J Clin Periodontol 2006; 33: 276–282 doi: 10.1111/j.1600-051X.2006.00900.x

Journal of Clinical Periodontology

Comparison of two automated periodontal probes and two probes with a conventional readout in periodontal maintenance patients

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Barendregt DS, Van der Velden U, Timmerman MF, van der Weijden GA. Comparison of two automated periodontal probes and two probes with a conventional readout in periodontal maintenance patients. J Clin Periodontol 2006; 33: 276–282. doi: 10.1111/j.1600-051X.2006.00900.x.

Abstract

Aim: The aim of the present study was to test in periodontal maintenance patients whether the systems for pressure control that have been commercially developed contribute to more reproducible probing depth measurements as compared with a manual probe.

Material and Methods: In 12 patients duplicate measurements were made at day 0 and 1 week later. In each patient four teeth with the deepest pockets were measured at six sites. In total 288 sites were available for comparisons. The Florida Probe® (FP) (159 N/cm^2), the Jonker Probe® (JP) (153 N/cm^2), the Brodontic® probe (BP) (255 N/cm^2) and the manual probe (MP) were used in a randomized scheme.

Results: Mean probing measurements showed for the FP and the JP lower recordings than for the BP and manual probe. The FP, the BP and the MP showed no differences between the duplicate measurements, except for the JP where the second measurement was deeper. Correlation coefficients between measurements at day 0 and 1 week show for the BP and the MP are 0.90 and 0.89, respectively, while for the FP and the JP they are 0.76 and 0.75, respectively.

Conclusion: The BP and the MP appear to be reliable tools for reproducible pocket depth measurements in periodontal maintenance patients.

Key words: force controlled probes; maintenance patients; probing pocket depth; reproducibility

Accepted for publication 29 December 2005

A periodontal probe till today remains the most important diagnostic tool in periodontal diseases. It is used to establish the presence and severity of the disease and also to assess the effect of periodontal treatment. The probe enables the clinician to determine pocket depth, attachment level, presence of plaque and calculus, and anatomical features of the root. Reliable measurements of the pocket depth and the attachment level are critical to both longitudinal clinical studies and routine clinical assessment in periodontal therapy. Current probing methods are subject to various errors, e.g. measurement outcomes are strongly dependent on probing force (Hassell et al. 1973, Van der Velden 1979, Mombelli et al. 1992). Therefore, variations in probing force appear to be evident between different examiners but also with a single examiner (Gabathuler et al. 1971). When measuring a pocket, the degree of probe tip penetration is also influenced by the presence of inflammation. Even with relatively high forces, the probe tip usually fails to reach the connective tissue attachment in healthy sites (Fowler et al. 1982). With low probing pressures, the probe tip generally stops at the level of intact connective tissue fibres or beyond in deep inflamed sites (Bulthuis et al. 1998).

During the last decades various pressure-sensitive automated probes have been developed to reduce the factor of variability of probing force (Chamberlain et al. 1985, Garnick et al. 1989). Some authors have reported an improved reproducibility of probing measurements (Abbas et al. 1982, Walsh et al.

1989, Osborn et al. 1990, Wang et al. 1995), whereas others found no improvement of the reproducibility when using constant force probes (Van der Velden et al. 1980, Kalkwarf et al. 1986, Watts 1987, Quirynen et al. 1993).

The Florida Probe® (FP) (Fig. 1) introduced by Gibbs et al. (1988) has shown to be more reproducible than manual probing in a number of studies (Gibbs et al. 1988, Magnusson et al. 1988, Yang et al. 1992). At present this probe is considered the ''golden standard'' of the automated probes based on the extensive research on the validity of the FP (Osborn et al. 1992, Grossi et al. 1996, Reddy et al. 1997). Also the Brodontic® probe (BP), with a spring-loaded hinged handle, was developed (Borsboom et al. 1981) to overcome the problem of varying probing forces. This probe showed a better reproducibility of probing depth measurements than a manual probe (Simons et al. 1987). Through its simple design this probe is an attractive solution to control probing pressures in daily practice and in field studies. Several studies have used this probe to ensure a constant pressure (Barendregt et al. 1996, Breen et al. 1997, Timmerman et al. 2000). However, up to now, it has not been compared with other pressure probes such as the FP. More recently a new probe was developed in the Netherlands (Jonker Probe® (JP)) (Fig. 2). The design of this automated probe is based on the constant force probe developed by Van der Velden (1978). Like the FP it has an electronic readout. The electronic recording of the measurements offers advantages for operators who work alone and it eliminates scribe errors in clinical research.

