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ORIGINAL ARTICLE

Relationship between plaque score and video-monitored brushing performance after repeated instruction—a controlled, randomised clinical trial

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Abstract
Objectives Aim of this prospective, randomised, controlled clinical trial was to use the modified bass technique (MBT) and a specific brushing sequence to investigate whether two types of instruction methods lead to differences in plaque reduction and whether plaque reduction is related to technique adoption.
Methods Ninety-eight participants were randomly assigned to three groups: (1) control, no instruction; (2) verbal instruction by means of a leaflet; and (3) verbal instruction supported by demonstration, no leaflet. Brushing performance was video monitored. Plaque score (Turesky modified QHI (T-QHI)) was measured at baseline, afterwards participants received instructions. After 2 weeks, T-QHI was measured for a second time, and participants were re-instructed. After another 2 weeks, T-QHI was measured for a third time.
Results At baseline, T-QHI did not differ between groups ((1) 1.99±0.51, (2) 1.90±0.51, (3) 1.93±0.56). The second measurement revealed an improvement of T-QHI in the instructed groups and in the non-instructed control group ((1) 1.80±0.47, (2) 1.58±0.58, (3) 1.64±0.58; n.s. between groups); in the intervention groups, remotivation achieved no further improvement ((1) 1.72±0.48, (2) 1.52±0.58, (3) 1.50±0.69; n.s. between groups and compared to second measurement). Improvement of T-QHI was not related to proper performance of technique or brushing sequence. Those who fully adopted the brushing technique, the sequence or both did not have lower plaque scores.
Conclusion Technical performance and effectiveness were not linked.
Clinical relevance Within the study setting, the MBT was not effective in reducing plaque scores. The general recommendation of the MBT should be re-evaluated in further studies.

Keywords Clinical trial · Hawthorn effect · Instruction · Toothbrushing technique · Plaque score · Video monitoring

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Introduction

It is generally accepted that the reduction of plaque accumulation reduces or prevents the occurrence of oral diseases like caries, gingivitis and periodontitis. To reduce the accumulation of plaque, mechanical tooth cleaning is the mainstay [1]. Different devices and implements have been developed to achieve the best reduction in plaque, such as manual toothbrushes in various designs, powered toothbrushes with different modes of action and interdental cleaning devices like floss or interdental brushes. Although the volume of powered toothbrush sales has notably increased in recent years, the use of a manual toothbrush is still the primary method for the majority of the population; in long-term studies, no disadvantages of using a manual toothbrush compared with a powered toothbrush have been found [2]. The major goal of toothbrushing is to remove plaque effectively with a concomitant protection of the oral soft and hard tissues; this can be achieved by correctly practicing a brushing technique. Various techniques have been developed, including different combinations of movements, and many studies have investigated the efficacy of these brushing techniques [3–6] in combination with different toothbrushes (for a review, see Jepsen [7]). Overall, these studies have

shown that no technique is superior for plaque removal. Nevertheless, the modified bass technique (MBT) is often recommended [8], although it seems to be a difficult technique to learn because it consists of a complex combination of vertical, horizontal and rotary movements [9]. These motion sequences require dexterity and concentration. Another point for consideration is that to achieve best plaque reduction, a systematic order or sequence in which the teeth are brushed may help to ensure that no surface will be forgotten. However, such sequences are also often complex and require much attention (Fig. 1) [10].

Studies investigating the adoption of an instructed technique have mostly measured the success of technique adoption by means of changes in plaque levels [11–13]. However, these studies have not shown whether the technique was actually adopted after instruction, for example, by videotaping each participant's technique. However, plaque levels can be influenced by several factors extrinsic to the adoption of the technique, such as brushing pressure [14], brushing duration [15] or participation in the study itself (Hawthorne effect [16]). Regarding this last point, the inclusion of a non-instructed control group is mandatory; however, several studies have not included such control groups. To achieve the best technique adoption possible, different instruction methods for brushing techniques or sequences have been developed including verbal instruction by means of a leaflet, demonstration of the technique via a model or instructions with videos [12, 17, 18]. Because technique adoption has mostly been measured via changes in plaque scores, no conclusions can be made yet about the efficacy of the different instruction methods on actual adoption and performance of the instructed technique.

