# In Vitro-Cleaning Efficacy of Interdental Brushes with Different Stiffness and Different Diameter

Diana Wolff[a]/Daniela Joerss[a]/C.E. Dörfer[a]

**Purpose:** The aim of this study was to evaluate the cleaning efficacy of interdental brushes with different stiffnesses, e.g. soft and hard interdental brushes with identical brush diameter.

**Materials and Methods:** Cylindrical soft and hard interdental brushes with diameters of 2,3 and 5 mm each were tested. Sixteen extracted human molars were fixed in split cast models to simulate eight interdental spaces. After coating the teeth with a dye to simulate plaque, digital photographs were taken from the proximal surfaces in a highly standardised set-up. The teeth were repositioned and the proximal surfaces were cleaned in a standardised manner. Post-brushing digital photographs were taken as before. After digital subtraction, the cleaned area was measured by pixel count and the relative cleaning efficacy was calculated.

**Results:** The cleaning efficacy values of soft and hard interdental brushes of corresponding size in extra-small, small, medium and large interdental spaces as well as overall showed no statistically significant difference. In small, medium and large interdental spaces, increasing brush diameters resulted in higher cleaning efficacy; these differences were statistically significant. Irregular values were seen in extra-small interdental spaces.

**Conclusion:** Both hard and soft interdental brushes cleaned the proximal tooth surfaces effectively. The filament stiffness had no statistically significant influence on the cleaning efficacy.

**Key words:** cleaning efficacy, filament stiffness, interdental brushes, mechanical plaque control

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Under physiological conditions, the interdental space is completely filled out and protected by the interdental papilla (Ash, 1993). The loss of epithelial attachment in this area creates proximal reservoirs for plaque. Due to the critical anatomical preconditions compared with oral or vestibular tooth surfaces the proximal area is not easy to clean (Dörfer et al, 2000). It requires the use of additional interdental cleaning aids. The use of interdental floss is often associated with handling difficulties, whereas interdental brushes (IB) are reported to be easy to apply. Moreover, IB proved to be more effective with respect to their cleaning efficacy than dental flosses and tooth picks (Bergenholtz and Olsson, 1984; Kiger et al, 1991; Christou et al, 1998). The most relevant difference between IB and other interdental cleaning aids (e.g. interdental floss or tooth picks) is their ability to reach concavities on the proximal surfaces of the teeth (Dörfer et al, 1997), which are widely prevalent in all types of teeth (Dörfer et al, 2000) and are regarded as a risk factor for the progression of periodontitis (Everett and Kramer, 1972; Gher and Vernino, 1980). IB are composed of filaments in a helical order, which are fixed in a double-layered and drilled stainless wire kernel. Most brushes are round in cross section and either cylindrical or conical, and provided in different sizes and stiffnesses (Dörfer et al, 1994). Hard IB display stiffer filaments, i.e. the ratio between filament diameter and length is higher than in soft IB. The aim of this study was to investigate the influence of the filament

[a] *University of Heidelberg Medical School, Department of Conservative Dentistry, Im Neuenheimer Feld 400, 69120 Heidelberg, Germany.*

***Reprint requests:*** *Dr. Diana Wolff, Im Neuenheimer Feld 400, 69120 Heidelberg, Germany. Tel: 0049 6221 5639887. Fax: 0049 6221 565074. Email: Diana.Wolff@med.uni-heidelberg.de*

