

MARC VOGEL<sup>1,3</sup>  
 MATTHIAS ASSENMACHER<sup>2</sup>  
 ANDREA GUBLER<sup>3</sup>  
 THOMAS ATTIN<sup>3</sup>  
 PATRICK R. SCHMIDLIN<sup>3</sup>

<sup>1</sup> Privatpraxis, Unterägeri,  
Switzerland

<sup>2</sup> Institut für Statistik, Ludwig-  
Maximilians-Universität,  
Munich, Germany

<sup>3</sup> Klinik für Zahnerhaltung und  
Präventivzahnmedizin,  
Zentrum für Zahnmedizin,  
Universität Zürich, Zurich,  
Switzerland

#### CORRESPONDENCE

Prof. Dr. Patrick R. Schmidlin  
 Klinik für Zahnerhaltung und  
 Präventivzahnmedizin  
 Zentrum für Zahnmedizin der  
 Universität Zürich  
 Plattenstrasse 11  
 CH-8032 Zurich  
 Tel. +41 44 634 34 17  
 Fax: +41 44 634 43 08  
 Email:  
 patrick.schmidlin@zsm.uzh.ch

SWISS DENTAL JOURNAL SSO 133:  
 576–583 (2023)  
 Accepted for publication:  
 3 April 2023

## Cleaning potential of interdental brushes around orthodontic brackets – an in vitro investigation

#### KEYWORDS

Orthodontics  
 Orthodontic bracket  
 Oral hygiene  
 Plaque  
 In vitro test

#### SUMMARY

This study evaluated the brushing efficacy of different interdental brushes (IDBs) around a multi-bracket appliance in vitro. In four models displaying misaligned and aligned teeth with and without attachment loss, the brushing capacities of three IDBs were tested: a waist-shaped IDB with a diameter of 9 mm at both ends and 5 mm in the middle (B1), a cylindrical brush with a diameter of 9 mm (B2) and one with 5 mm (B3). Before cleaning, the black teeth in the respective models were stained white with titanium (IV) oxide and the percentage of cleaned surface was planimetrically assessed. In addition, the forces applied to the IDBs were also recorded. The effect of brush and model on expected cleaning performance was examined using an analysis of variance (ANOVA).

The cleaning performance of the brushes in decreasing order was B2 > B3 > B1; no significant differences between the different tooth areas and models were found. With regard to force measurements, significant differences were found with the highest and lowest forces IDB (2) and (1), respectively. There was a significant correlation between force and cleaning performance: The higher the force needed the higher was the cleaning performance. In summary, this study showed that the cylindrical IDBs achieved a better cleaning performance than the waist-shaped IDB. Given some shortcomings of this first laboratory study, more research is still needed, but IDBs may represent a valuable yet still clinically underused tool.

## Introduction

Adequate mechanical plaque control is the key in maintaining good oral health, also in patients with fixed orthodontic multi-bracket appliances (ATAK et al. 1996; HUSER et al. 1990). The risk for oral pathologies like caries and periodontal inflammation can thereby be significantly reduced (LIU et al. 2011). Especially demineralization around brackets represents a severe problem (KUKLEVA et al. 2002; BUCK et al. 2011). Various studies have demonstrated that the use of specific fluoride sources and regular instruction in cleaning methods may have a significant impact to reduce the risk of caries (NORDSTRÖM & BIRKHED 2010; DUANE 2012). Moreover, the periodontal health condition of patients with multibracket appliances should be carefully monitored, and a good prophylaxis program and routine diagnostics must also be strictly envisaged in this regard. Studies have highlighted the clinical efficacy in preventing or at least reducing periodontal problems in patients with fixed orthodontic appliances under the premise of adequate oral hygiene (HUBER et al. 1987). In general, it remains a principal clinical concern in orthodontics that pathologies are not promoted by iatrogenic or even elective interventions.

With regard to mechanical aids for cleaning around brackets, various oral hygiene aids are available. Of course, the manual toothbrush remains the most common and established tool. When different electric toothbrushes are compared, the sonic powered brushes seem to perform better than the oscillating rotating counterparts (SCHÄTZLE et al. 2010). However, and in general, electric toothbrushes are not significantly superior to the manual toothbrush in terms of cleaning efficacy, especially when additional aids such as monobrushes and other cleaning agents for the inter-proximal areas are used (JACKSON 1991; ROSEMA et al. 2008). Still, most brushes display some deficits and do not reach all areas that are partially inaccessible due to brackets and wires. Therefore, additional aids are still warranted in patients with multibracket appliances for cleaning the buccal area between the brackets and the ligated archwire.

The use of interdental brushes (IDBs) around the plaque-retentive areas under the wires around brackets may be a supplementary method of caring for these areas even more efficiently, which was highlighted by a previous report based on the Zurich laboratory model for evaluating the accessibility and cleanability of interdental spaces in teeth with brackets (SCHMIDLIN et al. 2022). This study used a scoring system referring to six surfaces around brackets and showed that the gathered data can be applied either dichotomously (plaque present/yes/no), with quantitative numerical values (percentage of cleaned/uncleaned areas), or respective scores. The results re-

vealed subtle differences in terms of cleaning efficacy already between different interdental waist-shaped brushes with different filament numbers. The model could therefore also be used to compare the cleansing efficacy of waist-shaped IDBs to that of their straight cylindrical counterparts. A previous study has shown that – in the interdental area – waist-shaped brushes lead to significantly lower plaque scores, especially in difficult to access buccal and lingual line angles (CHONGCHAROEN et al. 2012).