Periodontal probing in patients with untreated periodontal disease might also be influenced by remaining calculus, plaque and overcontouring of restorations. In order to minimize this problem, Wang et al. (1995) selected patients in the maintenance phase. When testing for reproducibility, these subjects with relatively healthy reduced periodontium provide sites in which optimal probe angulation (Watts 1989, Karim et al. 1990) and positioning (Karim et al. 1990) can be facilitated.

The aim of the present study was to test in periodontal maintenance patients whether the systems for pressure control that have been commercially developed contribute to more reproducible probing depth measurements as compared with a manual probe.

Material and Methods

Patients

In total 12 periodontal maintenance patients were selected for the study. They had an initial diagnosis of moderate to advanced periodontitis, on the basis of manual probing depth measurements and radiographs. All sites had received initial periodontal therapy consisting of instruction in plaque control measures, supra/subgingival debridement and periodontal surgery when needed. Following the active treatment, they were enrolled in a three to four monthly maintenance protocol. In each patient four teeth (preferably first molars) showing at least at one site a pocket of $\geqslant 5$ mm were included in the study. For each selected tooth six sites were recorded, which resulted in 288 sites available for the study. These experimental teeth were equally distributed between the arches and incorporated shallow (<4 mm), moderate ($\geqslant 4$ and <7 mm) and deep sites ($\geqslant 7$ mm). In addition, at screening and selection, the level of gingival inflammation was evaluated through recording of the presence or absence of bleeding on manual probing (BOP).

Description of probes used

(a) Florida Probe® (FP, Florida Probe® Company, Gainesville, FL, USA) was equipped with a tapered tine with a diameter of 0.4 mm at the tip increasing to 0.5 mm at the 5 and 0.6 mm at the 10 mm marking (Fig. 1). The probing force was adjusted according to the manufacturers guidelines to 0.20 N resulting in a probing pressure of 159 N/cm^2 (Gibbs et al. 1998).
(b) Jonker Probe® (JP, Jonkers Data, Staphorst, the Netherlands). It has a tapered tine with a diameter at the tip of 0.5 mm increasing to 0.6 mm at the 5 and 0.7 mm at the 10 mm marking (Fig. 2). The probing force of JP was 0.30 N, achieving a probing pressure of 153 N/cm^2.
(c) Brodontic Probe® (BP, Prima, Byfleet, UK) with Williams markings. This probe has a spring-loaded hinged handle exerting a constant force. A tapered tine (Ash Dentsply, Weybridge, Surrey, UK) was mounted with a diameter at the tip of 0.5 mm increasing to 0.6 mm at the 5 and 0.7 mm at the 10 mm marking (Fig. 3). Based on Van der Velden et al. (1979), who used 240 N/cm^2 in maintenance patients, a probing force of 0.50 N was used to achieve a comparable probing pressure (255 N/cm^2).
(d) Conventional manual probe (Hu-Friedy, Chicago, IL, USA) with

Fig. 1. Florida Probe®

Fig. 2. Jonker Probe®

Fig. 3. Brodontic Probe®

Fig. 4. Conventional manual probe

Williams markings (Fig. 4). This probe had a tapered tine with a diameter of 0.5 mm at the tip increasing to 0.6 mm at the 5 and 0.7 mm at the 10 mm marking.

Probing depth measurements

Duplicate recordings were made with a 30 min. interval at the distobuccal (DB), midbuccal (B), mesiobuccal (MB), distolingual (DL), lingual (L) and mesiolingual (ML) sites at the four experimental teeth in each patient. This amounted to 288 evaluable sites. The recordings were performed at the first visit (day 0) and again at the second visit 1 week later (1 week). In each patient, each of the four selected experimental teeth was assigned to a random probing order according to a Latin square design. In all six sites of each experimental tooth, all four probes were used based on this assigned random order. This order remained the same for each individual tooth for the duplicate recording and the recordings 1 week apart. In order to minimize the effect of bias as a result of intra-examiner reproducibility, two examiners were chosen (M. P. and Y. IJ). Each examiner was assigned six patients and consequently 144 sites.

The probes were inserted parallel to the root surface and directed apically towards the perceived location of the apex of the root. When the pre-set force was reached (in case of the three pressure probes) the probing depth was recorded and stored by the computer software or, when appropriate, written down on a case record form by the assistant. With the manual probe and the BP the recordings were rounded off to the nearest whole millimeter.

