Clinical validation of Organic Plaque Simulation in Robot Toothbrushing Tests

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Objectives:

Robot testing of simulated plaque control is important for developing new toothbrushes and full mouth devices. Therefore, the aim was (i) to test a novel formulation of organic plaque simulating viscosity and adhesion of natural plaque and (ii) to estimate a valid accuracy of robot outcome in relation to clinical results of plaque control.

Material and Methods:

Clinical programme: After ethical approval (EK-UWH 552007), professional tooth cleaning and 3-day-plaque-regrowth was executed, and 22 calibrated subjects used in a Randomized Clinical Trial video-supported separated horizontal, and rotating, and vertical brushing movements for 20 s buccally/20 s lingually at 9 teeth 32 – 47 with force 3.5 N. Toothbrushes Dr. Best medium (TB1) and Interdent medium (TB2) (GlaxoSmithKline, Munich, Germany) were tested. Stained plaque was photographed and blind-coded at 18 planimetrical fields and at 10 risk fields using modified Navy-Plaque-Index (Lang et al. 2011) with PPI-Codes 0 (0%), 1(<50 %) and 2(>50 %) per each field.

Robot programme: The same brushes and techniques were tested. The cleaning outcome of simulated organic plaque in percentage per planimetrical field with Computer-assisted Planimetrical Plaque Assessment (APP) was blind-assessed with PPI. All clinical and robot data underwent statistical analysis by K-S-test, one-sample-t-test, Independent t-test of equality of means, W-M-W-U-Test of equality of medians and Agreement Rate AR of plaque removal.

Results:

Individual clinical plaque control pattern at two surfaces and two risk areas per tooth were well reproduced by robot brushing movements. The Agreement Rate of plaque removal by separated brushing movements at smooth surfaces was 85–100 % (TB1) and 89-99 % (TB2); at risk fields next to gum line 84-98 % (TB1) and 88-94 % (TB2). The single tooth analysis revealed best AR for teeth 42 (TB1 83-99 %), 42 (TB2 81-98 %) and 47 (TB2 75-98 %). Canines 43 exhibited the least AR 41 % for both brushes. All 24 tooth sites (buccally and lingually) and all risk areas exhibited in all 3 brushing movements with the 2 toothbrushes equal plaque control values (p = 0.05) or, alternatively, 21 out of 24 tooth sites showed equal values (most common p = 0.10).

Conclusions:

Robot toothbrushing with the formulation of organic plaque, simulating bio-physical parameters of natural plaque, is concordant with clinical plaque control at all teeth and all planimetrical areas. The clinically validated plaque simulation is recommended for complex dry and wet robot testing.

