CLINICAL ORAL IMPLANTS RESEARCH

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Effectiveness of different interdental brushes on cleaning the interproximal surfaces of teeth and implants: a randomized controlled, double-blind cross-over study

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Abstract

Objectives: To compare the interproximal cleansing efficacy of the novel, waist-shaped Circum® brush (Topcaredent®, Switzerland; CB) with that of a straight soft interdental brush (IB) (TePe®, Sweden; SB) on posterior surfaces.

Material & methods: Eight patients after completion of initial periodontal therapy abolished oral hygiene for 3 days. Baseline plaque scores (PII, Silness & Löe 1964) were assessed on eight surfaces of all premolars and molars. Subsequently, an instructed nurse applied at random one of the two IB, three times per interdental space . Following this, registration of the PII was repeated by the same blinded examiner. After a 2-week recovery, patients abolished oral hygiene practices for another 3 days. Again, pre-and post-brushing PII were recorded by the same examiner. The second IB was now applied.

Results: Patient mean PII and site PII were evaluated before and after application of the SB or CB respectively. Paired *t*-tests were performed to yield statistically significant differences. The reduction of biofilm from before to after the use of the IB on a subject basis was highly significant ($P < 0.0001$). The mean PII after the use of the CB was significantly lower than after the use of the SB ($P < 0.0001$). Comparing the PII of the line angles (MB, ML, DB, DL), significantly more biofilm had been removed by applying CB compared with SB ($P < 0.0001$). Moreover, comparing the PII of the buccal (MB, DB) or the lingual line angles (DL, ML) yielded a significantly higher reduction of biofilm in favour of the CB ($P < 0.0001$). The reduction of the PII in the mid-interproximal portion, both mesially and distally did not differ significantly between CB and ST. No biofilm reduction was seen on the buccal sites with either IB.

Conclusion: The application of the waist-shaped Circum® IB resulted in significantly lower PII scores than the use of a straight IB. This was predominantly due to the higher cleansing effect of the waist-shaped CB on the buccal and lingual line angles.

Interproximal areas of the dentition are the most difficult areas to clean and to keep clean (Lang et al. 1977; Galgut 1996). Implant sites are even more difficult for cleansing. Toothbrush bristles alone will not penetrate and clean interproximal spaces (Lang et al. 1973; Caton et al. 1993). As a consequence, periodontal disease most commonly develops in interproximal areas (Lövdal et al. 1958; Löe et al. 1965).

The removal of both supra and sub-gingival plaque is important in reducing the onset and severity of gingival disease (Carter et al. 1975; Bergenholtz & Brithon 1980). Regular and complete biofilm removal therefore helps in reducing the severity of periodontal diseases (Ash et al. 1964; Löe et al. 1965; Lindhe & Koch 1967; Löe 1969; Suomi et al. 1971).

The primary cleansing devices for home care biofilm removal are manual toothbrushes (Bass 1954). Nevertheless, these will not be sufficient to clean the dentition interproximally (Caton et al. 1993). Today, many devices for cleansing interproximal spaces are available on the market. One of the problems encountered may lie within the patient's compliance to use these devices for an adequate time necessary for interdental cleansing, usually requiring 4 min or more (Gjermo & Flötra 1970). Studies have demonstrated

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that approximately 10% of population only is regularly applying interdental devices (Ronis et al. 1993; Bakdash 1995; Kalsbeek et al. 2000).

The superiority in effectively penetrating the interproximal spaces axially and subgingivally for both dental floss and interdental brushes has been clearly documented (Waerhaug 1976 & 1981). In wide interdental spaces, interdental brushes were the most effective devices for cleaning (Gjermo & Flötra 1970).

Although efficient, dental floss is difficult to use, especially by older people and those patients with special needs. In such cases, the use of interdental brushes seems to be more preferable for optimal oral cleansing (Gjermo & Flötra 1970; Bergenholtz & Brithon 1980; Christou et al. 1998). Interdental brushes used in combination with toothbrushes have been more effective in biofilm removal in interproximal spaces than tooth brushing alone or the use of them in a combination with dental floss (Kiger et al. 1991).

