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Prospective Clinical Study

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

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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. MATERIALS 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].

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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
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. CONFLICTS OF INTEREST

The authors have no financial conflicts of interest.

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