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Running head: Cleaning efficacy around brackets

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The purpose of this laboratory study was to assess the potential cleaning efficacy of different tooth brushes around brackets in vitro.

Standard and Mini Diamond™ brackets were fixed on colored teeth in a special model, coated with white titanium oxide and brushed in a machine with the different manual tooth brushes (3 different Types: planar, staged and V-shaped bristle field) tested with horizontal motion for 1 minute. After brushing, the teeth were scanned and the black surfaces were planimetrically assessed using a grey scale. Tooth areas which were black again after brushing indicated tooth surface contact of the filaments. Remaining white tooth areas around the brackets indicated “plaque-retentive” niches.

In the most critical area of 2 mm around the brackets, there was no statistically significant difference between all the different tooth brushes evaluated. The untouched area ranged from 11 to 26 percent of the initially whitened tooth surface. By pooling the tooth brushes according to their design, the median cleaning efficacy v-shaped (73.1%) and staged (75.6%) tooth brushes resulted in significantly superior cleaning efficacy than planar tooth brushes (60.7%) for standard bracket. For the mini bracket type, staged tooth brushes showed a significantly better mean cleaning efficacy (77.8%) than planar (65%) and v-shaped (72.4%) tooth brushes.

Staged and V-shaped brush designs resulted in superior cleaning efficacy of teeth with fixed orthodontic attachments than tooth brushes with a planar bristle field. None of the tested tooth brushes showed consistent, significantly higher cleaning efficacy than the others in this in vitro experiment.

Introduction:

Patients undergoing orthodontic treatment with fixed appliances face a challenging oral hygiene situation. Orthodontic bands, brackets, and wires are impediments to brushing and flossing, thus facilitating the accumulation of plaque and compromising gingival health. It is well documented that orthodontic treatment with fixed appliances is accompanied by an increased risk of caries (Zachrisson, 1976; O'Reilly and Featherstone, 1987) and gingivitis (Legott et al., 1984; Huser et al., 1990). Microbiological changes after the insertion of orthodontic appliances have been demonstrated. Increasing numbers of *Streptococcus mutans* and lactobacilli after bonding of fixed appliances have been described (Liu et al., 2004). Other reports revealed statistically significant increases in suspected periodontal pathogens such as spirochetes, motile rods, and other gram-negative organisms (Perinetti et al., 2004).

Applications of fluoride and/or antibacterial agents are recommended to reduce these unwanted side effects (Øgaard et al., 1980, 1988). Such measures are, however, dependent on either frequent professional oral hygiene or patient compliance. Sealing of the enamel surface with resin-based bonding agents or even the application of veneers have been proposed to protect enamel against demineralization (Fornell et al., 2002; Miwa et al., 2001).

Effective brushing of teeth is, however, still the most important preventive measure. Numerous types of tooth brushes have been designed and promoted for orthodontic patients. However, no study has so far reported efficacy results of different "orthodontic tooth brushes" under standardized *in vitro* conditions.

The purpose of this study was to assess the cleaning efficacy of nine different tooth brushes currently marketed in Switzerland under standardized laboratory conditions using a well-established test method (Imfeld et al., 2000) and to quantify enamel areas with inadequate filament contact in a custom-made model of an upper anterior segment with bonded brackets.

MATERIAL AND METHODS:

The nine tooth brushes tested are listed in Table 1 and depicted in Figure 1. The brush-heads were mounted on a single-place automated brushing machine, which moved them over a custom-made tooth model of an anterior front segment. The gum line represented mild gingival recession. The model teeth were black and had brackets glued to the labial surfaces (Figure 2). On teeth 11 and 12, standard Twin Diamond™ (Ormco Europe AG, Al Amersfoort, Netherlands) brackets were placed, whereas on teeth 21 and 22 Mini Diamond™ (Ormco Europe AG) brackets were bonded with Transbond™ XT (3M Unitek, Monrovia, California, USA) according to the manufacture's guideline. Before brushing, all black tooth surfaces were coated with white titanium oxide simulating 100 percent plaque accumulation on the tooth surfaces. Tooth surfaces reappearing black after brushing had been touched by the filaments of the tested tooth brushes and were regarded as potentially cleaned. The total areas to be cleaned around the brackets were approximately 119mm^2 for the teeth with standard brackets (tooth 11: 70mm^2, tooth 12: 49mm^2) and 127mm^2 for the teeth with mini brackets (tooth 21: 75mm^2, tooth 22: 52mm^2). The load applied under the chosen experimental conditions was 250 g. Only horizontal movements were applied for one minute (30 mm excursion / 60 strokes) to simulate the most frequently used ineffective brushing method and to simulate a worst case scenario. One brush of each type was used six times on the same model with the bristles perpendicular to the tooth surfaces.

