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ORIGINAL RESEARCH ARTICLE

Impact of intraoperative CT on implant accuracy and reoperation rates in orbital floor reconstruction

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ABSTRACT

Background: Implant malposition is a leading cause of reoperation after orbital floor reconstruction. Intraoperative computed tomography (CT) enables immediate assessment and correction, however its impact on implant positioning accuracy and outcomes remains insufficiently studied.
Materials and Methods: This retrospective study included 86 patients with isolated orbital floor fractures treated with radiopaque implants between 2011 and 2023 at Uppsala University Hospital. Sixty-five patients underwent postoperative CT and 21 intraoperative CT. Eight senior surgeons from all Swedish university hospitals independently reviewed anonymized scans under hypothetical intraoperative and postoperative conditions, indicating whether they would adjust the implant intraoperatively or recommend reoperation postoperatively. In the intraoperative group, implant position was assessed on final CT obtained after any CT-guided adjustment. Actual re-intervention rates were recorded.
Results: Recommendations for implant adjustment were significantly more frequent in the postoperative CT group than in the intraoperative CT group (45% vs. 19%, $p = 0.042$). Unanimous agreement that no adjustment was required occurred more often in the intraoperative CT group (48% vs. 22%). Consensus among ≥3 experts favoring reoperation was observed in 20% of postoperative cases and in none of the intraoperative cases. The perceived need for reoperation was lower in the intraoperative than in the postoperative CT group (5% vs. 15%, $p = 0.45$), as were actual reoperation rates (5% vs. 11%, $p = 0.68$).
Conclusions: Intraoperative CT was associated with improved expert-assessed implant positioning. Although reoperation rates were lower in the intraoperative CT group, these differences did not reach statistical significance.

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Orbital floor fracture; orbital reconstruction; intraoperative computed tomography; implant malposition; reoperation rate

Introduction

Orbital floor fractures are a common result of midfacial trauma and often necessitate surgical intervention to restore orbital volume, support the globe, and prevent long-term complications such as enophthalmos and diplopia [1, 2]. Precise positioning of the orbital implant is a critical factor influencing functional and aesthetic outcomes [3].

Computed tomography (CT) is widely regarded as the gold standard for postoperative assessment of implant position. However, postoperative imaging limits the ability to identify and correct implant malposition during the initial procedure. Consequently, implant-related complications may only become evident after emergence from anesthesia, potentially delaying reoperation and increasing surgical complexity.

Intraoperative CT has emerged as a promising tool to address this limitation by enabling radiological visualization of implant placement, allowing surgeons to assess and correct implant positioning before wound closure [4]. Image quality for bone assessment has been shown to be largely comparable to conventional CT [5–7], and intraoperative CT is generally associated with a lower effective radiation dose [8, 9]. Shifting imaging from postoperative verification to intraoperative guidance may allow immediate correction of implant malposition and potentially reduce the need for subsequent reoperation [10].

Although intraoperative imaging is increasingly used in facial fracture surgery, robust evidence regarding its impact on implant accuracy and reoperation rates in orbital wall reconstruction remains limited.

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This study aims to evaluate the impact of intraoperative CT on clinical decision-making and outcomes in orbital floor repair, specifically examining whether intraoperative imaging influences expert assessment of implant positioning and the need for reoperation compared with standard postoperative CT.

Materials and methods

Study design

This retrospective study included all patients treated surgically for isolated unilateral orbital floor or combined orbital floor and medial wall fractures at Uppsala University Hospital, Sweden, between January 2011 and December 2023. The study was reported in accordance with the STROBE guidelines for observational studies. The primary outcome was expert-assessed need for implant adjustment. Secondary outcomes included perceived and actual reoperation rates.

The indications for surgery were CT-confirmed orbital fractures accompanied by either ocular motility restriction due to mechanical entrapment of extraocular muscles or significant orbital volume expansion with clinically evident or anticipated enophthalmos. Patients were eligible for inclusion if reconstruction was performed using a radiopaque orbital implant, either limited to the orbital floor or spanning both the orbital floor and the medial wall. Exclusion criteria were delayed surgical intervention exceeding 30 days post-injury, non-radiopaque implants and previous midfacial fractures. The surgeries were performed by five board-certified plastic surgeons at the Department of Plastic and Oral and Maxillofacial Surgery.