Test Material

Fig. 1-4: Stained clinical plaque after 3-day plaque regrowth (Fig.1); stained clinical plaque after brushing for 20 s with force 3.5 N (Fig.2); stained organic plaque simulation on KaVo teeth (Fig. 3); stained organic plaque simulation after robot brushing for 20 s with force 3.5 N (Fig. 4)
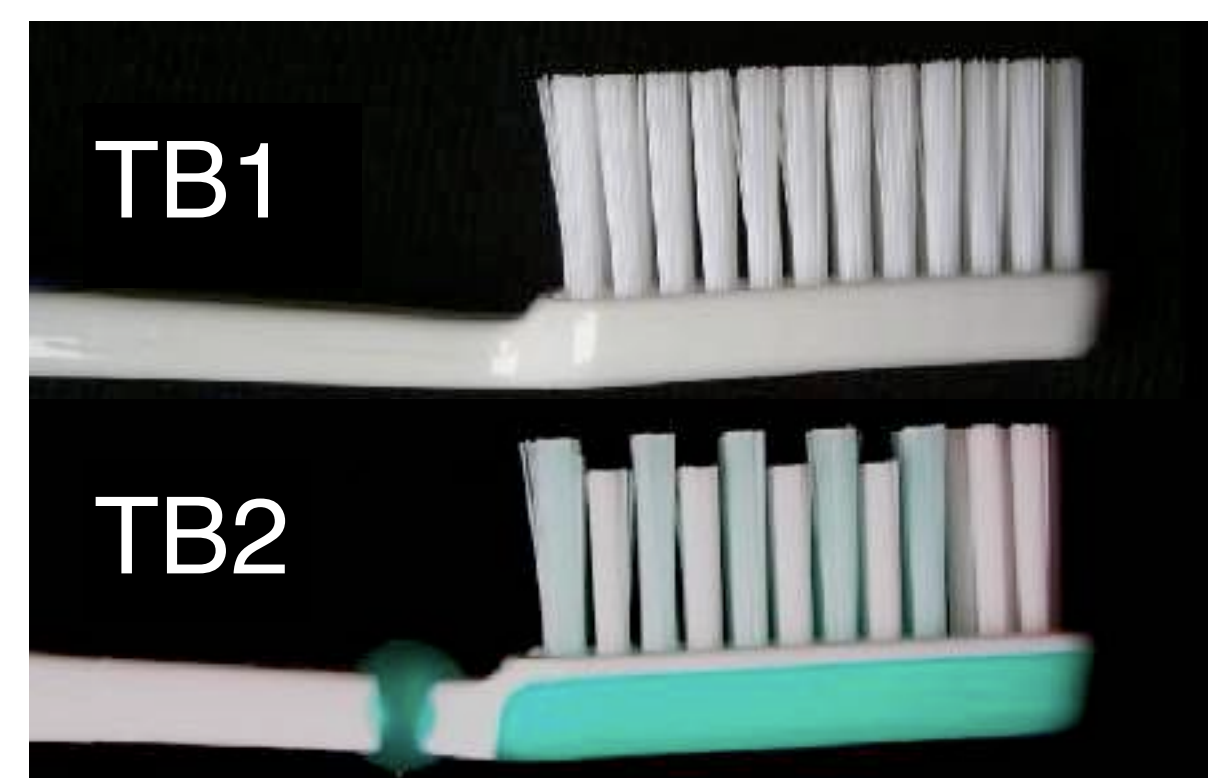
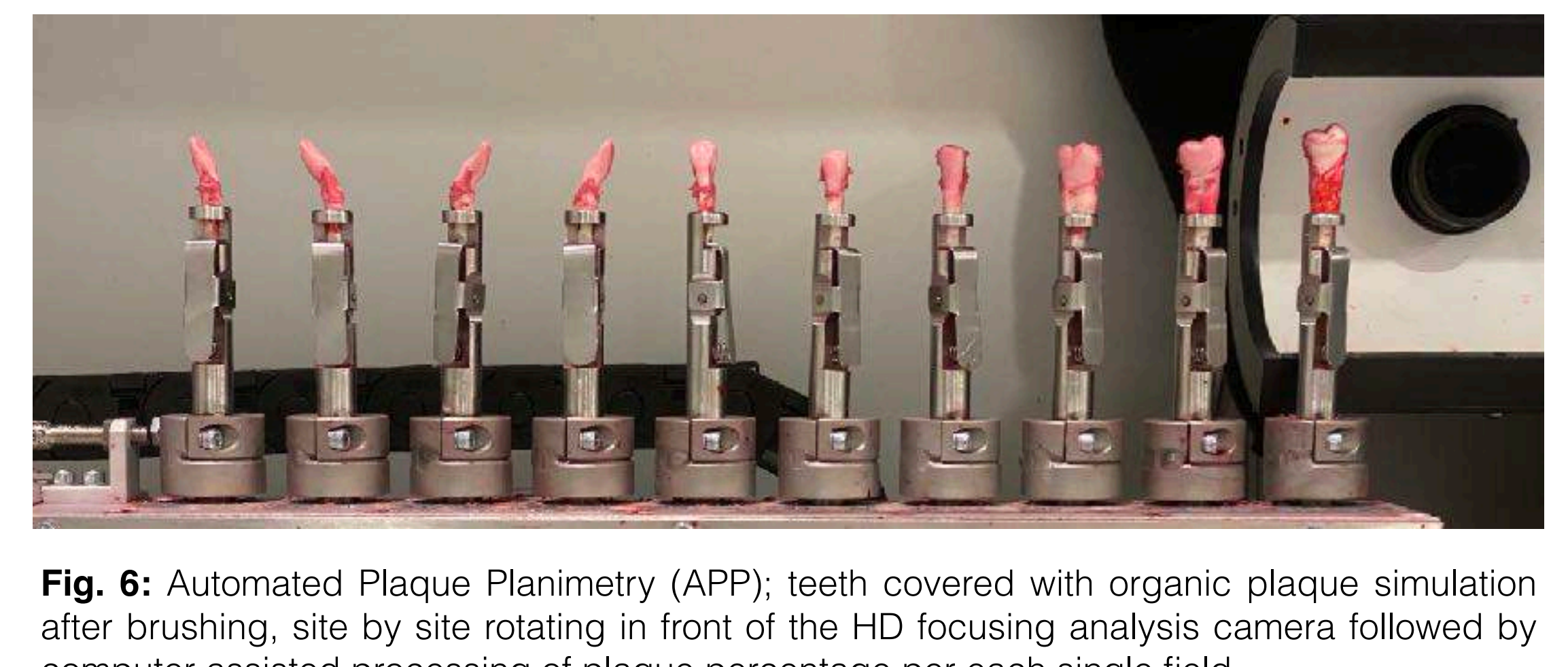Fig. 5: Toothbrushes Dr. Best Flat Cut medium (TB1) and Interdent medium (TB2)

