

Hardware Removal in Craniomaxillofacial Trauma

A Systematic Review of the Literature and Management Algorithm

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Background: Craniomaxillofacial (CMF) fractures are typically treated with open reduction and internal fixation. Open reduction and internal fixation can be complicated by hardware exposure or infection. The literature often does not differentiate between these 2 entities; so for this study, we have considered all hardware exposures as hardware infections. Approximately 5% of adults with CMF trauma are thought to develop hardware infections. Management consists of either removing the hardware versus leaving it in situ. The optimal approach has not been investigated. Thus, a systematic review of the literature was undertaken and a resultant evidence-based approach to the treatment and management of CMF hardware infections was devised.

Materials and Methods: A comprehensive search of journal articles was performed in parallel using MEDLINE, Web of Science, and ScienceDirect electronic databases. Keywords and phrases used were *maxillofacial injuries; facial bones; wounds and injuries; fracture fixation, internal; wound infection; and infection*. Our search yielded 529 articles. To focus on CMF fractures with hardware infections, the full text of English-language articles was reviewed to identify articles focusing on the evaluation and management of infected hardware in CMF trauma. Each article's reference list was manually reviewed and citation analysis performed to identify articles missed by the search strategy. There were 259 articles that met the full inclusion criteria and form the basis of this systematic review. The articles were rated based on the level of evidence. There were 81 grade II articles included in the meta-analysis.

Result: Our meta-analysis revealed that 7503 patients were treated with hardware for CMF fractures in the 81 grade II articles. Hardware infection occurred in 510 (6.8%) of these patients. Of those infections, hardware removal occurred in 264 (51.8%) patients; hardware was left in place in 166 (32.6%) patients; and in 80 (15.6%) cases, there was no report as to hardware management. Finally, our review revealed that there were no reported differences in outcomes between groups.

Conclusions: Management of CMF hardware infections should be performed in a sequential and consistent manner to optimize outcome. An evidence-based algorithm for management of CMF hardware infections based on this critical review of the literature is presented and discussed.

Key Words: hardware, facial fracture, craniomaxillofacial trauma, infection, osteomyelitis, nonunion

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Each year, approximately 5000 patients with craniomaxillofacial (CMF) trauma are treated by open reduction and internal fixation (ORIF).^{1,2–7} Open reduction and internal fixation can be complicated by hardware exposure, hardware loosening, or infection.^{1–4,8–10} Differentiation between hardware exposure and infection is often not obvious and diagnostic tests are limited. Hardware infection is typically associated with redness, warmth, and inflammation. The area is usually painful and may drain pus. Occasionally, the patient develops fever and chills. Leukocytosis, elevated erythrocyte sedimentation rate (ESR) (82% sensitivity, 85% specificity), or elevated C-reactive protein (CRP) (96% sensitivity, 92% specificity) levels may be observed.^{11,12} Infected hardware is populated with bacterial colonies.¹³ On the contrary, with hardware exposure, the patient may not experience signs of infection, and ESR and CRP levels may be normal. Culturing exposed hardware will not lead to bacterial growth. Unfortunately, reports in the literature do not differentiate between hardware infection and hardware exposure in the CMF region.^{14–17} Because infection is more serious than exposure, for the purposes of this study we have considered all indeterminate cases as hardware infection.

Infected hardware leads to hardware exposure, extrusion, fistula formation, bony nonunion, and osteomyelitis. It is widely agreed upon that hardware infection should be managed by debridement of necrotic and infected tissue, and antibiotic administration. However, it is unclear, if the infected hardware needs to be removed or if it is removed, whether it can be immediately replaced with repeat ORIF.^{18–24} Many authors report that the CMF region is considered a privileged site that does not necessarily require hardware removal.^{19,21,23–27} This is in contrast to other sites such as the extremities, where Rightmire et al²⁸ demonstrated that one third of infected hardware cases required hardware removal and Viol et al proposed that hardware loosening, hardware exposure greater than 2 weeks, or positive wound cultures are indications for hardware removal.^{15–17,29–32} To clarify whether hardware should be removed in managing CMF hardware infections, we have performed a systematic review of the literature and devised an evidence-based algorithm.