Based on this previous work, the aim of the present study was to establish a new in vitro model and to test the brushing efficacy of three commercially available IDBs with comparable diameters (two cylindrical ones at diameters of 5 and 9 mm, respectively, and one waist-shaped IDB at 9–5–9 mm) around orthodontic brackets in vitro. The null hypothesis was that all IDBs would clean equally with identical pressures applied.

## Materials and methods

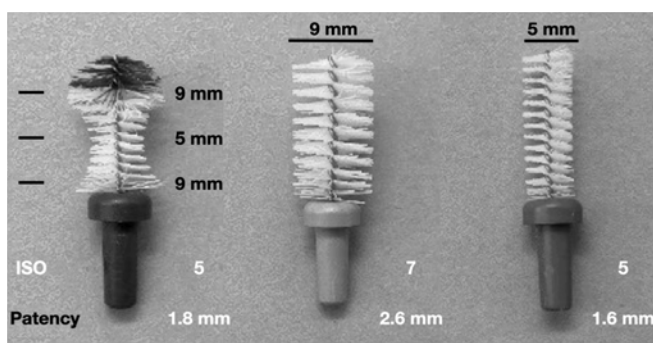
### Interdental brushes

Three IDBs with comparable filament size and diameter (Top Caredent, Zurich, Switzerland) were tested: a waist-shaped IDB with diameters of 9 mm at both ends and 5 mm in the middle (B1), a cylindrical brush with a diameter of 9 mm (B2) and one with a diameter of 5 mm (B3) (Fig. 1). The brush diameters were selected based on pre-tests on the models. The choice of the set of corresponding brushes was defined by a clinically acceptable patency in our models. To test the cleaning performance and the associated force for insertion into the interdental spaces, anatomic tooth models and a brushing machine were custom-made representing the maxillary anterior region from tooth 13 to 23.

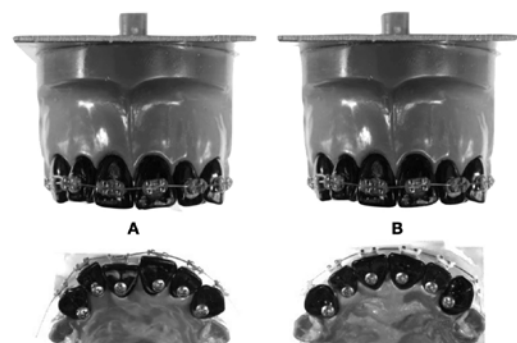
### In vitro tooth models

The model teeth were cast from black-colored acrylic resin and fitted into a pink-colored gingival mask to emulate the in vivo anatomy of four clinical situations as closely as possible (Fig. 2). For this purpose, model teeth (Kilgore International, Chicago, USA) were used as templates for the teeth and respective molds were fabricated using a duplicating silicone material (Siladent Dr. Böhme & Schöps GmbH, Goslar, Germany). The teeth were then cast from liquid acrylic with a black color (Siladent Dr. Böhme & Schöps GmbH, Goslar, Germany).

For the production of the gingival masks, anatomic models (Kilgore International, Chicago, USA) were used as a template for the soft-tissue mold. These were adapted by hand to simulate misaligned teeth with crowding and an aligned dentition. For this purpose, anatomic models were individually fabricated



**Fig. 1** Illustration of the different IDBs used in the present study with respective diameters and patency as well as ISO classification



**Fig. 2** Illustration of the two models representing misaligned teeth with crowding (A) and aligned teeth (B)

**Tab. 1** Averaged cleaning performance over all respectively located tooth surfaces after brushing with the different brushes (waist-shaped: B1; cylindrical 9 mm: B2; cylindrical 5 mm: B3) on the two models (A and B) expressed as percentage of cleaned surface (mean values and standard deviations)

Brush	Group (model)	incisal		middle		cervical	
		mesial	distal	mesial	distal	mesial	distal
B1	A	48 ± 27	39 ± 22	54 ± 14	57 ± 19	8 ± 10	13 ± 20
	B	57 ± 26	51 ± 20	52 ± 22	49 ± 24	2 ± 3	3 ± 4
B2	A	73 ± 25	82 ± 15	80 ± 22	86 ± 18	60 ± 21	59 ± 22
	B	79 ± 21	79 ± 22	80 ± 16	78 ± 20	31 ± 18	32 ± 22
B3	A	76 ± 17	65 ± 22	74 ± 17	59 ± 17	57 ± 19	42 ± 21
	B	63 ± 24	75 ± 23	62 ± 13	64 ± 22	29 ± 15	35 ± 22

and supplemented with wax (Belladi Ruscher modeling wax “Superior” pink, Shop Belladi Ruscher Schleusser GmbH, Amriswil, Switzerland) if needed. Replicas were then made (Siladent Dr. Böhme & Schöps GmbH, Goslar, Germany), and blocks were cast from liquid acrylic (1:1 A+B SilaPoly components A: Base with B: Catalysat reddish Lot: 49011542, RER: 24002, from Siladent Dr. Böhme & Schöps GmbH, Goslar, Germany), which were dyed pink (SilaPoly Color Lot: 2231548, REF 24002, Siladent Dr. Böhme & Schöps GmbH, Goslar, Germany). While the misaligned models were intended to simulate

