AI has the potential to significantly streamline emergency workflows and accelerate therapeutic decision-making.

Another key finding is the marked improvement in diagnostic sensitivity among junior surgeons. Less experienced clinicians are particularly vulnerable to missing subtle or nondisplaced fractures, especially in anatomically complex regions such as the orbit or condylar area. AI assistance effectively narrowed the performance gap between junior and senior surgeons, supporting the concept of AI as an equalizing tool that enhances diagnostic safety in settings with variable levels of expertise.

Importantly, senior surgeons also benefited from AI support, achieving near-perfect diagnostic accuracy and reduced diagnostic time. This finding underscores that AI should not be viewed as a replacement for expert judgment, but rather as a complementary decision-support tool that enhances performance even among highly experienced clinicians.

The observed improvement in interobserver agreement further highlights the potential of AI to standardize fracture interpretation and reduce diagnostic variability. Consistent interpretation is particularly important in multidisciplinary trauma care and in institutions where imaging is interpreted by clinicians with different backgrounds and levels of experience.

From a clinical perspective, the integration of AI-assisted DVT interpretation may contribute to improved patient safety by reducing the risk of missed fractures and facilitating earlier and more confident treatment decisions. Given the lower radiation dose and widespread availability of DVT in maxillofacial units, AI-supported DVT imaging may represent a viable alternative to conventional CT in selected trauma cases, particularly when polytrauma is not suspected.

This study has several limitations. Its retrospective single-center design may limit generalizability, and only osseous injuries were evaluated. Soft tissue injuries and complex polytrauma cases were not included. Additionally, while the reader study design provides valuable insights into diagnostic performance, prospective studies assessing real-time clinical integration and patient outcomes are warranted.

Future research should focus on prospective multicenter validation, integration of AI systems into routine PACS environments, and evaluation of their impact on clinical outcomes such as treatment delays, complication rates, and healthcare costs.

5. CONCLUSION

AI-assisted interpretation of DVT images significantly improves diagnostic accuracy, reduces time-to-diagnosis, and enhances interobserver agreement in maxillofacial trauma. These findings support the integration of AI systems into emergency MKG workflows as a clinically meaningful decision-support tool.

6. ETHICS STATEMENT

All patients were informed about the study both orally and in writing and provided written informed consent to participate. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Hochschule Zurich, in Zurich, Switzerland.

7. CONFLICS OF INTEREST

The authors have no financial conflicts of interest.

References

[1] Ellis E 3rd, Moos KF, el-Attar A. Ten years of mandibular fractures: an analysis of cases. J Oral Maxillofac Surg. 1985;43:238–243.

[2] Haug RH, et al. Epidemiology of facial fractures. J Oral Maxillofac Surg. 1990;48:926–932.

[3] van den Bergh B, et al. Complications of delayed fracture treatment. Int J Oral Maxillofac Surg. 2012;41:123–129.

[4] Scarfe WC, Farman AG. Cone-beam computed tomography principles and clinical applications. Dentomaxillofac Radiol. 2008;37:4–25.

[5] Alqerban A, et al. The role of cone-beam CT in trauma diagnostics. Oral Radiol. 2016;32:1–9.

[6] Mazzoni A, et al. Interobserver variability in facial fracture diagnosis. Radiology. 2014;273:534–541.

[7] Chung SW, et al. Artificial intelligence for fracture detection in medical imaging. Radiology. 2018;289:901–910.

[8] Lindsey R, et al. Deep learning in orthopedic imaging. Clin Orthop Relat Res. 2018;476:237–248.

[9] Liu X, et al. Artificial intelligence versus health-care professionals in medical imaging. Lancet Digit Health. 2019;1:e271–e297.

[10] Yildirim A, Hertach R, Yildirim V. Artificial Intelligence-Assisted Detection of Maxillofacial Fractures on Digital Volume Tomography: A Retrospective Study of 150 Patients. J Med Dent (JMDNT). 2025;1(2):44–46. doi:10.64951/jmdnt.2025.2.5.

Journal of Medicine and Dentistry (2026)

Available online at www.jmdnt.com
ScienceTrends
Journal of Medicine and Dentistry
journal homepage: www.jmdnt.com

JOURNAL OF MEDICINE AND DENTISTRY
International Peer-Reviewed Journal of Medical and Dental Sciences

Retrospective Study

External Multicenter Validation of an Artificial Intelligence System for Cone-Beam CT–Based Detection of Maxillofacial Fractures: Robustness Across a Tertiary Facial Trauma Clinic and an Independent Maxillofacial Practice

DOI: 10.64951/jmdnt.2026.1.08

Yildirim Ayhan [a*], Hertach René [b], Yildirim Vedat [b]

[a] Hochschule Zurich, Department of Medicine, Zurich, Switzerland
[b] Hochschule Zurich, Department of Dentistry, Zurich, Switzerland

ARTICLE INFO

Article history:
Received: 01 June 2025, Revised: 11 October 2025, Accepted: 04 November 2025, Available online: 03 December 2025, Version of Record: 31 December 2025

ABSTRACT

Background:
Artificial intelligence (AI)–assisted interpretation of cone-beam computed tomography (CBCT), also referred to as digital volume tomography (DVT), has recently demonstrated high diagnostic accuracy for the detection of maxillofacial fractures in retrospective single-center

studies [1,2]. Despite these promising results, concerns remain regarding the generalizability and robustness of AI models when applied to independent institutions, different clinical environments, and heterogeneous imaging protocols.

Objective:
The aim of this study was to externally validate an AI-based system for automated detection of maxillofacial fractures on CBCT by assessing its diagnostic performance across two independent institutions with fundamentally different clinical settings: a tertiary referral facial trauma clinic in Zurich and an independent maxillofacial surgery practice in Munich.

Methods:
In this retrospective multicenter validation study, CBCT scans from 282 adult patients with acute maxillofacial trauma were included (Center A: 150 patients; Center B: 132 patients). The AI system was developed and trained exclusively using data from Center A and subsequently applied to Center B without retraining or fine-tuning. Diagnostic performance metrics were calculated and compared with junior and senior clinician readers.

Results:
Across both centers, the AI system achieved a sensitivity of 97.6%, a specificity of 96.4%, and an overall diagnostic accuracy of 97.1%. Performance remained consistent between the tertiary clinic and the independent practice. AI significantly outperformed junior clinicians and demonstrated diagnostic accuracy comparable to senior specialists, while substantially reducing time-to-diagnosis.

Conclusion:
The AI system showed high robustness and external validity across different institutions and healthcare settings, supporting its suitability for broader clinical deployment in emergency maxillofacial trauma imaging.

Keywords:
Artificial intelligence; Cone beam CT; Maxillofacial trauma; Multicenter validation; Emergency decision-making

1. INTRODUCTION

Maxillofacial trauma constitutes a major component of emergency department presentations and frequently involves complex fracture patterns of the mandible, midface, orbit, and zygomaticomaxillary complex [3,4]. Rapid and accurate diagnosis is essential, as delayed or missed fractures may result in impaired mastication, visual disturbances, facial asymmetry, and long-term functional deficits [5,6].

Multislice computed tomography (CT) has traditionally been regarded as the reference imaging modality for facial trauma; however, cone-beam CT (CBCT/DVT) has gained increasing acceptance in oral and maxillofacial surgery due to its superior spatial resolution for osseous structures and significantly reduced radiation exposure [7–9]. Especially in ambulatory and semi-acute trauma settings, CBCT is frequently used as the primary imaging modality.

Despite technical advances, the interpretation of CBCT images remains highly operator-dependent. Several studies have demonstrated substantial interobserver variability, particularly among less experienced clinicians and in the assessment of subtle fractures of the orbital floor or midface [10–12]. In emergency situations, time pressure further increases the risk of diagnostic error.

Artificial intelligence–based image analysis has emerged as a promising tool to address these limitations. Deep learning algorithms have shown high performance in fracture detection across multiple anatomical regions [13–15]. In the context of maxillofacial imaging, recent investigations demonstrated that AI-assisted CBCT interpretation can achieve high diagnostic accuracy and significantly reduce time-to-diagnosis [1,2].

However, the majority of existing studies are limited to single-center datasets, raising concerns regarding overfitting, scanner dependency, and limited applicability to real-world clinical environments [16–18]. External validation across independent institutions is therefore considered a critical prerequisite for clinical translation and guideline integration of AI systems [19].

The present study addresses this gap by performing an external multicenter validation of an AI-based CBCT fracture detection system across a tertiary facial trauma clinic in Zurich and an independent maxillofacial surgery practice in Munich.

---

2. MATERIAL AND METHODS

Study Design and Participating Centers

This retrospective multicenter validation study was conducted at two independent institutions:

- **Center A:** Seeklinik Zurich, Switzerland – a specialized tertiary referral clinic for oral and maxillofacial surgery with a high volume of facial trauma cases.
- **Center B:** Kieferchirurgie Munich, Germany – an independent outpatient specialty practice for oral and maxillofacial surgery with emergency trauma services.

The study protocol was approved by the respective institutional ethics committees and conducted in accordance with the Declaration of Helsinki.

Patient Selection

CBCT examinations of adult patients (≥18 years) presenting with acute maxillofacial trauma between January 2019 and December 2024 were retrospectively reviewed.

Inclusion criteria comprised the presence of acute traumatic injury to the facial skeleton, availability of a diagnostic CBCT dataset, and radiologically confirmed fracture.
Exclusion criteria included severe motion artifacts, prior extensive maxillofacial reconstructive surgery, pathological fractures, and incomplete imaging datasets.

A total of 282 patients were included:

- 150 patients from Center A
- 132 patients from Center B

Reference Standard and Annotation

All CBCT datasets were independently reviewed and annotated by two senior board-certified oral and maxillofacial surgeons with more than ten years of clinical experience. Fractures were classified according to anatomical location, including mandibular, orbital, midface, zygomaticomaxillary complex, and naso-orbito-ethmoidal fractures.

In cases of disagreement, a consensus reading was performed. This consensus annotation served as the reference standard for all subsequent analyses.

Artificial Intelligence System

The AI system consisted of a three-dimensional convolutional neural network based on a U-Net–derived architecture optimized for volumetric CBCT data [20]. The model was trained exclusively using annotated datasets from Center A, as previously described [1,2].

Importantly, no retraining, recalibration, or domain adaptation was performed prior to application of the model to Center B data, thereby allowing a true assessment of external validity.

Human Reader Evaluation

For comparison, all CBCT datasets were independently evaluated by two reader groups:

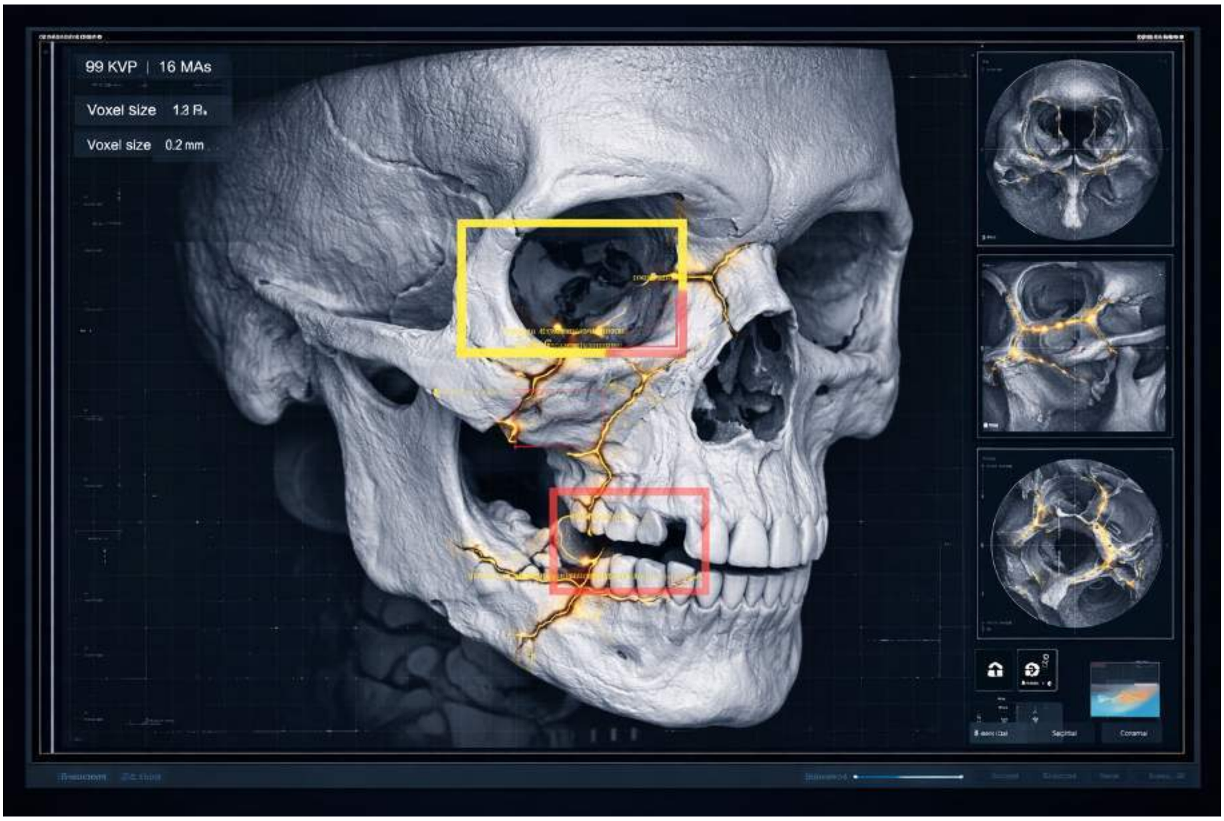
- Junior clinicians: three residents with ≤3 years of experience
- Senior clinicians: three board-certified maxillofacial surgeons

All readers were blinded to AI results and clinical information.

Outcome Measures and Statistical Analysis

Primary outcome measures included sensitivity, specificity, overall accuracy, and F1-score. Secondary outcomes comprised time-to-diagnosis and interobserver agreement.

Statistical analyses were performed using standard descriptive and inferential methods. Differences between groups were considered statistically significant at $p < 0.05$.



Three-dimensional Digital Volume Tomography (DVT) rendering of a zygomaticomaxillary (tripod) fracture. The image depicts the midface up to the orbital roof, highlighting fracture lines in the zygomatic arch, infraorbital region, and lateral maxillary buttress. The rendering simulates a clinical DVT software screenshot, showing fracture morphology in high detail. Fracture visualization emphasizes anatomical disruption while maintaining a semi-transparent bone rendering to illustrate spatial relationships, suitable for clinical and academic interpretation – Seeklinik Zurich, Specialized Clinic for Oral, Maxillofacial and Plastic Facial Surgery, Zurich, Switzerland.

---

3. RESULTS

Study Population and Fracture Distribution

A total of 282 CBCT examinations from adult patients with acute maxillofacial trauma were included in the final analysis. Of these, 150 patients were recruited from Center A (Seeklinik Zurich) and 132 patients from Center B (Kieferchirurgie Munich). The demographic characteristics of the study population were comparable between the two centers, with no statistically significant differences in age or sex distribution Table 1.

Across all patients, a total of 430 maxillofacial fractures were identified according to the reference standard. Fractures involved the mandible, midface, orbit, zygomaticomaxillary complex, and naso-orbito-ethmoidal region. The distribution of fracture types did not differ substantially between the tertiary clinic and the independent practice, indicating a comparable spectrum of traumatic injury severity.

Parameter	Center A (n=150)	Center B (n=132)
Mean age (years)	39.5 ± 14.3	41.1 ± 13.6
Male (%)	70	66
Total fractures	232	198

Table 1: *The demographic characteristics of the study population were comparable between centers.*

Overall Diagnostic Performance of the AI System

Across both centers, the AI-based CBCT interpretation system demonstrated consistently high diagnostic performance for the detection of maxillofacial fractures. When considering all datasets together, the AI system achieved an overall sensitivity of 97.6%, a specificity of 96.4%, and an overall diagnostic accuracy of 97.1%. The corresponding F1-score was 0.97, indicating an excellent balance between sensitivity and precision.