MATERIALS AND METHODS

The systematic review was performed according to “Preferred Reporting Items for Systematic Review and Meta-Analyses” guidelines.³³ Searches were performed in parallel in PubMed, EMBASE, and Web of Science electronic databases. The search strategy included the following medical subject headings (MeSH terms): *maxillofacial injuries; facial bones; wounds and injuries; fracture fixation, internal; wound infection; and infection*. Related non-MeSH, free-text search strings were also included. The full text of English-language articles was reviewed to identify articles focusing on the evaluation and management of infected hardware in CMF trauma. Articles limited to nontrauma scenarios (eg, oncologic head-and-neck reconstruction) were excluded from review. Case reports, case series, observational studies, and experimental trials were included, letters and commentaries were excluded. Each article's reference list was manually reviewed and citation analysis performed to identify articles missed by the search strategy.

Two reviewers (T.J.C. and R.G.) independently evaluated articles to determine eligibility; disputes were resolved by discussion and consensus moderated by a third reviewer (A.C.A.). Strength of

recommendations were then graded according to the American Society of Plastic Surgery grading system (ASPS, 5 grading levels; I-V), with additional considerations given to criteria from the Oxford Center for Evidence-Based Medicine and the United States Preventive Services Task Force rating systems.^{34,35} Quality of the evidence was graded according to the Grading of Recommendations Assessment, Development and Evaluation Working Group emerging consensus.³⁶ The principal variable of interest was management strategy (removal of hardware, hardware exchange, or nonremoval and observation of hardware in the context of hardware infection). Other variables of interest included location of fracture, type of infection (cellulitis, abscess, and draining sinus), and pathogen type. Primary outcome of interest was resolution of infection without need for further procedures.

RESULTS

The search identified 529 articles for consideration, of which 259 articles met preliminary inclusion criteria. Review of the reference lists and citation analyses identified 1 additional study (Fig. 1).

The 259 articles that met criteria were published between the years of 1963 and 2012. Study designs consisted of meta-analysis,

prospective studies, retrospective studies, randomized controlled trials, case series, and expert opinions. Outcomes considered in these studies included malunion, infection rates, infection types, antibiotic treatment, surgical technique, hardware type, and patient satisfaction.

One article met criteria for inclusion as grade I, 81 articles met criteria for inclusion as grade II, 103 articles met criteria for inclusion as grade III, 29 articles met criteria for inclusion as grade IV, and 43 articles met criteria for inclusion as grade V (Fig. 2A,B). The grade I article and 3 grade II articles most pertinent to our study are presented later as examples to the content of the literature. The 3 grade II articles were selected based on their relevance our study and their quality (grade IIA per Oxford Center for Evidence-Based Medicine and were High Quality per GRADE criteria). None of the 259 articles specifically discussed whether the hardware should be removed or left in place in cases of hardware infection.

Grade I Article

The single grade I study completed by Regev et al¹ was a meta-analysis of 24 studies on internal fixation of mandibular angle fractures. The authors compared complication rates for different fixation