In recent years, studies have shown that the maintenance care and the standard of the patient's home care were key factors for long-term stability of dental implants and the prevention of biological complications (Bauman et al. 1991; Silverstein & Kurtzmian 2006; Serino & Ström 2009).

Biofilm build-up is associated with clinical signs of inflammation both at implant and tooth sites (Zitzmann et al. 2001). Consequently, the regular and complete removal of it remains the key prerequisite in the prevention of such host responses. The effectiveness of interproximal cleaning devices used in interproximal areas between implants or implants and teeth therefore is of utmost importance.

The cleansing effect of interproximal cleaning devices was investigated in several studies throughout the years.

Forty years ago, one of the first studies evaluated three interdental cleansing devices (Gjermo & Flötra 1970). The first experiment compared the plaque removal effect of toothpicks against that of dental floss. Both devices yielded significant plaque reductions comparing before and after ($P < 0.001$) scores. When used in open wide interdental spaces, no difference between the cleansing effect of toothpicks and that of dental floss was observed.

More recently, Yost et al. (2006) compared the cleansing effect of the interdental brush Go-between® with two types of floss and an interdental cleaner. The result has shown significant differences of the plaque scores after having used the devices. However, there was no significant difference in plaque reduction between the devices. When all devices were compared, the results favoured the interdental brush ($P < 0.001$) only at the buccal sites. Another study (Jackson et al. 2006) confirmed these findings and revealed a significant reduction of plaque with both devices, but with no differences between dental floss and the interdental brush both for supra and subgingival plaque. However, the patients preferred interdental brushes.

Until now, there is limited evidence on the comparison of the plaque removing effectiveness of more recently propagated interdental brushes. When comparing the cleansing efficacy of dental floss with that of cylindrical-shaped and conical-shaped interdental brushes (Rösing et al. 2006), significant plaque reduction after usage was found in all three groups. However, both shapes of interdental brushes removed more plaque than did dental floss.

A waist-shaped interdental brush (Circum®) presents with more diameter at the base and tip and hence, may result in more contact to the teeth or prostheses at the lingual and buccal line angles when passing through the interproximal area. Moreover, when retrieved, the bristles might drag out more biofilm at the tooth angles resulting in a better cleansing effect than that of regular interdental brushes.

Hence, the purpose of this study was to assess the cleansing capacity of two interdental brushes in cleaning interproximal surfaces in the posterior region of the mouth both at tooth and implant sites: The waist-shaped Top Caredent Cirum®brush and the straight Extra soft TePe® Interdental brush. The Null-hypothesis of this study was that of no difference in interproximal cleansing effect between the two interdental brushes at both implant and tooth sites.

Material and methods

The study protocol has been submitted to and was approved by the *Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (HKU/HA HKW IRB)* (IRB Ref. UW 10-407).

Subjects

Eight patients who had been treated in Centre of Advanced Dental Care in the Prince Philip Dental Hospital at the University of Hong Kong were recruited for the study on the basis of their availability. After having been informed about the study procedures, the patients signed consent forms. Patients were recruited from January 2011 to May 2011.

Inclusion criteria

A subject had to meet all of the inclusion criteria listed to participate in this study:

- Open interproximal spaces from the canines to the second molars both in mandible and maxilla
- Size of resulting interproximal spaces had to be fit for the placement of a Top Caredent Circum® brush No. 3 (diameter 5-3-5 mm) or a No. 5 (diameter 7-4-7 mm).

Exclusion criteria

Subjects with any of the following criteria at baseline would be excluded from the study:

- Presence of oral diseases other than periodontitis
- Drugs consumption that may cause gingival enlargement such as Phenytoin®, Cyclosporin etc.
- Presence of uncontrolled Diabetes mellitus
- Tabacco consumption: Heavy smokers (a pack/day or more)
- Presence of gingival tissue swelling or suppuration with impossibility to apply cleaning devices

Study design

A cross-over design was used for the present clinical experiment (Fig. 1).

Each subject was asked to attend three appointments.

In the first visit, interdental spaces from the distal of the canines to the second molars were assessed, and the size of the interdental brushes to fit the interdental space was determined.

