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Structural Pathobiology of Cervical Wear by Robot Simulated 3-year Toothbrushing

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Objectives:

Occlusal wear in omnivorous animals, including man, is a natural phenomenon, the lifetime cervical wear is, in contrast, a risk for dentin hypersensitivity and hard tissue loss. Therefore, an ex-vivo study was aimed at (i) enamel and dentin loss, (ii) improvement of cervical conditions contributing to oral health by (iii) comparing ball joint toothbrushing with flexible neck manual toothbrush versus rigid toothbrushing with a conventional manual toothbrush.

Material and Methods:

Following ethical approval EC-UWH-SR-67-2021 random toothbrushing (44 strokes/tooth horizontally, rotating, vertically. 2x/d) with manual flexible ball-joint test brush vs. control brush with rigid handle and dentifrice Sensodyne Extra-fresh (Haleon/GSK, Weybridge, UK) was performed in an Artificial Oral Cavity with robot force 3.5 N on 14 human extracted teeth. Morphological features were examined by SEM using replication technique (LEO-1450, Zeiss). 3D-SEM analyses were carried out with a 4Q-BSE detector (SEM-515, Philips; Point Electronic, Halle).

Results:

Morphological feature coding 0-3 revealed four enamel patterns (abrasion marks, perikymata, prismless/prismatic enamel, enamel infractions), one dentin pattern (open tubules) and three cervical patterns (calculus, enamel overlapping cementum, root dentin overlapping enamel, gaps between enamel and cementum, enamel islands) due to 3-year random toothbrushing. Masked isolated enamel islands on root dentin were first time documented. Harmful changes: Enamel/dentin loss. Contributing to oral health: Removing hidden calculus; smoothing traumatic and iatrogenic damages. Best characterizing feature was removal of superficial prismless enamel opening prismatic structures. On average, 53.5nl less tooth structure was removed by test brush (24-50nl) vs. control brush (41-188nl). Adolescent teeth – no/negligible wear, young adult teeth – cementum wear undermining enamel, adult teeth – wear extending apically 100 – 1500 µm. Wilcoxon signed-rank test demonstrated significant differences between pre- and post-brushing for dental calculus removal ($p = 0.0078$) for both toothbrushes. Control brush showed significant differences in W-test for exposed prismatic enamel ($p = 0.0156$) and peninsula formation ($p = 0.0313$).

Conclusions:

Structural pathobiologic follow-up of men-made cervical wear by SEM and 3D-SEM elucidates negative as well as beneficial oral health- contributing micromorphology patterns of simulated 3-year random toothbrushing.

Ball joint neck flexibility of toothbrushes contributes to less damaging cervical wear compared to rigid toothbrushes.

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Fig. 1: Two dentition models were constructed, each with nine human teeth (4 incisors, 1 canine, 2 premolars, 2 molars: juvenile, adult, senior teeth in anatomic position). The six-axis robot (FS 02 N, Kawasaki Robotics, Akashi, Hyogo, Japan) was programmed for random brushing based on clinical validation.

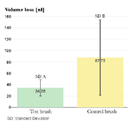

Fig. 2: Mean volume loss due to test brush is $\bar{x}_A = 34.25$. Mean volume loss due to control brush is $\bar{x}_B = 87.75$. Difference of means: $\bar{x}_B - \bar{x}_A = 53.5$ nl

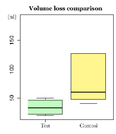

Fig. 3: Boxplot - The median in the manual control brush boxplot is near the 1st quantile, while the median of test brush is in the middle of the boxplot. This illustrates how the resulting volume losses of test brush were closer together. Whiskers range from 5% to 95% quantile.

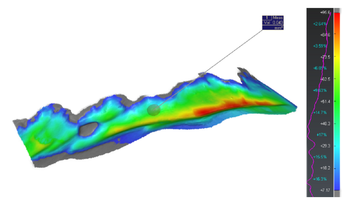

Fig. 4: The colour-coded surface model of the cervical wear lesion after toothbrushing shows the amount of root dentin loss. Blue - low, Red - high loss of dentin. Overall volume loss - 43 nl on cervical mesh surface of 1.538 mm². Height scale colour coding (in µm): Blue: 5 – 30 µm, green: 30 – 64 µm, yellow: 64 – 75 µm, red: 75 – 98 µm.

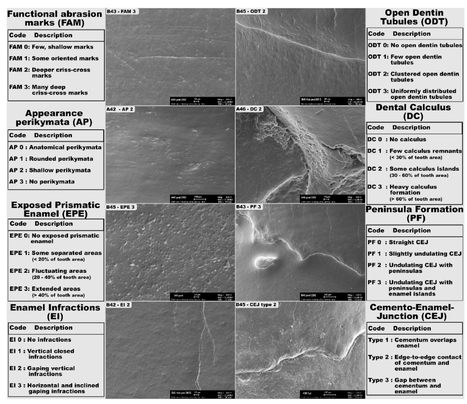

Fig. 5: Morphological feature coding of cervical wear. SEM-codes 0 – 3 in both groups (A – Test toothbrush, B – Control toothbrush followed by FDI-Number of single teeth: 42-Incisor, 43- Canine, 45-Premolar, 46-Molar). Magn. 100x, 400x (see magn. bar).

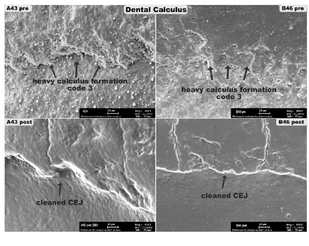

Fig. 6: Cervical wear region covered by dental calculus; Canine A43 (58 year old subject); CEJ–cemento-enamel junction, pre–baseline, post–after tooth-brushing/test.

Molar B46 (31 year old subject); pre–baseline, post–after toothbrushing/contr.

Magn. 400x.

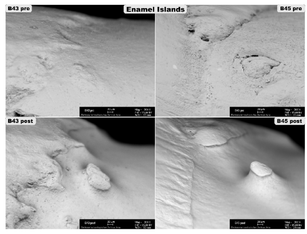

Fig. 7: Cervical wear causing exposure of enamel islands on root surface.
Canine B43 (58 year old subject) and premolar B45 (13 year old subject) after simulated 3-year toothbrushing. Above–baseline, below–post brushing.

Magn. 200x.

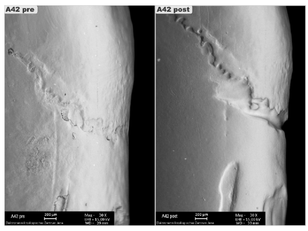

Fig. 8: Electron microscopic view of Incisor A42 (40 year old subject), pre-baseline with calculus masking the enamel cementum gap, post–after toothbrushing with rounded enamel edges and deepened gap.

Magn. 30x