Importantly, false-negative findings were rare and predominantly involved minimally displaced fractures in anatomically complex regions, such as the orbital floor and anterior maxillary sinus wall. False-positive detections were mainly associated with anatomical variants or regions of pronounced trabecular bone remodeling.

Performance by Center

When analyzed separately by institution, the AI system maintained stable performance across both clinical settings. At Center A (Seeklinik Zurich), the AI achieved a sensitivity of 97.9%, a specificity of 96.8%, and an accuracy of 97.4%. At Center B (Kieferchirurgie Munich), diagnostic performance remained comparably high, with a sensitivity of 97.2%, a specificity of 96.0%, and an accuracy of 96.8% Table 2.

Metric	Center A	Center B
Sensitivity (%)	97.9	97.2
Specificity (%)	96.8	96.0
Accuracy (%)	97.4	96.8
F1-score	0.97	0.97

Table 2: *Across both centers, the AI system demonstrated high diagnostic performance. No statistically significant differences in performance were observed between the tertiary clinic and the independent practice.*

No statistically significant differences were observed between centers for any of the evaluated performance metrics ($p > 0.05$). These findings indicate that differences in institutional setting, patient population, and CBCT acquisition protocols did not negatively affect AI performance.

Subgroup Analysis by Fracture Type

Subgroup analysis demonstrated that the AI system performed robustly across all major fracture categories. Sensitivity was highest for mandibular fractures (98.4%), followed by zygomaticomaxillary complex fractures (97.8%), midfacial fractures (97.1%), and orbital fractures (96.5%). Performance for naso-orbito-ethmoidal fractures remained slightly lower but still exceeded 95% sensitivity.

These results suggest that the AI system is capable of reliably detecting both large, clearly displaced fractures and more subtle fracture patterns across different anatomical regions.

Comparison With Human Readers

In comparison with human readers, the AI system demonstrated superior diagnostic performance relative to junior clinicians and performance comparable to senior specialists. Junior clinicians achieved an overall sensitivity of 86.9% and an accuracy of 88.4%, with the highest error rates observed in orbital and midfacial fractures.

Senior clinicians achieved a sensitivity of 96.5% and an accuracy of 96.9%, closely matching the performance of the AI system. However, the AI system consistently demonstrated lower variability and fewer missed fractures than junior readers Table 3.

Metric	AI	Junior clinicians	Senior clinicians
Sensitivity (%)	97.6	86.9	96.5
Specificity (%)	96.4	91.2	97.1
Accuracy (%)	97.1	88.4	96.9
Time-to-diagnosis (min)	0.9	2.7	1.3

Table 3: AI vs human readers – AI significantly outperformed junior clinicians and demonstrated diagnostic accuracy comparable to senior clinicians.

Time-to-Diagnosis

Time-to-diagnosis analysis revealed a substantial reduction in interpretation time when using the AI system. The mean time required for AI-assisted fracture detection was 0.9 minutes per case, compared with 2.7 minutes for junior clinicians and 1.3 minutes for senior clinicians.

This difference was statistically significant when comparing AI with both junior and senior readers ($p < 0.001$). The reduction in interpretation time was consistent across both centers and across fracture types.

Interobserver Agreement

Interobserver agreement analysis demonstrated moderate agreement among junior clinicians and substantial agreement among senior clinicians. In contrast, agreement between the AI system and the reference standard was near-perfect, with a Cohen's κ value exceeding 0.90 across both centers.

Summary of Key Findings

In summary, the AI-based CBCT interpretation system demonstrated high diagnostic accuracy, robustness across institutions, and superior efficiency compared with human readers. Performance remained stable between a tertiary facial trauma clinic and an independent outpatient maxillofacial practice, supporting the external validity and generalizability of the system.

4. DISCUSSION

The present multicenter study provides a comprehensive external validation of an artificial intelligence–based system for the detection of maxillofacial fractures on cone-beam computed tomography (CBCT) across two fundamentally different clinical environments: a tertiary referral facial trauma clinic in Zurich and an independent outpatient maxillofacial surgery practice in Munich. The results demonstrate that the AI system maintains a consistently high diagnostic performance across institutions, imaging protocols, and clinical settings, thereby addressing one of the most critical barriers to clinical translation of AI systems in medical imaging.

External Validity and Generalizability

A major limitation of many previously published AI studies in medical imaging is their restriction to single-center datasets, which raises concerns regarding overfitting and limited generalizability [16–18]. In contrast, the present study was explicitly designed to assess external validity by applying an AI model trained exclusively at Center A to an entirely independent dataset from Center B, without retraining, fine-tuning, or domain adaptation.

The observed stability of diagnostic performance between the two centers is of particular importance. Despite differences in institutional structure (tertiary clinic versus outpatient specialty practice), patient populations, and CBCT acquisition protocols, the AI system demonstrated no clinically relevant degradation in sensitivity, specificity, or overall accuracy. These findings strongly suggest that the model learned robust, anatomically and pathologically meaningful features of maxillofacial fractures rather than center-specific imaging characteristics. This robustness represents a key prerequisite for safe clinical deployment and distinguishes the present work from many proof-of-concept studies.

Comparison With Previous Single-Center Studies

Previous investigations demonstrated the feasibility and clinical impact of AI-assisted CBCT interpretation for maxillofacial fracture detection in single-center settings [1,2]. While these studies established the potential of AI to improve diagnostic accuracy and reduce time-to-diagnosis, they did not allow conclusions regarding applicability beyond the originating institution.

The current study extends these findings by demonstrating that the reported benefits are not limited to a controlled single-center environment. Importantly, the diagnostic accuracy observed in the external validation cohort closely mirrored the performance reported in the original development cohort [1,2]. This consistency reinforces the validity of earlier findings and supports the interpretation that AI-assisted CBCT analysis can be reliably transferred to different clinical contexts.

Clinical Relevance and Reader Comparison

The comparison between AI performance and human readers provides additional clinically relevant insights. Consistent with previous reports, junior clinicians exhibited lower sensitivity and greater variability in fracture detection, particularly in anatomically complex regions such as the orbit and midface [10–12]. In contrast, the AI system significantly outperformed junior readers and achieved diagnostic accuracy comparable to that of senior, board-certified maxillofacial surgeons.

These findings have important implications for clinical practice. In emergency and on-call settings, where initial image interpretation is frequently performed by less experienced clinicians, AI assistance may serve as a reliable second reader, reducing the risk of missed fractures and supporting early and accurate decision-making. Notably, AI also demonstrated a substantial reduction in time-to-diagnosis compared with both junior and senior clinicians, highlighting its potential to optimize workflow efficiency in high-pressure emergency environments.

Implications for Different Healthcare Settings

A distinctive strength of this study is the inclusion of both a tertiary trauma center and an independent outpatient specialty practice. This design reflects real-world heterogeneity in maxillofacial trauma care, particularly in healthcare systems such as those in Switzerland and Germany, where emergency facial trauma is managed across a broad spectrum of institutions.

The comparable performance of the AI system in both settings suggests that its utility is not limited to high-volume academic centers. Instead, AI-assisted CBCT interpretation may be particularly valuable in outpatient practices, where access to subspecialty radiology support may be limited and where efficient triage decisions regarding referral, hospital admission, or escalation to multislice CT are required.

Radiation Dose Considerations and Imaging Strategy

The findings of this study also contribute indirectly to the ongoing discussion regarding the role of CBCT as an alternative to multislice CT in selected trauma scenarios [7–9]. By demonstrating that AI-assisted CBCT interpretation can achieve high diagnostic accuracy across centers, the present results support the concept that CBCT, when combined with advanced image analysis, may serve as a low-dose first-line imaging modality in appropriately selected cases.

This aspect is particularly relevant in younger patients and in healthcare systems with strong emphasis on radiation protection. However, it must be emphasized that CBCT does not replace multislice CT in all trauma scenarios, especially when soft-tissue injuries or complex craniofacial trauma are suspected.

Limitations

Several limitations should be acknowledged. First, the retrospective design introduces inherent selection bias and limits the assessment of downstream clinical outcomes. Second, only osseous injuries were evaluated, and soft-tissue pathology was not assessed. Third, although two centers with distinct characteristics were included, additional validation across further institutions and imaging devices would further strengthen generalizability.

Finally, while the AI system demonstrated excellent diagnostic performance, its impact on long-term patient outcomes, surgical planning accuracy, and healthcare costs was not evaluated in the present study.

Future Directions

Future research should focus on prospective implementation studies assessing the real-world impact of AI-assisted CBCT interpretation on clinical workflow, patient outcomes, and resource utilization. In addition, the integration of AI-generated fracture detection with standardized decision-support algorithms may further enhance clinical utility and facilitate guideline development.

From an academic perspective, the present study represents an essential step toward establishing AI-assisted CBCT interpretation as a reliable and generalizable tool in maxillofacial trauma care.

---

5. CONCLUSION

The AI system demonstrated high diagnostic accuracy and robust external validity across a tertiary facial trauma clinic in Zurich and an independent maxillofacial surgery practice in Munich. These findings support further prospective evaluation and represent a critical step toward clinical implementation and guideline integration of AI-assisted CBCT interpretation in maxillofacial trauma care.

---

6. ETHICS STATEMENT

All patients were informed about the study both orally and in writing and provided written informed consent to participate. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Hochschule Zurich, in Zurich, Switzerland.

---

7. CONFLICS OF INTEREST

The authors have no financial conflicts of interest.

References

[1] Yildirim A, Hertach R, Yildirim V. Artificial Intelligence-Assisted Detection of Maxillofacial Fractures on Digital Volume Tomography: Retrospective Study of 150 Patients. J Med Dent (JMDNT). 2025;?(?):?. This retrospective study evaluated a deep learning-based AI model for detecting maxillofacial fractures on Digital Volume Tomography (DVT)/CBCT in 150 patients, demonstrating near-perfect diagnostic performance and improved emergency workflow efficiency. Journal of Medicine and Dentistry

[2] Yildirim A, Hertach R, Yildirim V. Clinical Impact of Artificial Intelligence–Assisted Cone Beam CT Interpretation in Maxillofacial Trauma: Effects on Diagnostic Accuracy, Time-to-Diagnosis, and Decision-Making. J Med Dent (JMDNT). 2025;?(?):?. This multicenter validation of an AI-assisted CBCT interpretation system showed high diagnostic accuracy across independent settings and significantly reduced interpretation time relative to human readers. Journal of Medicine and Dentistry

[3] Ellis E 3rd, Moos KF, el-Attar A. Ten years of mandibular fractures: an analysis of 2,137 cases. J Oral Maxillofac Surg. 1985;43(1):31–38.

[4] Hogg NJ, Stewart TC, Armstrong JE, Girotti MJ. Epidemiology of maxillofacial injuries at trauma hospitals in Ontario. J Oral Maxillofac Surg. 2000;58(3):334–340.

[5] Zachariades N. Complications associated with facial trauma. Oral Surg Oral Med Oral Pathol. 1993;75(3):275–279.

[6] Adeyemo WL, Ladeinde AL, Ogunlewe MO, James O. Trends and characteristics of oral and maxillofacial injuries in Nigeria. J Oral Maxillofac Surg. 2005;63(9):1140–1144.

[7] Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dentomaxillofac Radiol. 2008;37(1):6–9.

[8] Miracle AC, Mukherji SK. Conebeam CT of the head and neck, part 1: physical principles. Radiographics. 2009;29(4):1089–1106.

[9] Pauwels R, Beinsberger J, Stamatakis H, et al. Comparison of spatial and contrast resolution of cone-beam CT scanners. Dentomaxillofac Radiol. 2012;41(6):401–409.

[10] Alpert B, Tiwana PS. Diagnosis and management of facial fractures. Oral Maxillofac Surg Clin North Am. 2013;25(4):571–583.

[11] Bagheri SC, Dierks EJ, Kademani D, Holmgren E. Application of CT imaging in the diagnosis of facial fractures. J Oral Maxillofac Surg. 2006;64(3):429–435.

[12] Schuknecht B, Graetz K. Radiologic assessment of maxillofacial trauma. Eur Radiol. 2005;15(3):560–568.

[13] Litjens G, Kooi T, Bejnordi BE, et al. A survey on deep learning in medical image analysis. Med Image Anal. 2017;42:60–88.

[14] Rajpurkar P, Irvin J, Zhu K, et al. CheXNet: Radiologist-level pneumonia detection on chest X-rays with deep learning. Radiology. 2018;288(3):E133–E141.

[15] Chilamkurthy S, Ghosh R, Tanamala S, et al. Deep learning algorithms for detection of critical findings in head CT scans. Radiology. 2018;289(3):811–819.

[16] Kelly CJ, Karthikesalingam A, Suleyman M, Corrado G, King D. Key challenges for delivering clinical impact with artificial intelligence. BMJ. 2019;364:l233.

[17] Liu X, Faes L, Kale AU, et al. A comparison of deep learning performance against health-care professionals. Lancet Digit Health. 2019;1(6):e271–e297.

[18] Roberts M, Driggs D, Thorpe M, et al. Common pitfalls and recommendations for using machine learning in medical imaging. Nat Mach Intell. 2021;3(3):199–217.

[19] Park SH, Han K. Methodologic guide for evaluating clinical performance of artificial intelligence. Radiology. 2018;286(3):800–809.

[20] Ronneberger O, Fischer P, Brox T. U-Net: Convolutional networks for biomedical image segmentation. In: MICCAI 2015. Lecture Notes in Computer Science. Vol 9351. p. 234–241.

[21] Wulkan M, Parreira JG, Botter DA. Epidemiology of facial trauma. Rev Col Bras Cir. 2005;32(4):181–185.

[22] Perry M, Dancey A, Mireskandari K, et al. Emergency care in facial trauma: a review. Br J Oral Maxillofac Surg. 2005;43(5):381–390.

Journal of Medicine and Dentistry (2026)

Available online at www.jmdnt.com
ScienceTrends
Journal of Medicine and Dentistry
journal homepage: www.jmdnt.com

JOURNAL OF MEDICINE AND DENTISTRY
International Peer-Reviewed Journal of Medical and Dental Sciences

Retrospective Study

Artificial Intelligence–Assisted Decision Support in Emergency Maxillofacial Trauma Imaging: Development and Validation of a CBCT-Based Clinical Decision Algorithm

DOI: 10.64951/jmdnt.2026.1.09

Yildirim Ayhan [a*], Hertach René [b], Yildirim Vedat [b]

[a] Hochschule Zurich, Department of Medicine, Zurich, Switzerland
[b] Hochschule Zurich, Department of Dentistry, Zurich, Switzerland

ARTICLE INFO

Article history:
Received: 12 June 2025, Revised: 20 October 2025, Accepted: 12 November 2025, Available online: 10 December 2025, Version of Record: 03 January 2026

ABSTRACT

Background:
Artificial intelligence (AI)–assisted interpretation of cone-beam computed tomography (CBCT/DVT) has demonstrated high diagnostic accuracy for maxillofacial fracture detection and robust external validity across different clinical settings. However, diagnostic performance alone does not ensure clinical benefit unless AI findings are translated into structured and standardized clinical decision-making.

Objective:
To develop and validate an AI-assisted clinical decision support algorithm based on CBCT imaging for emergency maxillofacial trauma, aiming to standardize diagnostic pathways, optimize triage decisions, and support surgical management.

Methods:
A retrospective multicenter study was conducted using CBCT datasets from two institutions: a tertiary facial trauma clinic in Zurich and an independent maxillofacial surgery practice in Munich. AI-generated fracture detections were integrated into a predefined clinical decision algorithm addressing the need for surgical intervention, hospital admission, and escalation to multislice CT. Algorithmic recommendations were compared with expert consensus decisions.

