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Ultrasonic Biometer and Its Usage in an Assessment of Periodontal Soft Tissue Thickness and Comparison of its Measurement Accuracy with a Bone Sounding Method

Zastosowanie biometru ultradźwiękowego w badaniu grubości tkanek miękkich przyzębia i porównanie jego dokładności pomiarowej z metodą „bone sounding"

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Abstract

Background. The ability to identify a periodontal biotype accurately, and in particular knowledge of soft tissues thickness in the periodontium (GT – Gingival Thickness), have high influence on planning and conducting a treatment in all fields of dentistry, significantly affecting the final outcome.
Objective. To compare the measurement accuracy of an ultrasonic and invasive method (bone sounding) in evaluation of soft tissues thickness in the periodontium.
Material and Methods. 30 subjects of both sexes aged 19–51 (21 females and 9 males) with a normal periodontium, without systemic and local comorbidities, that could affect periodontal tissues, were examined. Soft tissues thickness was measured by a non-invasive method, using Pirop® Ultrasonic Biometer with the A-scan probe with 20 MHz frequency, with 1540 m/s ultrasonic impulse velocity and accuracy up to 0.01 mm, and by a puncturing – bone sounding method with an endodontic tool with a limiter, and measurement readouts were taken from a calibrator with 0.1 mm accuracy. Measurements were made in area near 20 teeth in each subject (incisive, canine and premolar teeth in both jaws), at two points by each tooth. GT1 – in the middle of a keratinized gingiva width, GT2 – 2 mm apically from the mucogingival junction. Results from both non-invasive (N) and invasive (I) examinations were compared. Measurement accuracy between the invasive and ultrasonic method were compared in various metric ranges. The ranges were divided to: w1 ≤ 0.500 mm, w2 0.501–0.750 mm, w3 0.751–1.000 mm, w3 1.001–1.250 mm, w4 > 1.251 mm.
Results. The mean value of all measurements with the N method was 0.784, and with the I method was 0.828. The difference was 0.044, and was statistically significant. In the invasive method, the GT1 and GT2 mean values were higher for all teeth. There were no statistically significant differences between the N and I method in GT1 points only by the tooth 32, and in GT2 by teeth 11, 21, 22, 31, 32. Although the difference were significant by the remaining teeth. The highest differences between mean values of soft tissues thickness in the periodontium in GT1 and GT2 points were observed in the lowest value range w1 ≤ 0.500 mm.
Conclusions. The results of measuring soft tissues thickness in the periodontium with the ultrasonic and invasive methods – bone sounding are very similar, but the differences among the values are statistically significant for most measurement points. The ultrasonic method seems to be more accurate, especially in the lowest value range, taking into consideration the imperfection of the invasive examination (**Dent. Med. Probl. 2011, 48, 4, 481–489**).

Key words: gingival thickness, ultrasonic method, invasive method, measurement.

Streszczenie

Wprowadzenie. Umiejętność prawidłowego rozpoznania biotypu przyzębia, a szczególnie znajomość parametrów grubości tkanek miękkich przyzębia (GT – *Gingival Thickness*) ma duży wpływ na planowanie i prowadzenie leczenia we wszystkich dziedzinach stomatologii, wpływa znacząco na wyniki kliniczne.
Cel pracy. Porównanie dokładności pomiarowej metody ultrasonograficznej i inwazyjnej – *bone sounding* w oznaczaniu grubości tkanek miękkich przyzębia.

