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## ORIGINAL ARTICLE

# Influence of teeth anatomical characteristics on the efficacy of manual toothbrushing manoeuvres

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## KEYWORDS

Toothbrushing;  
Dental plaque;  
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**Abstract Purpose:** The aim of the study was to investigate the efficacy of two toothbrushing techniques on the amount of plaque accumulation and to evaluate how the changes were correlated to the anatomical characteristics of the anterior maxillary arch.

**Methods:** Thirty subjects of both genders were included, they were asked not to brush for 12 h. Afterwards, they were asked to manually brush the left side of their maxillary arch with the modified Bass technique and the right side adopting the roll technique. The comparison of photographs taken before and after the manoeuvres, using a plaque disclosing agent, allowed the researchers to measure the changes in plaque accumulation measured using the Quigley and Hein plaque scoring classification. Linear regression analysis was used to evaluate the correlation between such changes and the teeth and arch anatomical characteristics.

**Results:** A mean reduction of  $9.6 \pm 5.2\%$  considering both arches after brushing was observed. The changes in plaque accumulation were not different between the two techniques. The length of the line obtained joining the contact point between the central incisors and the contact point between the second premolar and the first molar on the left side and the distance between that line and the lateral incisor on the same side positively correlated to the decrease in the plaque scores ( $P = 0.046$  and  $P = 0.044$ , respectively).

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*Conclusion:* Both tested techniques were effective in plaque removal in the anterior maxillary arches. However, the research for the anatomical factors influencing the amount of efficacy of the toothbrushing manoeuvres was inconclusive. We can hypothesise that the adoption of one adequate technique could be more important than the teeth characteristics.

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## 1. Introduction

Dental plaque has been defined as the diverse community of microorganisms found on the tooth surface as a biofilm, embedded in an extracellular matrix of polymers of a host and microbial origin (Marsh, 2004).

The accumulation of dental plaque on teeth and mucosal surfaces could be the initiating factor of a number of diseases and conditions that could have an important impact on the patients. Periodontal diseases, including gingivitis and periodontitis, are highly prevalent worldwide and they represent a major health problem for the entire population (Petersen and Ogawa, 2012).

The accumulation of plaque at and below the gingival margin is the most important risk factor for periodontal diseases, associated with an inappropriate and host inflammatory immune response (Chapple et al., 2015). For this reason, the prevention of plaque accumulation and the treatment of gingivitis should be considered as one fundamental preventive strategy for periodontitis (Chapple et al., 2015; Kinane et al., 2005).

Moreover, dental plaque accumulation is also the most important risk factor for the development of dental caries, one of the most prevalent chronic diseases in the world, affecting 60–90% of school-aged children and the majority of adults (Kassebaum et al., 2017).

Toothbrushing is the most widespread mean of personal plaque control in the world and is essential for the removal of plaque in order to contribute to good dental and periodontal health. Therefore, many factors such as the technique applied, the duration of brushing or physical factors such as the brushing force can influence the efficacy of the manoeuvre (Ganss et al., 2009). Toothbrushing can remove supragingival plaque on the tooth surfaces, but other devices (such as dental floss, interdental brushes, sticks and irrigators) are recommended to reach into the interproximal area (Worthington et al., 2019). Oral health care professionals generally recommend at least two minutes of brushing; the major effect of brushing on plaque reduction is reached after 30 s brushing time per quadrant, adding up to a total brushing duration of 120 s (Van der Weijden et al., 1993). The importance of examining specific aspects of toothbrushing, such as the evenness of the distribution of brushing time and the duration of circling movements has been proved, while focusing just on duration seems to neglect important information (Harnacke et al., 2015).

