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Effectiveness of the "CIOTIPlus"-system on cleaning of approximal surfaces

Introduction:
An efficient removal of biofilm plays a major role in the prevention of caries as well as gingivitis and periodontitis. In this respect, besides the professional hygiene measures performed in the dental practice, an effective, self-responsible, home-based oral hygiene should also take place. A predilection site for caries and gingivitis is represented by the tooth surfaces below the proximal contact points, which can hardly be cleaned with toothbrushes alone. The aim of the present cross-over pilot study was to investigate whether two-times brushing in accordance with the CIOTIPlus-System (**C**hewing, **I**nside, **O**utside, **T**ongue and **I**nterdental area, Plus: second brushing) using different brushing regimens (time and type of interdental hygiene tools) has an effect on interdental cleaning (IDC).

Methods:
15 subjects (7 females, 8 males, mean age 50.1 ± 6.5 years) were included in this study with a split-mouth design. On five appointments, each of which was preceded by a 72-hour plaque accumulation phase, ten brushing regimens were evaluated on their ability to clean the approximal surfaces; these regimens employed the use of a standard manual toothbrush and interdental hygiene tools. Six brushing regimens using the sequence "brushing – IDC-brushing" (flossing vs. flossing + interdental brushing vs. interdental brushing vs. soft picks vs. interdental brushing from vestibular and oral with or without gel) and four brushing regimens using the sequence "IDC – brushing – brushing" (flossing vs. interdental brushing vs. flossing + interdental brushing vs. soft picks) were tested. The participants were instructed to brush their teeth according to the "CIOTIPlus"-System. The Quigley-Hein Index (QHI) and the modified Approximal Plaque Index (QH-API) were determined at three time points in order to assess plaque reduction: before brushing (t0), after the first brushing and IDC (t1) as well as after the second brushing (t2).

Results:
At t1, a significant reduction of the QHI and QH-API values was observed in all groups compared to t0. The highest reduction of the QH-API was observed in the group "brushing – interdental brushing from vestibular and oral – brushing" (BI2B) (QH-API-t0-t1: 2.44 ± 0.45). At t2, the QHI and QH-API values were further significantly reduced in all groups. The greatest reduction of the QH-API was once again observed in the group BI2B (QH-API-t0-t2: 3.16 ± 0.41). However, after the second brushing, the group differences were very small (except for BI2B).

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Conclusion:
Interdental brushing from vestibular and oral seems to be the most effective IDC regimen for reducing the approximal plaque values. Second brushing, as part of the "CIOTIPlus"-System, leads to a higher plaque reduction on smooth and approximal surfaces compared to the one-time brushing, no matter what kind of interdental hygiene tools/ brushing regimens are used. Therefore, any cleaning performance deficits associated with the use of different hygiene tools in the approximal surfaces could be compensated using this approach.

Keywords: CIOTIPlus-System; interdental cleaning; plaque reduction; second brushing

1. Introduction

Mechanical plaque control and the removal of biofilm play a major role in the prevention of caries, gingivitis and periodontitis [4]; they represent an essential prerequisite for the long-term preservation of dental and oral health, not to mention general health. Preponderantly, patients use manual toothbrushes for mechanical plaque control as part of their self-responsible, home-based oral hygiene [30]. Reliable cleaning of the tooth smooth surfaces can be achieved using both manual and electric toothbrushes, if they are used correctly [38]. The most frequently recommended brushing technique by dentists is the "Bass technique" or modifications thereof [40]. However, this technique is difficult to learn. Studies have shown that this technique is hardly implemented by patients. In an investigation performed by Ganss et al. (2009), none of the 103 adult subjects in the study applied the "Bass Technique". The patients predominantly used rotationally movements (73.8 %), performed horizontal scrubbing movements (8.7 %), or combined these two movements together (13.6 %) [9]. The "scrubbing technique" is the primary technique which is learned from a very early age because it follows the individual movement pattern and is therefore easy to perform [41]. As motor skills continue to evolve later in life, the "Fones Technique", with its rotational motion pattern, can be easily learned [14]. These two techniques are often combined with a brushing system, which comprises of the following brushing sequence: first the chewing, followed by the outside and then the inside surfaces (COI-System) [41]. Research in the field of behavioral science has revealed that the techniques and behaviors, which are acquired in childhood, are often carried into adult life [34]. As a consequence, health-related behavioral changes in adulthood are more difficult to attain [3]. This would explain why the primary recommended "Bass technique" by dentists is not implemented by patients. However, there are no published findings demonstrating the superiority of the "Bass Technique" over other techniques. Much more important than the technique seems to be the adherence to a brushing system [11, 25].

Neither a manual nor an electric toothbrush can clean all the tooth surfaces, as they cannot fully penetrate into interdental area; thus, they are ineffective for cleaning the interdental surfaces [32]. However, effective cleaning of the interdental surfaces is of particular importance in the context of gingivitis and caries prophylaxis, because the tooth surfaces below the proximal contacts present a predilection site for caries and gingivitis [26]. In the fifth German oral health study (DMSV) a correlation was found between younger seniors using interdental hygiene tools and lower DMF-T values [17]. Interdental hygiene tools such as floss and interdental brushes are recommended when toothbrushes alone cannot sufficiently remove the interdental biofilm [10, 29]. However, user acceptance of these aids is classified as being low [31]. Zimmer and Lieding (2014) conducted a survey on a representative sample of the German population and found that only 23.2 % of the total population used dental floss and 15.1 % interdental brushes at least several times a week [44]. Thus, the authors concluded that a maximum of 38.3 % from the total population used dental floss or interdental brushes at least several times a week to clean interdental areas [44]. The use of interdental brushes seems to be easier for patients and it has also been shown, that they are more effective than dental floss in terms of approximal cleaning [7, 32]. Although, from a scientific standpoint neither the effectiveness of dental floss nor that of interdental brushes has been sufficiently proven [23, 27]. Nonetheless, the use of interdental cleaning tools is expressly recommended once a day to remove food rests and existing microorganisms [29]. In literature, no recommendations or references regarding the precise time of interdental cleaning exist. Thus, it remains unclear whether the patient should perform interdental cleaning before or after smooth surface brushing, and if the sequence of this action is relevant for plaque removal.

