World Journal of Surgery and Surgical Research

Research Article
Published: 08 Apr, 2020

Distribution of Available Sites for Internal Fixation of Zygomatic Complex Fractures and Its Effect on Treatment Outcome

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Abstract

Objective: To identify fractures sites from clinical and radiological assessment, verify fractures sites on surgical exploration, qualify fractures sites in terms of their amenability to sound internal fixation and to prepare frequency table of sites amenable for sound internal fixation and sites actually fixed out of total number of sites.

Materials and Methods: In 30 ZMC fracture patients, maximum possible number of fracture sites was noted out of zygomatic-frontal, infraorbital margin, zygomatic-maxillary buttress and zygomatic arch which was compared with sites noted on clinico-radiological examination, surgically exposed sites, sites amenable for fixation and actually fixed sites.

Results: ZMC fractures were commonly found of classes IIIB and VII according to Modified Rowe & Killey classification. Zygomatico maxillary buttress site was more commonly identified among clinical examination, radiological examination, surgically explored sites, sites found amenable for fixation, and sites actually fixed. Identified fracture sites by combined clinical & radiological examination were more common in class IIIB, IVA, VC and VII. Surgical exploration of identified sites was significantly done mainly on zygomatico maxillary buttress site to approach fractured ZMC complex. Among all sites, infraorbital rim was the site mostly found amenable for fixation. The most reliable and consistent site for actual fixation was fronto-zygomatic site.

Conclusion: The preferred method should be selected individually on the basis of fracture type and patient's characteristic. Successful surgical treatment is influenced by geometry and whether or not alignment may be consistently achieved by open reduction at single or multiple locations which may vary with surgeon's experience.

Keywords: Zygomatico-maxillary complex fractures; Fracture reduction; Sites amenable for fixation; Sites actually fixed; Treatment outcome

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Received Date: *01 Mar 2020*
Accepted Date: *03 Apr 2020*
Published Date: *08 Apr 2020*

Citation:
Singh Chawla JP, Iyer N, Sharma A, Ram Fry R, Bali A, Pandher PK. Distribution of Available Sites for Internal Fixation of Zygomatic Complex Fractures and Its Effect on Treatment Outcome. World J Surg Surgical Res. 2020; 3: 1216.

Introduction

The face remains the central focus of our gaze and occupies the most prominent part of human body rendering it vulnerable to injuries most commonly. The prominence of the zygomatic region, its convex shape and because it is a natural reaction to turn the head away from a threat, predisposes it or make it more vulnerable to injuries or fractures [1]. Trauma to this region can also result in concomitant fractures of the orbital floor & rim. Because of its position, it is the second most common mid-facial bone fractured after the nasal bones and overall represents 13% of all craniofacial fractures [1,2]. Disruption of the zygomatic position also carries functional, aesthetic and psychological significance, causing impairment of mandibular and ocular function or flattening of malar prominence. Therefore it is mandatory that zygomatic bone injury is properly diagnosed and adequately managed for both cosmetic and functional reasons [3,4].

Although recognition of various types of zygomatic fractures and their post-reduction stability is essential for correct diagnosis and proper treatment of zygomatic fractures but it should be fully recognized that the zygoma, upon dislocation, may rotate around a vertical axis and may be displaced medially, laterally, posteriorly or inferiorly, and that post-reduction stability differs considerably depending upon the direction of rotation or displacement of the fractured zygoma [5,6].

The preference for open reduction and internal fixation of zygomatic fractures using two or three

Table 1: Age & Gender distribution of patients.

Gender	Number of patients	Mean age (years)	Standard deviation (years)	Range (years)
Female	2 (6.67%)	37	21.21	22 to 52
Male	28 (93.33%)	33.64	12.89	13 to 79
Total	30	33.86	13.08	13 to 79

Table 2: Total no. of fracture sites identified.

	Infraorbital rim	Fronto-zygomatic site	Zygomatico-maxillary buttress	Zygomatic arch	Total
Clinical	22	17	28	14	81
Radiological	27	23	28	23	101
Clinical radiological	27	23	30	23	103
Surgically explored	10	13	29	0	52
Found amenable for fixation	9	11	26	0	46
Actually fixed	8	11	26	0	45
Total	54	58	111	23	246

point fixation has continued to grow in response to observations of inadequate results from conventional techniques or one point fixation technique, with the exception of management of isolated fractures of the zygomatic arch [7].

