CLINICAL EVALUATION OF TINE SHAPE OF 3 PERIODONTAL PROBES USING 2 PROBING FORCES

CHAPTER 4

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Periodontal disease results in the breakdown of periodontal attachment. The most common method to determine clinically the loss of periodontal attachment is measuring the depth of the periodontal lesion. Since the introduction by G.V. Black in 1915 of a periodontal probe with mm markings (Black 1915), it is still generally accepted that periodontal probing is one of the most useful diagnostic parameters to determine the presence and severity of periodontal lesions. Ideally the periodontal probe should measure the whole subgingival lesion, i.e. the distance from the edge of the gingival to the apical end of the junctional epithelium. Due to lack of accuracy and reproducibility of the measurements caused by variables which influence the location of the tip of a probe during measurement, the meaning and value of probing measurements have been criticized in the last 20 years (Listgarten 1980). Many studies have identified important factors which play a role in periodontal probing. The most important parameters are probing force periodontal health. The influence of these two parameters have been widely studied (Robinson et al. 1979, Van der Velden et al. 1980, Garnick et al. 1980, Polson et al. 1980, Hancock et al. 1981, Fowler et al. 1982, Garnick et al. 1989, Mombelli et al. 1992). Other variables which influence the probing measurements are probe positioning (Watts 1989), examiner variability (Abbas et al. 1982) and recording errors. These latter flaws can be prevented by training of the examiner(s) combined with the use of direct data entry (Gibbs et al. 1988). Only recently the tine shape of the periodontal probe has been evaluated.

Atassi et al. (1992) used two different probe tines (parallel and tapered) mounted in a Brodonic probe handle, set at a probing force of 0.25 N. Their results suggested that the tine shape of the periodontal probe may be important. When a difference in probing depth measurement occurred, a parallel-sided tine recorded a deeper reading than a tapered tine (Atassi et al.1992). However no statistical significant differences were found. One other tine shape is that of the WHO-probe. The tine of this probe has a ball-like tip followed by a shaft with a smaller diameter than the ball-like tip. The WHO-probe has been used to measure probing depth and to assess periodontal bleeding tendency in epidemiological studies (Ainamo et al. 1982). Some constant force probes are equipped with a ball-like tip, for example the “Probe with automated CEJ detection” (Jeffcoat et al. 1986) and the “Toronto Probe” (McCulloch et al. 1987). The purpose of the present study was to evaluate the influence of the tine shape of 3 different periodontal probes (parallel-sided, tapered, WHO) at 2 different probing forces (0.25 N and 0.50 N), on the measured probing depth in patients who recently received oral hygiene instruction and full mouth supra- and subgingival debridement.
Material and Methods

Probe tines

3 tines (Ash Dentsply, Weybridge, Surrey, England) with markings at every whole mm up to 10 mm and a tip diameter of 0.5 mm were used: (1) a parallel-sided tine with a diameter of 0.5 mm at the 5 mm and 10 mm marking; (2) a tapered tine with a diameter of 0.6 mm at the 5 mm and 0.7 mm at the 10 mm marking; (3) a WHO tine with a ball-like tip attached to a tapered shaft with a diameter just behind the ball of 0.35 mm, increasing at the 5 mm marking to 0.5 mm and on the 10 mm marking to 0.7 mm (fig 1). The 1 and 2 mm marking at the WHO tine were missing due to the small diameter just behind the ball-line tip of this tine. The tines were mounted in hinged handles exerting a constant force (Brodontic, Prima, Byfleet, England) which were adjusted either to 0.25 N or to 0.5 N (probing pressures 127 N/cm² respectively).

**Fig. 1.** Schematic drawings on scale of three different tine shapes which were mounted in Brodontic® handles and used for probing depth measurements.
Patients

A total of 12 patients, with a mean age of 44 years (range 27-66), with moderate to advanced periodontitis, as diagnosed on the basis of probing depth measurements and radiographs, were asked to participate in this study. A minimum of 4 teeth per quadrant was required. All patients had received a basic periodontal therapy consisting of instruction in plaque control measures and supra-/subgingival debridement, 4 weeks after finishing this periodontal therapy the patients were enrolled in the present study.

