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ORIGINAL ARTICLE

Tooth brushing habits in uninstructed adults—frequency, technique, duration and force

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Abstract Professional recommendations for individual oral hygiene mostly include tooth brushing at least twice daily for 2–3 min with gentle force using the Bass technique or modifications of it. This study evaluated whether habitual tooth brushing actually meets these standards. Uninstructed adults (n=103; mean age 31±6 years; 61 female, 42 male) with habitual manual tooth brushing were given a self-administered questionnaire about the frequency of brushing and a computer system recorded their brushing technique, duration and force. The majority (79.6%) of participants brushed twice daily. The mean brushing duration was 96.6±36.0 s, the mean brushing force was 2.3±0.7 N (max. 4.1 N), and no significant differences were found for quadrants. Most subjects (73.8%) brushed with circling, 8.7% with horizontal/scrubbing, 13.6% with horizontal/circling and 3.9% with vertical/sweeping movements. Modified Bass technique was not observed. When appropriate brushing habits were defined as brushing at least twice daily for 120 s with a brushing force of less than 3 N and with circling or vertical sweeping movements, only 25.2% of the participants fulfilled all criteria, emphasising the ongoing need for oral hygiene education.

Keywords Toothbrushing · Force · Duration · Frequency · Technique

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Introduction

Tooth brushing is essential for removal of plaque and debris in order to contribute to good dental and periodontal health. Most people, however, find it difficult to clean their teeth sufficiently, and the daily experience in dental practice is that patients exhibit plaque even though they reportedly engage in oral hygiene.

It is therefore not merely the attempt to clean the teeth, but rather the technique applied, the duration of brushing and physical factors such as the brushing force that affect the efficiency of plaque removal. The American Dental Association recommends brushing the teeth twice a day with gentle force and with circling or sweeping movements [2], but the modified Bass technique is also often recommended. Thorough brushing of the teeth should also last at least 2 min. These recommendations appear to be generally accepted and have been communicated for decades in the mass media, in public dental health education programmes and in the education of dental health professionals.

Over-vigorous oral hygiene habits, however, are thought to damage oral soft tissues and may cause dental hard tissue loss [23]. Tooth brushing is considered an aetiological factor for wedge shape defects [3] and has raised particular interest in the field of dental erosion, where tooth brushing abrasion is considered a significant co-factor for tooth surface loss [1, 10].

Oral hygiene education is not only knowledge transfer, but must consider current habits and personal skills. There is a large body of literature regarding the performance of oral hygiene measured by levels of dental plaque [7, 24], what actually occurs in real life, however, may considerably vary and is not well known. Little information is available about specific factors of the everyday oral hygiene habits

that are duration of tooth brushing [11, 13], habitual brushing force [6, 8] and the individual tooth brushing technique [20], the majority of these studies being published more than a decade ago. In addition, most publications have studied only one aspect of tooth brushing habits or used questionnaires rather than clinical observations or video recordings.

This study therefore gathered information about the current state of everyday tooth brushing habits in adults. Relevant factors included were brushing frequency, technique, duration and force as determined by a self-administered questionnaire, video recordings and computerised force recording.

Subjects, materials and methods

The study was performed according to the guidelines of Good Clinical Practice and was approved by the local Ethical Committee (No. 102/01; Ethik-Kommission des Fachbereichs Medizin der Justus-Liebig-Universität Giessen). One hundred three subjects participated, who reported that they had received no oral hygiene instructions in the past. Of these subjects, 61 were female and 42 were male, and the mean age was 31±6 (SD) years (46.6% 20–30 years old, 53.4% >30–50 years old). The group of subjects included out-patients of one author (S.P.) who worked in a dental practice.

Inclusion criteria were informed consent, good general health (especially no handicaps with respect to motor abilities), age between 20 and 55 years, habitual use of a manual tooth brush and less than four teeth missing. Exclusion criteria were dental or medical education (e.g. dental nurses/students, dentists), removable dentures or orthodontic devices, recent oral hygiene instruction and participation in oral hygiene programs.

