Trunnionosis in Total Hip Arthroplasty

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Outline

- THA Prosthetic Parts
- Definitions
- Basic Science of Corrosion Production
- Head-Neck Junction Material Combinations
  - CoCr-CoCr
  - Ti-CoCr
  - Ti-Ceramic
- Additional Influences on Taper Variability

Total Hip Arthroplasty Prostheses

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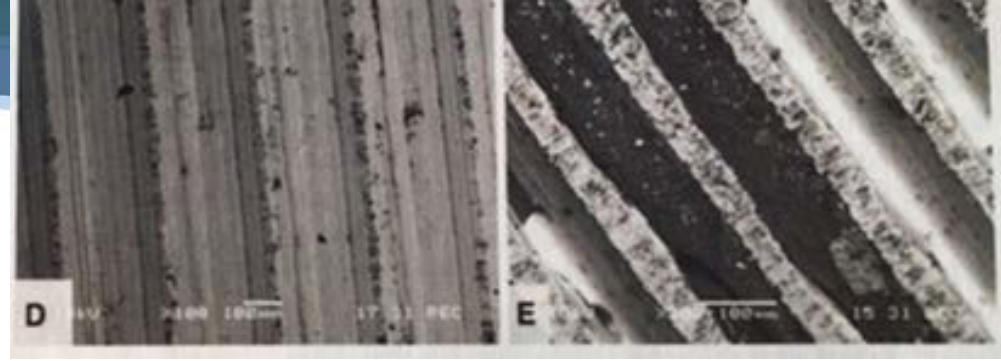
Mechanism of Trunnionosis



"Mechanically-Assisted Crevice Corrosion" (Goldberg, Gilbert, Jacobs)

Definitions:

Corrosion - The gradual destruction of materials, usually metals, by chemical reaction with their environment. Electrochemical oxidation reaction.

Crevice – space between two opposing surfaces where no contact is present and solution can reside (asperity-asperity contact)

Fretting – a contact damage process resulting from micromotion of interfacing metals (Szolwinski and Farris). Can damage the protective oxide layer in a crevice.

Passivation - the spontaneous formation of an ultrathin film (10 nanometers), known as a passive film, on the metal's surface that act as a barrier to further oxidation

Mechanically-Assisted Crevice Corrosion

- Mechanical fretting and wear
  - Disrupts the thin, protective oxide layers that border the crevice environment
- Underlying metallic substrate is exposed by mechanical damage in vivo
  - Re-passivation of the metal surfaces occurs
- Alters the voltage of the crevice environment
- Acidifies the fluid trapped in the crevice
- Electrochemical changes in crevice fluid interact with solution outside of crevice and potentiate corrosion reaction
  - “Complex interplay of metallurgical, chemical, electrical, and tribological factors”

Corrosion at the Head-Neck Taper as a Cause for Adverse Local Tissue Reactions After Total Hip Arthroplasty

H. John Cooper, MD, Craig J. Della Valle, MD, Richard A. Berger, MD, Matthew Tetreault, BA, Wayne G. Paprosky, MD, Scott M. Sporer, MD, and Joshua J. Jacobs, MD

Investigation performed at the Department of Orthopaedic Surgery, Rush University Medical Center, Chicago, Illinois

J Bone Joint Surg Am. 2012;94:1655-61

- 10 patients underwent revision for trunnion corrosion
  - January 1, 2009 to August 31, 2011
- 1.8% of 569 revision THA's performed at their institution
- Presented at a mean of 3.2 years after index procedure
- 8 women and 2 men with average age of 59.7 years