Materiał i metody. Zbadano 30 pacjentów obojga płci w wieku 19–51 lat (21 kobiet i 9 mężczyzn) ze zdrowym przyzębiem, bez chorób ogólnych i miejscowych mogących mieć wpływ na stan tkanek przyzębia. Grubość tkanek miękkich przyzębia była mierzona metodą nieinwazyjną z użyciem biometru ultradźwiękowego Pirop® w prezentacji A, sonda o częstotliwości 20 MHz, z szybkością fali 1540 m/s i dokładnością pomiaru 0,01 mm oraz metodą nakłuwania „*bone sounding*" z użyciem narzędzia endodontycznego z ogranicznikiem, a wartości pomiarowe odczytywano na kalibratorze z dokładnością do 0,1 mm. Pomiary prowadzono przy 20 zębach u każdego pacjenta (zęby sieczne, kły i zęby przedtrzonowe w szczęce i żuchwie), w dwóch punktach przy każdym zębie: GT1 – w połowie szerokości dziąsła zrogowaciałego, GT2 – 2 mm wierzchołkowo od połączenia śluzówkowo-dziąsłowego. Porównano wyniki uzyskane badaniem nieinwazyjnym (N) i inwazyjnym (I). Sprawdzono także dokładności pomiarowe między metodami inwazyjną i ultradźwiękową prowadzone w różnych zakresach metrycznych. Zakresy podzielono na: w1 ≤ 0,500 mm, w2 0,501–0,750 mm, w3 0,751–1.000 mm, w3 1.001–1.250 mm, w4 > 1.251 mm.
Wyniki. Średnia wartość dla wszystkich pomiarów metodą N wyniosła 0,784, a metodą I 0,828. Różnica wynosiła 0,044 i była istotna statystycznie. Dla wszystkich zębów wartości średnie GT1 i GT2 były większe w metodzie inwazyjnej. W punktach GT1 tylko przy zębie 32 i w punktach GT2 przy zębach 11, 21, 22, 31, 32 różnic istotnych statystycznie między badaniem N i I nie stwierdzono, a przy pozostałych zębach różnice były znamienne. W punktach GT1 i GT2 największe różnice między średnimi wartościami grubości tkanek miękkich przyzębia występowały w zakresie najmniejszych wartości w1 ≤ 0,500 mm.
Wnioski. Wyniki pomiaru grubości tkanek miękkich przyzębia metodą ultradźwiękową i inwazyjną – *bone sounding* są do siebie zbliżone, ale różnice między wartościami w większości miejsc pomiarowych są znamienne statystycznie. Biorąc pod uwagę niedoskonałości badania inwazyjnego wydaje się, że metodą dokładniejszą, szczególnie w przypadku cienkiego dziąsła, jest metoda ultrasonograficzna (**Dent. Med. Probl. 2011, 48, 4, 481–489**).

Słowa kluczowe: grubość dziąsła, metoda ultradźwiękowa, metoda inwazyjna, pomiar.

Practicing in various fields of dentistry requires an assessment of periodontal thickness with respect to anatomic and physiologic issues. It is particularly important to determine a dental plaque index, gingival index and parameter values indicating the location of a connective tissue attachment, gingival margin, mucogingival border relative to a cementoenamel junction and sounding depth in every dentogingival unit [1]. The assessment of thickness of the keratinized gingiva and movable mucosa on the jaw bones and the mucosa of the hard palate are becoming nowadays a standard practice [2].

Measured gingival thickness on the site of a planned surgical procedure with the necessity of making a flap allow to choose a method of shaping the flap with a full or partial thickness.

When covering dental recessions, while gingival thickness is under 0.7 mm, surgical procedures only with moving the flap should not be performed – free connective tissue grafts should be used instead [3]. When using barrier membranes, the tissues of keratinized gingiva have to be augmented at first, and then they should be utilized in the next stage of directed regeneration of periodontal tissues or they should be swapped for enamel matrix proteins. While planning an implantation procedure at a site with the thin mucosa, with its thickness measured earlier, the procedure has to be broaden with an implantation of a submucosal connective tissue [4]. Similarly, if thickness of the mucosa covering a toothless segment of an alveolar process is greater than biological width, that is determined for the patient, the subsequent augmentation of soft tissues can not be planned, and augmentation of a bone tissue should be planned instead. To increase predictability and efficacy of utilization of a potential donor site for connective tissue grafts, that are located on the mucosa of the hard palate, detailed assessment is needed. Knowledge of gingival thickness near teeth, that will support permanent prosthetic restorations, and in the first place near teeth that will be under the influence of orthodontic forces, allows to plan measures to avoid occurrence of periodontal recession, with the presence of a thin biotype [5].

Determination of soft tissues thickness in the periodontium with observational techniques, based on the comparison of a width to length proportion of medial crowns in incisive teeth in the jaw, measurements of a keratinized gingiva width and interdental papilla height, provide only the initial diagnosis [6, 7]. Similarly, visual assessment of gingival thickness during probing of gingival grooves with periodontal probe, based on tissues transparency, does not give a reliable result. Kan et al. [8] classified the biotype as thin, when a periodontometer was visible during probing of gingival grooves, or when gingival thickness above the alveolus after a tooth extraction was ≤ 1 mm. Biotype was classified as thick, when a periodontometer was not visible during probing of gingival grooves, or when gingival thickness above the alveolus after a tooth extraction was > 1 mm. Admittedly, there were no statistically significant differences in comparison of these two methods, conducted by Kan et al. [8], but the assessment was only to assign the results to a thin or thick biotype. Therefore measurements of periodontal soft tissues thickness are necessary. Such measurements can be made with invasive, minimally invasive or non-invasive techniques. The first one [9] includes soft tissue punctures with