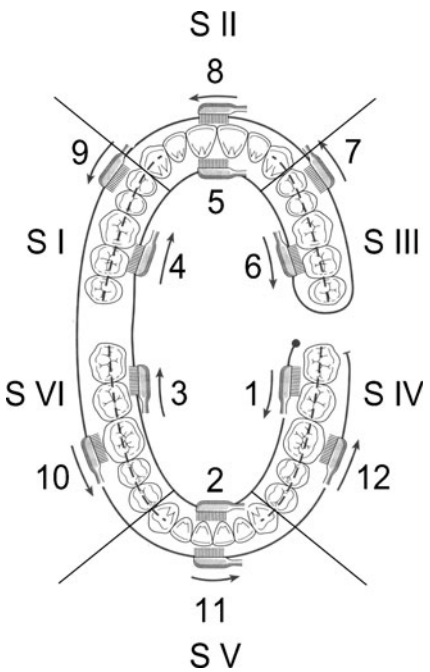

Fig. 1 This figure depicts the brushing sequence ([10] modified) for right-handers (a mirror-inverted scheme was used for left-handers). The *Arabic numbers* indicate the order of the brushing sequence and, accordingly, which brushing sequence point score can be recorded, if the respective position is reached in the right order. A higher score indicates that the participant performed the brushing sequence longer in the right order. The *Roman numerals* indicate the sextants in which the jaws were sectioned

In the present manuscript, results of a larger study are given, from which data about the adoption of an instructed technique after various instruction methods have already been published [9]. As to the knowledge of the authors, this study is the sole one, which investigated the adoption of a brushing technique and sequence by means of video recording. However, the best technique adoption is not helpful if it has no effect on plaque level or oral health. The aim of this part of data analysis of the larger study was to find out whether (I) the instruction of a brushing technique (MBT) and a brushing sequence by different methods led to a reduction in plaque levels and whether the reduction in plaque levels was related to the adoption of (II) the brushing technique and (III) the brushing sequence (investigated by video recording). Two different instructional methods were compared: verbal instruction using a leaflet and verbal instruction supported by a demonstration of the technique with a model but without a leaflet. Both instructed groups were compared with a non-instructed control group.

Participants, materials and methods

Participants

The study was conducted in the Dental Clinic, Department of Conservative and Preventive Dentistry at the University of Giessen. The study conformed to the Declaration of Helsinki and was performed in accordance with the guidelines of Good Clinical Practice. The research was approved by the local Ethical Committee (Ethik-Kommission des Fachbereiches Medizin der Justus-Liebig-Universität Giessen, application no. 05/05). All participants volunteered and were given oral and written information about the procedures and the purpose of the study. All of the participants gave informed consent.

The trial was planned as a prospective, single-centre, single-blind, three-cell study with an overall observation period of 5 weeks. Sample size calculation was performed with Cademo light 3.25 for Windows (BioMath GmbH, Gross Luesewitz, Germany). In a study with a comparable study population, a plaque score of 2.0±0.5 was measured after an over-night plaque accumulation. Brushing with a manual or powered toothbrush revealed a reduction to a score value of 1.2±0.5 [19]. Here, half of this reduction

(0.4) was defined as the clinical relevant difference. The calculation was performed as a multiple sampling test with two interventional against one control group. Under the assumption that the variance is 0.25, α=0.05 and β=0.2, a group size of 22 in the interventional groups was calculated. Therefore, under consideration of drop outs a sample size of 33 per group was planned [9]. Participants were students of the Justus-Liebig-University in Giessen who had no connections to dentistry or medicine. Participants were recruited by announcements in the local press and by notices on news boards.