Data collection

The patients were identified through ICD-10 coding from the database for surgical planning. Patients' data were collected from the electronic medical charts. Collected variables included age, sex, trauma mechanism, perioperative data, re-interventions, and clinical follow-up.

A total of 92 patients met the initial inclusion criteria. After applying the exclusion criteria, the final study cohort consisted of 86 patients. Five patients were excluded because of delayed surgery and one patient was excluded due to placement of a porous polyethylene sheet over the titanium mesh, which obscured imaging evaluation of implant positioning.

Surgical procedure

Access to the orbital floor was primarily achieved through a preseptal transconjunctival or a subciliary lower eyelid incision. In cases requiring broader visualization of the medial wall, a combined transconjunctival–transcaruncular approach was utilized.

The implants used were porous polyethylene with titanium mesh (Medpor®; Stryker Leibinger GmbH & Co. KG, Freiburg, Germany) or titanium mesh alone (Matrix MIDFACE®; DePuy Synthes, West Chester, PA, USA). All implants were screw fixated at the inferior orbital rim. In cases where the defect extended over both the orbital floor and lower half of the medial wall, a single combined implant was used to reconstruct the defect if the medial defect was substantial. In total 11 (13%) combined orbital floor and medial wall implants were used.

Imaging and follow up

Postoperative CT imaging was routinely performed within 24 h after surgery until 2019, when postoperative imaging was replaced by intraoperative CT at Uppsala University Hospital. After implementation in 2019, intraoperative CT became the standard imaging protocol for orbital floor reconstruction at our institution and was routinely performed in all eligible cases. Only one patient did not undergo intraoperative CT because the scanner was temporarily unavailable during service. Thus, use of intraoperative CT was determined by institutional practice rather than fracture complexity. Prior to this change, postoperative CT scans of the facial skeleton were acquired with a slice thickness of 0.5–1.0 mm. After 2019, intraoperative CT imaging was performed with a slice thickness of 0.5 mm. According to institutional dose calculations, the mean effective radiation dose of intraoperative CT was 0.12 mSv. For comparison, the mean effective radiation dose of conventional CT of the facial skeleton was 0.29 mSv.

Clinical follow-up was performed at 1 to 3 months postoperatively, with extended follow-up 6 to 12 months in patients with persistent symptoms or complications. The re-interventions were classified as early reoperations within 30 days and as secondary reconstruction thereafter.

Image review procedure

To evaluate the clinical impact of intraoperative CT in orbital floor fracture repair, eight senior facial trauma surgeons from Sweden's seven university hospitals were invited as expert evaluators. Two authors were affiliated with Uppsala University Hospital, the study site, and also participated as treating surgeons. The group represented three surgical specialties: plastic surgery, oral and maxillofacial surgery, and otorhinolaryngology. Prior to the review, all participants received standardized instructions outlining the study aim and assessment protocol.

The experts independently evaluated the 86 anonymized CT images. For each case, CT scans were viewed in bone window settings across three planes (axial, coronal, sagittal). The intraoperative CT scans represented the final imaging acquired during surgery, that is, after any implant adjustment.

Each scan was reviewed from two clinical perspectives:

1. Simulated intraoperative setting: Experts were asked to envision they had just placed the implant and performed a negative forced duction test. Based on the CT images, the experts were to answer whether they would have recommended intraoperative adjustment of the implant or if the implant position was acceptable.
2. Simulated postoperative setting: The same CT scan was then evaluated as if obtained in the postoperative period, again assuming a negative intraoperative forced duction test. In this scenario, the experts were asked to determine whether reoperation would be indicated, irrespective of the patient's symptoms.

Experts were blinded to clinical outcomes, including whether reoperations occurred. Assessments were submitted independently using a standardized electronic form and later analyzed to compare the perceived need for intraoperative adjustment versus postoperative reoperation.