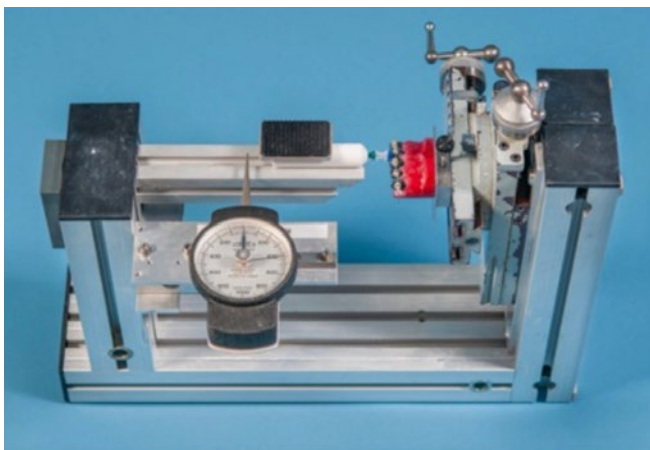
the situation at the beginning of orthodontic treatment, models with straight teeth aimed to simulate the situation after the orthodontic leveling phase.

Orthodontic brackets were placed on the buccal surfaces on all teeth as follows: Brackets (American Orthodontics, Washington, USA) were attached to the central buccal surfaces of the teeth vertically aligned to the respective tooth axis. In order to fix the brackets, small round notches were milled in the areas to be bonded, each 0.5 mm wide and deep (Maillefer rose drill D0023: RA medium, 28 mm, ISO 018, Densply, Charlotte, USA). A primer was then applied (SR Connect, Ivoclar Vivadent AG, Schaan, Liechtenstein) and cured for 20 seconds (Bluephase G2, Ivoclar Vivadent AG, Schaan, Liechtenstein). The brackets were then bonded with dual-curing material (Variolink Esthetic, Ivoclar Vivadent AG, Schaan, Liechtenstein), which was also light-cured for 20 seconds. A round 014 steel wire (Ormco Corporation, California, USA) with elastic rubber ligatures (G&H Orthodontics, Franklin, USA) was ligated into the brackets.

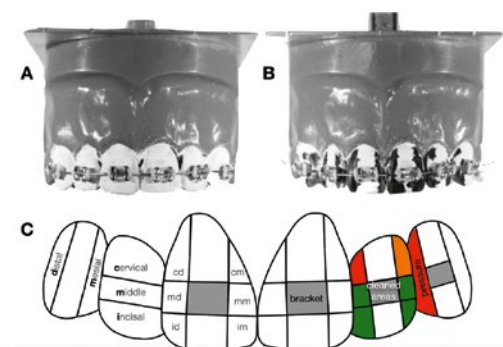
### Brushing device, cleaning and force evaluation process

For reproducible testing, a brushing device was custom-made to test the cleaning efficacy of the different IDBs (Fig. 3). The test apparatus was made of Kanya frames (Kanya AG, Rüti, Switzerland). The applied motion sequences were performed manually. With the aid of this appliance, the IDB was inserted into the labial surface between the brackets and the wire. The models were fixed in such a way that the tooth axes were horizontally positioned. The positioning of the models in the appliance was achieved by means of a cross table with an attached adapter. This cross table allowed the models to be aligned in the X and Y directions. In this setup, the cleaning efficacy and the pressure of the individual brushes could be determined in predefined sites (Fig. 4).

Before brushing, the black teeth were evenly coated with a titanium oxide suspension (suspension of titanium oxide in ethanol 26% by volume in a ratio of 1:3), which was carefully fixed using a hair dryer at a distance of 30 cm for 60 s. The coated models were then placed in the appliance. The spaces between teeth 13 to 23 of each model were tested. This resulted actually in five interdenal spaces. The IDBs were applied five times. Each of the sixteen models was cleaned once with each of the three test brushes. Subsequently, the tested models were digitally photographed with alignment to the respec-