In previous studies could be shown that a simple modification of one's home-based oral hygiene, in the form of second brushing in accordance with the "CIOTIPlus"-System, results in improved plaque removal, significantly reduced caries formation on root surfaces and crown margins in older people, as well as stabilized or improved periodontal conditions [12, 13]. Using this brushing system, the sequence of tooth cleaning is: first the chewing, followed by the inside, then the out-

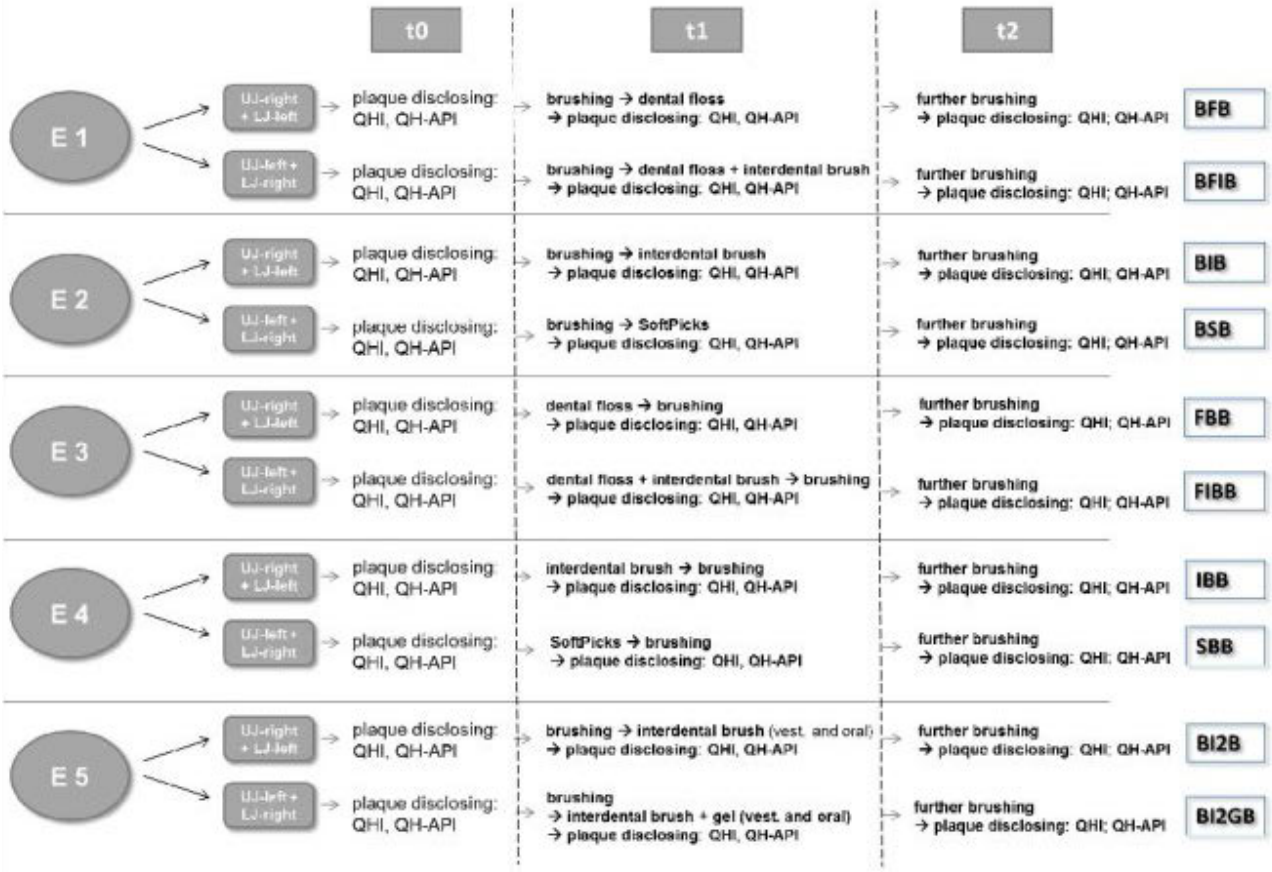

Figure 1 Clinical approach (E1–E5: Examination 1-5; UJ: Upper Jaw; LJ: Lower Jaw

side surfaces, after the tongue, and finally the approximal surfaces. Succeeding this first cleaning procedure, the patient brushes all of the tooth surfaces and the gums in a rotation motion with a same (pea-sized) amount of fluoride toothpaste again [12]. The purpose of the present cross-over pilot study was to investigate whether second brushing according to the "CIOTIPlus"-System, using different cleaning regimens (time point and type of interdental cleaning tools), has an effect on interdental cleaning.

2. Methods

2.1. Participants

The participants were randomly selected patients from the Department of Conservative Dentistry, Periodontology and Preventive Dentistry of the Hannover Medical School. Inclusion criteria for participation in the study was a remaining dentition of at least 20 teeth in the absence of any crown restorations, an age between 35–64 years, and a Periodontal Screening Index (PSI) < 2. Exclusion criteria included any physical disabilities that made adequate oral hygiene difficult, head/neck radiotherapy in the past, heavy smoking (> 10 cigarettes per day), and drug intake that could result in false clinical values (e.g. anticoagulants). Project participation was voluntary and could be revoked at any time without the need to give reasons. The project received a positive vote from the ethics committee of the Hannover Medical School (Vote No.: 1054–2011).

2.2. Study design and collected parameters

All examinations were performed by a practitioner with the support of an assistant. As part of the initial examination (E0), an anamnesis, a detailed oral examination and an evaluation of the PSI values was conducted on each participant. The dental plaque was visualized with the aid of a plaque disclosing solution (Mira-2-Ton, Hager & Werken, D-Duisburg) and a magnifying loupe (2.5-fold, Orascoptic Lupensysteme, Sigma Dental, D-Handewitt). In order to quantify the amount of plaque, the modified Quigley-Hein Plaque Index (QHI) according to Turesky [35] and the modified plaque index for assessing the extent of plaque in approximal areas based on the Quigley-Hein Plaque Index (=modified QH-API) [13] were used. The "CIOTIPlus"-System of tooth cleaning was explained, demonstrated and practiced. The system entailed first brushing the **c**hewing surfaces of teeth, followed by the **i**nside and then the **o**utside surfaces followed by the brushing of the **t**ongue for at least two minutes and lastly **i**nterdental cleaning (CIOTI). Afterwards, the already cleaned tooth surfaces including the gums were brushed systematically (CIO-System) with the same (pea-sized) amount of fluoride toothpaste in rotational movements for at least one minute (= Plus). Moreover, in preparation for the upcoming appointments, the sizes of the interdental brushes were

individually selected for each participant, so as to correspond to the dimensions of his/her interdental spaces (IAP-probe, Curaden Germany, D-Stutensee). In order to create uniform starting conditions, all of the participants received a professional tooth cleaning afterwards.