Focusing just on manual toothbrushing, several toothbrushing methods have been proposed: “Bass”, “Modified Bass”, “Stillman’s”, “Fone’s”, “Charter’s” and the “roll technique” (Wainwright and Sheiham, 2014). There is extensive literature on the subject of toothbrushing methods and dental

associations varied widely in the method of toothbrushing they recommend (Wainwright and Sheiham, 2014). With respect to plaque removal, studies of the efficacy of brushing methods are very rare and difficult to compare because of the significant heterogeneity in the experimental setting (Ganss et al., 2009). Even if it is not possible to recommend one particular method, there is a consensus that in individual patients a single accepted method should be adopted. The most effective brushing technique is the one that best fits the patient’s clinical characteristics (Hansen and Gjermo, 1971).

The aim of the present study was to evaluate plaque reduction on the anterolateral region of the maxillary arches after oral hygiene manoeuvres (manual toothbrushing) performed with two different techniques and to evaluate if the efficacy of such procedures was correlated to the anatomical characteristics of the teeth.

## 2. Materials and methods

The study was carried out following the instructions and the recommendations included in the Declaration of Helsinki for research on human subjects (World Medical Association, 2013). The study was performed as an observational investigation because the procedures were part of normal routine practice; for this reason, no approval by an Institutional Review Board/Ethical Committee was required. Data were anonymised for the statistical analysis.

### 2.1. Eligibility criteria

For the study, we included 30 subjects on the basis of the following inclusion criteria: (i) Both sexes, over the age of 18 years old; (ii) who are able to understand the requirements of the study and are willing and able to comply with its instructions and schedules; (iii) who had provided written informed consent to participate in the study prior to any study procedure; (iv) in general good health, in the opinion of the principal investigator as determined by the medical history and oral examination; (v) able to use a manual toothbrush; (vi) with at least 20 aligned teeth (from the second premolar to the second premolar for both arches); (vii) included in an oral hygiene program during the preliminary evaluation for orthodontic treatment; (viii) periodontally healthy (Lang and Bartold, 2018) and having a full-mouth bleeding score % (FMBS%) and full-mouth plaque score % (FMPS%) of less than 10%.

The exclusion criteria: (i) subjects with prosthetic reconstructions, such as crowns, veneers or bridges; (ii) subjects with calculus from the second premolar to second premolar for both arches.

A *post hoc* power analysis ( $\alpha = 0.05$ ) was performed, being power higher than 99%.

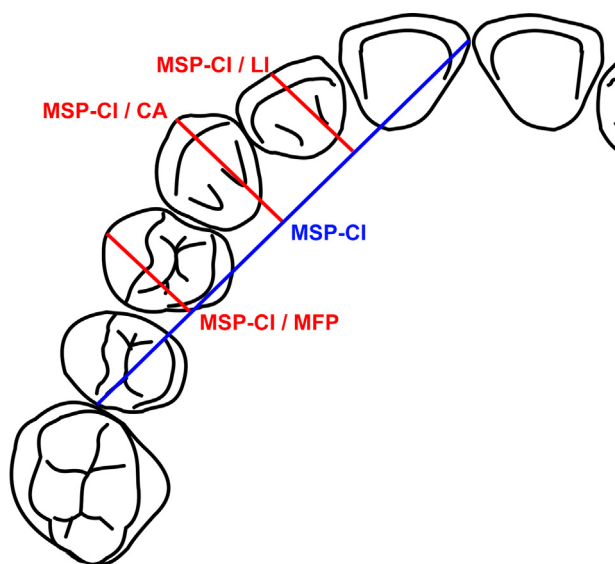
## 2.2. Outcomes

The primary outcome was the change in the Quigley and Hein plaque scoring classification (Quigley and Hein, 1962) (QHI) before and after toothbrushing, measured by the comparison between anonymised clinical radiographs before and after the oral hygiene procedures.

The secondary outcomes were: (i) the correlation between the primary outcome and the baseline characteristics of the subject (gender and age); (ii) the correlation between the primary outcome and the brushing technique; (iii) the correlation between the primary outcome and the ray of curvature of the arch between the first premolar and the lateral incisor of both sides measured on the occlusal view of the tri-dimensional model generated by scanning the arch; (iv) the correlation between the primary outcome and the distance between the teeth and the arch (between the first premolar and lateral incisor); (v) the correlation between the primary outcome and the distance between the line obtained joining the contact point between the central incisors and the contact point between the second premolar and the first molar of each and the most vestibular point of each tooth measured on an occlusal view. Fig. 1 shows the anatomical parameters considered.

