Assessment of Periodontal Tissues Damping Characteristics: Current Concepts and Clinical Trials

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THE REPRODUCIBILITY OF AN ELECTRONIC DEVICE for the assessment of periodontal tissues damping characteristics was judged by evaluating the inter-examiner, inter-device and day to day variations of the measurements (PTVs). Nine young periodontally healthy volunteers were examined by two examiners (EX-1 and EX-2) and two devices (D-1 and D-2) in the following sequence: EX-1 D-1, EX-2 D-1, EX-1 D-2, and EX-2 D-2. PTVs were obtained at 5 different occasions during the same day. In some instances examiner 2 measured higher scores than examiner 1 with both devices. This difference was statistically significant ($P = 0.05$), if the total of 900 measurements was considered. The measurements of device 2 were approximately 0.5 PTV units higher, also reaching a statistical significance ($P = 0.05$). This difference is of limited clinical significance. The day to day variation was evaluated by comparing the scores obtained at 8 a.m. with the ones at the four other periods. The lowest scores were measured at 8 a.m. Only the 11 a.m. and the 2 p.m. measurements differed significantly. The effect of hormonal changes during the menstrual cycle and of smoking habits on PTVs were also evaluated. Ten female periodontally healthy volunteers were examined three times a week, during a period of two menstrual cycles. No significant PTV changes were found during the menstrual cycle. The effect of the smoking habit on PTVs was tested on 23 periodontally healthy patients. Scores obtained from all teeth, which did not present marginal bone loss in the vicinity, were related to smoking habits (non-smoker, former smoker, current smoker). Statistically significant lower PTVs for non-smokers ($P = 0.03$) were only found for the inferior molar teeth. Nevertheless a propensity of non-smokers for lower PTVs was noted. *J Periodontol 1995; 66:165–170.*

Key Words: Reproducibility of results; dental instruments; periodontal diseases/diagnosis; tobacco/adverse effects; smoking/adverse effects; menstrual cycle.

All teeth with a healthy periodontium can be moved to a certain extent in a vestibulo-oral direction. This is called physiological tooth mobility and depends on the biophysical properties of the periodontal tissues. However, measuring mobility and especially assessing changes in tooth mobility is rather difficult. The easiest method is to tap the tooth in between two instrument handles to evaluate subjectively the distance between the two extreme positions. Although this approach seems very reproducible,[1] the need for an objective assessment is evident. Some methods, as the periodontometer of Mühlemann, are extremely complex and time consuming for daily practice.[2] The Periotest device[§] has been designed to provide an objective measurement of periodontal tissues damping characteristics, expressing it as a score called PTV (Periotest value).[3,4] It is a dynamic method offering the advantage that it does not require fixing a rigid measuring apparatus on the teeth.[3,4] Nevertheless, because of its limited interest from a periodontal point of view, this electronic device has received little attention in the scientific literature, except in conjunction with oral endosseous implants. In this application it offers an objective parameter for the evaluation of the bone-to-implant interface.[5-7] Future evaluations should encourage the use of this device to examine the damping characteristics of the periodontal ligament in periodontal diseases, such as marginal plaque related inflammation, subluxation, collagen metabolism anomalies, etc. For this reason it is

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necessary to judge its reproducibility, as well as to elucidate the day to day variation and the physiological situations that may affect the values. A good reproducibility would offer an objective and reproducible tool in clinical trials, while a judgment of the day to day variation and the physiological states that could affect the values would indicate the need for a correction factor and a more careful selection of the sample material when longitudinal studies are performed.

In these series of experiments, the reproducibility of the device by evaluating inter-examiner and inter-device differences, the day to day variation of the measurements, and the effect of smoking habits and hormonal changes during menstrual cycle on the PTVs was evaluated.

MATERIALS AND METHODS

The device consists of a handpiece connected by a cable to a unit which controls functions and analyzes measurements. Inside the handpiece, a metal rod is accelerated until it reaches its nominal speed, and contacts the tooth. Upon impact, the tooth is slightly deflected and the rod is decelerated. The faster the deceleration, the higher the stability and greater the damping of the periodontal tissues. The contact time between tooth and tapping head is the signal used for analysis by the system. Using the measured contact times in milliseconds, PTVs are calculated and based on a numerical scale from −8 to +50. According to the published data,[3,4,8,9] a physiological range exists for each tooth (for example: upper central incisors, 1 to 11; upper lateral incisors, 1 to 9; lower central incisors, 3 to 10; lower lateral incisors, 2 to 6; canines, −1 to 4; upper premolars, 0 to 9).