Statistics

Intrarater reliability was assessed by having one expert perform two independent evaluations with a 1-year interval between assessments and was quantified using Cohen's kappa. Interrater reliability among the eight experts was evaluated using Fleiss' kappa. Agreement categories were used descriptively to illustrate different levels of expert concordance rather than to define formal clinical decision thresholds.

Table 1. Patients' demographics ($n = 86$).

Patient characteristics	Total $n = 86$ (%)	Postoperative CT $n = 65$ (%)	Intraoperative CT $n = 21$ (%)
Male	47 (55)	35 (54)	12 (57)
Female	39 (45)	30 (46)	9 (43)
Age in years, mean (range)	47 (15–87)	47 (16–87)	46 (15–77)
Trauma mechanism			
Assault	30 (35)	22 (34)	8 (38)
Fall < 2 m	28 (33)	22 (34)	6 (29)
Sports	8 (9)	6 (9)	2 (10)
Bicycle	6 (7)	3 (5)	3 (14)
Motor vehicle	5 (6)	4 (6)	1 (5)
Fall > 2 m	2 (2)	2 (3)	0 (0)
Other	7 (8)	6 (9)	1 (5)

CT: computed tomography.

Patients' demographics and trauma mechanisms for the total cohort and imaging modality. Values are presented as number (%).

Unanimous agreement represented complete consensus, while increasing numbers of experts recommending adjustment or reoperation were reported to demonstrate patterns of agreement across the panel. Comparisons between the intraoperative CT and postoperative CT groups regarding implant adjustment and reoperation recommendations were performed using Fisher's exact test due to the small sample size and the binary nature of the outcomes. A p-value of <0.05 was considered statistically significant. All statistical analyses were performed using SPSS software.

Ethics

The study was approved by the Swedish Ethical Review Authority (Dnr 2023-07840-02) and conducted in accordance with the ethical standards of the Declaration of Helsinki.

Results

Patients' characteristics and injury mechanisms

The study cohort comprised 86 patients with isolated orbital floor fractures, of whom 65 underwent postoperative CT and 21 intraoperative CT. Baseline demographic characteristics and mechanisms of injury are presented in Table 1. The groups were comparable with respect to age, sex distribution, and trauma mechanism. The most common causes of injury in the overall cohort were interpersonal violence and low-energy falls.

Intraoperative implant adjustment

Intraoperative implant adjustment was performed in three cases (14%) in the intraoperative CT group. One case required a minor adjustment without repeat imaging, one required adjustment due to muscle entrapment detected by forced duction testing with subsequent confirmatory intraoperative CT, and one required two sequential adjustments guided by intraoperative CT, resulting in three acquisitions.

Early reoperation and secondary reconstruction

The early reoperation rate was 11% (7/65) in the postoperative CT group and 5% (1/21) in the intraoperative CT group ($p = 0.68$). The single reoperation in the intraoperative CT group occurred in the first patient treated after implementation of intraoperative CT and was attributed to limited initial experience in image interpretation rather than inadequate image quality. Among the eight early reoperations, three were due to isolated implant malposition, while five involved implant malposition combined with extraocular muscle entrapment.

After a minimum follow-up of 2 years, no secondary reconstructions were required in the intraoperative CT group. In the postoperative CT group, secondary reconstruction was performed in 3% (2/65) of patients. One case was due to enophthalmos with diplopia, and the other because of a palpable protruding implant edge.

Table 2. The experts intraoperative adjustment recommendation rates.

Expert	Total $n = 86$ (%)	Postoperative CT $n = 65$ (%)	Intraoperative CT $n = 21$ (%)	p
1	26 (30%)	24 (37%)	2 (10%)	0.027
2	28 (33%)	25 (38%)	3 (14%)	0.059
3	22 (26%)	20 (31%)	2 (10%)	0.082
4	33 (38%)	30 (46%)	3 (14%)	0.010
5	44 (51%)	37 (57%)	7 (33%)	0.080
6	37 (43%)	32 (49%)	5 (24%)	0.047
7	20 (23%)	20 (31%)	1 (5%)	0.018
8	50 (58%)	42 (65%)	8 (38%)	0.043

CT: computed tomography.

