Probing around teeth

Barendregt, D.S.

Citation for published version (APA):

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimers/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: https://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
DETECTION OF THE CEMTO-ENAMEL JUNCTION WITH THREE DIFFERENT PROBES:
AN “IN VITRO” MODEL

CHAPTER 3

D. S. Barendregt
U. van der Velden
M. F. Timmerman
H.M. Bulthuis
G. A. van der Weijden

Department of Periodontology, Academic Centre for Dentistry Amsterdam, The Netherlands
Loss of connective tissue attachment is an important parameter for the assessment of periodontal destruction and disease progression. In periodontal health the collagen fibrous attachment reaches up to the cemento-enamel junction (CEJ) (Schroeder et al. 1997). The CEJ can therefore serve as a fixed reference point to establish the degree of periodontal clinical attachment loss (CAL) (Glavind et al. 1967). Although CAL should ideally be measured from the base of the pocket to the CEJ, various factors including variation in probing force (Hassell et al. 1973; Van der Velden 1979; Mombelli et al. 1992), periodontal inflammation (Armitage et al. 1977, Van der Velden 1980, Fowler et al. 1982, Bulthuis et al. 1998), tactile and visual assessment errors (Watts et al. 1995), root morphology (Theil & Heaney 1991) and probe design (Barendregt et al. 1996) can affect the accuracy of probing pocket depth measurements. The CEJ is often positioned subgingivally and difficulties are experienced in the accurate clinical assessment of this anatomical landmark with a periodontal probe (Badersten et al. 1984). Where most periodontal parameters are liable to visual observational error, the CEJ is obviously liable to this phenomenon but also to tactile error due to lack of a clear demarcation (Watts, 1987). In addition, on the proximal surfaces the partial vertical course of the CEJ may increase difficulty in assessing the CEJ (Badersten et al. 1984). Therefore when combining probing pocket depth and assessment of the CEJ for measuring CAL, the possible measurement errors are additive and the accuracy suffers (Jeffcoat et al. 1986).

The existing literature on the validity of the clinical assessment of the CEJ is sparse. A measurement is valid if it is both accurate and precise (reproducible). In an effort to increase both accuracy and reproducibility of CEJ detection, different probe shapes have been used to increase tactility in finding the subtle demarcation indicative for the CEJ (Hug et al. 1983; Watts 1989; Reddy et al. 1997; Karpinia et al. 2004). However no clear conclusion can be provided based on these studies with respect to the “correct” probe design which will improve the accuracy.

With the difficulties of identifying the CEJ in studies on disease progression or the effect of periodontal treatment on the attachment level, other landmarks were explored for a valid clinical attachment measurement. Osborn et al. (1990) introduced the Florida Disk Probe® where the occlusal surfaces or the incisal edge of the tooth serves as a reference for the clinical attachment level. The reproducibility of this model of the Florida Probe® was tested by Marks and coworkers (1991). They showed, comparing clinical attachment level measurements from a stent with the Florida Probe® and the Florida Disk Probe®, that the latter probe was as reproducible in achieving (relative) clinical
attachment level measurements as the Florida Probe®. However, as discussed by the authors, when
the occlusal surface or the incisal edge is restored in the course of the investigation, this reference for
the relative attachment level is no longer valid. Pihlstrom et al. (1992) also studied the reproducibility
of relative probing attachment level measurements using a stent as a reference point. They concluded
that stents increase the intra- and inter-examiner reproducibility. Stents are therefore useful in studies
evaluating treatment modalities. However for monitoring disease progression based on the
attachment level measurements in large epidemiological studies, the CEJ is the reference point of
choice (Pihlstrom et al. 1992). Furthermore in order to evaluate clinically to what extent attachment
loss is present, the CEJ must be used. Thus valid assessment of the CEJ is a prerequisite for proper
estimation of the amount of periodontal breakdown. Therefore, the purpose of the present study was
to test the accuracy and precision with which the CEJ can be assessed using 3 commercially available
periodontal probes with different tip endings in both deciduous and permanent teeth.

