The Saudi Dental Journal (2014) **26**, 50–55

King Saud University

The Saudi Dental Journal

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ORIGINAL ARTICLE

Accuracy and reproducibility of probe forces during simulated periodontal pocket depth measurements

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Received 28 April 2013; revised 25 December 2013; accepted 11 February 2014
Available online 18 March 2014

KEYWORDS

Probing;
Force;
Periodontal probes;
Reproducibility;
Accuracy

Abstract *Aim:* The aim of the present study was to measure the accuracy and reproducibility of probe forces in simulated assessments of periodontal pocket depth. The study included experienced and inexperienced examiners and used manual and pressure-sensitive probes.

Materials and methods: Sixty-one participants were divided into seven groups and asked to probe selected anterior and posterior sites with three different probes (Williams 14W, Chapple UB-CF-15, and Vivacare TPS probes). The model was positioned on a digital electronic balance to measure force, which was recorded initially and after 15 min. Probe preferences were recorded. Accuracy was measured by comparing to a standardized 25 g force, and reproducibility was calculated for all duplicate measurements.

Results: The Vivacare probe produced the most accurate and most reproducible forces, whereas the Williams probe produced the least accurate and least reproducible forces. Probe forces were lighter at anterior sites compared to posterior sites at baseline. Probe forces were reduced at both sites after 15 min compared to baseline.

Conclusions: Vivacare TPS periodontal probes are more accurate and reproducible than Chapple and Williams probes. Many clinicians in this study preferred the Chapple probe.

1. Introduction

Periodontal pocket depth measurements are used to diagnose and manage periodontal disease (Anderson and Smith, 1988). There are three major elements that contribute to the accuracy of periodontal pocket depth measurements. The first is related to the nature of the disease process, and includes the root anatomy, subgingival obstruction, the tissue condition at the deepest part of the pocket, and pain provoked by probing. The second element concerns probe features, such as the probe

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Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

1013-9052
http://dx.doi.org/10.1016/j.sdentj.2014.02.001

type and shape, which can affect the accuracy and precision of pocket measurements. Finally, the operator technique can influence measurements, including probe angle, probe force, probing pattern, accuracy of the reference point, and training or calibration (Gabathuler and Hassell, 1971; Listgarten, 1972, 1980; Van Der Velden and De Vries, 1978; Goodson et al., 1982; Theil and Heaney, 1991).

Operator training/technique is considered the most vital determinants of reproducibility and accuracy (Ramfjord, 1959). To achieve optimum probe force reproducibility and accuracy, operators should use a measurement tool that enables these objectives. Although some studies show no significant differences in accuracy and reproducibility between naive and expert practitioners when using automated probes (Samuel et al., 1997; Baker et al., 1997), the need for training is still evident.

Probing is an uncomfortable procedure for the patient (Tupta-Veselicky et al., 1994), especially when the probe force exceeds 45 g (Waal, 1986). It has been suggested that probe forces between 20 and 25 g (i.e., 0.20–0.25 N) cause minimal discomfort and still enable accurate diagnostic readings (Polson et al., 1980; Garnick et al., 1989; Armitage et al., 1977). A number of periodontal probes have been developed and modified to achieve that force setting.

Previous studies (Hunter et al., 1994; Gillam et al., 1998) reported that Vivacare probes (VPs) provided more accurate and consistent probe pressures compared to other probe types. Recently, a Chapple probe (CP) was introduced in the UK for periodontal monitoring. The aim of the present study was to measure the accuracy and reproducibility of experienced and inexperienced examiners using the VP, CP, and Williams probe (WP).

2. Materials and methods

The present study was conducted to replicate the Gillam et al. (1998) study. A total of 61 practitioners participated in the study. Participants were divided into two main categories based on experience. The experienced group was trained to use periodontal probes and used them in daily practice. Practitioners in the inexperienced group had never used periodontal probes (Table 1). The experienced category (n = 42) included five groups 20 postgraduatestudents (10 periodontal (group 1) and 10 prosthodontic (group2)), 9consultants/specialists and specialist registrar (SPR) (group 3), 9 general dental practitioners (group 4), 4 qualified therapists/hygienists (group5).The range of practice time for the experienced group was between 2 and 34 years.The inexperienced category (n = 19) included 10 dental nurses (group 6) and 9 first-year dental students (group 7).