TABLE I Demographic and Initial Surgical Data

Case	Age *(yr)*	Sex	Body Mass Index *(kg/m^2)*	Femoral Component	Taper	Head Size, Neck Length *(mm)*	Interface	Time to Revision (After Index Op.) *(yr)*
1	66.5	F	31.9	Zimmer VerSys Beaded FullCoat	12/14	32, +3.5	Co alloy/Co alloy	3.4
2	65.0	F	24.3	Zimmer VerSys Beaded FullCoat	12/14	28, +10.5	Co alloy/Co alloy	6.5
3	69.9	F	25.2	Zimmer VerSys Beaded FullCoat	12/14	36, +7	Co alloy/Co alloy	4.3
4	58.1	F	27.2	Zimmer VerSys Beaded FullCoat	12/14	28, +10.5	Co alloy/Co alloy	5.1
5	41.1	F	28.0	Zimmer VerSys Beaded FullCoat LHC	12/14	32, +5	Co alloy/Co alloy	2.1
6*	61.5	M	27.3	Zimmer VerSys Beaded FullCoat Revision	12/14	32, +10.5	Co alloy/Co alloy	0.8
7	46.5	M	36.0	Zimmer VerSys Fiber Metal Taper	12/14	32, −3.5	Ti alloy/Co alloy	5.1
8	62.6	F	36.0	Zimmer M/L Taper, Kinectiv Modular Neck	12/14	32, +0	Ti alloy/Co alloy	0.7
9	55.5	F	32.1	DePuy Bantam Full Porocoat	10/12	28, +5	Co alloy/Co alloy	8.9
10*	70.4	F	25.2	Stryker Accolade	V40	36, +0	Ti alloy/Co alloy	2.2

*The patient was referred from another facility.