Data analysis

Analysis of probing measurements for the different probes was performed using the site as the unit of measurement repeats. Differences between probes, duplicates and week were tested using a mixed model analysis of variance corrected for examiner and patient effects. For differences between repeats and between day 0 and 1 week, the standard error (SE) and the 95% confidence interval (CFI) were calculated. Furthermore, correlation coefficients were calculated for all probes over all sites comparing day 0 and 1 week measurements. To test for systematic differences between sessions paired Student' *t*-tests were used. *p*-values of <0.05 were accepted as statistically significant.

Results

Overall, 96% first molars and 4% second pre-molars were evaluated. Table 1 shows the mean probing depths at screening and selection with the manual probe at site level. The mean probing depth over the 288 sites was 3.90 mm. The level of gingival inflammation, as assessed by bleeding on probing, was 21.5%. The mean results were subdivided into shallow (0–3.5 mm), moderately deep (4–6.5 mm) and deep sites (7–10 mm). The proportion of the shallow group was 51%, moderate deep sites, 41% and deep sites, 8%. Compared with the buccal/lingual sites, the mean probing depth at the approximal surfaces was higher up to the level of 4.54 mm and the proportion of moderately deep pockets was also higher (59%). The buccal/lingual sites offered primarily shallow pockets (90%) with a mean probing depth of 2.62 mm. The level of bleeding on probing at the approximal sites was 23% and 16% at the buccal/lingual surfaces.

Table 2 shows the mean overall results with the four probes. The mean probing depth as established with the FP and the (JP did not differ (3.33 *versus* 3.32), neither was there a difference between the BP and the manual probe (MP) (3.95 *versus* 3.93 mm). The FP and the JP measured a significantly lower mean probing depth than the BP and the MP. When subdividing the measurements into approximal and buccal/lingual sites, similar observations were made.

Duplicate measurements (sessions 1 and 2) at day 0 and at 1 week are shown in Table 3. The FP, the BP and the MP show no significant differences between the duplicate measurements. With the JP, however, at day 0 and 1 week, the second measurement was deeper and increased by 0.19 and 0.14 mm, respectively ($p = 0.01$).

When comparing mean probing depths at day 0 and 1 week (first session only) no significant differences for the duplicate assessment 1 week apart for any of the four probes were found (Table 4). The correlation coefficients between the first assessment at day 0 and 1 week are presented in the last column of Table 4. The automated probes show a comparable value, for the FP and for the JP (0.76 and 0.75, respectively). The BP and the MP show higher correlation coefficients between sessions of 0.90 and 0.89, respectively.

Figures 5a, b, c, d illustrates the frequency distribution of the differences between the measurements at day 0 and 1 week (first session) stratified in the categories shallow (<4 mm), moderate ($\geqslant 4$ and <7 mm) and deep sites ($\geqslant 7$ mm). The range of differences between two assessments for the probes over all sites with a conventional read-out (BP and MP) does not exceed

Table 1. Mean probing depths (mm), bleeding on probing (%) and shallow(S) moderate(M) deep(D) sites (%) based on screening measurements (Williams probe) over all sites, approximal and buccal/lingual

All patients ($n = 12$)	Mean (SD)	BOP	S (%)	M (%)	D (%)
All sites	3.90 (1.65)	21.5	51	41	8
Approximal	4.54 (1.40)	23	30	59	11
Buccal/lingual	2.62 (0.90)	16	90	10	0

Table 2. Overall mean probing depths (mm) for all probes over all sites, approximal and buccal/lingual sites

	All sites ($n = 288$)		Approximal ($n = 192$)		Buccal/lingual ($n = 96$)	
	mean	SD	mean	SD	mean	SD
Florida probe®	3.33*†	1.42	3.91*†	1.31	2.17*†	0.79
Jonker probe®	3.32*†	1.36	3.82*†	1.30	2.29*†	0.79
Brodontic® probe	3.95	1.52	4.59	1.37	2.66	0.81
Manual probe	3.93	1.59	4.61	1.45	2.57	0.80

*Significant difference with the Brodontic® probe $p < 0.05$.
†Significant difference with the manual probe $p < 0.05$.