A director of study was responsible for the duly realisation of the study. The clinical procedures, including the investigation, data evaluation, participant selection and recording and evaluation of the video films, were carried out by two investigators.

The inclusion criteria were: age of consent, dentition with a minimum of 24 teeth, and the regular use of a manual toothbrush. Exclusion criteria were: serious diseases, periodontitis, multiple recessions with an extent greater than one third of the root length, oral prostheses or appliances, medication with influence on plaque formation, allergies against dental materials, disabilities with influence on oral hygiene and habitual dental hygiene using the modified Bass technique.

Materials

The clinic provided each participant with an elmex® interX toothbrush (GABA International AG, Therwil, Switzerland) to be used during the study. The home dental care was carried out with the participant's own fluoridated toothpaste. No other oral hygiene products were allowed during the study, in particular those that impact plaque accumulation. Plaque was stained with a 0.5 % erythrosine solution. Professional tooth cleaning was performed with scalers (S204S7, SH6/77, Hu-Friedy Mfg. Co., Inc., Leimen, Germany), a rubber cup (Pro-Cup, art. no. 991/30, KerrHawe, Bioggio, Switzerland) and fluoridated polishing paste (Tri Fluor O Clean, art. no. 984, KerrHawe, Bioggio, Switzerland).

Procedure

For an overview of the procedures, see Fig. 2. The study comprised a total of four appointments for each participant. To establish the same baseline for each participant, plaque and supragingival calculus were professionally removed in the first appointment, but no oral hygiene instructions were given.

Videotaping and plaque scoring procedures were the same for all participants for all visits. Videotaping was performed through a mirror while participants habitually brushed their teeth before the first instruction at baseline (baseline filming), after the first instruction (post-instruction filming) and after the remotivation (post-remotivation filming). After toothbrushing, the success of brushing was measured via plaque score (baseline, T-QHI1; post-instruction, T-QHI2; post-remotivation, T-QHI3). The intention was to measure plaque removal that was achieved by brushing during videotaping; therefore, participants were asked to abstain from oral hygiene for at least 12 h before each appointment [13, 20].

Directly after videotaping and plaque scoring, instructions for the MBT and brushing sequence were given to the participants in the interventional groups (the leaflet instruction group and the demonstration group). For the instructions, a standardised text was used. In the leaflet instruction group, verbal instructions were given using a leaflet that contained the major steps of the MBT and the brushing sequence. In the demonstration group, verbal instructions were supported by a demonstration with a model, but no leaflet was used. Participants in both interventional groups were asked to practise the MBT and the brushing sequence at each toothbrushing during the training periods. In the control group, no instructions were given. Because oral hygiene instructions should not be withheld from the control group for ethical reasons, these participants received verbal instructions supported by a demonstration during their last visit after the last videotaping session (post-remotivation filming).

Evaluation criteria

For the measurements of plaque levels and of the adoption of brushing technique, jaws were divided into sextants (Fig. 1).

The plaque score was measured with the Turesky modified Quigley–Hein plaque index (T-QHI [21, 22]) after staining the plaque with an erythrosine solution. The T-QHI score was evaluated on two surfaces (buccal and oral) of all teeth. Plaque scores were calculated per sextant and, additionally, as an overall T-QHI score, for each participant.

The adoption of brushing technique was recorded as previously described in detail [9] and was measured per sextant and within each sextant per side (vestibular/oral) using the following scale:

- "Technique score 1: "technique not adopted" (inadequate back and forth movement; incorrect wiping out; no right angle between the tooth surface and toothbrush)
- Technique score 2: "technique partially adopted" (either the back and forth movement or the wiping out was correctly performed)
- Technique score 3: "technique totally adopted" (the horizontal as well as the vertical movements were correctly performed in terms of sequence and direction; the angle between tooth and toothbrush was correct)" [9]

The mean adoption score was calculated for each participant.