Three different probes were used in this study. The WP is a conventional first-generation probe, whereas the other probes contain pressure indicators. The WP (Hu-Friedy Mfg. Co., LLC, UK) had a flat end with a 0.5-mm tip diameter according to the manufacturer's specifications. The CP (Implantium, Shrewsbury, UK) and VP (Ivoclar Vivadent, Enderby, UK) each had a 0.5-mm diameter ball-end, according to the manufacturers' specifications. Pressure-indicating marks were present on the CP and VP. When the operator force reached 25 g, the shank moved up to match the mark. Before conducting the study, all examiners were given sufficient time to familiarize themselves with the various probe types.

Participants were asked to probe selected anterior and posterior sites on a model attached to a digital electronic balance (Salter Housewares, Tonbridge, UK), which was adjusted to zero prior to the exercise (Fig. 1). The balance was positioned so that the participant could not observe the digital reading. Probes were given randomly to each participant, and measurements for both sites for each probe type were recorded. After a 15-min break, each participant was asked to repeat the exercise. All probe measurements were recorded on a data collection form. Participants' probe preferences were also recorded after completion of the exercise.

Figure 1 Digital electronic scale (Salter Housewares, Tonbridge UK) was used to measure the probing force.

Table 1 Description of study participants (7 groups, n = 61).

Group Number	Participants	Gender		Total
		Female	Male	
	Experienced Participants (n = 42)			
1	Periodontal Postgraduate student	8	2	10
2	Prosthodontics Postgraduate student	4	6	10
3	Consultants, specialists and SPR	3	6	9
4	General dental practitioners (GDP)	3	6	9
5	Therapist and hygienist	4	0	4
	Inexperienced Participants (n = 19)			
6	Dental nurses	10	0	10
7	First year dental undergraduates students	5	4	9

Table 2 Mean probe force (gram) with 95% confidence interval and group accuracy in an ascending order for Vivacare TPS probe (Ivoclar Vivadent, Enderby, UK) (VP).

	Group Number	Mean		95% Confidence Interval				Group order by accuracy		SD	
		Initial*	15 min**	Lower Initial	Lower 15 min	Upper Initial	Upper 15 min	Initial	15 min	Initial	15 min
Probing force on anterior site using VP	1	25.80	19.80	17.96	13.86	33.64	25.74	2	2	6.056	6.293
	2	26.70	26.6	22.37	22.10	31.03	31.10	3	3	8.343	6.685
	3	28.11	22.78	21.70	17.64	34.52	27.92	1	1	10.963	8.297
	4	29.56	31.33	14.62	8.10	44.49	54.57	4	5	19.430	11.475
	5	23.75	24.50	−7.17	6.24	54.67	42.76	5	6	19.432	13.712
	6	51.00	30.70	−1.44	20.89	103.44	40.51	7	7	67.966	28.511
	7	53.11	33.11	.87	11.20	105.35	55.03	6	4	73.309	30.228
Probing force on posterior site using VP	1	25.30	24.50	19.39	17.94	31.21	31.06	2	6	7.549	6.165
	2	31.90	32.70	26.50	17.95	37.30	47.45	1	1	8.260	9.168
	3	28.00	25.00	21.12	13.88	34.88	36.12	3	3	8.944	14.465
	4	48.89	49.00	17.48	8.33	80.29	89.67	6	5	20.178	14.818
	5	48.25	22.75	−5.32	−.83	101.82	46.33	7	2	20.957	20.624
	6	29.60	22.70	15.17	18.29	44.03	27.11	5	7	33.669	31.058
	7	36.78	38.11	20.67	14.24	52.89	61.98	4	4	40.858	52.913

* Initial probing force.
** Probing force after 15 min.

