Minimal bone resorption after open treatment of mandibular condylar head fractures

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Abstract

Open treatment of condylar base and neck fractures is widely recommended, whereas treatment of condylar head fractures is still controversial and just is removal of osteosynthesis material. In this study, bone resorption and remodelling after open treatment of condylar head fractures were three-dimensionally (3D) assessed and correlated with clinical parameters in a medium follow-up. Of 18 patients with 25 condylar head fractures who underwent open reduction and internal fixation, clinical data and cone beam computed tomography (CBCT) datasets were analysed. Condylar processes were segmented in the postoperative and follow-up CBCT scans. Volumetric and linear changes were measured using a sophisticated 3D-algorithm. In the course after surgery, patients function and pain improved significantly. Low rates of postoperative complications were observed. All 3D measurements showed no significant bone resorption during the follow-up period. Open reduction of condylar head fractures leads to good patients outcomes and low rates of long-term complications. This study underlines the feasibility and importance of open treatment of condylar head fractures and may help to spread its acceptance as the preferred treatment option.

Introduction

Mandibular fractures are the most common craniofacial fractures with 25%–45% of cases involving the condylar process^[1,2]. The treatment of these condylar fractures has been controversial for years. Whereas for fractures located at the condylar neck and base, open treatment has become “gold standard”^[3–5] with superior function and outcomes compared to closed treatment; however, for condylar head fractures the discourse is ongoing. Despite existing nomenclature systems^[2,6,7], there is often no distinct differentiation between the types of condylar process fractures made in the literature^[8–10] which has resulted in Nussbaum et al. concluding that a meta-analysis is not feasible due to the inconsistency of reported fractures and nomenclature in the underlying studies^[11]. This is made more convoluted due to the different levels of fracture of the condylar process representing completely different, non-comparable types of diseases, morbidity, complications, and outcomes. The latest IBRA position paper did not clearly recommend open treatment for condylar head fractures (CHF)^[3]; however, in more recent studies, open treatment has been suggested and seems to be superior to closed treatment^[3,12–15]. In the authors’ opinion, the so-called closed treatment is likely to be no treatment at all, as any spontaneous repositioning of the fractured condylar head against muscular traction seems highly unlikely to occur. Open treatment of CHF is considered the only way to achieve long-term restoration of function and anatomically stable results with reconstruction of vertical height and prevention of occlusal disturbances^[14].

Osteosynthesis with two positional screws has proven to be appropriate for treating CHF^[16]. Although the removal of osteosynthesis material was formerly only recommended in cases of implant failure^[17,18], some of the latest studies using volumetric and three-dimensional evaluation of bone resorption strongly

recommend standardised removal four to six months after surgery to prevent screw protrusion and reduce the rate of subsequent joint disorders^[15,19–21].

Previous studies investigated bone resorption after open treatment of CHF using different techniques and made adverse conclusions in terms of screw/plate removal^[15,18,19]. The resorption seems to affect the lateral and dorsal aspects of the condylar head, rather than vertical height and articulating surface^[19,22,23].

In this study, we evaluated bone remodelling and resorption in our patient cohort after open treatment of CHF using three-dimensional and volumetric methods in a medium-term follow-up. The surgical and clinical parameters were found to be correlated.

Methods

Patient selection

In this retrospective two-centre analysis, the Department of Oral and Maxillofacial Surgery, Hannover Medical School, Hannover, Germany and the Department for Oral and Maxillofacial Surgery, Leipzig University Hospital, Leipzig, Germany, were screened for patients who presented with CHF between 2016 and 2020. Patients had to meet the following inclusion criteria:

1. Displaced condylar head fracture type M or P according to Neff et al.^[2], regardless of the degree of fragmentation (none, minor, major) and vertical apposition (complete, partial, or lost).
2. Open reduction and internal fixation (ORIF) were performed using positional screws with or without additional mini-plate osteosynthesis.
3. Complete patient documentation during follow-up of at least six months.
4. Postoperative and follow-up cone beam computed tomography (CBCT) scans of appropriate quality allowing for 3D-segmentation.
5. Fulfilled patient consent.