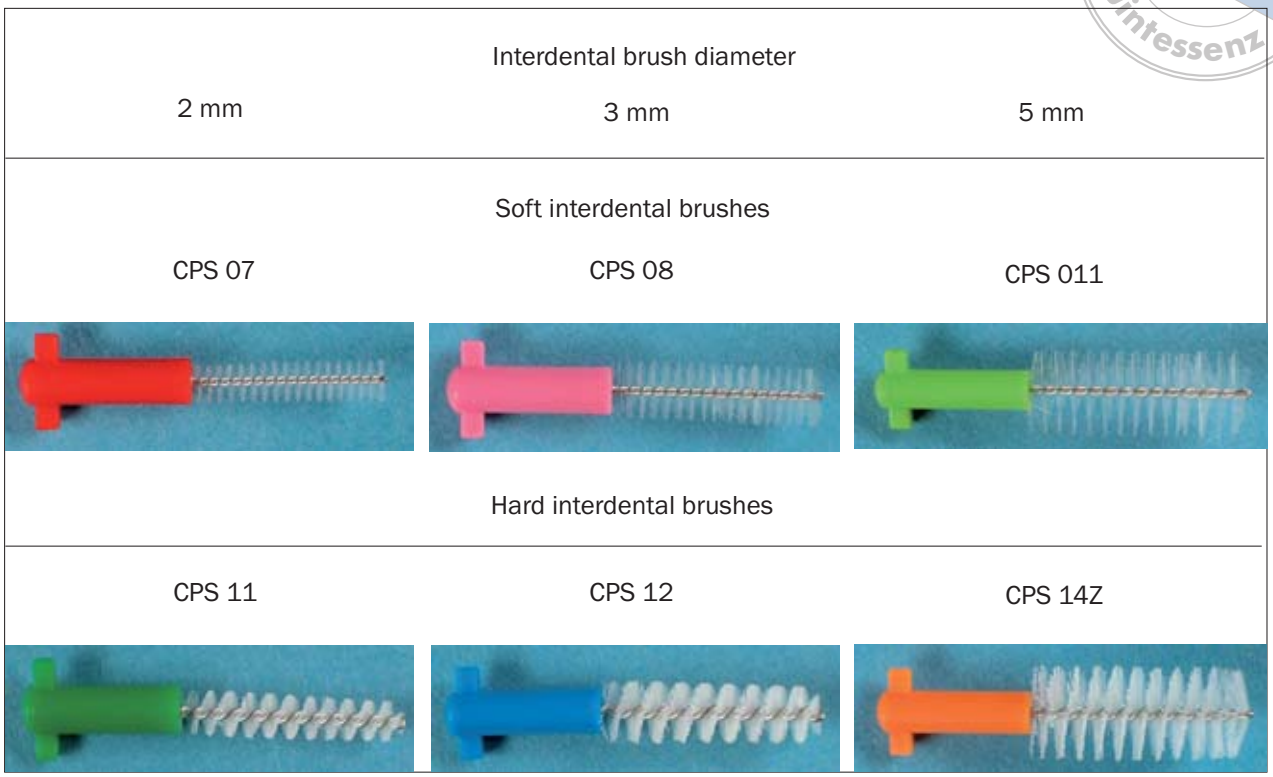



**Fig 1** Interdental brushes used in the study. CPS, Curaprox interdental brushes from Curaden AG, D-Tenningen.

stiffness on the cleaning efficacy of six commercially available cylindrical IB in an experimental in vitro set-up. The hypothesis was that hard IB show a better cleaning efficacy than soft IB. The corresponding null-hypothesis was that there will be no difference between the two types of IB.

## MATERIALS AND METHODS

Three corresponding pairs of soft and hard commercially available IB (Curaden AG, D-Tenningen) with diameters of 2, 3 and 5 mm respectively, were tested (Fig 1).

Extracted human teeth without caries and restorations were cleaned and embedded into resin to simulate the gingival level. They were fixed in pairs to a socket using a split cast to allow the removal and replacement of the teeth in a reproducible manner (Fig 2a). Eight interdental spaces were created, two each of extra-small, small, medium and large (Table 1). Prior to the measurements, the teeth were removed from the socket, fixed in front of a digital camera in a highly reproducible geometrical set-up. Again, a split cast design was used to ensure that the distance between the teeth and the camera and their exact positions were reproducible. Baseline images were taken and the teeth were then covered with a plaque substitute (Fig 2b). This was composed from a thin layer of Vaseline® petroleum jelly and a commercially available green dye indicator (Occlu®-Spray, Omnident®, Hager & Werken, D-Duisburg) as used by dental technicians to test the occlusion. Images were taken from all teeth after the coverage with the dye indicator (Fig 3). After recombining the two correlated teeth to an interdental space in their original relationship with the aid of the split cast, an IB was introduced into the interdental space and moved forth and back three times by hand with a span of approximately 5 mm (Fig 2c). The use of the IB in the interdental space led to the removal of the dye indicator at points where the filaments touched the surfaces of the teeth. After finishing the cleaning procedure, the teeth were separated without touching the interdental surface (Fig 2d), and images were taken from the proximal surfaces as described above (Fig 3). The use of the split cast design produced congruent images and allowed digital subtraction of both images using a standard pixel based program (Paint Shop Pro

**Table 1 Height and width of the four different sizes of interdental spaces in the in vitro set-up**

| Interdental space | | Height (mm) | Width (mm) | | Height (mm) | Width (mm) |
|---|---|---|---|---|---|---|
| Extra-small |  | 1.60 | 1.69 |  | 2.19 | 1.60 |
| Small |  | 2.82 | 2.70 |  | 3.28 | 2.05 |
| Medium |  | 3.51 | 3.63 |  | 3.87 | 1.93 |
| Large |  | 4.19 | 4.19 |  | 5.37 | 4.36 |

