

Effects of a Mechanical Interdental Cleaning Device on Oral Hygiene in Patients with Lingual Brackets

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Abstract: This study was aimed at determining the influence of a battery-operated interdental cleaning device (icd) (WaterPik Flosser) on the oral hygiene of 32 female right-handed patients (mean age 25.9 years) with lingual brackets in the upper (n = 29) and or in the lower arch (n = 25). Approximal plaque index (API) and bleeding on probing (BOP) were recorded at the lingual surfaces by a single blinded examiner before application (t0), on average 38.6 days after (t1), and again on average 46.0 days after (t2) the application of the icd. The patients used the icd once a day in the second and fourth quadrants only (icdq). In all quadrants (icdq and non-icd quadrants [n-icdq]), oral hygiene was performed with a manual toothbrush. Of the patients enrolled in the study, 96.9% found the icd subjectively very helpful to moderately helpful for cleaning their teeth and 65.6% had the subjective impression that their teeth were cleaner with the appliance. Despite those positive subjective assessments, an objective comparison of the icdqs with the n-icdqs revealed no statistically significant differences in the mean changes in API and BOP from t0 to t1, from t0 to t2, or from t1 to t2. Because there were spectacular improvements in API in all quadrants, the improvements could be interpreted as an outcome of the instruction and motivation given to the patients, the increasing awareness of oral hygiene, and the greater skill in using the toothbrush in the course of time. (*Angle Orthod* 2003;73:579–587.)

Key Words: Aesthetic appliances; Plaque reduction; Gingivitis

INTRODUCTION

Because of its outstanding aesthetic preconditions^{1–3} and its growing practicability regarding laboratory and clinical processes,^{4–9} lingual orthodontics accounts for an ever-increasing percentage of orthodontic treatments.¹⁰ Many papers dealing with the comfort of fixed lingual appliances¹¹ beyond mere refinement of the technical procedure or with achievable treatment outcomes^{12,13} were published in recent years. However, there were only sporadic reports and recommendations on oral hygiene in lingual orthodontics.^{14–20}

In contrast to treatment with fixed buccal appliances, for which various prophylactic procedures, toothbrushes, or mouthrinses have been scientifically investigated,^{21–23}

similar studies relating to treatment with lingual brackets have yet to be published. However, studies on oral hygiene, special brushing techniques, and oral hygiene aids would be even more important for therapy with lingual brackets than for therapy with labial brackets because control is more difficult from the lingual than from the buccal, and plaque accumulations, gingivitis, and demineralisation are not detected by the patient.

The aim of the present study was therefore to evaluate plaque accumulation and inflammation in patients who had already had lingual brackets fitted and to investigate the subjective and objective adjunctive value of a new battery-operated interdental cleaning device (icd) (Figure 1) to oral hygiene, ie, controlling or reducing preexisting plaque and inflammation.

MATERIALS AND METHODS

Initially, 48 right- and left-handed patients who had already had lingual braces fitted were examined for possible inclusion in this prospective longitudinal study. The lingual brackets (Ormco 7th generation, Ormco, Amersfoort, Netherlands) had originally been placed on the patient's cast with minimum positioning thickness.⁶ After sandblasting and conditioning the enamel with 37% phosphoric acid, the

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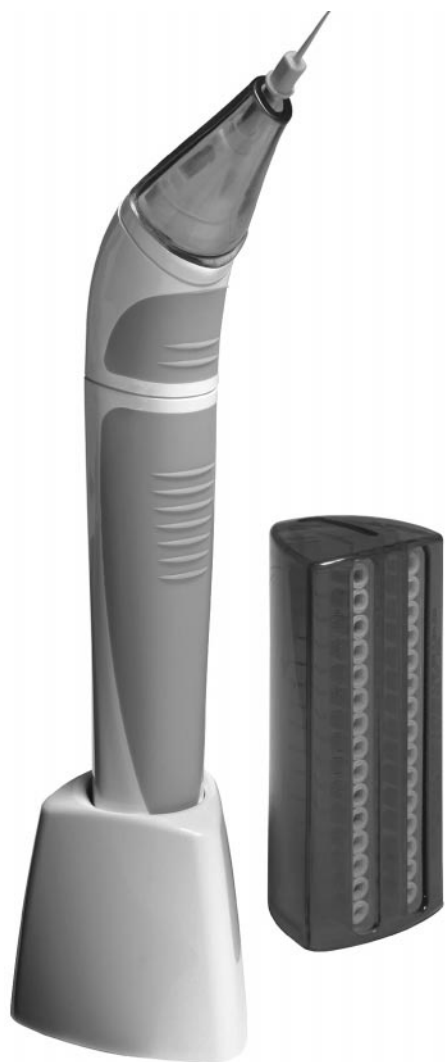