## 2.3. Treatment procedures

All subjects were asked not to brush their teeth for 12 h before the baseline visit. During the first visit, an impression of the maxillary arch was taken using polyvinyl siloxane material. Afterwards, after the application of one plaque disclosing agent (GC Tri Plaque ID Gel – GC Europe N.V., Leuven, Belgium), one intraoral frontal picture showing the region between the first premolars of the maxillary arch was taken;



**Fig. 1** Diagram representing the anatomical characteristics that were considered in the study. MSP: Maxillary second premolar; CI: central incisor; MSP-CI: line obtained joining the contact point between the central incisors and the contact point between the second premolar and the first molar; LI: lateral incisor; CA: canine; MFP: maxillary first premolar.

the photograph was taken using standardised settings (Baseline photograph) (Nikon D7100 with Nikon AF-S Micro Nikkor 105 mm f/2.8G IF-ED VR, Nikon Corporation, Tokio, Japan; ISO 200, f/32, 1/200). After adequate instructions delivered by one trained operator (FT), the subjects brushed their teeth on the vestibular side of the maxillary arch with a soft manual toothbrush (Curasept Daycare – Curasept Spa, Saronno (VA), Italy), using the two different techniques: the Roll technique for the right hemiarch and the Modified Bass technique for left's hemiarch (one minute for each hemiarch). After that, a plaque disclosing agent was applied and another photograph was taken with the same settings.

## 2.4. Statistical methods

Descriptive statistics for continuous variables showed the means and standard deviations. Frequencies were presented for not continuous variables. The normality of the distributions was assessed using the Shapiro-Wilk test. Differences between the normally distributed continuous variables were assessed using Student's *t*-test. The linear regression analysis served to evaluate the correlation between the anatomical variables and the outcomes of brushing manoeuvres. The level of significance was set at  $P < 0.05$ .

## 3. Results

A total of 30 subjects entered and concluded the protocol (18 females and 12 males). The mean age was  $25.0 \pm 3.6$  years old (range 20–36 years). With regard to the smoking status, 12 subjects were smokers at the time of the investigation. At the baseline, the mean FMPS% was  $70.0 \pm 14.2\%$ , and it was  $60.8 \pm 15.2\%$  after brushing ( $P < 0.05$ ), the difference was  $9.6 \pm 5.2\%$ . The measures of the anatomical variables are shown in Table 1. None of the anatomical parameters examined were found to be significantly correlated to the

**Table 1** Anatomical characteristics of the teeth.

	Right side	Left side	Difference
MSP-CI Length (mm)	32.13 ± 2.66	32.38 ± 2.77	NS
Distance MSP-CI and LI (mm)	4.77 ± 1.10	5.13 ± 0.78	NS
Distance MSP-CI and CA (mm)	6.53 ± 1.25	6.80 ± 0.92	NS
Distance MSP-CI and MFP (mm)	5.33 ± 1.06	5.80 ± 1.03	NS
Arch radius (mm)	23.67 ± 5.01	22.90 ± 4.59	NS
Arch length (mm)	35.23 ± 3.48	35.25 ± 4.17	NS
Arch curvature (degrees)	88.94 ± 16.60	92.65 ± 17.24	NS

MSP: Maxillary second premolar; CI: central incisor; MSP-CI: line obtained joining the contact point between the central incisors and the contact point between the second premolar and the first molar; LI: lateral incisor; CA: canine; MFP: maxillary first premolar; NS: not significant.