Fig. 6: Automated Plaque Planimetry (APP); teeth covered with organic plaque simulation after brushing, site by site rotating in front of the HD focusing analysis camera followed by computer-assisted processing of plaque percentage per each single field
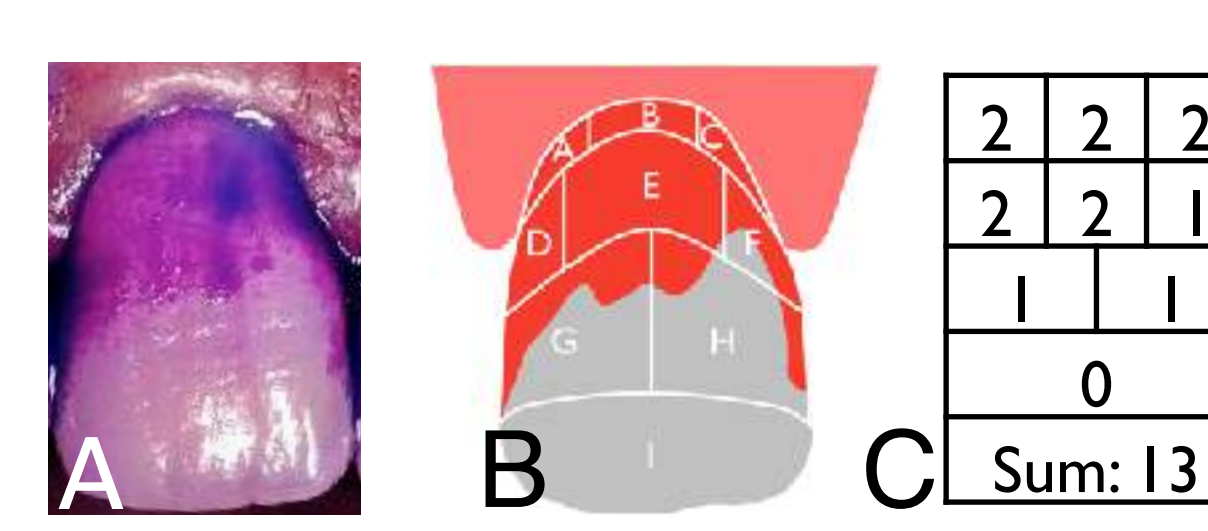
Fig. 7: Planimetrical fields at human teeth(A), clinical brushing