Material and Methods

Experimental tooth models

For this study, 70 permanent (third molars excluded) and 30 deciduous extracted intact human teeth
without restorations were selected. The group of permanent teeth included 10 incisors, 5 cuspids, 10
premolars and 10 molars of the upper and lower jaw respectively. The group of deciduous teeth
consisted of 3 upper incisors, 4 upper cuspids, 13 upper- and 10 lower molars. After having been
cleaned of debris and calculus, the teeth were individually mounted in plaster up to and including the
apical ½ of the root. Next an artificial gingiva was prepared of silicone rubber (Dublicil®, Komponente
A,B/Spec., Dreve-Dentamid, Germany) covering the remaining part of the root and the cervical part of
the crown up to half of the crown length, thus covering the complete CEJ (Fig. 1a).
CEMENTO-ENAMEL JUNCTION DETECTION “IN VITRO”

Probes

Three commercially available probes were investigated for their ability to identify the subgingival CEJ:

a) Conventional manual probe Merritt-B (Hu-Friedy, Chicago, USA) (Fig. 1b): this tapered probe has a rounded tip with a diameter of 0.5 mm and Williams markings at 1 mm intervals from 1 to 3, 5 and 7 through 10 mm.

b) CPITN probe (WHO) Hu-Friedy, Chicago, USA): the probe has a spherical ball-like tip with a diameter 0.5 mm. The probe was modified to have markings at each millimetre from 3 to 10 mm. The small dimensions at the tip of the probe did not allow for markings at the 1 and 2 mm (Fig. 1b)

c) Vivacare TPS probe: this probe is made of rigid metal and has a tip which is designed as a hemisphere with a diameter of 0.5 mm. The transition to the 0.2 mm tapered shaft sharply cuts back circumferentially to create a defined equatorial rim. This design supposed to improve the tactile sensation. Broad-banded black markings are present at a 3.0 to 5.0 and 8.0 to 11.0 mm distance from this rim. Finer calibrations at 1 mm intervals are present to provide a more accurate reading. The probe has a standardized pressure feature to increase the accuracy of
pocket depth assessments. For this study, which specifically looked at the CEJ, the force-controlled mechanism was locked (Fig. 1b).

![Fig. 1b: From left to right: 1) Conventional manual probe Merritt-B (Hu-Friedy, Chicago, USA), 2) Vivacare TPS probe and 3) CPITN probe (WHO) Hu-Friedy, Chicago, USA](image)

**Clinical assessment of the CEJ**

Four experienced examiners (2 periodontist and 2 dental hygienists) performed clinical measurements to detect the subgingival position of the CEJ in relation to the position of the artificial gingiva. Both the experimental permanent and deciduous tooth models were randomly divided into 3 sets. In order to achieve that all examiners assessed the same site with the three different probes, the clinical measurements were performed in 3 sessions, with an interval of at least 1 week. Per examiner in each session one of the 3 probes was assigned to one of the sets of experimental tooth models. The order in which the 4 examiners used the 3 probes was randomized. The sets were scored in a fixed sequence throughout the 3 sessions.

The duplicate recordings were made in each session with a 60 minutes interval at the distobuccal (DB), midbuccal (B), mesiobuccal (MB), distolingual (DL), lingual (L) and mesiolingual (ML) sites. Positional error for site and direction of probing was controlled by marking the location of these
6 sites with a distinct black vertical line made by a waterproof marker on the clinical crowns of the experimental teeth. The apical end of this vertical line stopped at the gingival margin (Fig. 1a). Each measurement was rounded off to the nearest millimeter. No attempts were made to blind the examiners to the probes since it was recognized that blinding, given the study design, would have been impossible.