FMPS% difference. The QHI values before and after brushing are shown in Fig. 2. The changes in QHI were not significantly different between the left and right side ( $P > 0.05$ ). The changes in the QHI scores in the left and right sides (taken separately) were not significantly related to any anatomical characteristic. The decrease in the QHI scores for both sides taken together was significantly negatively correlated to the FMPS% before treatment ( $B = 0.177$ ;  $CI95\%$ : 0.017–0.337;  $P = 0.033$ ), and positively to the length of the line obtained joining the contact point between the central incisors and the contact point between the second premolar and the first molar on the left side ( $B = 4.250$ ;  $CI95\%$ : 0.098–8.402;  $P = 0.046$ ) and to the distance between that line and the lateral incisor on the same side ( $B = 2.179$ ;  $CI95\%$ : 0.071–4.287;  $P = 0.044$ ).

#### 4. Discussion

The present study explored the correlation between anatomical characteristics of the maxillary anterior teeth and the amount of plaque removal after standard toothbrushing manoeuvres. Although some anatomical parameters appeared to be statistically correlated to the reduction of the plaque scores, the clinical significance of such a correlation should be considered carefully, also taking into account the confidence intervals of the odds ratios.

The external validity of the results has to be considered in light of the limitations of the study. Firstly, we made no sample size calculation but the *post hoc* power analysis supported the size of the sample chosen. Secondly, we decided to include only subjects using their right hand for brushing and, for this reason, the results could not be generalised to subjects using their left hand. Finally, we decided to measure some anatomical parameters of the arches that were chosen on the basis of the opinion of the operators, since, to the best of our knowledge, there are no other studies in the literature exploring the topic of how anatomy could influence oral hygiene

manoeuvres. In order to achieve more consistent results in the future, further studies should include a wider sample which could also allow researchers to perform the randomisation of the brushing techniques between the left and right side, and they should consider other areas of the arches. Moreover, other anatomical variables could be taken into consideration, such as tooth position and inclination and the presence of edentulous areas.

A number of published studies reported that there are several limitations in the possibility of achieving complete plaque removal after oral hygiene manoeuvres (Ganss et al., 2009; Harnacke et al., 2012a, 2012b, 2016; Quigley and Hein, 1962; van der Weijden and Hioe, 2005). As reported by Ganss et al. (2009), uninstructed adults usually brushed twice daily for a mean period of  $96.0 \pm 36.0$  s using a moderate force. Moreover, the most frequent brushing technique in the studied cohort was the use of circling movements (Ganss et al., 2009).

One systematic review of the literature published in 2005 explored the effectiveness of mechanical plaque removal in instructed subjects included in the considered clinical trials (van der Weijden and Hioe, 2005). The meta-analysis about the reduction of plaque accumulation, including a total of nine studies, found a small but significant difference in plaque accumulation after six months of individual oral hygiene. The authors concluded that much more must be done by dental professionals to increase the effectiveness of oral hygiene manoeuvres.

In general terms, many studies found several limitations in performing optimal oral hygiene and this was related to brushing time, which was demonstrated to be significantly heterogeneous even in instructed subjects (Ebel et al., 2019), and, less significantly, to brushing technique (Ebel et al., 2019; Harnacke et al., 2015). More precisely, the duration of the circling movements was positively correlated to better outcomes of oral hygiene manoeuvres (Harnacke et al., 2015).