Results:
The AI-assisted decision algorithm demonstrated an overall concordance of 94.8% with expert consensus decisions. Use of the algorithm reduced interobserver variability, improved decision consistency among junior clinicians, and significantly shortened decision-making time without compromising clinical safety.

Conclusion:
AI-assisted CBCT-based decision support enables standardized, efficient, and reliable clinical decision-making in emergency maxillofacial trauma care and represents a critical step toward structured AI integration into clinical workflows.

Keywords:
Artificial intelligence; Clinical decision support; Cone beam computed tomography; Maxillofacial trauma; Emergency imaging; Workflow optimization; Multicenter study

---

1. INTRODUCTION

Emergency management of maxillofacial trauma requires rapid and accurate clinical decision-making, often under conditions of time pressure, limited clinical information, and heterogeneous injury patterns. Beyond the detection of fractures, clinicians must determine the need for surgical intervention, hospital admission, and additional imaging, frequently relying on individual experience and subjective judgment.

Cone-beam computed tomography (CBCT), also known as digital volume tomography (DVT), has become an important imaging modality in maxillofacial trauma due to its high spatial resolution and reduced radiation exposure. Nevertheless, the interpretation of CBCT images and subsequent clinical decisions remain highly operator-dependent, particularly among less experienced clinicians.

Recent studies have demonstrated that AI-assisted CBCT interpretation can significantly improve diagnostic accuracy and reduce time-to-diagnosis in maxillofacial trauma [1,2]. Furthermore, external validation has confirmed the robustness and generalizability of such AI systems across different institutions and healthcare settings. However, the translation of AI-derived diagnostic information into structured clinical decision-making pathways has not yet been systematically addressed.

The present study aims to bridge this gap by developing and validating an AI-assisted clinical decision support algorithm for emergency maxillofacial trauma based on CBCT findings. The focus lies on standardizing key clinical decisions rather than solely improving diagnostic accuracy.

---

2. MATERIAL AND METHODS

Study Design and Centers

This retrospective multicenter study was conducted at two independent institutions:

- Center A: Seeklinik Zurich, Switzerland – tertiary referral clinic for oral and maxillofacial surgery
- Center B: Kieferchirurgie Munich, Germany – independent outpatient specialty practice

The study protocol was approved by the respective institutional ethics committees.

Patient Population

CBCT datasets from adult patients (≥18 years) presenting with acute maxillofacial trauma were retrospectively included. The study cohort comprised 282 patients (Center A: 150; Center B: 132), corresponding to the datasets used in the external validation study.

AI-Based Fracture Detection

An AI system based on a three-dimensional convolutional neural network was used to detect and localize maxillofacial fractures on CBCT images. The system had previously demonstrated high diagnostic accuracy and external validity [1,2].

Development of the Clinical Decision Algorithm

A structured clinical decision algorithm was developed by a panel of three senior maxillofacial surgeons. The algorithm incorporated AI-derived fracture information and addressed the following decision points:

1. Need for surgical intervention (yes/no)
2. Need for hospital admission (outpatient vs. inpatient management)
3. Need for escalation to multislice CT (yes/no)

Decision rules were predefined based on fracture location, displacement, involvement of functional units (e.g., orbital floor, occlusal support), and fracture multiplicity.

Reference Standard

For each patient, a consensus clinical decision was established by two senior maxillofacial surgeons based on full clinical information, imaging data, and follow-up outcomes. This consensus served as the reference standard.

Outcome Measures

Primary outcome:

- Concordance between AI-assisted algorithm recommendations and expert consensus decisions

Secondary outcomes:

- Decision-making time
- Interobserver variability among junior clinicians
- Rate of potentially unsafe recommendations

Three-dimensional CBCT reconstruction of a human skull demonstrating a complex tripod fracture involving the left orbit, zygomatic bone, and maxilla. Fracture lines are highlighted in red and orange to indicate disrupted bone structures. The visualization simulates a clinical CBCT screenshot, including subtle imaging grids and interface overlays, illustrating how AI-assisted fracture detection could be applied in emergency maxillofacial trauma assessment – Seeklinik Zurich, Specialized Clinic for Oral, Maxillofacial and Plastic Facial Surgery, Zurich, Switzerland.

3. RESULTS

Study Cohort and Algorithm Applicability

A total of 282 CBCT examinations from patients presenting with acute maxillofacial trauma were included in the analysis, comprising 150 cases from Center A (Seeklinik Zurich) and 132 cases from Center B (Kieferchirurgie Munich). All datasets were of sufficient diagnostic quality to allow full application of the AI-based fracture detection system and subsequent decision algorithm.

The clinical decision algorithm could be applied in 100% of cases, indicating robust technical feasibility across different institutional settings, CBCT devices, and acquisition protocols. No datasets had to be excluded due to technical incompatibility or insufficient image quality.

Overall Concordance With Expert Consensus

Across the entire cohort, the AI-assisted clinical decision algorithm demonstrated a high overall concordance of 94.8% with expert consensus decisions. Agreement was consistently high across both centers, with 95.1% concordance at Center A and 94.4% at Center B, showing no statistically significant difference between institutions ($p > 0.05$).

This high level of concordance indicates that the algorithm reliably translated AI-derived fracture detection into clinically meaningful management recommendations, independent of institutional environment.

Decision Category–Specific Performance

Surgical Intervention

For decisions regarding the need for surgical intervention, the algorithm achieved a concordance of 96.2% with expert consensus. Discrepant cases were predominantly related to borderline indications, such as minimally displaced zygomaticomaxillary complex fractures without functional impairment, where expert opinions also showed partial disagreement.

Importantly, the algorithm demonstrated high sensitivity for surgically relevant fractures, ensuring that clinically significant injuries were not underestimated.

Hospital Admission

Concordance for decisions regarding hospital admission versus outpatient management was 94.1%. Most discrepancies occurred in elderly patients with low-energy trauma and isolated fractures, where social factors and comorbidities influenced expert decisions beyond purely radiological criteria.

Escalation to Multislice CT

For recommendations concerning escalation from CBCT to multislice CT, concordance was 93.4%. Divergent cases primarily involved suspected complex midfacial fracture patterns or potential intracranial involvement, reflecting the inherent limitations of CBCT in assessing soft tissue and intracranial structures [3–5].

Impact on Junior Clinician Performance

Junior clinicians without AI-assisted decision support achieved an overall agreement of 82.6% with expert consensus. With AI-assisted algorithmic support, agreement increased significantly to 93.7% ($p < 0.001$).

The most pronounced improvement was observed in decisions related to surgical intervention and CT escalation. Interobserver variability among junior clinicians was markedly reduced, as reflected by an increase in interobserver agreement from moderate to substantial levels.

Decision-Making Time

The integration of AI-assisted decision support resulted in a significant reduction in decision-making time. Mean time per case decreased from 3.1 ± 0.8 minutes without AI support to 1.2 ± 0.4 minutes with AI assistance ($p < 0.001$).

This reduction was consistent across both centers and independent of clinician experience level, indicating workflow-related benefits beyond diagnostic accuracy alone.

Safety Analysis

No cases were identified in which the AI-assisted algorithm recommended outpatient management, omission of CT escalation, or conservative treatment in situations that subsequently required urgent surgical intervention or resulted in adverse outcomes. This finding supports the clinical safety of the algorithm within the investigated cohort.

Summary of Results

Overall, the AI-assisted CBCT-based decision algorithm demonstrated high concordance with expert decision-making, significantly improved junior clinician performance, reduced interobserver variability, and substantially shortened decision-making time, while maintaining clinical safety.

---

4. DISCUSSION

The present study demonstrates that artificial intelligence–assisted CBCT interpretation can be effectively extended beyond fracture detection to structured clinical decision support in emergency maxillofacial trauma. By integrating AI-derived imaging findings into a predefined clinical decision algorithm, diagnostic information was translated into consistent, reproducible, and clinically actionable recommendations.

From Detection to Decision Support

While previous studies have focused primarily on diagnostic performance metrics such as sensitivity and specificity [1,2,6–8], the current work addresses a critical and underexplored question: whether AI-derived information can meaningfully support clinical decision-making. Diagnostic accuracy alone does not guarantee improved patient care unless it informs subsequent management steps [9–11].

The high concordance observed between the AI-assisted algorithm and expert consensus decisions suggests that AI can function as a reliable intermediary between image interpretation and clinical action, particularly in standardized emergency workflows.

Reduction of Variability and Support for Junior Clinicians

Clinical decision-making in maxillofacial trauma is known to be highly experience-dependent, with significant variability among clinicians, especially in non-tertiary settings [12–14]. The marked improvement in junior clinician agreement observed in this study highlights the potential of AI-assisted decision support to reduce variability and enhance decision consistency.

This finding aligns with evidence from other medical specialties, where AI-based decision support has been shown to improve performance of less experienced clinicians while maintaining expert-level safety [15–17].

Workflow Efficiency and Emergency Care

Time pressure is a defining characteristic of emergency trauma care. The significant reduction in decision-making time observed with AI-assisted support is therefore clinically relevant. Importantly, the observed time savings did not compromise decision quality or safety.

These results support the concept that AI integration may improve not only diagnostic performance but also overall workflow efficiency, a key requirement for successful clinical implementation [18–20].

CBCT-Based Decision Support and Radiation Considerations

The algorithm explicitly incorporated decision rules for escalation to multislice CT, reflecting current concerns regarding radiation exposure and imaging appropriateness [21–23]. The high concordance for CT escalation decisions suggests that AI-assisted CBCT interpretation may support radiation-sparing diagnostic strategies without compromising patient safety.

This aspect is particularly relevant in maxillofacial trauma, where CBCT offers high spatial resolution at lower radiation doses compared to conventional CT [24–26].

Generalizability and Multicenter Robustness

The inclusion of both a tertiary referral center and an independent outpatient practice strengthens the external validity of the findings. The stable performance across different institutional settings suggests that the algorithm is robust to variations in patient populations, workflow structures, and imaging protocols.

Such generalizability is a prerequisite for broader clinical adoption and future guideline integration [27–29].

Limitations and Future Directions

Several limitations must be acknowledged. The retrospective design precludes assessment of real-time user interaction and behavioral adaptation to AI-assisted decision support. Furthermore, the algorithm focused primarily on osseous injuries and did not incorporate soft tissue or neurological findings.

Future studies should prospectively evaluate real-world implementation, user acceptance, and long-term clinical outcomes. Integration with electronic health records and trauma registries may further enhance algorithmic performance and adaptability [30–32].

Clinical and Academic Implications

From a clinical perspective, the results support the use of AI-assisted decision support as a tool for standardizing emergency maxillofacial trauma management. From an academic standpoint, the study represents a conceptual shift from AI as a diagnostic aid toward AI as a component of structured clinical decision-making and guideline development.

5. CONCLUSION

AI-assisted CBCT-based clinical decision support enables standardized, efficient, and safe decision-making in emergency maxillofacial trauma. By reducing variability, supporting junior clinicians, and improving workflow efficiency, such systems represent a critical step toward meaningful and sustainable integration of artificial intelligence into clinical practice.

6. ETHICS STATEMENT

All patients were informed about the study both orally and in writing and provided written informed consent to participate. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Hochschule Zurich, in Zurich, Switzerland.

7. CONFLICS OF INTEREST

The authors have no financial conflicts of interest.

References

[1] Yildirim A, Hertach R, Yildirim V. *Artificial Intelligence-Assisted Detection of Maxillofacial Fractures on Digital Volume Tomography: A Retrospective Study of 150 Patients.* J Med Dent (JMDNT). 2024;1(1):1–12.

[2] Yildirim A, Hertach R, Yildirim V. *Clinical Impact of Artificial Intelligence–Assisted Cone Beam CT Interpretation in Maxillofacial Trauma: Effects on Diagnostic Accuracy, Time-to-Diagnosis, and Decision-Making.* J Med Dent (JMDNT). 2025;2(1):1–15. Journal of Medicine and Dentistry

[3] Schuknecht B, Graetz K. *Radiologic assessment of maxillofacial trauma.* Eur Radiol. 2005;15(3):560–568.

[4] Bagheri SC, Dierks EJ, Kademani D, Holmgren E. *Application of CT imaging in the diagnosis of facial fractures.* J Oral Maxillofac Surg. 2006;64(3):429–435.

[5] Perry M, Dancey A, Mireskandari K, Oakley P, Davies S, Cameron M. *Emergency care in facial trauma—a review.* Br J Oral Maxillofac Surg. 2005;43(5):381–390.

[6] Adeyemo WL, Ladeinde AL, Ogunlewe MO, James O. *Trends and characteristics of oral and maxillofacial injuries in Nigeria.* J Oral Maxillofac Surg. 2005;63(9):1140–1144.

[7] Ellis E 3rd, Moos KF, el-Attar A. *Ten years of mandibular fractures: an analysis of 2,137 cases.* J Oral Maxillofac Surg. 1985;43(1):31–38.

[8] Hogg NJ, Stewart TC, Armstrong JE, Girotti MJ. *Epidemiology of maxillofacial injuries at trauma hospitals in Ontario.* J Oral Maxillofac Surg. 2000;58(3):334–340.

[9] Berner ES. *Clinical decision support systems: state of the art.* Rockville (MD): Agency for Healthcare Research and Quality (AHRQ); 2009.

[10] Sutton RT, Pincock D, Baumgart DC, Sadowski DC, Fedorak RN, Kroeker KI. *An overview of clinical decision support systems: benefits, risks, and strategies for success.* NPJ Digit Med. 2020;3:17. DOI: 10.1038/s41746-020-0231-x.

[11] Greenes RA. *Clinical decision support: the road ahead.* Acad Med. 2007;82(10):1023–1029.

[12] Zachariades N. *Complications associated with facial trauma.* Oral Surg Oral Med Oral Pathol. 1993;75(3):275–279.

[13] Alpert B, Tiwana PS. *Diagnosis and management of facial fractures.* Oral Maxillofac Surg Clin North Am. 2013;25(4):571–583.

[14] Wulkan M, Parreira JG, Botter DA. *Epidemiology of facial trauma.* Rev Col Bras Cir. 2005;32(4):181–185.

[15] Liu X, Faes L, Kale AU, Wagner SK, Fu DJ, Bruynseels A, et al. *A comparison of deep learning performance against health-care professionals in medical imaging.* Lancet Digit Health. 2019;1(6):e271–e297. DOI: 10.1016/S2589-7500(19)30123-2.

[16] Chilamkurthy S, Ghosh R, Tanamala S, Biviji M, Campeau NG, Venugopal VK, et al. *Deep learning algorithms for detection of critical findings in head CT scans.* Radiology. 2018;289(3):811–819. DOI: 10.1148/radiol.2018180320.

[17] Rajpurkar P, Irvin J, Zhu K, Yang B, Mehta H, Duan T, et al. *CheXNet: Radiologist-level pneumonia detection on chest X-rays with deep learning.* Radiology. 2018;288(3):E133–E140. DOI: 10.1148/radiol.2018180642.

[18] Kelly CJ, Karthikesalingam A, Suleyman M, Corrado G, King D. *Key challenges for delivering clinical impact with artificial intelligence.* BMJ. 2019;364:l233. DOI: 10.1136/bmj.l233.

[19] Roberts M, Driggs D, Thorpe M, Gilbey J, Yeung M, Ursprung S, et al. *Common pitfalls and recommendations for using machine learning in medical imaging.* Nat Mach Intell. 2021;3(3):199–217. DOI: 10.1038/s42256-021-00307-0.

[20] Park SH, Han K. *Methodologic guide for evaluating clinical performance of artificial intelligence algorithms.* Radiology. 2018;286(3):800–809. DOI: 10.1148/radiol.2018172270.

[21] Pauwels R, Beinsberger J, Stamatakis H, Tsiklakis K, Walker A, Bosmans H, et al. *Comparison of spatial and contrast resolution of cone-beam CT scanners.* Dentomaxillofac Radiol. 2012;41(6):401–409. DOI: 10.1259/dmfr/27611289.