**Microscopic assessment of the CEJ**

After all clinical CEJ assessments had been completed, a microscopic assessment was performed as true reference for the position of the CEJ. For the microscopic assessments the apical end of the black vertical line as used for the clinical assessments served as the reference point for the position of the gingival margin (Fig. 1a). After the silicone rubber gingiva was removed (Fig. 1a) the distance between the CEJ and apical end of the vertical marking, indicating the gingival margin, was determined using a stereomicroscope at 80x magnification and a caliper with an electronic readout at all six marked sites. The measurements were rounded off to one tenth of a millimeter.

**Statistical Analysis**

The site was used as the unit of analysis for the CEJ measurements of the 4 examiners and the 3 different probes. The site was used in this way since measurements were performed on extracted teeth with a randomly molded gingiva. Therefore independence between sites at each tooth could be assumed. The repeated measures analysis was performed entering PROBES, EXAMINERS, FIRST/SECOND MEASUREMENT as within subject factors and permanent/deciduous teeth as between factor. For the accuracy of the probes the microscopic assessment served as the true reference. The same model of repeated measures analysis was used for analyzing the difference with the microscopic measurement for each individual probing assessment.

Post Hoc testing was performed for differences between the examiners. To test for systematic differences between sessions and per examiner paired Student t-test were used. Intra-examiner paired assessments were also analyzed by percentage of agreement. The Pearson correlation coefficient was
used to test the inter-examiner paired readings. $P$-values of $<0.05$ were accepted as statistically significant.

**Results**

In Table 1 the results are presented of the microscopic assessment and the duplicate clinical assessments of the distance from the CEJ to the gingival margin with the three probes at permanent and deciduous teeth. At the permanent teeth the microscopic measurements showed a mean distance of 2.58 mm. Due to the orientation of the CEJ to the artificial gingiva the distance between the gingival margin and the CEJ ranged between 0.9 and 4.6 mm. The latter was found at a buccal surface. Interproximally the smallest distance was found between the gingival margin and the CEJ i.e. 0.9 mm. The microscopic assessment in the deciduous teeth ranged from 1.2 to 4.9 mm with a mean of 3.12 mm. The orientation of the CEJ to the artificial gingiva provided the smallest distance at the interproximal surface i.e. 1.2 mm.

The clinical measurements performed at the permanent teeth with the three probes showed a comparable range i.e. 0 to 5 mm. The mean assessment of the gingival margin to the CEJ ranged from 2.39 mm to 2.63 mm. With all three probes the second assessment in the permanent teeth was significantly deeper, ranging from 0.05 to 0.09 mm, compared to the first assessment. The clinical measurements at the deciduous teeth with the Merritt-B probe ranged from 1 to 6 mm, for the CPITN probe 1 to 5 mm and with the TPS probe 1 to 4 mm. The differences between the first and the second measurement were small, ranging from 0.01 to 0.07 mm more apical for the second measurement.
Table 1. Descriptives - The mean microscopic distance (in mm) from the CEJ to the gingival margin in permanent and deciduous teeth and the mean distance (in mm) of the 1st and 2nd assessment with the three probes (standard deviation in parenthesis).

<table>
<thead>
<tr>
<th></th>
<th>Permanent teeth (n=420)</th>
<th>Mean distance</th>
<th>Microscope</th>
<th>Meritt-B</th>
<th>CPITN</th>
<th>TPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1st assessment</td>
<td>2.58 (0.72)</td>
<td>2.63 (0.51)</td>
<td>2.47 (0.54)</td>
<td>2.39 (0.46)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2nd assessment</td>
<td>2.67 (0.55)</td>
<td>2.50 (0.55)</td>
<td>2.41 (0.47)</td>
<td></td>
</tr>
<tr>
<td>Overall Significance*</td>
<td></td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Deciduous teeth (n=180)

<table>
<thead>
<tr>
<th></th>
<th>Mean distance</th>
<th>Microscope</th>
<th>Meritt-B</th>
<th>CPITN</th>
<th>TPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.12 (0.63)</td>
<td>3.14 (0.45)</td>
<td>2.77 (0.37)</td>
<td>2.48 (0.37)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.13 (0.50)</td>
<td>2.80 (0.42)</td>
<td>2.50 (0.40)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Significance*</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* = Paired T-test for difference between 1st and 2nd assessment with the three probes