Data are shown as number of cases and percentages. The p-values reflect comparisons between the two imaging modalities using Fisher's exact test.

Intraoperative adjustment requirement according to expert panel

The mean proportion of cases in which implant adjustment was recommended by the expert panel was significantly higher in the postoperative CT group than in the intraoperative CT group ($p = 0.042$, Fisher's exact test) with 45% (29 of 65 cases) versus 19% (4 of 21 cases), respectively. This pattern was consistent within the expert panel, that is significant differences between groups were observed for five of the eight experts (Table 2).

Intrarater reliability yielded a Cohen's kappa coefficient of 0.82, with agreement in 80 of 86 cases (93%). Interrater reliability among the eight experts, assessed using Fleiss' kappa, was 0.64.

Reoperation requirement according to expert panel

One expert was excluded from the postoperative reoperation analysis because the expert declined to assess the need for reoperation based solely on CT imaging and a normal forced duction test at the end of surgery, lacking clinical outcome data. When CT scans were evaluated under the assumption that they had been obtained postoperatively, the mean perceived reoperation rate was 15%, corresponding to 10 of 65 cases, in the postoperative CT group, compared with 5%, corresponding to 1 of 21 cases, in the intraoperative CT group; the difference was not statistically significant ($p = 0.45$). Reoperation was recommended in the intraoperative CT group by two experts, whereas all seven experts recommended reoperations in the postoperative CT

Table 3. The experts reoperation recommendation rates.

Expert	Total $n = 86$ (%)	Postoperative CT $n = 65$ (%)	Intraoperative CT $n = 21$ (%)	p
1	5 (6%)	5 (8%)	0 (0%)	0.328
2	3 (3%)	3 (5%)	0 (0%)	1.000
3	4 (5%)	4 (6%)	0 (0%)	0.568
4	12 (14%)	12 (18%)	0 (0%)	0.034
5	22 (26%)	19 (29%)	3 (14%)	0.252
6	6 (7%)	5 (8%)	1 (5%)	1.000
7	20 (23%)	20 (31%)	0 (0%)	0.002

CT: computed tomography.

Data are shown as number of cases and percentages. The p-values reflect comparisons between the two imaging modalities using Fisher's exact test.

Table 4. Distribution of expert recommendation for intraoperative implant adjustment and corresponding actual reoperations and secondary surgery.

Number of experts recommending adjustment	Total $n = 86$ (%)	Postoperative CT $n = 65$ (%)	Intraoperative CT $n = 21$ (%)	Postoperative CT Reoperations	Postoperative CT Secondary surgery	Intraoperative CT Reoperations
0	24 (28%)	14 (22%)	10 (48%)	-	-	-
1	13 (15%)	9 (14%)	4 (19%)	-	-	-
2	9 (10%)	7 (11%)	2 (10%)	-	-	-
3	5 (6%)	4 (6%)	1 (5%)	-	-	-
4	8 (9%)	7 (11%)	1 (5%)	1	-	-
5	6 (7%)	5 (8%)	1 (10%)	2	1	-
6	4 (5%)	2 (3%)	2 (10%)	-	-	1
7	7 (8%)	7 (11%)	0 (0%)	1	-	-
8	10 (12%)	10 (15%)	0 (0%)	3	1	-

CT: computed tomography.

Number of experts in agreement on intraoperative adjustment and actual corresponding reoperations and secondary surgery performed.

group. Differences in perceived reoperation rates between groups were significant for experts from two centers, with rates of 18% versus 0% ($p = 0.034$) and 31% versus 0% ($p = 0.002$), respectively (Table 3).

Intrarater reliability for reoperation recommendations was assessed by repeated classification of radiographic images, with agreement observed in 83 of 86 cases, corresponding to 96.5% agreement and a Cohen's kappa coefficient of 0.71. Interrater reliability among the seven experts was assessed using Fleiss' kappa, which was 0.40.