The intra- and inter-examiner accuracy (compared to a target pressure of 25 g) and reproducibility for each of two measurements were calculated and analyzed. Paired samples tests were used to compare data from each probe and the difference(s) between groups. Differences between baseline and second measurements were analyzed using one-sample tests. All data were analyzed with the SPSS 18 software package (IBM Portsmouth, UK). P-values $\leqslant 0.05$ were considered statistically significant.

3. Results

Mean probe forces in grams (with 95% confidence intervals) for the three probes and the accuracy of each group of operators were compared to a standard force of 25 g. The results are arranged in ascending order according to probe type and group accuracy in Tables 2–4. The mean probe force for anterior teeth is also shown in Tables 2–4.

When comparing the mean probe force of each group and probe type to the 25-g standard force value, there was an overall increase in mean probe force when the WP was used. The mean probe force was reduced when the VP was used, except with the inexperienced group. The inexperienced group also achieved lower probe forces when using the CP.

In most groups, the mean probe forces were lower after the 15-min break compared to the initial probe force. However, groups 1 and 4 from the experienced category produced higher probe forces with the WP and CP after the 15-min break. Interestingly, the PG group (group 1 and 2) produced lower mean probe forces compared to the other groups. The PG group was closely followed by the Hygienist/Therapist group (group 5, n = 4), although the latter group had relatively few participants (Table 1). The mean probe forces on posterior teeth are shown in Tables 2–4.

When the VP was used, there was an overall reduction in the mean probe force, which was higher for the posterior than for the anterior teeth (Tables 2–4). The GDP group (group 4, n = 9) had a higher mean probe force compared to the other groups. The overall (anterior/posterior) mean values for the VP were more reproducible than those of the other probes ($P \leqslant 0.5$) based on comparisons between baseline and second measurements (Table 5).

3.1. Overall probe preference

Participant preferences for each probe type were analyzed (Table 6). The CP was preferred by 47.54% of participants and was the second favorite of 39.34% of participants. The WP was the first choice of 27.87% and a second choice for 31.15% of practitioners (n = 61). The VP was favored by 24.59% and was a second choice for 29.51% of participants. Almost half (45.9%) of the practitioners chose VP as their third-favorite probe (Fig. 2).

3.2. Probe preference according to group

Results indicated that 52% of inexperienced participants (Groups 6 and 7) preferred the CP (group 7 = 44.4%; group 6 = 60%). Almost half (45%) of experienced examiners (Group 1) preferred the CP, and 33.3% preferred the WP. Sixty percent of prosthodontists (Group 2) and 50% of hygienist/therapists (Group 5) preferred the VP. Half of Group 5 also preferred the WP, although there were only 4 participants in this group.

4. Discussion

This study compared probe forces obtained when the VP, WP, and CP are used. Hunter et al. (1994) and Gillam et al. (1998)

Table 3 Mean probe force (gram) with 95% confidence interval and group accuracy in an ascending order for Chapple UB-CF-15 probe (Implantium, Shrewsbury, UK) (CP).

	Group Number	Mean		95% Confidence interval				Group order by accuracy		SD	
		Initial*	15 min**	Lower Initial	Lower 15 min	Upper Initial	Upper 15 min	Initial	15 min	Initial	15 min
Probing force on anterior site using CP	1	21.70	24.60	16.81	19.97	26.59	29.23	1	1	6.832	6.467
	2	28.80	26.20	22.99	21.13	34.61	31.27	2	2	8.121	7.084
	3	46.78	31.44	12.08	21.55	81.48	41.33	5	5	8.206	8.382
	4	48.44	49.00	-2.79	9.98	99.68	88.02	6	6	9.972	9.767
	5	28.00	26.75	14.94	13.41	41.06	40.09	7	7	19.410	10.883
	6	35.10	31.50	27.97	24.51	42.23	38.49	3	3	45.141	12.866
	7	36.00	32.22	21.08	23.86	50.92	40.59	4	4	66.652	50.769
Probing force on posterior site using CP	1	23.50	27.70	15.26	20.94	31.74	34.46	7	1	4.126	9.452
	2	30.10	30.60	22.91	19.37	37.29	41.83	2	3	10.049	11.068
	3	46.67	32.67	23.14	24.16	70.19	41.17	5	6	10.536	11.265
	4	54.67	48.22	-6.99	17.08	116.32	79.36	6	5	10.657	12.974
	5	28.50	26.50	11.74	5.85	45.26	47.15	1	2	11.521	15.700
	6	31.30	27.70	23.68	29.64	38.92	35.76	3	7	30.606	25.165
	7	25.56	42.56	22.38	23.21	78.73	61.90	4	4	80.211	40.515

* Initial probing force.
** Probing force after 15 min.

