



■ HIP ARTHROPLASTY: MANAGEMENT FACTORIALS

Trunnion corrosion

WHAT SURGEONS NEED TO KNOW IN 2018

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Aims

To present a surgically relevant update of trunnionosis.

Materials and Methods

Systematic review performed April 2017.

Results

Trunnionosis accounts for approximately 2% of the revision total hip arthroplasty (THA) burden. Thinner (reduced flexural rigidity) and shorter trunnions (reduced contact area at the taper junction) may contribute to mechanically assisted corrosion, exacerbated by high offset implants. The contribution of large heads and mixed metallurgy is discussed.

Conclusion

Identifying causative risk factors is challenging due to the multifactorial nature of this problem.

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Trunnionosis is a potential cause for revision in total hip arthroplasty (THA),¹ however, this is not a new phenomenon. Corrosion at the head-neck junction was described in 1991² and a soft-tissue reaction around a metal-on-polyethylene (MoP) THA in 1988.³ Differential patterns of material loss at the head-neck junction may indicate several failure modes,⁴ and the co-existence of multiple modes of corrosion and wear has been demonstrated.⁵ These are now encompassed under the umbrella term of mechanically assisted crevice corrosion. This article serves as a critical review of the various contributing factors that have been proposed.⁶

Materials and Methods

The search strategy for this systematic review is presented in Table I, and study flow described in Figure 1.

Results

Prevalence. A total of 12 revisions for adverse tissue reaction due to trunnion corrosion were reported in a consecutive series of 4813 non-metal-on-metal (MoM) THAs, a 0.25% prevalence for revision.⁷ National Joint Registry (NJR) data for England, Wales, Northern Ireland and the Isle of Man, shows a revision

risk for adverse reactions to metal debris of 0.032% (249 of 789 397; 95% confidence interval (CI) 0.028 to 0.036%) in non-MoM THAs, compared with 3.7% in MoM THAs ($p < 0.001$).⁸ A consecutive series study of same-implant MoP THAs estimated a 1.1% prevalence of adverse local tissue reactions due to mechanically assisted crevice corrosion (based on symptoms, raised serum cobalt levels, cross sectional imaging and the absence of infection). These criteria correlated well with intra-operative findings.⁹

Revision for trunnionosis accounts for 1.8% to 3.3% of the total revision THA burden.^{7,10} Clinically relevant trunnionosis is reported in approximately 1%, not all of which results in revision. The proportion revised may rise in the future due to detection bias, and there is likely to be wide variation in unit prevalence due to differential use of implants and surgical technique.

Risk factors. Body mass index (BMI) $> 30\text{kg/m}^2$ was identified in a five-patient series of head-stem dissociations secondary to trunnion corrosion.¹¹ Laboratory studies have demonstrated increased micromotion (fretting wear) at the head-neck junction with increasing weight.¹² Increased BMI may contribute to the problem but robust evidence is lacking.

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Table I. Keywords for the literature search

Keywords	
1	Tru*nionosis
2	Tru*nion corrosion
3	Taperosis
4	Crevice corrosion
5	Fretting corrosion
6	Mechanically assisted crevice corrosion
7	1 OR 2 OR 3 OR 4 OR 5 OR 6

Search strategy: MEDLINE 1946 to 2017 Week 15, AMED (Allied and Complementary Medicine) 1985 to April 2017, CAB Abstracts 1973 to 2017 Week 14, Embase 1974 to 2017 Week 16. Searches were performed on 18 April 2017, using the keywords above appearing in any field. Searches were limited to studies published in the English language. We also searched the reference lists of articles identified by this search strategy and included additional studies deemed relevant

Head/stem material couples. Due to galvanic corrosion with mixed metal combinations at the head-neck junction, cobalt-chrome/cobalt-chrome couples are less susceptible to corrosion than cobalt-chrome/titanium or stainless steel couples.^{13,14} Corrosion was observed in 28% of similar metal couples, compared with 42% in mixed couples.¹³

No difference in the rate of material loss at the head-neck junction was identified when head-stem combinations from the same manufacturer were compared with those from different manufacturers.¹⁵ No difference was observed in material loss when cobalt-chrome heads were used on cobalt-chrome or stainless steel stems.¹⁶

Laboratory studies of different implant designs with 12/14 tapers have shown a higher grade of corrosion and greater variation in debris particle size with a stainless steel/stainless steel couple compared with a stainless steel/titanium couple.¹⁷ Taper length, taper angle, neck-shaft angle and offset were not investigated. Of note, '12' and '14' refer only to the proximal and distal diameter of the trunnion. Trunnion length and cone angle are independent of these diameters, hence compatibility between manufacturers is not guaranteed by the designation '12/14'.