an endodontic tool (bone sounding). The X-ray tomographic examination is minimally invasive [10, 11], and ultrasonic measurement of mucosal thickness is considered as a practically non-invasive method [12]. It is not a novel method [12, 13], but measurements of gingival thickness obtained with ultrasonic devices were till now very inaccurate in comparison with invasive methods, including an intraprocedural method of direct assessment of gingival thickness [14]. Difficulties in ultrasonic determination of mucosal thickness of the hard palate were reported [15, 16]. However, the unquestionable advantage of the ultrasonic method is its atraumatic performing, without the need of local anesthesia. In the previous paper [17] the authors introduced the Pirop® Ultrasonic Biometer intended for conducting measurements of soft tissues thickness covering bones of jaws in the oral cavity, and they also presented its potential usage.

The aim of this study is to compare the accuracy of an ultrasonic measurement with a bone sounding method, regarded as a gold standard in an assessment of periodontal soft tissue thickness.

Material and Methods

The study was conducted according to rules of medical ethics and the Declaration of Helsinki, in volunteers that were informed about the aim of the experiment, and they consented to it. The examinations were carried out by two dentists in MEDIDENT Specialist Outpatient Clinic in Gorlice in Poland. Conceptual supervision of the examinations was performed by the dentist with a 25-year professional experience.

Thirty healthy patients (21 females and 9 males) aged 19–51 were enrolled into the study. Clinical examination revealed the healthy periodontium in the assessed area, i.e. in the range of 15 to 25 teeth in the upper jaw and 35 to 45 in the mandible. The exclusion criteria included: 1) past surgical procedure in the examined region, 2) regnancy or breastfeeding, 3) drug therapy that might have influence on gingival thickness e.g. ciclosporin A, phenytoin derivates, etc., 4) cigarette smoking, 5) the usage of removable dentures and orthodontic apparatuses.

Invasive and ultrasonic examinations were conducted in all patients in the period of 10 minutes. According to guidelines proposed by da Silva et al. [9], for the sake of comparison of the both diagnostic methods' results, 2 measurement points of gingival thickness (GT) were marked on the each dentogingival unit. The first one (GT1) was located in the middle of the keratinized gingiva width, and the second one (GT2) 2 mm below the mucogingival junction. After application of infiltration anesthesia and 20-minute waiting period, the measurements were carried out, by puncturing tissues with an endodontic tool with a silicone limiter (Fig. 1). The tool was positioned perpendicularly to the bone that laid under, and was placed in the tissue on the depth of the bone, after that the limiter was placed on the surface of mucosa, thus obtaining the thickness measurement. Then the value of the measurement was read on the calibrator – a thickness meter intended for prosthetic crowns – under × 2.5 optical magnification (Fig. 2). The accuracy of the measurement reached 0.1 mm. At the same points, subsequent ultrasonic measurements were made using Pirop® Ultrasonic Biometer (Fig. 3). It is the instrument with the A-scan probe with 20 MHz frequency, with 1540 m/s ultrasonic impulse velocity, intended to measure gingival thickness, in the range 0.25 to 6 mm, and accuracy up to 0.01 mm. The round

Fig. 1. The invasive examination in GT1 and GT2 points marked on the mucosa with a marker pen

Ryc. 1. Badanie inwazyjne w oznaczonych markerem na błonie śluzowej punktach GT1 i GT2

Fig. 2. Readout of the GT value with a caliper, obtained with the invasive method

Ryc. 2. Odczyt z użyciem kalibromierza wartości GT uzyskanej metodą inwazyjną

Fig. 3. The ultrasonic examination in GT1 and GT2 points marked on the mucosa with a marker pen

Ryc. 3. Badanie ultradźwiękowe w oznaczonych markerem na błonie śluzowej punktach GT1 i GT2

front of the tapered head has 1.7 mm in diameter. In order to examine gingival thickness, chlorhexidine gel was applied on the head of the probe that was applied to an external surface of the mucosa, without pressuring soft tissues, perpendicularly in relation to an underlying bone or tooth. The instrument was sending 10 ultrasonic pulse-waves when powered on, which was returning to the instrument after their reflection from hard tissues. The distance traveled by an ultrasonic pulse-wave was automatically converted to gingival thickness, and a mean measurement result with a standard deviation was calculated from 10 measurements (Fig. 4). The measurement was repeated, if the standard deviation of the mean value from 10 automatic measurements exceeded 0.05 mm.