Probing depth measurements

For the purpose of this study, recordings were made with all six possible time/force combinations (three tines and two forces) at all interproximal surfaces from the buccal aspect as well as midbuccal and midlingual, of all teeth present (third molars excluded). Measurements were performed in 3 sessions with a 1-week interval. The 6 tine/force combinations were distributed over the patients and sessions in such a way that, at a given site, comparisons could be made between either the same force with different tines or different forces with the same tine. Per session 2 tine/force combinations were used and a repeated probing with each tine/force combination was performed with an interval of 15 min. A given tine/force combination was used in either the first and third quadrant or in the second and fourth quadrant. The order of the use of tine/force combinations was randomized over the patients and sessions. The probes were always inserted parallel to the root surface and the probe was directed apically toward the perceived location of the apex of the root. When the preset force was reached the probing depth was recorded to the nearest whole mm.

Data analysis

Differences in probing depths for each tine shape and probing force combination within each site were averaged per patient. Patient mean differences were analysed by use of the one sample Wilcoxon test for symmetry. Most often 8 patients contributed data for comparisons, while some comparisons were made on data from 4 subjects. P-values of <0.05 were accepted as statistically significant. The reproducibility of the repeated probing depth measurements was described with the weighted Cohen’s Kappa ($k$) for reliability (Cohen 1960). Systematic differences between sessions were tested.
using the McNemar test. The $k$ statistic indicates the extent to which the actual degree of agreement improves upon chance. It is suggested by Landis & Koch (1977) that a score $>0.4$ indicates moderate agreement, $>0.6$ substantial agreement and $>0.8$ good agreement.

**Results**

**Reproducibility of measurements**

Table 1 shows an overview of the repeated measurements. The number of sites measured per tine/force combination varied from 597 to 621 sites. The majority (> 99 %) of all repeated measurements were within 1 mm of the initial values. The $k$ values ranged from 0.72 for the parallel-sided tine with 0.5 N, to 0.79 for the WHO tine using 0.5 N. If shallow probing depths (< 3 mm) as assessed by the first measurement, were not included in the analysis, the majority of the disagreement disappears and $k$ values of $>0.8$ were calculated (data not shown). No significant differences between the means of the first and second measurements were found, although mean values of the second measurement tended to be marginally higher.

<table>
<thead>
<tr>
<th>Tine/Force Combination</th>
<th>1st measurement</th>
<th>2nd measurement</th>
<th>$\kappa$</th>
<th>≤3 mm</th>
<th>4-5 mm</th>
<th>≥6 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>0.25 N</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parallel-sided</td>
<td>605</td>
<td>2.4±1.2</td>
<td>2.5±1.2</td>
<td>0.74</td>
<td>514</td>
<td>80</td>
</tr>
<tr>
<td>Tapered</td>
<td>617</td>
<td>2.4±1.2</td>
<td>2.4±1.1</td>
<td>0.75</td>
<td>523</td>
<td>76</td>
</tr>
<tr>
<td>WHO</td>
<td>601</td>
<td>2.7±1.2</td>
<td>2.7±1.2</td>
<td>0.76</td>
<td>491</td>
<td>91</td>
</tr>
<tr>
<td><strong>0.50 N</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parallel-sided</td>
<td>621</td>
<td>2.7±1.3</td>
<td>2.8±1.3</td>
<td>0.72</td>
<td>497</td>
<td>112</td>
</tr>
<tr>
<td>Tapered</td>
<td>597</td>
<td>2.5±1.3</td>
<td>2.6±1.3</td>
<td>0.79</td>
<td>468</td>
<td>109</td>
</tr>
<tr>
<td>WHO</td>
<td>613</td>
<td>2.9±1.5</td>
<td>2.9±1.5</td>
<td>0.79</td>
<td>435</td>
<td>151</td>
</tr>
</tbody>
</table>