Table 3. Mean values and differences of duplicate measurements (mm) at Day 0 and 1 Week (session 1 and 2)

$n = 288$	Day 0 (mean)						1 Week (mean)					
	Session 1	Session 2	Difference 1–2	SE	95% CFI		Session 1	Session 2	Difference 1–2	SE	95% CFI	
					lower	upper					lower	upper
Florida probe®	3.29	3.41	– 0.12	0.06	– 0.24	0.00	3.32	3.29	0.03	0.06	– 0.09	0.16
Jonker probe®	3.22	3.41*	– 0.19	0.06	– 0.30	– 0.07	3.25	3.38*	– 0.14	0.05	– 0.24	– 0.03
Brodontic® probe	3.90	3.96	– 0.06	0.04	– 0.13	0.10	3.93	4.02	– 0.08	0.03	– 0.13	0.01
Manual probe	3.91	3.93	– 0.02	0.04	– 0.09	0.05	3.92	3.95	– 0.03	0.03	– 0.09	0.04

CFI, confidence interval.

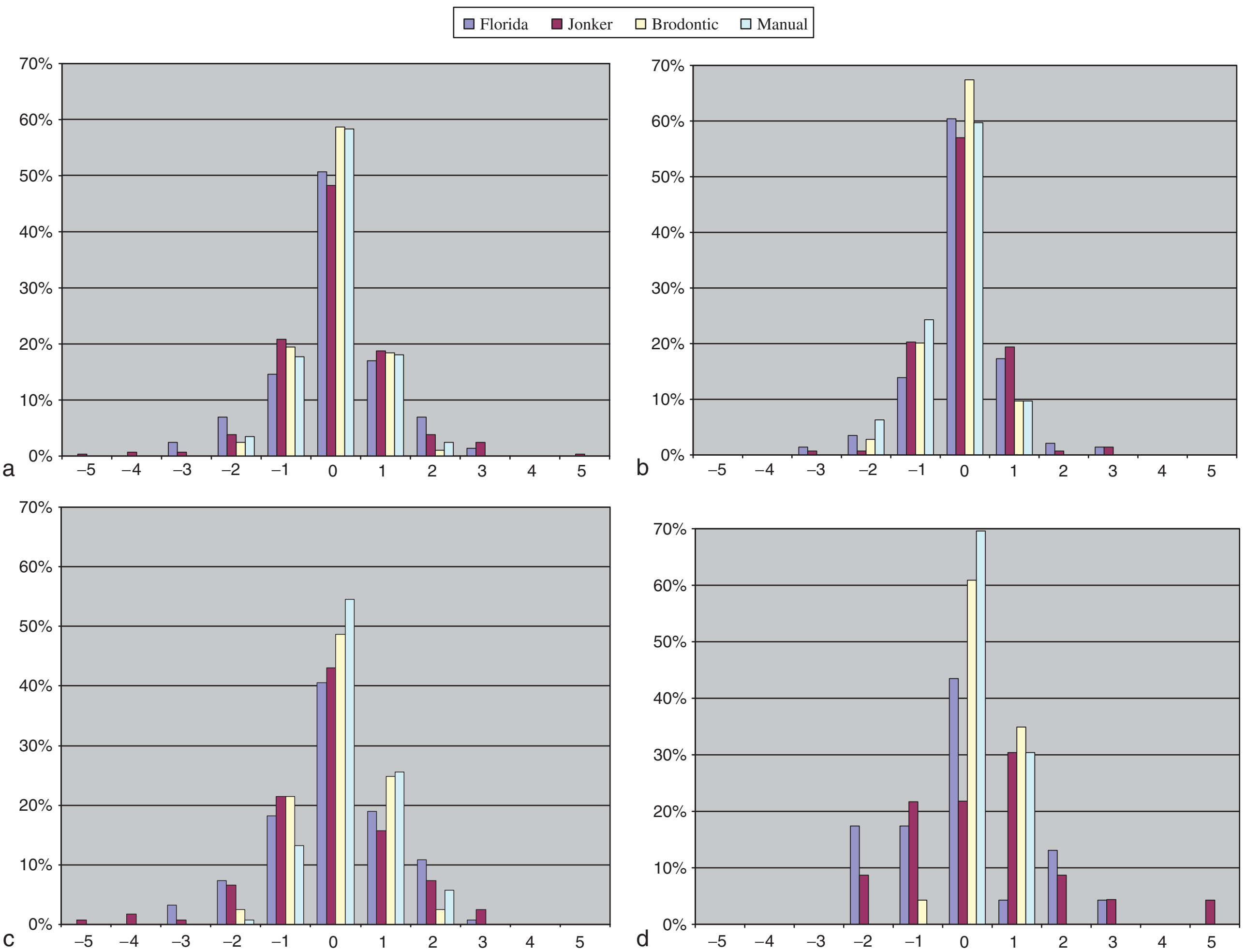

Fig. 5. (a) Frequency distribution of differences between measurements at day 0 and 1 week for all sites. (b) Frequency distribution of differences between measurements at day 0 and 1 week for shallow sites ($n = 144$). (c) Frequency distribution of differences between measurements at day 0 and 1 week for moderately deep sites ($n = 121$). (d) Frequency distribution of differences between measurements at day 0 and 1 week for deep sites ($n = 29$).

between – 2 and 2 mm. The range for the FP is – 3 to 3 mm and for the JP even – 5 to 5 mm. In 48–59% of the assessments no differences were observed between the 4 probes. The measurement error between – 1 and 1 mm is found in 94% of the cases with the BP and 96% with the MP. In comparison, the FP showed in 84% of the measurements between – 1 and 1 mm error and the JP, 88%.

Discussion

In this study three commercially available pressure probes and a manual probe were tested for their ability to provide reproducible measurements. A good range in probing depths should be available in order to compare these different probes in a proper way. As a result of the inclusion criteria used in this study, pockets of ⩾4 mm amounted to 49%. In comparison, Wang et al. (1995) pre-

Table 4. Differences and correlation coefficients at day 0–1 week (session 1) for all sites

$n = 288$	Difference	SE	95% CFI		Correlation coefficient
			lower	upper	
Florida probe®	– 0.03	0.06	– 0.15	0.09	0.76
Jonker probe®	– 0.03	0.06	– 0.15	0.10	0.75
Brodontic® probe	– 0.04	0.04	– 0.15	0.01	0.90
Manual probe	– 0.02	0.05	– 0.11	0.07	0.89

CFI, confidence interval.