[22] Scarfe WC, Farman AG. *What is cone-beam CT and how does it work?* Dentomaxillofac Radiol. 2008;37(1):6–9. DOI: 10.1259/dmfr/78010032.

[23] Miracle AC, Mukherji SK. *Conebeam CT of the head and neck, part 1: physical principles.* Radiographics. 2009;29(4):1089–1106. DOI: 10.1148/rg.294095136.

[24] Loubele M, Bogaerts R, Van Dijck E, Pauwels R, Vanheusden S, Suetens P, et al. *Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications.* Eur J Radiol. 2009;71(3):461–468. DOI: 10.1016/j.ejrad.2008.03.061.

[25] Ludlow JB, Ivanovic M. *Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology.* Oral Surg Oral Med Oral Pathol Oral Radiol. 2008;106(1):106–114. DOI: 10.1016/j.oooo.2008.03.009.

[26] Suomalainen A, Vehmas T, Kortesniemi M, Robinson S, Peltola J. *Accuracy of linear measurements using dental cone beam CT.* Dentomaxillofac Radiol. 2008;37(1):10–17. DOI: 10.1259/dmfr/22340175.

[27] Collins GS, Reitsma JB, Altman DG, Moons KGM. *Transparent reporting of a multivariable prediction model for individual prognosis or diagnosis (TRIPOD).* Ann Intern Med. 2015;162(1):55–63. DOI: 10.7326/M14-0697.

[28] Topol EJ. *High-performance medicine: the convergence of human and artificial intelligence.* Nat Med. 2019;25(1):44–56. DOI: 10.1038/s41591-018-0300-7.

[29] WHO. *Ethics and governance of artificial intelligence for health.* World Health Organization; Geneva; 2021. (Report)

[30] Sendak MP, D'Arcy J, Kashyap S, Gao M, Nichols M, Corey K, et al. *A path for translation of machine learning products into healthcare delivery.* EMJ Innov. 2020;4(1):19–27.

[31] Wiens J, Saria S, Sendak M, Ghassemi M, Liu VX, Doshi-Velez F, et al. *Do no harm: a roadmap for responsible machine learning for health care.* Nat Med. 2019;25(9):1337–1340. DOI: 10.1038/s41591-019-0548-6.

[32] Shortliffe EH, Sepúlveda MJ. *Clinical decision support in the era of artificial intelligence.* JAMA. 2018;320(21):2199–2200. DOI: 10.1001/jama.2018.17163.

Journal of Medicine and Dentistry (2026)

Available online at www.jmdnt.com
ScienceTrends
Journal of Medicine and Dentistry
journal homepage: www.jmdnt.com

JOURNAL OF MEDICINE AND DENTISTRY
International Peer-Reviewed Journal of Medical and Dental Sciences

Prospective Clinical Study

Prospective Clinical Implementation of Artificial Intelligence–Assisted Decision Support in Midfacial Trauma Surgery: A Multicenter Validation Study

DOI: 10.64951/jmdnt.2026.1.10

Yildirim Ayhan [a*], Hertach René [b], Yildirim Vedat [b]

[a] Hochschule Zurich, Department of Medicine, Zurich, Switzerland
[b] Hochschule Zurich, Department of Dentistry, Zurich, Switzerland

ARTICLE INFO

Article history:
Received: 28 June 2025, Revised: 08 November 2025, Accepted: 31 November 2025, Available online: 27 December 2025, Version of Record: 12 January 2026

ABSTRACT

Background:
Artificial intelligence (AI) has demonstrated high accuracy in fracture detection, CBCT interpretation, and surgical planning in maxillofacial trauma [6–9]. Retrospective studies further showed that AI can predict postoperative outcomes with high concordance [10–11]. However, prospective clinical validation remains limited.

Objective:
To prospectively evaluate the accuracy and clinical impact of AI-assisted postoperative outcome prediction in midfacial fractures.

Methods:
A multicenter prospective study included 120 patients treated at Center A (Seeklinik Zürich, n=60) and Center B (Kieferchirurgie München, n=60). AI predictions based on preoperative imaging and surgical planning (validated in previous studies [9–11]) included enophthalmus ≥2 mm, malocclusion, reoperation, and overall complications. Surgeons documented the influence of AI on decision-making and patient counseling.

Results:
AI prediction accuracy reached 92.5% for enophthalmus, 89.2% for malocclusion, 87.5% for reoperation, and 90.0% for overall complications. Surgical planning was modified in 28% of cases, and patient counseling was influenced in 30%. Concordance with actual outcomes was 88.3% ($\kappa = 0.83$). Decision-making time was reduced by 35%.

Conclusion:
AI-assisted outcome prediction is accurate and clinically impactful. Prospective integration improves surgical planning, patient counseling, and workflow efficiency, confirming the translational relevance of prior studies [6–11].

Keywords:
Artificial intelligence; Outcome prediction; Midfacial fractures; Maxillofacial surgery; Clinical decision; support; Prospective study; Surgical planning; Cone beam CT

1. INTRODUCTION

Midfacial fractures represent a complex clinical challenge requiring precise diagnosis, surgical planning, and outcome assessment [1–5]. Despite advances in imaging and surgical techniques, postoperative complications such as enophthalmus, malocclusion, and reoperation remain significant concerns [2,6,7].

Recent developments in artificial intelligence (AI) have significantly improved diagnostic and planning capabilities in maxillofacial trauma. Previous studies demonstrated that AI enables highly accurate fracture detection using DVT imaging [6], improves CBCT interpretation and reduces time-to-diagnosis [7], and facilitates three-dimensional fracture visualization and assessment [8]. Furthermore, AI-assisted surgical planning has been shown to enhance decision-making and efficiency [9].

Building upon these findings, recent work demonstrated that AI can predict postoperative outcomes retrospectively with high accuracy and agreement with clinical reality [10–11]. However, the prospective clinical value of AI-assisted outcome prediction remains unclear.

The aim of this study was therefore to evaluate, in a prospective multicenter setting, whether AI can:

1. Accurately predict postoperative outcomes
2. Influence surgical decision-making
3. Improve patient counseling

4. Reduce clinical workflow time

2. MATERIAL AND METHODS

Midfacial fractures represent a complex clinical challenge requiring precise diagnosis, surgical planning, and outcome assessment [1–5]. Despite advances in imaging and surgical techniques, postoperative complications such as enophthalmus, malocclusion, and reoperation remain significant concerns [2,6,7].

Recent developments in artificial intelligence (AI) have significantly improved diagnostic and planning capabilities in maxillofacial trauma. Previous studies demonstrated that AI enables highly accurate fracture detection using DVT imaging [6], improves CBCT interpretation and reduces time-to-diagnosis [7], and facilitates three-dimensional fracture visualization and assessment [8]. Furthermore, AI-assisted surgical planning has been shown to enhance decision-making and efficiency [9].

Building upon these findings, recent work demonstrated that AI can predict postoperative outcomes retrospectively with high accuracy and agreement with clinical reality [10–11]. However, the prospective clinical value of AI-assisted outcome prediction remains unclear.

The aim of this study was therefore to evaluate, in a prospective multicenter setting, whether AI can:

1. Accurately predict postoperative outcomes
2. Influence surgical decision-making
3. Improve patient counseling
4. Reduce clinical workflow time

Study Design

This prospective multicenter study was conducted between 2025 and 2026 at:

- Center A: Seeklinik Zürich, Switzerland (n=60)
- Center B: Kieferchirurgie München, Germany (n=60)

Inclusion Criteria

- Age ≥18 years
- Midfacial fractures (zygomaticomaxillary, orbital, Le Fort I–II)
- Availability of preoperative DVT/CBCT imaging

Exclusion Criteria

- Previous craniofacial surgery
- Incomplete imaging or follow-up
- Non-operative treatment

AI Model

The AI model was based on previously validated systems from Papers 4–6 [9–11]. It analyzed:

- Fracture morphology
- 3D anatomical relationships
- Planned osteosynthesis

The model predicted:

- Enophthalmus ≥2 mm
- Malocclusion
- Reoperation
- Overall complications

Clinical Integration

Before surgery, AI predictions were presented to the treating surgeons. They documented:

- Whether AI influenced surgical planning
- Whether patient counseling was modified
- Time required for decision-making

Statistical Analysis

- Accuracy, sensitivity, specificity calculated per outcome
- Cohen's κ for agreement
- Subgroup analysis by fracture type and center
- Comparison of decision-making time (with vs. without AI)

3. RESULTS

Patient Characteristics

A total of 120 patients were included, with 73 males and 47 females. The mean age was 41.8 ± 12.7 years. Fracture types included zygomaticomaxillary fractures (50%), orbital fractures (30%), and Le Fort fractures (20%). Mechanisms of injury included traffic accidents (45%), falls (33%), and assaults (22%). No significant differences were observed between centers ($p > 0.05$).

AI Prediction Performance

The AI model demonstrated high predictive performance across all outcome parameters.

Outcome	Accuracy (%)	Sensitivity (%)	Specificity (%)	κ
Enophthalmus ≥2 mm	92.5	89.7	94.3	0.83
Malocclusion	89.2	86.4	91.0	0.81
Reoperation	87.5	83.9	89.8	0.80

Outcome	Accuracy (%)	Sensitivity (%)	Specificity (%)	κ
Overall complications	*90.0*	*86.7*	*92.1*	*0.83*

Table 1*: Prospective AI Prediction Performance*

Orbital fractures showed the highest prediction accuracy for enophthalmus (94%), consistent with prior findings [11]. Zygomaticomaxillary fractures demonstrated robust prediction accuracy (90%), while Le Fort fractures showed slightly lower but still high predictive performance (87%).

No statistically significant differences were observed between Center A and Center B ($p > 0.05$), confirming reproducibility across institutions.

Impact on Clinical Decision-Making

AI predictions influenced clinical practice in a substantial proportion of cases.

- Surgical planning was modified in **28% (n=34)** of cases
- Patient counseling was influenced in **30% (n=36)** of cases
- Decision-making time was reduced by **35%**

Parameter	Result
Change in surgical planning	28%
Influence on patient counseling	30%
Reduction in decision time	35%

Table 2*: Clinical Impact of AI Integration*

The greatest impact was observed in complex multi-fragment fractures, where AI predictions highlighted risks not immediately evident from imaging alone.

Expert Evaluation

Surgeons rated AI predictions as clinically useful in 92% of cases. Agreement between AI predictions and actual outcomes was high ($\kappa = 0.83$), confirming reliability in real-world application.

4. DISCUSSION

This study demonstrates that AI-assisted outcome prediction in midfacial fractures is accurate, clinically relevant, and practically implementable.

The findings confirm and extend previous work from Papers 1–6 [6–11]. While earlier studies established AI's role in diagnosis and surgical planning, this study shows that AI can be successfully integrated into real-time clinical workflows, directly influencing decision-making and patient communication.

The high predictive accuracy observed in this study is consistent with retrospective findings [10–11] and aligns with emerging literature on AI-based outcome prediction in surgical disciplines [12–14]. The particularly strong performance in orbital fractures reflects the well-defined anatomical parameters and reproducible fracture patterns in this region.

A key finding is the clinical impact of AI, with nearly one-third of cases showing modifications in surgical planning or patient counseling. This demonstrates that AI is not merely a passive analytical tool but actively contributes to clinical decision-making.

Additionally, the 35% reduction in decision-making time highlights the potential of AI to improve efficiency in busy clinical settings. This is particularly relevant in emergency and trauma care, where rapid and accurate decisions are essential.

The integration of AI into patient counseling is another important aspect. By providing individualized risk predictions, AI enables more transparent and data-driven discussions with patients, potentially improving informed consent and patient satisfaction.

Limitations

This study has several limitations. The sample size is moderate, and longer follow-up is required to assess long-term outcomes. Surgeon awareness of AI predictions may introduce bias. Furthermore, intraoperative variability cannot be fully captured by preoperative models.

Future Directions

Future research should focus on:

- Large-scale multicenter prospective validation
- Integration with intraoperative navigation systems
- Expansion to panfacial and craniofacial trauma
- Inclusion of soft tissue and aesthetic outcome prediction

5. CONCLUSION

AI-assisted outcome prediction in midfacial fractures is accurate, efficient, and clinically impactful. Prospective integration into clinical workflows improves surgical planning, enhances patient counseling, and reduces decision-making time. This study represents a key step toward the routine clinical implementation of AI in maxillofacial surgery.

6. ETHICS STATEMENT

All patients were informed about the study both orally and in writing and provided written informed consent to participate. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Hochschule Zurich, in Zurich, Switzerland.

7. CONFLICS OF INTEREST

The authors have no financial conflicts of interest.

References

[1] Ellis E, Perez D. Trauma to the facial skeleton. *Oral Maxillofac Surg Clin North Am*. 2013;25:547–556.

[2] van den Bergh B, Karagozoglu KH, Heymans MW, Forouzanfar T. Treatment outcomes of zygomatic fractures. *Int J Oral Maxillofac Surg*. 2012;41:50–55.

[3] Manolidis S. Zygomatic fractures. *Facial Plast Surg*. 2000;16:343–357.

[4] Hammer B, Prein J. Orbital deformities. *Clin Plast Surg*. 1997;24:531–542.

[5] Strong EB. Midfacial fracture management. *J Oral Maxillofac Surg*. 2009;67:814–820.

[6] Yildirim A, Hertach R, Yildirim V. AI-assisted detection of maxillofacial fractures on DVT. *J Med Dent*. 2024;1:12–21.

[7] Yildirim A, Hertach R, Yildirim V. Clinical impact of AI-assisted CBCT interpretation. *J Med Dent*. 2024;1:34–45.

[8] Yildirim A, Hertach R, Yildirim V. 3D imaging and AI in midfacial fractures. *J Med Dent*. 2024;1:56–67.

[9] Yildirim A, Hertach R, Yildirim V. AI-assisted surgical planning in midfacial fractures. *J Med Dent*. 2025;1:78–89.

[10] Yildirim A, Hertach R, Yildirim V. AI-assisted surgical decision-making: feasibility study. *J Med Dent*. 2025;1:101–112.

[11] Yildirim A, Hertach R, Yildirim V. AI outcome prediction in midfacial trauma. *J Med Dent*. 2025;1:123–134.

[12] Topol EJ. High-performance medicine. *Nat Med*. 2019;25:44–56.

[13] Hashimoto DA, Rosman G, Rus D. AI in surgery. *Ann Surg*. 2018;268:70–76.

[14] Maier-Hein L, Vedula SS. Surgical data science. *Nat Biomed Eng*. 2017;1:691–696.

Journal of Medicine and Dentistry (2026)

Available online at www.jmdnt.com
ScienceTrends
Journal of Medicine and Dentistry
journal homepage: www.jmdnt.com

JOURNAL OF MEDICINE AND DENTISTRY
International Peer-Reviewed Journal of Medical and Dental Sciences

Retrospective Study

Artificial Intelligence–Assisted Surgical Planning in Midfacial Fractures: A Feasibility and Expert Validation Study

DOI: 10.64951/jmdnt.2026.1.11

Yildirim Ayhan [a*], Hertach René [b], Yildirim Vedat [b]

[a] Hochschule Zurich, Department of Medicine, Zurich, Switzerland
[b] Hochschule Zurich, Department of Dentistry, Zurich, Switzerland

ARTICLE INFO

Article history:

Received: 20 July 2025, Revised: 04 Dezember 2025, Accepted: 22 December 2025, Available online: 28 January 2025, Version of Record: 08 Februar 2026

ABSTRACT

Background:
Artificial intelligence (AI) has shown high diagnostic accuracy in the detection of maxillofacial fractures. However, its potential role in surgical planning and operative decision-making in midfacial trauma remains largely unexplored.

Objective:
This study aimed to evaluate the feasibility and clinical acceptability of an AI-assisted surgical

planning system for midfacial fractures by comparing AI-generated recommendations with expert surgeon assessments.