Five follow-up examinations (EU1-E5) ensued, each of which was preceded by a 72-hour plaque accumulation phase (no home-based oral hygiene and no use of oral hygiene products or dental care products such as menthol-containing candies or chewing gum). After the examination, an associated "washout phase" for at least 2 days was followed, during which the participants performed home-based oral hygiene with their usual oral hygiene tools. After this phase, the next 72-hour plaque accumulation phase began.

At each examination, the dental plaque was first visualized like in E0 and the modified QHI and the modified QH-API [13] were recorded (t0). For each participant, the entire dentition was not assessed as a whole. Instead, the upper right jaw and lower left jaw were combined together and evaluated separately from the upper left jaw and the lower right jaw in a split-mouth design.

Subsequently, the participants were instructed to brush their teeth systematically for at least 2 minutes; this always involved brushing the tooth smooth surfaces in the sequence chewing, inside and outside surfaces, followed by the brushing of the tongue (CIOT system) with a standard manual toothbrush (1–2–3 Classic Care/OralB, Procter & Gamble, Sulzbacher am Taunus) and toothpaste with medium abrasiveness (Elmex Sensitive Professional Repair and Prevent, CP GABA, D-Hamburg). The cleaning of the interdental surfaces varied in terms of the type of cleaning tool employed and time point of application, so that a total of 10 different cleaning regimens resulted (see Fig. 1): six of the regimens employed the sequence "brushing – interdental cleaning" and four of the regimens applied the sequence "interdental cleaning – brushing". The tools used for performing interdental cleaning included dental floss (EssentialFloss waxed/OralB, Procter & Gamble, Sulzbacher am Taunus), interdental brushes (CPS prime, Curaden Germany, D-Stutensee) with or without low abrasive Gel (Paroex toothpaste, Sunstar GUM, D-Schönau), and an elastic, metal-free interdental brush with rubber bristles (Soft-Picks Advanced, Sunstar GUM, D-Schönau). After this, the plaque was stained again using a plaque disclosing solution and the QHI and QH-API values were recorded (t1). The participants were then instructed to brush the already cleaned tooth surfaces including the gums systematically with the same (pea-sized) amount of fluoride toothpaste in rotational movements for at least one minute (=plus). Following the second brushing, the QHI and QH-API values were once again recorded after staining with the plaque disclosing solution (t2).

A cross-over design was applied in the study. Due to the cross-split-mouth design, two cleaning regimens could be evaluated together per examination appointment, thus giving rise to a total of 10 groups (Fig. 1). At the end of each examination, the teeth of the participants were professionally cleaned.

The tooth brushing tasks for all tooth surfaces were carried out by the participants themselves (hands-on brushing) and controlled by the examiner during each examination. However, the tools for cleaning the approximal surfaces were handled by the examiner himself/herself (hands-on-flossing/brushing). Thus, the interdental cleaning tools used for the approximal surfaces were used on each subject in the same way. Both approximal surfaces were cleaned with two up and down movements using dental floss. The floss was then removed as a loop out of the approximal space. When the interdental brushes and soft picks were employed, after their insertion into the approximal space, each approximal surface was cleaned using two horizontal brushing movements ("X-Technique"). The brushes were then removed obliquely out of the approximal space in an occlusal and vestibular direction. In the two groups where interdental brushes were used from vestibular and oral, the same procedure was repeated orally. Following each interdental cleaning procedure, the brushes were rinsed and cleaned under running water.

2.3. Statistical Analysis

Data analysis was performed using the statistical analysis program SPSS/PC Version 23.0 for Windows (SPSS Incorporation, Chicago, IL, USA). All the collected data were analyzed following pseudonymisation. For the clinical parameters, the mean values with standard deviations were calculated. The comparison of means between groups and time points was performed using independent sample t-tests. The level of significance was set at p 0.05.

3. Results

Fifteen participants (7 females, 8 males) with an average age of 50.1 ± 6.5 years were included in the present study. At baseline (E0), the subjects displayed an average QHI of 2.06 ± 0.46 and an average QH-API of 3.63 ± 0.39.

Before the first brushing (t0), an average QHI of 2.85 ± 0.39 and an average QH-API of 3.79 ± 0.40 were found in all groups (Tables 1 and 2). After the first brushing (t1), both the QHI and the QH-API decreased significantly in all groups (QHI: 1.26 ± 0.46, QH API: 1.92 ± 0.65) ($p < 0.0001$). The largest QHI reduction was in the group "brushing – interdental brushing from vestibular and oral – brushing" (BI2B) (QHI-t0-t1: 1.89 ± 0.30) and the lowest reduction was noted for the group "brushing – soft picks – brushing" (BSB) (QHI-t0-t1: 1.36 ± 0.31). In terms of QH-API, the greatest reduction was in the group "brushing – interdental brushing from vestibular and oral – brushing" (BI2B) (QH-API-t0-t1: 2.44 ± 0.45) and the smallest reduction was observed in the group "brushing – flossing – brushing" (BFB) (QH-API-t0-t1: 1.37 ± 0.52) (Tables 1 and 2). On average, the subjects brushed with the manual toothbrush for 2.18 ± 0.18 minutes.