sented their data in maintenance patients on 20% of pockets $\geqslant$4 mm. Mayfield et al. (1996) based their conclusions on a percentage of approximately 17% of pockets of $\geqslant$5 mm, while in the present study the percentage amounts to 36%. Reddy et al. (1997) presented data including 54% pockets of $\geqslant$5 mm. However, their sites were obtained in untreated moderate to advanced periodontitis patients. Taking into account the aforementioned studies, the present study appears to have a clinically representative study population providing a wide range of probing depths (Table 1). It is therefore feasible to assume that the results in this study are applicable for measurements of probing depths in periodontal maintenance patients.

The influence of probing pressures on the results of probing depth measurements has been studied by several authors (Hassell et al. 1973, Van der Velden 1979, Mombelli et al. 1992). The FP and the JP used pressures of 159 and 153 N/cm^2, respectively, whereas the BP was set to a pressure of 255 N/cm^2. As no differences in mean probing depths were found between the MP and the BP (Table 2), it is likely that a comparable probing pressure was exerted by the MP. The difference in probing pressures could therefore explain the higher mean probing depths with the BP and the MP as compared with the FP and the JP. As it has been shown that the periodontal condition greatly influences the results of probing depth measurements (Robinson et al. 1979, Polson 1980, Van der Velden 1980, Hancock et al. 1981, Fowler et al. 1982, Garnick et al. 1989, Bulthuis et al. 1998), in the present study all comparisons for the four probes were made at the same sites, thereby controlling for the influence variations in periodontal inflammation. Based on the studies where different probing pressures were used to evaluate the true attachment level with the aforementioned probing systems (Van der Velden 1979, Fowler et al. 1982, Bulthuis et al. 1998), it is likely that the probe tip of the two automated probes employing relatively low probing pressures did not reach the bottom of the pocket in the present study population of relatively healthy maintenance patients. Further research is needed to establish the possible consequences for the prediction of the long-term stability of the periodontal condition on the basis of probing depth measurements with relatively low or high probing pressures.

