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SHORT COMMUNICATION

Repeatability of ultrasonic determination of gingival thickness

Hans-Peter Müller · Kefah M. Barrieshi-Nusair · Eija Könönen

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Abstract The aim of the present study was to assess the degree of disagreement of ultrasonic measurements of gingival thickness at different teeth. Gingival thickness was determined in 33 volunteers with plaque-induced gingivitis. Facial/buccal gingiva was measured at the level of the gingival sulcus depth. Measurements were repeated after 2 and 4 weeks. A repeated measures, two-level (occasion, subject), variance components model revealed a within-subject variance of 0.187 mm^2 resulting in a repeatability coefficient of 1.20 mm. When modeling level 1 (occasion) variance as a function of tooth type, respective error terms were used for calculating 95% repeatability coefficients for different teeth. Unreliable measurements were largely confined to upper and lower second and third molars. Error terms were lowest (0.03–0.05) at upper canines and first premolars as well as lower anterior teeth and premolars, where repeatability coefficients of 0.5 to 0.6 mm could be estimated. It was concluded that performance of the device was best at certain tooth types with rather thin gingiva. The present resolution and rather high degree of disagreement may preclude, however, detection of minute increases in thickness in the micrometer range, which seem to occur during gingivitis.

Keywords Gingival dimensions · Repeatability · Ultrasound · Plaque-induced gingivitis · Multilevel modelling · Complex level 1 variation

H.-P. Müller (✉) · K. M. Barrieshi-Nusair · E. Könönen
Department of Surgical Sciences, Faculty of Dentistry,
Kuwait University,
P.O. Box 24923, Safat 13110, Kuwait
e-mail: hp.muller@hsc.edu.kw

Introduction

Plaque-induced gingivitis is usually assessed by considering certain cardinal symptoms of inflammation, redness and swelling; and bleeding tendency after certain mechanical manipulation. So far, gingival edema could only be assessed visually in a very subjective manner. In an attempt to more accurately measure dimensional changes during gingivitis experiments, 3-D laser scanning technology has recently been introduced with some promising results [12]. However, measurements are made indirectly on stone model casts and are limited to few interdental papillae. Ultrasonic technology may be more suitable for in situ determination of changes in gingival volume at numerous sites in the oral cavity. However, lack of reproducibility of measurements may limit the usefulness of available devices in experimental gingivitis trials. Information on quantification of disagreement of ultrasonic measurements is very limited. When using a widely distributed ultrasonic A-scanner working at 5 MHz, correlation coefficients for repeat measurements were different in various parts of the oral cavity [10]. However, repeatability coefficients were not given. To assess the suitability of this ultrasonic device for monitoring gingival edema in a planned experimental gingivitis trial, the present study was conducted in a steady-state plaque environment to quantify the disagreement of repeat measurements.

Materials and methods

The study protocol had been reviewed and approved by Kuwait University Faculty of Dentistry's Ethical Committee. The study population was recruited among fifth- and sixth-year dental students. Inclusion and exclusion criteria

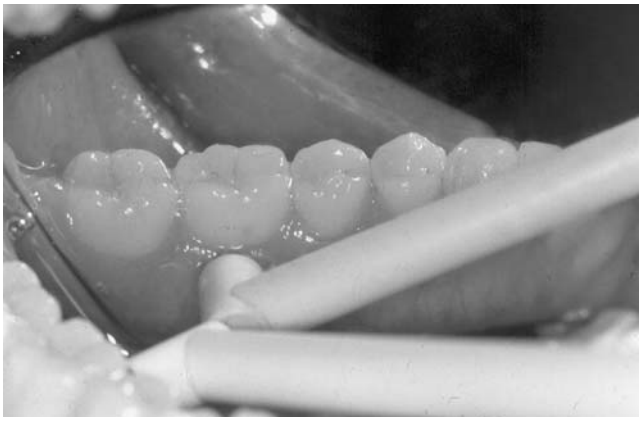

Fig. 1 Location of transducer probe on the gingiva

had been described elsewhere [8]. Volunteers were systemically healthy but presented with mild to moderate plaque-induced gingivitis of various extents. Thirty-three women participated and gave, after briefing on aim and procedures, their written consent for participation. Mean (±standard deviation) age of the participants was 22±1 years, and the mean number of erupted teeth was 29±3. A prophylaxis session was provided 1 week before clinical examination.