The methodology described[4] for assessing damping characteristics of the periodontium using this device consists of the handpiece held in an horizontal position with the start button on top. An orthoradial percussion just in the middle of the vestibular tooth surface and perpendicular to the labial surface is done twice for each tooth. The measurement value is given by the synthetic voice and is also indicated digitally. An average of both PTVs obtained is calculated and half scores can be used.

Inter-Examiner, Inter-Device Reproducibility and *Per Diem* Variation

Nine young volunteers (5 females; 4 males; age range 20 to 23 years) with teeth surrounded by a healthy periodontium were examined following informed consent. Exclusion criteria were periodontal probing depths of more than 3 mm, bleeding on probing exceeding 25% of the sites, bruxism or cranio-mandibular dysfunction, orthodontic treatment during the last 3 years, antibiotic treatment during the last 6 months, and missing or restored canine or Ramfjord teeth (numbers 16, 21, 24, 36, 41, and 44).

The 6 Ramfjord teeth and the 4 canines were measured with the methodology described above. Measurements were performed by two examiners (EX-1 and EX-2) with two different devices (D-1 and D-2) in the following sequence: EX-1 D-1, EX-2 D-1, EX-1 D-2, and EX-2 D-2. This sequence was maintained throughout the study. Before each measurement, the device was calibrated by delivering a series of taps (16 impacts) on a plastic cap firmly maintained on top of the handpiece. Only measurements with the device on calibration 11 or 12 (manufacturer's instructions) were performed. If the calibration was correct, the device was turned-off and the batteries were recharged. The PTVs were obtained at 5 different occasions during the same day (8 a.m., 9 a.m., 11 a.m., 2 p.m., and at 5 p.m.).

For the statistical analysis, the paired *t*-test was used to evaluate the differences of PTVs in the inter-examiner and inter-device trials. The day to day variation was also evaluated with the paired *t*-test by comparing the PTVs at 8 a.m. with those at 9 a.m., 11 a.m., 2 p.m., and 5 p.m., respectively. A level of significance of 0.05 was chosen, with equality of measurements as a null hypothesis.

Effect on PTV of the Hormonal Changes During the Menstrual Cycle

The following study was designed in order to elucidate the effect on PTVs of the hormonal changes during the menstrual cycle.

Ten young female volunteers participated, following informed consent (age range from 20 to 25 years; mean = 21.6; S.D. = 1.68). The anonymity of the participants was guaranteed for evident reasons and to assure blind measurements by using coded diaries for menstrual cycle timing. Exclusion criteria were periodontal probing depths of more than 3 mm, bleeding on probing exceeding 25% of the sites, bruxism or cranio-mandibular dysfunction, orthodontic treatment during the last 3 years, and missing or restored teeth. Information regarding age, general health, smoking habits, pregnancy, hormonal or antimicrobial medications, and menstrual cycle characteristics were obtained by a questionnaire and filed according to a code number. All of the subjects had good general health; none had missing or crowned teeth; none were pregnant; two were current smokers with a consumption of 8 and 5 cigarettes per day for a period of 8 and 4 years, respectively; three subjects took hormonal contraceptives; and only one reported irregular periods.

PTVs were obtained from every tooth from first molar to first molar, with the methodology described above. The measurements were done on every patient three times a week, during a period of two months, at the same hour of the day, and by the same examiner. The patients were instructed to report in a diary the first and the last day of the menstrual period. After two months, all the information compiled was organized by the assigned code number.

The duration of the menstrual cycle of each subject was calculated. The first day was the first day of the menstruation and the last day of the cycle was the first day of the second menstruation. The menstrual cycle was divided into four phases according to the hormonal changes (Fig. 1).