The results of the present study show that the reproducibility of the automated force controlled probes is somewhat lower compared with the BP and the MP. When comparing the probing measurements from day 0 and 1 week, differences of 2 mm and more were found for the automated probes and especially the JP (Figs 5a, b, c, d). Bulthuis et al. (1998) showed that in inflamed situations, low probing pressures are sufficient in order to reach the histological bottom of the pocket. However, these authors also suggested that, when using light forces, the examiner may run the risk of not entering the orifice of the pocket with the probe tip. This would especially be the case in more healthy sites, where the gingival margin lies tight around the neck of the tooth. Interestingly in the present study, Fig. 5b shows a difference of 3 mm for the JP and the FP in the shallow group, where the range of pocket depths lies between 0 and 3.5 mm (mean pocket depth of 2.62 mm). This suggests that at some sites these particular probes did not enter the pocket. This phenomenon could easily explain why the BP and the MP show less variability as they use higher pressures. This suggestion is consistent with the findings of Wang et al. (1995). In their study with periodontal maintenance patients, the manual probe also proved to be more reproducible than the automated force-controlled probe. The pressure of this probe was set to 156 N/cm^2 comparable with the pressure used for the FP and the JP in the present study. Waerhaug (1952) suggested that in more healthy situations, in order to reach the ''true'' bottom of the pocket with light forces, a thinner probe is needed. As the FP has a smaller diameter at the tip of the probe than the JP, it may be more capable of entering the pocket with a healthy marginal gingiva. This could explain the larger variation of measurements between day 0 and 1 week with the JP than with the FP. Another explanation for the lower reproducibility of the automated probes could be the bulky anterior part of the electronic probes. This does make it difficult to get adequate access to posterior probing (Wang et al. 1995). The reproducibility of the JP may also be influenced by the total length of the tine of the probe and the sleeve in which it runs (Fig. 2). With increasing dimensions of this measuring device, it will become more difficult to reach the posterior sites of the dentition. Comparing lengths of the MP (16 mm) and the FP (22 mm) with the JP (32 mm) it is evident that the greater dimensions of the JP will make it more difficult to manipulate inside the mouth of a patient. This suggestion is supported by the finding that the differences between repeated measurements with a magnitude of 3 mm and more were found mainly on the disto-lingual molar sites with both the JP and FP. The greater dimensions of the JP may have also been responsible for the finding that on day 0 and 1 week the JP obtained deeper probing depth measurements at the second probing procedure. At the second probing, the examiner may have remembered the difficulties in putting the probe in the right position. Such an increase in deeper measurements at the second probing procedure was not found for the FP, the BP and the MP. This lack in differences between duplicate measurements seems to be in contrast to the literature, as Janssen et al. (1988) observed deeper measurements in a second, third and fourth session on the same day using a force-controlled probe (approximately 240 N/cm^2). Therefore, Janssen et al. (1988) suggested that two duplicate measurements should be averaged to get a more accurate score. Based on the data presented in this study, this does not appear to be necessary as the expected deeper second measurement (Janssen et al. 1988) was not observed with the FP, the BP and the manual probe in this study.

It has been generally accepted in the literature that a difference between two probing measurements with a time interval of 2 months or more that exceeds three times the standard deviation (0.80–0.92 mm in the study of Badersten et al. (1984) is the result of disease or therapy. For all four probes, a high proportion of the measurements showed differences within -1 and 1 mm (84–96%). When these data are compared with other studies such as Badersten et al. (1984), Watts et al. (1987), Mayfield et al. (1996) and Breen et al. (1997), the present data are within the same range. The BP and the manual probe showed a high correlation coefficient (0.90–0.89) between repeated examinations (Table 4). This corresponds with the data presented by Mayfield et al. (1996), where the manual probe, in a comparable protocol and patient group, showed similar correlation coefficients. Some studies have reported that constant force probes are more accurate (Gibbs et al. 1988, Walsh et al. 1989), while other studies prefer the manual probe (Osborn et al. 1990, Wang et al. 1995, Mayfield et al. 1996). The present study has shown that the manual probe in the hands of the experienced examiner has a good reproducibility.

In conclusion, the automated probes showed a lower level of reproducibility than the BP and the MP. In addition, because of the lower probing pressure of the FP and the JP these probes measured less deep as compared with the BP and the MP. It is suggested that a pressure level of approximately 250 N/cm^2 may be needed in periodontal maintenance patients as otherwise in a number of cases the probe fails to enter the pocket. As in this study a good reproducibility was achieved and similar probing depth recordings were obtained as compared with the pressure-controlled BP, the manual probe still remains a reliable tool in daily periodontal practice.

Acknowledgements

The authors wish to thank Y. IJzerman and M. Piscaer for their effort and perseverance in facilitating this study in patient selection and data collection.