After the second brushing (t2), the QHI and QH-APIs were further significantly reduced in all groups

	QHI										
	total	**BFB**	**FBB**	**BIB**	**IBB**	**BFIB**	**FIBB**	**BSB**	**SBB**	**BI2B**	**BI2GB**
t0	2.85 ± 0.39	2.78 ± 0.45	2.85 ± 0.43	2.81 ± 0.37	2.77 ± 0.43	2.79 ± 0.42	2.87 ± 0.48	2.84 ± 0.37	2.89 ± 0.34	2.94 ± 0.30	2.97 ± 0.29
t1	1.26 ± 0.46	1.35 ± 0.45	1.13 ± 0.48	1.25 ± 0.54	1.17 ± 0.55	1.42 ± 0.45	1.26 ± 0.43	1.48 ± 0.43	1.21 ± 0.41	1.05 ± 0.47	1.26 ± 0.31
t2	0.48 ± 0.33	0.53 ± 0.34	0.47 ± 0.34	0.57 ± 0.44	0.42 ± 0.30	0.60 ± 0.40	0.48 ± 0.27	0.56 ± 0.36	0.44 ± 0.31	0.37 ± 0.21	0.42 ± 0.23
t0–t1	1.59 ± 0.38 (55.79%)	1.43 ± 0.40 (51.44%)	1.72 ± 0.38 (60.35%)	1.56 ± 0.41 (55.52%)	1.60 ± 0.40 (57.76%)	1.37 ± 0.35 (49.1%)	1.61 ± 0.43 (56.1%)	1.36 ± 0.31 (47.89%)	1.68 ± 0.27 (58.13%)	1.89 ± 0.30 (64.29%)	1.71 ± 0.30 (57.58%)
t0–t2	2.37 ± 0.38 (83.16%)	2.25 ± 0.41 (80.94%)	2.38 ± 0.42 (83.51%)	2.24 ± 0.41 (79.72%)	2.35 ± 0.31 (84.84%)	2.19 ± 0.43 (78.49%)	2.39 ± 0.44 (83.28%)	2.28 ± 0.32 (80.28%)	2.45 ± 0.25 (84.78%)	2.57 ± 0.23 (87.41%)	2.55 ± 0.36 (85.59%)

Table 1 QHI of all groups at different time points (t0, t1, t2), as well as QHI differences between t0–t1 and t0–t2.
BFB: brushing-flossing-brushing; FBB: flossing-brushing-brushing; BFIB: brushing-flossing+interdental brushing-brushing; FIBB: flossing+interdental brushing-brushing-brushing; BIB: brushing-interdental brushing-brushing; IBB: interdental brushing-brushing-brushing; BSB: brushing-soft picks-brushing; SBB: soft picks-brushing-brushing; BI2B: brushing-interdental brushing from vestibular and oral-brushing; BI2GB: brushing-interdental brushing from vestibular and oral with gel-brushing

(QHI: 0.48 ± 0.33, QH API: 1.02 ± 0.50) ($p < 0.0001$). The largest reduction of QHI was in the group "brushing – interdental brushing from vestibular and oral – brushing" (BI2B) (QHI-t0-t2: 2.57 ± 0.23) and the lowest reduction was in the group "brushing – floss + interdental brushing – brushing" (BFIB) (QHI-t0-t2: 2.19 ± 0.43). With respect to the QH-API values, the greatest reduction of the QH-API was in the group "brushing – interdental brushing from vestibular and oral – brushing" (BI2B) (QH-API-t0-t2: 3.16 ± 0.41) and the smallest reduction was seen in the group "brushing – flossing – brushing" (BFB) (QH-API-t0-t2: 2.40 ± 0.48) (Tables 1 and 2). On average, the subjects brushed 1.40 ± 0.31 minutes with the manual toothbrush during the second brushing.

3.1. Time point of approximal surface cleaning

Comparing the group "brushing – interdental cleaning" (BFB, BIB, BFIB, BSB, BI2B, BI2GB) and the group "interdental cleaning – brushing" (FBB, IBB, FIBB, SBB), there were no significant differences in the plaque index values for the smooth and approximal surfaces, neither after the first (t1) nor after the second brushing (t2) (Fig. 2).

3.2. Type of cleaning tool used

With respect to smooth surface cleaning, no significant differences in the reduction of the plaque index value were observed for the different hygiene tools, neither after the first (t1) nor after the second (t2) brushing. In the approximal area, the group "interdental brushing from vestibular and oral" (BI2B, BI2GB) showed significantly higher reductions in the plaque index value after the first brushing (t1) than the groups "dental floss" (BFB, FBB)" ($p < 0.0001$), "floss + interdental brushing" (BFIB, FIBB) ($p = 0.37$), "interdental brushing" (BIB, IBB) ($p = 0.006$) and "soft picks" (BSB, SBB) ($p < 0.0001$). Following the second brushing (t2), the group "interdental brushing from vestibular and oral" (BI2B, BI2GB) still displayed the highest reduction of the approximal plaque index value. Statistical significance, however, was achieved only when it was compared to the groups "dental floss" (BFB, FBB) ($p < 0.0001$), "interdental brushing" (BIB, IBB) ($p = 0.006$) and "soft picks" (BSB, SBB) ($p < 0.0001$). The lowest reduction of the approximal plaque index value was seen for the group "dental floss" (BFB, FBB), both after the first (t1) and after the second (t2) brushing. The lower reduction was statistically significant only after the first brushing (t1) with respect to the groups "interdental brushing vestibular and oral" (BI2B, BI2GB) ($p < 0.0001$) and "interdental brushing" (BIB, IBB) ($p = 0.036$). After the second brushing, there were no significant differences between the groups "floss" (BFB, FBB), "floss + interdental brushing" (BFIB, FIBB), "interdental brushing" (BIB, IBB) and "soft picks" (BSB, SBB) (Table 3).

A general summary of the QH-API and QHI values is presented in tables 4 and 5. The groups "floss" (BFB, FBB), "floss + interdental brushes" (BFIB, FIBB), "interdental brushes" (BIB, IBB), "soft-picks" (BSB, SBB) and "interdental brushing from vestibular and oral" (BI2B, BI2GB) are further divided with respect to the oral and vestibular surfaces of the maxilla and