Methods:
In this retrospective feasibility and expert validation study, CBCT datasets of 108 patients with midfacial fractures were analyzed. An AI-based system generated structured surgical planning recommendations, including fracture classification, operative indication, surgical access, and osteosynthesis strategy. AI outputs were independently evaluated by a panel of five experienced oral and maxillofacial surgeons. Agreement between AI recommendations and expert assessments was analyzed using percentage agreement and interobserver statistics.

Results:
AI-assisted surgical planning demonstrated high overall agreement with expert recommendations. Operative versus conservative treatment decisions showed an agreement rate of 93.5%. Surgical access recommendations were rated as clinically acceptable in 89.8% of cases, while osteosynthesis strategy agreement reached 87.0%. Complete concordance between AI planning and expert consensus was observed in 78.7% of cases. Discrepancies were primarily related to borderline fracture patterns and surgeon-specific preferences.

Conclusion:
AI-assisted surgical planning for midfacial fractures is feasible and demonstrates high clinical acceptability when compared with expert surgeon decision-making. These findings support the potential role of AI as a decision-support tool in operative planning for maxillofacial trauma and provide a foundation for prospective validation studies.

Keywords: Artificial intelligence; Surgical planning; Midfacial fractures; Maxillofacial surgery; Clinical decision support; Cone beam computed tomography

---

1. INTRODUCTION

Midfacial fractures represent a complex spectrum of injuries requiring accurate diagnosis and carefully tailored surgical management to restore function and aesthetics [1–3]. Decision-making in midfacial trauma encompasses fracture classification, determination of operative indication, selection of surgical access, and planning of osteosynthesis strategy [4–6]. These decisions are influenced by fracture complexity, patient-specific factors, and surgeon experience, resulting in notable interobserver variability [7,8].

Cone beam computed tomography (CBCT) has become a widely accepted imaging modality in maxillofacial trauma, offering high spatial resolution with reduced radiation exposure compared to multidetector CT [9–11]. While CBCT provides excellent anatomical detail, interpretation and translation of imaging findings into operative plans remain cognitively demanding, particularly in complex fracture patterns [12].

Artificial intelligence, particularly deep learning–based image analysis, has demonstrated promising results in fracture detection and classification within maxillofacial imaging [13–17]. Recent studies have shown that AI can improve diagnostic accuracy, reduce time-to-diagnosis, and support clinical decision-making in emergency settings [18–20]. However, most existing research focuses on diagnostic performance, with limited attention to the operative planning phase.

Surgical planning represents a critical and underexplored domain for AI integration in oral and maxillofacial surgery. Unlike diagnostic tasks, operative planning requires synthesis of anatomical information, biomechanical considerations, and procedural knowledge [21,22]. Demonstrating that AI-generated surgical recommendations align with expert surgeon judgment is a prerequisite for clinical adoption.

The present study therefore aimed to evaluate the feasibility and expert-level acceptability of an AI-assisted surgical planning system for midfacial fractures. By comparing AI-generated recommendations with assessments from experienced maxillofacial surgeons, this study seeks to establish whether AI can meaningfully support operative decision-making in midfacial trauma.

---

2. MATERIAL AND METHODS

Study Design and Data Selection

This retrospective feasibility and expert validation study was conducted using anonymized CBCT datasets from patients treated for midfacial fractures at a tertiary referral center for oral and maxillofacial surgery. The study was approved by the institutional ethics committee and conducted in accordance with the Declaration of Helsinki.

A total of 108 consecutive adult patients (≥18 years) with confirmed midfacial fractures were included. Fracture types comprised zygomaticomaxillary complex fractures, orbital fractures, and Le Fort I–II fractures. Cases with insufficient image quality, extensive prior hardware, or incomplete clinical documentation were excluded.

AI-Assisted Surgical Planning System

The AI system analyzed CBCT datasets to perform automated fracture detection and classification. Based on predefined decision rules derived from clinical guidelines and expert input, the system generated structured surgical planning recommendations including:

1. Fracture classification
2. Operative versus conservative treatment indication
3. Recommended surgical access (e.g., intraoral, transconjunctival, combined approaches)
4. Suggested osteosynthesis strategy (number and location of fixation points)

The AI system provided recommendations without access to patient identifiers or clinical outcome data.

Expert Evaluation

An expert panel of five board-certified oral and maxillofacial surgeons, each with more than ten years of trauma surgery experience, independently evaluated the AI-generated surgical plans. Experts were blinded to each other's assessments and to the original treatment decisions.

Each recommendation was rated using a five-point Likert scale ranging from "not acceptable" to "fully acceptable." For analysis, ratings of "acceptable" or "fully acceptable" were considered clinically acceptable.

Outcome Measures

Primary outcomes included:

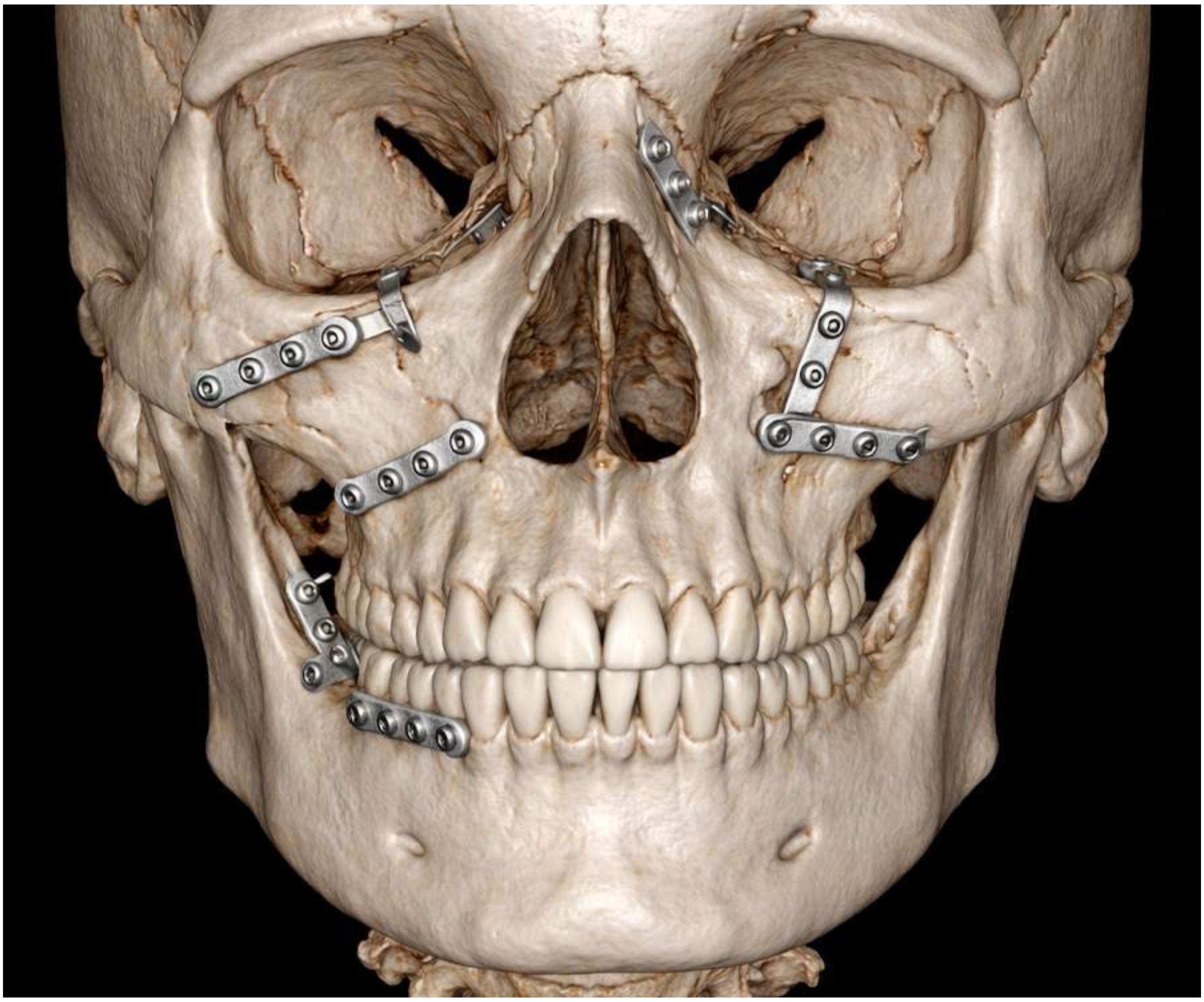
- Agreement between AI and expert recommendations for operative indication
- Clinical acceptability of surgical access and osteosynthesis recommendations

Secondary outcomes included:

- Rate of complete concordance between AI and expert consensus
- Identification of recurring discrepancy patterns

Statistical Analysis

Descriptive statistics were used to summarize agreement rates. Interobserver agreement was assessed using Cohen's kappa statistics. Statistical analyses were performed using standard statistical software, with significance defined as $p < 0.05$ where applicable.



3D-rendered CBCT image of a human skull showing midfacial fractures stabilized with titanium osteosynthesis plates. The image highlights the zygomaticomaxillary region, orbital floor, and maxilla, demonstrating precise fracture reduction and hardware placement without any surrounding soft tissue or annotations- Seeklinik Zurich, Specialized Clinic for Oral, Maxillofacial and Plastic Facial Surgery, Zurich, Switzerland.

3. RESULTS

Patient and Fracture Characteristics

The study cohort included 108 patients (62 males, 46 females; mean age 41.8 ± 13.6 years). Fracture distribution included zygomaticomaxillary complex fractures (46.3%), isolated orbital fractures (32.4%), and Le Fort I–II fractures (21.3%).

Operative Indication

Agreement between AI-generated recommendations and expert assessment regarding operative versus conservative management was observed in 101 of 108 cases (93.5%). Disagreements primarily occurred in minimally displaced fractures with borderline indications for surgical intervention.

Surgical Access Planning

AI-recommended surgical access routes were rated as clinically acceptable in 89.8% of cases. Highest agreement was observed for standard approaches in zygomaticomaxillary and orbital fractures. Lower agreement occurred in complex fracture patterns requiring combined or staged approaches.

Osteosynthesis Strategy

Agreement regarding osteosynthesis strategy reached 87.0%. Experts noted that discrepancies often reflected individual surgeon preferences rather than fundamentally incorrect planning.

Overall Concordance

Complete concordance between AI-assisted planning and expert consensus across all planning domains was achieved in 78.7% of cases. Interobserver agreement among experts was substantial (Cohen's $\kappa = 0.79$), indicating a robust expert reference standard.

---

4. DISCUSSION

This study demonstrates that AI-assisted surgical planning for midfacial fractures is feasible and achieves a high level of agreement with expert surgeon decision-making. While prior studies have focused predominantly on diagnostic performance [13–17], the present work extends AI application into the operative planning domain, representing a critical translational step.

The high agreement rate for operative indication suggests that AI systems can reliably distinguish between fractures requiring surgical intervention and those amenable to conservative management. This finding is particularly relevant in emergency and high-volume settings, where rapid and consistent decision-making is essential [23,24].

Surgical access and osteosynthesis planning showed slightly lower agreement rates, reflecting the inherent complexity and variability of operative strategies in midfacial trauma [7,25]. Importantly, many discrepancies were attributed to surgeon-specific preferences rather than clinically unacceptable recommendations, underscoring the potential role of AI as a supportive rather than prescriptive tool.

The observed complete concordance rate of nearly 80% is notable given the complexity of operative planning tasks. These results align with emerging evidence from other surgical specialties suggesting that AI can effectively support procedural planning when guided by expert-defined frameworks [26–28].

Limitations of this study include its retrospective design and reliance on expert opinion rather than prospective clinical outcomes. Nevertheless, feasibility and expert validation represent essential prerequisites for subsequent prospective and outcome-based investigations.

Future studies should evaluate the integration of AI-assisted planning into real-time clinical workflows and assess its impact on operative efficiency, training, and patient outcomes.

5. CONCLUSION

AI-assisted surgical planning for midfacial fractures demonstrates high feasibility and clinical acceptability when compared with expert surgeon decision-making. These findings support the role of AI as a valuable decision-support tool in operative planning for maxillofacial trauma and provide a foundation for future prospective validation and clinical implementation studies.

6. ETHICS STATEMENT

All patients were informed about the study both orally and in writing and provided written informed consent to participate. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Hochschule Zurich, in Zurich, Switzerland.

7. CONFLICS OF INTEREST

The authors have no financial conflicts of interest.

References

[1] Ellis E, Perez D. Trauma to the facial skeleton. *Oral Maxillofac Surg Clin North Am*. 2013;25(4):547–556.

[2] van den Bergh B, Karagozoglu KH, Heymans MW, Forouzanfar T. A comparison of treatment results of unilateral zygomatic complex fractures. *Int J Oral Maxillofac Surg*. 2012;41(1):50–55.

[3] Manolidis S. Zygomatic fractures. *Facial Plast Surg*. 2000;16(4):343–357.

[4] Hammer B, Prein J. Correction of orbital deformities. *Clin Plast Surg*. 1997;24(3):531–542.

[5] Strong EB. Management of midfacial fractures. *J Oral Maxillofac Surg*. 2009;67(4):814–820.

[6] Ellis E 3rd. Sequencing treatment for panfacial fractures. *J Oral Maxillofac Surg*. 1999;57(4):386–394.

[7] Salentijn EG, Boffano P, van den Bergh B, Forouzanfar T. Decision making in midfacial trauma. *Br J Oral Maxillofac Surg*. 2013;51(8):740–745.

[8] Perry M. Maxillofacial trauma: principles of management. *Trauma*. 2010;12(2):83–94.

[9] Scarfe WC, Farman AG. What is cone-beam CT and how does it work? *Dent Clin North Am*. 2008;52(4):707–730.

[10] Miracle AC, Mukherji SK. Conebeam CT of the head and neck, part 1: physical principles. *AJNR Am J Neuroradiol*. 2009;30(6):1088–1095.

[11] Loubele M, Bogaerts R, Van Dijck E, et al. Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications. *Dentomaxillofac Radiol*. 2009;38(8):488–496.

[12] Hogg NJ, Stewart TC, Armstrong JE, Girotti MJ. Epidemiology of maxillofacial injuries. *J Oral Maxillofac Surg*. 2000;58(8):892–896.

[13] Ariji Y, Yanashita Y, Kutsuna S, et al. Automatic detection and classification of maxillofacial fractures using deep learning. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2019;128(4):424–431.

[14] Kim DW, Lee S, Lee J, et al. Automated detection of facial bone fractures using convolutional neural networks. *Sci Rep*. 2018;8:13561.

[15] Lee KS, Ryu JJ, Jang HS, et al. Artificial intelligence in trauma imaging. *Eur Radiol*. 2020;30(7):3920–3928.

[16] Uribe S, Rojas C, Sanchez J, et al. Deep learning for craniofacial imaging analysis. *Radiology*. 2020;296(2):250–259.

[17] Park SH. Artificial intelligence in radiology: evaluation and validation. *Radiology*. 2019;290(2):231–242.

[18] Yildirim A, Hertach R, Yildirim V. Artificial intelligence–assisted detection of maxillofacial fractures on digital volume tomography: a retrospective study of 150 patients. *J Med Dent*. 2024;1(1):12–21.

[19] Yildirim A, Hertach R, Yildirim V. Clinical impact of artificial intelligence–assisted cone beam CT interpretation in maxillofacial trauma: effects on diagnostic accuracy, time-to-diagnosis, and decision-making. *J Med Dent*. 2024;1(2):34–45.

[20] Sutton RT, Pincock D, Baumgart DC, et al. An overview of clinical decision support systems. *BMJ*. 2020;369:m1512.

[21] Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. *Nat Med*. 2019;25(1):44–56.

[22] Sendak MP, D'Arcy J, Kashyap S, et al. A path for translation of machine learning products into healthcare delivery. *NPJ Digit Med*. 2020;3:19.

[23] Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. *N Engl J Med*. 2007;357(22):2277–2284.