*Table 1. Mean probing depth (mm) and standard deviations (SD) of repeated measurements within the same session with a 15 min interval, with ($\kappa$) values for reliability; distribution of sites among three subgroups of sites, based on the first measurement.*
Comparisons at 0.25 n (127 N/cm²) (Table 2)

Parallel versus tapered. The parallel-sided tine used with a probing force of 0.25 N, measured significantly deeper compared to the tapered tine (mean difference 0.22 mm, Table 2). In Fig. 2A the distribution of the differences is presented. It can be seen that 67% of the compared sites showed no difference. However the parallel-sided tine measured deeper probing depths (up to 3 mm) in 23.5% and shallower in 9.5% of the cases. When the sites were grouped according to their region in the dental arch, it was observed that sites in the different regions on average were deeper with the parallel-sided tine than with the tapered tine (Table 2).

WHO versus parallel. The WHO tine showed slightly deeper mean probing depths compared to the parallel-sided at 0.25 N (2.5 mm versus 2.4 mm respectively). This resulted in a mean difference of 0.12 mm, but no statistical significant difference was observed (Table 2). In this comparison, 61% of the probing depth measurements did not differ, while 24% of the sites showed deeper readings of up to 4 mm using the WHO tine compared to the parallel-sided tine (Fig 2B). In the remaining 15.5% of the sites, the parallel-sided tine recorded deeper probing depths. When the sites were grouped according to their region in the dental arch, we found that the measurements recorded for the WHO tine were not significantly deeper (Table 2).

WHO versus tapered. This comparison showed the greatest mean difference between 2 probing procedures at 0.25 N: we calculated a mean difference of 0.38 mm over all sites (Table 2). The distribution of the differences showed no difference in 57%, of the sites, but in 36% of the sites the use of the WHO tine resulted in a deeper probing depth (Fig 2C). Similar results were found when the sites were grouped according to their region in the dental arch (Table 2).
Parallel versus tapered. The results showed that the parallel-sided tine recorded deeper readings than the tapered which resulted in a mean difference of 0.17 mm (Table 3). In 67% of the comparisons, there was no difference; in 22.5% the parallel-sided tine and in 10.5% the tapered tine recorded a 1 or 2 mm deeper probing depth (Fig 3A). However the difference between the parallel-sided and
TINE SHAPE AND POCKET DEPTH

tapered tine were less pronounced than with 0.25 N. When sites were grouped to their position in the dental arch, it was found that in the anterior and anterior interproximal regions no difference could be determined between the parallel-sided tine and the tapered tine (Table 3).

**WHO versus parallel.** Mean differences in probing measurements between the WHO and the parallel-sided tine (0.17 mm) were significant (Table 3). In 55% of the comparisons, the measurements did not differ: however, the WHO recorded in 31% a deeper probing depth. The parallel-sided tine surpassed the WHO in 15% of the sites (Fig 3B). In all subgroups of sites, deeper probing depths were recorded with use of the WHO tine resulting in significant mean differences (Table 3).

**WHO versus tapered.** Finally, the mean difference between the WHO tine and the tapered tine was significant (Table 3). In 30% of the sites the WHO penetrated > 1 mm deeper and in 11% of the comparisons the tapered tine assessed a deeper site (Fig 3C). Again in all subgroups of sites significant deeper probing depths were recorded with use of the WHO tine (Table 3). As seen in the comparison between parallel-sided and tapered, the values for mean differences between the WHO and tapered tine at 0.5 N was less pronounced than at 0.25 N.