Clinical parameters and outcome measures

Pre-, intra-, and postoperative data from patient records was collected and analysed. In addition to aetiology and clinical parameters, TMJ-related parameters—such as maximal interincisal opening (MIO) laterotrusion, deviation and occlusion—and TMJ-related pain and joint noises were observed at two time points (T1 and T2).

3D segmentation and analysis

CBCT scans were performed in clinical routine intra- or immediately postoperatively (T1) for verification of repositioning and positioning of osteosynthesis, as well as during the follow-up examinations (T2).

For the three-dimensional analysis of condylar heads, the whole mandibular rami were segmented, using MITK Workbench (German Cancer Research Center, (DKFZ) Division of Medical Image Computing, Heidelberg, Germany). DICOM data sets were imported into MITK Workbench, which features an “Otsu” algorithm for automated threshold-based segmentation^[24]. A standardised configuration was applied (nine regions and 70 histogram bins). Segmentations were corrected and processed using morphological operations like gap closing and hole filling. Smoothed STL files were generated and exported (Fig. 1a/b). To reduce osteosynthesis-related scattering, osteosynthesis material was segmented, visualised and, if necessary, subtracted (Fig. 1b). Volumetric and metric measurements were processed in Artec® Studio 15 (20 rue des Peupliers, L-2328, Luxembourg). To separate the condylar processes, the 3D-segmentations of T1 and T2 were imported, superimposed, and cut at a line through the most inferior point of the sigmoid notch and the posterior boundary of the mandibular foramen (Fig. 1c/d). Setting a cut line closer to the fractured, and potentially irregular, condylar head might be prone to error; however, the superimposition of the postoperative (T1) and follow-up (T2) segmentations prior to cutting allowed for splits at exactly the same line. This further reduces any possible methodological volume deviations. The volumes of the isolated condylar processes were calculated using Artec® Studio 15. For metric measurements of remodelling, a Cartesian coordinate system was projected onto the condylar head to determine the offset between T1 and T2 in the transverse, sagittal, and longitudinal orientations (Fig. 2).

Statistical analysis

Statistical analyses were performed using Microsoft Excel® 2019 (Microsoft, Redmond, WA, USA) and ‘R’ (The R Foundation for Statistical Computing, c/o Institute for Statistics and Mathematics, Wirtschaftsuniversität Wien, Vienna, Austria). Means, standard deviations, and medians were calculated, and t-tests were used to compare values. Pearson’s correlation was calculated to correlate resorption and clinical parameters.

Study Approval

This study was approved by the local ethics review committee (Hannover Medical School) (study no.: 8163_BO_K_2018). All included patients provided informed consent.

Results

Screening of department databases yielded 30 patients meeting the inclusion criteria, of which 12 patients were lost to follow-up. Eighteen patients with eligible datasets at both time points were included in this study. These patients led to a total of 25 openly treated CHF.

Fracture topography and classification

All fractures were condylar head fractures according to AO classification^[2]. Seven fractures (38.9%) were bilateral, and 10 were associated with additional mandibular fractures (55.6%) (Table 1). Comminuted fractures with more than two condylar head fragments occurred in 61.1% of the fractures.

Demographics & Aetiology

Gender distribution was nearly even with 12 male (57.1%) and nine female (42.9%) patients. Their ages at the date of surgery ranged from 17 to 76 years, with a mean of 43.1 ± 3.9 years. The most common cause of trauma were falls, followed by traffic accidents. The mean follow-up period was 15.1 ± 2.2 month.

Clinical and surgical parameters

Preoperative maximal interincisal opening (MIO) was reduced to 19.75 ± 3.07 mm. It significantly improved to 40.47 ± 1.7 mm during follow up ($p = 0.0005$) (Table 1). Patient's pain improved as well from 5.0 ± 0.61 (VAS) preoperative to 0.33 ± 0.19 during follow up ($p = 0.008$). Deviation during mouth opening was observed in five patients during follow-up. The mean laterotrusion of both sides was 5.56 ± 0.83 mm. No patient showed severe TMJ function, and only one patient showed an occlusal disturbance. No further long-term complications, such as facial nerve palsy, salivary fistulae, or clinically apparent arthrosis, occurred.