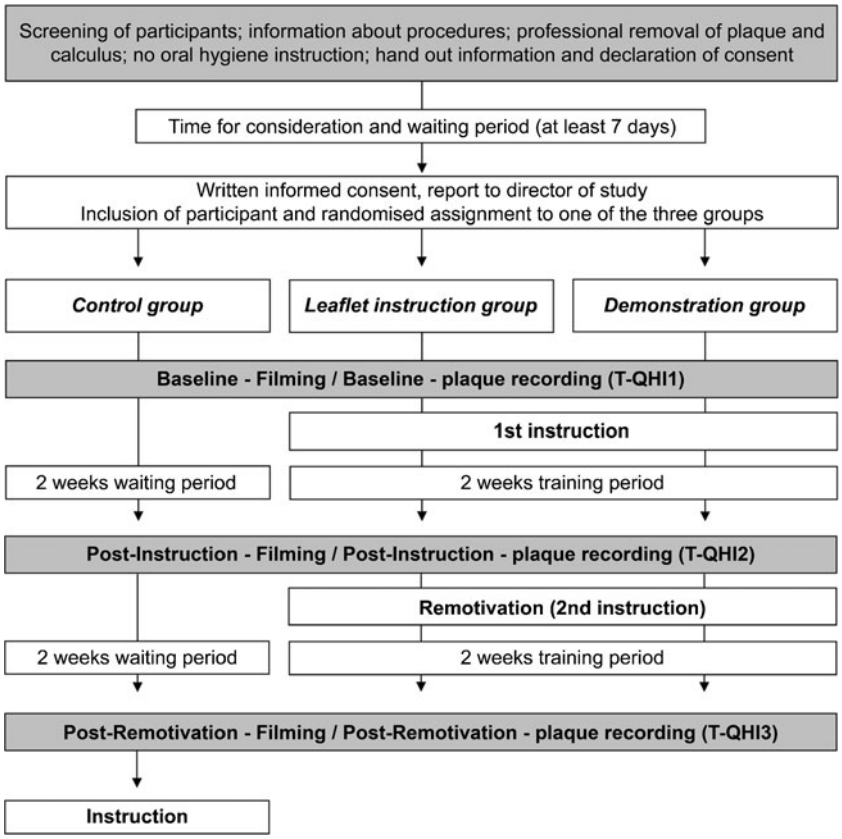

Fig. 2 Flow-chart of the study procedures

To measure whether the brushing sequence had been adopted, a point score from 0 to 16 was given [9], depending on whether each position was reached in the correct sequence. As for the measurement of plaque levels, the occlusal surfaces were of minor relevance so only the scores for the smooth surfaces (scores between 0 and 12) were analysed (Fig. 1).

Investigators were carefully trained and calibrated. One investigator (Investigator 1) carried out the measurement of the plaque levels, the tooth cleaning and the instruction. The second investigator (Investigator 2) was responsible for recording and evaluating the videos. Investigator 2 was unaware of the group classification of the participants; therefore, the video evaluation was performed blind.

For calibration, Investigator 1 was trained in plaque staining and measurement. The training for evaluating plaque level measurement was performed by means of photos depicting the different plaque levels. The multiple measurements of plaque levels revealed an intra-examiner kappa value of 0.81. The same photos were used for plaque measurement throughout the entire study to avoid drifting between plaque levels. This investigator was also intensively trained in instruction of participants in role plays and the study director periodically attended the participants' instruction sessions, to check consistency. For calibration of video assessment, investigator 2 evaluated three films ten times for technique and brushing sequence. Reproducibility was ±0.09 for the technique score. The agreement between the ten evaluations of each of the three films in assessing the brushing sequence was 100 %.

Randomisation and statistical analysis

Randomisation was performed using computer-generated random numbers that were then allocated to one of the instructional groups. The numbers were sealed in opaque envelopes and opened by Investigator 1 at each participant's first appointment.