Expert consensus on implant adjustment and reoperation

In the intraoperative CT group, 48% of cases (10/21) were rated as acceptable without the need for implant adjustment by all eight experts, compared with 22% (14/65) in the postoperative CT group. Conversely, in 15% of postoperative CT cases (10/65), all experts unanimously recommended implant adjustment, whereas no intraoperative CT cases received unanimous recommendations for adjustment (Table 4).

Regarding reoperation, 86% of cases (18/21) in the intraoperative CT group were not considered to require reoperation by any expert, compared with 58% (38/65) in the postoperative CT group ($p = 0.34$). In 20% of postoperative CT cases (13/65), three or more experts recommended reoperation, whereas no such consensus was observed in the intraoperative CT group ($p = 0.06$) (Table 5).

Correlation between expert assessment and clinical outcomes

The observed early reoperation rate was 11% (7/65) in the postoperative CT group and 5% (1/21) in the intraoperative CT group. Notably, all early reoperations occurred in cases in which four or more experts had recommended intraoperative implant adjustment based on imaging findings (Table 4).

No secondary reconstructions were required in the intraoperative CT group. In contrast, secondary reconstruction was performed in 3% (2/65) of patients in the postoperative CT group. In one of these patients, secondary reconstruction was prompted by a sharp implant edge at the orbital rim. Although none of the experts recommended reoperation based on imaging alone, five experts would have recommended intraoperative implant adjustment. In the second patient, secondary reconstruction was performed due to diplopia and enophthalmos caused by a slightly undersized implant. In this case, one expert recommended reoperation based on imaging, while all eight experts indicated that intraoperative adjustment would have been appropriate.

Discussion

Orbital floor reconstruction remains one of the most technically demanding procedures in facial fracture surgery due to the orbit's complex three-dimensional anatomy, limited surgical exposure, and the need for precise implant contouring and positioning while avoiding injury to delicate orbital structures. Suboptimal implant positioning is a well-established cause of postoperative complications such as diplopia, enophthalmos, and muscle entrapment, which may ultimately necessitate reoperation [1, 3, 11]. Consequently, methods that allow more accurate intraoperative assessment of implant placement are of considerable clinical interest.

Intraoperative CT imaging enables direct evaluation of fracture reduction and implant positioning and may reduce reliance on postoperative imaging and the need for reoperation. In this study, intraoperative CT was associated with improved expert-assessed implant positioning and numerically more favorable clinical outcomes compared with postoperative CT. Although the study was underpowered for some endpoints, the overall pattern consistently favored the intraoperative CT group.

Table 5. Distribution of expert recommendation for reoperation and corresponding actual reoperations and secondary surgery.

Number of experts recommending reoperation	Total $n = 86$ (%)	Postoperative CT $n = 65$ (%)	Intraoperative CT $n = 21$ (%)	Postoperative CT Reoperations	Postoperative CT Secondary surgery	Intraoperative CT Reoperations
0	56 (65%)	38 (58%)	18 (86%)	-	1	1
1	12 (14%)	10 (15%)	2 (10%)	1	1	-
2	5 (6%)	4 (6%)	1 (5%)	1	-	-
3	8 (9%)	8 (12%)	0 (0%)	2	-	-
4	2 (2%)	2 (3%)	0 (0%)	-	-	-
6	3 (3%)	3 (5%)	0 (0%)	3	-	-

CT: computed tomography.

This table presents the number of cases in which 0 to 7 experts recommended reoperation, in the total study group, the postoperative CT group and the intraoperative CT group. Actual corresponding early reoperations and secondary reconstructions performed in the respective CT groups are also shown. There were no secondary reconstructions in the intraoperative CT group.

A key finding was the significantly lower proportion of cases in which experts recommended implant adjustment in the intraoperative CT group compared with the postoperative CT group (19% vs. 45%). Moreover, nearly half of the intraoperative CT cases were unanimously judged acceptable, more than twice the proportion observed in the postoperative CT group. Conversely, unanimous recommendations for implant adjustment occurred only in the postoperative CT group. These findings suggest that intraoperative CT enables correction of implant malposition before surgical completion, resulting in more accurate final positioning.

