Prefrontal hemodynamic activity evoked by occlusal discomfort
近赤外分光法による噛みあわせ違和感の検出

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Aim of study

- We used functional near-infrared spectroscopy (fNIRS) to measure prefrontal brain activity accompanying the physical sensation of oral discomfort.
- We investigated prefrontal activity in the simulated occlusal discomfort in healthy volunteers and in the dental outpatients with occlusal discomfort syndrome (ODS: 咬合違和感症候群[1]), who has vague complaints in the intraoral area such as occlusal discomfort without any identifiable organic cause.

Experiment 1: healthy volunteer study [2]

Participants: 25 young adults with normal stomatognathic function (14 males, 11 females, 28.9±1.6 years)

Simulated occlusal discomfort:

- Grinding the teeth with tasteless and odorless metal strip (96 μm) at their first molar of the habitual chewing side (Fig. 1).

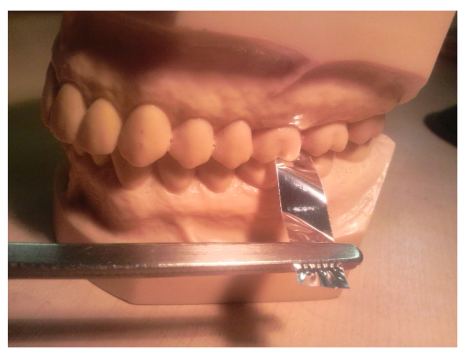

Figure 1. Simulation of occlusal discomfort using active grinding paradigm

fNIRS data acquisition:

- A block design with alternating 30s of grinding and 40s of rest for 5 times.
- A 22-channel fNIRS probes were positioned over the prefrontal cortices (Fig. 2).
- Participants performed the grinding task with and without metal strips. To cancel out the motion artifact, the differential Oxy/deoxy hemoglobin responses (ΔHbO/ΔHHb) were used for the further analysis.

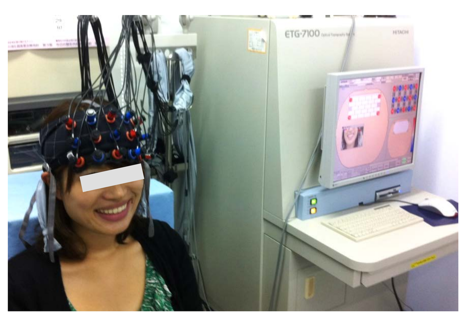

Figure 2. a whole-head type fNIRS measurement (Hitachi Med. ETG-7100)

ΔHbO/ΔHHb= HbO/HHb (grinding w/ strips) – HbO/HHb (grinding w/o strips)

Subjective evaluation of perceived occlusal discomfort:

- All participants evaluated the subjective severity of discomfort using a visual analog scale (VAS). The VAS varied from 0 (a state with no discomfort at all) to 100 (a state of intolerable discomfort).

Correlation between fNIRS signals and discomfort strength:

- Correlation between the cumulative ΔHbO signals (area under the curve (AUC) during grinding period) and the ΔVAS (difference of VAS: between with and without strips) was calculated to determine the prefrontal area that responds to the change in the perceived strength of occlusal discomfort.

Regional brain activity related to occlusal discomfort:

- Regional brain activities corresponding to the ΔHbO signals were identified using statistical parametric mapping (NIRS-SPM[3]) with a generalized linear model (GLM).

Experiment 2: ODS patients study

Participants: 6 ODS patients (1 male, 5 females, 49.5±7.5 years) and 8 age- and sex-matched dental patients without ODS

fNIRS data acquisition:

- A block design with 10s of holding the metal strip in the mouth,15s of gentle grinding, and 30s of rest.
- A 4-channel wireless fNIRS probes were positioned over the prefrontal cortices (Fig. 3). Skin and cortical blood flow were simultaneously recorded with optical probes with two different inter-probe intervals (4mm and 30mm).
- The thickness of metal strips was gradually increased from 0μm to the threshold thickness in which participants perceived occlusal discomfort (12-72μm, no statistical difference in the threshold thickness between patient groups).