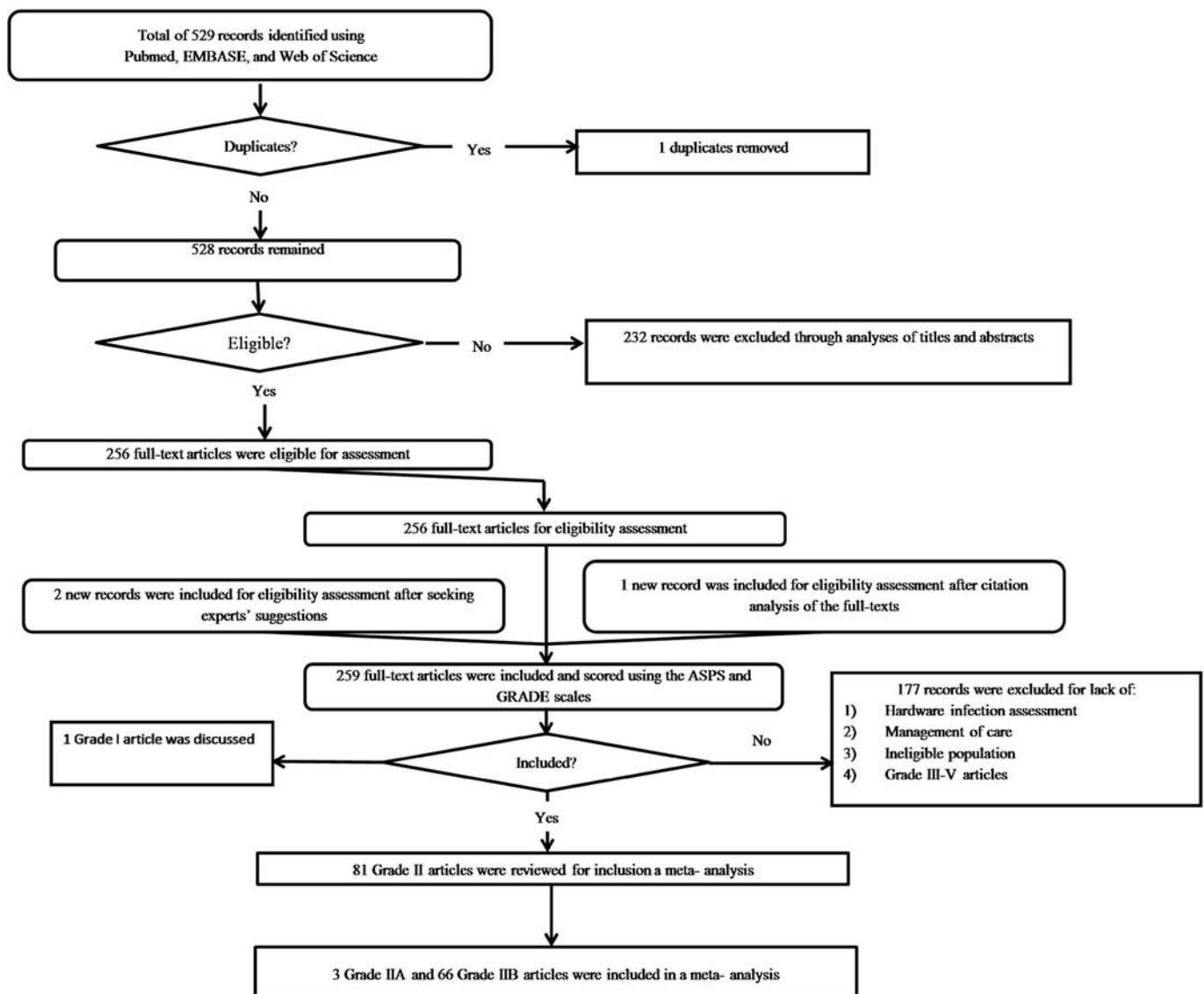
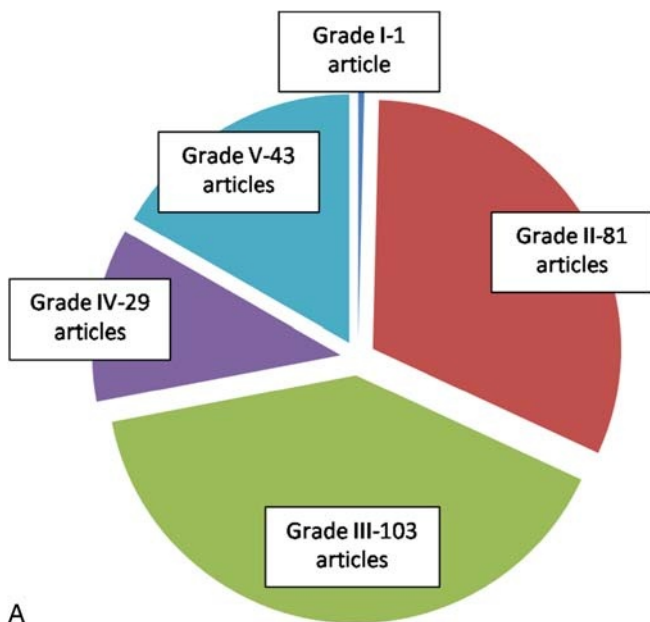


FIGURE 1. Flow chart of citations included in the systematic review.