This study was conducted and designed to evaluate the feasibility and efficacy of surgical approaches and internal fixation sites of various available fracture sites of zygomatic complex fractures and their effect on treatment outcome.

Aim and Objectives

The purpose of this study was to prospectively determine the available sites of internal fixation in zygomatic-complex fractures and its effects on treatment with evaluation of sites of fractures from clinical and radiological assessment, verification of the sites of fractures on surgical exploration, qualification of the sites of fracture in terms of their amenability to sound internal fixation, preparation of a frequency table of sites amenable to sound internal fixation out of the total number of sites, preparation of a frequency table of number of sites fixed in each case out of total number of the cases, study of the outcome of reduction and fixation as a function of number of sites fixed and to study occurrence and progress of complications as a function of number of sites fixed.

Materials and Method

A prospective study, which was approved by the Institutional Ethics Committee and Board of Studies, was conducted comprising of all patients with zygomatico-complex fractures from Emergency Department of the Associated Medical College and from out patients section (O.P.D.) of the Department of Oral & Maxillofacial Surgery of the dental college. All the patients had been informed about the study and an informed consent had been taken.

Patients

30 Patients aged between 18 years to 65 years of any gender having isolated zygomatic complex fractures who were fairly fit for surgery and anesthesia (ASA grade 1 & 2) were included.

Method of Study

1. In total 30 patients who reported with zygomatic complex fractures were included in this study.

2. Zygomatic complex fractures were diagnosed and classified on presentation to the outpatient department or emergency ward, using a combination of clinical and radiological examination.

3. Radiographical analysis included submentovertex and occipitomental views or CT scan, if required.

4. Routine biochemical investigations were done along with preanesthetic checkup as a part of the surgical protocol.

5. Base-line data collected included age, gender, fracture pattern, fracture classified, associated injuries, treatment modalities, surgical approaches, complications, and fixation methods and sites.

6. All patients were planned for open reduction and internal fixation using bone plates with standard surgical protocols.

7. A maximum possible number of fracture sites were surgically exposed out of zygomatic-frontal, infraorbital margin, zygomatic-maxillary buttress and zygomatic arch. This number was compared with sites noted on clinical and radiological examination.

8. The nature of the fracture at each site was noted with special consideration to access amenability to sound internal fixation.

9. A frequency table of sites amenable to sound internal fixation out of the total number of sites had been prepared.

10. Internal fixation with suitably selected bone plates was performed. Non-compression, mono-cortical and non-locking bone plates were used.

11. A frequency table of number of sites fixed in each case out of total number of the cases had been prepared.

12. Outcome of the treatment was assessed to see stability of reduction and fixation till the end of 6 months after surgery.

13. Correlation of this outcome to number of sites fixed had been estimated.

14. The occurrence and progress of complications as a function of number of sites fixed has been calculated.

15. Statistical analysis was performed using Excel® and vassarstat.net for mean distribution, Chi Square Test and Fisher Exact Probability Test. Correlations were duly noted and recorded to prognosticate the influence of variables.

Table 3: Total number of identified fracture sites based on classification (Clinical Radiological).

	Infraorbital rim	Fronto-zygomatic site	Zygomatico-maxillary buttress	Zygomatic arch	Total
I	-	-	1	-	1
IIIA	4	3	4	2	13
IIIB	8	7	8	7	30
IVA	3	3	4	4	14
IVB	4	2	4	2	12
VB	3	2	3	2	10
VC	1	1	1	1	4
VII	4	5	5	5	19
Total	27	23	30	23	103

Results

In our study (Table 1), a total number of 30 patients who fulfilled inclusion criteria were operated for isolated Zygomatic Complex Fractures, 28 were male and 2 were female patients (respectively 93.33% and 6.67% of patients) aged 13 years to 79 years (mean age, 33.86 years).