Intra-examiner reproducibility

For the intra-examiner reproducibility the mean difference between the first and second assessment of the distance from the CEJ to the gingival margin is presented by examiner for each of the three probes (Table 2). In permanent teeth the difference varied between -0.18 and 0.04 mm with Merritt-B probe, -0.24 and 0.08 mm for the CPITN probe and -0.13 and 0.10 mm for the TPS probe. Repeated measures analysis showed a significant effect of the examiners on the difference between of the first and second assessment. Post-testing showed that the estimation of the CEJ by examiner 3 was significantly deeper at the second assessment with all three probes but amounted to 93% of agreement within ±1 mm (p<0.05). Examiner 1 assessed the CEJ with the Merritt-B probe the second time more apical but achieved with all probes 99% agreement. The overall percentage agreement for differences in between the -1 and +1 mm was for all probes the same (95%).

In deciduous teeth the mean difference varied between -0.04 and 0.07 mm with Merritt-B probe, -0.13 and 0.03 mm for the CPITN probe and -0.13 and 0.08 mm for the TPS probe (Table 2). The
Repeated measure analysis showed that examiners had a significant effect on the comparison of the first and second assessment except for the Merrit-B probe. Post-testing showed no significant difference between the two assessments for all examiners with the Merrit-B probe. Examiners 3 and 4 proved with all three probes to be the most reproducible of the four examiners. The overall percentage of agreement for differences between the -1 and +1 mm was for the Merrit-B probe and the TPS probe 98%. The CPITN probe showed a 96% of agreement.

Table 2. Intra-examiner reproducibility - the mean difference (in mm) between the 1st and 2nd assessment of the distance from the CEJ to the gingival margin presented by examiners with the three probes in permanent and deciduous teeth (standard deviation in parenthesis).

<table>
<thead>
<tr>
<th></th>
<th>Merritt B</th>
<th>% agreement</th>
<th>CPITN</th>
<th>% agreement</th>
<th>TPS</th>
<th>% agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Permanent teeth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>examiner 1</td>
<td>-0.06 (0.55) ♦</td>
<td>99%</td>
<td>-0.01 (0.69)</td>
<td>99%</td>
<td>-0.04 (0.56)</td>
<td>99%</td>
</tr>
<tr>
<td>examiner 2</td>
<td>-0.09 (0.87) ♦</td>
<td>91%</td>
<td>-0.08 (0.88)</td>
<td>98%</td>
<td>-0.12 (0.75) ♦</td>
<td>96%</td>
</tr>
<tr>
<td>examiner 3</td>
<td>-0.18 (0.82) ♦</td>
<td>95%</td>
<td>-0.24 (0.79) ♦</td>
<td>93%</td>
<td>-0.13 (0.83) ♦</td>
<td>94%</td>
</tr>
<tr>
<td>examiner 4</td>
<td>-0.04 (0.85) ♦</td>
<td>93%</td>
<td>-0.08 (0.91)</td>
<td>90%</td>
<td>-0.10 (0.84) ♦</td>
<td>92%</td>
</tr>
</tbody>
</table>