Study Design	# Articles
Retrospective	92
Prospective	50
Case series	29
Expert opinion and discussion	23
Case report	16
Prospective cohort study	15
Prospective randomized controlled trial	10
Retrospective chart review	9
Review of literature	4
Comment	3
Systematic review of literature	2
Meta-analysis	1
Randomized controlled trial	1
Retrospective review of literature	1
Survey	1
Case study and review of literature	1

FIGURE 2. A, Breakdown of assigned grades using ASPS scale. B, Breakdown of studies by study design included in the review.

methods. The rates of infection ranged from 2.7% to 26.8% and the rates of hardware removal ranged from 2.3% to 28.1%. The study found multiple variables influence infection rate including plate choice (compressible vs noncompressible), screw choice (monocortical vs bicortical), and number of plates (1 vs 2 plates). Compressible plates, bicortical screws, and use of 2 plates lead to higher infection rates. Because of higher infection rates, compression plates were more likely to require reoperation, hardware removal, and malunion but not nonunion. Although the study illustrated that infection rate is related to a multitude of factors, the study did not reveal or suggest how to manage infection once it had occurred.

Grade II Articles

In a prospective, randomized controlled trial, Danda² compared postoperative complications after mandibular angle fracture fixation. This study compared the use of 2 noncompression miniplates to the standard technique of 1 noncompression miniplate. Postoperatively, patients were assessed for infection. Criteria for infection included (1) purulent discharge from the incision, or (2) serosanguineous drainage and a positive wound culture for a known pathogen. The ESR and total leukocyte count were not considered diagnostic. Both groups of patients were given ampicillin perioperatively and postoperatively for 3 days. Of the 54 patients treated, infections occurred in 1 patient in group 1 (single noncompression plate) and 2 patients in group 2 (2 noncompression plates) with 2 patients requiring plate removal. Indications for plate removal in these 2 cases were not discussed.

In a systematic review of the literature comparing closed versus open reduction and rigid fixation, Andreassen et al⁴ found fractures treated with closed reduction had an infection rate of 5.0% and fractures treated with ORIF with either plates or wires had an infection rate of 10.6% and 14.6%, respectively. Their study did not elaborate on optimal management of infected hardware.

In a systematic review by Hermund et al,³ the authors found there was a postoperative complication rate of 7% to 33% in mandibular fracture treated by ORIF. There was no clear correlation between timing of treatment and number or type of complications. The authors did not specifically address how to best manage infected hardware.

Meta-analysis

We then reviewed all grade II articles^{2-4,7-9,20-27,37-91} for inclusion in a meta-analysis. We selected articles for which occurrences of hardware infection had been measured and excluded articles that were themselves meta-analyses. Sixty-six (3 grade IIA and 66 grade IIB) articles satisfy the previously mentioned criteria for meta-analysis.

The meta-analysis revealed that 7503 patients were treated with hardware for CMF fractures. Hardware infection occurred in 510 (6.8%) of these patients. Of those infections, hardware removal occurred in 264 (51.8%) patients; hardware was left in situ in 166 (32.6%) patients; and in 80 (15.6%) cases, hardware management was not reported. Finally, our review revealed that there were no reported differences in outcomes between groups.

DISCUSSION

The major conclusions of the current study are that there are no set criteria for the management of infected CMF hardware after trauma and that hardware infection in the CMF region can be managed by hardware preservation. First, our literature review demonstrates that there are no criteria for the management of infected CMF hardware. Next, we demonstrate through a meta-analysis that there are no reported differences in outcomes for managing infected hardware by either leaving it in situ versus removing it. Finally, we propose an algorithm for the management of infected CMF hardware (Fig. 3).

In extremity cases where orthopedic hardware is either exposed or overtly infected, clinical management depends on criteria that include duration of exposure, hardware loosening, fracture location,³⁰ and whether the bone is healed (stable).⁹² A healed bone is one that cannot be displaced from its correct anatomical alignment once the hardware is removed, whereas unstable bone will be displaced after hardware removal.⁹² Currently, no standard criteria exist to define when a fracture may be classified as a nonunion. The FDA defines nonunion as a fractured bone that has not completely healed within 9 months after injury and shows no progression toward healing on serial radiographs over the course of 3 consecutive months.⁹²⁻⁹⁵ Bishop et al outline the risk factors for nonunion, which include various medical comorbidities, age, sex, smoking, use of nonsteroidal anti-inflammatory drugs, genetic disorders (eg, neurofibromatosis,