	QH-API										
	total	**BFB**	**FBB**	**BIB**	**IBB**	**BFIB**	**FIBB**	**BSB**	**SBB**	**BI2B**	**BI2GB**
t0	3.79 ± 0.40	3.92 ± 0.48	3.80 ± 0.50	3.88 ± 0.39	3.76 ± 0.38	3.82 ± 0.38	3.79 ± 0.47	3.86 ± 0.35	3.79 ± 0.40	3.69 ± 0.34	3.64 ± 0.30
t1	1.92 ± 0.65	2.55 ± 0.51	1.98 ± 0.57	2.04 ± 0.66	1.77 ± 0.44	2.10 ± 0.74	1.63 ± 0.57	2.33 ± 0.56	2.07 ± 0.49	1.25 ± 0.44	1.51 ± 0.47
t2	1.02 ± 0.50	1.51 ± 0.51	1.21 ± 0.47	1.13 ± 0.46	0.99 ± 0.41	0.89 ± 0.41	0.87 ± 0.46	1.35 ± 0.42	1.16 ± 0.41	0.53 ± 0.28	0.59 ± 0.27
t0–t1	1.87 ± 0.62 (49.34%)	1.37 ± 0.52 (34.95%)	1.82 ± 0.65 (47.89%)	1.84 ± 0.66 (47.42%)	1.99 ± 0.38 (52.93%)	1.72 ± 0.85 (45.03%)	2.16 ± 0.56 (56.99%)	1.53 ± 0.51 (39.64%)	1.72 ± 0.38 (45.38%)	2.44 ± 0.45 (66.12%)	2.13 ± 0.46 (58.52%)
t0–t2	2.77 ± 0.54 (73.09%)	2.40 ± 0.48 (61.22%)	2.59 ± 0.59 (68.16%)	2.75 ± 0.60 (70.88%)	2.77 ± 0.43 (73.67%)	2.93 ± 0.57 (76.7%)	2.92 ± 0.51 (77.04%)	2.51 ± 0.46 (65.03%)	2.63 ± 0.49 (69.39%)	3.16 ± 0.41 (85.64%)	3.05 ± 0.42 (83.79%)

Table 2 QH-API of all groups at different time points (t0, t1, t2), as well as QH-API differences between t0–t1 and t0–t2
BFB: brushing-flossing-brushing; FBB: flossing-brushing-brushing; BFIB: brushing-flossing+interdental brushing-brushing; FIBB: flossing+interdental brushing-brushing-brushing; BIB: brushing-interdental brushing-brushing; IBB: interdental brushing-brushing-brushing; BSB: brushing-soft picks-brushing; SBB: soft picks-brushing-brushing; BI2B: brushing-interdental brushing from vestibular and oral-brushing; BI2GB: brushing-interdental brushing from vestibular and oral with gel-brushing

mandible. In general, after the first (t1) and second (t2) brushing, higher plaque index value reductions were observed on the vestibular smooth and vestibular approximal surfaces than on the opposing orally located ones ($p < 0.0001$). Moreover, a higher reduction of the plaque index value occurred for the upper jaw in comparison to the lower jaw ($p < 0.0001$). Comparing the plaque index values only on oral surfaces between the lower and upper jaw, greater reductions were observed for the lower jaw at both time points (t1 and t2) ($p > 0.0001$).

The group "interdental brushing from vestibular and oral" (BI2B, BI2GB) displayed the highest reduction in plaque index values for each approximal surface. In comparison to the groups "floss" (BFB, FBB) and "soft picks" (BSB, SBB), this was significantly greater in every area.

4. Discussion

The results of the present study show that the plaque index value can be significantly more reduced by second brushing as compared to one-time brushing, given that patients brush according to the instructed system. These findings are similar to the results of previous studies [13]. There could be shown that, also in approximal areas, significantly more plaque removal resulted after second brushing than after one-time brushing, even if no additional hygiene tools were used for approximal surfaces. More specifically, after the first brushing, the reduction in the plaque index value averaged 22.64 % for smooth 3.95 % for proximal surfaces. After the second brushing, a significantly higher reduction in the plaque index values was observed for both smooth (54.72 %) and approximal surfaces (24.69 %) [13]. The aim of the current study was to evaluate the effect of an additional cleaning of the proximal surfaces, using different hygiene tools in combination with a second brushing, on the reduction of the plaque index value on the smooth and approximal surfaces. Compared to the results of Günay and Meyer-Wübbold (2018), in the present study higher reductions in the plaque index values were observed on both the smooth and approximal surfaces after the first brushing, which was combined with a separate cleaning of the interdental areas with different hygiene tools. This yielded a 55.79 % and a 49.34 % reduction of plaque index value on smooth and approximal surfaces, respectively. The second brushing, which was not combined with a separate cleaning of the interdental spaces, once again significantly increased plaque reduction in the area of smooth (83.16 %) and approximal surfaces (73.09 %). These results suggest that a separate cleaning of the approximal surfaces, through the correct use of different hygiene tools, achieves an additional reduction of the plaque index value in both smooth and approximal surface areas. This effect can be further significantly increased, once again, by a second brushing.

In a review by Slot et al. [33], various studies which evaluated the effectiveness of the manual toothbrush in terms of plaque removal were presented. The article reported a reduction of the QHI by an average of 30 % [33]. Similar values were observed in a prior evaluation of second brushing, too [13]. A reduction of the plaque index value by slightly less

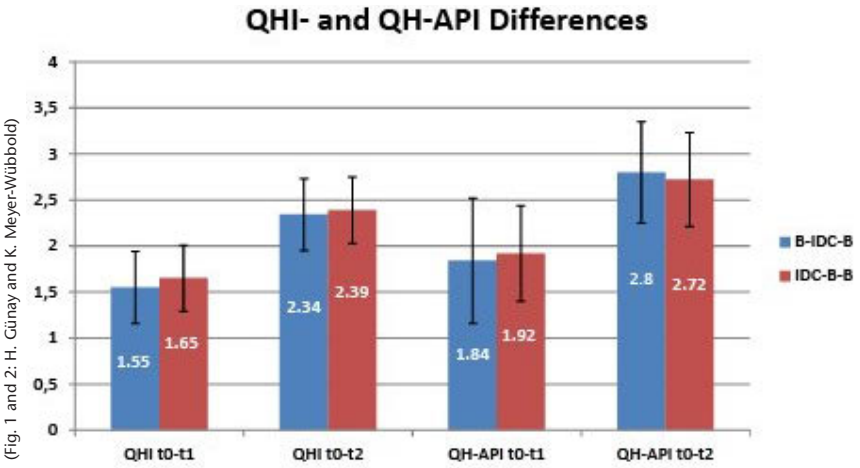

Figure 2 QHI and QH-API differences between t0–t1 and t0–t2 of the groups "brushing-interdental cleaning-brushing"/B-IDC-B (BFB, BIB, BFIB, BSB, BI2B, BI2GB) and "interdental cleaning-brushing-brushing"/IDC-B-B (FBB, IBB, FIBB, SBB)

than a third was observed on the smooth surfaces after the first brushing procedure in both investigated groups [13]. In the current study, on the other hand, the overall QHI after the first brushing was reduced by a little over half (difference QHI t0-t1 55.79 %). Noteworthy here is that the first brushing was combined with interdental cleaning in the present study. Thus, the higher reduction of the QHI suggests that the cleaning of the approximal surfaces using different hygiene tools also has an influence on plaque reduction in the area of the smooth surfaces.

