Supporting Information

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Abrasive of Enamel Surface by Scratching an Aluminum Sphere for 60 Cycles

Figs. 1 and 2 show a microwear striation on the enamel surface formed after a single cycle of drag using an aluminum sphere. Further tests involving 60 drag cycles (each with maximum Hertzian contact pressure of 0.98 GPa) were conducted to simulate chewing. As shown in Fig. S1, more enamel chips were found embedded in the surface of the aluminum sphere after 60 cycles, indicating that the amount of enamel wear depends on number of chew cycles.

Microwear on Enamel Surface by Brass Sphere

To further confirm tooth wear by soft particles, chewing simulations were repeated for 60 cycles using a brass sphere (0.9 mm in radius) with a maximum Hertzian contact pressure of 1.61 GPa. As shown in Fig. S2, resulting scratches on the dental surfaces indicate that enamel is also abraded by brass particles.

Unique Microwear Mechanism of Tooth Enamel

Tooth enamel differs fundamentally in the way it wears compared with normal metal materials. According to Hertzian contact theory, the critical contact pressure $P_y$ corresponding to the initial yield of material can be determined by (32)

$$P_y = 1.60\sigma_y.$$  \[S1\]

Here, $\sigma_y$ is the yield stress of the material. For most materials, the hardness $H$ is about 2.8 times yield stress (19, 33),

$$H = 2.8\sigma_y.$$  \[S2\]

Combining Eqs. S1 and S2, we obtain

$$P_y = 0.57H.$$  \[S3\]

Given the hardness of enamel $H = 4.62$ GPa, the $P_y$ for the initial yield of enamel was estimated as 2.63 GPa based on Eq. S3. However, based on our experimental results (see Fig. 4), the $P_y$ was estimated as 0.74 GPa, only 0.16 times its hardness. Such low critical contact pressure $P_y$ may be attributed to the unique microstructure of tooth enamel. Hydroxyapatite crystallites are glued together by proteins, and tissue removal requires only that contact pressure be sufficient to break the bonds holding the enamel together.

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Fig. S1. Enamel chips embedded in the surface of the aluminum sphere after 60 cycles. (A) SEM image of wear topography on the aluminum sphere. (B–D) Detail of the wear area in A, B, and C, respectively. (E) Enamel chips (a–d) in C were confirmed by the Ca and P peaks in the EDX spectrum. The EDX detection on the original area (e) in A was conducted for comparison (confirming the Aluminum substrate).
Fig. S2. An AFM image and cross-section profiles of a wear area on an enamel surface after 60 simulated chew cycles using a brass sphere.