FIGURE 1. The WaterPik Flosser. The battery-operated device has a snap-on attachment to hold the flosser tips, which are made of flexible yet firm nylon. Their orally directed end is rounded to protect the gingiva. They are conically shaped to facilitate access to the interproximal spaces and move up and down at 10,000 oscillations per minute as soon as the device is switched on. This action scrapes off the plaque in the interdental spaces. A new flosser tip should be inserted for each application. For this purpose, the snap-on attachment can be inserted into the hole of the topmost flosser tip in the dispenser if the handpiece is held upright.

brackets had been indirectly bonded in situ, using a transfer tray.

All patients met the following inclusion criteria: they gave their informed consent; they were systemically healthy; they were not under medication (apart from contraceptives), they were not pregnant or lactating; they had no history of periodontal treatment; any periodontal disease was confined to “gingivitis associated with dental plaque only without other contributing factors” according to the classification of periodontal diseases and con-

ditions issued by the American Academy of Periodontology (1999).²⁴ Smoking habits and the subjective assessment of the icd (WaterPik Flosser, Intersanté GmbH, Bensheim, Germany) (Figure 1) were evaluated by a patients’ questionnaire.

To supplement the patients’ subjective assessment of the icd with an objective assessment, one single examiner—a university lecturer with many years’ experience—blinded to the treatment status of the quadrants recorded a modification of the approximal plaque index (API)²⁵ and bleeding on probing (BOP)²⁶ in a systematic manner and in a special form (Table 1).

To determine the reliability of the assessments of the single investigator according to the method of Bland and Altman^{27,28} the examiner carried out repeated test assessments of the API of 10 test persons in the run-up to the investigation (first intraorally and then on two different days on a series of 10 intraoral photographs of those test persons). The investigator was also trained in and tested for gentle probing (less than 0.25 N) on two different days.

The investigation was carried out at three timepoints: before application of a mechanical icd (baseline, t0) and at two timepoints (t1, t2) after application of the icd (for time interval between timepoints see Results). After one single session of instruction in using the device, the patients were advised on the importance of using the icd only once a day in each approximal space of the second and fourth quadrants only (interdental cleaning device quadrants, icdq) for 10 seconds.

In all quadrants, ie, in both the icdq and the noninterdental cleaning device quadrants (n-icdq, first and third quadrants) the teeth were cleaned with a manual toothbrush (Elmex 29, Gaba GmbH, Lörrach, Germany). The patients were instructed to rinse out any coarse food residues with water before cleaning their teeth and then to brush their teeth according to the modified Bass technique for three minutes.²⁹ The occlusal surfaces were to be cleaned by sagittal toothbrush movement. The patients were instructed about the importance for study purposes of not using any oral hygiene aids apart from the icd and the toothbrush, of performing oral hygiene in the evening before the morning scheduled for examination, and of neither eating nor brushing their teeth in the morning before the examination.

The study was carried out in the year 2001.

Statistics

Statistical analysis was performed with SPSS 10.0 for Windows.

The Wilcoxon signed rank test for related samples was used to evaluate differences in API/BOP in each single quadrant between timepoints t0 and t1, t0 and t2, and t1 and t2.