References

Abbas, F., Hart, A. A., Oosting, J. & van der Velden, U. (1982) Effect of training and probing force on the reproducibility of pocket depth measurements. *Journal of Periodontal Research* **17**, 226–234.

Badersten, A., Nilveus, R. & Egelberg, J. (1984) Reproducibility of probing attachment level measurements. *Journal of Clinical Periodontology* **11**, 475–485.

Barendregt, D. S., Van der Velden, U., Reiker, J. & Loos, B. G. (1996) Clinical evaluation of tine shape of 3 periodontal probes using 2 probing forces. *Journal of Clinical Periodontology* **23**, 397–402.

Borsboom, P. C., ten Bosch, J. J., Corba, N. H. & Tromp, J. A. (1981) A simple constant-force pocket probe. *Journal of Periodontology* **52**, 390–391.

Breen, H. J., Rogers, P. A., Lawless, H. C., Austin, J. S. & Johnson, N. W. (1997) Important differences in clinical data from third, second, and first generation periodontal probes. *Journal of Periodontology* **68**, 335–345.

Bulthuis, H. M., Barendregt, D. S., Timmerman, M. F., Loos, B. G. & van der Velden, U. (1998) Probe penetration in relation to the connective tissue attachment level: influence of tine shape and probing force. *Journal of Clinical Periodontology* **25**, 417–423.

Chamberlain, A. D., Renvert, S., Garrett, S., Nilveus, R. & Egelberg, J. (1985) Significance of probing force for evaluation of healing following periodontal therapy. *Journal of Clinical Periodontology* **12**, 306–311.

Fowler, C., Garrett, S., Crigger, M. & Egelberg, J. (1982) Histologic probe position in treated and untreated human periodontal tissues. *Journal of Clinical Periodontology* **9**, 373–385.

Gabathuler, H. & Hassell, T. (1971) A pressure-sensitive periodontal probe. *Helvetica Odontologica Acta* **15**, 114–117.

Garnick, J. J., Keagle, J. G., Searle, J. R., King, G. E. & Thompson, W. O. (1989) Gingival resistance to probing forces. II. The effect of inflammation and pressure on probe displacement in beagle dog gingivitis. *Journal of Periodontology* **60**, 498–505.

Gibbs, C. H., Hirschfeld, J. W., Lee, J. G., Low, S. B., Magnusson, I., Thousand, R. R., Yerneni, P. & Clark, W. B. (1988) Description and clinical evaluation of a new computerized periodontal probe–the Florida probe. *Journal of Clinical Periodontology* **15**, 137–144.

Grossi, S. G., Dunford, R. G., Ho, A., Koch, G., Machtei, E. E. & Genco, R. J. (1996) Sources of error for periodontal probing measurements. *Journal of Periodontal Research* **31**, 330–336.

Hancock, E. B. & Wirthlin, M. R. (1981) The location of the periodontal probe tip in health and disease. *Journal of Periodontology* **52**, 124–129.

Hassell, T. M., Germann, M. A. & Saxer, U. P. (1973) Periodontal probing: interinvestigator discrepancies and correlations between probing force and recorded depth. *Helvetica Odontologica Acta* **17**, 38–42.

Janssen, P. T., Drayer, A., Faber, J. A. & van Palenstein Helderman, W. H. (1988) Accuracy of repeated single versus averages of repeated duplicates of probing depth measurements. *Journal of Clinical Periodontology* **15**, 569–574.

Kalkwarf, K. L., Kaldahl, W. B. & Patil, K. D. (1986) Comparison of manual and pressure-controlled periodontal probing. *Journal of Periodontology* **57**, 467–471.

Karim, M., Birek, P. & McCulloch, C. A. (1990) Controlled force measurements of gingival attachment level made with the Toronto automated probe using electronic guidance. *Journal of Clinical Periodontology* **17**, 594–600.

Magnusson, I., Clark, W. B., Marks, R. G., Gibbs, C. H., Manouchehr-Pour, M. & Low, S. B. (1988) Attachment level measurements with a constant force electronic probe. *Journal of Clinical Periodontology* **15**, 185–188.

Mayfield, L., Bratthall, G. & Attstrom, R. (1996) Periodontal probe precision using 4 different periodontal probes. *Journal of Clinical Periodontology* **23**, 76–82.