For the statistical analysis the examined teeth were classified in 6 groups (group 1, incisors; 2, canines; 3, pre-

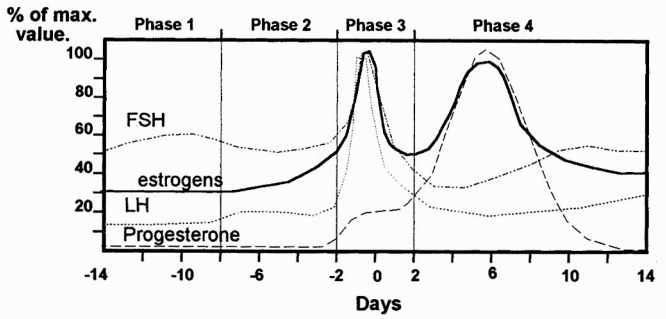

Figure 1. Graphic display of the 4 phases of the menstrual cycle according to the hormonal changes.[12] FSH: follicle stimulant hormone; LH: lutein hormone; Day 0 is the ovulation. Phase 1 lasts 5 to 7 days and during this period, there is a slight premenstrual rise in the level of FSH which lasts for 3 to 4 days. This change is preceded by a fall in the circulating levels of progesterone and estrogens. During phase 2 there is a progressive rise in the level of plasma estrogens. At the same time there is a corresponding fall in the level of FSH and either a small rise or no significant change in the level of LH. During phase 3 the plasma levels of LH increase and last for 16 to 24 hours. There is a concomitant rise in FSH. The level of plasma estrogens, (which reaches a peak value prior to ovulation) starts to fall, while that of progesterone starts to rise. Phase 4 is characterized by a vast increase in the level of plasma progesterone and estrogens. The endocrine function of the resultant corpus luteum gradually increases, reaching a maximal secretion of progesterone 6 to 7 days after ovulation.

molars-upper jaw; 4, premolars-lower jaw; 5, molars-upper jaw; 6, molars-lower jaw). The mean PTV for every phase of the menstrual cycle was calculated for each tooth group. Each subject was treated as a block variable, and the time as the variable of interest. The data were analyzed using the general linear model (GLM) procedure of SAS.

Effect of Smoking on PTV

The following blind study was designed in order to determine whether the PTVs for patients without marginal bone loss are different in current smokers, former smokers, and non-smokers.

The study group was comprised of 23 periodontally healthy patients (14 female, 9 male; age range 20 to 61 years), who participated on the basis of informed consent. Exclusion criteria were periodontal probing depths of more than 3 mm, bleeding on probing exceeding 25% of the sites, bruxism or cranio-mandibular dysfunction, and orthodontic treatment during the last 3 years. Information regarding age, examined teeth and smoking habits is shown in Table 1. Only the teeth without periodontal breakdown were considered for the study. This was verified by assessment of bone and attachment level using intra-oral radiographs and a pocket probe respectively. Teeth with bone loss > 2 mm were not included. All the patients had good general health and a minimum of 18 teeth.

The individuals who never smoked were called non-smokers. Those individuals currently smoking five or more cigarettes a day were considered smokers. Individuals who had previously smoked, but stopped more than 1 year ago, were labeled former smokers.

Table 1. Subjects, Age, and Examined Teeth According to Smoking Habits

	N	Age Range	(mean)	Tooth Group 1	2	3	4	5	6	Total
Current smokers	4	27–61	(42.7)	9	10	5	6	2	3	35
Former smokers	5	25–46	(38.6)	15	11	4	8	3	1	42
Non-smokers	14	20–58	(34.7)	105	61	43	50	24	27	310
Total	23	20–61	(36.9)	129	82	52	64	29	31	387

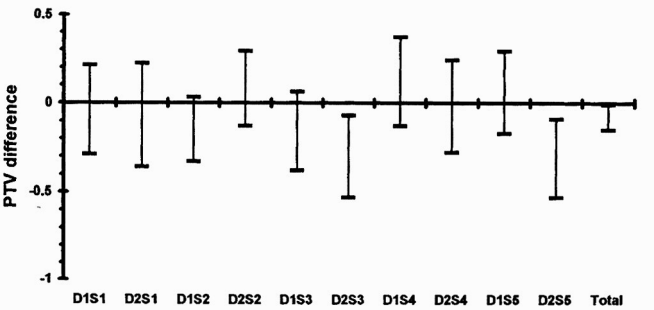

Figure 2. Graphic display of the 95% confidence intervals of the differences in PTVs obtained, between the two different examiners (Ex1 - Ex2). The unit of measure was the PTV obtained for each examined tooth. The vertical axis represents the PTV differences obtained between Ex1 and Ex2. While the horizontal axis corresponds to the zero line (inter-examiner difference of zero). The vertical lines that cross the zero line represent the range of inter-examiner differences found. These vertical lines are labeled according to the corresponding session (8 a.m., S1; 9 a.m., S2; 11 a.m., S3; 2 p.m., S4; and 5 p.m., S5) and device (device 1 = D1, device 2 = D2). The total difference is also displayed (Total). In some instances examiner 2 measured higher PTV than examiner 1 with both devices. Only in two instances was the level of significance reached (D2S3 and D2S5).

