Mixing Implants of Differing Metallic Composition in the Treatment of Upper-extremity Fractures

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abstract
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Mixing implants with differing metallic compositions has been avoided for fear of galvanic corrosion and subsequent failure of the implants and of bone healing. The purpose of this study was to evaluate upper-extremity fractures treated with open reduction and internal fixation with metallic implants that differed in metallic composition placed on the same bone. The authors studied the effects of using both stainless steel and titanium implants on fracture healing, implant failure, and other complications associated with this method of fixation. Their hypothesis was that combining these metals on the same bone would not cause clinically significant nonunions or undo clinical effects from galvanic corrosion.

A retrospective review was performed of 17 patients with upper-extremity fractures fixed with metal implants of differing metallic compositions. The primary endpoint was fracture union. Eight clavicles, 2 proximal humeri, 3 distal humeri, 3 olecrans, and 1 glenoid fracture with an average follow-up 10 months were reviewed. All fractures healed. One patient experienced screw backout, which did not affect healing.

This study implies that mixing implants with differing metallic compositions on the same bone for the treatment of fractures does not adversely affect bone healing. No evidence existed of corrosion or an increase in complications with this method of treatment. Contrary to prior belief, small modular hand stainless steel plates can be used to assist in reduction of smaller fracture fragments in combination with anatomic titanium plates to obtain anatomic reduction of the fracture without adversely affecting healing.

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ERRATUM

This article has been amended to include a factual correction. An error was identified subsequent to its original printing (2013; 36[9]:e1175-e1179), which was acknowledged in an erratum printed in 2014; 37(2):77. The online article and its erratum are considered the version of record.
Many materials are used for fracture fixation. The biomaterials need to be biocompatible, resistant to corrosion, and resistant to wear. Some of the most commonly used metals are stainless steel 316L, titanium alloys, and cobalt chrome. These metals have been used for manufacturing implants because of their resistance to corrosion and good biocompatibility.

Although stainless steel and titanium alloys are biocompatible, they are subject to various types of corrosion, including galvanic, fretting, and pitting. Galvanic corrosion has long been a feared complication of combining metallic implants of differing metallic compositions inside the body. This type of corrosion occurs as a result of an electrochemical potential created by the contact of 2 different metals in an electrochemical medium, which causes the release of ions from the metals. The galvanic corrosion can weaken the properties of the plate and screws, causing failure of fracture fixation and perhaps pain and swelling of the surrounding tissue.

The use of implants with differing metallic compositions has been avoided in practice for fear of causing galvanic corrosion in vivo. Recent in vitro studies have shown that the combination of stainless steel and titanium causes no more corrosion than if either were used alone. To the current authors’ knowledge, no study to date evaluates the use of orthopedic implants with differing metallic compositions on the same bone in vivo for fracture fixation. The senior author (J.I.) frequently uses a combination of anatomically contoured titanium plates and stainless steel mini-locking plates for the treatment of complex upper-extremity fractures. The mini-locking plates are used to join smaller fracture fragments to allow for anatomic reduction of the larger fragments. The purpose of this study was to evaluate upper-extremity fractures treated with open reduction and internal fixation (ORIF) using implants of differing metallic composition in close contact with each other on the same bone to determine whether this technique is safe and whether clinically significant complications occur.

**Materials and Methods**

After institutional review board approval, a retrospective review was performed of all upper-extremity fractures undergoing ORIF by the senior author between January 2002 and October 2009. All surgeries were performed at 2 private academic-affiliated institutions. The main inclusion criterion was an isolated upper-extremity fracture that required ORIF with stainless steel and titanium implants placed on the same bone. Patients with infections, use of allografts, polytrauma, prior surgery on the fracture, and implants made of similar metals only and patients lost to final follow-up were excluded. Operative reports, radiographs, and clinical notes were reviewed.

All patients were followed until clinical and radiographic union was achieved. Radiographic union was defined as cortical bridging on at least 2 views, and clinical union was defined as the absence of pain at the fracture site. Patient age, sex, comorbidities, complications, time to union, and length of follow-up was evaluated for all patients. The primary endpoint of the study was radiographic union.