An association between titanium stems and increased fretting corrosion at the head-neck junction has been reported in a comparison of cobalt-chrome/cobalt-chrome, cobalt-chrome/titanium and ceramic/cobalt-chrome couples. The use of ceramic heads reduced but did not eliminate corrosion.¹⁸

Retrieval analysis has demonstrated lower mean corrosion scores with Oxidised Zirconium (Oxinium, Smith & Nephew, Memphis, Tennessee) heads compared with cobalt-chrome (1.9, SD 0.7 *versus* 2.5, SD 1.0; $p < 0.001$);¹⁹ corroborating the findings of other studies.²⁰ Comparison of non-oxidised zirconia/cobalt-chrome and cobalt-chrome/cobalt-chrome couples also identified lower fretting corrosion;²¹ similar to a comparative retrieval study of alumina compared with cobalt-chromium heads,²² and a matched study comparing corrosion of retrieved stems associated with either a ceramic or cobalt-chromium head.²³ Oxinium heads conferred no advantage over cobalt-chromium in a retrieval analysis of 16 matched stems (eight Oxinium heads, eight cobalt chrome heads).²³

Increased corrosion is associated with lower flexural rigidity of the neck, typical of titanium stems with narrow diameter necks.¹³

Amalgamating heterogeneous data is difficult but it appears combining titanium stems and cobalt-chrome heads may predispose to trunnionosis.

Head diameter. Wear analysis of a series of 5/17 retrieved large diameter (> 40 mm) MoM THAs revealed increased wear at the head-neck junction, but normal wear at the articulating surface suggesting an association between large heads and trunnionosis.²⁴ Finite element analysis of head-neck junctions demonstrated increased maximum stress on the trunnion as head diameter increased from 28 mm to 40 mm.²⁵ Significantly higher corrosion scores were observed on the trunnion of revised stems with 36 mm when compared with 28 mm heads.²⁶ Corrosion at the head taper is observed in almost all (99/110) large head (> 36 mm) MoM THRs, with similar wear at the head taper to the bearing surfaces.²⁷ Matched (taper design, manufacturer, time *in vivo* and head length) analysis of 23 femoral heads of 32 mm diameter and 28 mm heads revealed greater corrosion scores for the 32 mm femoral heads.²⁸ Analysis of NJR data showed a relative risk of adverse reaction to metal debris (ARMD) revision 2.8 times (95% CI 1.74 to 4.36) higher in 36 mm MoP bearings compared with 28 mm and 32 mm ($p < 0.001$).⁸

Other studies have refuted an association between trunnionosis and head size. Corrosion in the head taper was observed in 93% of 154 revised MoP THAs; however, no correlation between Goldberg score¹³ and head size was identified,²⁹ corroborating the findings of similar retrieval studies.^{19,20}

Currently evidence is conflicting for the association of head size with trunnion corrosion. Head size may play a role.

Head length and offset. In small case series, high offset and low neck-shaft angles were identified as a contributing factor.³⁰ Higher total fretting scores are seen in high-offset stems when there is control for other variables.³¹ Trunnion corrosion scores seem to show a parabolic relationship with head offset, with lower scores for neutral offsets.¹⁹ This may be related to deviation away from the neutral point