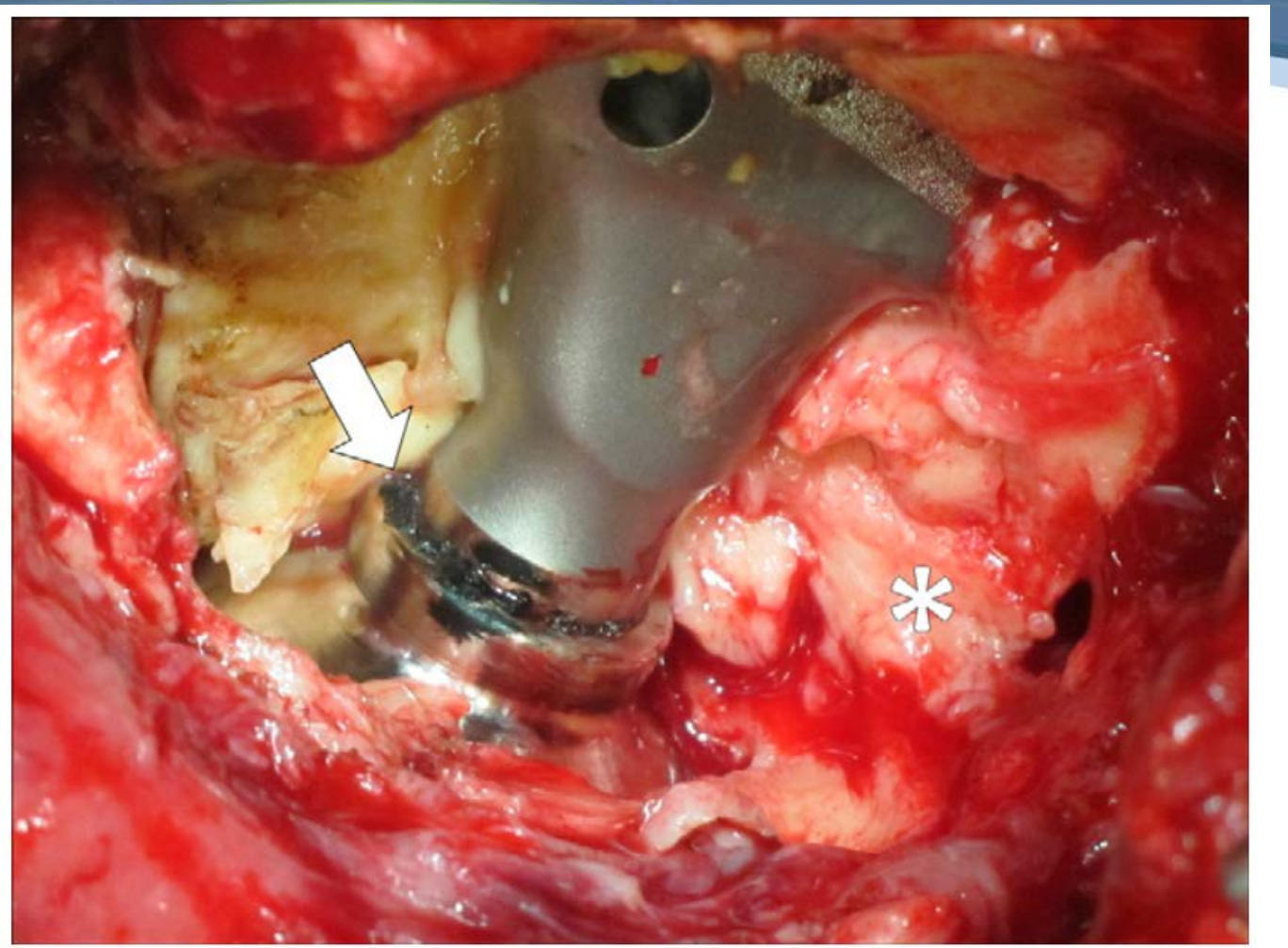
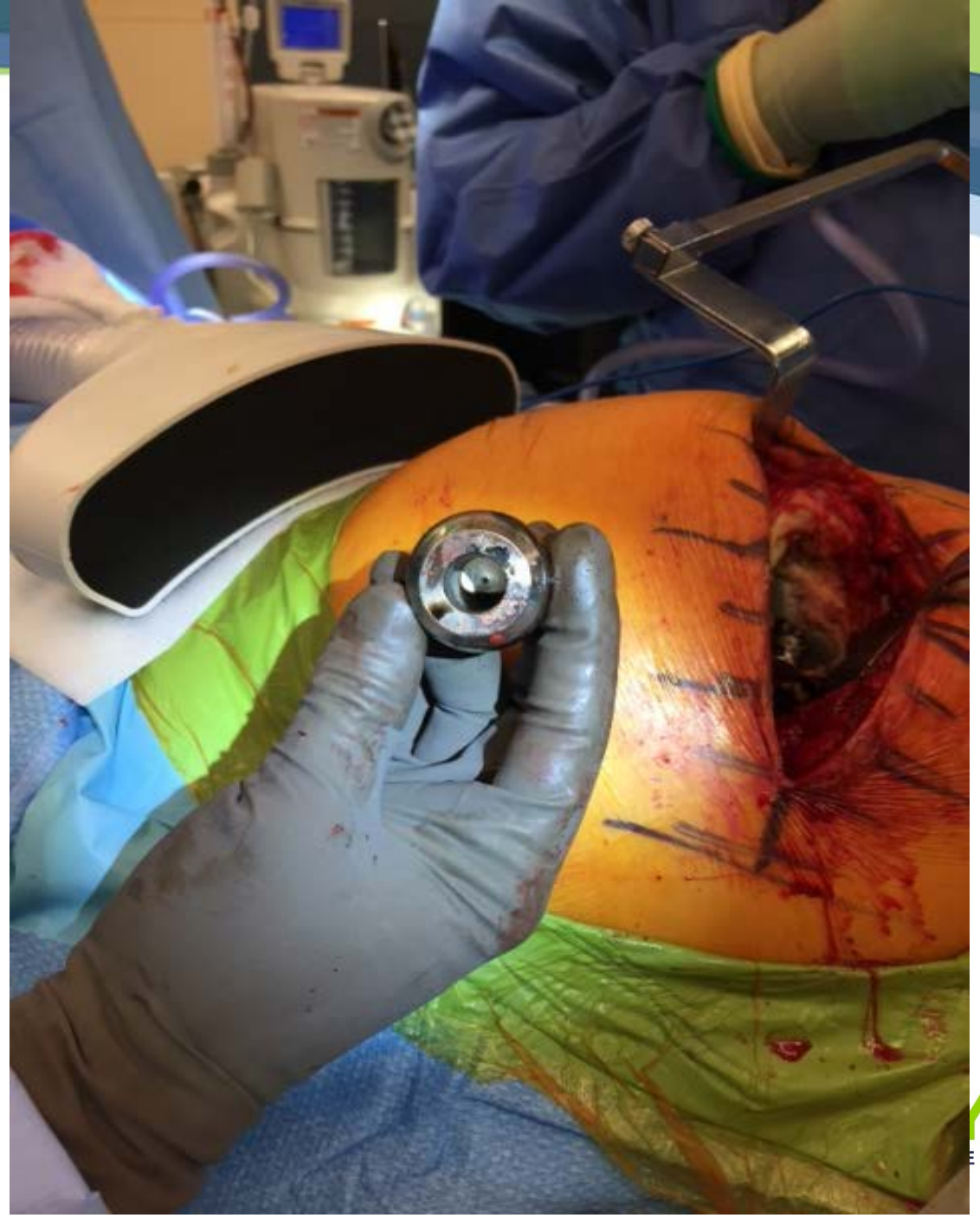