After every treatment, the teeth were scanned (Hewlett Packard C1750A, Houston, Texas, USA), images were digitized, and the percentage of cleaned surface (re-appearing black) was measured planimetrically using custom-made software with a grey scale threshold. The measurements were made at three zones of interest, namely the cervical, the incisal and the bracket area. The latter was defined as extending 2 mm around the brackets (Figure 3).

Statistical analysis was performed with StatView Version 4.51 (Abacus Concepts Inc., Berkeley, California, USA). The results of the cleaning efficacy, expressed as percentage of the cleaned area, were reported using median values and interquartile ranges (IQR). The Kruskal–Wallis one-way test of variance was used for individual comparison of the brush types. Bonferroni adjustment was applied for multiple testing.

To compare the two different bracket sizes, the Wilxon-signed rank test was applied for each tooth brush type. The level of significance was set at $\alpha = 0.05$.

RESULTS

The results of the planimetric assessment of the median cleaning efficacy (cleaned or uncleaned area expressed as a percentage of the total area) of the tested tooth brushes for the 3 evaluated areas are depicted in Table 2.

Regarding the effect in the area 2 mm around the brackets, there was no statistically significant difference between 9 different tooth brushes. The uncleaned areas ranged from 11 to 26 percent of the initially coated tooth surfaces. This corresponds to a cleaning efficacy of 74 to 89 percent.

In the cervical area no statistically significant differences could be found. Only Candida Parodin showed a superior cleaning performance compared with all other brushes and yielded cleaning percentages of almost 100%.

In the incisal regions of the custom made tooth model, no tooth brush showed statistically superior results. All tooth brushes left only minute remaining white areas thus showing a 96 to 100 percent cleaning efficacy.

For all tooth brush types there were *no* statistically significant differences determined for the two types of brackets.

The median cleaning efficacy of the three tooth brush types (planar, v-shaped,staged) and bracket sizes (standard Twin, mini) are depicted in Figure 4. For the standard bracket type, v-shaped (73.1%) and staged (75.6%) tooth brushes resulted in significantly superior cleaning values than planar tooth brushes (60.7%). Even though there was no significant difference between the v-shaped and staged tooth brushes, the latter tended to achieve a better result in its cleaning ability. For teeth with mini brackets (teeth 21 and 22), however, staged tooth brushes showed a significantly better median cleaning efficacy (77.8%) than planar tooth brushes (65%) and also yielded better results than v-shaped brushes (72.4%). The v-shaped tooth brushes showed a higher median percentage of cleaned tooth surfaces than the planar brushes, but this did not reach statistical difference.

DISCUSSION

This study used an established method with model teeth and a brushing machine to evaluate the efficacy of 9 tooth brushes to tooth surfaces around bonded brackets. An additional aim was to reveal the problem zones when brushing horizontally. The tuft designs of the manual brushes were: plane, v-shaped or staged.

In patients undergoing orthodontic treatment with fixed appliances effective plaque removal is significantly compromised and accumulation of plaque and the development of gingival inflammation and overgrowth are well-acknowledged problems (Heasman et al. 1998). The present study found no statistical differences in the efficacy of the nine brushes tested. No brush was superior at either the smooth, bracket or incisal surfaces. The percentages of uncleaned tooth areas for each brush at smooth surfaces were consistently lower than at bracket areas. All brushes failed to reach the area around the brackets as well as the interbracket span. The cervical and incisal tooth areas, as well as the gingival margins, also proved to be difficult to clean.