5.0, JASC Corporation, Minneapolis, MA, USA) (Fig 3) (Dörfer et al, 1997; Dörfer and Weidtmann, 1998). After converting the subtraction image into a black and white bitmap (Scion Image, Scion Corporation, Frederick, MA, USA) (Fig 3), an area of interest was defined to cut out the background and the resin of the base. The cleaning efficacy value is based on a digital subtraction of highly reproducible images of the proximal surfaces before and after cleaning by counting pixels. To adjust for the different interdental spaces, the percentage of the cleaned surface in relation to the totally cleaned surface was calculated [relative cleaning efficacy (%)] (Dörfer, 1999; Dörfer and Weidtmann, 1998). From every type of brush, 12 cycles of cleaning were performed in every interdental space by one investigator. During the testing, hard and soft brushes were used at random, using a computer-generated random list. A new brush was used for every test. The investigator, who made the image analysis, was blinded with respect to the brushes used.

### *Statistical analysis*

The data were entered into a statistical software package (SPSS 10.0, SPSS Inc., Chicago, USA). Mean values were calculated for all interdental spaces. Differences between corresponding interdental brush sizes of the two stiffnesses were tested for statistical significance by the paired t-test. The differences between the different brush sizes of the same stiffness were tested for statistical significance by analysis of variance (ANOVA) followed by Scheffé's procedure as post hoc test.

## RESULTS

The relative cleaning efficacies for the three types of soft and hard IB ordered by the size of interdental spaces are shown in Table 2.

In all four interdental space sizes (extra-small, small, medium and large), as well as overall, the clean-

**Fig 2a** Split cast model of a simulated interdental space.

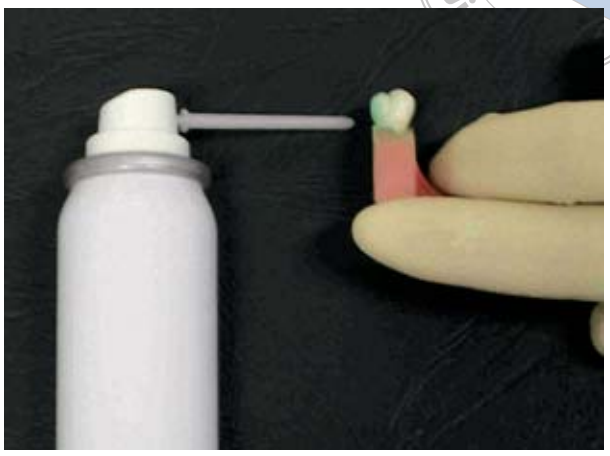


**Fig 2b** Coating of both proximal surfaces with a dye to simulate plaque.

**Fig 2c** Repositioning of the teeth and cleaning of the proximal surfaces with IB.

**Fig 2d** Post-brushing situation.

ing efficacy values were similar. The overall relative cleaning efficacies (%) for the soft IB of 2, 3 and 5 mm were 11.73 ± 6.6, 18.4 ± 7.6 and 24.2 ± 7.5, and for the hard IB 12.4 ± 7.1, 19.3 ± 6.9 and 26.6 ± 10.1 respectively. A comparison of the relative cleaning efficacy values between soft and hard IB of corresponding size with a paired t-test yielded no statistically significant differences.

In extra-small (only hard IB), small, medium and large interdental spaces, increasing diameter of the IB resulted in statistically significant higher cleaning values (ANOVA, $p < 0.05$). In extra-small interdental spaces, the soft IB showed no regular increase of cleaning efficacy; as a result, the p-value shows no statistically significant difference. The results are summarised in detail in Table 2.

## DISCUSSION

Interdental brushes are regarded as one of the most effective aids for preventing the tissues of the interdental area from disease (Bergenholtz and Olsson, 1984; Kiger et al, 1991; Christou et al, 1998; Schmage et al, 1999). They are relatively easy to handle and clean the proximal tooth surfaces of the two adjacent teeth in one step. This ease of use makes them superior to dental floss. Floss has to be inserted by passing the proximal contact, which is related to a risk of traumatizing the interdental papillae, the lips and fingers (Lakind, 1975; Goldman, 1979; Abrams and Kopczyk, 1983; Hallmon et al, 1986; Rawlinson, 1987; Freeman and Stephens, 1999; Crain et al, 2000).