Repeated measures ♦ $p<0.001$  $p<0.05$  $p<0.001$

Overall % agreement 95% 95% 95%

<table>
<thead>
<tr>
<th></th>
<th>Merritt B</th>
<th>% agreement</th>
<th>CPITN</th>
<th>% agreement</th>
<th>TPS</th>
<th>% agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deciduous teeth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>examiner 1</td>
<td>-0.04 (0.54) ♦</td>
<td>99%</td>
<td>-0.11 (0.66) ♦</td>
<td>98%</td>
<td>-0.09 (0.66)</td>
<td>98%</td>
</tr>
<tr>
<td>examiner 2</td>
<td>-0.04 (0.74) ♦</td>
<td>96%</td>
<td>-0.13 (0.77) ♦</td>
<td>94%</td>
<td>-0.13 (0.63) ♦</td>
<td>98%</td>
</tr>
<tr>
<td>examiner 3</td>
<td>-0.07 (0.67) ♦</td>
<td>97%</td>
<td>-0.06 (0.69) ♦</td>
<td>97%</td>
<td>-0.04 (0.66)</td>
<td>99%</td>
</tr>
<tr>
<td>examiner 4</td>
<td>-0.02 (0.59) ♦</td>
<td>99%</td>
<td>-0.03 (0.74)</td>
<td>94%</td>
<td>-0.08 (0.77) ♦</td>
<td>95%</td>
</tr>
</tbody>
</table>

Repeated measures ♦ NS  $p<0.05$  $p<0.01$

Overall % agreement 98% 96% 98%

% agreement is expressed as the difference between the 1st and 2nd assessment within the interval of -1 mm to +1 mm
♦ the overall effect of the examiner on the reproducibility of the duplicate measurement using 1st and 2nd assessment.
A negative value represents a deeper measurement in the 2nd assessment.
♦ Post testing using Student T-test, significant differences between duplicate measurements ($p<0.05$)
**Inter-examiner reproducibility**

All examiners assessed the same site in duplicate with the same probe. Based on the mean distance from the gingival margin to the CEJ for each of the 3 probes per examiner, the inter-examiner reproducibility was evaluated (Table 3). In both permanent and deciduous teeth the examiner had a significant effect on the recorded location of the CEJ. In permanent teeth the assessments of the CEJ by the four examiners ranged from 1.87 mm with the TPS probe by examiner 2 to 3.15 mm assessed by examiner 1 with the Merrit-B probe. In the deciduous teeth examiner 2 with the TPS probe and examiner 3 with the CPITN probe assessed the lowest mean value of 2.34 mm. The highest mean value of 3.24 mm was recorded by examiner 2 with the Merrit-B probe.

In permanent teeth the inter-examiner correlations for the paired assessments with the Merrit-B probe of the four examiners ranged from 0.37 to 0.53 (Pearson Correlation). The CPITN probe showed a comparable correlation between the examiners ranging from 0.36 to 0.52 and the correlation for the TPS probe ranged from 0.25 to 0.48. The inter-examiner correlations in the deciduous teeth with the Merrit-B probe were higher than in than permanent teeth, ranging from 0.40 to 0.60. The CPITN and the TPS showed lower correlations ranges (0.08 to 0.48 and 0.12 to 0.44 resp.).

*Table 3. Inter-examiner reproducibility - the mean (in mm) of the duplicate estimations per examiner of the distance from the gingival margin to the CEJ for each of the 3 probes in permanent and deciduous teeth (standard deviation in parenthesis).*