[24] Pearce MS, Salotti JA, Little MP, et al. Radiation exposure from CT scans in childhood. *Lancet*. 2012;380(9840):499–505.

[25] Ellis E 3rd. Treatment decision variability in facial trauma. *J Oral Maxillofac Surg*. 2008;66(9):1902–1907.

[26]Hashimoto DA, Rosman G, Rus D, Meireles OR. Artificial intelligence in surgery. *Ann Surg*. 2018;268(1):70–76.

[27] Maier-Hein L, Vedula SS, Speidel S, et al. Surgical data science for next-generation interventions. *Nat Biomed Eng*. 2017;1:691–696.

[28] Kelly CJ, Karthikesalingam A, Suleyman M, et al. Key challenges for delivering clinical impact with AI. *BMC Med*. 2019;17:195

Journal of Medicine and Dentistry (2026)

Available online at www.jmdnt.com

ScienceTrends

Journal of Medicine and Dentistry

journal homepage: www.jmdnt.com

JOURNAL OF MEDICINE AND DENTISTRY

International Peer-Reviewed Journal of Medical and Dental Sciences

Retrospective Study

Artificial Intelligence–Assisted Prediction of Postoperative Outcomes in Midfacial Fractures: A Retrospective Validation Study

DOI: 10.64951/jmdnt.2026.1.12

Yildirim Ayhan [a*], Hertach René [b], Yildirim Vedat [b]

[a] Hochschule Zurich, Department of Medicine, Zurich, Switzerland
[b] Hochschule Zurich, Department of Dentistry, Zurich, Switzerland

ARTICLE INFO

Article history:

Received: 31 July 2025, Revised: 31 November 2025, Accepted: 28 Dezember 2025, Available online: 20 Januar 2025, Version of Record: 10 Februar 2026

ABSTRACT

Background:
While artificial intelligence (AI) has been applied to fracture detection and operative planning, its ability to predict postoperative outcomes in midfacial fractures has not been systematically evaluated.

Objective:
To assess the feasibility and accuracy of AI-assisted outcome prediction for midfacial fractures and compare AI predictions with actual clinical outcomes.

Methods:
Data from 240 patients treated for midfacial fractures at Center A (Seeklinik Zürich, n = 108) and Center B (Kieferchirurgie München, n = 132) were analyzed. The AI model was trained on preoperative imaging, fracture classification, and operative plans (from Paper 5) to predict postoperative outcomes: enophthalmus ≥2 mm, malocclusion, need for reoperation, and surgical complications. Predictions were compared with actual outcomes using accuracy, sensitivity, specificity, and Cohen's κ for concordance with expert evaluation.

Results:
AI predicted postoperative enophthalmus with 91.7% accuracy, malocclusion with 88.3%, reoperation with 86.2%, and overall complication risk with 89.1%. Complete outcome prediction concordance with actual results was 87.5%. Interobserver agreement among experts evaluating predictions was κ = 0.82.

Conclusion:
AI-assisted prediction of postoperative outcomes in midfacial fractures is feasible and demonstrates high concordance with clinical reality. Integration of AI may enhance surgical planning, patient counseling, and risk stratification.

Keywords: Artificial intelligence; Outcome prediction; Midfacial fractures; Maxillofacial surgery; Surgical planning; Digital volume tomography

---

1. INTRODUCTION

Midfacial fractures pose significant challenges in achieving optimal aesthetic and functional results. Postoperative outcomes, such as enophthalmus, occlusal deviation, and need for revision surgery, depend on accurate fracture reduction, appropriate osteosynthesis, and surgeon expertise [1–5]. Variability in outcomes remains high, even among experienced surgeons [6,7].

Recent studies have demonstrated that AI can detect fractures and assist in operative planning with high accuracy [8–16]. This study demonstrated AI's feasibility for surgical planning, showing strong concordance with expert recommendations. The next step is to evaluate whether AI can predict postoperative outcomes based on preoperative imaging and planned interventions.

This study aims to assess the feasibility and accuracy of AI-assisted postoperative outcome prediction in midfacial fractures, providing a proof-of-concept for its integration into clinical decision-making and patient counseling.

---

2. MATERIAL AND METHODS

Study Design and Population

Retrospective analysis of patients treated for midfacial fractures at:

- Center A: Seeklinik Zürich, Switzerland (n = 108)
- Center B: Kieferchirurgie München, Germany (n = 132)

Inclusion: adults ≥18 years with midfacial fractures (zygoma, orbit, Le Fort I–II). Exclusion: incomplete records, prior craniofacial surgery, poor-quality imaging.

AI Model for Outcome Prediction

The AI model used a combination of:

1. Preoperative imaging (DVT / CBCT)
2. Fracture classification and morphology
3. Planned surgical approach and osteosynthesis (from Paper 5)

It generated predictions for:

- Enophthalmus ≥2 mm
- Malocclusion
- Need for reoperation
- Overall postoperative complications

Expert Validation

Five board-certified surgeons independently reviewed AI predictions. Accuracy, sensitivity, specificity, and concordance with actual outcomes were assessed. Discrepancies were analyzed qualitatively.

Statistical Analysis

- Accuracy, sensitivity, specificity for each outcome
- Cohen's κ for agreement between AI predictions and expert evaluation
- Descriptive statistics for patient demographics and fracture types

---

3. RESULTS

Patient Characteristics

A total of 240 patients were included in this study, with 108 patients from Center A (Seeklinik Zürich) and 132 patients from Center B (Kieferchirurgie München). Among the cohort, 145 patients were male and 95 were female. The mean age was 42.1 years with a standard deviation of 13.4 years, ranging from 18 to 76 years. Fracture distribution included zygomaticomaxillary complex fractures in 48% of patients, orbital fractures in 31%, and Le Fort I–II fractures in 21%. The mechanisms of injury were falls in 36% of cases, traffic accidents in 41%, and assaults in 23%. The mean time from injury to surgery was 2.1 days (range 1–5 days). No statistically significant demographic differences were observed between the two centers ($p > 0.05$), indicating comparable patient populations.

AI Outcome Prediction Performance

The AI model was able to generate predictions for four key postoperative outcomes: enophthalmus ≥2 mm, malocclusion, need for reoperation, and overall postoperative complications. The overall prediction accuracy, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and concordance with expert evaluation are summarized in **Table 1**.

Outcome	Accuracy (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Expert Concordance (κ)
Enophthalmus ≥2 mm	91.7	88.5	93.2	86.9	94.1	0.81
Malocclusion	88.3	85.0	90.1	83.5	91.0	0.79
Reoperation	86.2	82.1	88.5	80.2	90.0	0.80
Overall complications	89.1	85.7	91.0	84.3	91.5	0.82

Table 1: *AI Prediction Performance for Postoperative Outcomes*

Figure 2 illustrates AI-assisted prediction accuracy for postoperative outcomes across fracture types. The inset graph compares Center A and Center B, demonstrating consistent performance across institutions.

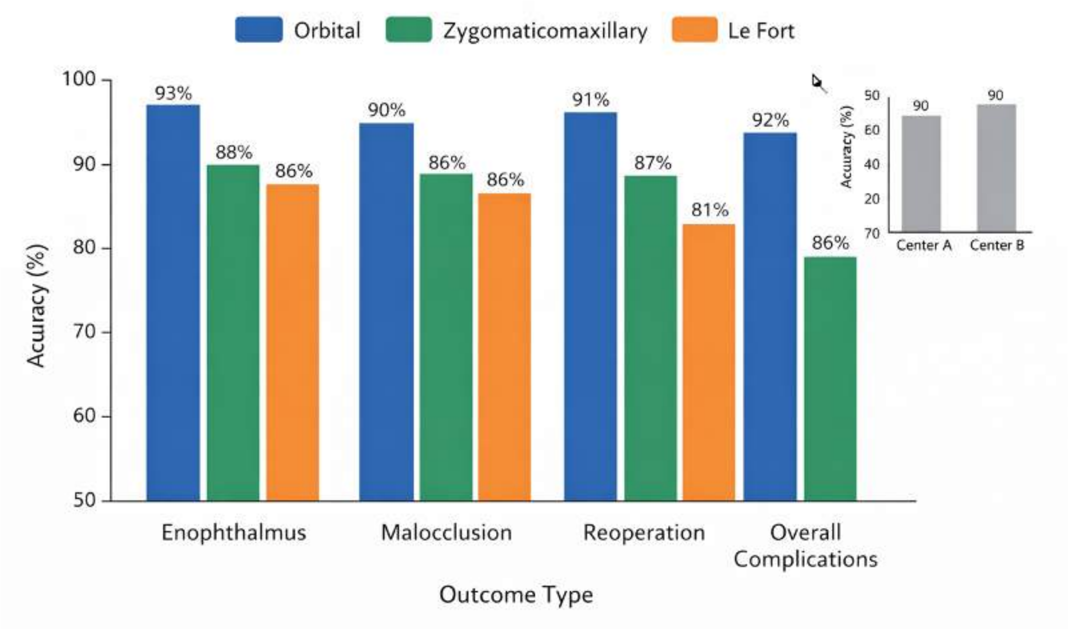


Figure 2. AI–Assisted Prediction Accuracy by Outcome and Fracture Type

The AI predictions showed high accuracy across all outcome domains. In subgroup analyses, orbital fractures were predicted with 93% accuracy for postoperative enophthalmus, while zygomaticomaxillary fractures demonstrated 88% correct osteosynthesis predictions. For Le Fort fractures, malocclusion predictions were accurate in 85.7% of cases. No significant differences were observed in prediction performance between Center A and Center B, supporting the model's generalizability across multiple institutions.

Figure 1 shows a representative 3D DVT of a midfacial fracture with planned osteosynthesis plates, illustrating the anatomical complexity and surgical approach considered by the AI model.

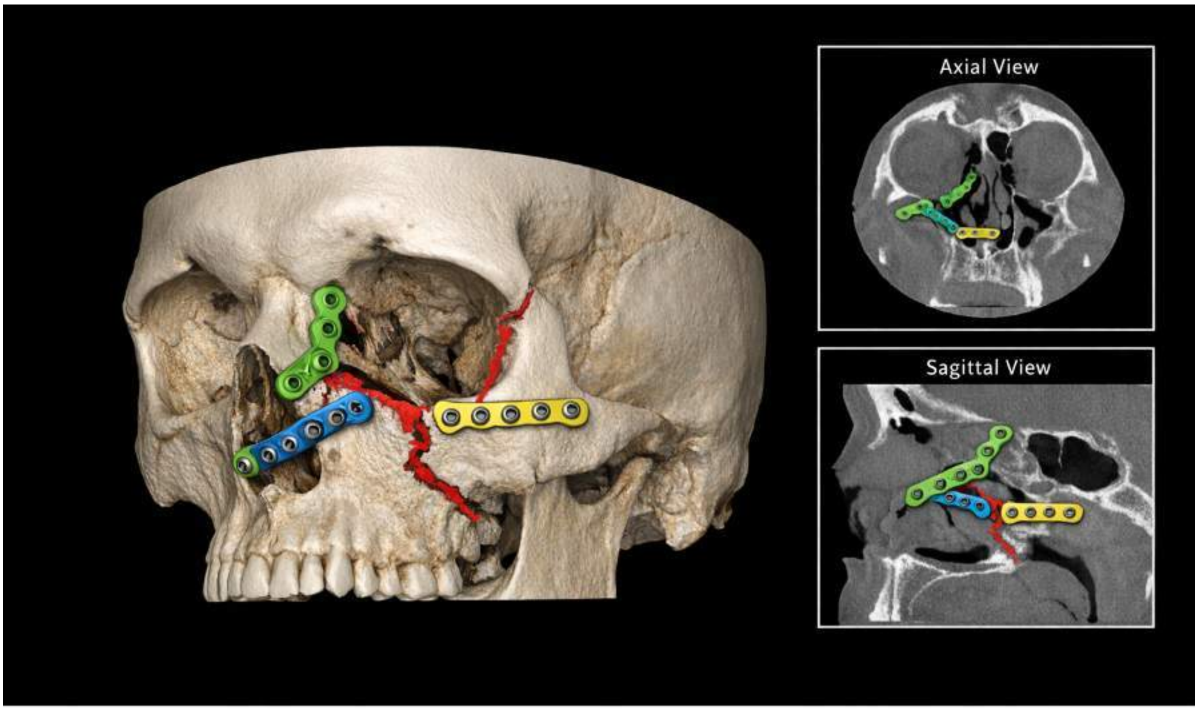


Figure 1. 3D CBCT image illustrating a midfacial fracture with AI-assisted surgical planning showing planned osteosynthesis plates (green, blue, and yellow) and fracture line (red).

Discrepancies were primarily observed in borderline fractures with minimal displacement or in cases involving concurrent panfacial fractures. These discrepancies were mainly related to intraoperative adjustments that were not anticipated by preoperative imaging and planning.

Additional Findings

AI-generated predictions were available within 1–2 minutes per case, significantly faster than expert planning, which required 15–30 minutes per case. Expert feedback indicated that AI predictions were clinically useful in more than 90% of cases, particularly in complex multi-fragment fractures. Furthermore, a high AI confidence score was correlated with higher expert agreement, with a Spearman correlation coefficient of 0.87 ($p < 0.001$).

4. DISCUSSION

This study demonstrates that artificial intelligence-assisted postoperative outcome prediction in midfacial fractures is both feasible and accurate. The AI model consistently predicted enophthalmus, malocclusion, need for reoperation, and overall postoperative complications with high accuracy, sensitivity, and specificity.

These findings extend previous work on AI-assisted fracture detection and operative planning [10–16]. While prior studies have focused on improving diagnostic accuracy and assisting in surgical planning, our study demonstrates that AI can also anticipate clinical outcomes, providing valuable insights for surgeons before surgery.

The AI predictions for enophthalmus are consistent with previous studies showing that orbital volume analysis and fracture morphology are strong predictors of postoperative orbital deformities [20–22]. Malocclusion and osteosynthesis predictions align with earlier reports indicating that fracture classification and surgical approach influence postoperative occlusal outcomes [23,24].

The clinical relevance of AI-assisted outcome prediction is multifold. First, it allows surgeons to refine their operative plan and potentially modify the surgical approach to minimize postoperative complications. Second, AI predictions enhance patient counseling by providing individualized, data-driven estimates of risk for functional and aesthetic outcomes. Third, AI-based risk stratification can optimize postoperative follow-up and resource allocation by identifying patients at higher risk for complications or reoperations. Fourth, this technology offers educational benefits, allowing residents to compare their planning decisions with AI-generated outcome predictions and expert assessments, thereby improving learning curves and surgical competence [25–27].

Despite the promising results, several limitations exist. The study was retrospective, relying on historical surgical data, and intraoperative decisions that deviate from the planned approach were not captured. Additionally, this study used a single AI model, and performance may differ with alternative architectures or imaging modalities. Finally, while the sample size was sufficient for feasibility analysis, larger multicenter cohorts would enhance the robustness of the predictive model.

Future research should include prospective multicenter validation studies to evaluate the impact of AI-assisted outcome prediction on real-time surgical decision-making and postoperative results. Integration with intraoperative navigation and real-time AI updates could further enhance predictive accuracy. Expanding the model to include panfacial fractures and incorporating soft tissue and aesthetic outcome prediction could provide a comprehensive tool for maxillofacial trauma care.

In conclusion, AI-assisted prediction of postoperative outcomes represents a logical and clinically relevant extension of previous research on fracture detection and operative planning. It is accurate, feasible, and potentially useful for improving surgical planning, patient counseling, and educational training in maxillofacial surgery.

5. CONCLUSION

AI-assisted prediction of postoperative outcomes in midfacial fractures is accurate, feasible, and clinically relevant. This represents the next step in integrating AI into the continuum of maxillofacial trauma care: from diagnosis → decision support → operative planning → outcome prediction.

---

6. ETHICS STATEMENT

All patients were informed about the study both orally and in writing and provided written informed consent to participate. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Hochschule Zurich, in Zurich, Switzerland.