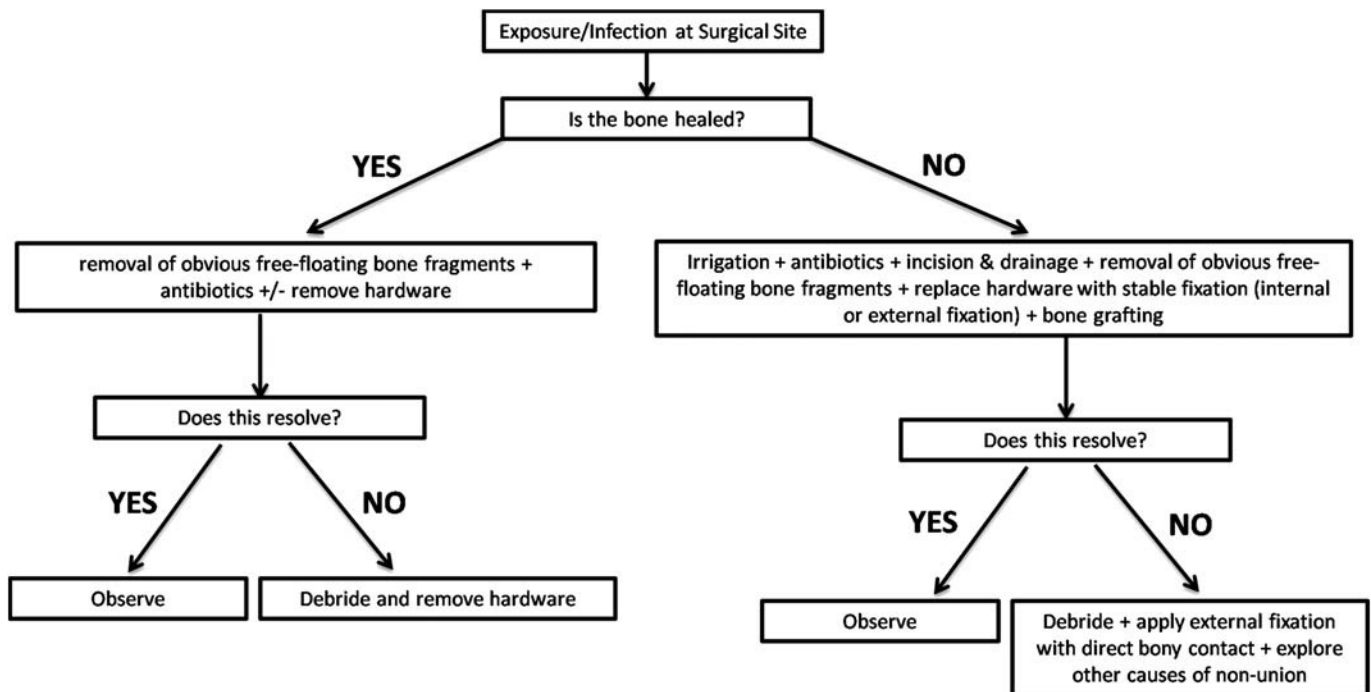


FIGURE 3. Proposed management algorithm for treatment of infected hardware in CMF trauma patients. Infection can occur after ORIF of a CMF fracture. The treatment for such infections depends on whether the bone is stable. In addition, antibiotics are often used, as both IV and PO with the typical duration lasting about 6 weeks.

osteogenesis imperfecta, and osteopetrosis), metabolic disease, and nutritional status.^{92–94} Osteomyelitis may also lead to unstable bone. Pathogens proliferate in the devitalized tissue leading to fracture nonunion. Osteomyelitis could be caused by infected hardware or could cause hardware to become infected. In the extremities, infected nonunion has been treated with aggressive surgical debridement with hardware removal, local and systemic antibiotics, revision open reduction and internal fixation or external fixation with correction of deformity, and bone grafting.^{96,97} If the bone is stable, surgical removal of involved hardware is possible without compromising bony stability.^{98–105}