outcome (B), Planimetrical Plaque Index PPI Scores (Lang et al. 2011) (C)
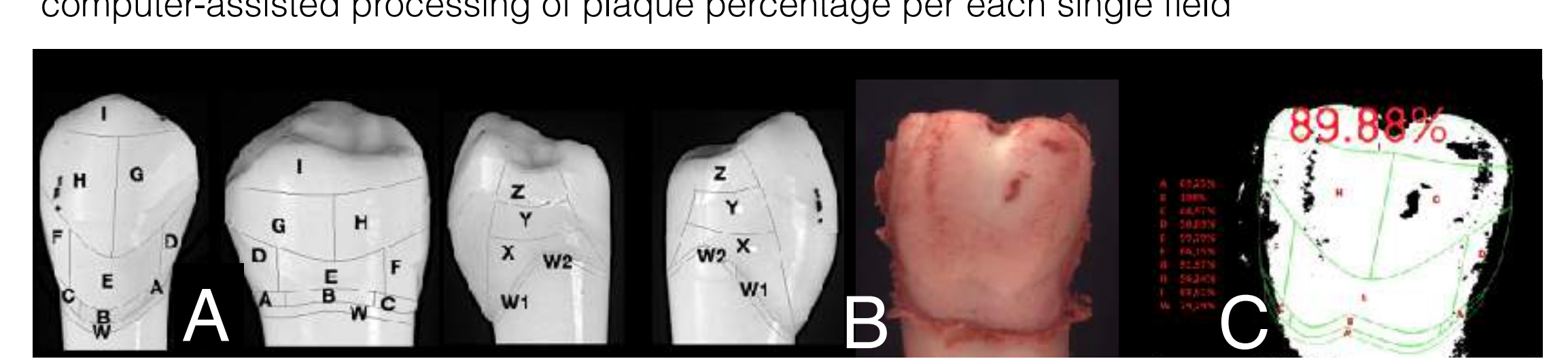
Fig. 8: Planimetrical fields at human teeth (A), in-vitro brushing outcome on molar tooth (B), Automated Planimetrical Plaque Assessment (APP) (C)
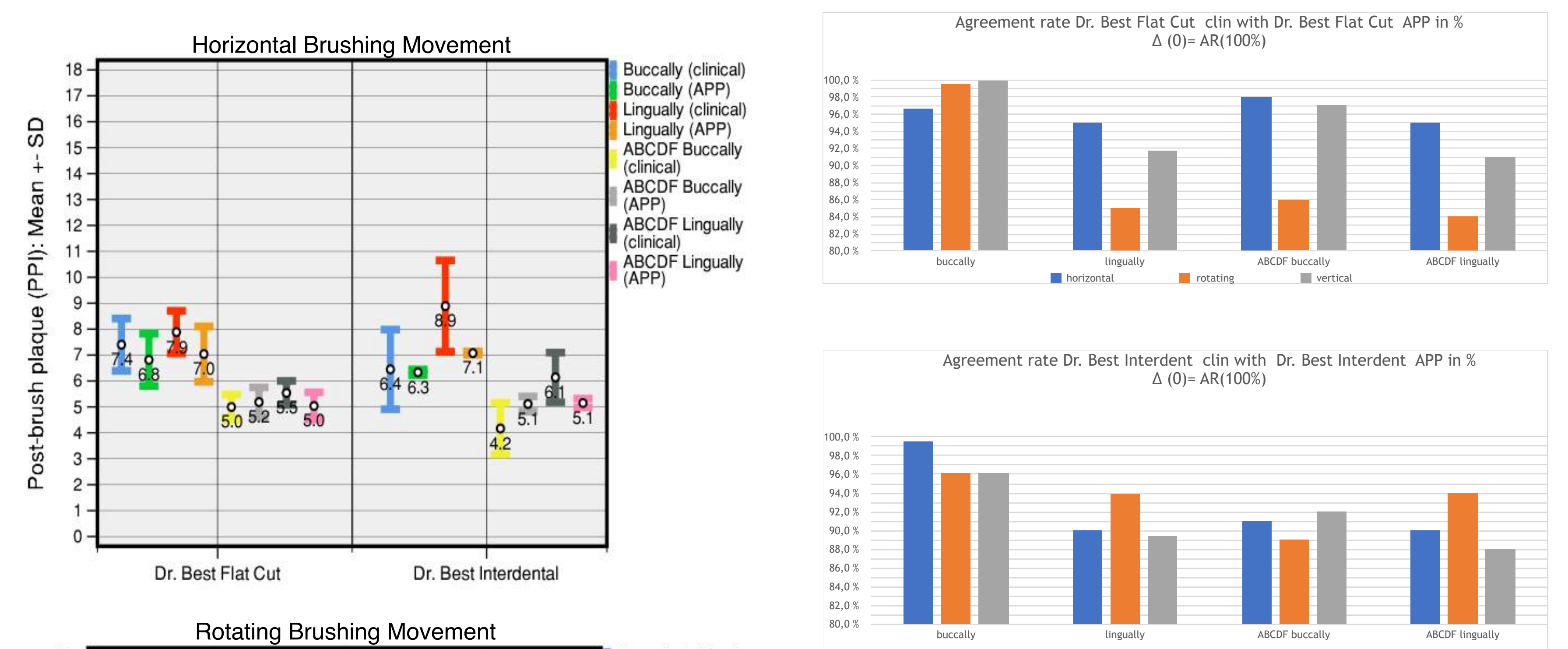
Fig. 9-11: Error bars of clinical and robot toothbrushing