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Evaluation of one-point fixation surgery with computer-aided root mean square deviation in zygomaticomaxillary complex fractures

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ABSTRACT

Aims: Our paper aimed to present the results of the one-point fixation method in zygomaticomaxillary fractures by computer-aided mirror image superimposition with root mean square (RMS) deviation.

Methods: One-point fixation performed zygomaticomaxillary complex fracture patients (n=18) by one surgeon were included in our study. Virtual 3D data of preoperative and postoperative CT-scan images was obtained by Slicer software. Sagittal plan mirror image superpositioning were used to obtain RMS data by Slicer. Mirror image superimposition of the undamaged side to the broken side in preoperative CT-scan imaging was referred as group B or broken group. Superposition of the repaired side's postoperative imaging to the preoperative broken side was measured as group R or repair group in order to examine zygomatic bone's postoperative spatial location. Superpositioned mirror 3D images of the non-traumatic side onto post-fixation 3D in postoperative data was measured as group M or mirror group. RMS deviation values of the groups obtained by Slicer were statistically compared.

Results: Shapiro-Wilk test of groups were demonstrated normal distribution of the data for each group with no difference ($p>0.05$). In order to compare between groups, paired t-test covariance analysis were shown statistically similar data distrubition between experimental groups ($p>0.05$).

Conclusion: Considering the nature of maxillofacial surgery, which disapproves even millimetric errors, we believe that the mean square root deviation will become standard as it allows three-dimensional evaluation and precise mathematical measurements. Besides, in accordance with the recent literature, this study might pay the way for future studies that would increase the usage of the one-point fixation method conducted on larger case series, as this method prevents lower eyelid complications without a visible scar.

Keywords: Maxillofacial surgery, facial fractures, 3D imaging, 3D segmentation, root mean square, RMS

INTRODUCTION

The zygomatic bone defines the outer width and lateral projection of the face. This projection is called in the literature mid-lateral projection or malar eminence. However, the location and projection of the zygomatic bone cause widespread fracture incidence.[1] In addition to providing malar projection, the zygoma body originates in mimic musculature such as zygomatic muscles. Therefore, 3D reduction and fixation of zygomatic bone is mandatory for both aesthetic and functional outcomes in facial expression.[2] Today, reduction and rigid fixation is the golden standard for maxillofacial surgery. In zygomatic bone fracture repair many studies suggested three or two-point fixation methods.[3] Nevertheless, some studies reported that the one-point fixation method assures adequate rigidity without lower eyelid-related complications. This single-point repair method has become popular over time, as it requires a single incision intraorally which results in no visible scar.[1]

With its three-dimensional complex structure and joints of the bone, zygoma fractures may require three-dimensional measurement methods instead of reduction parameters such as distance measurements.[4] In addition, the contribution of zygomatic bone to the orbital cavity and maxillary sinus makes volume assessment compulsory in zygomatic trauma cases. Today, the widespread use of computed tomography in the diagnosis and treatment of facial fractures has allowed virtual three-dimensional postoperative evaluation. With computer-

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aided programs, not only distance measurements but also spatial positional changes and volumetric differences can be determined in millimeters.[5] Root mean square (RMS) or quadratic mean is a measurement mathematical standardization value that is unique to 3D imaging methods to obtain point-to-point or surface-to-surface data for every millimeter.[6,7] Our study aimed to determine the postoperative precise position of the zygoma with open-source computer-aided three-dimensional spatial and volumetric measurements and to investigate the effectiveness of the single-point fixation method with RMS in zygoma fractures.