Statistics were performed at the end of the study; no interim analysis was planned or performed. Analyses were conducted using the Statistical Package for Social Sciences for Windows (SPSS 15.0, Chicago, IL, USA). For group comparisons of the mean T-QHI scores, an analysis of variance was conducted (ANOVA with Tukey's post hoc.) For the comparisons of different video recordings within one group, *t* tests for paired samples were used. The significance level was set to 0.05.

Results

Ninety-eight participants were included in the study, from which 33 were each randomly assigned to the control and the demonstration groups. Thirty-two participants were

assigned to the leaflet instruction group. The mean age of participants was 26.6±4.5 years.

After the second visit, four participants were excluded because they already knew the MBT (control group, two and leaflet instruction group, two). Ten participants failed to return for the third visit (control group, three; leaflet instruction group, three; and demonstration group, four). Another seven participants did not return to the fourth visit (control group, one; leaflet instruction group, three; demonstration group, three). The final number of participants in the study was 77 (control group, 27; leaflet instruction group, 24; and demonstration group, 26).

Plaque score depending on instruction mode

At baseline (T-QHI1), the T-QHI did not differ significantly between groups (control group, 1.99±0.51; leaflet instruction group, 1.90±0.51; demonstration group, 1.93±0.56; n.s.). The post-instruction plaque measurement (T-QHI2) revealed a significant reduction of plaque scores in all groups (compared with T-QHI1: control group, $p \leq 0.05$; leaflet instruction group and demonstration group, $p \leq 0.001$); however, no differences were found among the three groups (control group, 1.80±0.47; leaflet instruction group, 1.58±0.58; demonstration group, 1.64±0.58; all comparisons n.s.). The post-remotivation plaque measurement (T-QHI3) showed no further reduction of plaque levels (compared with T-QHI2, n.s. in all groups), but the initial improvements in plaque reduction were maintained (compared with T-QHI1, $p \leq 0.01$ for all groups). At T-QHI3, no differences between groups were found (control group, 1.72±0.48; leaflet instruction group, 1.52±0.58; demonstration group, 1.50±0.69; all comparisons n.s.). The results per sextant and measurement point are displayed in Fig. 3.

Relation between the T-QHI scores and the adoption of the technique and/or the sequence, independent of the instruction mode

The adoptions of brushing technique and sequence have already been described in detail [9].

A descriptive analysis was performed, investigating the relationship between the adoptions of the technique or the sequence and the reduction of plaque score independent of the instruction mode (Table 1). The percentage of participants who thoroughly adopted the brushing technique (technique score, 3) was 30 % after the first instruction and 46 % after the remotivation (second instruction). After both the first instruction and the remotivation, 24 % were fully performing the technique. Regarding brushing sequence, 40 % obtained a score of 12 after the first instruction, and this percentage increased to 65 % after the remotivation (second instruction). However, only 38 % obtained a score of 12 both after the first instruction and after the remotivation. Two major points can be observed from Table 1; first, the individual improvements in brushing performance and in adopting the brushing sequence were not related to individual improvement in T-QHI. The participants who completely adopted the brushing technique and/or the brushing sequence showed T-QHI scores comparable to the mean T-QHI values for all instructed participants, independent of the mode of instruction. Second, even if the number of participants who adopted the technique or the sequence increased from post-instruction videotaping to post-remotivation videotaping, the intersection of participants who adopted the technique at both timepoints was much smaller, indicating that different people adopted the technique or the sequence at different time points.