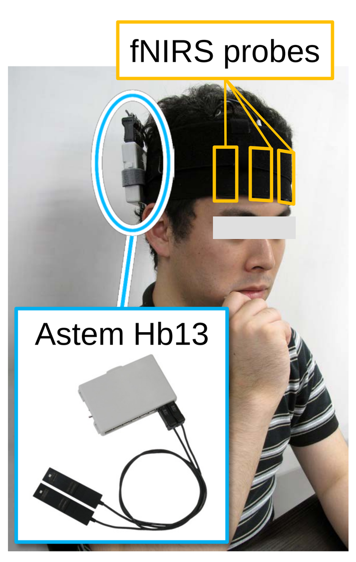

Figure 3. Wireless fNIRS measurement in a clinical setting (ASTEM Hb13)

Exp. 1: Occlusal discomfort induces prefrontal activity

- The HbO responses of selected channels in the frontopolar and dorsolateral prefrontal cortices increased in participants who reported increased severity of occlusal discomfort during grinding metal strips, while they decreased in those who reported no change or decreased occlusal discomfort (Fig. 4a).
- Most of the prefrontal channels showed significant correlation between AUC and subjective severity of occlusal discomfort (Fig. 4cd). GLM analysis of ΔHbO signals demonstrated that participants who reported severe or moderate discomfort showed common neural activity in Brodmann area 9/10 (Fig. 4e: n=13, p<0.05, uncorrected).

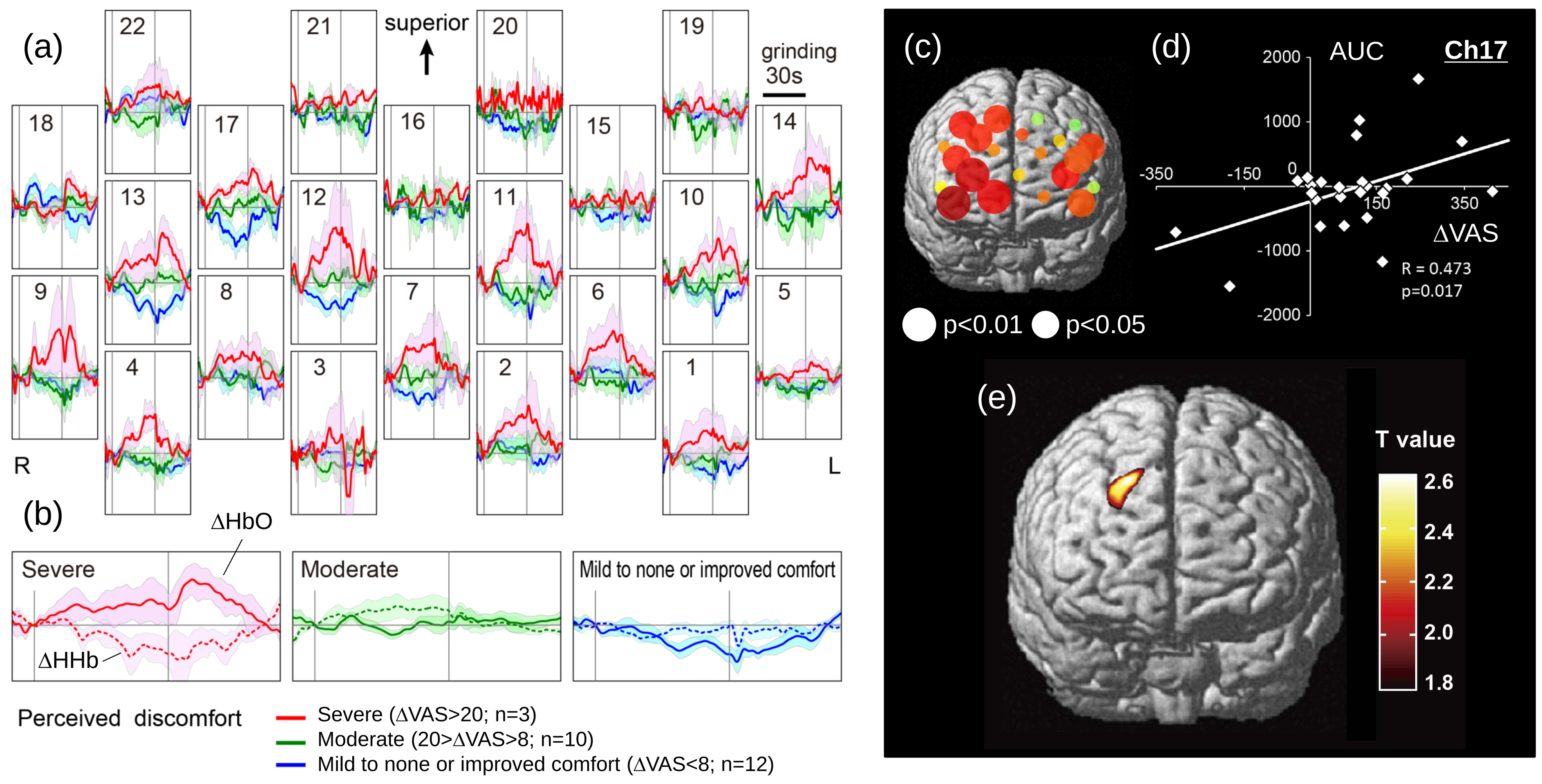

Figure 4. Comparison of the time-course of mean hemodynamic responses in participants with different severities of perceived discomfort (a, b) and results of channel-based correlation analysis between ΔHbO AUC responses and reported severities of perceived discomfort (ΔVAS: c,d) and GLM analysis (e). Only ΔHbO responses were shown in (a) for better visibility.