The daily mean cigarette consumption was 21.7 (range 5 to 40; S.D. = 12.11) and 22.5 (range 5 to 75; S.D. = 22.03) among smokers and former-smokers, respectively. The mean duration of the smoking habit was 26.2 years (range 4 to 50; S.D. = 18.31) and 13.6 years (range from 4 to 24; S.D. = 6.67), respectively.

The examined teeth were grouped as described above. PTVs were obtained from all the remaining teeth without marginal bone loss between the first molars, and with equal distribution between both jaws, using the methodology described above. The mean PTV for each group of teeth was calculated and related to smoking habits (non-smoker, former smoker, smoker). A one-way analysis of variance (ANOVA) test was used with PTVs as dependent-variable and smoking habits as independent-variable. The following hypotheses was tested: μ_{PTV} of non-smokers = μ_{PTV} of former smokers = μ_{PTV} of smokers.

RESULTS

Inter-Examiner Reproducibility

In some instances examiner 2 measured higher PTV than examiner 1 with both devices. This difference was statistically significant ($P = 0.05$), if the total of 900 measurements are considered (90 measurements 5 times a day with two devices) (Fig. 2). Here, the limits of the 95% confi-

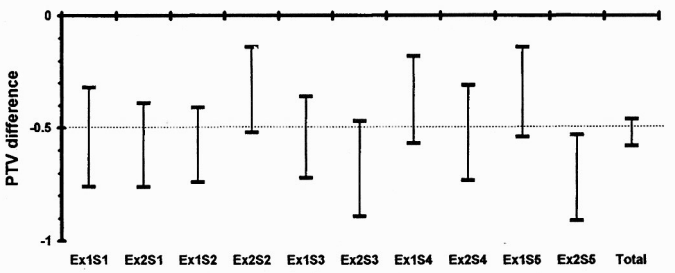

Figure 3.Graphic display of the 95% confidence intervals of the differences in PTVs obtained with the two devices (device 1 - device 2). The unit of measure was the PTV obtained for each examined tooth. The vertical axis represents the PTV differences obtained between device 1 and device 2. While the horizontal axis corresponds to the zero line (inter-device difference of zero). The vertical lines that cross the zero line represent the range of inter-device differences found. These vertical lines are labeled according to the corresponding session (8 a.m., S1; 9 a.m., S2; 11 a.m., S3; 2 p.m., S4; and 5 p.m., S5) and examiner (Ex1 and Ex2). The total difference is also displayed (Total). Measurements of device 2 are approximately 0.5 measuring unit higher. When a shift of 0.5 units is applied as a correction factor (dotted line), no significant difference can be observed (with the exception of Ex2S5).

dence interval were −0.01 and −0.15. If, on the other hand, the measurements are grouped per session and device, only in two instances (D2S3 and D2S5) was the level of significance reached (Fig. 2). The limits of the 95% confidence interval in this case, were 0.37 and −0.53 (Fig. 2).

Inter-Device Reproducibility

The total number of measurements considered was also 900 (90 measurements 5 times a day by both examiners). The measurements of device 2 were approximately 0.5 PTV units higher (the limits of the 95% confidence interval were −0.46 and −0.58), reaching a statistical significance (P = 0.05) (Fig. 3). Moreover, when a shift of 0.5 PTV units was applied as a correction factor, no significant difference could be observed (Fig. 3). However, this difference is of limited clinical significance.

Day to Day Variation

The day to day variation was evaluated by comparing the PTVs obtained at 8 a.m. with those at the other four periods. The total number of measurements was 1,440 (360 measurements in each period). The lowest values were measured at 8 a.m. The measurements at 9 a.m., 11 a.m., 2 p.m., and 5 p.m. were higher, but only the 11 a.m. and 2 p.m. measurement differences reached statistical significance.