When the total number of fracture sites identified on clinical examination, radiological examination, both clinical & radiological, surgically explored sites, sites found amenable for fixation and actually fixed were analyzed in Table 2, cited similar results as evident in the literature. Out of possible 120 fracture sites in 30 patients of Zygomatic Complex Fractures, 103 (79.23%) fracture sites were found by combined clinical & Radiological Examination which were almost equal among Infraorbital Rim, Fronto-Zygomatic Site, Zygomatic-Maxillary Buttress and Zygomatic Arch. Depending on many factors like age, sex of patient, the situation and extent of severity and displacement of fractured segments, fracture site type and decision of operating surgeon, out of total number of fracture sites identified clinically and radiologically, 52 (50.04%) sites were surgically explored. After reduction of fractured Zygomatic complex fractures, it was found that 46 (44.66%) fracture sites were found amenable for fixation and as per stability needs of reduced fractured segments, 45 (43.69%) fracture sites were actually fixed. On comparison of four fracture sites identified, Zygomatic Maxillary Buttress was found in highest number (91.33%) among clinical examination, Radiological examination, surgical exploration, sites found amenable for fixation and sites actually fixed and other sites identified were 50.6%, 50%, 24.67% for Infraorbital Rim, Fronto-Zygomatic site and Zygomatic Arch respectively.

In our study represented by Table 3, fractures sites were observed by combined clinical & radiological examination on basis of classification system used, maximum (30) number of fracture sites (29.12%) were seen in patients with lateral rotation around vertical axis and a higher (19) number of fracture sites (18.44%) in complex fractures in comparison to fracture sites (13) found in medial rotation around vertical axis (12.62%); medial rotation around longitudinal axis (13.6%); lateral rotation around longitudinal axis (11.65%). Fracture sites were identified in the descending order as VC (100%), VII (95%), IIIB (93.75%), IVA (87.5%), VB (83.33%), IIIA (81.25%), IVB (75%) and I (25%). This finding can be attributed to the fact of type of displacement, severity of the displacement, type of rotation and degree of rotation of each fracture type according to the classification system used.

Table 4: Percentage identification of fracture sites.

	Identified	Not identified	Percentage (%)
Clinical	81	39	67.50%
Radiological	101	19	84.17%
Clinical radiological	103	17	85.83%

Table 5: Percentage surgical exploration of fracture sites.

Site	Total	Explored	Percentage (%)
Infraorbital rim	27	10	37.03%
Fronto-zygomatic site	23	13	56.52%
Zygomatico-maxillary buttress	30	29	96.67%
Total	80	52	86.67%

Table 6: Percentage surgically explored sites found amenable for fixation.

Site	Total fracture sites explored	Found amenable for fixation	Percentage (%)
Infraorbital rim	10	9	90
Fronto-zygomatic site	13	11	84.61
Zygomatico-maxillary buttress	29	26	89.66
Total	52	46	88.46

Table 4 shows fracture sites identified on clinical examination, radiological examination and combined clinico-radiological examination out of total provisional 120 fractures sites from 30 Zygomatico-maxillary fracture patients. 67.5% and 84.17% fracture sites were identified on clinical examination and radiological examination respectively. But on combined clinic-radiological examination it was found in 85.83% sites which is higher than clinical and radiological examination individually which come to the fact that combined clinic-radiological examination should be preferred. These differences were statistically highly significant (P=0.0006).

Table 5 shows surgical exploration of identified fracture sites by combined clinical & radiological examination. 96.67% of identified Zygomatico-Maxillary Buttress sites were exposed surgically which was highest in comparison to Fronto-Zygomatic Site (56.52%) and Infraorbital Rim (37.03%).

Table 6 represents the surgically exposed fracture sites which were found amenable for fixation. Although no significant differences have been observed in surgically explored Infraorbital Rim, Fronto-Zygomatic site & zygomatico-maxillary buttress site in their amenability for fixation, but infra-orbital fracture site (90%) was found a little higher in the amenability for fixation than Zygomatic-

Table 7: Percentage surgically explored fracture sites actually fixed.

Site	Total number of sites exposed	Actually fixed	Percentage (%)
Infraorbital rim	10	8	80
Fronto-zygomatic site	13	11	84.61
Zygomatico-maxillary buttress	29	26	89.66
Total	52	45	86.53

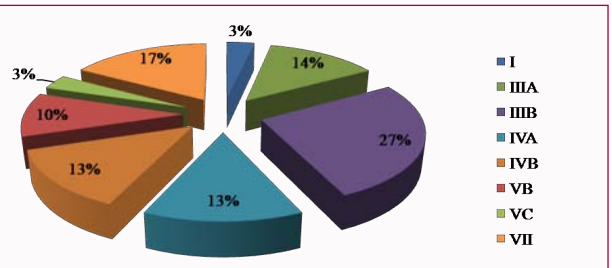

Figure 1: Distribution of classes of patients with zygomatic complex fractures (Modified Rowe & Killey).

maxillary buttress site (89.66%) and Fronto-Zygomatic site (84.61%).