The obtained data were subject of a statistical analysis. For all of the measurements average values and standard deviations were calculated. Additionally, for the measurements conducted near analogous teeth in the upper jaw and the mandible on the left and the right side, e.g. 11/21, 35/45 etc. a variance analysis was carried out. A hypothesis was made, that the values of measurement of the mucosal thickness in GT1, GT2 and GT1+GT2 points will be the same for an invasive and ultrasonic method. Additionally, the authors also compared measurement accuracy between the invasive and ultrasonic method, conducted in various metric ranges. The ranges were divided to: w1 ≤ 0.500 mm, w2 0.501–0.750 mm, w3 0.751–1.000 mm, w3 1.001–1.250 mm, w4 > 1.251 mm.

T-student test for dependent measures was used to verify the hypothesis, and a significance level had the value of $p \leq 0.05$.

Results

In the comparative analysis of measurement values of the non-invasive (N) and invasive (I) method in GT1, GT2 points and the comparison of GT1+GT2 mean values, the authors found that mean values were higher in the invasive method for each tooth. The differences between the invasive and non-invasive method were statistically significant in all instances for both GT1+GT2 and GT2 points, except the tooth 32. However, the measurement values of both presented methods in soft tissues thickness in the periodontium in GT1 points were statistically significant for teeth 15, 14, 13, 24, 25, 45, 43, 42, 41, 33, 35, differences were borderline for teeth 12, 23, 44, 34, and for teeth 11, 21, 22, 31, 32 there were no differences.

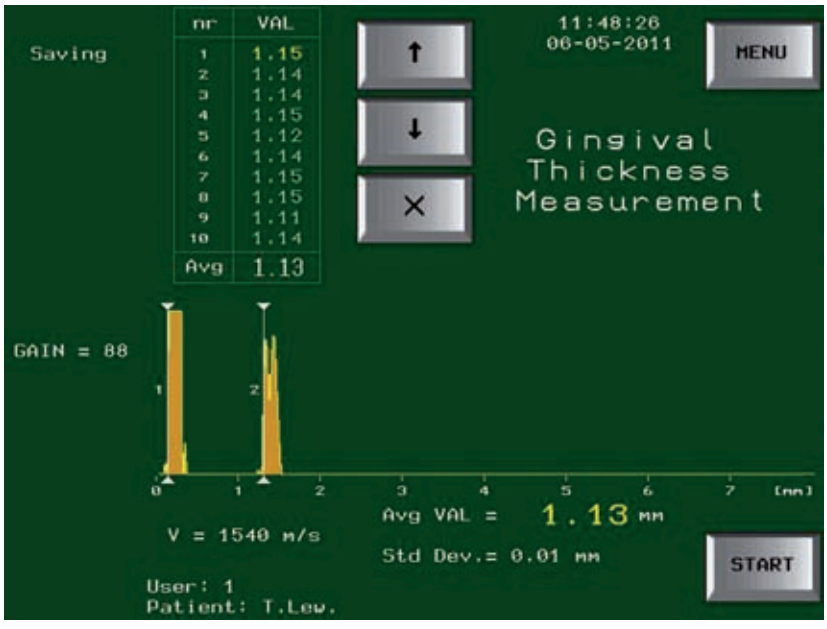

Fig. 4. The diagram with ultrasonic measurement results, that is displayed on a monitor screen, a mean value of thickness and a standard deviation

Ryc. 4. Wykres z rezultatami pomiarów USG powstający na ekranie monitora, średnia wartość grubości dziąsła i odchylenie standardowe

The mean value of all measurements with the N method was 0.784 (1200 measurements), and with the I method was 0.828. The difference was 0.044. In the Table 1 there are mean values with the standard deviations for measurements of soft tissues thickness in the periodontium made for GT1 and GT2 points, near individual teeth with the non-invasive and invasive method, and this is illustrated on Figure 5.