Clinical periodontal examinations at six sites of every tooth present consisted of measurements of gingival sulcus depth and attachment level. Bleeding on probing was recorded. No further mechanical manipulation of gingival was done, as it was assumed that bleeding, as described in this paper, corresponds to bleeding tendency of the marginal portion of gingiva in gingivitis. Finally, presence of calculus and amount of supragingival plaque according to the plaque index [14] were determined. Gingival thickness at mid-facial/buccal sites of each tooth was determined ultrasonically (Krupp SDM®, Austenal Medizintechnik, Cologne, Germany). The 5-MHz A-scanner, its principle, and the measurement procedure have been described elsewhere [2]. The 4-mm transducer probe is placed to the moistened surface of the gingiva with its base about 0.5 mm apical to the gingival margin (Fig. 1). Soft tissue thickness is measured within 2–3 s while the device transmits an acoustic signal, measurements to the next 0.1 mm. Examinations were repeated after 2 and 4 weeks. All 33 students participated after 2 weeks and 28 volunteered also after 4 weeks. At each visit, volunteers were advised not to alter their oral hygiene habits.

Repeatability of subsequent measurements of gingival thickness included analysis of data pairs, calculation of bias, and graphical display. For calculating the overall 95% repeatability coefficient [1], the within-group variation was determined in a two-level (occasion, subject) repeated measures variance components model. By entering tooth type, as defined by 15 dummy variables, into the model, and allowing complex level 1 variation, error terms for different tooth types could be determined [3]. Statistical software was used (MLwiN 2.02, Centre for Multilevel Modeling, Bristol University, Bristol, UK).

Results

Volunteers had mild or moderate plaque-induced gingivitis. Between 4 and 53%, sites bled on probing (mean, 22±11%). Only few sites had increased sulcus depths of >4 mm at partially erupted third molars (no loss of attachment). On average, 64±19% sites were covered by supragingival plaque. Some traces of supragingival calculus were found at lower anterior teeth. During the study period, no changes in clinical conditions were noticed. The distribution of values for gingival thickness at different tooth types is shown in Fig. 2. The highest median values (and largest subject variation) were found at maxillary third and mandibular second and third molars. There was no systematic error (bias) between measurements made after

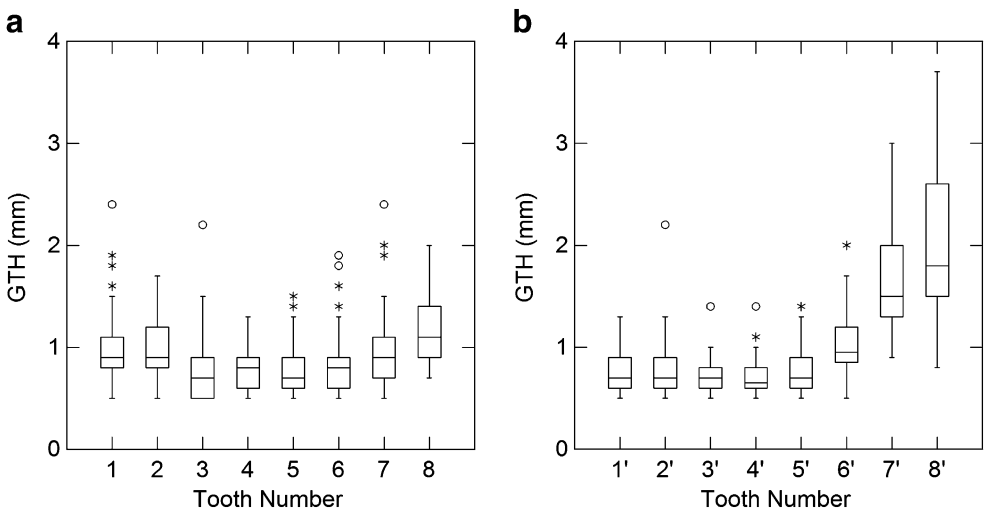

Fig. 2 *Box plots* illustrating the distribution of measurements of gingival thickness (*GTH*) at different tooth types in **a** the maxilla (*1–8*) and in **b** the mandible (1′–8′). Median, upper, and lower quartiles, lowest and largest non-outlier values, as well as mild (*asterisks*, between 1.5 and 3 times the inter-quartile range, *IQR*) and extreme outliers (*circles*, more than 3 times the *IQR*) are given

different time intervals (Table 1). Mean differences were close to 0. According to a repeated measures, two-level, variance components model (occasion, subject), an overall estimate across the three examinations revealed a repeatability coefficient of 1.20 mm. Complex level 1 variation was allowed for studying error terms for different tooth types. Level 1 variance estimates for different tooth types are presented in Table 2. Rather unreliable ultrasonic measurements were confined to lower second and, in particular, upper and lower third molars, where estimates of repeatability coefficients were 1.3 and 2.6 mm, respectively. Error terms were lowest (0.03–0.05) at the upper canines and first premolars as well as lower anterior teeth and premolars.

Discussion

Although a series of four periodontal examinations during a 6-month period in a steady-state plaque environment recently revealed very low biserial correlations of gingival bleeding after probing at the site level [9], it was not expected in this study that measurable differences in gingival thickness would occur during the study period of 4 weeks. In an environment where volunteers were asked not to change oral hygiene habits, intra-oral topographical distribution of supragingival plaque is very consistent, well-defined, and symmetric [11]. Thus, measurement error has to be regarded as the main source for variation in gingival thickness over time.