In this context, however, the Candida Parodin tended to be the most effective brush moving horizontally in a largely uncontrolled manner, back and forth over the rows of vestibular teeth parallel to the occlusal plane (simulating a “scrub technique”). This cleaning technique is the most widespread technique and mainly used by children, whose manual dexterity lags behind that of adults (Unkel et al., 1995; Peretz and Gluck, 1999) and despite the efforts of the dental profession to instruct patients to adopt other more convenient brushing techniques. But different studies comparing the plaque-removing efficacy of different tooth brushing methods have shown small or no differences (Shifter et al, 1983). Improvement in oral hygiene may rather is not as dependent upon the development of better brushing methods as upon improved performance by the persons using any one of the accepted methods (Frandsen, 1985).

In an attempt to facilitate plaque control in orthodontic patients, however, specially designed manual tooth brushes have been developed. Brushes with V-shaped longitudinal grooves trimmed into the bristle field were manufactured to improve brushing around brackets and arch wires, although their effectiveness in reducing gingivitis compared with conventional brushes is questionable (Williams et al., 1987). Such staged

brushes showed significantly superior cleaning efficacy in this *in vitro* experiment independent of the bracket area size.

The findings (Figure 4) confirm the results of a previous *in vitro* study (Sander et al., 2005) which showed that different bristle arrangements such as lowered bristles in the middle of the brushfield had improved cleaning efficacy than planar bristle fields. Tooth brushes with a flat profile proved to be unsatisfactory for the cleaning of teeth with brackets. It has, however, also been shown that certain tooth brushes have different cleaning effects when used with varying forces of application. At high load soft or fine bristles may become twisted resulting in a lower cleaning efficacy. With low force, interaction with the tooth surfaces increases, since soft bristles allow penetration into the interproximal and interbracket area (Sanders et al., 2005).

Since manually applied contact force may vary during the brushing cycle (Fraleigh et al., 1967; Perinetti et al., 2004; Phaneuf et al., 1962) the present results must be clinically verified. Extrapolation to the clinical situation is not directly possible and no conclusive statements as to the cleaning efficacy of any specific toothbrush should be drawn from the present experiment.

Conclusions:

Staged and V-shaped brush head designs outperformed planar brushes in cleaning efficacy of teeth with fixed orthodontic attachments. None of the single tested tooth brushes showed a significantly higher cleaning efficacy in this *in vitro* experiment. The test method proved to be practicable and effective, but the results must be verified in a clinical study.

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Table 1: Technical data of tooth brushes tested in the present study

	Tooth brush	Brush field	Filament Diameter (mm)	Filament height (mm)	Number of filaments per Hole	brush head
A	**Paro M 43** ESRO, Kilchberg, Switzerland	Planar	0.20	11	43	1548
B	**Curaprox CS 5460 „ultra soft“** Healthaco Breitschmid, Kriens, Switzerland	Planar	0.10	8.4	170	6630
C	**Meridol** GABA, Therwil, Switzerland	Planar	0.18	11.4	38-52	1406 – 1924
D	**Oral-B Ortho** Procter & Gamble, Schwalbach a. T., Germany	V-shaped	0.2	10.5	46	1'380
E	**Curaprox CD 060 ortho** Healthaco Breitschmid, Kriens, Switzerland	V-shaped	0.17	7-9.9	42	1’344
F	**Candida Parodin** Bürstenfabrik Ebnat-Kappel, Ebnat-Kappel, Switzerland	Staged	0.17 (conical) 0.15 (round)	9-11.25	54 (conical) 66 (round)	2'252 – 2416
G	**Ortho Pro** Orthodontic store, Gaithersburg, Maryland, USA	Staged	0.18	8.5-9.5	50	1’700
H	**PARO Ortho** ESRO, Kilchberg, Switzerland	Staged	0.17 and 0.18	8.5-9.5	50	1’250
I	**Emoform sensitive** Dr. Wild & CO AG, Basel, Switzerland	Staged	0.20	8.8-10.6	30	1’110

Table 2: Percentage of untouched (uncleaned) tooth surfaces of teeth 12, 11, 21 and 22 (IQR = Inter Quartile Range)