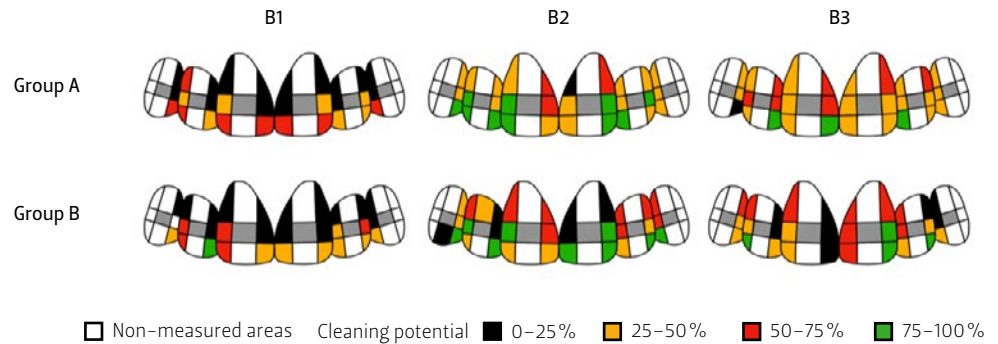


**Fig. 3** Experimental setup showing the measuring device



**Fig. 4** Coated tooth model before (A) and after brushing (B). The cleaned areas are visible as black or dark gray areas. Cleaning potential and pressure was measured on predefined areas around the brackets and visualized with colors (C) (more details in the text).

**Fig. 5** Visual representation of the approximal cleaning results for the different brushes (B1-3) and two model types (groups A/B). In our test setup, the cylindrical brushes performed better than the waist-shaped one, especially on the cervical region. For more information, please consult the materials and methods section.



tive interdental spaces. This resulted in five images per model. The resulting 2D images were evaluated with the aid of a planimeter. The surfaces of the evaluated teeth were divided into eight regions around the brackets. Each surface was evaluated individually, and the percentage of cleaned area was calculated. Tooth areas that were free of the white coating after the brushing test and appeared black or gray again were considered to be potentially cleaned (IMFELD et al. 2000).

The cleaning efficacy of the different brushes was visualized arbitrarily on the basis of the cleaning efficacy as follows:

- between 0 to 24.9% (black)
- between 25 to 49.9% (red)
- between 50 to 74.9% (orange)
- between 75 to 100% (green)

For the measurement of the applied forces, the device was modified with a force gauge, which was additionally attached and allowed for measurements in the range between 0 cN to 1000 cN. Depending on the design of the IDB and the available space, more or less pressure was required. The forces were also visualized arbitrarily on the basis of the cleaning efficacy: Green stood for little applied pressures, and therefore easy handling at respective pressures ranging from 0 to 200 cN was defined. Ranged between 200 to 500 cN indicated an elevated required pressure and more difficulty to apply and clean (orange), whereas the color red stood for pressures at >500 cN, i.e. the wire of the brush started bending, or the brush could not even be inserted (>1000 cN).

### Data presentation and statistics

Statistical analysis was performed using the computer software R (R CORE TEAM 2021) with the aid of the packages dplyr (WICKHAM et al. 2022), ggplot2 (WICKHAM 2016), and xtable (DAHL et al. 2019).

The effect of brush and model on expected cleaning performance was examined using an analysis of variance (ANOVA). Categorization of the cleaning performance was only for visualization and not for subsequent analyses. A significance level of  $\alpha = 0.05$  was used for all statements made here. Categorization of the pressures applied was only for visualization and not for the subsequent analyses. A significance level of  $\alpha = 0.01$  was used for all statements made here.

### Results

The results of the cleaning potential are numerically provided in Table I and graphically elucidated in Figure 5. The latter clearly shows distinct cleaning features and differences between the different brushes with better cleaning tendencies favoring the cylindrical brushes, slightly preferring those with the larger diameter. The waist-shaped IDB showed clear deficits in the cervical and sometimes in the middle area. A clear cleaning pattern between the different models and tooth alignment conditions was not evident. In general, mean cleaning values over 75% were rarely observed and – if – mostly for the thick cylindrical brush in the incisal and middle areas. A clear difference between mesial and distal areas was not evident.

The lowest pressures were clearly observed within all models treated with the thin IDB, followed by the waist-shaped IDB, which also showed low pressure profiles for the models representing misaligned teeth and therefore interproximal steps and increased spaces. The aligned models showed medium pressure forces toward the middle of the tooth arch (Tab. II and Fig. 6). The IDB with the thicker diameter evidently showed the highest pressures.

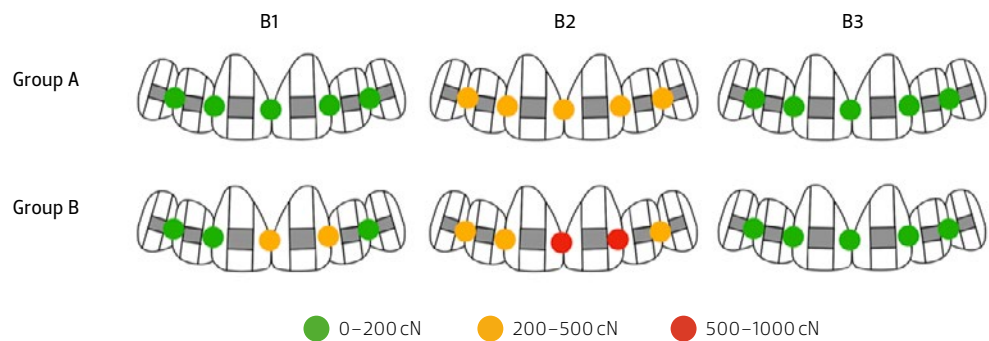
Overall, the results showed that the interaction of both influencing variables, the anatomic model type and the type of the brush, had no significant effect on the cleaning performance.