Prior to the application of the brushes, biofilm build-up was allowed for 3 days of abolished oral hygiene practices. The patient's mouth was used as a model, and all the cleaning procedures were performed by the same trained dental surgery assistant. The interdental brush was guided through the interdental spaces of all molars and premolars three times. The respective sizes of the interdental brushes for the cleansing are indicated in Table 1.

Randomization was performed by the toss of a coin. In Group 1, every interproximal posterior space was cleaned three times applying the Top Caredent waist-shaped Circum® brush first (Fig. 2). Following this, the residual plaque deposits were assessed.

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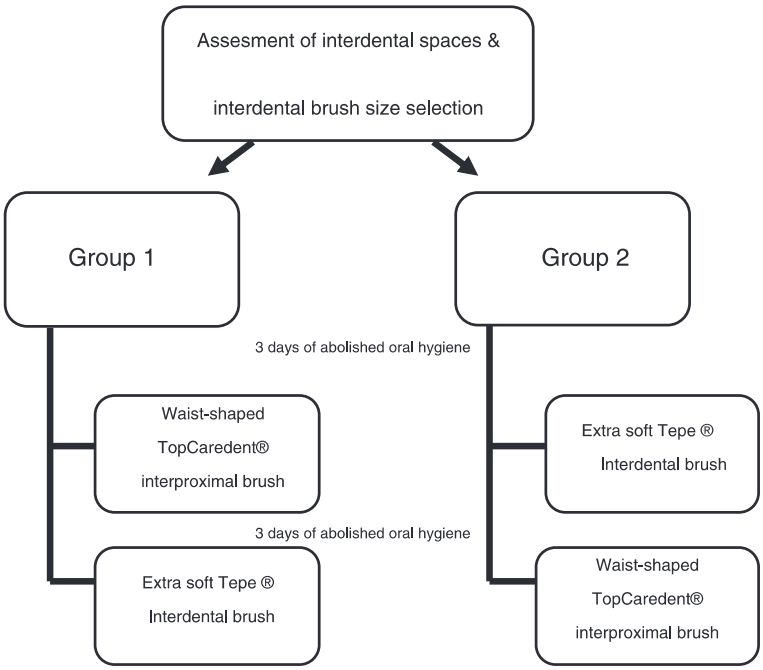

Fig. 1. Flow chart of clinical procedures.

Table 1. **Sizes of waist-shaped Circum® brush (Topcaredent®; CB) as test and straight soft interdental brush (Tepe®; SB) as control applied in the eight volunteers of the study**

Case	Age	Gender	Circum® brush number	TePe® Extra soft colour	No. of teeth and implants	Group
1	65	F	5	Blue	12	1
2	26	F	3	Red	15	2
3	28	F	3	Red	15	2
4	57	M	5	Blue	12	2
5	49	M	5	Blue	11	1
6	52	M	3	Red	13	2
7	41	M	5	Blue	13	2
8	56	F	3	Red	11	1

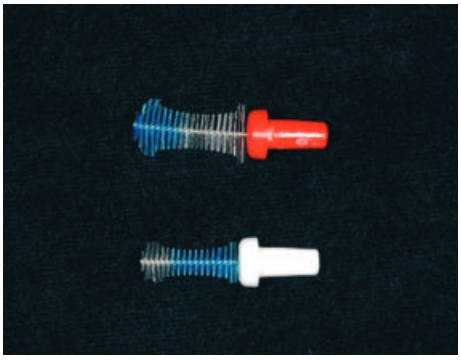

Fig. 2. Waist-shaped Circum® (Topcaredent; CB): No. 3 – white (5-**3**-5 mm), No. 5 – red (7-**4**-7 mm).

Fig. 3. Straight soft IB (TePe®; SB) : red 3 mm diameter, blue 4 mm diameter.

Subsequently, the patients were dismissed and asked to come back for a second performance after another abolishment of oral hygiene practices for 3 days.

In the second test, the patients applied the Extra soft TePe® Interdental brush (Fig. 3) three times in each posterior interdental space, following which the residual plaque deposits were again assessed.

Group 2 performed the same procedures as Group 1, except that the Extra soft TePe® Interdental brush was applied in the first, and the Top Caredent Circum® brushes in the second test period after 3 days of abolished oral hygiene practices.