Bracket area	**12 (IQR)**	**11 (IQR)**	**21 (IQR)**	**22 (IQR)**
Paro M 43	25 (7)	18 (4)	16 (5)	20 (5)
Curaprox CS 5460	26 (9)	23 (10)	18 (6)	20 (14)
Meridol	18 (9)	16 (6)	13 (6)	18 (5)
Candida Parodin	24 (8)	12 (9)	12 (6)	13 (5)
Oral-B Ortho	17 (4)	16 (8)	13 (4)	16 (9)
Curaprox CD 060 Ortho	17 (5)	14 (5)	11 (1)	15 (4)
Ortho Pro	20 (3)	18 (6)	15 (5)	19 (1)
Paro Ortho	18 (8)	14 (7)	14 (7)	15 (8)
Emoform Sensitive	19 (4)	15 (2)	12 (2)	17 (2)
Cervical area				
Paro M 43	21 (7)	19 (3)	15 (2)	13 (7)
Curaprox CS 5460	9 (2)	10 (2)	7 (3)	11 (8)
Meridol	12 (17)	22 (17)	10 (14)	16 (19)
Candida Parodin	0 (0)	1 (3)	0 (0)	2 (2)
Oral-B Ortho	11 (4)	9 (4)	8 (3)	18 (3)
Curaprox CD 060 Ortho	5 (4)	6 (5)	5 (6)	10 (4)
Ortho Pro	8 (3)	7 (2)	4 (2)	13 (5)
Paro Ortho	9 (2)	5 (4)	6 (3)	13 (7)
Emoform Sensitive	7 (6)	3 (2)	3 (2)	7 (3)
Incisal area				
Paro M 43	3 (2)	3 (2)	2 (2)	3 (2)
Curaprox CS 5460	4 (4)	2 (1)	2 (1)	4 (3)
Meridol	0 (0)	0 (0)	0 (1)	1 (2)
Candida Parodin	0 (0)	0 (0)	0 (0)	0 (0)
Oral-B Ortho	1 (1)	1 (1)	2 (1)	2 (1)
Curaprox CD 060 Ortho	2 (1)	1 (1)	1 (1)	2 (1)
Ortho Pro	1 (2)	1 (1)	1 (1)	3 (2)
Paro Ortho	1 (2)	1 (1)	1 (1)	3 (2)
Emoform Sensitive	2 (5)	0 (1)	1(1)	1 (1)