A self-administered questionnaire was used to obtain data about frequency of brushing; brushing habits were recorded on video. Participants were aware of the recording but were unobserved during brushing sitting in front of a mirror with an integrated video camera. They used their own habitual tooth brush, which was connected to strain gauges and calibrated directly before recording. They were asked first to perform their habitual daily tooth brushing, and then to repeat their habitual brushing quadrant-wise as directed by an instruction sheet. Brushing time (s) and brushing technique (modified Bass technique, circling, horizontal/scrubbing, horizontal/circling, vertical/sweeping) were obtained, the mean and maximum brushing force (N) was determined for each individual (overall and additionally for each quadrant).

The recording system consisted of a mirror with an integrated video camera (FlyCam Ultra II, LifeView, USA), a custom-made sterilisable connection device for manual tooth brushes and special software. The brushes were firmly connected with a fitting attached to a device with two integrated strain gauges; these translated the flexing of the brush during use into different voltages. To relate signals to forces, calibration was performed directly before brushing by hanging standardised weights at the mid-point of the head of each individual toothbrush (range 0–10 N). Special software was programmed for data acquisition and transfer to Microsoft Excel software. Brushing force and time data were transferred simultaneously to the same data file. On the video film, a time scale was permanently visible so that respective brushing sequences could be easily identified.

Intra-examiner reproducibility was excellent; repeated assessment of 10 videos revealed a kappa value of 1 ($p \leq 0.001$) for classification of brushing technique. No significant differences were found for brushing force and duration values.

To evaluate the influence of the measuring device, 10 participants were asked to repeat the brushing sequence with and without the device; both trials were recorded on video. All subjects perfectly reproduced their brushing habits. To evaluate the reproducibility of the entire procedure, 10 participants repeated the video session after 10 days; these data are presented in Table 1.

Statistics

Statistical procedures were performed with Statistical Package for Social Sciences software (SPSS 10.0; SPSS

Table 1 Reproducibility of brushing time (s) and brushing force (N) given as mean±standard deviation

	1. Brushing procedure (n=10)	2. Brushing procedure (n=10)
Duration	109.5±52.9	103.6±38.6
Overall brushing force		
Mean brushing force	2.4±0.8	2.5±0.9
Max. brushing force	5.5±1.9	5.8±1.8
1st quadrant		
Mean brushing force	2.1±1.0	2.4±0.9
Max. brushing force	3.4±1.3	4.0±1.4
2nd quadrant		
Mean brushing force	2.4±1.0	2.4±0.9
Max. brushing force	3.7±1.4	3.8±1.4
3rd quadrant		
Mean brushing force	2.1±0.9	2.2±1.0
Max. brushing force	3.9±1.6	4.2±1.7
4th quadrant		
Mean brushing force	2.2±0.8	2.3±0.8
Max. brushing force	3.8±1.2	3.6±1.1

Differences were not statistically significant

Inc., 233 S. Wacker Drive, Chicago, Illinois 60606). Data (brushing duration and force) were checked for normal distribution (Kolmogorov–Smirnov test). Since values were sufficiently normally distributed in all groups, differences between males and females (brushing duration and force) were analysed using *t*-tests for independent samples, and differences between quadrants (brushing force) were analysed with *t*-tests for dependent samples. The correlation coefficient (Pearson) was determined for the mean and maximum brushing forces. Categorical data were compared using chi-square tests. The level of significance was set at 0.05.

Results

The questionnaires revealed that 11.7% of the participants brushed once, 79.6% twice and 8.7% more than twice daily. From the video recordings, it was found that the majority brushed with circling movements (73.8%); 13.6% brushed with horizontal/circling, 8.7% with horizontal/scrubbing and 3.9% with vertical/sweeping movements. None used the Bass technique or any modification of it. No gender differences were found for brushing technique. Most of the participants were right-handed (93.2%); only 6.8% were left-handed or used both sides.