Table 7 shows the surgically explored fracture sites in which actual fixation took place. The total actual fixation was done in 86.53% surgically explored fracture sites. The actual fixation was done more in zygomatico-maxillary buttress site (89.66%) and less on infraorbital rim site (80%) although Infraorbital rim site was found more amenable for fixation than Zygomatico-maxillary buttress site. The frontozygomatic site has been actually fixed as much it was found amenable for fixation indicating the fact that fronto-zygomatic is the best site to stabilize the fractured segment, if found amenable for fixation after surgical exploration.

In Figure 2, Comparison of 1-point, 2-point and 3-point fracture sites was done in accordance to surgically explored sites, sites found amenable for fixation and sites actually fixed. 15 (50%) were approached through one surgical approach only, 8 (26.67%) were approached through two surgical approaches and only 7 (23.33%) cases necessitate the operating surgeon to expose the fracture through three surgical approaches. Out of total 30 cases, 28 cases were found amenable for fixation among which 14 (50%) cases were of one point surgical exploration, 8 (28.57%) were of two point surgical exploration and 6 (21.43%) were belonged to 3-point surgical exploration, concluding to the finding that sites found amenable for fixation were 93.33%, 100%, 85.71% for 1-point, 3-point and three point respectively. The actual fixation took place was in 26 cases (86.67%), out of which 12 (46.15%) required 1-point fixation, 9 (34.61%) required 2-point fixation of fracture sites and 5 (19.24%) required 3-point fixation of surgically explored fracture sites, concluding to the finding that actual fixation was done in 12 (80%), 8 (100%) and 5 (71.42%) cases of 1-point, 2-point and 3-point surgically explored sites. Additionally, one case of 3-point surgically explored was fixed at 2 fracture sites depending on the stability resulted after its 2-point fixation.

Discussion

Various methods for the repair of zygomatic complex fractures have been advocated, with emphasis on the types of incision, methods of fixation, and indications for orbital floor exploration. [6,8,9].

The correct three-dimensional reduction and restoration of the

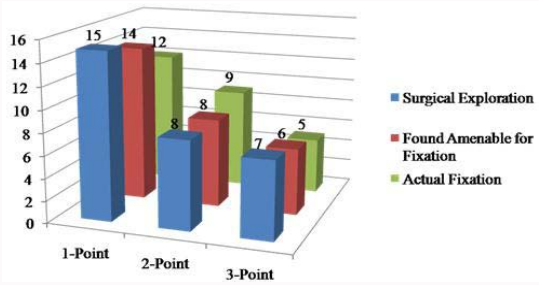

Figure 2: Comparison of 1-Point, 2-Point and 3- Point fracture sites surgically explored, found amenable for fixation and actual fixation.

premorbid facial contours require adequate exposure of the fracture sites. Following exposure, precise reduction at the frontozygomatic, zygomaticomaxillary, and infraorbital buttresses is imperative. Maintaining the correctly reduced configuration is best achieved by miniplate osteosynthesis. Three-point alignment does not necessitate rigid fixation at all three pillars [10,11].

To date, several controversial studies have been conducted regarding the optimal extent of fixation to stably maintain the bone segments that were reduced. This may basically vary depending on the pattern of the bone fracture, that is, whether it is a comminuted fracture, and the type of injuries that patients sustained. However, whether the smallest extent of fixation would produce a maximal extent of the effectiveness in various methods has been considered [8,12-15].

The incidence of number of males is consistent or a little higher than already found in, Kovacs & Ghahremani [16], Hwang & Kim [17], Rana et al. [5] but the mean age is consistent with these previous published reports. Although the patients included were from 13 to 79 years of age, 88.67% of the fractures occurred in those between 22 years and 45 years of age (26 out of 30 patients). This variation probably correlates to the kind of activities in which individuals of both genders engage in as well as to their age groups. The sex distribution is markedly higher for males than for females in our society because males are more exposed to risk activities such as driving motorcycles, involvement in interpersonal violence events and external environment during commuting as well as during their jobs resulting in a greater social and economic involvement by young adult males.