Fig. 2

Intraoperative photograph demonstrating corrosion (arrow) at the modular head-neck taper between the femoral component and a collared (+10.5-mm) head. The pseudocapsule is markedly hypertrophic and avascular (asterisk), which is typical of this adverse local tissue reaction.



Revision Surgery Solution

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TABLE III Revision Surgery and Postoperative Data

Case	Revision Procedure	Head Size *(mm)*	Head Type	Liner	Preop. Cr Level *(ng/mL)*	Preop. Co Level *(ng/mL)*	Postop. Co Level *(ng/mL)*	Complications
1	Head + liner exchange	32	Ceramic	Elevated rim	3.28	8.89	0.54 at 6.1 mo	Recurrent instability
2	Head + liner exchange	28	Ceramic	Constrained	3.16	1.67	0.36 at 22.0 mo	—
3	Head + liner exchange, acetabular revision	36	Ceramic	Neutral	1.94	10.80	—	—
4	Head + liner exchange	36	Ceramic	Neutral	0.60	6.30	—	—
5	Head + liner exchange	32	Ceramic	Elevated rim	1.23	7.21	0.20 at 14.0 mo	—
6	Head + liner exchange, irrigation and debridement	32	Ceramic	Constrained	1.69	42.45	8.93 at 2.2 mo	—
7	Head + liner exchange, acetabular revision	40	Metal	Neutral	0.18	2.72	0.18 at 12.0 mo	—
8	Head + liner exchange	32	Ceramic	Elevated rim	0.21	3.17	—	—
9	Head + liner exchange	28	Metal	Constrained	3.18	1.60	—	—
10	Head + liner exchange	36	Ceramic	Elevated rim	0.18	2.79	1.18 at 3.6 mo	—

- 8/10 patients revised to a ceramic head with a Titanium sleeve
  - Theoretic concerns about ceramic head fracture on damaged taper
  - Avoiding Cobalt alloy with any modular junction
- 1/10 Recurrent Instability

Conclusions

- Corrosion must be on the differential
  - Painful Non-MoM THA
- Metal levels need to be investigated
- Standard ESR/CRP, hip aspiration if necessary
- MARS MRI
- Revision of taper interface
  - Ti Sleeve with Ceramic head
  - Longevity and resistance to corrosion?

Do Ceramic Femoral Heads Reduce Taper Fretting Corrosion in Hip Arthroplasty? A Retrieval Study

- Kurtz SM, et al. CORR. 2013.
- Matched cohort study design
  - 50 ceramic head-stem pairs
  - 50 CoCr head-stem pairs
  - Stems were matched between the cohorts with either proprietary titanium alloy TMZF (54%), Ti-6Al-4V (29%), or CoCr alloy (17%)
- 12-year ongoing retrieval collection from 12 clinical revision centers throughout US
- Power analysis revealed sample size of 100 sufficient

Cohorts

Cohorts matched for

- Implantation time
- Flexural rigidity
  - Shown to be significant in development of corrosion (Goldberg, et al. CORR. 2002)
- Lateral offset