The frequency distribution with respect to brushing duration and force is given in Fig. 1. The mean brushing duration was 96.6±6.2 s (max. 215); 15% of participants brushed less than 60 s and 22.3% more than 120 s. The mean brushing force was 2.3±0.7 N (max. 4.1); 12.6% of participants used 1.5 N or less and 17.5% 3 N or more. The mean maximum force was 5.2±1.7 N (max. 10.5). No significant differences were found for quadrants (Fig. 2). There was a strong correlation between mean and maximum force (r=0.86; $p \leq 0.001$); individuals with a mean

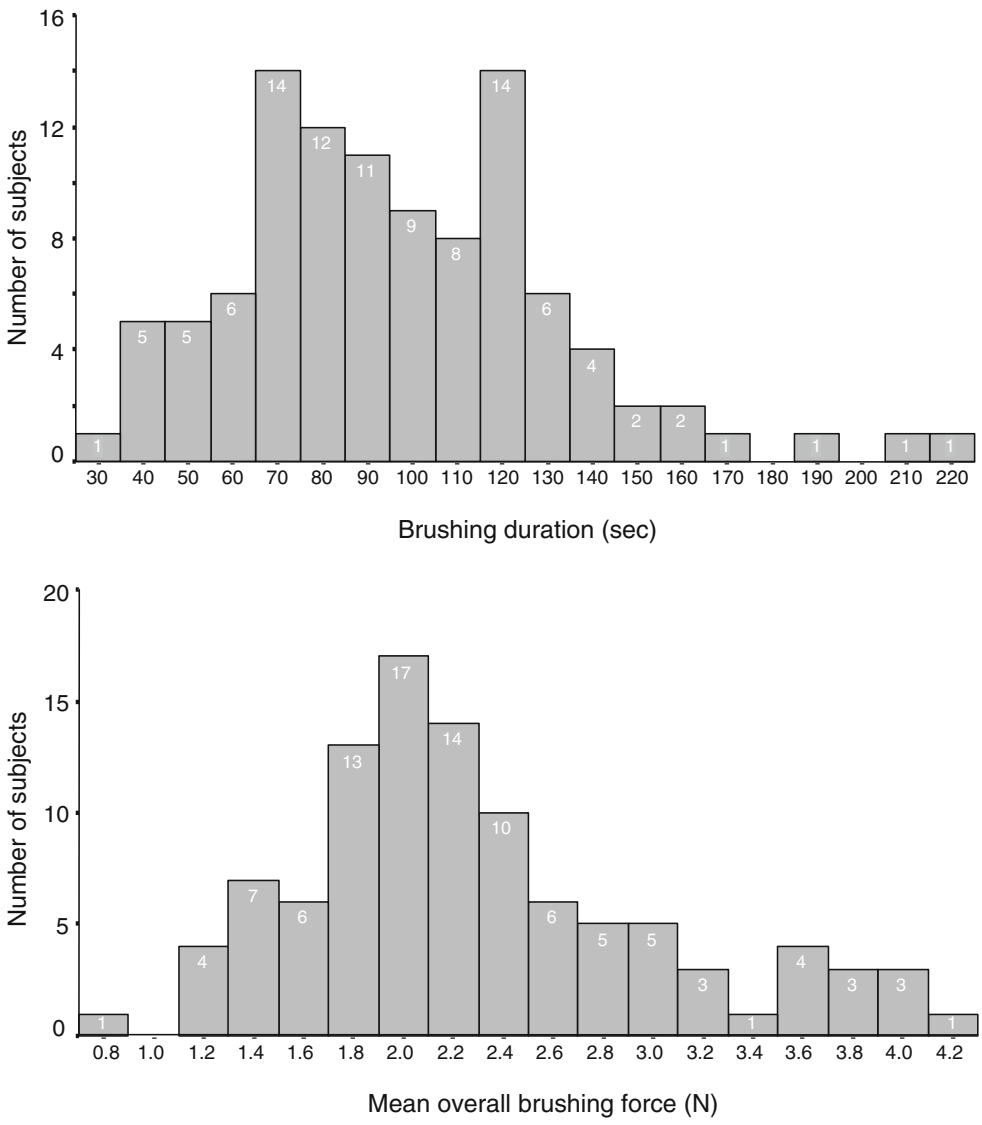

Fig. 1 Histogram of brushing duration and force

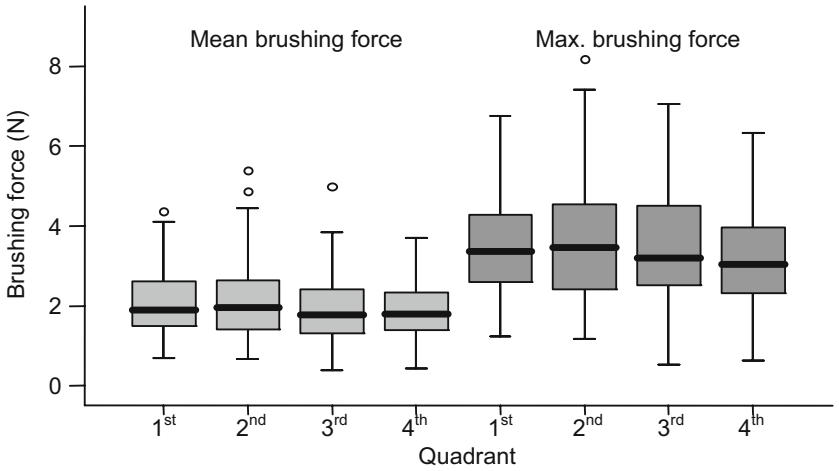

Fig. 2 Box plot of the mean and maximum brushing force per quadrant. The *boxes* represent the 25.0 and 75.0 percentile with the inner line defined as the median. Minimum and maximum values are represented by *horizontal lines*, o=outliners. For both mean and maximum brushing forces, no significant differences were found between quadrants

brushing force of below 2 N did not reach maximum values over 4 N.

Brushing duration was similar for females and males (97.9±24.0 versus 94.4±29.0 s respectively; n.s.) but the males had significantly higher mean (2.1±0.7 versus 2.5± 0.8 N respectively; $p \leq 0.05$) and maximum (4.9±1.4 versus 5.7±1.9 N respectively; $p \leq 0.05$) brushing force.

If appropriate brushing habits are defined as brushing at least twice daily for ≥120 s with a brushing force ≤3 N and with circling or vertical sweeping movements, only 25.2% of the participants fulfilled all criteria.

Discussion