METHODS

This retrospective study was carried out with the permission of Hatay Mustafa Kemal University Clinical Researches Ethics Committee (Date: 17.02.2022, Decision No: 2022/02-36). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Data Collection

Twenty-eight patients who underwent one-point fixation due to zygoma fracture between 2018 and 2021 were included in the study. Patients whose CT-scan imaging resolutions were low (more than two millimeters) were excluded from the study since because exact measurements could not be made due to plaque or screw artifacts (n=18). High-resolution Maxillofacial CT DICOM data obtained before and after the surgery was processed in Slicer 4.10.0 open-source software program to obtain a virtual 3D image of the skeleton (Figure 1). The preoperative and postoperative topographic structure of the facial skeleton was revealed by marking the sella turcica, porion, nasion, and basion points that are not included in the fracture area (Figure 2). These marking points were referred to determination of sagittal plans. Sagittal plans were used for comparison of the same sides as superposition. Sagittal plans also were used for comparison of the mirror sides as superimposition. Point-to-point data for every millimeter on the surfaces were revealed by Slicer as RMS. To compare spatial positional changes and volumetric differences in millimeters. RMS deviations were measured.

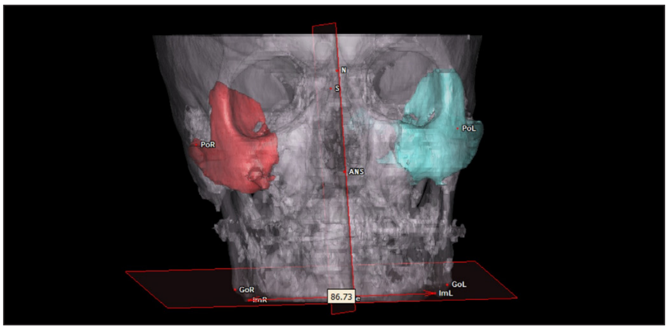

Figure 2. Topographic marking and determining the axles from virtual 3D.

3D Evaluation and Measurement

Mirror image superimposition of the undamaged side to the broken side in preoperative CT-scan imaging was obtained by the software and RMS deviations was measured (group B or broken group). RMS deviation values are calculated for this group to assess the extent of deviation from the intact (mirror) side. To compare