**Tab. II** Applied force (in cN) for bending the tested brushes from the incisal direction (mean values and standard deviations)

Brush	Group (model)	13/12	12/11	11/21	21/22	22/23
B1	A	120 ± 0	140 ± 0	153 ± 12	123 ± 6	89 ± 8
	B	100 ± 0	133 ± 12	243 ± 15	210 ± 17	130 ± 10
B2	A	320 ± 0	380 ± 0	400 ± 20	353 ± 12	277 ± 15
	B	413 ± 15	500 ± 20	507 ± 12	533 ± 15	420 ± 10
B3	A	65 ± 4	85 ± 5	88 ± 2	71 ± 3	55 ± 3
	B	79 ± 4	95 ± 1	100 ± 0	123 ± 15	90 ± 10



**Fig. 6** Visual representation of the pressures applied during insertion of the different brushes (B1–3) among the two model types (groups A/B). For more information, please consult the materials and methods section.



Thus, it can be concluded that the effectiveness of the brushes does not depend on the anatomic model used. However, the type of the brush used as well as the anatomic model have a significant effect on the cleaning performance (Tab. III).

## Discussion

This study applied a novel in vitro setup for screening the cleaning potential of interdental brushes (IDBs) around orthodontic brackets in standardized tooth models mimicking selected clinical situations, i.e. aligned and misaligned teeth with and without attachment loss, respectively. For this purpose, a brushing machine was modified for reproducible and standardized manual brushing cycles allowing the measurement of cleaning ability and applied forces.

Our hypothesis that all brushes clean equally well was rejected. Nevertheless, while the cylindrical IDB with larger diameter performed best, it also displayed the highest application force. In contrast, the small diameter cylindrical IDB showed less cleaning efficacy, however, the results were still better than the ones achieved with the waist-shaped counterpart. This is in contrast to the general understanding that waist-shaped IDBs clean better especially in difficult to clean areas (SCHNABL et al. 2020; BAUMGARTNER et al. 2019). Nevertheless, one has to keep in mind, that this particular IDB design was originally intended to be applied for approximal spaces around teeth and implants (CHONGCHAROEN et al. 2012; CHEN et al. 2020; PAQUÉ et al. 2020). It seems that a simple parallel insertion under an archwire around brackets using a simplified straight back-and-forth movement in the axis of the tooth does not represent a comparable situation. In general, factors like filament thickness, length, orientation and density influence patency, contact capacity and thus cleaning efficacy as well as the required force for insertion. Although all IDBs were fabricated from the same company displaying comparable filaments and arrangements, ISO and patency numbers are different in the three tested brushes. The ISO

standard also classifies IDBs according to their patency or passage hole diameter (PHD). The latter thereby actually describes the smallest “interdental space” (simply represented as a round whole in a metal plate in mm) into which a respective IDB fits without bending the wire. This approach currently still represents the only reliable or reproducible method that enables to compare IDBs of different size and arrangement (SEKUNDO & STAEHLE 2020). However, using the ISO number alone is not sufficient to distinguish between different sizes (STAEHLE et al. 2021). To learn how these parameters relate to orthodontic applications additional work is needed.

Not surprisingly, the wide cylindrical IDB with the greatest ISO and patency number revealed the greatest forces during insertion and – in line with this – represented the best cleaning potential. This, because the filaments were wide and provided over the whole instrumentation length a good contact potential and pressure. Notably, as a critical observation during the setup of the experiments, the wires also tended to slightly bent under some instances; in a few cases, the IDB could not even be inserted. However, this also reflects the fine line between cleaning efficacy and possible damage potential. In this context, a higher risk for gingival trauma should also be considered. Given these findings, one can consider this brush – despite displaying actually the best results – not necessarily and generally recommendable for daily use due to potential handling characteristics and maybe even the risk of injury including also the risk of bracket detachment and wire displacement or bending.

The use of IDBs for cleaning the difficult-to-clean areas around brackets is not new. Previous evidence from systematic reviews could, however, not show that the general use of IDBs is recommendable for orthodontic patients with multibracket appliances (GOH et al. 2013). Clinical studies already showed that cylindrical IDBs can be successfully used for cleaning and plaque reduction (BOCK et al. 2010). Especially for removing food debris, this brush type shows better results. Unfortunately, the overall availability of literature in that respect remains scarce.

The presented model and approach could be a valuable screening tool for the screening of IDBs and other devices in general and represent a valuable additional method to the ISO classification, which seems to have limitations when selecting proper instruments for this specific indication. But additional research is needed in this regard.