Table 4 Mean probe force (gram) with 95% confidence interval and group accuracy in an ascending order for Williams 14W probe (Hu-Friedy Mfg. Co., LLC, UK) (WP).

	Group Number	Mean		95% Confidence interval				Group order by accuracy		SD	
		Initial*	15 min**	Lower Initial	Lower 15 min	Upper Initial	Upper 15 min	Initial	15 min	Initial	15 min
Probing force on anterior site using WP	1	31.80	37.60	22.64	23.25	40.96	51.95	1	5	12.805	10.376
	2	48.70	44.30	27.85	25.97	69.55	62.63	5	3	14.841	13.472
	3	48.89	39.67	28.71	29.31	69.06	50.02	3	1	26.246	20.057
	4	93.78	95.11	-1.55	-29.74	189.10	219.96	2	2	29.147	25.617
	5	31.75	30.50	8.13	13.99	55.37	47.01	7	7	54.198	18.435
	6	75.00	67.20	23.28	19.97	126.72	114.43	6	6	72.300	66.022
	7	66.78	36.11	25.12	21.94	108.44	50.28	4	4	124.015	162.424
Probing force on posterior site using WP	1	43.10	46.30	29.76	32.50	56.44	60.10	5	5	12.339	8.583
	2	44.20	65.60	24.49	38.06	63.91	93.14	1	3	18.651	16.764
	3	53.00	36.56	23.49	23.67	82.51	49.44	2	7	27.555	17.198
	4	97.11	103.78	-21.98	-29.42	216.20	236.97	3	1	38.389	19.293
	5	33.75	30.50	14.12	16.84	53.38	44.16	7	6	46.985	25.330
	6	134.60	46.60	22.18	28.48	247.02	64.72	4	2	154.934	38.492
	7	54.89	30.56	18.77	17.34	91.00	43.78	6	4	157.159	173.281

* Initial probing force.
** Probing force after 15 min.

previously compared the VP and WP. By including these probes in our study, we were able to compare the accuracy and reproducibility of these existing probes with previously published data and include comparisons to the recently introduced CP.

The probe force used by the operator may affect both pocket depth and patient comfort. The present study demonstrated that the VP was the most accurate and reproducible probe compared to a 25-g standard, consistent with previous studies (Bergenholtz et al., 2000; Gillam et al., 1998; Hunter et al., 1994). The mean probe force was generally lighter on the anterior compared to the posterior teeth, even though the examiners were asked to probe the anterior teeth before the posterior teeth. Probe force for each practitioner was determined twice, at baseline and after a 15-min break. Interestingly, the mean probe force was lighter after the 15-min break, which may suggest that improvement occurred between the evaluations. The 15-min interval was used based on data from Van der Velden and de Vries (1980), who reported that allowing a 15-minute interval between initial and repeated probes in the clinical environment reduced the risk of

Table 5 Probe force accuracy compared to 25 g (by probe type).

	Mean level of significance		Level of significance with 95% CI LOWER		Level of significance with 95% CI UPPER	
	Initial*	15 min**	Initial*	15 min**	Initial*	15 min**
Probing force on anterior site using VP+	.063	.352	−.57	−2.39	20.31	6.62
Probing force on posterior site using VP	.002	.077	3.45	−.68	14.88	12.95
Probing force on anterior site using WP++	.000	.004	17.44	8.80	49.51	44.51
Probing force on posterior site using WP	.001	.003	19.85	10.02	67.82	46.37
Probing force on anterior site using CP+++	.016	.017	1.98	1.30	18.48	12.44
Probing force on posterior site using CP	.034	.002	.77	3.57	18.25	14.53

* Initial probing force.
** Probing force after 15 min.
\+ Vivacare TPS probe (Ivoclar Vivadent, Enderby, UK).
\+\+ Williams 14 W probe (Hu-Friedy Mfg. Co., LLC, UK).
\+\+\+ Chapple UB-CF-15 probe (Implantium, Shrewsbury, UK).