Discussion

In the present controlled, randomised clinical trial, the adoption of the MBT in addition to a brushing sequence was investigated by videotaping. The awareness of being filmed may impact the presentation of oral hygiene habits; however, previous studies have shown that filming participants through a mirror has only a negligible impact on their behaviours [23, 24]. The study group consisted of students because the aim was to examine subjects with good learning ability and dexterity. Thus, it was not surprising that the baseline T-QHI value was relatively low. Although the values were in the lower range of the T-QHI scores for published studies investigating oral hygiene improvement [7, 25], they were also in accordance with the levels observed in several studies (e.g., Angerholm [26] and van Swol et al. [27]). The MBT is assumed to be particularly effective in the cervical area, which is represented by scores 1 and 2 of the T-QHI, making this group particularly suitable for the goals for the present study. The Turesky modified Quigley and Hein index [21, 22] for plaque scoring was chosen because it is often used in clinical studies and has the advantages of being easy to learn and having good reproducibility. The T-QHI is named as the "best alternative for the time-consuming planimetrical plaque analysis" in studies "for the evaluation of antiplaque procedures such as toothbrushing and chemical antiplaque agents" [28]. Furthermore, it is described that "the high number of categories", e.g. of the modified Navy index "results in a decreased reproducibility" [28]. Even though the T-QHI does not explicitly measure the proximal areas, this index is comparable to the more complex and detailed Rustogi modified Navy index in its sensitivity for differentiating toothbrush efficacy [29] and has the advantage that it measures the cervical region, those areas in which the MBT should be particular effective. A number of published studies have measured the success of toothbrushing by calculating the