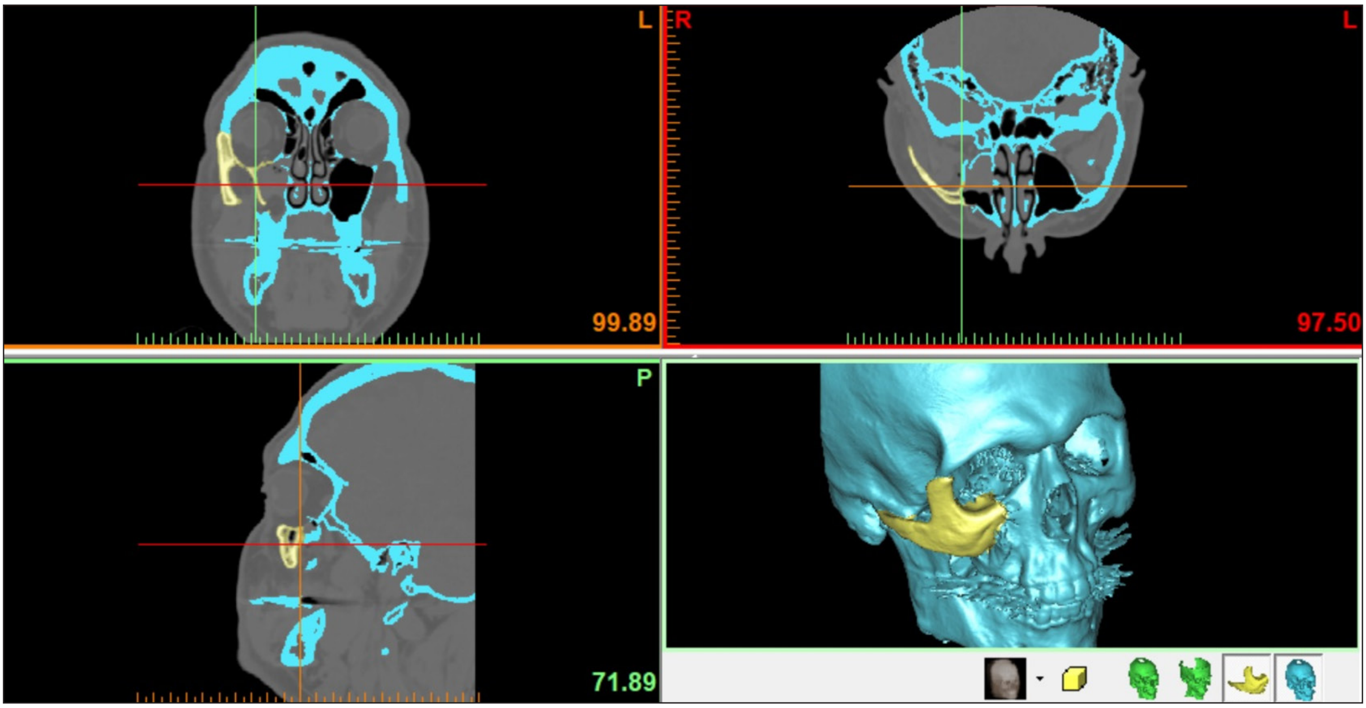

Figure 1. Virtual 3D data obtained with maxillofacial CT DICOM data.

zygomatic bone spatial location after repair, the superposition of the repaired side's postoperative data to the preoperative data broken side was obtained by the software and RMS deviation was measured (group R or repair group which represents the postoperative condition following single-point fixation surgery). RMS deviation values are calculated in this group to assess the postoperative spatial position of the zygomatic bone relative to the fractured side. In postoperative CT-scan, superimpositioned mirror 3D images of the non-traumatic side onto post-fixation 3D imaging, point-to-point RMS deviation values are calculated for this group, likely for the purpose of comparing and evaluating the symmetry of the repaired zygomatic bone, in comparison to Groups B and R by open-source software (group M or mirror group) and RMS values were statistically measured (**Figure 3**).

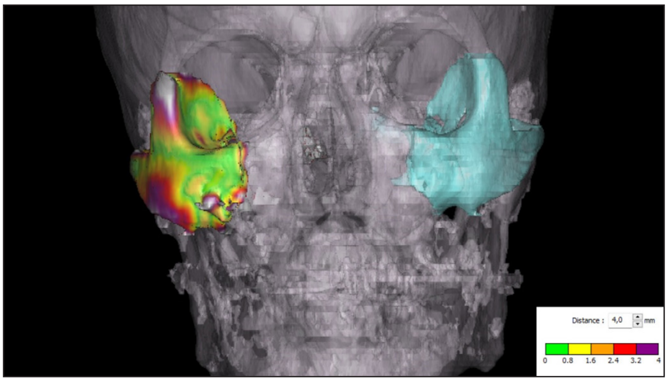

Figure 3. Superpositioning and determining RMS deviation (right lower corner: RMS deviation scale with colors).

Statistical Analysis

The data obtained by Slicer software was statistically evaluated with G*Power (latest ver. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). The conformity of the data to the normal distribution was evaluated with the Shapiro-Wilk Test since the number of samples was less than thirty. In addition, Skewness and Kurtosis values were calculated. Since normally distributed data were collected in a single dependent group, the Paired t-test was used for covariance analysis. $p>0.05$, there was no statistically significant difference between the data, and the distribution of the data was similar.

RESULTS

In order to evaluate data distrubitions of each group Shapiro-Wilk Test was used. In the broken group which represents the preoperative condition of the fractured side, p=0.457 was found by the Shapiro-Wilk Test. Skewness and Kurtosis values were calculated as 0.581 and -0.275, respectively. It was observed that the distribution was normal in the broken group.

In the repair group which includes the comparison of pre and postoperative change of single-point fixation surgery due to ZMC fractures, p=0.642 was found by the Shapiro-Wilk Test. Skewness and Kurtosis values were calculated as 0.359 and -0.896, respectively. It was observed that the distribution was normal in the repair group.