outcomes at smooth surfaces, interdental sites and risk areas next to the gum line (ABCDF)
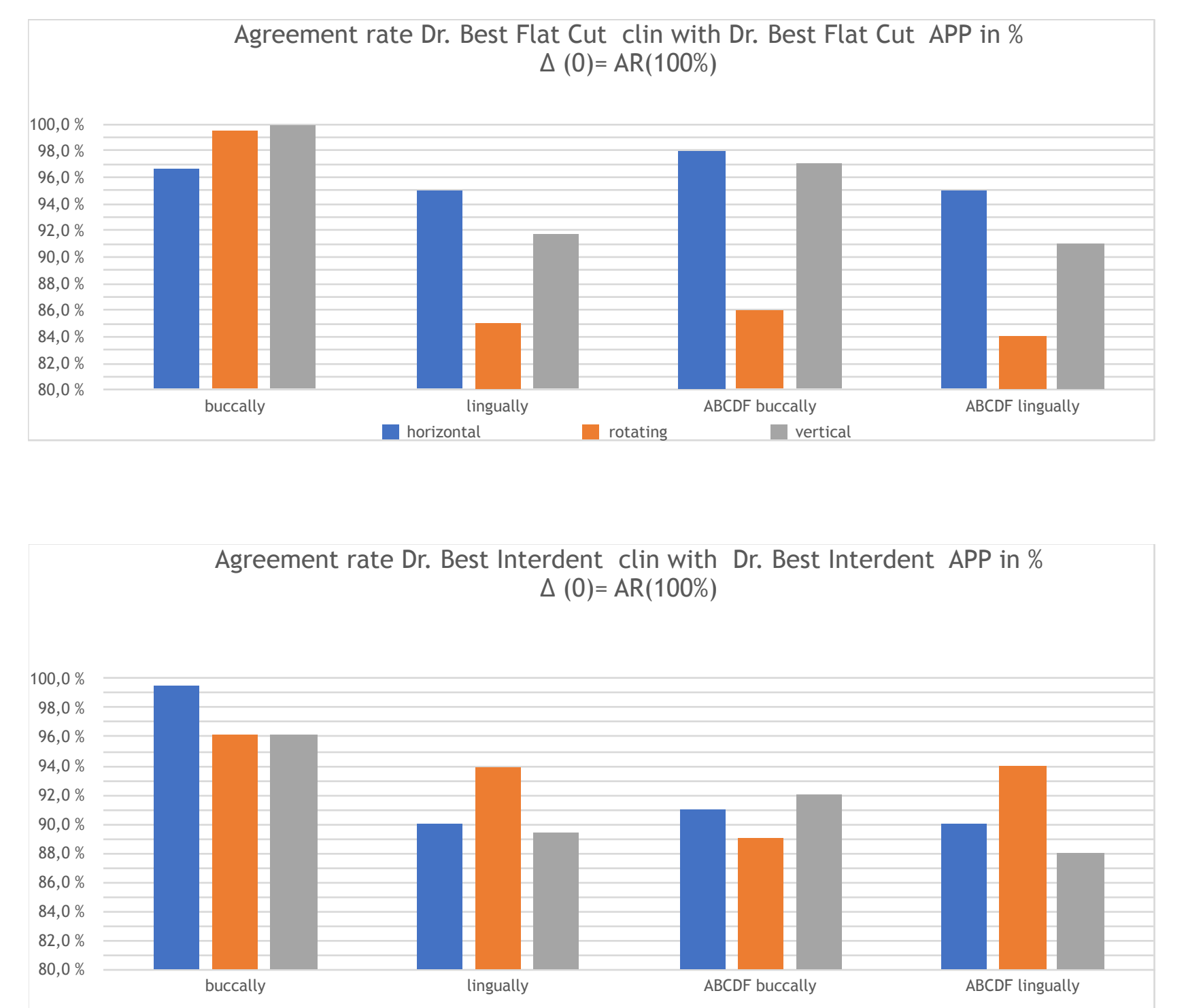
Fig. 12: The Agreement Rate is highest at buccal sites for both brushes, lowest at lingual sites for both brushes; horizontal brushing shows the best AR, followed by vertical brushing, and, last but not least by rotating brushing.