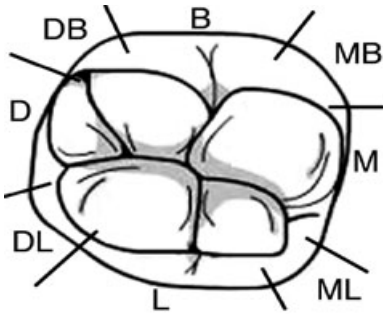

Fig. 4. Graphic scheme showing the area of plaque score assessments (DB, distobuccal; B, buccal; MB, mesiobuccal; M, mesial; ML, mesiolingual; L, lingual; DL, distolingual; D, distal).

Clinical parameters

The Plaque Index (Silness & Löe 1964) was assessed by one blinded and calibrated examiner (NPL) at eight areas of the teeth or implants separately (buccomesial, buccodistal. linguomesial, linguodistal, midbuccal, midlingual, mesial and distal; Fig. 4). The reproducibility of the examiner was 92% (Lang et al. 2010).

Statistical analysis

Microsoft® Excel for Windows® 7 was used for data collection. Statistical analysis was calculated by The Statistical Package for the Social Science for Windows (SPSS v19.0; SPSS Inc, Chicago, IL, USA).

Mean PlI of before and after cleansing were compared using Student's *t*-test for paired samples. Level of significance is set at $\alpha = 0.05$.

Mean PlI of between cleansing procedures were compared using Student's *t*-test for paired samples. Level of significance is set at $\alpha = 0.05$.

Frequency analyses of individual PlI scores of 0,1 vs. 2,3 were compared using Mc Nemar test for 1. mesio-lingual and disto-lingual line angles, 2. mesio-bucal and disto-buccal line angles, 3. buccal, 4. lingual, 5. Distal, 6. Mesial, 7. mesio-lingual, disto-lingual,mesio-buccal and disto-buccal line angle scores.

Results

The subjects consisted of four men and four women (aged 26–65 years, average age: 46.75 years). Four patients used Circum® brushes size 3 and four patients used Circum® brushes size 5 for the study.

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The dentition of the patients merely represents a model to test the efficacy of the IB in removing biofilm in the interproximal area. Both teeth and implants present were used. A total of 102 teeth and implants and 816 sites were assessed.

Overall mean plaque score (Table 2)

Mean baseline plaque score applying the test device (Circum ®) was PlI = 1.89 (SD: 0.03). After intervention, the mean plaque score applying the test device (Circum ®) was PlI = 0.45 (SD: 0.08). The difference was highly significant ($P < 0.0001$).

Mean baseline plaque score applying the control device (TePe®) was PlI = 1.88 (SD: 0.10). After intervention, the mean plaque score applying the control device (TePe ®) was PlI = 1.02 (SD: 0.21). Again, the difference was highly significant ($P < 0.0001$).

After intervention, the mean plaque score (mean PlI = 0.45 (SD: 0.08) for the Circum® IB was significantly lower than the mean plaque score (mean PlI = 1.02 (SD: 0.21) of the TePe® IB ($P < 0.0001$) as well.

The PlI for both test (Circum®) and control (TePe®) interdental brushes before and after the cleansing procedures are indicated in Table 2. Overall, mean PlI, mean PlI of the four line angles, mean PlI of the buccal line angles, the lingual line angles and the four sites are separately presented (Mesial, distal, mid-buccal, mid-lingual).

Mean plaque scores at line angles (Mesio-buccal,Disto-buccal,Mesio-lingual and Disto-lingual) (Table 2)

The mean baseline line angle plaque score applying the test device (Circum®) was PlI = 1.97 (SD: 0.17). After intervention, the mean line angle plaque score applying the test device (Circum ®) was PlI = 0.33 (SD: 0.53). The difference was highly significant ($P < 0.0001$).

The mean baseline line angle plaque score applying the control device (TePe®) was PlI = 1.96 (SD: 0.21). After intervention, the mean line angle plaque score applying the control device (TePe ®) was PlI = 1.39 (SD: 0.63). Again, the difference was highly significant ($P < 0.0001$).