In the mirror group which represents the postoperative condition of the zygomatic bone on the non-fractured (mirror) side, p=0.877 was found by the Shapiro-Wilk Test. Skewness and Kurtosis values were calculated as 0.315 and 0.405, respectively. It was observed that the distribution was normal in the mirror group.

Since the data were normally distributed and collected in a single dependent group, as a post-hoc test paired samples t-test was used. It was observed that there was no significant difference and similar data distribution were revealed between the groups (p=0.096) within the analysis of covariance with paired samples t-test (**Table**).

Table. Paired samples t-test results

Paired t-test	N	Mean	SD	SEM
Group B	15	5.2973	2.46578	0.63666
Group R	15	5.5993	2.70028	0.69721
paired samples		0.30200	0.65502	0.16912
			t=1.786	p=0.096

DISCUSSION

Zygomatic Bone provides height, width, and projection for the lateral side of the facial skeleton.[1] Due to its complex location on the mid-face, zygomatic bone fractures are the second most common facial fractures following the nasal bone.[2,3] Therefore, since it allows 3D evaluation, the gold standard in the diagnosis is a maxillofacial CT scan (**Figure 4**).[4]

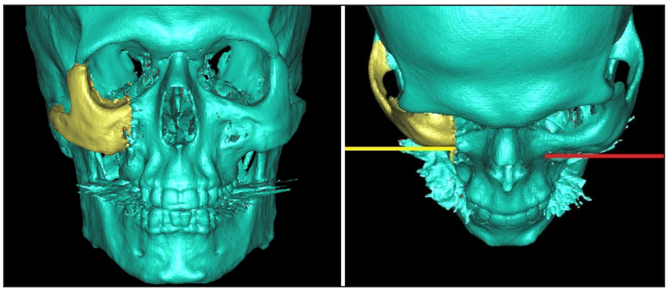

Figure 4. 3D evaluation and diagnosis of ZMC fracture with CT scan (a: isolating and marking the zygomatic bone, b: visualizing the rate of collapse).

Considering both aesthetic and functional outcomes, zygomatic bone repair is extremely complex and related to the surgeon's experience.[2] The most common treatment method for Zygomaticomaxillary Complex (ZMC) fractures is an open reduction with internal fixation. In the literature, many studies recommended three-point fixation as a golden standard, and subsequently, the two-point fixation method was suggested by some of the authors.[3] One-point fixation was revealed to reduce complication rate and to avoid lower lid incisions and possible ophthalmic complications and revision surgeries, one-point fixation was recommended recently.[8-10] Meanwhile, other advantages of one-point fixation could be counted as no visible scar, easy-to-apply, shorter anesthesia duration, and less necessity of assistance.[2] In our study, ophthalmologic complications that may develop due to lower eyelid incisions were not observed in patients regarding the one-point fixation method. In addition, step deformity in the lower orbital rim was not observed in the patients. The results of our study are compatible with the literature in terms of the advantages such as the absence of ophthalmological complications, which are mentioned above, regarding the single point fixation method.

Linear or volume-based measurement methods used in maxillofacial surgery in the past, provide insufficient accuracy and remain old-fashioned.[11-13] On the other hand, one of the main concerns in maxillofacial surgery is the impossibility of pre-traumatic radiological evaluation.[14,15] Today, it's possible to perform three-dimensional evaluations with 3D imaging and spatial positioning or superimposition with advanced software technologies (**Figure 5**).[16-18] This development has paved the way for the use of advanced mathematical measurements with high consistency and the level of evidence in maxillofacial surgery.[5,19] RMS deviation ensures a 3D imaging-based point-to-point standardized evaluation method.[6,20,21]

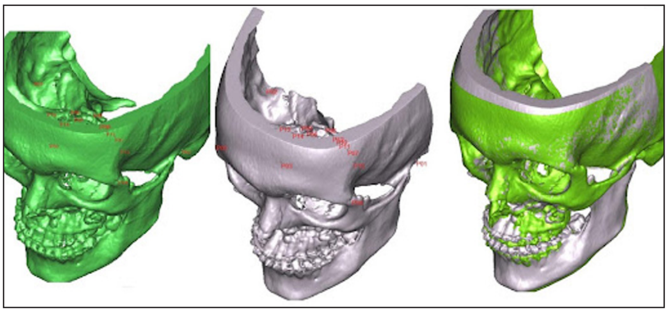

Figure 5. Superpositioning to evaluate results (left: before, middle: after repair, right: superposition of a and b).