In the clinical situation, the cleaning efficacy of mechanical aids for the interdental plaque removal can

**Table 2 Relative cleaning efficacy (%) ± SD (standard deviation) of soft and hard IB in the four different interdental space sizes and overall**

| Interdental space | Hardness of brush | Brush diameter 2 mm | 3 mm | 5 mm | p-value (ANOVA) |
|---|---|---|---|---|---|
| Extra-small | Soft IB | 18.2 ± 5.1 | 25.6 ± 8.8 | 24.0 ± 4.8 | 0.069 |
| | Hard IB | 17.7 ± 4.3 | 22.7 ± 7.7 | 28.8 ± 7.8 | 0.001 |
| | p-value (paired t-test) | 0.82 | 0.31 | 0.07 | |
| Small | Soft IB | 12.0 ± 3.8 | 20.3 ± 3.6 | 27.0 ± 8.8 | 0.001 |
| | Hard IB | 12.3 ± 7.0 | 22.8 ± 3.6 | 28.9 ± 12.8 | 0.001 |
| | p-value (paired t-test) | 0.93 | 0.20 | 0.57 | |
| Medium | Soft IB | 8.5 ± 5.5 | 14.2 ± 7.1 | 21.0 ± 10.1 | 0.021 |
| | Hard IB | 11.5 ± 9.5 | 16.0 ± 8.1 | 21.2 ± 7.8 | 0.007 |
| | p-value (paired t-test) | 0.10 | 0.35 | 0.89 | |
| Large | Soft IB | 7.5 ± 6.3 | 13.4 ± 5.8 | 24.8 ± 4.6 | 0.001 |
| | Hard IB | 8.2 ± 3.1 | 15.6 ± 3.4 | 27.4 ± 10.7 | 0.001 |
| | p-value (paired t-test) | 0.80 | 0.15 | 0.53 | |
| Overall | Soft IB | 11.73 ± 6.6 | 18.4 ± 7.6 | 24.2 ± 7.5 | 0.001 |
| | Hard IB | 12.4 ± 7.1 | 19.3 ± 6.9 | 26.6 ± 10.1 | 0.001 |
| | p-value (paired t-test) | 0.32 | 0.38 | 0.10 | |

be observed indirectly by the means of gingivitis reduction only. Therefore, an in vitro set-up was developed that allowed the removal and replacement of pairs of teeth in a reproducible manner. To simulate the intraoral variations in the shape and size of interdental spaces, the teeth were selected to form different shapes of interdental spaces. This in vitro set-up, therefore, imitated a high variety of different clinical situations under controlled conditions and allowed evaluation of the cleaning behaviour by direct observation.

Being an experimental in vitro study, the present investigations also have limitations, which are inherent to such types of studies. This is primarily that the physical characteristics of the plaque substitute used are not necessarily similar to the physical properties of the intraoral plaque biofilm. Therefore, the experiment tests the contact of the filaments to the tooth surfaces only. However, IB have been proven to remove plaque and therefore the results should in part be related to this clinical evidence.

This in vitro study indicates, as seen in the previous literature (Dörfer et al, 1995), that the diameter of the IB in relation to the size of the interdental space is highly correlated to their cleaning efficacy.

However, we observed an irregular increase of cleaning efficacy values with soft IB in extra-small interdental spaces. The 3 mm IB cleaned better than the 2 mm IB and, surprisingly, also slightly better than the 5 mm