**Results**

Seventeen patients met the inclusion criterion to be included in the study. Average patient age was 47.1 years (range, 18-80 years). The study group comprised 11 men and 6 women with a total of 8 clavicle, 3 olecranon, 3 distal humeri, and 2 proximal humeri fractures and 1 glenoid fracture. Thirteen patients had acute fractures of the upper extremity treated by ORIF using standard approaches for the fracture types. The remaining 4 patients had subacute clavicle fractures that were impending nonunions. Each patient had the combination of stainless steel and titanium plates placed in close proximity on the same bone. Small modular hand locking plates were used to aid in reduction of comminuted fragments to facilitate anatomic reduction of the main fracture site. All smaller plates were used as provisional fixation and not to improve healing. These plates were stainless steel mini-locking plates (Modular Mini LCP System; Synthes, Paoli, Pennsylvania), and the titanium plates were precontoured anatomic plates for the upper extremity (Acumed Plating System; Acumed, Hillsboro, Oregon, and S3 Proximal Humerus Plate; DePuy, Warsaw, Indiana).

All 17 patients experienced fracture healing, and no nonunions occurred. Average time to union was 81 days (range, 50-140 days) for clavicle fractures, 177 days (range, 72-269 days) for distal humerus fractures, 147 days (range, 73-221 days) for proximal humeri fractures, 143 days for glenoid fractures, and 71 days (range, 43-114 days) for olecranon fractures. Average length of follow-up was 301 days (range, 52-1672 days). Bone morphogenetic protein was used to supplement healing in 11 patients, and demineralized bone matrix was used in 2 patients.

Three patients had significant comorbidities, including diabetes mellitus (n=2) and diabetes mellitus with smoking (n=1). Seven (44%) complications occurred in the series, including 1 superficial wound infection that resolved with oral antibiotics, 1 screw backout, 1 brachial plexitis, 1 transient radial nerve neuropraxia, 1 unresolved ulnar nerve palsy, and 1 superficial wound infection after a secondary procedure for elbow arthrofibrosis. The patient with ulnar nerve palsy had a distal humerus fracture that underwent ORIF with an ulnar nerve transposition.

No patient in the series had persistent symptoms of pain at the fracture site or local reactions to the mixed metals. No patient required revision surgery to aid in fracture healing or due to hardware failure. One patient who had elbow arthrofibrosis underwent an open release, hardware removal, and heterotopic bone resection.
DISCUSSION

Using dissimilar metals in orthopedic implants has been thought to cause undesirable effects, including galvanic corrosion, inflammatory responses, metal sensitivity reactions, systemic effects, and possibly implant failure. According to basic science, the most noble metal would act as a cathode and the least noble metal as the anode. Given that interstitial fluid is a conductive medium, electrons flow from the active metal to the noble metal and cause accelerated corrosion of the noble metal. The loss of electrons is termed oxidation. When a metal is involved in an oxidation process, corrosion can be seen (ie, pits and rust). If a metal is oxidized in vivo, then the plate can weaken and possibly fracture. Resultant motion at the fracture site could theoretically result in fracture nonunion. The corrosion reactions have been shown to interfere with the osteoblastic proliferation and differentiation in vitro. This was the current authors’ initial concern with using dissimilar metals in patients. Another theoretical problem is soft tissue reactions from the oxidation products, which could manifest as swelling, erythema, infections, and pain.

Most of the orthopedic literature comprises studies from in vitro experiments and in animals. Most studies on the corrosion of implants are performed in Hanks’ solution, Ringer’s solution, and artificial saliva. Stainless steel implants have shown degradation caused by pitting, crevice, stress, and galvanic corrosion leading to the release of metallic products from the implants. Titanium alloys have better corrosion resistance due to the self-passivation that occurs in vivo. Self-passivation is a process in which a passive film forms over the implant that becomes thicker with time and is thought to be protective against corrosion. Due to in vitro studies showing the possibility that corrosion can be a concern in any implant, mixing metals has been advised against because the potential of galvanic corrosion poses a threat to the life of the implant. This may be more of a concern for arthroplasties in which the implants are replacing an anatomical part and longevity is required for success of the implant. In fracture fixation, the metal serves as a buttress or structural support for the healing bone and is only needed until the bone has healed, which may pose less of a concern for implant failure once the bone has healed.