The mean surgical time was 120.09 ± 9.03 minutes per fracture. Most commonly for fracture osteosynthesis, two positioning screws were used (60.0%), followed by three positioning screws (12%), and one 4-hole osteosynthesis plate (12%) (Table 1). Seven patients showed joint noise during the follow-up (38.33%). Standard osteosynthesis materials with screw diameters between 1.5 and 2.0 mm were used.

Morphological alterations of the condylar head

Mean condylar head volume decreased from 3022.01 ± 825.77 mm³ at T1 to 2878.8 ± 735.60 mm³ at T2, however this difference was not significant ($p = 0.52$) (fig. 3). The mean volume difference was 143.21 ± 465.72 mm³. Mean mandibular ramus height decreased by 1.55 ± 1.65 mm ($p = 0.172$). Mean transversal condyle width decreased increased by 1.162 ± 1.96 mm ($p = 0.086$) and mean sagittal condyle width changed by 0.45 ± 1.601 mm³ ($p = 0.575$). All changes in the linear measurements were not statistically significant. Morphological alterations in CBCT at T2, however, commonly indicated remodelling and resorption (Table 2). Three patients underwent secondary surgery and plate removal after the follow-up CBCT (T2).

Discussion

There are several previous studies on bone remodelling after surgical treatment of CHF^[15,18,19], each of which uses a different analytical approach. Recent studies have described either three-dimensional or

volumetric measurements; therefore, we decided to combine both measurements of volumetric alterations and two-dimensional changes of the condylar head, which were modified according to Skroch et al. 2020^[19]. By using sophisticated automated segmentation algorithms in the present study, the volume bias during segmentation is reduced. The splitting of mandibular segmentations for volumetric assessment has been modified in this study, as we have seen a bias in the determination of the condylar head baseline due to fracture-related alterations in anatomy. The previously described projection of a sphere into the pole zone of the condylar head could be prone to bias^[2]; therefore, we set the cutting line lower, through the most inferior point of the sigmoid notch and the posterior boundary of the mandibular foramen (fig. 1) to prevent interference with osteosynthesis material and trauma-related deformities of the condylar head and neck. These points are reliably recognisable during the segmentation process. This does not affect the total volumetric resorption measurements, but the calculated relative resorption could be estimated to be lower as the reference volume increased. During segmentation and volume measurement, osteosynthesis material outside the condylar heads was excluded. As no surgery to the TJR occurred between T1 and T2 in this study, another reason for bias could be avoided.

In CBCT scans during follow-up in this study, remodelling of the fractured condylar heads was frequently observed (Table 1), even though there was no significant change in the condylar head volumes and linear dimensions. These findings match those of previous studies on this topic, which could not prove any significant volumetric changes either^[15,19]. Johner et al. observed a volumetric decrease of 15.29%, without any significance as well^[15]. In our study the mandibular ramus height decreased by a median of 0.84 mm without being statistically significant; however, a similar amount of loss of vertical ramus height was observed in previous studies^[18,19,22]. The influence of comminution, dislocation, fracture location, and the presence of additional fractures is unlikely due to the small sample sizes. The studies mentioned before were also unable to demonstrate statistically significant correlations^[19,20]. A general removal of osteosynthesis material was not performed in this study, except from those cases with osteosynthesis failure (n=1) or intraarticular screws (n=4). Still, the removal of osteosynthesis is point of discussion, unfortunately our data do not allow for any advice on this issue.

