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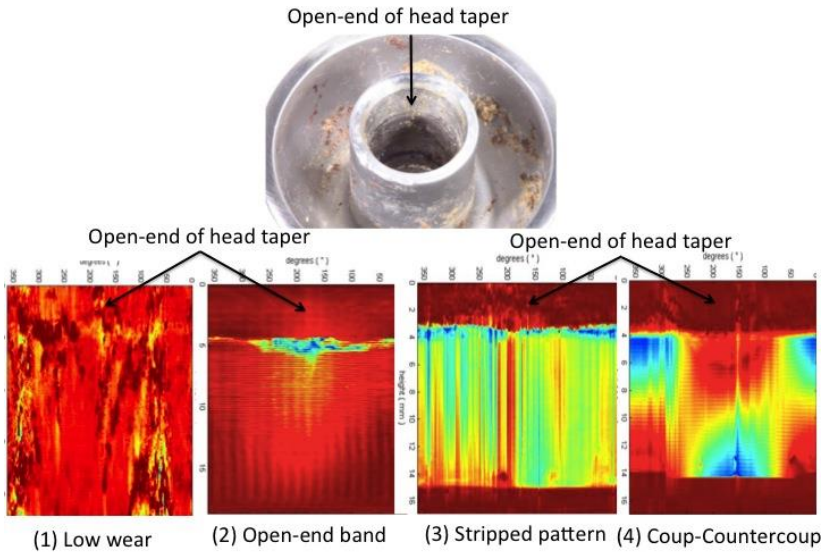
Identifying The Pattern of Material Loss at the Head-Neck Junction Wear Helps Determine the Mechanism of Failure of Metal on Metal Total Hip Replacements

Material loss at the Head-Neck junction accounts for a third of the total volume material loss in contemporary metal-on-metal total hip replacements. It is speculated that the material loss is the result of corrosion and mechanical wear (fretting). High volumes of material loss have been reported, especially from the head taper. There is only one report on characterizing the pattern of material loss and this was in a very small number of cases (n=5). Our aim was to identify the different material loss patterns at the head taper and their corresponding mechanisms

We retrospectively analysed a series of retrieved Large Head Metal on Metal Total Hip Replacements (155 cups, 155 femoral heads and 4 stems). We measured material loss on the bearing surfaces and the head-neck junction using well-published metrology methods. Furthermore we collected patient (age, gender and time of primary/revision operations), pre-revision (cobalt and chromium blood metal ion, oxford hip score, cup orientation and implant position) implant (cup and head size, manufacturer and corrosion severity) data. Finally we used surface analysis techniques (microscopy and spectroscopy) to identify fretting, imprinting and the material composition of debris. We devised a novel four-group classification and two blinded engineers classified the material loss patterns using wear maps derived from the metrology analysis

We observed four distinct patterns of taper surface material loss at our retrieval centre and we set out to characterize these types and relate them to patient, implant and clinical variables. The four groups of material loss patterns were defined as: (1) Low wear (n= 63), (2) Open-end band (n=32), (3) Stripped material loss (n=54) and (4) Coup-Countercoup (n=6) (*Figure*). The Interobserver Reliability Kappa score was 0.78 ($p<0.001$) indicating substantial agreement between the two examiners.
Analysis of variables between the groups identified significantly different head sizes (highest: Group 2, p=0.000), corrosion severity (highest: Group 2, p=0.004) and time to revision (highest: Group 3, p=0.040).

We identified four different material loss patterns each with its own mechanism. Corrosion was identified as the principal mechanism in Groups 1 and 3. Group 1 head-neck junctions are thought to have a better seal with less fluid ingress in the junction. Group 3 head-neck junctions are attacked by corrosion either circumferentially, or unilaterally, along the whole engagement length. Mechanically assisted corrosion was the principal mechanism in Group 2. The higher friction torque opens up the open-end part of the junction and the ingressing fluid accelerates the corrosion. Extensive fretting was also observed under the scanning electron microscope. Intra-operative surgical damage was identified as the principal mechanism in Group 4, with only 6 components. The patterns and the mechanisms of material loss at the head-neck junction contribute to the understanding of large head metal-on-metal hip replacements. As a result, better implants can be designed in the future.
Clinically, these findings suggest that head size and head taper-trunnion fit are the main factors that determine the longevity of the head-neck junction. On the other hand, patients selection does not influence the integrity of the junction.

Table 1: The Classification of Material Loss Patterns

Group	Material Loss Description	Number
1. Low wear	Volume less than 1 mm^3	63
2. Open-end	A band at the open-end	32
3. Stripped	Axisymmetrical and Asymmetrical	54
4. Coup-countercoup	Two distinct areas on opposite ends of the junction	6