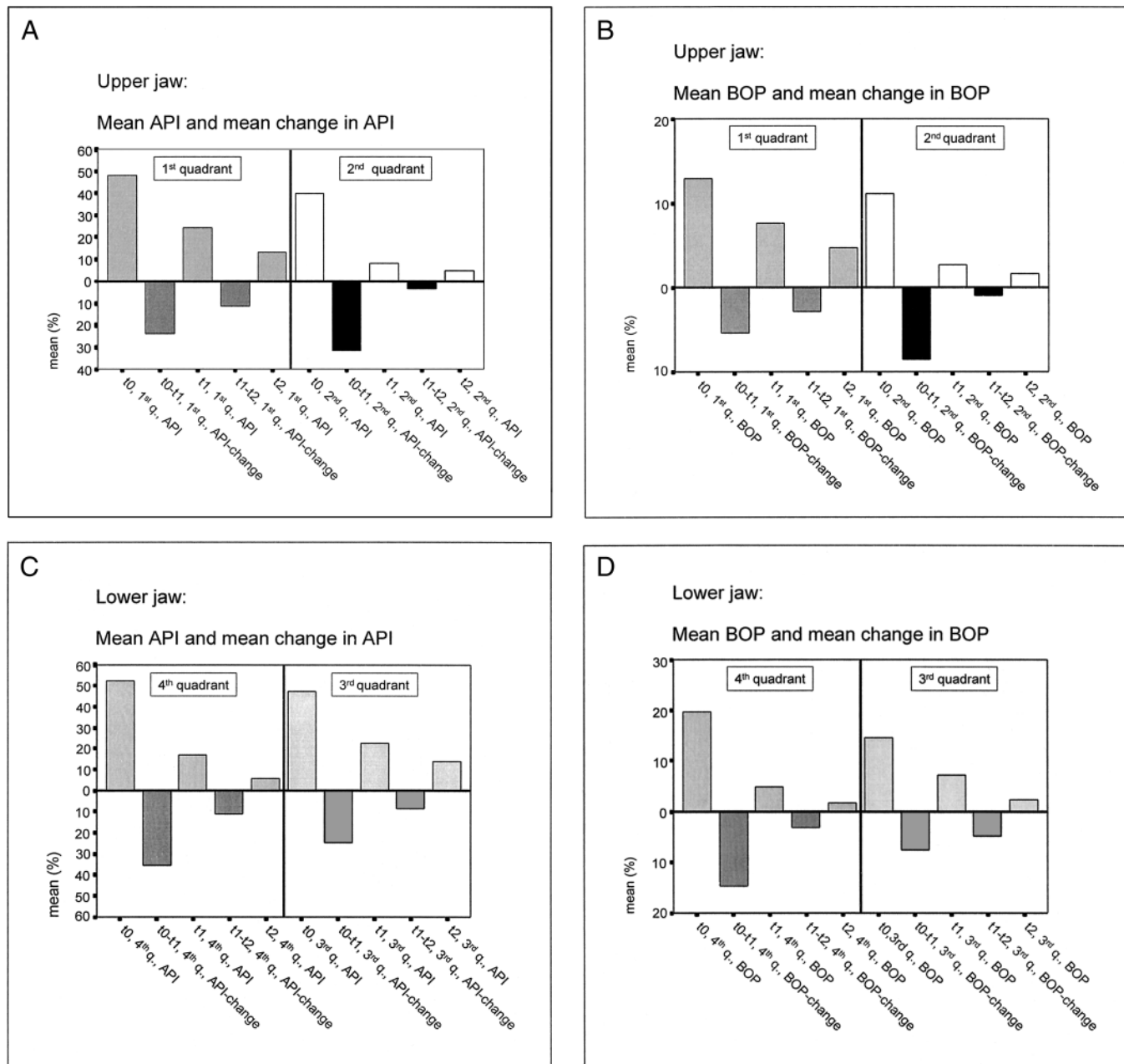


FIGURE 2. (A) Mean API and mean change in API in the upper jaw. (B) Mean BOP and mean change in BOP in the upper jaw. (C) Mean API and mean change in API in the lower jaw. (D) Mean BOP and mean change in BOP in the lower jaw.

The Mann-Whitney *U*-test for independent samples was applied:

- To check for any differences in API and BOP between the icdq and the n-icdq in each jaw at t0, t1, or t2.
- To check for any differences between the icdq and the n-icdq in each jaw for changes in API/BOP from t0 to t1, from t0 to t2, and from t1 to t2.
- To check for differences in API and BOP and for mean changes in API and BOP between smokers and non-smokers, women taking contraceptives vs women not tak-

ing contraceptives, and women giving the icd a better subjective assessment vs women giving it a poorer subjective assessment.