Brushing habits were analysed with a special device for measuring brushing force and by monitoring videos of participants brushing. The obvious advantage of video monitoring is that tooth brushing is recorded objectively instead of relying on questionnaires. On the other hand, the awareness of being filmed as well as the measuring device itself might have influenced results. Repeated recordings both with and without the measuring device, however, showed a remarkable reproducibility of all variables. Mierau et al. [15] arrived at similar conclusions when assessing brushing habit patterns in the course of nine sessions; variations in force, duration and technique as well as in the sequence of brushing positions and number of changes of brushing sites were small. Similar effects were observed by MacGregor and Rugg-Gunn [12], who found that awareness of filming did not cause subjects to brush significantly longer.

A further methodological problem in the present study was that complex analysis of brushing habits was only possible for a limited number of participants. The group of subjects included in the present study was therefore necessarily highly selective, even though attempts were made to cover a reasonable age range and to equally include both males and females. Regardless, brushing frequency as a basic oral hygiene parameter was in good accordance with findings from a recent representative study on oral health in Germany [14]; thus within these limitations the study group, even though not representative, reasonably represented average oral hygiene habits.

The specific oral hygiene parameters investigated here were brushing technique, duration and force. All of these factors have been discussed in the literature with respect to plaque removal and damage to soft and hard oral tissues.