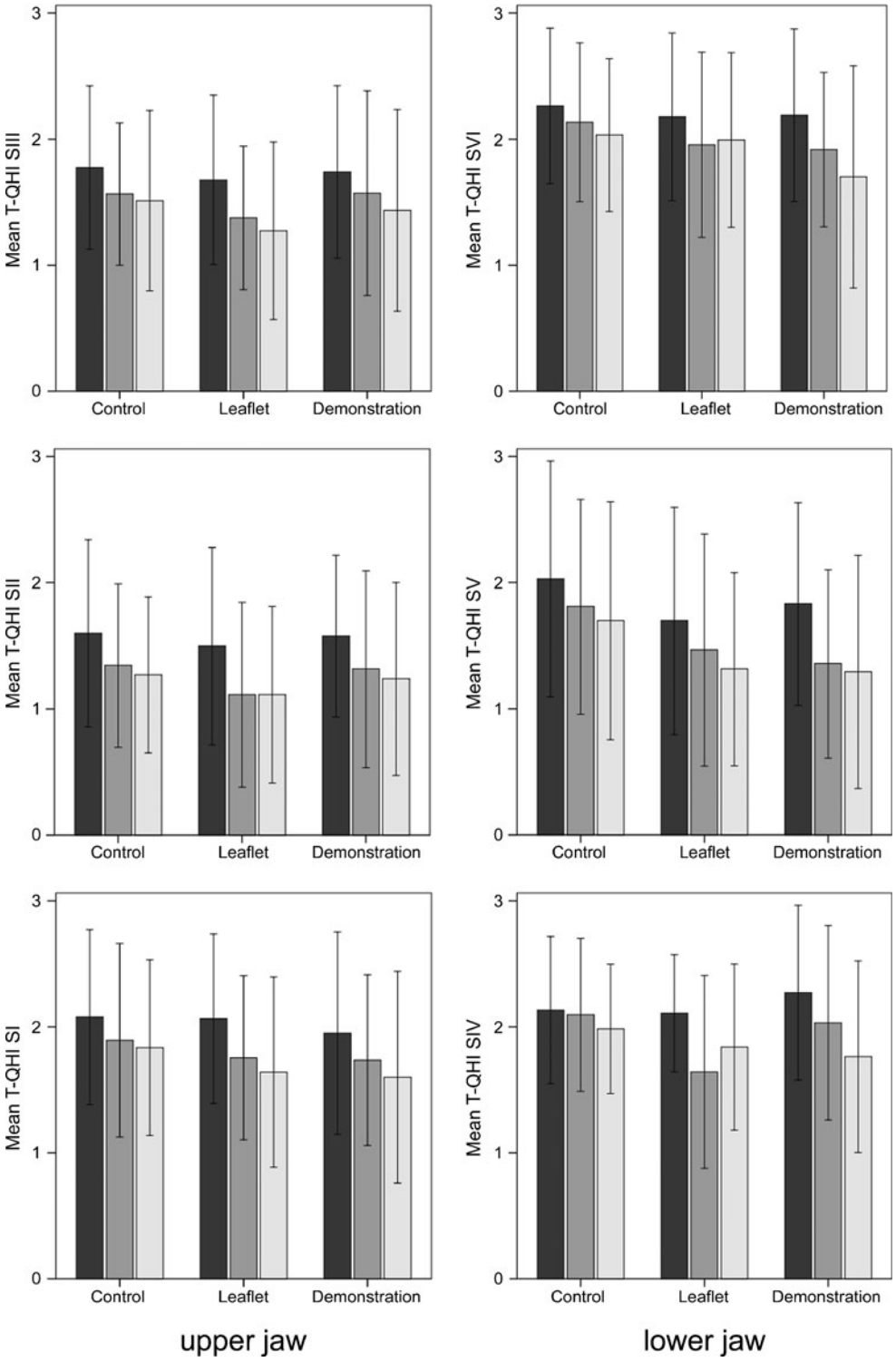

Fig. 3 The mean T-QHI values and standard deviations for each sextant by group and by measurement point (*black column*, baseline (*T-QHI1*); *medium grey column*, post-instruction plaque measurement (*T-QHI2*); *light grey column*, post-remotivation plaque measurement (*T-QHI3*))

difference between pre- and post-brushing plaque scores (e.g. [12, 14, 20, 30]). In the present study the participants were videotaped through a mirror while brushing their teeth; however, the disclosure of plaque with a revelator would have provided feedback to the participants, most likely influencing their individual brushing behaviours. Such feedback can also be given during the pre-brushing scoring if participants are aware of their own plaque scores, which is quite conceivable for the examined group. Therefore, only a post-brushing measurement was performed.

Only minor differences between the leaflet instruction group, the demonstration group and the control group were detected. In the control group, an approximately 20 % reduction in the plaque score was found, which was comparable to

Table 1 The mean T-QHI scores (±standard deviation) of participants who received instruction (independent of the instruction method), of participants who totally adopted the technique (independent of the instruction method), of participants who reached a score of at least 12 for the brushing sequence (independent of the instruction method and meaning that all smooth surfaces were brushed in the correct order) and of participants who achieved the goals for both technique and sequence (descriptive presentation of the results)

Mean T-QHI of	All instructed participants	Mean T-QHI of those participants, who totally adopted the technique			Mean T-QHI of those participants, who adopted the sequence up to score 12			Mean T-QHI of those participants, who totally adopted the technique and the sequence up to score 12		
		After first instruction *N*=17	After remotivation *N*=23	After both the first instruction and remotivation *N*=12	After first instruction *N*=20	After remotivation *N*=26	After both the first instruction and remotivation *N*=15	After first instruction *N*=11	After remotivation *N*=12	After both the first instruction and remotivation *N*=6
Baseline (T-QHI1)	1.91±0.53 N=63	1.78±0.53	1.80±0.51	1.78±0.55	1.99±0.42	2.01±0.46	1.99±0.37	1.92±0.45	1.93±0.48	1.88±0.34
Post-instruction (T-QHI2)	1.61±0.58 N=56	1.50±0.44		1.58±0.47	1.73±0.52		1.76±0.58	1.65±0.40		1.66±0.51
Post-remotivation (T-QHI3)	1.51±0.64 N=50		1.54±0.62	1.48±0.60		1.69±0.66	1.69±0.60		1.81±0.64	1.73±0.60

the measured values in the instructed groups. On the one hand, these results are probably due to the Hawthorn effect, which can account for up to 25 % of the improvement in a parameter under investigation [16, 31]. On the other hand, prolonged brushing, as was observed in the present study [9], can also lead to an increase in plaque removal [15, 32].