In this context, one has to clearly highlight the limitations of this simplified laboratory approach. Of course, the teeth and alignment modalities are arbitrarily and exemplarily chosen and do not reflect individual cases. Therefore, the results cannot be generalized. In addition, the movement of

**Tab. III** Results of the ANOVA evaluation

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
<b>Brush</b>	2	31908.26	15954.13	34.24	0.0000
<b>Model</b>	1	1962.49	1962.49	4.21	0.0417
<b>Brush: model</b>	2	800.05	400.02	0.86	0.4256
<b>Residuals</b>	174	81084.61	466.00		

the IDBs is very much simplified. Additional 3D adaptive cleaning motions were not considered. However, this may rather lead to an underestimation of the overall cleaning efficacy, since the number of strokes was limited and the cleaning not individually optimized by adapting the brushes. Another drawback of this study was the coating, which may not have been complete and uniform and certainly did not reflect an actual natural biofilm or debris. However, it ensured the determination of contact brushing by easy removal of the dried slurry. Notably, the model setting for a correct horizontal insertion direction in the areas of interest was individually adjusted by hand each time. This could theoretically have led to slight differences in the angulation or position. A completely automated and standardized method would be warranted. In addition, the wire that was used in our study represents a rather thin and flexible wire for short-time leveling. The bending characteristics of maybe thicker wire types could additionally interfere with the evaluated parameters, and respective differences have not been taken into considerations. In conclusion, this study showed that the cylindrical IDBs achieved a better cleaning performance than the waist-shaped IDB when applied in this setup. Given the above-mentioned methodological considerations and shortcomings, more research is certainly needed in this context, however, IDBs may represent a valuable but still clinically underused tool that merits further investigation.

## Zusammenfassung

### Einleitung

Bei Patienten mit festsitzenden kieferorthopädischen Multi-bracket-Apparaturen ist es besonders wichtig, die mechanische Plaque-Entfernung optimal zu gewährleisten, um durch Plaque bedingte Folgeschäden wie Karies oder Gingivitis zu verhindern. Ziel dieser Studie war die Etablierung einer In-vitro-Modellreihe zur Testung der Reinigungseffizienz verschiedener Interdentalbürsten der bukkalen Flächen um kieferorthopädische Brackets einer Multibracket-Apparatur. Dafür wurden neue Zahnmodelle und eine neue Bürstmaschine verwendet.

### Material und Methoden

Getestet wurden drei Interdentalbürsten (IDB): (B1) eine taillierte IDB, die an beiden Enden einen Durchmesser von 9 mm und in der Mitte einen von 5 mm aufwies, sowie zwei zylindrische Bürsten mit korrespondierenden Durchmessern zum Vergleich (B2 und B3). Zum Testen der Reinigungsleistung und der dazugehörigen Kraft für das Einführen in die Interdentalräume wurden Zahnmodelle hergestellt und eine Bürstmaschine modifiziert. Die Zahnmodelle wurden der Anatomie der Oberkieferfront 13–23 nachempfunden. Die Modellzähne wurden aus schwarz eingefärbtem Kunststoff gegossen und in eine Gingivamaske eingepasst. Es wurden zwei Modelltypen erstellt: Ein Modell wies verschachtelte Zähne auf (A), während das andere eine gerade Zahnreihe repräsentierte (B). Auf den Bukkalflächen wurden kieferorthopädische Brackets angebracht, und es wurde ein runder 014er-Draht einligiert. Anschliessend wurden die Zahnmodelle mit Titan(IV)-Oxid weiss eingefärbt. Mit einer Testapparatur mit genormter Modellpositionierung konnte manuell ein reproduzierbarer Bewegungsablauf der zu testenden Interdentalbürsten parallel zu den Zahnflächen simuliert werden. Dabei wurden die Interdentalbürsten von inzisal in die Labialfläche zwischen den Brackets und dem Draht eingeführt. Für die Auswertung

wurden die gereinigten Flächen planimetrisch erfasst. Die Apparatur wurde ebenfalls für eine Kraftmessung modifiziert und ein Kraftmessgerät angebracht. So konnte der Druck in cN gemessen werden, der aufgewendet werden musste, um die Interdentalbürste in den bukkalen Raum zwischen den Brackets und dem einligierten Draht einzuführen. Der Einfluss von Bürste und Modell sowie der Interaktion zwischen Bürste und Kraft auf die Reinigungsleistung wurden mittels einer ANOVA analysiert.

### Resultate

Die mit Abstand beste Reinigungsleistung zeigte die breitere zylindrische Bürste. Zwischen den Reinigungsleistungen bei den einzelnen Zahnzwischenräumen und Modellen gab es einen signifikanten Unterschied. Auch bei der Kraftmessung gab es einen deutlich wahrnehmbaren Unterschied; hier zeigte die Bürste mit der grössten Reinigungsleistung auch die grösste Kraftanwendung, gefolgt von der taillierten und der dünneren zylindrischen IDB. Die Korrelation zwischen Reinigungsleistung und Kraft erwies sich ebenfalls als signifikant: Je höher die benötigte Kraft, desto höher war die Reinigungsleistung.

### Diskussion

Zusammenfassend wurde die dünnere zylindrische IDB von den drei getesteten Bürsten für den klinischen Gebrauch approximal um kieferorthopädische Brackets am besten eingestuft, da das Verhältnis von Kraft für das Einführen und Reinigungsleistung insgesamt das beste Resultat erzielte. Die taillierte IDB wies keine bessere Reinigungsleistung auf. Allerdings muss eingeräumt werden, dass mit der bestehenden Gängigkeit der taillierten Bürsten noch grössere Durchmesser hätten verwendet und das Resultat dementsprechend theoretisch hätte verbessert werden können. In diesem Zusammenhang sind weitere vergleichende Studien notwendig und geplant.