Tab. 1: Single tooth analysis: Examples of incisors (42), canines (43), and molars (46). Post-brush planimetrical plaque index (PPI), comparison of clinical and robot APP data per single teeth.

Tab. 2: Independent t-test for equality of means of plaque removal (assessed with PPI) between robot programme and clinical programme – separated by toothbrushes and brushing movements; test statistic of planimetric t-test (t), degrees of freedom (df), significance value (p), difference of means of observations between robot program and clinical program, standard error of the mean difference (se). The independent t-test of means demonstrates the equality of all plaque removal parameters

Tab. 3: Wilcoxon-Mann-Whitney-U-Test of equality of medians/rank sums of plaque removal (assessed with PPI) between robot program and clinical program – separated by toothbrushes and brushing movements, test statistic of non-parametric Mann-Whitney-Test (U), normalized test statistic (Z), significance value (p). The W-M-W-U-Test of means demonstrates the equality of all plaque removal parameters
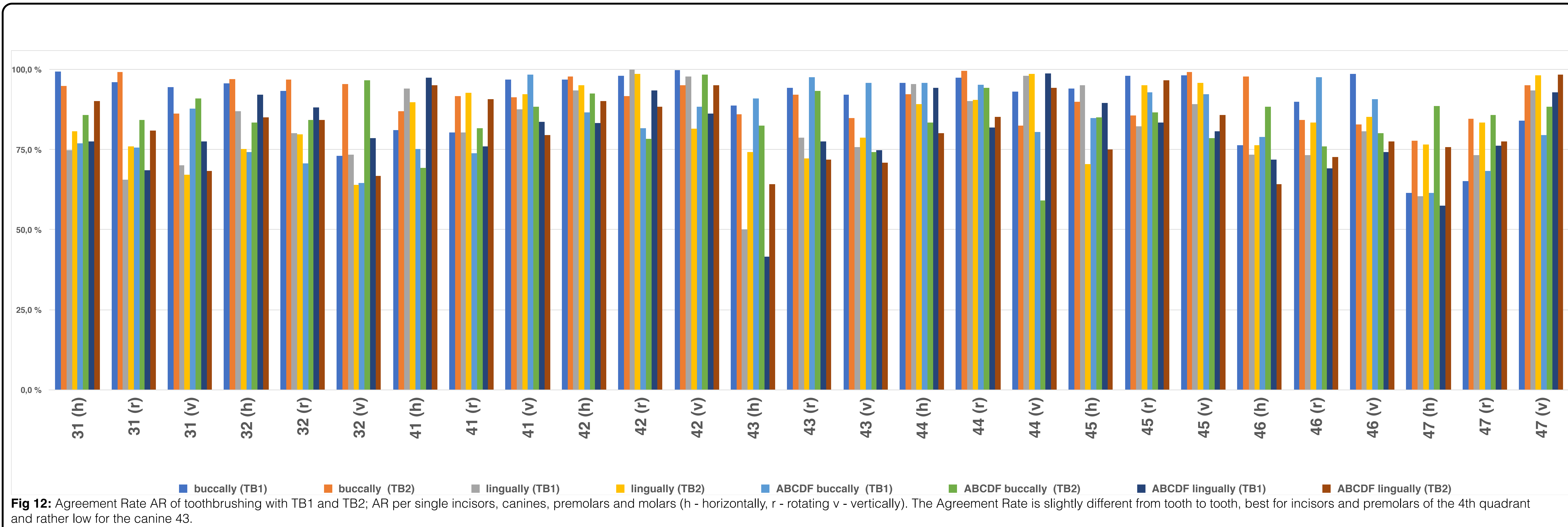
Fig 12: Agreement Rate AR of toothbrushing with TB1 and TB2; AR per single incisors, canines, premolars and molars (h – horizontally, r – rotating v - vertically. The Agreement Rate is slightly different from tooth to tooth, best for incisors and premolars of the 4th quadrant and rather low for the canine 43.