In the present study, a reduction of the plaque index values of more than two thirds could be achieved in terms of smooth and approximal surface plaque removal after the second brushing procedure (difference QHI t0-t2 83.16 %, difference QH-API 73.09 %). It should be noted that second brushing resulted in a longer brushing time. The participants brushed the smooth surfaces with the manual toothbrush an average of 2.18 ± 0.18 minutes during the first and 1.40 ± 0.31 minutes during the second brushing procedure, respectively, resulting in a total smooth surface cleaning time of 3.58 ± 0.40 minutes. Increasing brushing time can reduce plaque removal both when using manual and electric toothbrushes [19, 37, 42]. It has been observed that 1-minute and 2-minute tooth brushing results in an average plaque reduction of 27 % and 41 %, respectively [33]. In a survey performed on a representative sample of the German population, 75 % of the respondents answered that they brushed for 2 to 3 minutes (44 % 2 minutes, 32 % 3 minutes) [44]. However, there is often a disparity between estimated and actual brushing time [28]. In order to exemplify this, one study showed that the actual average duration of a brushing session of 68.8 seconds was perceived by subjects as being 148.1 seconds, more than twice as long [28]. In light of these findings, it seems to be more effective to advise patients to brush two-times according to a certain system (e.g. CIOTI-Plus), and thus indirectly increase the duration of brushing, rather than to just recommend an increase in the duration of brushing. The etiological factors contributing to tooth abrasion have been described in literature as including toothpaste abrasiveness, toothbrush hardness, toothbrush contact pressure, brushing technique, as well as the frequency or duration of brushing [2]. Although the brushing time is indeed increased by second brushing, the present study finds that the subjects did not mechanically clean the smooth surfaces with the toothbrush for an excessively long time. As mentioned before, the brushing time of the smooth surfaces was noticeably less than 5 minutes. Thus, two-times brushing should have no influence on the formation of tooth abrasion. It must also be emphasized that the CIOTIPlus-System employed in this study is not a "double" brushing in the literal sense. The addition of "Plus" does not mean that the entire brushing process is once again repeated in the same way; rather, it denotes that a same (pea-sized) amount of fluoride toothpaste is applied on all tooth surfaces, which are then brushed with a toothbrush in circular/rotating movements, which of course, this leads to a corresponding mechanical cleaning of the teeth and gums.

In the CIOTI-System, the cleaning of approximal surfaces is performed at the end after the brushing of the smooth surfaces and tongue has been completed. The aim here is to clarify to the patient that the cleaning of the approximal surfaces has to be completed separately and thus requires time and concentration. For this reason, in the present study, only the time used for smooth surface brushing was recorded, while the time used for interdental cleaning was omitted.

The cleaning of approximal surfaces using special hygiene tools, in addition to brushing with a toothbrush, results in more plaque removal in approximal surfaces than brushing alone [18, 32]. The results of the present study suggest that interdental brushes applied from vestibular and oral appear to be the most effective for reducing the plaque index value in approximal areas in comparison to other tested interdental cleaning tools. The second highest reduction of the plaque index value in the approximal area was observed in the group "dental floss + interdental brushes", followed by the groups "interdental brushes" and "soft picks". The lowest reduction in the approximal plaque index value was found in the "dental floss" group. Other studies show similar results. Slot et al. (2008) published a systematic review concerning the effectiveness of interdental brushes on plaque removal as well as their effect on various clinical parameters such as bleeding and pocket depths. Among other findings, the authors came to the conclusion that brushing teeth in

QHI and QH-API differences										
	floss (BFB, FBB)		floss + interdental brush (BFIB, FIBB)		interdental brush (BIB, IBB)		SoftPicks (BSB, SBB)		interdental brush vest. and oral (BI2B, BI2GB)	
	QHI	QH-API	QHI	QH-API	QHI	QH-API	QHI	QH-API	QHI	QH-API
t0–t1	1.57 ± 0.40	1.59 ± 0.62	1.49 ± 0.40	1.94 ± 0.74	1.58 ± 0.39	1.91 ± 0.53	1.52 ± 0.33	1.62 ± 0.46	1.80 ± 0.30	2.29 ± 0.48
t0–t2	2.31 ± 0.41	2.49 ± 0.53	2.29 ± 0.44	2.93 ± 0.54	2.29 ± 0.36	2.76 ± 0.51	2.36 ± 0.99	2.57 ± 0.47	2.56 ± 0.29	3.10 ± 0.41

Table 3 QHI and QH-API differences between t0–t1 and t0–t2 of the groups "flossing" (BFB, FBB), "flossing + interdental brushing" (BFIB, FIBB), "interdental brushing" (BIB, IBB), "soft picks" (BSB, SBB) and "interdental brushing from vestibular and oral gel" (BI2B, BI2GB)

combination with the use of interdental brushes removed more plaque than brushing teeth alone; also, interdental brushes removed more interdental plaque than dental floss or dental sticks [32]. Likewise, the current study also observed higher approximal plaque index value reductions for interdental brushes compared to dental floss. The differences were significant when the interdental brushes were used from both vestibular as well as oral. Investigations have shown that interdental brushes, which are inserted into the approximal areas only from vestibular, clean the oral surfaces of the interdental areas less effectively than the vestibular surfaces [39]. This could be confirmed in the present study as well. The use of interdental brushes from both vestibular and oral reduced approximal plaque more significantly in the vestibular and oral surface areas than interdental brushes used only from vestibular.

After the second round of brushing, there were no significant differences in the reduction of plaque index values between the groups "dental floss", "dental floss + interdental brushes", "Interdental brushes" and "soft picks", neither on smooth nor on approximal surfaces. This result suggests that any possible "deficiencies" in the area of approximal plaque control related to the use of different hygiene tools can be compensated by brushing one's teeth two-times.