*Table 3.* Mean differences (mm) per comparison ± standard deviations, calculated on n patient mean differences per site, obtained with a parallel-sides, tapered or WHO tine at 0.5 N probing force (255 N/cm²), for all sites and for subgroups of sites.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Comparison (n=4)</th>
<th>Comparison (n=8)</th>
<th>Comparison (n=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>parallel-sided minus tapered</td>
<td>WHO minus parallel-sided</td>
<td>WHO minus tapered</td>
</tr>
<tr>
<td>All sites</td>
<td>0.22±0.25*</td>
<td>0.17±0.16*</td>
<td>0.20±0.19*</td>
</tr>
<tr>
<td>Anterior a)</td>
<td>-0.01±0.25*</td>
<td>0.23±0.22**</td>
<td>0.18±0.21*</td>
</tr>
<tr>
<td>Posterior b)</td>
<td>0.25±0.18*</td>
<td>0.15±0.16*</td>
<td>0.24±0.23*</td>
</tr>
<tr>
<td>Interproximal</td>
<td>0.22±0.20*</td>
<td>0.25±0.23**</td>
<td>0.32±0.26*</td>
</tr>
<tr>
<td>Ant. Interprox</td>
<td>0.01±0.38*</td>
<td>0.32±0.33*</td>
<td>0.34±0.26**</td>
</tr>
<tr>
<td>Post. Interprox</td>
<td>0.31±0.21*</td>
<td>0.19±0.20*</td>
<td>0.33±0.36*</td>
</tr>
</tbody>
</table>

* p<0.05
** p<0.01
a) This includes incisors and cuspids.
b) This includes premolars and molars
Comparisons of two probing forces (Table 4)

For all three tines, it was evident that a higher probing force resulted overall in deeper measurements (Table 4).

Table 4. Mean differences (mm) per comparison ± standard deviations, calculated on n patient mean differences per site, obtained with a parallel-sides, tapered or WHO tine at 0.25 N probing force (127 N/cm²) and at 0.5 N probing force (255 N/cm²), for all sites and for subgroups of sites.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Parallel-sided (n=4) 0.5 N minus 0.25 N</th>
<th>Tapered (n=8) 0.5 N minus 0.25 N</th>
<th>WHO (n=4) 0.5 N minus 0.25 N</th>
</tr>
</thead>
<tbody>
<tr>
<td>All sites</td>
<td>0.32±0.32*</td>
<td>0.34±0.17*</td>
<td>0.39±0.24*</td>
</tr>
<tr>
<td>Anterior &lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.28±0.29*</td>
<td>0.31±0.17**</td>
<td>0.43±0.38*</td>
</tr>
<tr>
<td>Posterior &lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.37±0.34*</td>
<td>0.35±0.32**</td>
<td>0.40±0.22*</td>
</tr>
<tr>
<td>Interproximal</td>
<td>0.41±0.45*</td>
<td>0.36±0.31*</td>
<td>0.36±0.29*</td>
</tr>
<tr>
<td>Ant. Interprox &lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.35±0.34*</td>
<td>0.41±0.35*</td>
<td>0.44±0.49*</td>
</tr>
<tr>
<td>Post. Interprox &lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.50±0.49*</td>
<td>0.32±0.33*</td>
<td>0.24±0.19*</td>
</tr>
</tbody>
</table>

* p<0.05  
** p<0.01  
<sup>a</sup> This includes incisors and cuspids.  
<sup>b</sup> This includes premolars and molars.
Discussion

An abundance of clinical investigating variables associated with periodontal probing, are available in the literature. Many of these investigators have established the importance of probing force (for example, see references Hassel et al. (1973); Van der Velden (1979); Mombelli et al. (1992)) and the condition of the periodontal tissues (van der Velden et al. (1980); Garnick et al. (1980); Polson et al. (1980); Hancock et al. (1981); Fowler et al. (1982)). However, so far little attention has been payed to the actual shape of the tine in such studies. Although two studies have mentioned the influence of tine shape on the penetration into the periodontal lesion (Van der Velden 1980; Garnick et al. 1980) this parameter was not investigated. The results from a recent study by Atassi et al. (1992) suggest that tine shape may be of importance. But in the latter study no significant differences were observed between the parallel-sided and tapered tines. In contrast in de present study we did observe differences in clinical probing measurements between these tines. The difference in results between our study and the one from Atassi et al. (1992) may be related to the difference in periodontal condition of the tissues. Atassi and co-workers measured sites in patients who had received oral hygiene instructions and subgingival debridement. In our study the patients had received the same kind of treatment plus subgingival debridement. In our patients the results clearly show that in addition to the probing force, the shape of the probe tine is a factor that influences the recorded probing depth.