None revised for adverse local tissue reaction

Scoring for Fretting and Corrosion

4-point scoring technique

- 1 -- Fretting <10% surface and no corrosion damage
- 2 – Fretting >10% surface and/or corrosion confined to one or small areas
- 3 – Fretting >30% and/or aggressive local corrosion attack with corrosion debris
- 4 – Fretting over majority >50% with severe corrosion attack and abundant corrosion debris

Scanning Electron Microscopy examination

Clinical data

- Implantation time, age, sex, BMI, UCLA activity score, reason for revision

Results

Fretting and corrosion scores were lower for the stems in the ceramic-metal cohort

- Ceramic-metal
  - Median score of 2
  - Corrosion deposits outside head-neck junction 0/50 (0%)
- Metal-metal
  - Median score of 3
  - Corrosion deposits outside head-neck junction 3/50 (6%)

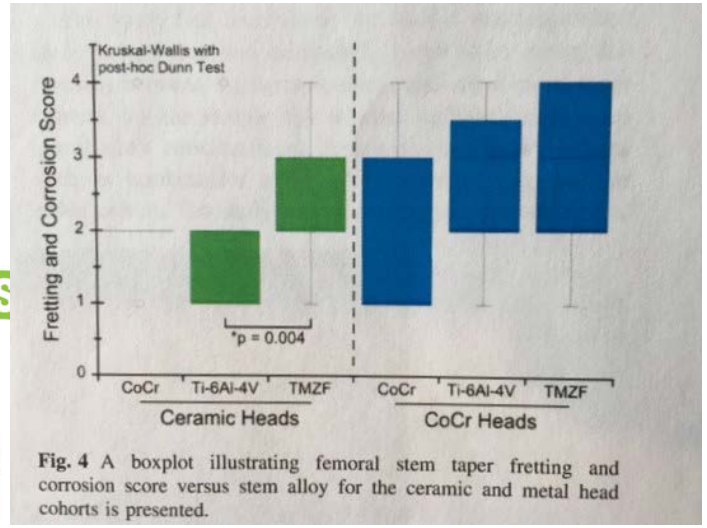


Fig. 4 A boxplot illustrating femoral stem taper fretting and corrosion score versus stem alloy for the ceramic and metal head cohorts is presented.

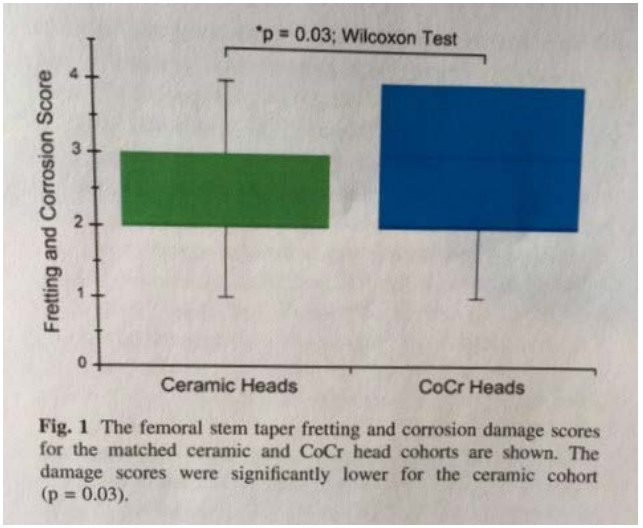


Fig. 1 The femoral stem taper fretting and corrosion damage scores for the matched ceramic and CoCr head cohorts are shown. The damage scores were significantly lower for the ceramic cohort ($p = 0.03$).