Recent studies have shown that the combination of dissimilar screws and plates (titanium and stainless steel combinations) did not cause a higher weight loss or metal release of ions in vitro and may be safe for clinical use. Few reports in the literature report the corrosion of metals in vivo. Taylor and Wilson reported 2 tissue reactions and 2 infections caused by the corrosion between cerclage wires and Kuntscher nails. More recent literature on the spine showed that the galvanic potentials between dissimilar metals do not cause an increase in the corrosion of either metal. Another study showed that when a broken guidewire made of stainless steel was left in direct contact with a titanium screw in vivo in an animal model, no cellular response occurred. The current authors are not aware of any studies to date that have evaluated the effects of the use of dissimilar metals in vivo.

The authors reviewed cases in which a titanium plate was used in conjunction with a stainless steel plate on the same bone for fracture fixation. The plates were placed in close proximity to each other and frequently had screws in contact with each other inside the canal or almost touching each other on the cortex. The major concern, as reported in prior studies, is when the metals (stainless steel plate and titanium screw) are in direct contact with each other. The concern in the current study was that the implants of dissimilar metals were in close proximity on the same bone in the same biological milieu, which posed a concern for the possibility of galvanic corrosion.

This method of fixation was used because the senior author frequently uses stainless steel mini-locking plates to resemble comminuted fracture fragments prior to fixing the major fracture fragments with anatomically contoured titanium plates. The senior author felt that bridging fixation of the comminuted fragments would lead to a malunion that would be clinically unacceptable. By using the mini-locking plates to reduce the comminuted fragments, a better reduction, and thus better outcome, could be achieved.

No nonunions occurred. The time to union may be longer than typical for these fractures and can be attributed to more extensive dissection and the possibility of galvanic corrosion; however, the galvanic corrosion was not clinically relevant because all fractures went on to union (Table). In addition, no effects from potential soft tissue reactions were observed in any patient because none had residual pain at the implant site, soft tissue reaction, or deep infection. One screw backout occurred, but no implant fractures occurred from fatigue, which would have been presumed to be caused by corrosion. The complication rate was 44%. The complications observed were infections, arthrofibrosis, and nerve injuries, which can be presumed to be due to commonly seen surgical complications and not due to the use of dissimilar metals.

This study has several limitations. One limitation is the sample size of 17 patients. With more patients who had undergone this fixation method, some implant failures and possible reactions to the use of dissimilar metals may have been encountered. Another limitation is the limited follow-up. The patients were only followed until fracture union. The authors were unable to determine whether these patients had any complications after fracture healing. The study’s results apply only to fracture fixation excluding periprosthetic fractures, which could respond differently after fixation due to the overall amount of metal in these cases. One could presume that it is unlikely that...
any complications occurred because the patients would have likely returned to be evaluated.

Another limitation of the study was that it used only radiographs to evaluate the proximity of the plates to one another. Exact measurements could not be obtained using this 2-dimensional imaging method, and computed tomography scanning may have helped determine whether the screws were in contact with one another inside the bone or on the cortex. If none of the metals were in contact, the study’s results may have changed. Given that the interstitial fluid is a highly conductive medium, the authors believe that if the corrosion were of real clinical concern, more complications would have occurred related to the dissimilar metals in the same biological milieu.

**CONCLUSION**

The authors believe that using titanium and stainless steel plates in close proximity on the same bone causes no undue clinical consequences in fracture fixation. Although galvanic corrosion seems to be a real entity in in vitro studies, it was not shown to occur clinically in this study. The authors do not advocate the use of dissimilar metals as a primary treatment method; however, in the event that these are the only implants available at a given institution, it seems clinically safe to use titanium and steel plates for fracture fixation if it helps achieve a good reduction.

**REFERENCES**