Other studies also show that interdental brushes appear to be more effective than dental floss in terms of approximal cleaning performance [7]. Additionally, they find that interdental brushes are easier for patients to use. However, the use of interdental brushes can give rise to problems, which reduces user acceptance. The brushes can easily bend if they are used improperly, which not only greatly reduces their durability, but also leads to a high trauma potential of interdental soft tissues [8] or the danger of tooth hard substance damage [6]. The elastic, metal-free interdental brushes with rubber bristles, which have been on the market for some time, are intended, on the one hand, to be more user-friendly and, on the other hand, to reduce the disadvantages of interdental brushes with metal cores. Studies could show that metal-free interdental brushes with rubber bristles were similarly effective in plaque removal as compared to interdental brushes with metal-cores and nylon bristles over an observation period of 3 to 4 weeks [1, 15]. However, in a one-time application, Abouassi et al. (2014) observed significantly higher plaque reduction when using interdental brushes with metal cores and nylon bristles as compared to the metal-free interdental brushes with rubber bristles, which is in conformance with the results of the present study; the reductions in the approximal plaque index values were found to be higher for interdental brushes than for soft picks. After 4 weeks of use, Abouassi et al. (2014) found no significant differences in the plaque reduction between the two types of brushes. The authors account for these difference in the one-time application to be related to patient compliance. In a survey, the authors found out that the patients preferred the metal-free interdental brushes with rubber bristles over metal-core interdental brushes with nylon bristles; this lead them to the conclusion that the participants had consequently used metal-core interdental brushes for home-based oral hygiene less frequently [1]. Interdental space size varies not only between patients, but also within a dentition. This implies that for an effective cleaning of the interdental space, interdental hygiene tools should be individually selected beforehand, not only taking into consideration the shape and size of the interproximal surfaces, but also user skill and acceptance.

In literature, there are no recommendations or indications with regards to whether the interdental cleaning should be carried out before or after smooth surface brushing. A cleaning of the interdental spaces before smooth surfaces could have the advantage that one already displaces the adhering plaque in the area with the tools for interdental space cleaning and this dislocated plaque could then be better removed with a toothbrush. Additionally, it could also be assumed that the brushing of smooth surfaces prior to interdental cleaning may be contra productive because an incorrect usage of the toothbrush has the potential to press even more plaque into the interdental area, thus making it more difficult to remove after. In the present study, after the first cleaning in the area of the ap-

QHI-API difference												
	total		floss (BFB, FBB)		floss + interdental brush (BFIB, FIBB)		interdental brush (BIB, IBB)		SoftPicks (BSB, SBB)		interdental brush vest. and oral (BI2B, BI2GB)	
	t0–t1	t0–t2	t0–t1	t0–t2	t0–t1	t0–t2	t0–t1	t0–t2	t0–t1	t0–t2	t0–t1	t0–t2
UJ vest.	2.86 ± 0.94	3.73 ± 0.75	2.65 ± 0.93	3.6 ± 0.65	2.78 ± 1.08	3.81 ± 0.85	3.11 ± 0.98	3.82 ± 0.87	2.53 ± 0.73	3.45 ± 0.61	3.24 ± 0.79	3.99 ± 0.67
UJ pal.	0.87 ± 0.74	1.71 ± 0.75	0.54 ± 0.55	1.46 ± 0.67	0.87 ± 0.86	1.89 ± 0.76	0.81 ± 0.66	1.62 ± 0.81	0.72 ± 0.61	1.53 ± 0.66	1.41 ± 0.71	2.06 ± 0.71
LJ vest.	2.47 ± 0.94	3.32 ± 0.72	1.99 ± 1.05	2.85 ± 0.84	2.67 ± 0.99	3.61 ± 0.52	2.58 ± 0.89	3.33 ± 0.69	2.33 ± 0.79	3.19 ± 0.71	2.81 ± 0.79	3.59 ± 0.58
LJ lin.	1.29 ± 0.83	2.33 ± 0.89	1.14 ± 0.86	2.15 ± 0.93	1.33 ± 0.77	2.33 ± 0.89	1.19 ± 0.73	2.27 ± 0.85	1.02 ± 0.76	2.12 ± 0.85	1.76 ± 0.86	2.77 ± 0.85

Table 4 QH-API differences between t0–t1 and t0–t2 of the groups "flossing" (BFB, FBB), "flossing + interdental brushing" (BFIB, FIBB), "interdental brushing" (BIB, IBB), "soft picks" (BSB, SBB) and "interdental brushing from vestibular and oral gel" (BI2B, BI2GB) divided into the vestibular and oral surfaces of the upper jaw (UJ) and lower jaw (LJ)

proximal and the smooth surfaces, slightly higher reductions in the plaque index value were in fact observed in the groups that performed interdental cleaning before smooth surface brushing. However, this was statistically significant only when dental floss was used in approximal areas. Similar results were reported by Mazhari et al. (2018). The authors were able to show that significantly more plaque could be reduced, both approximally and overall, in the group where floss was first used before tooth brushing as compared to the group in which brushing was first performed and then followed by flossing [21]. Nonetheless, the results of the present study lead to the general conclusion that the sequence of the cleaning procedure is not clearly relevant for plaque reduction in the interdental areas.

Not all of the participants in the present study used interdental hygiene tools as part of their home-based oral hygiene and they were therefore not equally adept in using these tools. Preliminary examinations showed that there were big differences in the ability to use interdental hygiene tools between individuals. Thus, it could be determined that the participants were not able to independently reach all approximal surfaces. A standardized use of the hygiene tools through patient self-use would not have been possible, as this would have produced distorted results in the evaluation of the cleaning performance of each hygiene tool. Winterfeld et al. (2014) assessed the brushing behavior and use of floss of 101 young adults using video surveillance. The authors found that, although almost half used floss, only 2 of the adults used it adequately (vertical movements) and only one reached all approximal surfaces [43]. They support the claim made by Sambunjak et al. (2011), in that, often an inadequate flossing technique is employed, resulting in insufficient cleaning of approximal surfaces [27, 43]. In order to be able to circumvent these disadvantages and to create equal conditions, the cleaning of the approximal surfaces was performed by the examiner in the present study. Moreover, the examiner always employed each type of hygiene tool in the same way for each subject. The aim of this pilot study was primary to evaluate which interdental cleaning tool has the potential to lead to the highest possible reduction of the plaque index value, given the circumstances that they are applied correctly in combination with second brushing. The present study design simulates "ideal conditions" with regard to interdental cleaning. The use of interdental brushes from vestibular and oral not only requires a certain degree of skill, but also attention towards the design of the interdental brushes. Due to the user's limited visibility from oral, interdental brushes with a longer, more ergonomically-shaped handle would certainly permit better viewing conditions as well as an easier insertion of brushes into the interdental area from oral. Further investigations are needed in order to evaluate the implementation of home-based, self-responsible oral hygiene.