$P \leq .05$ was defined as significant.

RESULTS

Patients

Four of the initial 48 patients with lingual brackets were left-handed. Because the statistical analysis revealed signif-

TABLE 1. Explanation of Evaluation of API and BOP

API	BOP
Based on a yes/no decision (ie, it is not the amount of plaque that is recorded but only the presence or absence of plaque). API as evaluated in the present study differed from the original description ^{25,26} in that evaluation was confined to the lingual interproximal spaces of all teeth, the percentage data were assigned to the lingual interproximal spaces of single quadrants (one quadrant = seven interproximal spaces = 100%), and staining for evaluation of API was renounced.	Based on a yes/no decision (ie, it is not the amount of bleeding that is recorded but only the presence or absence of bleeding). BOP as evaluated in the present study differed from the original description ^{25,26} in that evaluation was confined to the lingual interproximal spaces of all teeth and the percentage data were assigned to the lingual interproximal spaces of single quadrants (one quadrant = seven interproximal spaces = 100%). BOP was recorded within 20 s of gentle probing (less than 0.25 N) vertically to the lingual approximal pockets with a standard manual periodontal probe with a diameter of 0.45 mm (PCPUNC 15, HU Friedy, Leimen, Germany).

icant differences between right-handed and left-handed subjects regarding BOP in the fourth quadrant at t0 ($P \leq .026$), the left-handed subjects had to be excluded from the study, ie, only right-handed subjects were enrolled.

Because men proved to have a significantly better API at t0 in first quadrant ($P \leq .003$), men were excluded from the study, and only female patients were enrolled ($n = 32$, mean age 25.9 years, range 12.5–48.7, SD 9.3).

Seven women had lingual brackets in the upper arch only, three in the lower arch only, and 22 in both arches. Thus 29 upper and 25 lower arches with lingual brackets were covered by the study. Twenty-four of the patients (75%) were nonsmokers, eight were smokers (25%) (mean number of cigarettes per day 2.0, SD 4.2, range 4–15), and twelve women were taking contraceptives (37.5%).

Subjective assessment of the appliance as evaluated by patients' questionnaires

The icd was rated as “very helpful” in cleaning their teeth by 46.9% of the patients, “moderately helpful” by 50%, and “not helpful at all” by only 3.1%. The subjective perception that their teeth were “cleaner” with the appliance was held by 65.6% of the patients, “slightly cleaner” by 34.4% of the patients, and no patient considered their teeth less clean with the icd. The patients rated handling of the icd as “very good” 12.5%, “good” 65.6%, “moderate” 15.6%, and “poor” 6.3%.

Compared with the conventional aids for oral hygiene (dental floss/interdental brush) that they had been using before the study began, 50% of the patients were of the opin-

TABLE 2. Comparison of API and BOP at the Lingual Surfaces of the Upper Arch ($n = 29$)

	Mean (%) [SD] /Range/	First Quadrant (n-icdq)			Second Quadrant (icdq)		
		P [t0 vs t1]	P [t0 vs t2]	P [t1 vs t2]	Mean Change [t0 vs t1 (%)] [SD] /Range/	Mean Change [t0 vs t2 (%)] [SD] /Range/	Mean Change [t1 vs t2 (%)] [SD] /Range/
API		.001	.000	.005	24.0 [28.1] /-28.6–71.4/	35.2 [28.5] /-28.6–100.0/	11.1 [18.2] /-28.6–50.0/
API (t0)	48.2 [27.6] /0.0–100.0/						39.8 [33.2] /0.0–100.0/
API (t1)	24.2 [16.7] /0.0–57.1/						8.3 [12.7] /0.0–42.9/
API (t2)	13.0 [13.5] /0.0–42.9/						4.9 [8.4] /0.0–28.6/
BOP		.035	.037	NS	5.4 [14.8] /-16.6–42.9/	8.3 [18.4] /-33.3–42.9/	2.9 [13.4] /-33.3–33.3/
BOP (t0)	12.9 [17.5] /0.0–42.9/						11.2 [12.8] /0.0–42.9/
BOP (t1)	7.5 [14.2] /0.0–42.9/						2.6 [5.9] /0.0–16.7/
BOP (t2)	4.7 [10.4] /0.0–40.0/						1.6 [4.9] /0.0–16.7/

n-icdq indicates noninterdental cleaning device quadrant (quad.); icdq = interdental cleaning device quadrant; P = P value; NS = not significant ($P > .05$); t0 = before application of the icd; t1 = first appointment after application of the icd; t2 = second appointment after application of the icd.