Although the findings were not consistent with the findings in the study which proposed this classification by Yanagisawa (Figure 1) [6], but few findings like fractures rotated medially and laterally and complex fractures are similar with Knight & North [18], Chuong & Kaban [19], Calderoni et al. [20], Hwang & Kim [17], Salentin et al. [21], which otherwise used other ways of classification systems for Zygomatic fractures.

The findings extracted from Table 2 were similar to the findings by Hwang & Kim [17] in which 78.9% of Zygomatic Maxillary Buttress site was found and used in treatment (highest among all four sites of ZMC in that study) which is contrary to the findings of Calderoni et al. [20] who found Inferior orbital rim as the most common fracture site (73.5%) followed by lateral wall (49.2%). The average number of fracture sites identified was 3 per patient which is higher than 2 per patient as per Calderoni et al. [20] We preferred an initial approach through an intraoral incision, arguing that greater stability is achieved by fixing the zygomaticomaxillary buttress, and

only if necessary access the remaining fracture sites. This concept was also used by previous studies as in Ellis & Kittidumkerng [8]; Gomes et al. [22] but some authors like Calderoni et al. [20] used Inferior subciliary approach as the primary approach in 89.7% patients, lateral brow (19%) or upper vestibular incisions (14.3%) and experienced some type of complication in 24.8% cases. The main disadvantage of single approach in all cases may limit exposure in some severe fractures.

Specifically, the intraoral methods include the transverse buccal sulcus incision for access to the infratemporal space and the Caldwell-Luc approach for access to the orbital floor and Zygomatic body and the latter allowed placement of antral packing for stability, when necessary as also given by Chuong & Kaban [19]. These were the main reasons to use Zygomatico-Maxillary buttress site to be used primarily as a first choice which also showed statistically highly significant results ($p<0.0001$). This is similar fact as given by Kim & Lee et al. [10] whose study demonstrated that surgical exposure at the Zygomatico-Maxillary Buttress site through a gingivobuccal incision was effective for tripod fractures without comminution of lateral orbital rim fractures. If the lateral and inferior orbital walls are adequately reduced, this surgical technique results in a successful outcome to avoid long-term aesthetic, sensory, or ocular consequences and stable reduction can be achieved which is essential in the treatment of ZMC fractures. After Zygomatico-Maxillary Buttress site, the site selected was Fronto-Zygomatic as this approach provided excellent access to the infratemporal fossa for zygoma elevation and to the zygomaticofrontal suture for fixation. Direct transorbital elevation via infraorbital and fronto-zygomatic incisions were used when the zygoma was impacted and when the fractured zygoma is unstable after reduction.

When surgically explored fracture sites were distributed based on classification system used. The Zygomatic maxillary buttress approach was the only incision in 14 patients (46.67%) which was little higher as given by Gomes et al. [22] (42.24%), next followed by its association with Fronto-Zygomatic Site (16.67%) and with Infraorbital Rim site (10%). The fronto-zygomatic site was the only approach in 1 (3%) patient. Opposite findings have been retrieved from a study by Chuong & Kaban [19] in which Zygomatico-maxillary approach was used in 1.4%, Frontozygomatic site was approached in 10.1% cases, infraorbital approach was used in 2.9% patients, Frontozygomatic site and infraorbital site were approached together in 71.6% cases. All together, in our study, Infraorbital rim, frontozygomatic site and zygomatico-maxillary buttress sites were surgically exposed in 7 (23.33%) patients which was only 14.91% in study by Gomes et al. [22] Overall, the Zygomatico-Maxillary buttress approach was used in 29 (96.67%) patients; the infraorbital approach in 10 (33.33%) and fronto-zygomatic site approach was used in 13 (43.33%) patients. These findings are almost consistent with the findings by Olate S et al. [7] in which 91.5%, 35.9%, 25.4% for Zygomatico-maxillary buttress infraorbital rim and fronto-zygomatic site respectively. Again, contrary findings have been retrieved from a study by Chuong & Kaban [19] in which 1.4%, 50.7%, 76.8% were used for Zygomatico-Maxillary Buttress site, Frontozygomatic site and infraorbital rim respectively. As stated by Yanagisawa in 1973 [6].