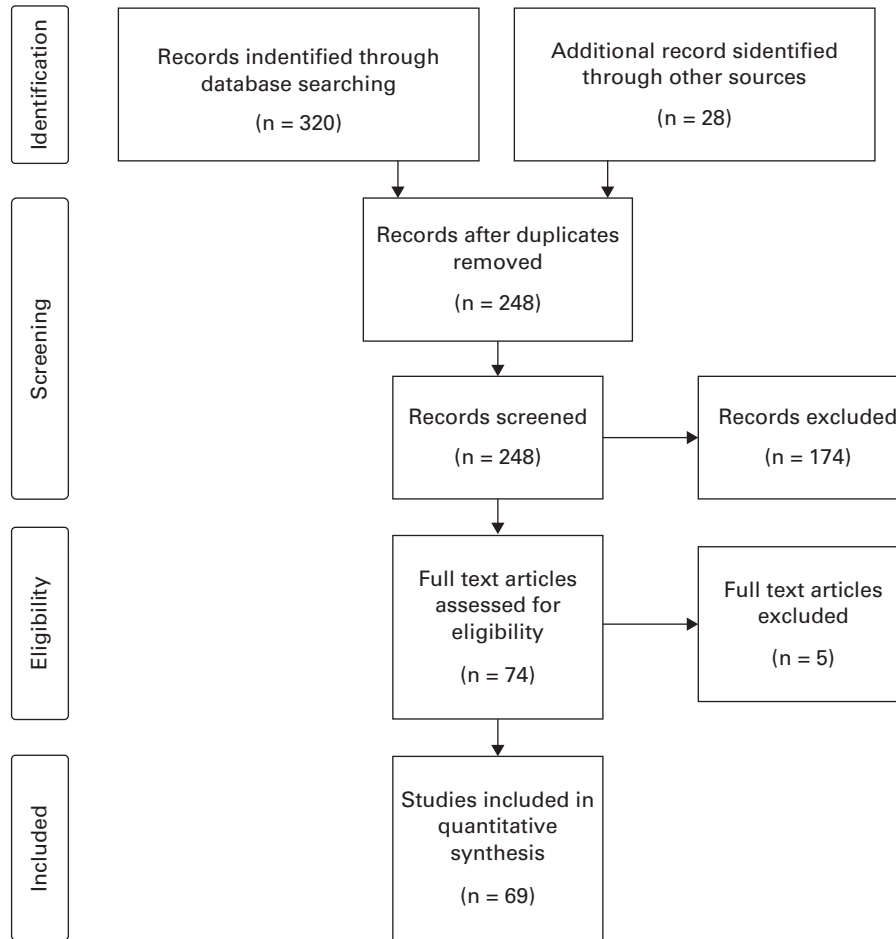


Fig. 1

Study flow diagram: A total of 320 records were identified from searching the literature; two reviewers (JB and MW) independently screened the abstracts of these records to identify potentially relevant articles for inclusion in this review. After screening, 41 studies were included in this review and an additional 28 studies were identified via reference lists and other sources. There was no disagreement between reviewers.

where femoral head centre and stem taper gage point coincide²⁰ and decreased taper engagement area.³¹ Laboratory assessment of loading reveals rocking of the head on the trunnion for higher offset heads.¹⁴ Asymptomatic MoP THA patients have shown an association between increased femoral offset and elevated serum cobalt levels.³²

A large retrieval comparison of two different stems with 12/14 tapers of different lengths found no discernible differences in corrosion scores in multivariate analyses controlled for head offset, implantation time, taper flexibility and patient weight.³³

Reducing the contact area between the head and trunnion or increasing the lever arm is likely to lead to reduced stability and hence increased risk of mechanically assisted corrosion.

Taper geometry. The move towards shorter, thinner trunnions to allow compatibility with ceramic heads and to increase impingement free range of movement is a potential risk factor for trunnion corrosion.^{34,35} The 11/13 S-ROM

taper (DePuy, Leeds, United Kingdom) in comparison with the 12/14 appears protective in MoP THA.³⁶⁻³⁸ It is suggested that shorter trunnions reduce contact areas, and sit completely within the head taper increasing edge loading and contact stress at the base. Thinner trunnions are associated with a reduced cross-sectional area contributing to micromotion and exacerbating fluid ingress. However, the thin 11/13 taper has been shown to have low flexural rigidity³⁹ and to be associated with the greatest corrosion in comparison to other designs, seen maximally at the base of the trunnion, potentially due to a combination of fluid ingress and greater torque.⁴⁰

In contrast, analysis of three taper types from 40 large MoM THA retrievals showed no correlation between taper design, corrosion score and volumetric wear.⁴¹ Greater fretting scores were associated with thicker tapers with longer contact lengths but implantation time, head offset and taper surface roughness were not accounted for. No correlation has been observed between taper angle clearance and

visual fretting-corrosion scores in either ceramic or metal heads.⁴²

The association between taper geometry and trunnion corrosion is inconclusive.

Assembly impact forces. A linear relationship between impaction force and disassembly force has been demonstrated.^{43,44} Improved contact between trunnion ridges and head taper (9% to 100%) has been shown as assembly force is increased from 500 N to 8000 N.⁴⁵ Impaction forces of at least 4 kN are required to improve pull off strength and reduce micromotion, hence corrosion.^{46,47} Impaction onto a dry trunnion results in higher resistance to fretting.^{14,48}

Other studies have shown no association between impaction force and fretting corrosion, although an angular mismatch between the head and neck assembly did increase fretting corrosion.¹²

Although a definitive association between assembly force and trunnionosis has not been established, it seems prudent to aim for higher head-neck stability using impaction forces between 4 kN and 8 kN with a dry taper junction and a well-centred head.