Significant Predictors of Corrosion

- Ceramic-Metal Taper Junctions
  - **Stem alloy, head material, and body weight**
    - Significant predictors of fretting and corrosion damage
  - Implantation time, lateral offset, head size, type of ceramic
    - Not significant
    - However, underpowered (power <25%)
- Metal-Metal Taper Junctions
  - None of the patient or device variables was a significant predictor of stem corrosion

Trunnion Surface Topography

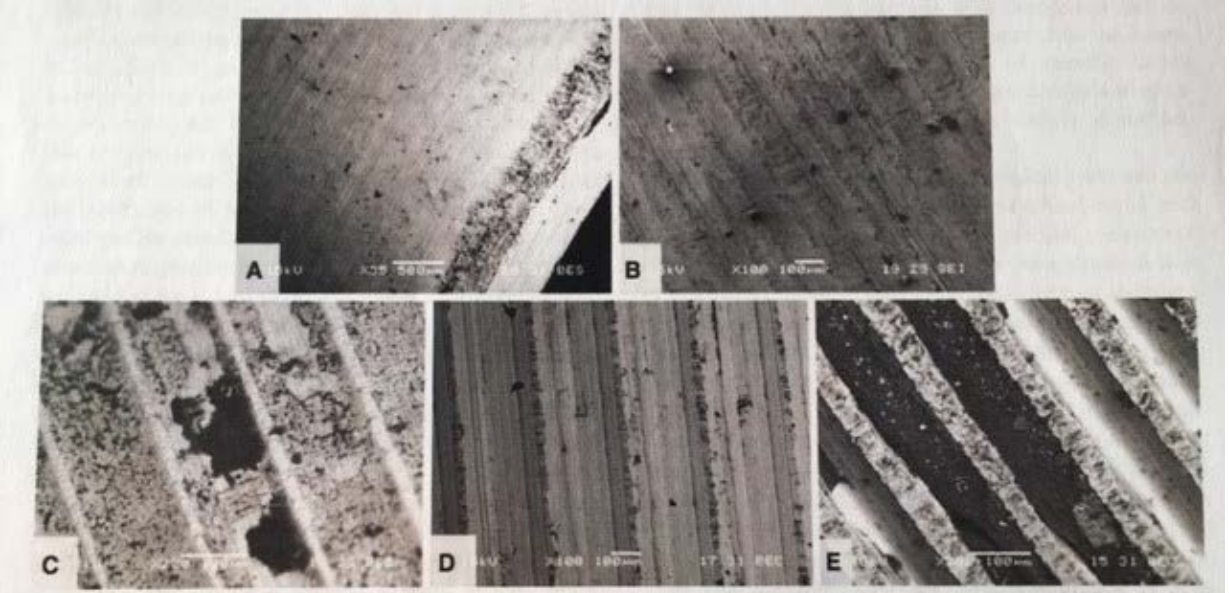
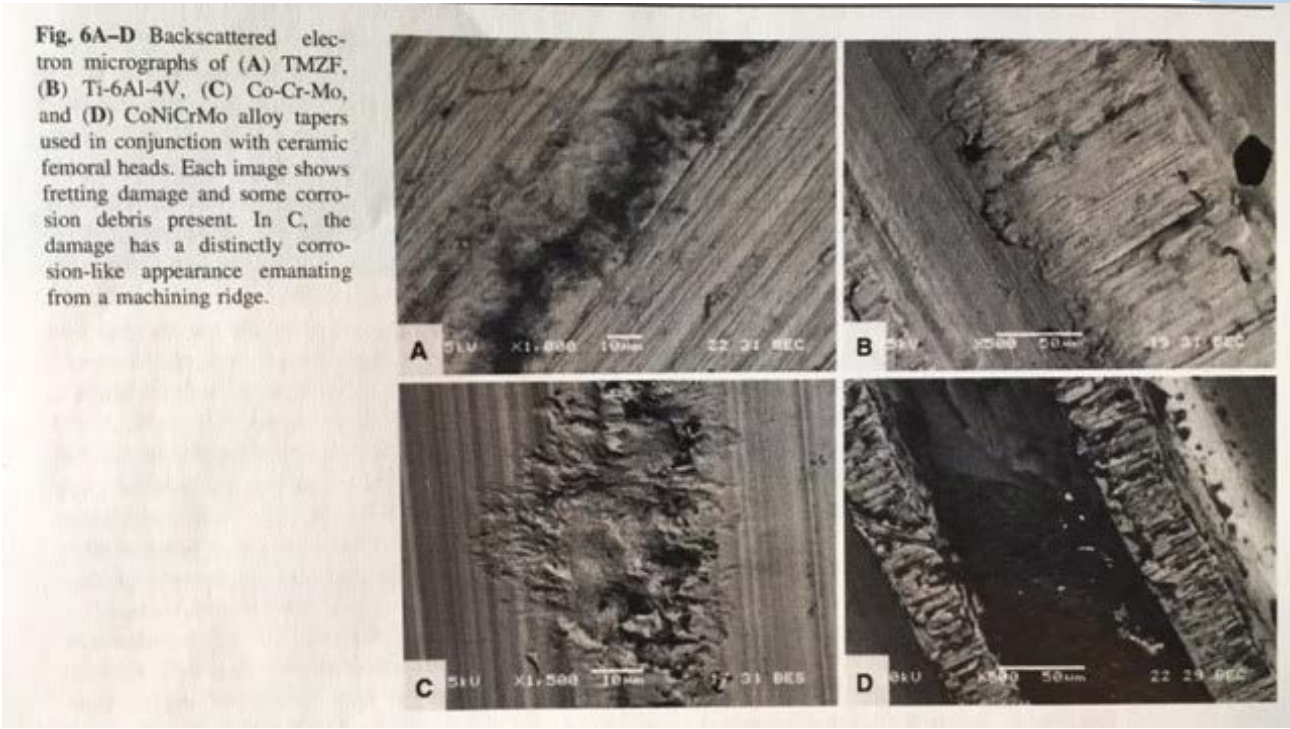