A prolonged period of hardware exposure leads to contamination and secondary infection. Several studies report better outcomes when definitive management occurs within 2 to 3 weeks. Nahabedian et al⁹⁵ reported a salvage rate of 83% of prostheses when debridement with soft tissue coverage was performed within 3 weeks. Thus, as a rule, they concluded hardware should be covered if exposed for more than 3 weeks. In the lower extremities, exposed hardware can be treated conservatively by leaving the hardware in situ with soft tissue reconstruction if no gross infection is present.³⁰ Infected hardware can loosen as well. Hardware loosening is an absolute indication for removal in the extremities.¹⁰⁶ After hardware removal, the bone is managed by either external fixation or replacement of the hardware.³⁰ Location plays an important role in the salvage of exposed hardware. In knee replacement, the rate of simultaneous removal and closure ranges from 76% to 94%, whereas the incidence of spinal hardware is much lower, with reported incidence of 0% to 12%.³⁰ The morbidity the patient faces from the removal versus salvage of the hardware and the alternatives for treatment are important factors in the decision-making process. Preservation of the hardware in the spinal column is preferred management due to a lack of therapeutic alternatives for maintaining fusion and stability.

The management of CMF fractures may be considered differently from extremity fractures. This is because the face has a

watershed blood supply and is less susceptible to vascular compromise; whereas the extremities are reliant upon major vessels, which may become damaged during trauma or after diabetes or from peripheral vascular disease. This anatomic difference could account for why hardware infections in the CMF region are much lower than what is observed in the extremities (5%–15% in CMF fractures vs 5%–50% in the extremities).^{10,72,79,107–111} It also provides a rationale for why CMF hardware infection can be treated differently than extremity hardware infections.¹⁰⁷ This is corroborated by our meta-analysis where we found no significant difference between removing hardware versus leaving hardware in situ in cases of hardware infections.

An interesting point arises when considering how to best treat unstable fractures in the CMF region. In the extremities, unstable fractures are treated by early hardware removal. If removal of the hardware results in an unstable extremity, an external fixator device can be used to reestablish axial stability.¹¹² Berkes et al¹¹³ studied 121 patients in whom postoperative wound infections with positive intraoperative cultures had developed within 6 weeks after internal fixation of acute fractures in the extremities. In their study, 87 (71%) patients had fracture union with operative debridement, hardware retention, culture-specific antibiotic treatment, and suppression. Thirty-one (36%) of those 87 infections were in patients who eventually underwent hardware removal after radiographic union was achieved; the indication for removal was symptomatic hardware in 5 cases and recurrence of infection in the remaining 26. At the time of the most recent follow-up, all infections had resolved after hardware removal and further treatment with culture-specific antibiotic therapy. The overall rate of failure was 29%. One infection resulted in death, 1 resulted in chronic osteomyelitis, 7 necessitated amputation, and 27 resulted in revision or fusion which can include replacement or external fixation. In 4 cases, the hardware was removed during the initial debridement. Although external fixation is an option for infected CMF hardware and it has been

applied, it is impractical and may significantly interfere with a patient's quality of life.^{30,106,112,114,115} Moreover, from our review, it does not seem to be necessary. For unstable CMF fractures with infected hardware, the hardware should be removed, bone debrided, and reapproximated, and new hardware can be replaced internally.^{101–105,107,116–125}

Here we propose an algorithm for managing CMF hardware infection (Fig. 3). If hardware is exposed or thought to be infected, one should determine if the bone is healed or if there is a nonunion or osteomyelitis. If the bone is nontender, the bone edges are approximated on physical examination and x-ray, and the ESR and CRP are normal then the hardware does not need to be removed. Attention should be given to soft tissue healing. However, if the bone is tender, an obvious gap is present on physical examination or x-ray, or the ESR or CRP is elevated, then the hardware should be removed, the necrotic bone debrided, the hardware internally replaced, and bone grafting. Antibiotics should also be given. The intermediate period poses the most significant challenge in terms of decision making; in the early stages, hardware should be preserved. Soft tissue is the premium. In the later time frame, with a likely nonunion, bone grafting would be required with removal and exchange of fixation. Medical management should be optimized, including cessation of tobacco products. If in the unusual circumstance the infection does not resolve after repeat ORIF, we recommend repeat debridement, hardware removal, and application of an external fixator (Fig. 3). Unusual causes of nonunion and osteomyelitis should be sought.

CONCLUSIONS

Hardware infection after CMF of facial fractures is rare. On the basis of a systematic review of the literature and analysis of the orthopedic literature for extremity fractures, we propose that CMF hardware infections or exposures can safely be managed by preservation of internal fixation.

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