Intraoperative implant adjustment was performed in 14% of cases, underscoring the clinical relevance of imaging. Despite these corrections, experts still recommended adjustment in 19% of cases, likely reflecting differences between retrospective image-based assessment and real-time surgical decision-making, where exposure, implant stability, operative time, and perceived risk influence intraoperative choices.

Interpretation of the reoperation data requires consideration of the distinction between intraoperative implant adjustment and postoperative reoperation. Implant adjustment reflects an opportunity to optimize implant positioning during surgery, whereas reoperation additionally depends on clinical symptoms, patient burden, and expected benefit. The early reoperation rate was higher in the postoperative CT group (11% vs. 5%), although not statistically significant. The single reoperation in the intraoperative CT cohort occurred during early implementation and was attributed to uncertainty in image interpretation, suggesting a learning curve rather than a limitation of the modality.

The present findings are consistent with previous literature. A prior study reported intraoperative revision rates of 31% in isolated orbital fractures, highlighting the frequency with which implant adjustments are identified when intraoperative imaging is available [12]. In the absence of intraoperative imaging, reported revision rates due to implant malposition range from 6.5% to 23% [3, 13–16], which aligns with the 11% early reoperation rate observed in the postoperative CT group in this study.

Secondary surgery for enophthalmos has been reported in 3–8% of cases following orbital floor repair [2, 17–19]. In this study, no secondary surgery was required in the intraoperative CT group, and only one patient (2%) in the postoperative CT group underwent secondary surgery due to enophthalmos. As intraoperative adjustment was recommended by all experts in this case, it is conceivable that secondary surgery might have been avoided had intraoperative CT been used. However, reoperation rates vary depending on criteria and follow-up duration, and enophthalmos may develop despite anatomically adequate reconstruction due to soft-tissue changes not preventable by intraoperative CT imaging [20–22].

A major strength of this study is the structured, blinded assessment by eight senior craniofacial trauma surgeons representing all Swedish university hospitals. Intrarater reliability supported assessment stability, and interrater reliability demonstrated agreement for implant adjustment. Agreement for reoperation was only moderate, likely reflecting that reoperation decisions depend on factors not captured by imaging alone, including symptoms, ocular motility, functional impairment, and patient-related considerations

Several limitations should be considered. The study included five surgeons and was conducted over a prolonged period, during which surgical technique, experience, or other surgeon-related factors may have evolved and contributed to differences between groups. In addition, evaluators may have distinguished between conventional postoperative CT and intraoperative CT images based on inherent image characteristics. This potential lack of complete modality blinding could have introduced observer bias. The intraoperative CT cohort was relatively small, limiting statistical power for some outcomes. Furthermore, experts, including the operating surgeons, recommended implant adjustment in more cases than were ultimately performed. This discrepancy likely reflects differences between retrospective image-based evaluation under controlled conditions and live surgical decision-making. Finally, expert agreement was greater for implant adjustment than for reoperation, demonstrating that reoperation decisions incorporate additional clinical considerations beyond imaging findings alone. Important clinical outcomes, including diplopia, ocular motility, enophthalmos, patient-reported outcomes, and patient satisfaction, were not systematically collected and therefore could not be incorporated into the analyses. This limitation should be considered when interpreting reoperation recommendations based solely on imaging. Given these limitations, future multicenter studies with larger cohorts are needed to further explore the impact of intraoperative CT on implant adjustment, reoperation, and functional outcomes.

Conclusions

Intraoperative CT imaging allows direct evaluation and adjustment of orbital implants and was associated with a statistically significant reduction in expert-judged malposition rates. Although both the perceived and actual reoperation rates were lower in the intraoperative CT group, these differences did not reach statistical significance. These findings support intraoperative CT as a useful adjunct to improve implant accuracy and potentially reduce the need for reoperation in orbital floor reconstruction.

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