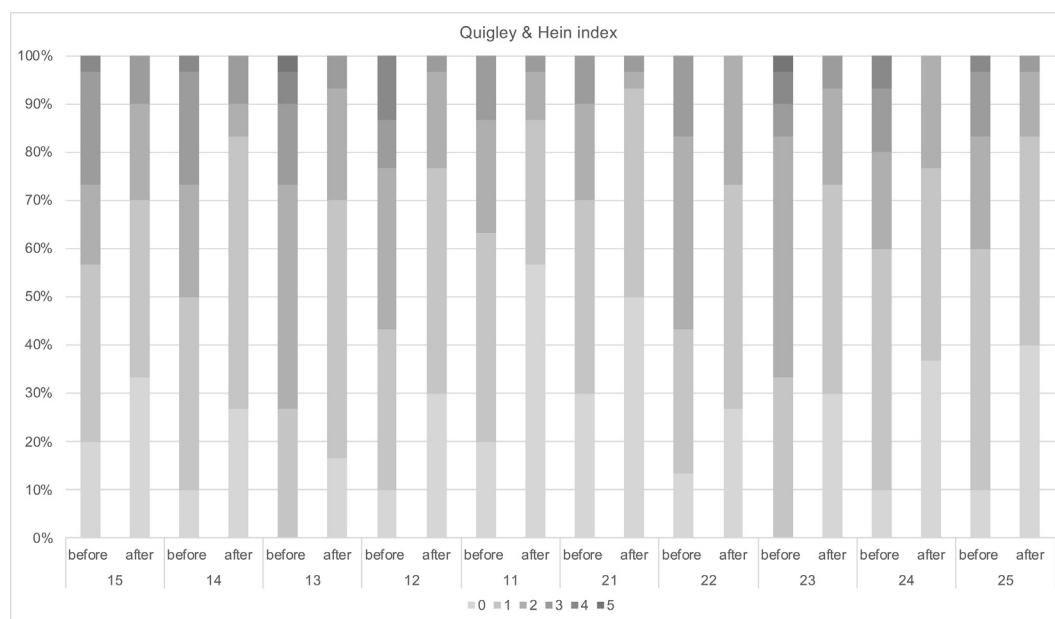


Fig. 2 Quigley and Hein index before and after brushing.

Deinzer et al. (2018) aimed at finding an “upper limit” of what could be reached in terms of plaque accumulation reduction by oral hygiene manoeuvres of dental professionals. A total of 127 subjects (dentists, dental students and dental assistants) were included in the investigation using manual/powered toothbrush (Deinzer et al., 2018). Very interestingly at least 10% of the dental surfaces presented plaque accumulation after brushing in all the groups, proving that complete removal of any deposit of dental biofilm over the dental surface is extremely difficult to be achieved.

Several studies explored which are the subjective determinants of oral health behaviour (Brein et al., 2016; Buunk-Werkhoven et al., 2011a, 2011b, 2011c). The authors found that socio-psychological aspects, in general, could influence oral hygiene behaviour (Buunk-Werkhoven et al., 2011c). One recently published study by Brein et al. (2016) found that oral health knowledge in general, adherence to subjective norms and income are related to brushing behaviour.

Few studies were published accounting for plaque distribution in relation to tooth anatomy. One paper published in 1965 (Lilienthal et al., 1965) found that anterior teeth were cleaner than posterior ones. This assumption was coherent with what was presented by other authors, who also found that maxillary teeth were usually cleaned better than mandibular ones (Soder et al., 2003). In the present study, the investigators did not clearly find a difference between premolar teeth and incisors since the distribution of plaque appeared substantially homogeneous. Moreover, in contrast to the study by Addy et al. (1987), the left and right sides demonstrated a similar amount of plaque accumulation. One study on a cohort of children that underwent orthodontic treatment reported that plaque accumulation could improve after teeth alignment, even though the reduction was hypothesised to be mostly correlated to behavioural changes than to teeth position (Davies et al., 1991). Other studies on orthodontic treatment confirmed this assumption (Abu Alhajja and Al-Wahadni, 2006; Ashley et al., 1998).

In conclusion, there is not sufficient evidence of one correlation between the anatomical characteristics of anterolateral maxillary arches and plaque level changes as measured after toothbrushing. The presence of plaque before brushing is one factor influencing the amount of plaque present after oral hygiene manoeuvres. However, we can admit that the tested brushing techniques were effective in reducing the amount of plaque on the vestibular surfaces. More studies are needed to better understand how teeth characteristics could influence the efficacy of toothbrushing manoeuvres.

#### Ethical statement

The study was performed as an observational investigation because the procedures were part of the normal routine practice; for this reason, no approval by an Institutional Review Board/Ethical Committee was required. Data were anonymized for statistical analysis.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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