Mombelli, A., Muhle, T. & Frigg, R. (1992) Depth-force patterns of periodontal probing. Attachment-gain in relation to probing force. *Journal of Clinical Periodontology* **19**, 295–300.

Osborn, J., Stoltenberg, J., Huso, B., Aeppli, D. & Pihlstrom, B. (1990) Comparison of measurement variability using a standard and constant force periodontal probe. *Journal of Periodontology* **61**, 497–503.

Osborn, J. B., Stoltenberg, J. L., Huso, B. A., Aeppli, D. M. & Pihlstrom, B. L. (1992) Comparison of measurement variability in subjects with moderate periodontitis using a conventional and constant force periodontal probe. *Journal of Periodontology* **63**, 283–289.

Polson, A. M. (1980) Interrelationship of inflammation and tooth mobility (trauma) in pathogenesis of periodontal disease. *Journal of Clinical Periodontology* **7**, 351–360.

Quirynen, M., Callens, A., van Steenberghe, D. & Nys, M. (1993) Clinical evaluation of a constant force electronic probe. *Journal of Periodontology* **64**, 35–39.

Reddy, M. S., Palcanis, K. G. & Geurs, N. C. (1997) A comparison of manual and controlled-force attachment-level measurements. *Journal of Clinical Periodontology* **24**, 920–926.

Robinson, P. J. & Vitek, R. M. (1979) The relationship between gingival inflammation and resistance to probe penetration. *Journal of Periodontal Research* **14**, 239–243.

Simons, P. & Watts, T. (1987) Validity of a hinged constant force probe and a similar, immobilised probe in untreated periodontal disease. *Journal of Clinical Periodontology* **14**, 581–587.

Timmerman, M. F., Van der Weijden, G. A., Abbas, F., Arief, E. M., Armand, S., Winkel, E. G., Van Winkelhoff, A. J. & Van der Velden, U. (2000) Untreated periodontal disease in Indonesian adolescents. Longitudinal clinical data and prospective clinical and microbiological risk assessment. *Journal of Clinical Periodontology* **27**, 932–942.

Van der Velden, U. (1978) Errors in the assessment of pocket depth in vitro. *Journal of Clinical Periodontology* **5**, 182–187.

Van der Velden, U. (1979) Probing force and the relationship of the probe tip to the periodontal tissues. *Journal of Clinical Periodontology* **6**, 106–114.
Van der Velden, U. (1980) Influence of periodontal health on probing depth and bleeding tendency. *Journal of Clinical Periodontology* **7**, 129–139.
Van der Velden, U. & de Vries, J. H. (1980) The influence of probing force on the reproducibility of pocket depth measurements. *Journal of Clinical Periodontology* **7**, 414–420.
Waerhaug, J. (1952) The gingival pocket. Anatomy, pathology, deepening and elimination. *Odontolologisk Tidskrift* **60**, 21–27.
Walsh, T. F. & Saxby, M. S. (1989) Inter- and intra-examiner variability using standard and constant force periodontal probes. *Journal of Clinical Periodontology* **16**, 140–143.
Wang, S. F., Leknes, K. N., Zimmerman, G. J., Sigurdsson, T. J., Wikesjo, U. M. & Selvig, K. A. (1995) Reproducibility of periodontal probing using a conventional manual and an automated force-controlled electronic probe. *Journal of Periodontology* **66**, 38–46.
Watts, T. (1987) Constant force probing with and without a stent in untreated periodontal disease: the clinical reproducibility problem and possible sources of error. *Journal of Clinical Periodontology* **14**, 407–411.
Watts, T. L. (1989) Probing site configuration in patients with untreated periodontitis. A study of horizontal positional error. *Journal of Clinical Periodontology* **16**, 529–533.
Yang, M. C., Marks, R. G., Magnusson, I., Clouser, B. & Clark, W. B. (1992) Reproducibility of an electronic probe in relative attachment level measurements. *Journal of Clinical Periodontology* **19**, 541–548.

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Clinical relevance

Scientific rationale: Many factors such as probing force, tip diameter/shape and periodontal health influence periodontal probing measurements. Various probe systems have been developed to standardize aforementioned factors, but are not generally accepted for use in daily practice. Is the manual probe still reliable?

Principal findings: All four probes tested showed a good reproducibility. The FP and JP perform similarly, but the latter measured the duplicate measurements deeper. The BP and the manual probe showed the highest correlation between the repeated measurements.

Practical implications: The manual probe is still a reliable tool in daily periodontal practice.