Figure 1: Illustration of the nine tooth brushes tested

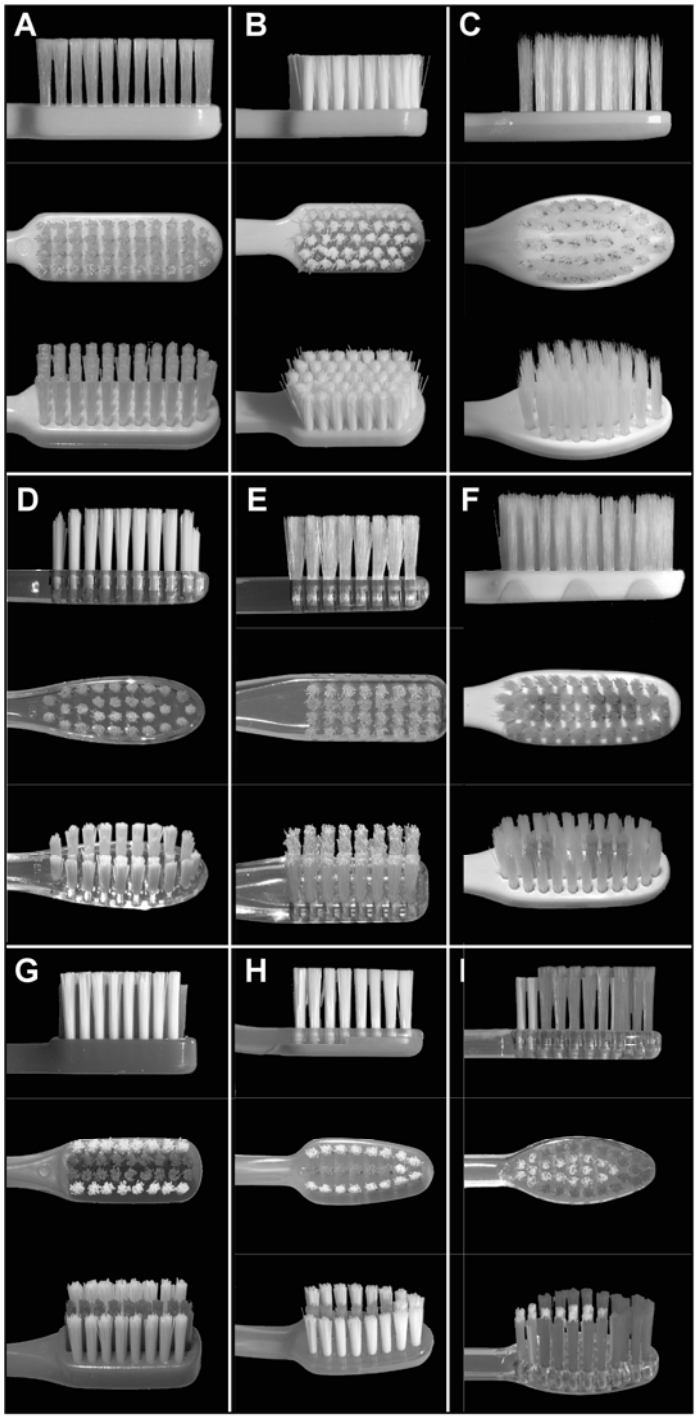


Figure 2: Custom-made tooth model of an anterior front segment with glued brackets glued to the labial surfaces (on teeth 11, 12, 13: standard Twin Diamond™ brackets, on teeth 21, 22 and 23 Mini Diamond™ brackets).

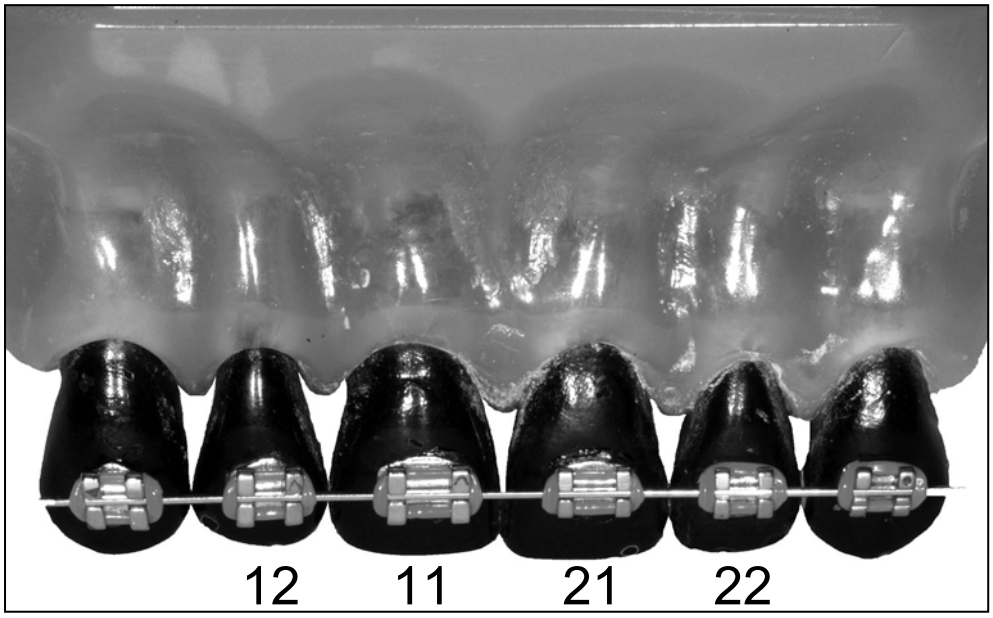


Figure 3: Three zones of interest, the cervical, the incisal and the bracket area. The latter was defined as extending 2 mm around the brackets.