Very little valid information appears to exist regarding the degree of disagreement of either repeat ultrasonic measurements or in comparison with certain 'gold standards'. For example, in previous exercises, derivation of reported unreliability was not given [4] or the phenomenon of mathematic coupling [5, 16] disregarded when differences between measurements done by ultrasound and direct piercing the mucosa were plotted against piercing measurements only [13]. Moreover, serious concerns have been raised regarding correlation/regression analysis in method comparison [1, 6]. Instead, disagreement of measurement should be quantified. In a previous study [10], despite extensively reporting correlation coefficients, an attempt was actually made to quantify disagreement of ultrasound measurements of oral mucosa by calculating standard deviations of differences divided by the square root of 2, the measurement error. Values of between 0.26 (mid-facial/mid-lingual locations) and 0.54 mm (palatal locations) were reported. Assuming normal distribution of differences, these values may be translated into repeatability coefficients of 0.72 and 1.50 mm. Measurement of thick tissue in retromolar areas was found to be unreliable. In the present study, an overall repeatability coefficient of 1.20 mm was calculated. It can therefore be assumed that 95% of repeat measurements lie within boundaries of more than 1 mm. It must indeed be questioned whether this degree of reliability is sufficient for accurately assessing the expected minute increases of gingival swelling in experimental gingivitis trials. Further analyses revealed considerable complex level 1 variation of the measurements with measurements at certain teeth being accompanied with higher measurement variation. Lowest variability was found at teeth with thinnest gingiva, according to Fig. 1, namely upper canines and first premolars and lower anterior teeth and premolars. Measurements were poorly reproducible, in particular, at lower third molars where gingiva was by far thickest. Another possible explanation for complex level 1 variation is the various width of facial gingiva, which certainly adds additional variation to measurements due to difficulties in locating the same measurement point.

Recently, a novel sonographic B-scan device had been tested in periodontal situations, which were simulated in a

Table 1 Mean differences of repeat (1–3) measurements of gingival thickness (GTH), standard deviations (SD), and 95% repeatability coefficients (C_R) in mm

	Mean	SD	C_R
GTH2–GTH1	−0.016	0.348	0.682
GTH3–GTH2	0.014	0.309	0.606
GTH3–GTH1	−0.003	0.374	0.733

Table 2 Level 1 (occasion) variance modeled as function of tooth type (encoded by l=15 dummy variables)

	Variance estimate (standard error)	C_R
Maxilla		
Central incisor	0.102 (0.011)	0.885
Lateral incisor	0.121 (0.013)	0.964
Canine	0.052 (0.006)	0.632
1st premolar	0.044 (0.005)	0.581
2nd premolar	0.083 (0.009)	0.798
1st molar	0.055 (0.006)	0.650
2nd molar	0.113 (0.012)	0.931
3rd molar	0.216 (0.033)	1.287
Mandible		
Central incisor	0.031 (0.004)	0.488
Lateral incisor	0.044 (0.005)	0.581
Canine	0.028 (0.003)	0.464
1st premolar	0.031 (0.004)	0.488
2nd premolar	0.044 (0.005)	0.581
1st molar	0.092 (0.010)	0.840
2nd molar	0.257 (0.028)	1.404
3rd molar	0.904 (0.155)	2.634

Variances were estimated from $\sigma^2_{e0} + 2\sigma_{e0l} + \sigma^2_{el}$. Note that all terms σ^2_{el} were 0, see Healy [3] for further details. Estimates of 95% repeatability coefficients C_R in mm.

pig cadaver model [15]. Based on only nine replicate measurements, the authors calculated a rather low repeatability coefficient of 0.44 mm. However, considering the low number of observations, the seemingly quite favorable limits of agreement (−0.4, 0.48 mm) have very high 95% confidence intervals (not given in the original paper) of about −0.7 to −0.1 (lower limit) and 0.2 to 0.8 mm (upper limit). Whether the device actually presents an advantage might therefore be questioned.

The strength of the present ultrasonic device lies certainly in the investigation of anatomical soft tissue dimensions for which it had actually been developed. It has successfully been applied in the description of subject variation in gingival dimensions, the so-called gingival phenotypes, identification of suitable areas for harvesting connective tissue grafts, clinical monitoring of biodegradation dynamics of implanted membranes for guided tissue regeneration, as well as surgical root coverage, for review see [7]. Considering the rather large probe diameter of 4 mm, measurement resolution of 0.1 mm, and considerable disagreement of measurements found in our and in the latter study [15], the minute increases in thickness in the micrometer range, which seem to occur during gingivitis [12], can hardly be detected by ultrasonometry with presently available devices. Suitable ultrasonic devices are still highly demanded for precise measurements in both periodontology and implant dentistry.

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