## Résumé

### Introduction

Chez les patients porteurs d'appareils orthodontiques fixes à brackets multiples, il est particulièrement important d'assurer une élimination mécanique optimale de la plaque dentaire afin d'éviter les dommages qu'elle peut provoquer, comme la carie et la gingivite. L'objectif de cette étude était de créer une série de modèles in vitro pour tester l'efficacité du nettoyage, par différents types de brochettes interdentaires, des surfaces vestibulaires situées autour des brackets orthodontiques d'un appareil multi-brackets. Pour ce faire, de nouveaux modèles de dents et une nouvelle machine à brosser ont été utilisés.

### Matériaux et méthodes

Trois brochettes interdentaires (BID) ont été testées: une BID cintrée d'un diamètre de 9 mm à chaque extrémité et de 5 mm au centre (B1), et à titre comparatif, deux brochettes cylindriques de diamètres correspondants (B2 et B3). Pour tester l'efficacité du nettoyage et la force nécessaire à l'introduction dans les espaces interdentaires, des modèles de dents ont été réalisés et une machine à brosser a été modifiée. La réalisation des modèles dentaires s'est inspirée de l'anatomie de la région des 13–23 du maxillaire antéro-supérieur. Les dents modèles ont été coulées en résine de couleur noire et ajustées dans un masque gingival. Deux types de modèles ont été réalisés: un modèle présentait des dents imbriquées, alors que l'autre était constitué d'une rangée de dents alignées de façon rectiligne (B). Des

brackets orthodontiques ont été placés sur les faces vestibulaires et un fil métallique de 014 section ronde y a été ligaturé. Puis les modèles de dents ont été colorés en blanc avec de l'oxyde de titane (IV). Avec un appareil de test utilisant un positionnement normalisé du modèle de brosse interdente à tester, il a été possible de simuler manuellement, pour chaque modèle testé, un mouvement reproductible parallèle aux surfaces dentaires. Lors du test, les brossettes interdentaires ont été insérées par voie incisale sur la face vestibulaire, entre les brackets et le fil métallique. Pour l'évaluation, les surfaces nettoyées ont été déterminées et enregistrées par planimétrie. L'appareillage a également été modifié, avec ajout d'un dynamomètre pour permettre la mesure de la force appliquée. Ainsi, il a été possible de mesurer en cN la pression à exercer pour l'insertion de la brosse interdente dans l'espace vestibulaire situé entre les brackets et le fil métallique ligaturé. L'influence, sur la performance de nettoyage, du type de brosse et du modèle dentaire, d'une part, et de l'interaction entre la brosse et la force exercée, d'autre part, a fait l'objet d'une analyse de variance (ANOVA, *analysis of variance*) globale.

## Résultats

C'est la brosse cylindrique la plus large qui a présenté, et de loin, les meilleures performances de nettoyage. La différence

des performances de nettoyage a été significative pour les différents espaces interdentaires et pour les différents modèles. La mesure de la force appliquée a également montré une différence notable; à cet égard, la brosse ayant la plus grande capacité de nettoyage a également nécessité l'application de la force la plus grande, suivie par la BID cintrée et enfin par la BID cylindrique plus fine. La corrélation entre la performance de nettoyage et la force requise s'est également révélée significative: la performance de nettoyage était d'autant meilleure que la force requise était plus grande.

## Discussion

En résumé, parmi les trois brossettes testées, c'est la BID cylindrique plus fine qui a été la mieux classée pour l'utilisation clinique au niveau interproximal autour des brackets orthodontiques, car le rapport entre la force d'insertion et l'efficacité de nettoyage a obtenu le meilleur résultat global. La BID cintrée n'a pas obtenu une meilleure performance de nettoyage. Il faut toutefois admettre qu'il aurait été possible d'utiliser des brossettes cintrées de diamètre encore plus grand que les modèles standard utilisés, ce qui aurait permis théoriquement d'améliorer les résultats. Dans ce contexte, d'autres études comparatives sont nécessaires, et prévues.

