Mixing Metals During Operative Fixation and Reconstruction in the Appendicular Skeleton: Is There a Detrimental Clinical Impact That Translates from Theoretical In Vivo Galvanization?

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INTRODUCTION: Orthopaedic surgeons have traditionally been advised against mixing varying metal types to avoid the potential for in vivo galvanization and corrosion found in early animal models. However, clinical practice often includes the use of mixed metals (MM) with seemingly minimal adverse outcomes. The purpose of this study was to retrospectively analyze patients who have undergone operative reconstruction with MM to report any related complications.

METHODS: Between 2017-2022, our institutional fracture and reconstruction registry was screened for inclusion. Inclusion criteria included any patient with 'mixed' fixation defined as contact and proximity within the bone (≤10mm) determined by patients with complete radiographs and records with 1yr minimum follow up. All patients were operated by 2 trauma fellowship trained surgeons with extensive experience in complex adult reconstruction. Patient baseline characteristics, perioperative data, and postoperative data including radiographs and complications were collected. We identified 549 potential patients, of which 241 were determined to have been treated with MM implants and 110 met minimum 1 yr follow-up criteria.

RESULTS: The final analysis included 110 patients, with a mean age of 63±15.1 years, mean BMI of 29.0±8.0 kg/m2, and mean Charlson Comorbidity Index (CCI) of 2.6±1.9. Fifty-one percent of the MM implants had direct metal on metal contact, and the average distance between non-contacting metals was 0.58±0.3cm. The most common combination of metals was titanium+stainless steel (43%) and titanium+cobalt chromium (44%). The most common combination of MM implants was cerclage wire on arthroplasty implant (40%), followed by plate on arthroplasty implant (21%), and plate on nail (16%). The most common area of MM implants was within the femur (64%). At an average follow-up period of 24.7 ± 14.7 months, hardware-related complications were recorded in 29 of 110 patients(26%), with 26 (90%) of these patients necessitating reoperation at an average of 19.0 ± 15.5 months after index procedure. Five of these patients (19%) underwent reoperation for infection, while all 11 patients (10%) that had painful hardware underwent subsequent removal of hardware procedures, and three patients (3%) underwent joint manipulation concurrent with their removal of hardware procedures for post operative joint contractures. There were 4 patients who experienced implant loosening; 2 were due to a mechanical fall and 2 were due to infectious etiology and all 4 patients required reoperation. However, there was no evidence of metal-on-metal galvanic corrosion observed on radiographic evaluation prior to reoperation or identified intraoperatively at the time of reoperation. Binary logistic regression analysis did not reveal any significant associations between hardware related complications and age, sex, smoking status, ASA scores, direct MM implant contact, proximity of MM implants ≤10mm, or type of MM.

DISCUSSION AND CONCLUSION: Patients who received MM implants showed no radiographic signs of corrosion and had a similar rate of hardware-related complications as general orthopaedic procedures reported in historic literature. While theoretical concerns exist regarding use of MM implants, these findings suggest that the consequence of such combinations in clinical practice may not be as significant as previously suggested.

Table 1. Implant Data

	Mixing Metals (n=110)
Direct Metal Contact, n(%)	54 (51%)
Distance Between Differing Metals Without Contact (cm), mean ± SD	0.58 ± 0.3
Mixing Metals Material, n(%)	
Titanium + Stainless Steel	47 (43%)
Titanium + Cobalt Chromium	48 (44%)
Stainless Steel + Cobalt Chromium	8 (7%)
Titanium + Stainless Steel + Cobalt Chromium	7 (6%)
Configuration of Implants with Mixed Metals, n(%)	
Head on Stem	1 (1%)
Nail on Joint implant	1 (1%)
Plate on Joint implant	23 (21%)
Plate on Joint implant; Plate on Nail	2 (2%)
Plate on Joint implant; Plate on Nail; Nail on Joint implant	1 (1%)
Plate on Joint implant; Wire on Joint implant	4 (4%)
Plate on Joint implant; Wire on Joint implant: Wire on Plate	1 (1%)
Plate on Joint implant; Wire on Plate	3 (3%)
Plate on Nail	18 (16%)
Plate on plate	4 (4%)
Screw on Joint implant	2 (2%)
Screw on Plate	2 (2%)
Screw on plate; Screw on Nail	1 (1%)
Screw on plate; Screw on Joint	1 (1%)
Wire on Joint implant	44 (40%)
Wire on Plate	2 (2%)
Implanted Areas, n(%)	
Elbow	3 (3%)
Femur	70 (64%)
Femur + Tibia	1 (1%)
Hip	8 (7%)
Hip + Femur	1 (1%)
Humerus	4 (4%)
Knee	2 (2%)
Knee + Femur + Tibia	2 (2%)
Radius	1 (1%)
Radius/Ulna	1 (1%)
Shoulder	1 (1%)
Tibia/Fibula	5 (5%)
Tibia	10 (9%)
Tibio-Talo-Calcaneal	1 (1%)

Table 2. Outcomes

	Mixing Metals (n=110)
Follow-up (months), mean ± SD	24.7 ± 14.7
Radiographic or Clinical Signs of Galvanic Corrosion at Final Follow-up	0 (0%)
Postoperative Hardware Related Complications, n(%)	29 (26%)
Broken Hardware	1 (1%)
Fracture	3 (3%)
Hardware Loosening due to infectious etiology	2 (2%)
Hardware loosening s/p Fall	2 (2%)
Infection	9 (8.2%)
Painful Hardware†	11 (10%)
Periprosthetic fracture	1 (1%)
Reoperation due to Hardware Related Issues*, n(%)	26 (24%)
I&D	3 (3%)
I&D + ROH	2 (2%)
IMN + Prophylactic fixation	1 (1%)
ORIF	1 (1%)
Percutaneous arthrodesis + Percutaneous fixation	1 (1%)
ROH	5 (5%)
ROH + Heterotopic ossification excision	1 (1%)
ROH + Joint Manipulation	3 (3%)
Revision DFR	1 (1%)
Revision Knee arthroplasty	1 (1%)
ROH + Prophylactic fixation	1 (1%)
ROH + Saucerization + Nonunion treatment	1 (1%)
THA Revision	3 (3%)
THA Revision + ORIF + Prophylactic fixation	1 (1%)
Total Hip Arthroplasty Explant + ROH + Femur ORIF + prophylactic fixation	1 (1%)
Time to Reoperation (months), mean ± SD	19.0 ± 15.5

*There was no evidence of galvanic corrosion observed intraoperatively, †one patient developed heterotopic ossification concurrent with painful hardware.