Fig. 5A–E SEMs of five different design and materials for the male taper of ceramic-metal trunnions. (**A**) TMZF (Stryker Orthopaedics, Mahwah, NJ, USA) × 35 BEC, (**B**) Ti-6Al-4V (Zimmer, Inc, Warsaw, IN, USA) × 100 SEI, (**C**) Ti-6Al-4V (Wright Medical Technology, Inc, Arlington, TN, USA) × 220 BEC, (**D**) Co-Cr-Mo (DePuy Orthopaedics, Inc, Warsaw, IN, USA) × 100 BEC, (**E**) Co-Ni-Cr-Mo (Zimmer) × 100 BEC. SEI = secondary electron imaging; BEC = backscattered electron contrast image. A is a ground surface, whereas **B**–**E** have machining grooves present. Also shown are fretting scars and corrosion and biological debris present. For grooved implants, only the groove tips show evidence of fretting corrosion damage.

Fig. 6A–D Backscattered electron micrographs of (**A**) TMZF, (**B**) Ti-6Al-4V, (**C**) Co-Cr-Mo, and (**D**) CoNiCrMo alloy tapers used in conjunction with ceramic femoral heads. Each image shows fretting damage and some corrosion debris present. In C, the damage has a distinctly corrosion-like appearance emanating from a machining ridge.



- Machining topography of tapers highly variable
- Similar appearance throughout cohorts
- Corrosion score differences not attributed to surface topography

Mechanically Assisted Crevice Corrosion

- Ceramic femoral heads
  - ***Only*** the metal male taper engaged in the oxide abrasion and repassivation process
  - Less overall taper junction corrosion
- Conclusion
  - Ceramic mitigates, but does not completely eliminate corrosion
  - Taper designs varied
    - All showed evidence of fretting and corrosion, as expected of a modular connection

Why doesn't a clinically significant reaction occur in everyone?

- Impaction strength
  - Increased force linearly increases taper strength (Rehmer, et al. Clin Biomech. 2012; Pennock, et al. JOA. 2002)
- Long Head-Neck extensions
  - Neck length did not have any effect on fretting or corrosion scores (Goldberg, et al)
- Large head sizes, trunnion design
  - Inconclusive (Mont, et al. J Orthopaed Traumatol. 2016)
- Surface Topography
  - Increased fretting and corrosion in rough versus smooth tapers (Panagiotidou, et al. J Orthop Research. 2013)
- Contamination of the taper upon impaction
  - Contamination increases variability of taper (Lavernia, et al. AJO. 2009)
- Patient biologic factors???

Thank You!

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Hip and Knee Reconstruction

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