## References

- ATAK NE, SANDY JR, ADDY M:** Periodontal and microbiological changes associated with the placement of orthodontic appliances. A review. *J Periodontol* 67(2): 78-85 (1996).
- BAUMGARTNER G, WIEDEMEIER DB, HOFER D, SENER B, ATTIN T, SCHMIDLIN PR:** In vitro cleaning potential of waist-shaped interdental brushes. *Swiss Dent J* 12;129: 360-367 (2019).
- BOCK NC, VON BREMEN J, KRAFT M, RUF S:** Plaque control effectiveness and handling of interdental brushes during multibracket treatment - a randomized clinical trial. *Eur J Orthod* 3: 408-413 (2010).
- BUCK T, PELLEGRINI P, SAUERWEIN R, LEO MC, COVELL DA JR, MAIER T, MACHIDA CA:** Elastomeric-ligated vs self-ligating appliances: a pilot study examining microbial colonization and white spot lesion formation after 1 year of orthodontic treatment. *Orthodontics (Chic.)* 12: 108-121 (2011).
- CHEN Q, GE Y, CHAI J, FENG H, LIU J, PAN S:** The Effectiveness of Waist-Shaped and Straight-Shaped Interdental Brushes in Cleaning Implant Overdenture Attachments: A Self-Controlled Clinical Trial. *J Oral Implantol* 46: 594-601 (2020).
- CHONGCHAROEN N, LULIC M, LANG NP:** Effectiveness of different interdental brushes on cleaning the interproximal surfaces of teeth and implants: a randomized controlled, double-blind crossover study. *Clin Oral Implants Res* 23: 635-640 (2012).
- DUANE B:** 5,000 ppm F dentifrice for caries prevention in adolescents. *Evid Based Dent* 13: 43-44 (2012).
- DAHL DB, SCOTT D, ROOSEN C, MAGNUSSON A, SWINTON J:** xtable: Export Tables to LaTeX or HTML. R package version 1.8-4. <https://CRAN.R-project.org/package=xtable> (2019).
- GOH HH, FERNANDEZ MAULEFFINCH LM:** Interspace/interdental brushes for oral hygiene in orthodontic patients with fixed appliances. *Cochrane Database Syst Rev* 18: CD005410 (2013).
- HUBER SJ, VERNINO AR, NANDA RS:** Professional prophylaxis and its effect on the periodontium of full-banded orthodontic patients. *Am J Orthod Dentofacial Orthop* 91: 321-327 (1987).
- HUSER MC, BAEHNI PC, LANG R:** Effects of orthodontic bands on microbiologic and clinical parameters. *Am J Orthod Dentofacial Orthop* 97: 213-218 (1990).
- IMFELD T, SENER B, SIMONOVIC I:** In-Vitro-Untersuchung der mechanischen Wirkung von handelsüblichen Handzahnbürsten. *Acta Med Dent Helv* 5: 37-47 (2000).
- JACKSON CL:** Comparison between electric toothbrushing and manual toothbrushing, with and without oral irrigation, for oral hygiene of orthodontic patients. *Am J Orthod Dentofacial Orthop* 99: 15-20 (1991).
- KUKLEVA MP, SHETKOVA DG, BEEV VH:** Comparative age study of the risk of demineralization during orthodontic treatment with brackets. *Folia Med (Plovdiv)* 44: 56-59 (2002).

- LIU H, SUN J, DONG Y, LU H, ZHOU H, HANSEN BF, SONG X: Periodontal health and relative quantity of subgingival *Porphyromonas gingivalis* during orthodontic treatment. *Angle Orthod* 81: 609–615 (2011).
- NORDSTRÖM A, BIRKHED D: Preventive effect of high-fluoride dentifrice (5,000 ppm) in caries-active adolescents: a 2-year clinical trial. *Caries Res* 44: 323–331 (2010).
- PAQUÉ PN, ATTIN T, ENDER A, AL-MAJID A, WEGEHAUPT F, SENER B, SCHMIDLIN PR: Impact of interdental brush shape on interpapillary cleaning efficacy – a clinical trial. *Sci Rep* 13; 10: 7922 (2020).
- R CORE TEAM: R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org> (2021).
- ROSEMA NA, TIMMERMAN MF, VERSTEEG PA, VAN PALENSTEIN HELDERMAN WH, VAN DER VELDEN U, VAN DER WEIJDEN GA: Comparison of the use of different modes of mechanical oral hygiene in prevention of plaque and gingivitis. *J Periodontol* 79: 1386–1394 (2008).
- SCHNABL D, GOEBEL G, KADLETZ A, GAENZER H, STEINER R, LAIMER J, KAPFERER-SEEBACHER I: Cleansing efficacy of waist-shaped inter-dental brushes. A randomized-controlled crossover study. *J Clin Periodontol* 47: 30–35 (2020).
- SEKUNDO C, STAEHLE HJ: Mapping the Product Range of Interdental Brushes: Sizes, Shapes, and Forces. *Oral Health Prev Dent* 18: 343–354 (2020).
- SCHÄTZLE M, SENER B, SCHMIDLIN PR, IMFELD T, ATTIN T: In vitro tooth cleaning efficacy of electric toothbrushes around brackets. *Eur J Orthod* 32: 481–489 (2010).
- SCHMIDLIN PR, SCHMIDLIN AD, GUBLER A, ATTIN T, LUSSI A: Plaque bei Brackets: Probleme und Lösungen. *Swiss Dent J* 132: 354–355 (2022).
- STAEHLE HJ, FRESE C, SEKUNDO C: Mechanical plaque control of the interdental space with the “Heidelberg set”. *Quintessence Int* 52: 176–186 (2021).
- WICKHAM H: *Ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag, New York. <https://ggplot2.tidyverse.org> (2016).
- WICKHAM H, FRANÇOIS R, HENRY L, MÜLLER K: *dplyr: A Grammar of Data Manipulation*. R package version 1.0.9. <https://CRAN.R-project.org/package=dplyr> (2022).