Effect of Hormonal Changes During the Menstrual Cycle

No statistically significant difference between the four phases for each tooth group (experiment wise error rate = 0.05) was found. The present study showed that there is no significant changes on PTV during the menstrual cycle of 10 periodontally healthy women. This lack of fluctuation is

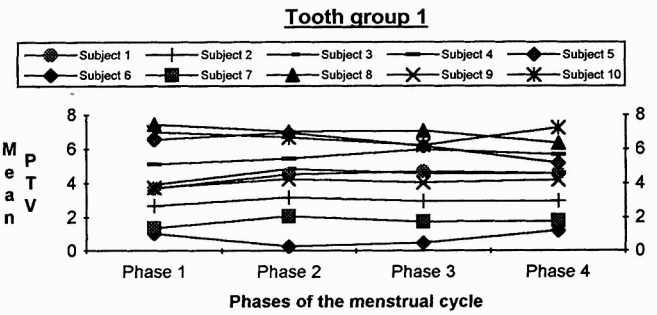

Figure 4. Graphic display of the fluctuation of mean PTVs of incisors during the menstrual cycle of 10 periodontally healthy subjects. No statistically significant difference between the four phases (experiment wise error rate = 0.05) was found.

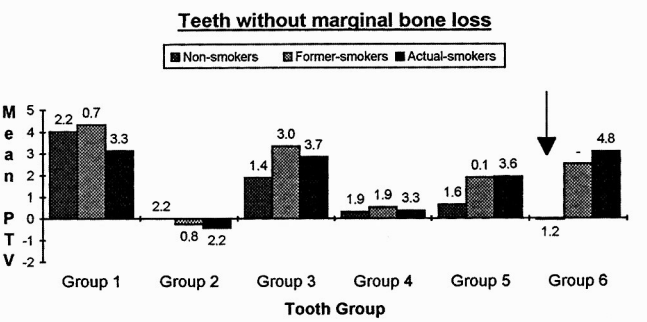

Figure 5. Graphic display of the mean PTV and standard deviation of teeth without marginal bone loss of non-smokers, former smokers and smokers. Standard deviations are shown on the top of the bars (except for tooth group 6 of former smokers that had only one sample). Group 1, incisors; 2, canines; 3, premolars-upper jaw; 4, premolars-lower jaw; 5, molars-upper jaw; and 6, molars-lower jaw. A statistically significant lower PTV was found in non-smokers for group 6 (arrow). Non-smokers show lower PTVs than former and current smokers, except for groups 1 and 2 (incisors and canines).

displayed for tooth group 1 (incisors) in Figure 4. The other tooth groups showed similar results.

Effect of Smoking

In the present study, a statistically significant result (P = 0.03) was only found in the inferior molar teeth (arrow, Fig. 5). Furthermore it is interesting to consider that non-smokers had lower PTVs than former and current smokers, except for tooth group 1 and 2 (incisors and canines) (Fig. 5).

DISCUSSION

Inter-Examiner, Inter-Device Reproducibility and per Diem Variation

Reproducibility was good for all parameters (operator, device, time). In the inter-examiner and inter-device trials, the maximal width of the 95% confidence interval was smaller than half of a PTV unit when considering the measurements grouped per session (groups of 90 measurements), and

smaller than 20% of a PTV unit if we consider the total difference (groups of 900 measurements).

In the inter-examiner trial, the values of the 95% confidence interval were concentrated mainly around zero (between 0.37 and −0.53) (Fig. 2), while in the inter-device trial the same analysis showed an almost constant difference of half of a PTV unit between the two devices (between −0.14 and −0.91) (Fig. 3). Differences of half of a PTV unit are not clinically meaningful, especially if we take into consideration that an increase or decrease of 1 PTV unit represents a very small difference in damping characteristics or in visible mobility. Moreover, physiological tooth mobility covers a range of 10 measuring units.[9] On the other hand, as far as longitudinal studies are concerned, a correction factor for each device should be considered if multiple devices are being used throughout the study.