ion that the icd led to a “clear-cut saving in time,” 34.4% found “no difference,” and 15.6% claimed to take more time with the icd. When the orthodontic treatment was completed, 87.5% of the patients planned to continue using the icd, whereas 12.5% did not.

Reliability of the investigator’s API and BOP assessments

Reliability tests showed that 95.6% of the scoring differences (API) on the photographs, 95.0% of the scoring differences “photograph vs intraoral examination,” and 95.2% of the probing force differences (BOP) of the single investigator were within two standard deviations.

Objective assessment of oral hygiene by API and BOP

The results for the upper and the lower arch are reported separately below.

Upper arch API (Table 2, Figure 2A).

- At t0, there was no statistically significant difference between the icdq and the n-icdq.
- From t0 to t1, the API fell significantly in each quadrant, with no statistically significant difference between the icd and the n-icdq in the mean change in API.
- At t1, the API was statistically significantly lower in the icdq.
- From t1 to t2, the API fell in each quadrant (significantly in the n-icdq), with no statistically significant difference

between the icd and the n-icdq in the mean change in API.

- At t2, the API in the icdq was statistically significantly lower than in the n-icdq.

Upper arch BOP (Table 2, Figure 2B).

- At t0, there was no statistically significant interquadrant difference.
- From t0 to t1, the BOP fell significantly in both quadrants, with no statistically significant difference between the icd and the n-icdq in the mean change in BOP.
- At t1, the BOP did not differ statistically significantly between the icdq and the n-icdq.
- From t1 to t2, no statistically significant improvement of BOP was recorded in either quadrant, and there was no statistically significant interquadrant difference in the mean change in BOP.
- At t2, there was no statistically significant interquadrant difference in BOP.

Lower arch API (Table 3, Figure 2C).

- At t0, there was no statistically significant difference between the icdq and the n-icdq.
- From t0 to t1, the API fell significantly in each quadrant, with no statistically significant difference between the icd and the n-icdq in the mean change in API.
- At t1, there was no statistically significant interquadrant difference in API.
- From t1 to t2, the API fell significantly in both quadrants,

TABLE 2. Extended

			Second Quadrant (icdq)			P (First vs Second Quadrant at t0 or t1 or t2)	P (Mean Changes Over Times in the first vs second Quadrant)
P [t0 vs t1]	P [t0 vs t2]	P [t1 vs t2]	Mean Change [t0 vs t1 (%)] [SD] /Range/	Mean Change [t0 vs t2 (%)] [SD] /Range/	Mean Change [t1 vs t2 (%)] [SD] /Range/		
.000	.000	NS	31.6 [30.1] /-14.3-100.0/	34.9 [31.5] /0.0-100.0/	3.4 [11.0] /-16.7-42.9/	NS	(t0 vs t1) NS
						.000	(t1 vs t2) NS
						.014	(t0 vs t2) NS
.006	.004	NS	8.6 [14.0] /-16.7-42.9/	9.6 [14.4] /-16.7-42.9/	1.0 [7.3] /-16.7-16.7/	NS	(t0 vs t1) NS
						NS	(t1 vs t2) NS
						NS	(t0 vs t2) NS

TABLE 3. Comparison of API and BOP at the Lingual Surfaces of the Lower Arch (n = 25)