After intervention, the mean line angle plaque score (mean PlI = 0.33 (SD: 0.53) for the Circum® IB was significantly lower than the mean line angle plaque score (mean PlI = 1.39 (SD: 0.63) of the TePe® IB ($P < 0.0001$) as well.

Mean plaque score at buccal sites (Table 2)

The mean baseline buccal plaque score applying the test device (Circum ®) was PlI = 1.72 (SD: 0.48). After intervention, the mean buccal plaque score applying the test device (Circum ®) was PlI = 1.33 (SD: 0.62). The difference was highly significant ($P < 0.0001$).

The mean baseline buccal plaque score applying the control device (TePe®) was PlI = 1.67 (SD: 0.53). After intervention, the mean buccal plaque score applying the control device (TePe ®) was PlI = 1.42 (SD: 0.42). Again, the difference was highly significant ($P < 0.0001$).

After intervention, the mean buccal score was PlI = 1.33 (SD: 0.62) for the Circum® IB, and the mean buccal score was PlI = 1.42 (SD: 0.62) for the TePe® IB. This difference, however, was not statistically significant.

Mean plaque score at lingual sites (Table 2)

The mean baseline lingual plaque score applying the test device (Circum ®) was PlI = 1.55 (SD: 0.56). After intervention, the mean lingual plaque score applying the test device (Circum ®) was PlI = 0.91 (SD: 0.51). The difference was highly significant ($P < 0.0001$).

The mean baseline lingual plaque score applying the control device (TePe®) was PlI = 1.55 (SD: 0.52). After intervention, the mean lingual plaque score applying the control device (TePe ®) was PlI = 1.21 (SD: 0.53). Again, the difference was highly significant ($P < 0.0001$).

After intervention, the mean lingual plaque score (mean PlI = 0.91 (SD: 0.51) for the Circum® IB was significantly lower than the mean lingual plaque score (mean PlI = 1.21 (SD: 0.53) of the TePe® IB ($P < 0.0001$) as well.

Mean plaque score at interproximal sites (Table 2)

The mean baseline mesial and distal plaque score applying the test device (Circum ®) was PlI = 1.99 (SD: 0.10). After intervention, the mean mesial and distal plaque score applying the test device (Circum ®) was PlI = 0.0 (SD: 0.0). The difference was highly significant ($P < 0.0001$).

The mean baseline mesial and distal plaque score applying the control device (TePe®) was PlI = 1.98 (SD: 0.20) and PlI = 1.99 (SD: 0.17) respectively. After intervention, the mean mesial and distal plaque score applying the control device (TePe ®) was PlI = 0.0 (SD: 0.0). Again, the difference was highly significant ($P < 0.0001$).

After intervention, the mean mesial and distal score was PlI = 0.0 (SD: 0.0) for the Circum® IB, and the mean mesial and distal score was PlI = 0.0 (SD: 0.0) for the TePe® IB. There was no statistically significant difference.

Frequency analyses of sites with PlI = 0 &1 vs. PlI = 2 & 3

At the *line angles* (total of 408 sites), the Mc Nemar test revealed a significant improvement of the plaque score categories from before to after the interventions ($P < 0.0001$) for both test and control devices (Fig. 5).

At the buccal line angles and lingual line angles (total of 204 sites each)(Mesio-buccal and Disto-buccal), the Mc Nemar test showed a significant improvement of the plaque score categories from before to after the interventions ($P < 0.0001$) for both test and control devices (Fig. 6). Note that following the cleansing procedure, none of the lingual line angle sites demonstrated a PlI = 2 & 3 after applying the Circum® brush.