<table>
<thead>
<tr>
<th>Permanenent teeth</th>
<th>Merrit-B</th>
<th>CPITN</th>
<th>TPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>examiner 1</td>
<td>3.15 (0.64)²,³,⁴</td>
<td>3.00 (0.70)²,³,⁴</td>
<td>2.73 (0.70)²,⁴</td>
</tr>
<tr>
<td>examiner 2</td>
<td>2.10 (0.75)¹,³,⁴</td>
<td>2.00 (0.77)¹,³,⁴</td>
<td>1.87 (0.63)¹,³,⁴</td>
</tr>
<tr>
<td>examiner 3</td>
<td>2.50 (0.68)¹,²,⁴</td>
<td>2.33 (0.67)¹,²,⁴</td>
<td>2.66 (0.69)²,⁴</td>
</tr>
<tr>
<td>examiner 4</td>
<td>2.81 (0.63)¹,²,³</td>
<td>2.54 (0.68)¹,²,³</td>
<td>2.29 (0.54)¹,²,³</td>
</tr>
<tr>
<td>ANOVA</td>
<td><em>p&lt;0.001</em></td>
<td><em>p&lt;0.001</em></td>
<td><em>p&lt;0.001</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Deciduous teeth</th>
<th>Merrit-B</th>
<th>CPITN</th>
<th>TPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>examiner 1</td>
<td>3.32 (0.53)³,⁴</td>
<td>2.98 (0.46)²,³</td>
<td>2.54 (0.49)²</td>
</tr>
<tr>
<td>examiner 2</td>
<td>3.42 (0.73)³,⁴</td>
<td>2.78 (0.66)¹,³,⁴</td>
<td>2.34 (0.55)¹,⁴</td>
</tr>
<tr>
<td>examiner 3</td>
<td>2.67 (0.57)¹,²,⁴</td>
<td>2.34 (0.54)¹,²,⁴</td>
<td>2.43 (0.60)⁴</td>
</tr>
<tr>
<td>examiner 4</td>
<td>3.13 (0.47)¹,²,³</td>
<td>2.98 (0.44)²,³</td>
<td>2.62 (0.52)²,³</td>
</tr>
<tr>
<td>ANOVA</td>
<td><em>p&lt;0.001</em></td>
<td><em>p&lt;0.001</em></td>
<td><em>p&lt;0.001</em></td>
</tr>
</tbody>
</table>

¹,²,³,⁴ = Post-Hoc testing; significant differences between examiners (*p<0.05*)
CHAPTER 3

Accuracy

To test the accuracy of the three probes the mean difference between the microscopically assessed position of the CEJ and the mean clinical assessment of the CEJ relative to the gingival margin was calculated (Table 4). Based on repeated measures analysis, all probes differed in their assessment of the CEJ. In permanent teeth the Merrit-B probe was the most accurate (-0.05mm) showing no significant difference with the microscopic assessment. Both the CPITN probe and the TPS probe (0.11 mm and 0.19 mm respectively) assessed the CEJ more coronal than the actual position.

In the deciduous teeth the Merrit-B probe was most accurate in relation to the microscopic assessment (-0.02mm). Both the CPITN probe and the TPS probe stopped coronal of the CEJ (0.35 mm and 0.63 mm respectively). Comparing the accuracy of the different probes between the permanent and the deciduous teeth no significant difference was observed using the Merritt-B probe. In the deciduous teeth the CPITN probe and the TPS probe assessed the CEJ more coronally than the true position comparing to the permanent teeth (0.35mm vs. 0.11 and 0.63mm vs. 0.19 respectively.).

Table 4. Accuracy – Percentage of accuracy and the mean difference (in mm) between the microscopic assessment and the mean measurement (in mm) of the location of CEJ with the 3 probes, for each of the 4 examiners, in permanent and deciduous teeth (standard deviation in parenthesis)

<table>
<thead>
<tr>
<th></th>
<th>Merritt</th>
<th>CPITN</th>
<th>TPS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Permanent teeth</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>examiner 1</td>
<td>-0.57 (0.67)*</td>
<td>-0.42 (0.67)*</td>
<td>-0.15 (0.63)*</td>
</tr>
<tr>
<td>examiner 2</td>
<td>-0.49 (0.85)*</td>
<td>-0.58 (0.82)*</td>
<td>-0.71 (0.73)*</td>
</tr>
<tr>
<td>examiner 3</td>
<td>-0.11 (0.88)*</td>
<td>-0.24 (0.78)*</td>
<td>-0.07 (0.88)</td>
</tr>
<tr>
<td>examiner 4</td>
<td>-0.23 (0.82)*</td>
<td>-0.04 (0.73)</td>
<td>-0.29 (0.68)*</td>
</tr>
</tbody>
</table>

| **Deciduous teeth** |       |       |     |
| examiner 1   | -0.20 (0.51)* | 0.14 (0.55)* | 0.57 (0.58)* |
| examiner 2   | -0.29 (0.67)* | 0.34 (0.68)* | 0.78 (0.55)* |
| examiner 3   | -0.45 (0.75)* | 0.78 (0.73)* | 0.68 (0.68)* |
| examiner 4   | -0.02 (0.56)  | 0.14 (0.61)* | 0.49 (0.61)* |