All the surgically explored fracture sites in which actual fixation have been done was distributed. Although the judgment of surgical exploration of various sites and their combinations were almost correct with the actual fixation of that fracture sites except in few cases. In 2 out of 14 cases in which only zygomatico-maxillary buttress sites were surgically explored were not fixed even when they were found amenable for fixation. The reason behind was the actual anatomic reduction of fractured segments and both cases were of lateral rotation around longitudinal axis but in two other cases of this class required frontozygomatic site exposure along with zygomatico-maxillary buttress site for reduction and their instability after reduction require fixation of surgically explored fracture sites indicating fractures of lateral rotation around longitudinal axis were 50% stable after reduction. The stability and exactness was a debated issue with regard to the number of plates and points where fixation should be undertaken. As the tensile forces are greater at the fronto-zygomatic site, all these sites which were found amenable for fixation were actually fixed. In patients who received 1-point fixation (46.17%), all these were zygomatico-maxillary buttress site (100%) as none of the case had frontozygomatic site or infraorbital rim fixation alone. These findings were against Olate et al. [7] in which 1-point fixation was present in zygomatico-maxillary buttress site (54.2%), infraorbital rim (6%) and frontozygomatic site (2%). When 2 point fixations were distributed, all the cases had fixation at zygomatico-maxillary buttress site and along with that other site fixed was frontozygomatic in 66.67% cases or infraorbital rim in 33.33% cases. In all the patients in which 3 fracture sites were found amenable for fixation were actually fixed except in one case of lateral rotation around vertical axis. In this case infraorbital site was not fixed actually because the fracture which was fractured component which was found unstable after reduction became stable after fixation at other two sites. Finally, for total rigid internal fixation, zygomatico-maxillary buttress site was fixed in 92.85% cases, infraorbital rim in 88.89% cases and frontozygomatic site in 100% cases. These findings were lower in Olate S et al. [7] in which it was 86.9%, 27.5% and 25.5% for zygomatico-maxillary buttress, infraorbital rim and fronto-zygomatic site respectively. Rigid internal fixation was done in 93.33% sites which were found amenable for fixation require one or more points of fixation, this value is higher than found with Chuong & Kaban [19] (85.5%), Knight & North [18] (40%).

In lieu of the data extracted from Figure 2, Hwang & Kim [17] used 1 point, 2-point or three point fixation for fractures in 31.83%, 57.96% and only 10.21% respectively. All the above findings were significantly similar to the study by Holmes & Matthews [23] in which out of 33 patients, 17 (51.51%) cases were treated with one surgical approach and single point fixation, 12 (36.36%) cases were treated with two point surgical exposure, two point alignment with two point fixation and 3 (15.15%) cases were treated three-point alignment by direct visualization of fracture sites but with fixation at one site only i.e. fronto-zygomatic suture. By combining three-point alignment and reduction technique with miniplate fixation at the frontozygomatic suture, the surgeon was assured that the reduction was correct and that adequate stabilization has been achieved. The ratio of sites surgically explored to sites actually fixed was 1.25, 1 and 1.4 for 1-point, 2-point and 3-point fracture sites respectively which was 1.8, 1.08 and 1 in a study conducted by Chuong & Kaban [19]. In a study conducted by Makowski GJ et al. [11], at least three points were explored in all the patients owing to direct visualization of their ZMC fractures and fixation was done randomly at three points (58%), three or more points (21%) and at two points (21%) after achieving adequate reduction. And significantly concluded that three point visualization with liberal rigid fixation resulted in less number of complications that were proportional to severity of injuries sustained.

On the contrary, in our study, findings retrieved from Figure 2 indicate that there was no significance (p=0.975) in one point, two point or three point surgical exploration, sites found amenable for fixation and actual fixation done by which a conclusion can be made that diagnosis, classification, treatment planning, evaluation for approach/approaches selection, adequacy of reduction and adequacy of fixation were the key factors in the treatment of zygomatic complex fractures.

In our study, there was no displacement after adequate fixation reported in postoperative radiographs on follow-up. But in three case little asymmetry reported which might be due to soft tissue loss that resulted in aesthetic compromise and this correlates with findings of Holmes & Mathews [24] and Gandi et al. [25] With regard to ophthalmic signs like diplopia, our results obtained were in accordance with the results of Holmes & Mathews [24]. Six neurological deficits were found in our study for 2 months to 3 months and resolved gradually after six months.

Conclusion

There are many treatment possibilities for ZMC fractures, but the preferred method should be selected individually on the basis of type of fracture and patient's characteristic. Successful surgical treatment is influenced by geometry and whether or not alignment may be consistently achieved by open reduction at single or multiplate locations which may vary with the individual surgeon's experience.

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