Table 6 Probe preferences for all participants.

	Vivacare Vivacare TPS probe (Ivoclar Vivadent, Enderby, UK)	Williams 14 W probe (Hu-Friedy Mfg. Co., LLC, UK)	Chapple UB-CF-15 probe (Implantium, Shrewsbury, UK)
Preference 1	24.59%	27.87%	47.54%
Preference 2	29.51%	31.15%	39.34%
Preference 3	45.9%	40.98%	13.11%

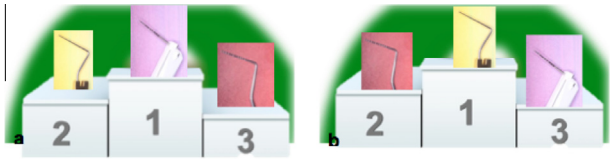

Figure 2 (a) Accuracy of the probes compared to a set 25 g standard. (b) Probe preference of the participants (n = 61).

bleeding. We observed higher mean probe forces in the GDP group compared to the untrained group, which included dental nurses and first-year dental students.

All examiners in the study were more concerned with matching the alignment markings (indicating that the correct pressure was achieved) on the pressure-sensitive probes rather than the directions of the probes in the pockets. In clinical situations, reliance on matching alignment markings at 20/25 g may lead to under- or over-estimation of the pocket depth (Larsen et al., 2009; Bulthuis et al., 1998). Examiner preferences were evaluated after the probe force evaluations. Most examiners preferred the handle design and the prominent marking system of the CP. These preferences outweighed the knowledge that the probe was not as accurate, in terms of force, as the VP. Interestingly, some of the examiners did not consider the pressure-sensitive probes to be better. Although the VP was more accurate and reproducible than the other probes, some participants did not rate this probe their favorite. Practitioners reported that matching the pressure indicator markings was difficult, and that the probe was unfamiliar. It should be noted that the VP is no longer commercially available in the UK. The WP, which is the standard periodontal probe used in the dental hospital, was the practitioners' least favorite probe.

The present study indicated that a number of improvements would enhance clinician training. For example, the model used for measuring anterior and posterior sites was based on a model described by Hunter et al., 1994 and Gillam et al., 1998. This model is limited in that it was originally designed for oral hygiene demonstrations rather than for measuring periodontal pockets. It has been suggested that a specifically designed silicone-based periodontal model would overcome the limitations of the current model. Furthermore, using an improved periodontal model with attached sensors on the selected probes may simulate the clinical situation more accurately and be more beneficial for teaching probing techniques to students. The use of a vacuum-formed stent during simulated probe force evaluations may also be useful in standardizing the positioning of the probe at the designated sites on the model, enabling more meaningful comparisons between and within participants' measurements.

The results of the present study indicated that the VP produced the most accurate and reproducible probe forces, although the WP is commonly used for periodontal measurements in the dental hospital and most of the participants were familiar with using the probe. Nevertheless, the WP

demonstrated the highest mean probe force of the three probes tested. The CP was recently introduced into clinical practice in the UK, and there are limited data on its clinical accuracy and reproducibility. The mean probe force of the CP was more accurate than the WP but less accurate compared to the VP measurements. This finding was true for initial and repeated measurements. However, the CP was preferred by participants due to the marking system, handle design, and ease of use.

Inexperienced operators and general dental practitioners produced less accurate probe forces than their more experienced colleagues. Therefore, the use of constant pressure probes may enhance training of all practitioners. The use of this measurement tool may help standardize periodontal measurements and should be beneficial to clinicians before and during their clinical training.

5. Conclusions

The VP is more accurate and more reproducible compared to the CP or WP. The CP was preferred by most clinicians in this study.

Conflict of interest

The authors report no conflicts of interest related to this study.

Acknowledgements

Sharif S Islam (Dental Public Health) who provided statistical advice.

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