	Mean (%) [SD] /Range/	Fourth Quadrant (icdq)			Third Quadrant (n-icdq)		
		P [t0 vs t1]	P [t0 vs t2]	P [t1 vs t2]	Mean Change [t0 vs t1 (%)] [SD] /Range/	Mean Change [t0 vs t2 (%)] [SD] /Range/	Mean Change [t1 vs t2 (%)] [SD] /Range/
API		.000	.000	.004	35.6 [32.2] /-14.3-85.7/	46.9 [32.8] /0-100.0/	11.3 [16.4] /-16.7-42.9/
API (t0)	52.5 [33.0] /0.0-100.0/						47.4 [32.2] /0.0-100.0/
API (t1)	16.9 [16.7] /0.0-50.0/						22.3 [14.3] /0.0-50.0/
API (t2)	5.7 [9.2] /0.0-33.3/						13.7 [13.9] /0.0-40.0/
BOP		.001	.001	NS	14.8 [18.6] /0.0-66.6/	17.9 [22.1] /0.0-83.3/	3.0 [9.2] /-16.7-33.3/
BOP (t0)	19.7 [22.9] /0.0-83.3/						14.7 [19.2] /0.0-83.3/
BOP (t1)	4.9 [9.6] /0.0-33.3/						7.1 [14.1] /0.0-57.1/
BOP (t2)	1.8 [5.0] /0.0-16.7/						2.3 [7.9] /0.0-28.6/

n-icdq indicates noninterdental cleaning device quadrant (quad.); icdq = interdental cleaning device quadrant; P = P value; NS = not significant ($P > .05$); t0 = before application of the icd; t1 = first appointment after application of the icd; t2 = second appointment after application of the icd.

with no statistically significant difference between the icd and the n-icdq in the mean change in API.

- At t2, the API in the icdq was statistically significantly lower than in the n-icdq.

Lower arch BOP (Table 3, Figure 2D).

- At t0, there was no statistically significant interquadrant difference.
- From t0 to t1, the BOP fell significantly in both quadrants, with no statistically significant difference between the icd and the n-icdq in the mean change in BOP.
- At t1, the BOP did not differ statistically significantly between the icdq and the n-icdq.
- From t1 to t2, no statistically significant improvement in BOP was recorded for either quadrant, and there was no statistically significant interquadrant difference in the mean change in BOP.
- At t2, there was no statistically significant interquadrant difference in BOP.

Influence of smoking habits on the assessment of API and BOP

- There were no significant differences between smokers and nonsmokers in any of the investigated parameters.

Influence of contraceptives on the assessment of API and BOP

- The mean change in BOP in the second quadrant (icd-q) from t0 to t1 was significantly lower in women not taking

contraceptives (mean 4.4%, SD 11.9, range -16.7-33.0) than in those taking contraceptives (mean 16.4, SD 14.7, range 0.0-42.9) ($P \leq .043$).

Influence of age on the assessment of API and BOP

Significant differences between women under 24 years of age and older women were recorded for the following parameters:

- From t1 to t2, the mean change in API in the second quadrant (icdq) was significantly better in younger women (mean 8.5%, SD 13.0, range 0.0-42.9) than in older women (mean -0.28%, SD 7.8, range -16.7-14.3) ($P \leq .032$).
- From t1 to t2, the mean change in BOP in the second quadrant (icdq) was significantly better in younger women (mean 9.9%, SD 13.4, range 0.0-33.3) than in older women (mean -2.1%, SD 11.4, range -33.3-16.6) ($P \leq .025$).

Influence of time interval between investigations

To check for any influence of the investigation period on the results, each of the groups was divided in the region of the median value. This yielded different median values for the period between t1 and t2 for patients with lingual brackets in the upper arch (n = 29) and in the lower arch (n = 25).

- From t0 to t1, no statistically significant differences were recorded between women who were examined within 29

TABLE 3. Extended

Third Quadrant (n-icdq)						P (Third vs Fourth Quadrant at t0 or t1 or t2)	P (Mean Changes Over Times in the third vs fourth Quadrant)
P [t0 vs t1]	P [t0 vs t2]	P [t1 vs t2]	Mean Change [t0 vs t1 (%)] [SD] /Range/	Mean Change [t0 vs t2 (%)] [SD] /Range/	Mean Change [t1 vs t2 (%)] [SD] /Range/		
.003	.000	.005	25.1 [31.2] /-40.0-85.7/	33.7 [35.0] /-40.0-100.0/	8.6 [14.9] /-14.3-42.9/	NS	(t0 vs t1) NS
						NS	(t1 vs t2) NS
						.030	(t0 vs t2) NS
.012	.003	NS	7.5 [15.6] /-14.3-50.0/	12.4 [19.9] /-14.3-83.3/	4.9 [15.1] /-28.6-57.1/	NS	(t0 vs t1) NS
						NS	(t1 vs t2) NS
						NS	(t0 vs t2) NS