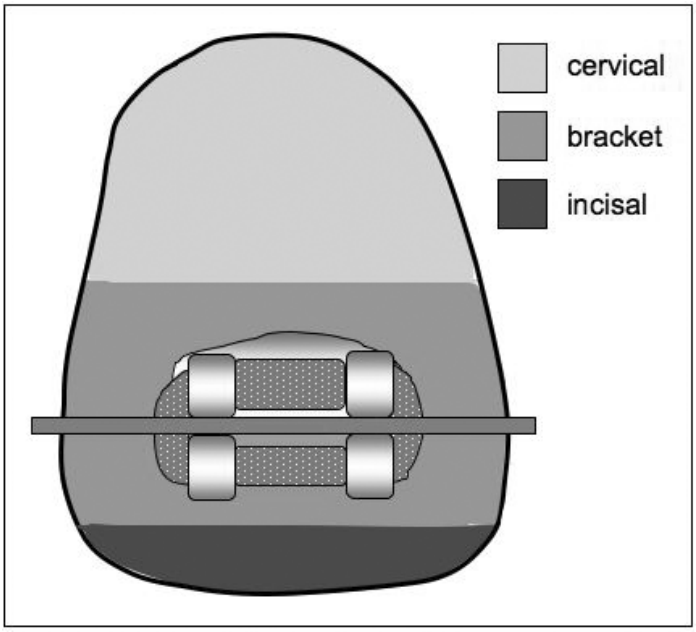
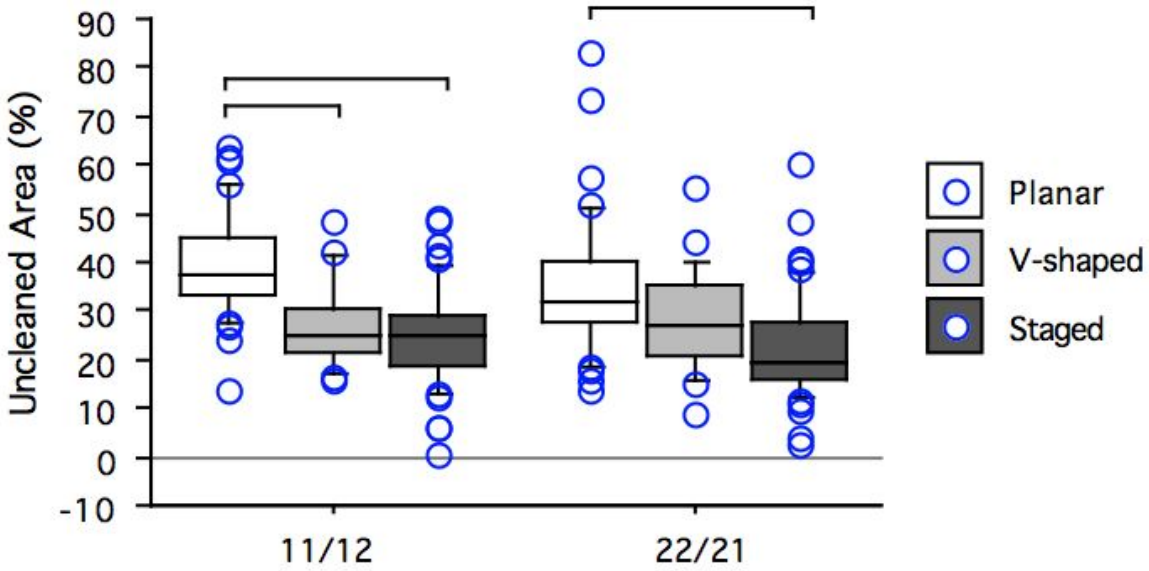


Figure 4: Corresponding box plots depicting the percentage of untouched (uncleaned) tooth surfaces of the teeth 11/12 (standard Twin Diamond Brackets) and 22/21 (Mini Diamond Brackets) for planar, v-shaped and staged tooth brushes (Horizontal Bars: Medians; Boxes: inter-quartile areas; Error Bars: 10th and 90th percentile; dots: extreme values)



Significant differences are indicated with bars ($p < 0.05$)