Investigations

Metal ion levels. A serum cobalt threshold of 1.6 ng/mL, in association with unexplained hip pain, stiffness or limping in non-septic MoP THA has been shown to be predictive of trunnion corrosion at revision.⁹ Intra-articular cobalt and chromium levels are significantly higher for trunnionosis cases when compared with patients undergoing revision for other causes, potentially contributing to observed soft tissue reactions.⁴⁹ Differential elevation of serum cobalt over chromium levels and cobalt levels of > 1 ppb are associated with adverse local tissue reactions secondary to corrosion.⁵⁰ The risk of pseudotumour formation increases with cobalt levels above 7 ppb, cut off levels for discussion with patients about the risk of revision of 5 ppb for cobalt and 2.5 ppb for chromium have been suggested in the context of hip resurfacing.⁵¹

There is not a precise level at which ion levels should precipitate revision surgery. The measurement of intra-articular cobalt and chromium levels may be a useful adjunct, as discussed by McGrory et al.⁴⁹

Imaging. Adverse local tissue reactions associated with the presence of corrosion debris at the head-neck junction following MoP THA have been observed by multiple authors.^{3,10,52-57} Intra-operative findings form a spectrum ranging from mild macroscopic trunnion corrosion to aggressive pseudotumour formation. Histological analysis reveals features consistent with aseptic lymphocyte-dominated vasculitis-associated lesions (ALVAL). Metal artefact reduction sequence (MARS) MRI findings include muscle oedema, atrophy, tissue necrosis, marrow oedema, osteolysis, extracapsular fluid collections and synovitis.⁵⁸ Capsular thickness > 3 mm, periprosthetic fluid and complex synovitis strongly correlated with soft tissue damage

and trunnion damage. Hip arthroscopy has also been advanced as a possible adjunct for examining the head-neck junction prior to revision surgery if there is diagnostic uncertainty.⁵⁹

Soft-tissue changes can be assessed using cross-sectional imaging which is an important part of investigation.

Treatment

The decision to avoid the morbidity associated with stem revision in a well-fixed stem with no macroscopic trunnion damage is appealing. Some authors suggest it is safe to revise a metal head to a new metal head in trunnion corrosion,⁶⁰ however most recommend cleaning the trunnion and using a new ceramic head with a titanium taper sleeve^{10,61} particularly if the old trunnion is not compatible with the use of a modern ceramic.⁶² Although the mechanical properties at the head-neck junction are not impaired by placing a new cobalt-chrome head on a corroded cobalt-chrome trunnion, placing a new cobalt-chrome head on a corroded titanium trunnion is associated with a 73% increase in interface motion compared with a new cobalt-chrome/titanium interface.⁶³

The majority of reported cases in which titanium sleeve adaptors have been used are for well-fixed uncemented titanium stems. There is less evidence regarding stainless steel or cobalt chrome stems. *In vitro* studies of non-corroded interfaces have shown only very minor differences in fretting corrosion when a ceramic head is used in conjunction with a titanium sleeve on stainless steel, cobalt chrome and titanium stems.⁶⁴

For macroscopically intact trunnions, we recommend the use of a ceramic head in combination with a sleeve of complementary metallurgy to the stem, if available. It should be noted that whilst ceramic heads decrease metal release caused by head-taper fretting and corrosion,^{18,22,23,65,66} a ceramic head does not eliminate the possibility of trunnion corrosion.⁶⁷

In conclusion, the use of ceramic compared with metal heads in the primary setting significantly reduces the incidence of trunnionosis but there is an increase in implant costs. Ceramic heads may be economical on a societal scale.⁶⁸ For patients < 85 years, ceramic-on-polyethylene is cost effective if the cost differential to MoP was \$325 or less. At \$600, ceramic is only cost effective for patients < 65 years.⁶⁹ There is not enough evidence to suggest that Oxinium heads further reduce the risk of trunnionosis over ceramic.

Among non-MoM bearing hip replacements in the NJR, the risk of ARMD revision surgery by primary bearing surface was greatest for ceramic-on-ceramic 0.055% (75 of 135 267; 95% CI 0.044 to 0.070), and similar for both MoP 0.024% (125 of 526 951; 95% CI 0.020 to 0.02) and ceramic-on-polyethylene 0.023% (29 of 124 656; 95% CI 0.016 to 0.033).⁸

We currently recommend the use of ≤ 36 mm head sizes, the judicious use of ceramic heads, neutral offset wherever possible and an assembly force of 4 kN to 8 kN in dry conditions for the reduction of risk factors associated with trunnionosis.



Take home message:

- Trunnionosis currently accounts for approximately 2% of the revision THA burden

- Thinner, shorter trunnions may contribute to mechanically assisted corrosion and the observation of trunnionosis.
- Correct assembly with adequate force, ceramic heads of ≤ 36 mm diameter and the use of neutral head length and stem offset where possible may reduce the occurrence of trunnionosis.

Author contributions:

J. Berstock: Literature searches, Screening, Analysis, Writing the paper.
M. Whitehouse: Literature searches, Screening, Analysis, Writing the paper.
C. P. Duncan: Writing the paper.

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