TABLE 4. Significant Correlations Between Subjective and Objective Assessment of the icd

Question: How Did You Find the Handling of the icd?	Quadrant	Parameter	Timepoint	Answer "Very Good to Good" Mean (%) [SD] /Range/ (n)	Answer "Moderate to Poor" Mean (%) [SD] /Range/ (n)	P Value
See above	IV	API	t0	45.0 [32.3] /0.0-100/ (20)	82.7 [12.0] /71.4-100/ (5)	.024
See above	IV	API	t1	13.8 [16.2] /0.0-50.0/ (20)	29.6 [13.1] /16.7-42.9/ (5)	.033
See above	IV	API (mean change)	t0-t2	38.6 [30.7] /0.0-100/ (20)	79.8 [16.3] /57.1-100/ (5)	.015
See above	IV	API (mean change)	t1-t2	7.4 [15.4] /-16.7-42.9/ (20)	26.7 [10.8] /16.7-42.9/ (5)	.007
See above	IV	BOP	t1	1.5 [4.8] /0.0-16.7/ (20)	18.1 [13.2] /0.0-33.3/ (5)	.001
See above	IV	BOP (mean change)	t1-t2	0.0 [5.4] /-16.7-16.7/ (20)	15.2 [11.8] /0.0-33.0/ (5)	.001

days and women who were examined after 29 days or more.

- From t1 to t2, there was a statistically significant difference in the BOP of the first quadrant (n-icdq) at t1 between women who were examined within 41 days (n = 14) and women who were examined after 41 days or more (n = 15) ($P \leq .02$).

Relationship between subjective assessment of icd handling and objective findings (Table 4)

API and BOP at t1 in the fourth quadrant were significantly worse in patients giving the icd a poorer subjective assessment than in those patients giving it a better subjective assessment, whereas the mean changes in API and BOP were significantly better in those patients giving the icd a poorer subjective assessment than in those patients giving it a better subjective assessment.

DISCUSSION

The present study is the first to have quantified plaque accumulation and gingivitis in a group of patients with

lingual brackets over a mean time period of three months. Previously, only plaque accumulation had been recorded and only over a shorter time period: Sinclair et al³⁰ measured the plaque index according to the method of Löe³¹ in 17 patients with lingual brackets one month after the start of treatment. The plaque index (49%) determined by Sinclair et al³⁰ is in accordance with the API levels recorded in the present study before application of the icd. Sinclair et al³⁰ as well as Miyawaki et al³² (the latter observing retrospectively that patients with lingual brackets in both arches had significantly more dental hygiene problems than those with a labial appliance in both arches) recommended that special emphasis should be placed on oral hygiene of patients with lingual brackets. In view of the results of the present study, this recommendation is endorsed.

Because the indices used for evaluation of plaque and gingivitis are reliable and timesaving, they could also be readily used in subsequent comparative studies. The API used in the present study is a very strict index because it measures plaque only in the relatively inaccessible interdental spaces. Because it is easy to record, it has

asserted itself on a broad basis in routine dental practice.²⁶, pp. 252–253

The yes/no decision made for BOP facilitates evaluation of the absence or presence of gingivitis and reduces the risk of errors resulting from incorrect assessment of the intensity of bleeding, a problem inherent in other indices. For this reason, the BOP index has gained broad acceptance in routine periodontal practice.²⁶, pp. 249–250 Although there is a general agreement that BOP is a reliable sign of gingival inflammation, whether the tissues bleed depends on a variety of factors besides the extent of inflammation, ie, angulation of the probe, time factor for the appearance of bleeding, insertion force of the probe.³³ To overcome these factors, the examiner always performed the probing vertically, recorded BOP within 20 seconds, and was trained in gentle probing to overcome the problem of no pressure-controlled probe being used. Whether the tissues bleed on probing also depends on the performance of oral hygiene procedures shortly before the examination. Thus, patients were instructed to perform oral hygiene the evening before the morning of the examination and to neither eat nor brush their teeth in the morning before the examination.