Discussion

This study has clearly demonstrated the superiority in cleansing effectiveness of the Circum® interdental brush (CB) over the straight control brush (TePe®) (SB). Eight subjects had been drawn to the study contributing with a total of 816 tooth and implant sites. The subjects merely represented a model for testing the efficacy of the IB brushes. To determine the size of the difference in removing biofilm between the two brushes, a reverse power analysis was performed (Cohen 1988). Following the equation (; $Power = \frac{ES\alpha\sqrt{n}}{\delta}$ when ES = (the effect size or the mean difference), n = the number of

Table 2. **Mean (SD) of plaque score for all sites assessed before and after the cleansing procedure (a) plaque score before and after application is significantly different ($P < 0.0001$) (b) plaque score after application of Circum® and Tepe® is significantly different ($P < 0.0001$)**

		Overall score	Four line angles	Buccal line angles	Lingual line angles	Buccal	Lingual	Mesial	Distal
Circum®	Before	1.89 (0.03)	1.97 (0.17)	1.96 (0.21)	1.99 (0.12)	1.72 (0.48)	1.55 (0.56)	1.99 (0.10)	1.99 (0.10)
	After	0.45a (0.08)	0.33a (0.53)	0.61a (0.59)	0.04a (0.21)	1.33a (0.62)	0.91a (0.51)	0.00a (0.00)	0.00a (0.00)
TePe®	Before	1.88 (0.10)	1.96 (0.21)	1.96 (0.22)	1.97 (0.21)	1.67 (0.53)	1.55 (0.52)	1.98 (0.20)	1.99 (0.17)
	After	1.02 a,b (0.21)	1.39 a,b (0.63)	1.18 a,b (0.64)	1.60 a,b (0.53)	1.42 a (0.62)	1.21 a,b (0.53)	0.00 a (0.00)	0.00 a (0.00)

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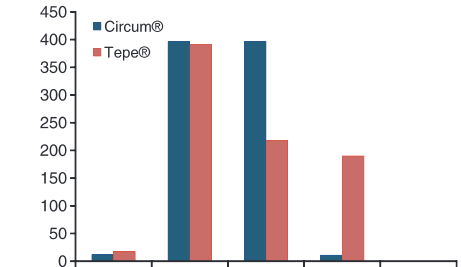


	0+1 Before	2+3 Before	0+1 After	2+3 After	
Circum®	12	396	397	11	
Tepe®	17	391	218	190	

Fig. 5. Plaque score distribution (PlI 0 & 1 vs. 2 &3) before and after the cleansing procedure for Circum® and TePe® brushes respectively.

subjects and δ = the standard deviation) assuming power of 80% and a level of significance (α) at 0.05, the minimum detectable effect size (MDES) can be calculated. For the patient level, the effect size of mean plaque scores before and after using CB = 0.41, the effect size of mean plaque scores before and after using SB = 0.8 and the effect size of mean plaque scores after using CB and SB = 1.2. A high ES of 1.2 means that the mean plaque score difference between the two brushes after application had to be at-least PlI = 1.2 to be detected. As the detectable size was high (PlI = 1.2) and yet, the result indicated significantly differences, the reverse power analysis of this study confirmed a power of 80% of the present study at an α = 0.05.

The cleansing effectiveness for both the CB and the SB resulted in significant mean biofilm reductions, when before and after application was compared at the subject and site levels in this study. This cleansing effect is in agreement with previous studies (Kiger et al. 1991; Jared et al. 2005, Jackson et al. 2006; Rösing et al. 2006; Yost et al. 2006). However, when the two interdental brushes of the present study were compared after application, there was no significant difference at both mesial and distal sites, both yielding zero scores. This, in turn, means that both CB and SB are effective in purely interproximal cleansing.

However, there were highly significant differences in biofilm removal after the application of the CB compared with SB at the line angles, both buccally and lingually. Hence, the cleansing efficacy of the CB clearly surpasses that of the SB. It has to be kept in mind, however, that the efficacy of the brush itself, and not the capacity of the subject to clean interproximally, was evaluated in the present study. Obviously, better cleaning effects may be obtained with straight IB by well-instructed patients under the correct anatomical conditions and adequate time allocation. In the present study, subjects were selected to provide adequate space in the interdental or inter-implant region to fit Circum® IB of the sizes No.3 or No. 5. The control SB was chosen accordingly. Hence, the cleansing procedure that was standardized and performed by a specially trained certified dental surgery assistant allowed the direct comparison between the two devices.