In our study, within the scope of our investigation, the pivotal rationale behind segregating the subjects into three distinct cohorts is to methodically assess and juxtapose the postoperative positioning of the zygomatic bone among patients who have undergone single-point fixation surgery. Broken group is allocated to serve as a benchmark, denoting the preoperative zygomatic configuration. Repair group, on the other hand, signifies the postoperative state on the side affected by the fracture, while mirror group encapsulates the analysis of zygomatic symmetry or correspondence with the non-fractured side in comparison to broken and repair groups. Our work was found that the RMS deviation values before and after the repair performed with the single-point-fixation method were correlated with the RMS deviation values of the mirror image of the fractured side and the healthy side (**Figure 6**). This finding can be evaluated as paving the way for the use of the mirror image of the healthy side and the RMS value in the evaluation of the repair.

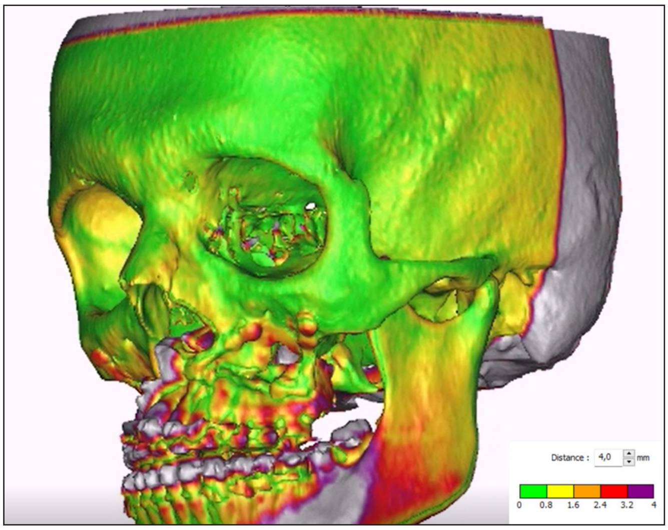

Figure 6. RMS deviation analysis after repair (right lower corner: RMS deviation scale).

A successful surgical repair is expected to show symmetry with the unbroken side. In our study, the distribution of RMS values was found to be expected and similar when the single point fixation repaired side and the mirror image of the healthy side were compared. This could be shown as evidence of the symmetry of the repaired zygomatic bone with the mirror image of the intact side.

Limitations

The constraint in our investigation may be attributed to a restricted sample size, which is a recognized limitation. Furthermore, it is important to note that our study did not entail a comparative analysis of single-point, two-point, and three-point fixation methods over an extended duration. As a result, lower lid complications stemming from the other two surgical techniques were incorporated as supplementary data, drawing upon recent scholarly sources.

CONCLUSION

In maxillofacial surgery, even submillimetric error margins are known to have negative effects on surgical evaluation and planning. We believe that the mean square root value may become the standard evaluation method in maxillofacial surgery since it allows three-dimensional evaluation and precise mathematical measurement. Thus, with the root mean square, further clinical trials would be able to use artificial intelligence to evaluate maxillofacial surgery results.

Recent surgical practice puts the one-point fixation method forward as a scarless, fast, and easy-to-apply method that eliminates the ophthalmological-based lower eyelid complications that cause the most headaches for the surgeon after zygomatic bone fracture repair.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Hatay Mustafa Kemal University Clinical Researches Ethics Committee (Date: 17.02.2022, Decision No: 2022/02-36).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Author Contributions: All the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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