Exp. 2: ODS patients show unique HHb pattern

- ODS patients showed task-dependent increase of HHb signals, which was quite different from those of control patients without ODS (Fig. 5ab).
- This is due to neither motion artifact nor skin blood flow response, because fNIRS signals recorded with small inter-probe interval did not show such time courses (Fig. 5cd). All four prefrontal channels showed similar tendency.

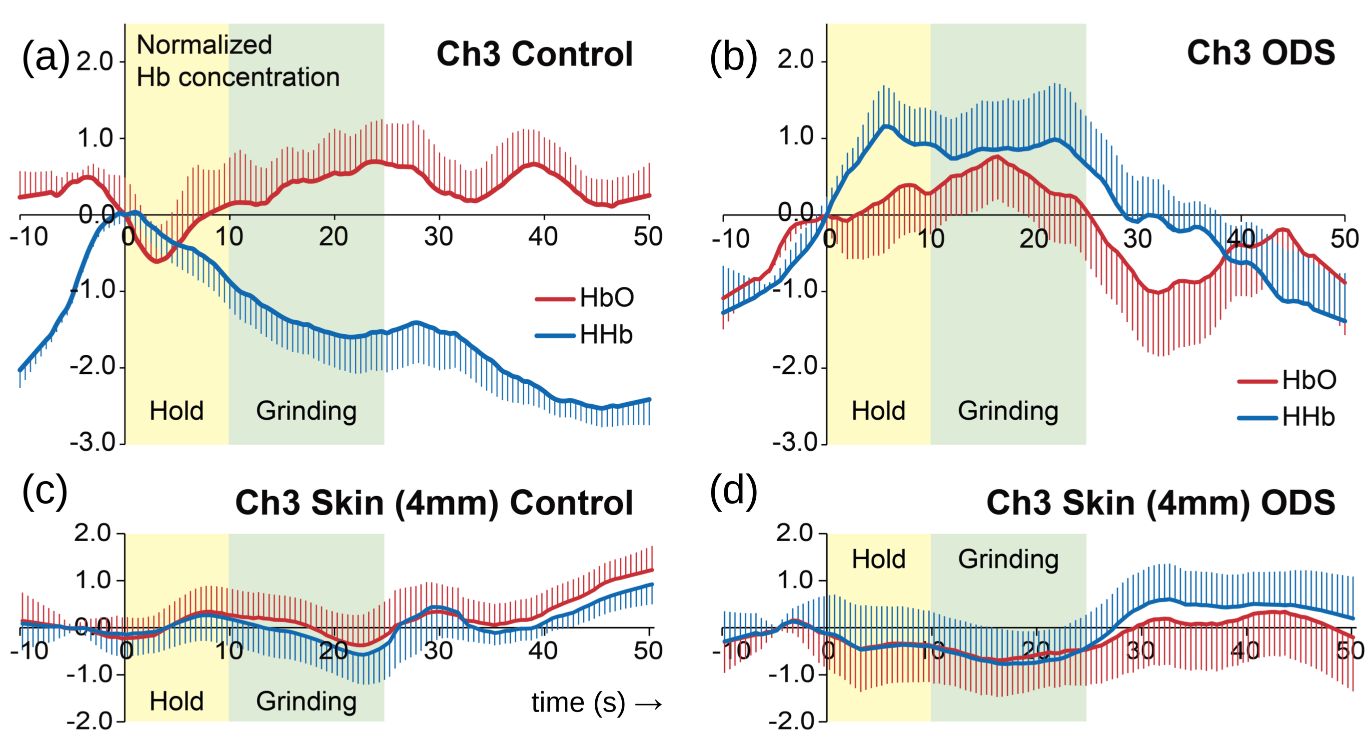

Figure 5. Comparison of grinding-related fNIRS signals in dental patients with (a,c) and without ODS (b,d). Despite the typical activation pattern found in control patients, ODS patients shows unique pattern of HHb increase. Skin blood flow was comparable between groups (c,d).

Discussion and Summary

- Prefrontal hemodynamic responses could be a possible marker to detect the subjective sense of occlusal discomfort in healthy volunteers.
- ODS patients showed specific HHb increase after they put metal strip into their mouth, even before they perform grinding (duration of "Hold" in Fig. 5b), which may reflect the excessive attention to the intraoral sensation. Study with larger number of ODS patients are necessary.

References

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