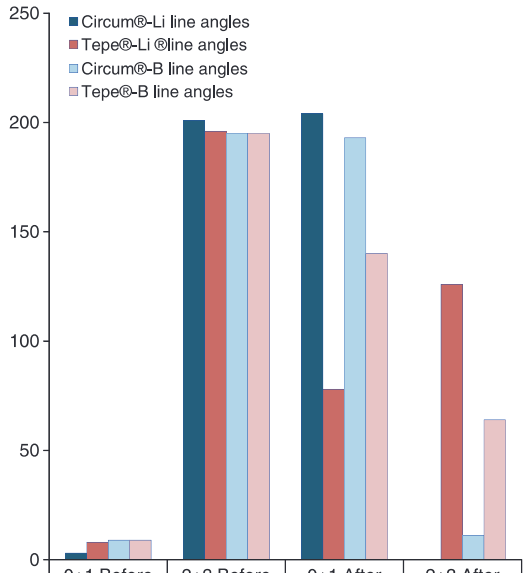
For this evaluation, the original Plaque Index (Silness & Löe 1964) was modified for the assessment of the line angles.

A similar approach was chosen in a comparative study to evaluate the cleansing efficacy of IB and dental floss in periodontitis patients (Christou et al. 1998). In this study, special attention was given to the biofilm reduction at the four line angles. Indeed, IB application resulted in superior efficacy in biofilm removal than did dental floss.

There are only very few studies that compared the efficacy of two different interdental brushes in removing biofilm. In one study (Rösing et al. 2006), the plaque removal effect of conical IBs vs. cylindrically shaped IBs was compared. Although a significant biofilm removal from baseline was documented with both brushes, there were no significant differences between the two different designs indicating that both cylindrical as well as conical IB may have satisfactory cleansing efficacy. It has to be realized, however, that the biofilm removal at the line angles was not assessed in the said study.

The present study aimed at a comparison of two completely different IB design. A novel product, the waist-shaped Circum® brush (CB) was to be tested against a standard size and straight interdental brush (SB). The results showed significant differences in biofim removal effectiveness for CB over SB for all aspects of the tooth or implant evaluated except the buccal sites that were not affected by IB application. The waist-shaped brush that had a larger diameter at the base and the tip when passed through the proximal contact certainly provided more friction to the teeth or prosthesis at the lingual line angles. In addition, when retrieved, the bristles may have removed more biofilm at the line angles, thus resulting in a better cleansing effect than the SB. Biofilm removal at lingual sites was also superior with the CB, although IBs are not necessarily designed to clean on the lingual aspects of teeth or implants. This, in turn, means that the larger diameter end bristles even reach to the mid-lingual aspect.

The present study is different from many of the studies that instructed the patients of how to use interdental brushes and asked them to come back for examination later on (e.g. Bassiouny & Grant 1981, Christou et al.



	0+1 Before	2+3 Before	0+1 After	2+3 After
Circum®-Li line angles	3	201	204	0
Tepe®-Li ®line angles	8	196	78	126
Circum®-B line angles	9	195	193	11
Tepe®-B line angles	9	195	140	64

Fig. 6. Plaque score distribution (PlI 0 & 1 vs. 2 &3) before and after application of Circum® and TePe® IB at lingual (Li) and buccal (B) line angles.

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1998, Jared et al. 2005). In those studies, an effect in biofilm removal is the combined result of the efficacy of the IB applied, the design of the handle of the IB, the skills and dexterity of the patient and the motivation to devote sufficient time and energy into interproximal cleansing. Moreover, studies with patient performance usually provide data on the changes in the host response, such as reduction in bleeding on probing and/or probing depth reduction. The present study was not designed to test those possible effects. Standardization was the important feature of the study design, and only the effectiveness in cleansing was to be evaluated.

Both CB and SB used in the present study were of a super soft type. These characteristics may be addressed when elaborating on the cleansing efficacy of a brush. However, no influence of bristle stiffness on cleansing efficiency has been documented in an *in vitro* study comparing hard and soft bristle IBs (Wolff et al. 2006).

In conclusion, the application of the waist-shaped Circum® IB resulted in significantly lower PlI scores than the use of a straight IB. This was predominantly due to the much higher cleansing effect of the waist-shaped Circum® brush on the buccal and lingual line angles.

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