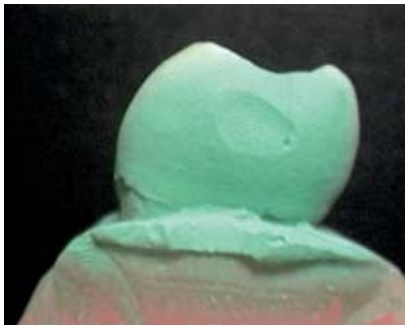
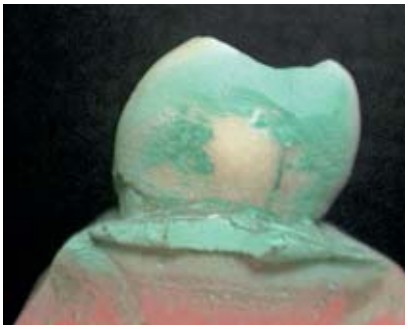
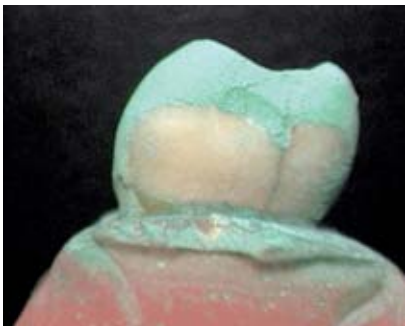
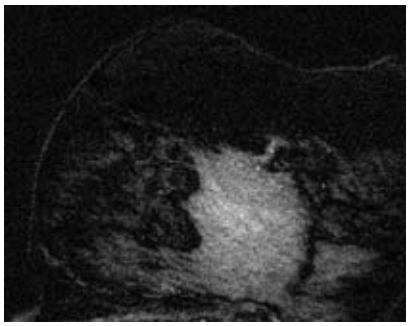
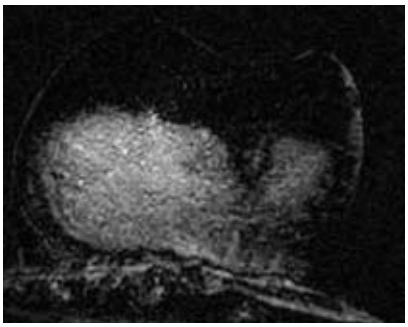
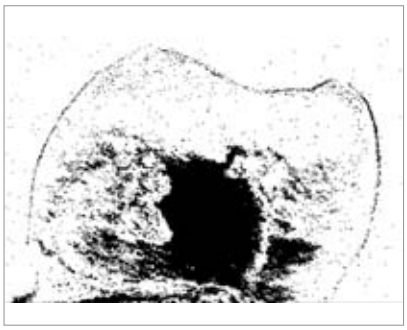
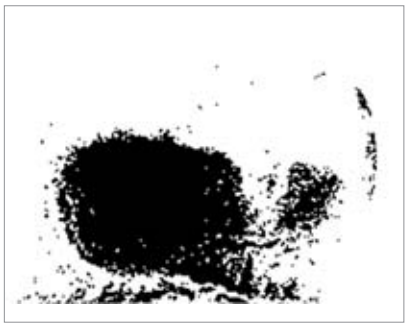
| | CPS 011 (soft IB, 5 mm) | CPS 14Z (hard IB, 5 mm) |
|---|---|---|
| Pre-brushing digital image |  |  |
| Post-brushing digital image |  |  |
| Digital subtraction image (Paint Shop Pro 5.0) |  |  |
| Black and white bitmap (Scion Image) |  |  |

**Fig 3** Pre- and post-brushing images, digital subtraction images and black and white images. CPS, Curaprox interdental brushes from Curaden AG, D-Tenningen.

IB. This could be interpreted as having reached a maximum cleaning efficacy with the 3 mm IB, and that a larger sized IB does not improve the efficacy further. A closer look at the cleaning mechanism shows that the cleaning efficacy of IB depends on the elasticity of the filaments, which bend during insertion into the interdental space. The energy that the filaments are loaded with by the force necessary for insertion will be transferred to the interdental tooth surface as long as the deformation of the filaments is in an elastic phase according to Hook's law.

When a very large brush is applied, the filaments start to overlay like a parachute when inserted into the interdental space and become clotted instead of transferring the bending energy to the tooth surface. It is possible that this mechanism is responsible for the unexpected low cleaning value of the 5 mm, soft IB. The irregularity was only observed with soft IB. Hard IB showed a regular increase of cleaning efficacy from the 3 mm to the 5 mm brush in the same situation. The stiffer filaments of hard IB might account for increased stability during the insertion process, which prevents overlaying.

Finally, the expectation that the stiffer filaments of hard IB would clean better than the more flexible filaments of soft IB was not proven. Soft and hard IB of corresponding diameter cleaned similarly. Therefore, the hypothesis of a better cleaning efficacy of hard IB compared with soft IB of the same diameter turned out to be incorrect.

Certainly, the application of interdental brushes is much easier on the model than in the mouth, especially in posterior segments. However, comparing the model and the clinical situation, both brush types are subject to this facilitation. Therefore, when transferring the results to the clinical situation, it becomes clear that both brush types are effective and can be used in patients equally. The flexible bristles of soft IB might be easier to insert and more comfortable to use for some patients. The dentist or the dental hygienist must give instructions about what size of interdental brush should be used in which interdental space, but the stiffness of the interdental brush can be chosen according to the patients preferences.

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