In the present investigation, a "split-mouth design" was used. This design was chosen to minimize the number of examination appointments, while still testing a maximum number of brushing regimens. The often described disadvantage of a "carry-across effect" [16] does not apply to the results of the current study, given that only a mechanical cleaning was performed and a subsequent evaluation of the plaque indices. This one-time mechanical cleaning has no systemic effect, which could lead to a "carry-across effect". Another disadvantage with a "split-mouth design" lies in the missing barrier between the jaw halves. In

QHI difference												
	total		floss (BFB, FBB)		floss + interdental brush (BFIB, FIBB)		interdental brush (BIB, IBB)		SoftPicks (BSB, SBB)		interdental brush vest. and oral (BI2B, BI2GB)	
	t0–t1	t0–t2	t0–t1	t0–t2	t0–t1	t0–t2	t0–t1	t0–t2	t0–t1	t0–t2	t0–t1	t0–t2
UJ vest.	2.76 ± 0.74	3.30 ± 0.69	2.80 ± 0.82	3.39 ± 0.72	2.58 ± 0.80	3.12 ± 0.78	2.76 ± 0.81	3.20 ± 0.74	2.65 ± 0.66	3.22 ± 0.57	3.01 ± 0.54	3.54 ± 0.55
UJ pal.	0.56 ± 0.49	1.36 ± 0.55	0.51 ± 0.45	1.22 ± 0.58	0.40 ± 0.40	1.33 ± 0.55	0.54 ± 0.50	1.33 ± 0.57	0.62 ± 0.53	1.47 ± 0.51	0.71 ± 0.55	1.47 ± 0.51
LJ vest.	2.17 ± 0.72	2.81 ± 0.99	2.08 ± 0.82	2.85 ± 0.66	2.12 ± 0.68	2.56 ± 0.84	2.10 ± 0.59	2.76 ± 0.47	2.15 ± 0.70	2.85 ± 0.67	2.37 ± 0.78	3.03 ± 0.63
LJ lin.	0.96 ± 0.66	1.96 ± 0.71	0.97 ± 0.61	1.82 ± 0.69	0.88 ± 0.71	1.88 ± 0.70	0.98 ± 0.72	1.90 ± 0.66	0.82 ± 0.59	1.92 ± 0.76	1.15 ± 0.66	2.28 ± 0.66

Table 5 QHI differences between t0–t1 and t0–t2 of the groups "flossing" (BFB, FBB), "flossing + interdental brushing" (BFIB, FIBB), "interdental brushing" (BIB, IBB), "soft picks" (BSB, SBB) and "interdental brushing from vestibular and oral gel" (BI2B, BI2GB) divided into the vestibular and oral surfaces of the upper jaw (UJ) and lower jaw (LJ) (Tab. 1–5: H. Günay und K. Meyer-Wübbold)

the present study, this disadvantage was irrelevant because the mesial approximal surfaces of the central incisors were not included in the assessment, and hence, did not affect the results. All participants were right-handed. In general, it is assumed that the right half of the jaw is more difficult for right-handed people to clean than the left side. A "cross-split-mouth design" was thus intentionally chosen in order to avoid any possible distortions of the results. For each participant, the right upper jaw and left lower jaw were combined together and evaluated separately with respect to the left upper jaw and right lower jaw.

Already in 1948 Bass recommended the use of a system for tooth brushing [5]. In particular, the oral surfaces of mandibular teeth often have more hard and soft plaque than the other tooth surfaces and are neglected during home-based oral hygiene [22]. For this reason, it was recommended that tooth brushing should begin with the inside surfaces of teeth [22, 24]. However, studies have shown that patients predominately brush the vestibular surfaces first [21]. Van der Sluijs et al. (2018) found that there was no significant difference in the reduction of plaque across the dentition, regardless of whether patients initially brushed the oral or vestibular surfaces first [36]. The patients achieved a plaque reduction of 55 % when they started brushing the inside surfaces of the teeth and 58 % when they began with outside surfaces [36]. However, for the lingual surfaces, it was determined that the plaque index could be reduced more if brushing was started from lingual; the authors thus observed a reduction of the plaque index by 73 % when brushing was initially performed from lingual and 67 % when it began from vestibular. However, this difference was not statistically significant [36]. In the current study, the teeth were brushed according to the CIOTI-System. The brushing of the chewing surfaces preceded the brushing of the inside surfaces because, on the one hand, patients find it easier to begin brushing on the chewing surface, and on the other hand, the toothpaste gets the chance to be distributed evenly in the mouth concomitantly with occlusal brushing. In the present investigation, despite prior brushing of the inside surfaces, a notable lower plaque index value reduction was achieved orally in comparison to vestibular after the first brushing, for both the smooth and proximal surfaces; this is consistent with the findings of other studies. Van der Sluijs et al. also reported a smaller plaque reduction for the oral surfaces (67–73 %) compared to the vestibular surfaces (82–83 %) [36]. However, the second brushing procedure applied in this study noticeably reduced this difference. Hence, second brushing seems to have the potential to reach the "problematic areas" associated with home-based oral hygiene.

5. Conclusion

Interdental brushes used from vestibular and oral appear to be the most effective for reducing the plaque index value in approximal surfaces when compared to other interdental cleaning tools. The time point of interdental cleaning (before or after the brushing of smooth surfaces) has no great influence on the reduction of the plaque index value. Furthermore, interdental cleaning should be performed separately and requires time, which is why specifying a general time for home-based oral hygiene is not effective. Second brushing achieves a higher reduction of the plaque index value than one-time brushing for both the smooth and approximal surfaces, regardless of which type of hygiene tool is used for interdental cleaning. Regarding the approximal cleaning, second

brushing can compensate for cleaning "deficiencies" owing to the use of different hygiene tools. It also seems to have the potential to reach the "problematic areas" during home-based oral hygiene, as well as the oral surfaces.

Conflicts of interest:

The authors declare that there is no conflict of interest within the meaning of the guidelines of the International Committee of Medical Journal Editors.

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