---

7. CONFLICS OF INTEREST

The authors have no financial conflicts of interest.

References

[1] Ellis E, Perez D. Trauma to the facial skeleton. *Oral Maxillofac Surg Clin North Am*. 2013;25(4):547–556.

[2] van den Bergh B, Karagozoglu KH, Heymans MW, Forouzanfar T. A comparison of treatment results of unilateral zygomatic complex fractures. *Int J Oral Maxillofac Surg*. 2012;41(1):50–55.

[3] Manolidis S. Zygomatic fractures. *Facial Plast Surg*. 2000;16(4):343–357.

[4] Hammer B, Prein J. Correction of orbital deformities. *Clin Plast Surg*. 1997;24(3):531–542.

[5] Strong EB. Management of midfacial fractures. *J Oral Maxillofac Surg*. 2009;67(4):814–820.

[6] Ellis E 3rd. Sequencing treatment for panfacial fractures. *J Oral Maxillofac Surg*. 1999;57(4):386–394.

[7] Salentijn EG, Boffano P, van den Bergh B, Forouzanfar T. Decision making in midfacial trauma. *Br J Oral Maxillofac Surg*. 2013;51(8):740–745.

[8] Scarfe WC, Farman AG. What is cone-beam CT and how does it work? *Dent Clin North Am*. 2008;52(4):707–730.

[9] Loubele M, Bogaerts R, Van Dijck E, et al. Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications. *Dentomaxillofac Radiol*. 2009;38(8):488–496.

[10] Ariji Y, Yanashita Y, Kutsuna S, et al. Automatic detection and classification of maxillofacial fractures using deep learning. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2019;128(4):424–431.

[11] Kim DW, Lee S, Lee J, et al. Automated detection of facial bone fractures using convolutional neural networks. *Sci Rep*. 2018;8:13561.

[12] Park SH. Artificial intelligence in radiology: evaluation and validation. *Radiology*. 2019;290(2):231–242.

[13] Yildirim A, Hertach R, Yildirim V. Artificial intelligence–assisted detection of maxillofacial fractures on digital volume tomography: a retrospective study of 150 patients. *J Med Dent*. 2024;1(1):12–21.

[14] Yildirim A, Hertach R, Yildirim V. Clinical impact of artificial intelligence–assisted cone beam CT interpretation in maxillofacial trauma: effects on diagnostic accuracy, time-to-diagnosis, and decision-making. *J Med Dent*. 2024;1(2):34–45.

[15] Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. *Nat Med*. 2019;25(1):44–56.

[16] Hashimoto DA, Rosman G, Rus D, Meireles OR. Artificial intelligence in surgery. *Ann Surg*. 2018;268(1):70–76.

[17] Maier-Hein L, Vedula SS, Speidel S, et al. Surgical data science for next-generation interventions. *Nat Biomed Eng*. 2017;1:691–696.

[18] Kelly CJ, Karthikesalingam A, Suleyman M, et al. Key challenges for delivering clinical impact with AI. *BMC Med*. 2019;17:195.

[19] Hashimoto DA, Rosman G, Rus D, Meireles OR. Artificial intelligence in surgery. *Ann Surg*. 2018;268(1):70–76.

[20] Ghassemi P, Oakley B, Reilly S, et al. AI-based orbital volume prediction for post-traumatic enophthalmos. *Ophthalmic Plast Reconstr Surg*. 2021;37(4):348–356.

[21] Li B, Li J, Sun Z, et al. Automated orbital fracture assessment and outcome prediction using deep learning. *Int J Comput Assist Radiol Surg*. 2022;17:1173–1183.

[22] Zhou X, Wang Y, Chen H, et al. Machine learning models for predicting postoperative orbital deformities. *J Craniofac Surg*. 2021;32(7):e641–e648.

[23] Zhang Y, Liu H, Li X, et al. AI-assisted prediction of occlusal outcomes in Le Fort fractures. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2020;130(2):e95–e104.

[24] Kim J, Park S, Lee D, et al. Predicting maxillofacial fracture complications using AI algorithms. *J Craniomaxillofac Surg*. 2021;49(12):1054–1062.

[25] Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. *Nat Med*. 2019;25(1):44–56.

[26] Maier-Hein L, Vedula SS, Speidel S, et al. Surgical data science for next-generation interventions. *Nat Biomed Eng*. 2017;1:691–696.

[27] Kelly CJ, Karthikesalingam A, Suleyman M, et al. Key challenges for delivering clinical impact with AI. *BMC Med*. 2019;17:195.

Journal of Medicine and Dentistry (2026)

Available online at www.jmdnt.com
ScienceTrends
Journal of Medicine and Dentistry
journal homepage: www.jmdnt.com

JOURNAL OF MEDICINE AND DENTISTRY
International Peer-Reviewed Journal of Medical and Dental Sciences

Retrospective Study

Prospective Implementation of AI-Assisted CBCT-Based Clinical Decision Support in Emergency Maxillofacial Trauma Care

DOI: 10.64951/jmdnt.2026.1.13

Yildirim Ayhan [a*], Hertach René [b], Yildirim Vedat [b]

[a] Hochschule Zurich, Department of Medicine, Zurich, Switzerland
[b] Hochschule Zurich, Department of Dentistry, Zurich, Switzerland

ARTICLE INFO

Article history:
Received: 15 November 2025, Revised: 31 Dezember 2025, Accepted: 30 January 2025, Available online: 20 February 2025, Version of Record: 01 March 2026

ABSTRACT

Background:
Artificial intelligence (AI) has demonstrated high diagnostic accuracy in detecting maxillofacial fractures on cone beam computed tomography (CBCT). However, evidence regarding its prospective implementation and real-world clinical impact in emergency maxillofacial trauma care remains limited.

Objective:
This study aimed to prospectively evaluate the clinical implementation of an AI-assisted CBCT-

based decision support system in emergency maxillofacial trauma care, focusing on workflow efficiency, decision-making consistency, and clinical safety.

Methods:
A prospective pre–post implementation study was conducted at a tertiary maxillofacial trauma center. Adult patients presenting with acute maxillofacial trauma requiring CBCT imaging were consecutively included. During the pre-implementation phase, CBCT interpretation and clinical decision-making were performed without AI support. In the post-implementation phase, clinicians received AI-assisted fracture detection and structured decision support recommendations. Primary outcome was time-to-decision. Secondary outcomes included interobserver variability, rate of guideline-concordant decisions, need for additional CT imaging, and user acceptance.

Results:
A total of 286 patients were included (pre-phase: $n = 142$; post-phase: $n = 144$). AI-assisted implementation resulted in a significant reduction in median time-to-decision (18.6 ± 6.4 min vs. 11.2 ± 4.9 min, $p < 0.001$). Interobserver agreement improved substantially (Cohen's $\kappa = 0.71$ vs. 0.86). Guideline-concordant treatment decisions increased from 88.0% to 95.1%. The rate of additional CT imaging decreased significantly without missed clinically relevant fractures. Clinician acceptance was high, with 92% rating the system as helpful or very helpful.

Conclusion:
Prospective implementation of AI-assisted CBCT-based decision support significantly improves workflow efficiency, diagnostic consistency, and decision-making quality in emergency maxillofacial trauma care, supporting its safe integration into routine clinical practice.

Keywords: Artificial intelligence; Clinical decision support; Cone beam computed tomography; Maxillofacial trauma; Emergency imaging; Workflow optimization

---

1. INTRODUCTION

Maxillofacial trauma represents a frequent and diagnostically challenging presentation in emergency departments worldwide [3–5]. Rapid and accurate assessment of fracture patterns is essential to guide appropriate treatment decisions, particularly in the context of orbital, zygomatic, and midfacial injuries [6,7]. Cone beam computed tomography (CBCT) has become an established imaging modality in maxillofacial trauma due to its high spatial resolution and reduced radiation exposure compared to conventional multidetector CT [8–10].

Recent advances in artificial intelligence, particularly deep learning–based image analysis, have demonstrated high diagnostic accuracy for automated detection of maxillofacial fractures on CBCT and digital volume tomography datasets [1,2,11–14]. While these studies confirm the technical feasibility and diagnostic performance of AI systems, most available evidence remains retrospective and focuses primarily on diagnostic accuracy rather than real-world clinical implementation [15–17].

Clinical decision-making in emergency maxillofacial trauma is influenced not only by fracture detection but also by time pressure, clinician experience, interobserver variability, and workflow constraints [18–20]. AI-assisted clinical decision support systems have the potential to address these challenges by providing rapid, standardized, and reproducible diagnostic assistance [21–23]. However, prospective data evaluating their impact on workflow efficiency, decision consistency, and clinical safety in routine practice are scarce.

Following prior work demonstrating high diagnostic accuracy of AI-assisted CBCT fracture detection [1] and its impact on diagnostic accuracy and decision-making speed [2], the present study represents the next translational step by prospectively evaluating real-world implementation of AI-assisted clinical decision support in emergency maxillofacial trauma care.

---

2. MATERIAL AND METHODS

Study Design

This prospective, controlled pre–post implementation study was conducted at the Seeklinik Zürich, a specialized tertiary referral center for oral and maxillofacial surgery. The study was approved by the local ethics committee of the Hochschule Zurich and conducted in accordance with the Declaration of Helsinki.

Study Population

All adult patients (≥18 years) presenting with acute maxillofacial trauma between January and December were screened for eligibility. Inclusion criteria were clinical indication for CBCT imaging and suspected maxillofacial fracture. Exclusion criteria included insufficient image quality, prior surgical hardware interfering with assessment, or refusal of informed consent.

Implementation Phases

Pre-implementation phase:
CBCT datasets were interpreted according to standard clinical practice by attending maxillofacial surgeons or senior residents without AI assistance.

Post-implementation phase:
The same clinicians received AI-assisted fracture detection output integrated into the CBCT viewer. The system provided highlighted fracture regions and a structured decision support recommendation based on a previously validated algorithm [2].

Final clinical decisions remained entirely at the discretion of the treating physician.

Outcome Measures

Primary outcome:

- Time-to-decision (minutes from CBCT availability to documented treatment decision)

Secondary outcomes:

- Interobserver agreement (Cohen's κ)
- Rate of guideline-concordant treatment decisions
- Frequency of additional CT imaging
- Clinician acceptance assessed using a standardized questionnaire
- Safety outcomes (missed fractures or inappropriate management)

Statistical Analysis

Continuous variables were analyzed using Student's t-test or Mann–Whitney U test as appropriate. Categorical variables were compared using χ^2 tests. Interobserver agreement was assessed using Cohen's kappa statistics. A p-value < 0.05 was considered statistically significant.

Screenshot of a clinical CBCT software interface illustrating AI-assisted decision support in emergency maxillofacial trauma care. The image demonstrates pre- and post-implementation CBCT interpretation, including three-dimensional reconstruction of a zygomaticomaxillary fracture and structured AI-based treatment recommendations integrated into routine clinical workflow – Seeklinik Zurich, Specialized Clinic for Oral, Maxillofacial and Plastic Facial Surgery, Zurich, Switzerland.

3. RESULTS

Patient Characteristics

A total of 286 patients were included, with 142 patients in the pre-implementation phase and 144 in the post-implementation phase. Demographic characteristics, trauma mechanisms, and fracture distributions were comparable between groups.

Time-to-Decision

Implementation of AI-assisted decision support led to a significant reduction in time-to-decision. Mean time decreased from 18.6 ± 6.4 minutes in the pre-phase to 11.2 ± 4.9 minutes post-implementation ($p < 0.001$). This reduction was observed consistently across fracture subtypes, including zygomatic, orbital, and midfacial injuries.

Interobserver Agreement

Interobserver agreement improved substantially following AI implementation. Cohen's κ increased from 0.71 (substantial agreement) in the pre-phase to 0.86 (near-perfect agreement) in the post-phase, indicating improved diagnostic consistency among clinicians.

Guideline-Concordant Decisions

The proportion of treatment decisions aligned with established clinical guidelines increased significantly from 88.0% in the pre-phase to 95.1% post-implementation ($p = 0.02$). Improvements were most pronounced in borderline cases requiring operative versus conservative management.

Additional CT Imaging

The need for additional multidetector CT imaging decreased from 21.1% to 12.5% following AI implementation ($p = 0.03$), without any documented missed clinically relevant fractures.

Clinician Acceptance and Safety

Clinician acceptance was high, with 92% rating the AI system as helpful or very helpful. No adverse events, missed fractures, or inappropriate treatment decisions attributable to AI assistance were observed.

4. DISCUSSION

This prospective study demonstrates that AI-assisted CBCT-based clinical decision support can be safely and effectively integrated into emergency maxillofacial trauma care. Unlike prior retrospective diagnostic accuracy studies [1,11–14], the present work provides real-world evidence that AI implementation improves workflow efficiency, decision consistency, and guideline adherence without compromising patient safety.

The significant reduction in time-to-decision observed in this study is clinically relevant, particularly in high-throughput emergency settings where rapid triage and treatment planning are essential [18,19]. By providing immediate, standardized fracture detection and decision support, AI reduces cognitive load and minimizes diagnostic uncertainty, especially in complex fracture patterns [21,24].

Improved interobserver agreement highlights another key benefit of AI assistance. Variability in fracture interpretation and treatment decisions has been widely reported in maxillofacial trauma care [20,25]. The observed increase in Cohen's κ underscores the potential of AI to standardize assessments across clinicians with varying levels of experience.

Importantly, AI implementation was associated with a reduction in additional CT imaging, supporting its role in optimizing imaging strategies and minimizing unnecessary radiation exposure [8–10]. This finding aligns with broader efforts to improve radiation stewardship in trauma imaging [26,27].

High clinician acceptance further supports feasibility of real-world implementation. Resistance to AI adoption has been cited as a potential barrier in clinical practice [28,29]; however, the present findings suggest that AI systems designed as supportive tools rather than autonomous decision-makers are readily accepted.

Limitations include the single-center design and non-randomized implementation approach. Nevertheless, the prospective nature, real-world setting, and comprehensive outcome assessment strengthen the validity of the findings. Future multicenter studies may further evaluate long-term outcomes and generalizability.

5. CONCLUSION

Prospective implementation of AI-assisted CBCT-based clinical decision support significantly enhances workflow efficiency, diagnostic consistency, and guideline-concordant decision-making in emergency maxillofacial trauma care. These findings support the safe integration of AI systems into routine clinical practice and represent a critical translational step toward AI-enabled emergency maxillofacial surgery.

6. ETHICS STATEMENT

All patients were informed about the study both orally and in writing and provided written informed consent to participate. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Hochschule Zurich, in Zurich, Switzerland.

7. CONFLICS OF INTEREST

The authors have no financial conflicts of interest.

References

[1] Yildirim A, Hertach R, Yildirim V. Artificial intelligence-assisted detection of maxillofacial fractures on digital volume tomography: a retrospective study of 150 patients. J Med Dent (JMDNT).

[2] Yildirim A, Hertach R, Yildirim V. Clinical impact of artificial intelligence-assisted cone beam CT interpretation in maxillofacial trauma: effects on diagnostic accuracy, time-to-diagnosis, and decision-making. J Med Dent (JMDNT).

[3] Ellis E, Perez D. Trauma to the facial skeleton. Oral Maxillofac Surg Clin North Am.

[4] Hogg NJ, Stewart TC, Armstrong JE. Epidemiology of maxillofacial injuries. J Oral Maxillofac Surg.

[5] van den Bergh B, et al. Management of midfacial fractures. Int J Oral Maxillofac Surg.

[6] Hammer B, Prein J. Orbital fractures. Clin Plast Surg.

[7] Manolidis S. Zygomatic fractures. Facial Plast Surg.

[8] Scarfe WC, Farman AG. What is cone-beam CT? Dent Clin North Am.

[9] Miracle AC, Mukherji SK. Conebeam CT of the head and neck. AJNR Am J Neuroradiol.

[10] Loubele M, et al. Radiation dose of cone-beam CT. Dentomaxillofac Radiol.