Regarding the instructed groups, the first instruction caused 19 % of participants to fully adopt the MBT in the leaflet instruction group and 41 % in the demonstration group. The remotivation improved brushing performance to 25 % full adoption in the leaflet instruction group and 62 % in the demonstration group [9]. Although the demonstration of the brushing technique was superior to the leaflet instructions in terms of the percentage of participants who adopted the technique, and though the remotivation led to a further increase in technique adoption, the T-QHI values were the same in both groups at each time of assessment both in the total T-QHI value and in the T-QHI values per sextant (Fig. 3). This finding is in clear agreement with other studies showing neither differences in plaque values between differently instructed groups [33] nor an improvement in plaque reduction due to a remotivation compared with a control group that has not been remotivated [34]. Other studies have shown the superiority of visually based instruction methods over verbally based instructions [11, 12]. However, powered toothbrushes were used in these two studies, and thus, the findings cannot be directly compared with the results of the present study.

Regarding the differences between the sextants, the T-QHI values in the second and fifth sextants were somewhat lower than in the other sextants. This result is consistent with Renton-Harper et al. [12], who showed that plaque reduction after instruction is higher on the anterior teeth than on the posterior teeth. The same applies for the upper and lower teeth; the T-QHI values were worse for the lower than for the upper jaw, in both the present and in the cited study [12]. It is mostly said that the right side of the jaw is more difficult to brush for a person who is right-handed and vice versa for left-handers. This assumption was in tendency confirmed by the plaque values of the first and the third sextants (upper jaw), although the differences between the sextants were small. For the lower jaw, this could not be confirmed.

The adoption of a brushing technique (or sequence) itself and its relationship with plaque score has not yet been investigated. Even if differences in technique adoption and sequence were found depending on the mode of instruction used [9], it is of major interest, whether any adoption of technique or sequence is related to an improvement of plaque removal, independent of the mode of instruction. Therefore, all participants who completely adopted the technique achieved a sequence score of 12 or higher (meaning that at least all smooth surfaces were brushed in the correct order), or reached the goals for both technique and sequence

after the first instruction, after the remotivation, or after both, have been subsumed. The T-QHI scores of these subsumed groups have been compared with the mean T-QHI score for all instructed participants (Table 1). Interestingly, there was no difference in the improvement in T-QHI values between those who completely adopted the trained parameter and those who were instructed. The participants who completely adopted the technique showed slightly lower T-QHI values at baseline and after both sets of instructions. The absolute reduction in the T-QHI values, however, was similar. Nevertheless, participants who completely adopted the technique and the sequence after both instructions tended to score below the mean. Therefore, adoption of the technique and the sequence are not related to a reduction in plaque score. It is quite possible that the previous brushing technique, which is normally performed automatically and is not controlled, is still present in the information processing systems of the brain [35]. Changing habits and automatic processes is quite difficult [35] and requires consistent training to fully adopt the new movements [36]. Therefore, it is possible that although the new technique has been adopted, it is still not in long-term memory and requires active control by the brain and a great deal of attention. It is known that two controlled process (active control of the correct technique and active control of plaque removal) cannot be performed at the same time [36]. Hence, an automatically performed technique might be more effective in plaque reduction because more attention can be channelled towards sufficient plaque removal. Admittedly, a contrary phenomenon may also occur. If the more complex brushing technique (MBT) is committed to long-term memory, it could be that precisely performed movements become more and more imprecise in the routine if the training was not adequate. Adequate training means the regular performance of controlled movements [35], under supervision if possible. Complex techniques, such as the MBT, most likely require very accurate performance of the movements to achieve sufficient plaque removal. However, both theories remain speculative at this point. In general, there is a lack of studies investigating the psychological underpinnings of learning new oral hygiene skills [37]. Therefore, the considerations discussed here should be analysed in controlled, clinical, long-term studies.

In conclusion, within the setting of the study, the MBT was not effective in reducing plaque scores; technical performance and effectiveness were not linked. As a consequence, the general recommendation of the MBT should be re-evaluated in further studies.

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Conflict of interest The authors declare that they have no conflict of interest.

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