Current understanding of the impact of brushing technique is surprisingly incomplete and equivocal. There is some evidence of an association between gingival recession or cervical wear and oral hygiene habits, but it is unclear which factors are involved [3, 19]. Scrubbing may be one aetiological factor for gingival recession [18, 22]. Against this background, it was satisfactory that the majority of the participants brushed with circling or vertical sweeping movements and only less than 10% were scrubbers. On the other hand, none of the subjects demonstrated an elaborated technique, particularly the modified Bass technique. With respect to plaque removal, studies of the efficacy of brushing methods [9] are sparse and difficult to compare because of differences in experimental conditions. Even though it is not feasible to recommend one particular method, there is consensus that in individual patients a single accepted method should be adopted. Considering the present findings, patients probably will present with non-specific brushing techniques and need sufficient support to establish a method appropriate for their respective needs.

The major effect of brushing on plaque reduction is reached after 30 s brushing time per quadrant [26], adding up to a total brushing duration of 120 s. Findings from studies investigating the amount of time spent on brushing revealed that this is not reached in daily life. Older studies estimated that brushing time ranges between 30 and 60 s

[26]. The present results were in part encouraging since the mean brushing time was more than 90 s, but only 20% of the subjects reached the recommended brushing time; this finding emphasises the importance of further education, and it must be considered that patients usually believe that they spend more time on brushing than they actually do [21].

A further purpose of this study was to investigate brushing force during habitual brushing. It has been demonstrated that when brushing force is increased, more plaque is removed [27]. This effect was found under controlled conditions but was not confirmed during habitual brushing [25, 27]. Brushing force might be therefore of greater relevance to trauma of soft and hard tissues. Particularly in the context of erosion, knowledge of habitual brushing force is especially relevant for in vitro or in situ experimental designs in this field.

The mean brushing force of 2.3±0.7 N found in the present study was somewhat lower than findings reported earlier (267±73 g, [27]; 2.96±0.8 N vertical force [6]; 330±109 g [25]; 301 and 471 g, SD not given [8]); this discrepancy might have been due to random effects from selection of groups and methodological variance, but could also indicate increased knowledge of the potential risks of soft and hard tissue loss.

Only very few studies have investigated the association between brushing force and gingival recession or cervical wear by means of computerised measurements [4, 16, 28]. It appears that there is a correlation between force and gingival recession [4] since subjects with severe, minor and no recession exhibited mean forces of 3.8±0.5, 2.4±0.4 and 2.1±0.3 N, respectively. [16]. It was also found that subjects with wedge-shaped lesions had significantly higher mean brushing force than subjects without cervical wear (2.9±0.4 versus 2.1±0.3 N) [28]. It may be possible to conclude from these studies that tooth brushing force should not exceed 3 N. In the present study, this would mean that roughly one-fifth of the participants may be at long-term risk of gingival recession and cervical tooth wear, although the majority exhibited appropriate brushing force. It must also be considered that subjects with low to average mean brushing force could also reach force peaks. Upon examination of mean and maximum brushing forces, however, it was found that the individual range of brushing forces was relatively constant and in a narrow frame.

It has further been proposed that when brushing force is an aetiological factor for wear, lesions should occur more frequently in quadrants opposite to the hand holding the brush. This notion assumes higher brushing force in the respective quadrants, which in the present study was found neither for the mean nor for the maximum values recorded. This result is corroborated by the finding that the prevalence of cervical wear is similar in both sides of the mouth [5, 17].

As to brushing habits with respect to gender, the only significant difference was in brushing force, which was slightly higher in males. The order of magnitude, however, was small and cannot be assumed to be of clinical relevance. This result supports the finding that gender poses no risk for abfraction [5]. The notion that women are more aware of oral hygiene and also more motivated and skilful was not confirmed in the present study.

Conclusion

In the majority of subjects, appropriate frequency and brushing force was observed, but efforts should be made to increase the brushing duration. Even though scrubbing was rare while circling movements were predominant, none of the participants showed an elaborate brushing technique. When using a strict definition of appropriate brushing habits being defined as brushing at least twice daily for 120 s with a brushing force not exceeding 3 N and with circling or vertical sweeping movements, even 25.2% of the participants fulfilled all criteria. Nonetheless the study reveals that the remarkable efforts made in public health education programmes, individual oral hygiene consultations in dental practice and in mass media still need to be strengthened.

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

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