**Permanent versus Deciduous**

<table>
<thead>
<tr>
<th></th>
<th>NS</th>
<th>p&lt;0.001*</th>
<th>p&lt;0.001*</th>
</tr>
</thead>
</table>

* paired T-test comparing mean probe assessment with microscopic assessment. A negative value represent a deeper probing measurement than the microscopic assessment

m,c,t ANOVA for differences between probes; significant differences between probes (p<0.001), m=Merritt, c=CPITN, t=TPS.

ANOVA comparing permanent teeth and deciduous teeth.
Fig. 2 a, b, c, shows the accuracy of the three probes based on the frequency distributions of the difference between the microscopically assessed position of the CEJ and the mean CEJ assessment relative to the gingival margin. In permanent teeth with the Merritt-B probe 33% of the measurements corresponded with the microscopic assessment of the CEJ. Whilst in 26% the probe tip was 0.5 mm apical and in 18% 0.5 mm coronal of the CEJ. In all, 95% of the measurements fall within the interval of -1 to +1 mm. In the deciduous teeth the Merritt-B corresponded in 41% of the measurements with the microscopically assessed position of the CEJ. In 99% the difference lies within the -1 to +1 mm interval.

Fig. 2a Frequency distribution of the difference between the CEJ estimation with the Merrit B probe as compared to the microscopic assessment with 0.5mm increments in permanent and deciduous teeth

The measurements with the CPITN probe in permanent teeth were in 36% in accordance with the microscopically assessed position of the CEJ. In 24% the probe tip was 0.5mm apical and in 21% 0.5 mm coronal to the CEJ. In all, 91% of the measurements fall within the interval of -1 to +1 mm. In the deciduous teeth the CPITN probe corresponded in 29% of the measurements with the actual position of the CEJ. In 59% the CEJ was estimated coronal of the CEJ.
The TPS probe assessments in permanent teeth corresponded in 35% of the measurements exactly with the actual position of the CEJ. Whilst in 36% the assessment was 1 mm coronal to the CEJ. In all, 93% of the measurements fall within the interval of -1 to +1 mm. In the deciduous teeth the TPS probe corresponded in 41% of the measurements to the CEJ while in 37% the CEJ was estimated more coronally.
Discussion

The most important clinically detectable change during periodontal breakdown is loss of connective tissue attachment relative to its original location at the CEJ. The CEJ can serve as a fixed reference point but is not easily identified especially when it is still covered by gingival tissue. Therefore clinical evaluation of the accuracy of CEJ assessments has the impracticality of not being able to obtain the true value without extraction or surgical intervention (Hug et al. 1983). In the literature clinical studies claiming to test accuracy (Karpinia et al. 2004; Janssen et al. 1998) fail to do so. Based on the study design presented, without a true value, the data presented only represent the reproducibility of the methods tested. The “in vitro” study design of the present study provides an optimal situation for obtaining the true value and therefore testing the accuracy of the three probes used. Factors influencing an accurate estimation of the CEJ, such as the presence of calculus and restorations, were avoided by selecting teeth without restorations and careful cleaning of the teeth.