Most other studies compared patients' TMJ function using the well-established helkimo index. This index was initially described in 1978 by Helkimo^[25] for the classification of patients with temporomandibular joint disorders. Since then, it has been widely used for the classification and documentation of any kind of TMJ disorder, including fractures of the TMJ; however, this index does not sufficiently reflect the characteristics of patients with TMJ fracture or deformities in the course of TMJ trauma. To mitigate this, we used MIO, laterotrusion, and joint pain separately to compare patients' functions. Our clinical findings show significant improvements in TMJ function and pain between T1 and T2, with no severe TMJ disorders or long-term complications at T2. Open treatment of CHF is supported by the findings of our study and those of previous studies with low resorption and good clinical patient outcomes. Therefore, we strongly recommend the open treatment for condylar head fractures, as it is still not widely performed. However, further prospective clinical trials are required to confirm this trend and avoid shortcomings of a retrospective approach.

Open treatment of condylar head fractures leads to low bone resorption with no significant alterations in the course after surgery. Patients showed good TMJ function and outcomes with low long-term complication rates. These findings, as well as the latest literature, promote the open reduction and osteosynthesis of condylar head fractures.

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Declarations

Author contributions (names must be given as initials)

Conception and design: MN, RZ, BL, NCG; data acquisition and analysis: MN, DH, AZ, AB; interpretation of data: MN, DH, RZ; manuscript draft and revision: MN, RZ, AS, AB, AZ, BL, NCG; approval of final version: MN, NCG, AZ, AB, AS, BL, DH, RZ

Conflict of interest

None.

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Tables

Table 1: Fracture classification

clinical parameter	No. of cases [%]	
	total	n = 18
<u>Cause of trauma</u>		
fall	12	66.7
traffic accident	5	27.8
violence	1	5.6
<u>Fracture classification</u>		
non/- slightly displaced	1	5.6
displaced	13	72.2
comminuted and displaced	11	61.1
<u>Additional fractures</u>		
median	7	38.9
paramedian	3	16.7
collum	3	16.7
total cases with additional fractures	10	55.6
<u>Osteosynthesis type</u>		
2 positioning screws	15	60.0
3 positioning screws	3	12.0
1 x 4 hole plate	3	12.0
2 plates	2	8.0
Others	2	8.0
<u>Follow up CBCT diagnosis</u>		
no change	6	24.0
resorption	14	56.0
arthrosis	3	12.0
osteosynthesis failure	1	4.0
intraarticular screw	4	16.0
sequester	1	4.0
callus	4	16.0

Table 2: Patients function and surgery time

Clinical parameter	Mean	SEM	p
MIO preop [mm]	19,71	3,51	
MIO follow up [mm]	40,47	1,70	0,0001
Laterotrusion follow up[mm]	5,56	0,83	
pain preop (VAS)	5,00	0,61	
pain follow up (VAS)	0,33	0,19	0,008
surgical time pre fracture [min]	120,09	9,03	

Figures

Figure 1

(A) Follow-up CBCT-scan of a 21 years old male patient with a bilateral fracture of the condylar head. Segmentation of the left mandibular ramus in MITK Workbench ® (yellow) and the generated smoothed STL-file (green) are shown. (B) Same patient as (A) with segmented and visualised osteosynthesis material (black arrow, three positioning screws). (C) Lateral view on the superimposition of segmentations of CBCT-scans at T1 (green) and T2 (red) (Artec Studio®); condylar neck of T2 (red) already split at the defined line (yellow) between most inferior point of the sigmoid notch and the most posterior boundary of the mandibular foramen. (D) Dorsal view of (C); remodelling of the condylar head is clearly visible with loss of height. Especially at the lateral aspect callus and resorption at the screw head are visible (black arrow).

Figure 2

(A) Dorsal view on a follow up (T2) CBCT-scan segmentation of the left condylar neck of a 32 years old male patient. Linear measurements at the greatest extent in transverse and longitudinal orientation are shown, performed in Artec Studio®. (B) Lateral view on the same segmentation as in (A) with linear measurement in the sagittal orientation.

Condylar head and neck volume

Figure 3

Boxplot of condylar neck volume [mm³] postoperative (T1) and follow up (T2); no significant difference between both examinations was seen, $p = 0.52$, (median, box height: interquartile range, whiskers: lowest and highest value).