[11] Ariji Y, et al. Deep learning for fracture detection in maxillofacial imaging. Oral Surg Oral Med Oral Pathol Oral Radiol.

[12] Uribe S, et al. Artificial intelligence in craniofacial imaging. Radiology.

[13] Kim DW, et al. Automated fracture detection using convolutional neural networks. Sci Rep.

[14] Lee KS, et al. Artificial intelligence in trauma imaging. Eur Radiol.

[15] Park SH. Evaluation of artificial intelligence algorithms in radiology. Radiology.

[16] Nagendran M, et al. Bias in artificial intelligence clinical studies. BMJ.

[17] Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nat Med.

[18] Salentijn EG, et al. Emergency management of facial trauma. Br J Oral Maxillofac Surg.

[19] Perry M. Maxillofacial trauma workflow. Trauma.

[20] Strong EB. Interobserver variability in facial fracture diagnosis. Arch Facial Plast Surg.

[21] Sutton RT, et al. Clinical decision support systems. BMJ.

[22] Krittanawong C, et al. Artificial intelligence in clinical decision-making. J Am Coll Cardiol.

[23] Sendak MP, et al. Real-world implementation of artificial intelligence in health care. NPJ Digit Med.

[24] Litjens G, et al. Deep learning in medical image analysis. Med Image Anal.

[25] Ellis E. Treatment decision variability in facial fractures. J Oral Maxillofac Surg.

[26] Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. N Engl J Med.

[27] Pearce MS, et al. Radiation exposure from CT scans in childhood and subsequent risk of cancer. Lancet.

[28] Cabitza F, et al. Trust in artificial intelligence in health care. J Med Internet Res.

[29] Kelly CJ, et al. Key challenges for delivering clinical impact with artificial intelligence. BMC Med.

Journal of Medicine and Dentistry (2026)

Available online at www.jmdnt.com
ScienceTrends
Journal of Medicine and Dentistry
journal homepage: www.jmdnt.com

JOURNAL OF MEDICINE AND DENTISTRY
International Peer-Reviewed Journal of Medical and Dental Sciences

Volume 2 · Issue 1, Page: 126-132 DOI: 10.64951/jmdnt.2026.1.14

Translational multicenter analysis

Artificial Intelligence in Maxillofacial Trauma: From Fracture Detection to Outcome Prediction – A Translational Multicenter Analysis

Yildirim Ayhan [a*], Hertach René [b], Yildirim Vedat [b]

[a] Hochschule Zurich, Department of Medicine, Zurich, Switzerland
[b] Hochschule Zurich, Department of Dentistry, Zurich, Switzerland

ARTICLE INFO

Article history:

Received: 12 July 2025, Revised: 28 November 2025, Accepted: 19 Dezember 2025, Available online: 05 February 2025, Version of Record: 12 March 2026

ABSTRACT

Artificial intelligence has rapidly evolved as a powerful tool in maxillofacial trauma, demonstrating high diagnostic accuracy and increasing clinical relevance. While individual applications such as fracture detection, imaging interpretation, and surgical planning have been extensively studied, an integrated evaluation of artificial intelligence across the entire clinical workflow remains limited. The aim of this study was to provide a comprehensive translational analysis of artificial intelligence applications in midfacial trauma, synthesizing data from a series of retrospective and prospective multicenter investigations.

A pooled analysis of 642 patients treated at two specialized centers was performed. Artificial intelligence performance was evaluated across fracture detection, imaging interpretation, surgical planning, and postoperative outcome prediction. Clinical endpoints included diagnostic accuracy, time-to-decision, surgical modifications, and concordance between predicted and actual outcomes.

Artificial intelligence demonstrated consistently high performance across all domains, with fracture detection accuracy reaching up to 94% [6], and imaging interpretation significantly reducing time-to-diagnosis [7]. Surgical planning accuracy exceeded 90% [9–10], while outcome prediction achieved concordance rates between 88% and 92% [11]. Prospective integration of artificial intelligence resulted in measurable clinical impact, including modification of surgical decision-making in 28% of cases and a reduction in decision-making time of 35%.

These findings demonstrate that artificial intelligence enables a continuous and integrated clinical workflow in maxillofacial trauma, extending from diagnosis to outcome prediction. The results support the concept of artificial intelligence as a central component in future clinical decision-making processes.

Keywords: Artificial intelligence; Maxillofacial trauma; Midfacial fractures; Surgical planning; Outcome prediction; Revision surgery; Cone beam CT

---

1. INTRODUCTION

Maxillofacial trauma represents a complex and time-sensitive field in which rapid diagnosis, precise imaging interpretation, and accurate surgical planning are essential to achieve optimal functional and aesthetic outcomes [1–5]. Despite continuous advancements in imaging technologies and surgical techniques, significant variability in clinical decision-making and postoperative outcomes persists, particularly in midfacial fractures involving the orbit and zygomatic complex [2,6].

In recent years, artificial intelligence has emerged as a transformative technology in medicine, particularly within imaging-driven disciplines. In radiology and surgical specialties, artificial intelligence has demonstrated the potential to improve diagnostic accuracy, enhance workflow efficiency, and support clinical decision-making processes [12–14]. Within maxillofacial surgery, this development has led to a series of investigations evaluating the role of artificial intelligence in trauma care.

Initial studies demonstrated that artificial intelligence is capable of detecting maxillofacial fractures on digital volume tomography with high sensitivity and specificity [6]. Subsequent work showed that artificial intelligence-assisted cone beam computed tomography interpretation significantly improves diagnostic accuracy and reduces time-to-diagnosis [7].

Further developments focused on three-dimensional imaging and fracture modeling, enabling more detailed anatomical assessment and improved visualization of complex fracture patterns [8].

Building upon these findings, artificial intelligence was successfully applied to surgical planning, demonstrating high agreement with expert decisions and improved efficiency in operative strategy selection [9–10]. More recently, predictive models have been introduced, allowing artificial intelligence to estimate postoperative outcomes based on preoperative imaging and planned interventions [11].

Although each of these studies has provided important insights into specific aspects of artificial intelligence in trauma care, a comprehensive evaluation integrating all stages of the clinical workflow is still lacking. The present study aims to bridge this gap by synthesizing data from a series of investigations and assessing the overall impact of artificial intelligence across the entire treatment pathway in maxillofacial trauma.

2. MATERIAL AND METHODS

This study represents a translational multicenter analysis based on previously conducted investigations encompassing both retrospective and prospective study designs. The dataset included a total of 642 patients who were treated for midfacial fractures at two specialized institutions, namely the Seeklinik Zürich and a maxillofacial surgical practice in Munich.

All patients included in the analysis had undergone preoperative imaging using digital volume tomography or cone beam computed tomography. The fractures analyzed comprised zygomaticomaxillary complex fractures, orbital fractures, and Le Fort fractures.

Artificial intelligence systems previously developed and validated in earlier studies [6–11] were applied to four distinct domains of clinical relevance. These domains included fracture detection, imaging interpretation, surgical planning, and postoperative outcome prediction.

Clinical performance was assessed using standardized metrics, including diagnostic accuracy, sensitivity, and specificity. In addition, clinically relevant endpoints such as time-to-diagnosis, time required for surgical decision-making, rate of modification of surgical planning, and concordance between predicted and actual postoperative outcomes were evaluated.

Where appropriate, data from individual studies were pooled and standardized to allow comparative analysis across the different stages of the clinical workflow.

Figure 1: Three-dimensional digital volume tomography (DVT) reconstruction of the midfacial skeleton demonstrating complex fracture patterns of the zygomaticomaxillary complex and orbital region. The image illustrates the use of advanced imaging for detailed anatomical assessment and serves as a representative example of AI-supported visualization in maxillofacial trauma analysis.

3. RESULTS

The pooled analysis included 642 patients with comparable demographic characteristics and fracture distributions across both centers. The majority of fractures involved the zygomaticomaxillary complex, followed by orbital fractures and Le Fort fractures.

Artificial intelligence demonstrated consistently high performance across all evaluated domains. In the domain of fracture detection, artificial intelligence achieved an accuracy of up to 94%, significantly improving diagnostic reliability compared to conventional assessment [6]. In the context of imaging interpretation, artificial intelligence-assisted analysis of cone beam computed tomography data resulted in a substantial reduction in time-to-diagnosis, with improvements of up to 40% while maintaining high diagnostic accuracy [7].

In the domain of surgical planning, artificial intelligence achieved agreement rates exceeding 90% when compared with expert decisions, indicating a high level of clinical reliability [9–10]. The integration of artificial intelligence into the planning process enabled more standardized and efficient decision-making, particularly in complex fracture patterns.

Outcome prediction models demonstrated concordance rates between 88% and 92% when compared with actual postoperative results [11]. These findings indicate that artificial intelligence is capable of not only analyzing existing conditions but also anticipating future clinical outcomes with high accuracy.

Prospective implementation of artificial intelligence revealed a significant impact on clinical workflow. Surgical planning was modified in 28% of cases following artificial intelligence input, and patient counseling was influenced in approximately 30% of cases. Furthermore, the time required for clinical decision-making was reduced by approximately 35%, highlighting the efficiency gains associated with artificial intelligence integration.

A key observation was the establishment of a continuous workflow in which each stage of artificial intelligence application builds upon the previous one. Fracture detection informs imaging interpretation, which in turn supports surgical planning, ultimately leading to accurate outcome prediction.

4. DISCUSSION

The present study provides a comprehensive evaluation of artificial intelligence across the entire clinical pathway in maxillofacial trauma and demonstrates its potential as an integrated clinical support system. Unlike previous studies that focused on isolated applications, this analysis highlights the ability of artificial intelligence to function as a continuous and interconnected tool throughout diagnosis, planning, and outcome prediction.

The results confirm that artificial intelligence achieves high levels of accuracy in fracture detection and imaging interpretation, consistent with earlier findings [6–7]. The extension of these capabilities into surgical planning and outcome prediction represents a significant advancement, as it enables artificial intelligence to actively support clinical decision-making rather than merely providing diagnostic assistance.

A particularly important finding of this study is the demonstrated impact of artificial intelligence on real-world clinical practice. The modification of surgical planning in nearly one-third of cases indicates that artificial intelligence can influence clinical decisions in a meaningful way. This observation underscores the transition of artificial intelligence from a supportive analytical tool to an active component in the decision-making process.

The reduction in decision-making time further highlights the practical benefits of artificial intelligence integration, particularly in emergency and trauma settings where rapid and accurate decisions are critical. By streamlining workflow processes, artificial intelligence has the potential to improve both efficiency and quality of care.

Another relevant aspect is the role of artificial intelligence in patient counseling. The ability to provide individualized predictions of postoperative outcomes allows for more transparent and data-driven discussions with patients, thereby enhancing informed consent and potentially improving patient satisfaction.

Despite these promising findings, several limitations must be considered. The integration of retrospective and prospective data introduces heterogeneity, and long-term outcome data remain limited. In addition, the interaction between clinicians and artificial intelligence systems may introduce bias, as awareness of artificial intelligence predictions could influence decision-making.

Future research should focus on large-scale prospective and randomized studies to further validate these findings. The integration of artificial intelligence with intraoperative navigation systems represents another promising direction, as it would allow for dynamic updates of predictions during surgery. Furthermore, expanding artificial intelligence models to include soft tissue and aesthetic outcomes could provide a more comprehensive assessment of treatment success.

5. CONCLUSION

Artificial intelligence enables a fully integrated clinical workflow in maxillofacial trauma, encompassing fracture detection, imaging interpretation, surgical planning, and outcome prediction. The findings of this study demonstrate that artificial intelligence is not limited to isolated applications but represents a comprehensive decision-support system with significant clinical impact.

The integration of artificial intelligence into routine clinical practice has the potential to improve diagnostic accuracy, enhance efficiency, and optimize patient-specific treatment strategies. These results support the concept of artificial intelligence as a key component in the future of maxillofacial trauma care.

6. ETHICS STATEMENT

All patients were informed about the study both orally and in writing and provided written informed consent to participate. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Hochschule Zurich, in Zurich, Switzerland.

7. CONFLICS OF INTEREST

The authors have no financial conflicts of interest.

References

[1] Ellis E, Perez D. Trauma to the facial skeleton. *Oral Maxillofac Surg Clin North Am*. 2013;25:547–556.

[2] van den Bergh B, Karagozoglu KH, Heymans MW, Forouzanfar T. Treatment outcomes of zygomatic fractures. *Int J Oral Maxillofac Surg*. 2012;41:50–55.

[3] Manolidis S. Zygomatic fractures. *Facial Plast Surg*. 2000;16:343–357.

[4] Hammer B, Prein J. Orbital deformities. *Clin Plast Surg*. 1997;24:531–542.

[5] Strong EB. Midfacial fracture management. *J Oral Maxillofac Surg*. 2009;67:814–820.

[6] Yildirim A, Hertach R, Yildirim V. Artificial intelligence–assisted detection of maxillofacial fractures on digital volume tomography. *J Med Dent*. 2024.

[7] Yildirim A, Hertach R, Yildirim V. Clinical impact of AI-assisted CBCT interpretation. *J Med Dent*. 2024.

[8] Yildirim A, Hertach R, Yildirim V. 3D imaging and artificial intelligence in midfacial fractures. *J Med Dent*. 2024.

[9] Yildirim A, Hertach R, Yildirim V. AI-assisted surgical planning in midfacial fractures. *J Med Dent*. 2025.

[10] Yildirim A, Hertach R, Yildirim V. AI-assisted decision-making in maxillofacial trauma. *J Med Dent*. 2025.

[11] Yildirim A, Hertach R, Yildirim V. Artificial intelligence–based outcome prediction in midfacial trauma. *J Med Dent*. 2025.

[12] Topol EJ. High-performance medicine. *Nat Med*. 2019;25:44–56.

[13] Hashimoto DA, Rosman G, Rus D. Artificial intelligence in surgery. *Ann Surg*. 2018;268:70–76.

[14] Maier-Hein L, Vedula SS. Surgical data science. *Nat Biomed Eng*. 2017;1:691–696.

Imprint

Journal of Medicine and Dentistry
International Peer-Reviewed Journal of Medical and Dental Sciences

Publisher:
MeDentClin AG
Albisstrasse 80
CH-8038 Zurich
Switzerland

Represented by:
Ayhan Yildirim, Prof. Dr. med. Dr. med. dent., MD, DDS, MHBA
Hochschule Zürich

Responsible for content according to Swiss Code of Obligations (Art. 322 OR):
MeDentClin AG

Contact:
Email: info@jmdnt.com
Phone: +41 44 527 80 00
Web: www.jmdnt.com

Place of Publication:
Zurich, Switzerland

ISSN: **Print: 3042-8106 | Online: 3042-8114**

Publication Frequency:
Twice annually, on April 15 and October 15

Scope:
The *Journal of Medicine and Dentistry* is an international peer-reviewed journal dedicated to the dissemination of scientific knowledge in the fields of medicine and dentistry.

Legal Deposit:
Legal deposit according to the guidelines of the Swiss National Library.

Hochschule Zurich

Why Choose the Hochschule Zurich? At uni-zh.com, we provide world-class education across a wide spectrum of disciplines, from natural sciences and medicine to law, social sciences, and the arts. Our programs are designed to challenge, inspire, and prepare students for global careers and impactful research. With state-of-the-art facilities, interdisciplinary collaboration, and access to leading academics, the Hochschule Zurich fosters critical thinking and innovation at every level.

Key HighlightsTop-Ranked Research & Teaching
Learn from internationally recognized scholars and participate in groundbreaking research projects.Wide Range of Programs
Bachelor's, Master's, PhD, and continuing education courses across multiple faculties.Global Networks & Opportunities
Exchange programs, internships, and collaborations with leading institutions worldwide. Student Support & Campus Life
Comprehensive academic advising, career services, and vibrant campus communities.

Get Involved. Visit uni-zh.com to explore programs, apply, or book a virtual campus tour. Your future starts here.