Mühlemann reported that physiological tooth mobility is dependent on the time of day measurements are taken when using the Periodontometer.[2] We observed a slight increase of the PTVs at 11 a.m. and at 2 p.m. (compared to the 8 a.m.), but this increase could not be observed at 9 a.m. or 5 p.m. The differences observed at 11 a.m. and 2 p.m. were statistically significant, but it is doubtful this variance is clinically meaningful (the mean difference was smaller than 20% of a PTV unit). A distinction should be made between the Periodontometer that measures tooth mobility and this system that measures the periodontal tissues damping characteristics. Lukas et al.[10] observed that "the periodontium behaves different when recovering from a static deflection rather than from a percussion."

Since in this study, we could not avoid performing several measurements on the same teeth, one may think that could alter the final values. But in an earlier experiment (unpublished data), the authors observed that repeated tapping of a tooth, while using this device, did not alter the PTVs, even after 10 or 20 registrations. This was also confirmed by Schulte et al.,[11] who state that "there is no interference between multiple measurements at one minute intervals."

Inter-examiner and day to day differences were extremely small. Therefore, from a scientific point of view, the most interesting feature of the device is that it would not be necessary to have all the measurements performed by the same investigator or at the same time during the day. For longitudinal studies, when several devices are being used, differences between devices can be calculated for the data presentation.

In this study only teeth in young subjects with a healthy periodontium were measured. The recorded PTVs ranged between −4 and +7. Patients with periodontitis or with a healthy but reduced periodontium could have much higher PTVs. Further studies should be aimed to judge whether or not the reproducibility of the device is as reliable in those situations as it was among young periodontally healthy subjects.

Effect of Hormonal Changes During the Menstrual Cycle on PTV

The menstrual cycle is divided in two phases corresponding to the pre- and post-ovulation period. The periodontal reactions during this period are linked to the hormonal changes. For that reason in this study the menstrual cycle was divided into four continuous phases[12] according to hormonal changes (Fig. 1).

The effects of female sex hormones during the menstrual cycle on the periodontal ligament and tooth supporting alveolar bone have rarely been investigated.[13-15] It is undoubtedly possible that these structures react to changes in endocrine activity in a similar way the connective tissue does in other parts of the body.[16] These combined effects should alter the biophysical properties of the connective tissue system. In respect to the tooth supporting structures, this would be reflected by less resistance towards forces acting on the crown of a tooth and accordingly by a reduction on the capacity to dissipate the forces (damping characteristics) and increased tooth mobility.

Our results agree with those of Schulte and Lukas[4] that "the stage of the menstrual cycle in females has no significant influence on the PTV." The effects of pregnancy on the periodontium are more pronounced and commonly observed[16] probably since production of sex hormones is manifold that during the menstrual cycle.

Effect of Smoking on PTV

The mechanisms by which cigarette smoking may negatively influence periodontal tissues are relatively unstudied. There is evidence that cigarette smoking exerts both systemic and local effects. The reports that smokers with periodontitis have less gingival bleeding[17] and inflammation[18] than non-smokers support the hypothesis that smoking exerts local effects. Tobacco smoke contains cytotoxic and vasoactive substances, including nicotine, which may mediate these local effects.[19] The systemic effects of cigarette smoking on the host are well documented and include inhibition of peripheral blood and oral neutrophil function, reduced antibody production, and alteration of bronchoalveolar and peripheral blood immunoregulatory T cell subset ratios.[19] Smoking is known to be associated with a reduction of bone mineral content[20] and recently related to periodontal bone loss.[21] Thus, cigarette smoking affects multiple biological systems and, according to the literature,[18,22,23] may be considered the most important environmental factor associated with periodontal diseases in industrial populations.

Since marginal bone loss is an important covariable when the influence of smoking on PTV is considered, only teeth without any periodontal breakdown were included in this study. Because of this, the sample was probably too small (see Table 1) and only one statistically significant difference could be established between PTV of smokers and non-smokers, namely for lower molars (arrow Fig. 5). Nevertheless, we could detect a propensity of non-smokers to have lower PTVs.

This device has demonstrated a mechanism to provide an objective and reproducible measurement of the periodontal tissues damping characteristic of teeth with a healthy periodontium, even during menstrual cycles. On the other hand, according to our results and other reports, smoking is a variable that should be controlled in studies of periodontitis. Nevertheless, the reproducibility of the device and the clinical meaning of the measurements when performing on teeth with periodontal breakdown still remain to be elucidated.

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