The results of the present study seem to indicate that the WHO tine can measure deeper than the other two tines. Both at 127 N/cm² and 255 N/cm² probing pressure. We speculate that the characteristic shape of the WHO tine generates the least tissue resistance during probing which results in a more apical position in the periodontal lesion compared to the other two tine shapes. A possible explanation for this phenomenon can be found in the specific shape of the tine which may lead to the evasion of the adhesive strength of the periodontal tissues. When a periodontal probe is inserted into the periodontal lesion the soft tissue is pushed aside consuming a certain amount of energy. The tapered tine has to prolong this push because its diameter increases as it enters the lesion and has to withstand the resistance caused by the formentioned adhesive strength. Immediately after insertion the periodontal tissues adhering to the tine cause resistance which increase as the tine penetrates further into the lesion. The basis for this theoretical background can be found in de field of the ground conditions.
mechanics. Before construction work can be started, calculations are made for the adhesive strength of piles, based on the kind of soil in which they are placed (Terzaghi et al. 1967). The adhesive strength is formulated by: (1) the surrounding types of soil, i.e. the periodontal tissues (healthy or inflamed); (2) the perimeter of the pile, i.e. probe tine; (3) the length of the pile to which it has penetrated into the soil, i.e. the tine length which has entered the periodontal lesion. In the case of the WHO tine we hypothesize that the adhesion to the sudden decrease of diameter just behind the ball-like tip. Therefore the same energy or force applied to all three probe tines may result in a deeper subgingival position for the WHO-tine where less energy is consumed by adhesion of tissues. We speculate that especially in shallow and moderately deep sites the WHO tine looses less energy through adhesive strength since the apparent favourable design is located up to the 5 mm marking. Due to the tapered design of the shaft of the WHO tine the diameter of this probe increase over the diameter of the parallel-sided tine after the 5 mm marking (fig 1). Therefore we feel it is currently unclear whether the WHO tine will yield comparable results in periodontal lesions >5 mm. This question could not be addressed in our study since the present material consisted of a large proportion of relatively shallow sites although the patients were selected on the basis of moderately to advanced periodontitis. The proportion of shallow moderately deep and deep sites before therapy was comparable to Badersten et al (1981). The basic periodontal treatment as provided to these patients resulted in gingival recession and probing depth reduction (data not shown) comparable to previous described results (Badersten et al. 1981. Claffey et al 1991).

In the literature different probing pressures (e.g. probing force per area) have been reported to reach the histological bottom of a periodontal lesion (Garnick et al. (1980); Polsen et al. (1980); Van der Velden et al. (1980)). According to the above mentioned hypothesis these apparent discrepancies in earlier studies may be explained by the tine shape. For example Garnick et al. (1980) and Polson et al. (1980) applied probing forces of 286 and 260 N/cm2 respectively on a tapered tine to reach the histological bottom of the lesion. The parallel-sided tine from Van der Velden et al. (1980) needed only 240 N/cm2 to reach the same histological position. Although it is hard to compare these three studies it seems that they form additional evidence that tine shape is a factor that plays a role in periodontal probing.
We conclude from the current study that the tine shape of the periodontal probe is an additional parameter which does influence probing depth. It is conceivable that accurate probing depth measurements could be obtained using the WHO tine with a lower probing pressure than has been suggested in the past. The lower probing force also may lead to a less painful experience for the examined patient.

Acknowledgements

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References


Black, G.V. (1915) *Special dental pathology*; Fig 267. Chicago: Medico Dental Publishing Co.