Simultaneous recording of the modified API and BOP was also a means of detecting those patients who brushed their teeth only before the respective appointments and whose oral hygiene standards between appointments were only moderate or poor.³⁴ The fact that the initial mean BOP of the group was no higher than 19.7% confirms that the long-term oral hygiene of the group was satisfactory but still open to improvement, as reflected in the follow-up examinations.

The improvement in API and BOP in all quadrants from one examination timepoint to the next is open to three hypotheses. The patients developed increasing skills (practice effect) in using the manual toothbrush, or instruction in an additional aid for interdental care sensitised the patients to the aspect of dental hygiene and motivated them to better overall care from which the n-icd quadrants also benefited, or enrollment in a study on oral hygiene spurred the patients to clean their teeth more efficiently.

The design of the present study offered the advantage of intraindividual comparison. This ruled out the possibility of the result of the study being influenced by the varying degree of manual skill among the patients. On the other hand, the split-mouth design of the present study in contrast to a parallel group study design, where some patients use an icd and some do not, has the inherent risk of some patients knowingly or unknowingly using interdental cleaning either in the wrong quadrants or in all quadrants. To minimise this risk, great care was taken in explaining to the patients in detail the importance of using the icd in the second and fourth quadrants only.

The reliability of the assessments in our study was assured by the fact that one single examiner, a university lecturer and clinician with many years of experience, assessed

API and BOP. The reliability of the examiners' API assessments and probing forces was checked with the method of Bland and Altman and, after repeated "test assessments", revealed 95% or more of the scoring/probing force differences of those assessments to be within two standard deviations. This is sufficient according to the definition of a reproducibility coefficient adopted by the British Standards Institution.³⁵

One point open to criticism is that the investigator's assessments were not checked against those of a second specialist, so there is still a theoretical possibility that her evaluations were too high or too low. However, this would be a systematic error that would have no influence whatsoever on the mean changes between the examination timepoints.

The investigator was trained in gentle probing. Although additional calibration of the investigator and determination of her reliability/reproducibility regarding BOP would be desirable, determination of BOP is an invasive procedure that precludes repeated measurements and, thus, determination of the conformity between repeat measurements.

The results might theoretically have been biased by a heterogeneous population regarding smoking habits, intake of contraceptives, age, API and BOP at t0, time intervals between t0, t1, and t2 and subjective assessment of the appliance. This problem was solved by measuring not only the absolute API and BOP values at the examination timepoints but also the mean changes between t0 and t1, t1 and t2, and t0 and t2.

The effect of smoking is reported inconsistently in the literature.^{36,37} In the present study, it proved to have no effect on API or BOP or on their mean changes. Contraceptive intake, age of patients, interval between examinations, and subjective assessment of the icd had no constant influence either on both of the investigated parameters or throughout the entire study period. Any influence on the entire study that might distort the results is therefore negligible.

CONCLUSIONS

Special emphasis should be placed on the oral hygiene of patients with lingual brackets.

Excellent oral hygiene is possible in patients with lingual brackets after instruction and motivation.

The more pronounced decrease in API compared with BOP could be attributed to the baseline API having been higher than the baseline BOP, permitting a greater reduction.

The icd was given a very positive subjective assessment by the patients. This positive subjective impression was verified objectively at the clinical examination timepoints t1 and t2. The API and BOP were invariably lower or significantly lower in the icdqs than in the n-icdqs. However, spectacular improvements in API and BOP were recorded

at the clinical examination in all quadrants, ie, also in those in which the icd was not used, and there were no significant differences in the mean changes over times between icd and n-icd quadrants. The improvements in all quadrants could be interpreted as an outcome of the instruction and motivation given to the patients, the increasing awareness of oral hygiene or the greater skill in using the toothbrush in the course of time.

Further investigations are needed to evaluate the efficiency of the icd in patients without and with buccally fixed orthodontic appliances and are also needed to assess the value of other interdental hygiene aids such as dental floss for patients with lingual brackets.

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