Hug et al. (1983) in estimating the CEJ showed, also in both intra- and inter-examiner comparisons, a low reproducibility. The intra-examiner reproducibility of probing measurements from the stent to the gingival margin showed the highest reproducibility (Watts 1987). The stent to the CEJ showed the least reproducibility with measurement errors within ± 1 mm. Clark et al. (1987) compared the intra-examiner reproducibility for probing depth and attachment level when measuring from a custom occlusal stent or the CEJ. Increased reproducibility was observed with attachment level measurements using the stent. The level of intra-examiner agreement for CEJ measurements was 72% within ± 1 mm. Because of the limitations of a custom occlusal stent for epidemiological field studies, they stated that the traditional CEJ method seems to be the only possible option. In the present study the intra-examiner reproducibility in assessing the CEJ in the permanent teeth was for all probes 95% within ± 1 mm of difference. This result is comparable to Badersten et al. (1984). They showed an intra-examiner reproducibility of 90% within ± 1 mm. Based on the data of the present study in the deciduous teeth using the Merrit B probe, the intra-examiner reproducibility was even higher. In 98% the assessments were between -1 and +1 mm and showing no significant differences between the four examiners using the Merrit-B probe. In all, the intra-examiner reproducibility in the present study is good and the Merrit-B probe performed best in the deciduous teeth.
Analysis of the inter-examiner reproducibility showed significant differences between all four examiners. This is also apparent from the Pearson correlation coefficients. In comparison to the results reported by Clark et al. (1987), the inter-examiner reproducibility when assessing the CEJ in a subgingival position, the Pearson correlation coefficient amounted to 0.59 between the 2 examiners. In the present study the highest correlation in the permanent teeth was 0.53 between examiner 1 and 2. The lowest was found for the TPS probe between examiner 3 and 4 (0.25). In the literature no studies are available as comparison for the inter-examiner correlation in deciduous teeth. It is clear from these data that all examiners differed in assessing the CEJ and inter-examiner reproducibility is relatively poor.

When improving the accuracy and the reproducibility of CEJ probing measurements, one of the variables is the probe itself. In the literature several designs have been used with one common feature i.e. a distinct sharp edge at the probe tip for improved tactility. Compared to a conventional probe tip, the modified design by Hug et al. (1983) was not able to increase the accuracy, while Watts et al. (1989) showed an improved reproducibility for the modified Cross calculus probe with an offset scale. Karpinia et al. (2004) and Preshaw et al. (1999) used a probe with, at the tip, a diameter of 1.25mm for CEJ assessments. Although showing reproducible measurements the large diameter at the tip suggests limited subgingival access. The TPS probe (Vivadent) used in the present study has a rim surrounding the side of the ball with a 0.5 mm diameter. The manufacturer claims that this aids in the detection of the cemento-enamel junction (Mayfield et al. 1996). As the TPS probe, the spherical ball-like tip design of the WHO probe might also provide a better tactility. In this study the TPS probe and also the CPITN probe estimated the location of the CEJ on average more coronally. The conventional Merrit-B probe proved to be the most accurate in assessing the actual position of CEJ. The same difference in accuracy is clear in the deciduous teeth. Again the TPS probe and the CPITN probe positioned the CEJ more coronally than the actual position. Based on the results in this study, we may conclude that probes tested in this study with a specific design suggested to improve the tactility, do not lead to more accurate measurements.

It can be speculated that, due the enamel surface texture close to the CEJ as described by Schroeder et al. (1988), assessing the CEJ becomes difficult. The enamel of the permanent tooth surface close to the CEJ appears either smooth or micro pitted, with perikymata running more or less parallel to the CEJ. Along the latter, nodules and patches of irregular size and form occur as well.
CEMENTO-ENAMEL JUNCTION DETECTION "IN VITRO"

(Schroeder et al. 1988). The higher tactility of the TPS probe and the CPITN probe may have been suggestive to assess irregular surface texture to be the CEJ. The same phenomenon might be true for the deciduous teeth. Together with the surface texture, the globosity (Ceppi et al. 2006) may have induced more probing errors with the TPS probe and the CPITN probe.

Conclusions

The Merritt-B probe proved to provide the most accurate assessment of the subgingival location of the CEJ relative to the gingival margin in both permanent and deciduous teeth. The intra-examiner reproducibility was good in deciduous teeth with the Merrit-B probe. Inter-examiner reproducibility was relatively poor in both permanent and deciduous teeth. Examiners assessing the CEJ should be trained performing repeated measurements to increase reproducibility for valid recordings.

Acknowledgements

The authors like to express their sincere thanks to Esther Reijerse and Marion van Dijk for their help in performing the CEJ measurements.

References