The analysis of variance did not show differences between the measurement values of gingival thickness for analogous teeth in dentition quadrants 1, 2 and 3, 4. In the analysis of the mean values of measurements in individual subgroups of the measurement value range (w1, w2, w3, w4, w5) the authors found that the higher values measured in the GT1 points occurred for the invasive method in w1, w2, w3 and w4 subgroups. In these subgroups the differences were statistically significant (p values can be found in the I column). In the w5 subgroup, the mean values have no statistically significant differences (slightly higher mean value occurred in the invasive method). The difference among the mean values in the w1 subgroup was 0.062 mm, w2 – 0.038 mm, w3 – 0.043 mm, w4 – 0.021 mm, and in the w5 – 0.005 mm. For narrower measurement ranges there was a higher difference among the measurements. Similarly, the values measured with the invasive method in GT2 points were statistically significant in the w1, w2 and w3 subgroups, but in the w4 and w5 they were lower, without the statistically significant difference. In GT2 points there were also higher differences among the mean values of gingival thickness for the lowest value range in the w1 subgroup. This is presented in the Table 2 and Table 3 and also in Figure 6 and 7.

Discussion

The comparative analysis, performed for the invasive and ultrasonic examination of soft tissues thickness in the periodontium, showed indeed

Table 1. Mean values of gingival thickness measurements (GT1, GT2, GT1+2) for individual teeth obtained with the non-invasive (N) and invasive (I) method

Tabela 1. Średnie wartości pomiarów grubości dziąsła (GT1, GT2, GT1+2) dla poszczególnych zębów badane metodą nieinwazyjną (N) i inwazyjną (I)

Tooth (Ząb)	GT1			GT2			GT1+2		
	N (mm)	p	I (mm)	N (mm)	p	I (mm)	N (mm)	p	I (mm)
15	0.91 (±0.28)	0.017	0.95 (±0.26)	0.70 (±0.23)	0.001	0.76 (±0.20)	0.80 (±0.28)	0.000	0.85 (±0.25)
14	0.90 (±0.30)	0.027	0.95 (±0.33)	0.64 (±0.23)	0.002	0.70 (±0.21)	0.77 (±0.30)	0.000	0.83 (±0.30)
13	0.94 (±0.27)	0.019	0.98 (±0.28)	0.64 (±0.29)	0.001	0.70 (±0.27)	0.79 (±0.32)	0.000	0.84 (±0.30)
12	1.04 (±0.29)	0.094	1.07 (±0.29)	0.70 (±0.26)	0.009	0.75 (±0.21)	0.87 (±0.32)	0.002	0.91 (±0.30)
11	1.16 (±0.33)	0.622	1.17 (±0.30)	0.66 (±0.21)	0.001	0.72 (±0.20)	0.91 (±0.37)	0.008	0.94 (±0.34)
21	1.09 (±0.29)	0.138	1.12 (±0.27)	0.64 (±0.23)	0.005	0.69 (±0.22)	0.87 (±0.35)	0.002	0.91 (±0.33)
22	1.10 (±0.24)	0.426	1.11 (±0.22)	0.67 (±0.26)	0.000	0.73 (±0.24)	0.89 (±0.33)	0.001	0.92 (±0.30)
23	0.91 (±0.30)	0.057	0.94 (±0.26)	0.60 (±0.20)	0.000	0.65 (±0.17)	0.76 (±0.30)	0.000	0.80 (±0.26)
24	0.91 (±0.30)	0.027	0.95 (±0.29)	0.62 (±0.20)	0.000	0.67 (±0.19)	0.77 (±0.29)	0.000	0.81 (±0.28)
25	0.91 (±0.28)	0.000	0.98 (±0.28)	0.78 (±0.29)	0.000	0.83 (±0.28)	0.85 (±0.29)	0.000	0.91 (±0.29)
45	0.95 (±0.27)	0.000	1.01 (±0.25)	0.68 (±0.17)	0.000	0.74 (±0.17)	0.81 (±0.26)	0.000	0.87 (±0.25)
44	0.88 (±0.19)	0.086	0.90 (±0.18)	0.62 (±0.19)	0.000	0.69 (±0.17)	0.75 (±0.23)	0.000	0.79 (±0.21)
43	0.85 (±0.24)	0.041	0.88 (±0.25)	0.57 (±0.21)	0.001	0.64 (±0.19)	0.71 (±0.27)	0.000	0.76 (±0.25)
42	0.84 (±0.32)	0.009	0.87 (±0.31)	0.69 (±0.30)	0.020	0.74 (±0.25)	0.77 (±0.31)	0.001	0.81 (±0.28)
41	0.80 (±0.30)	0.006	0.84 (±0.27)	0.63 (±0.22)	0.002	0.68 (±0.23)	0.72 (±0.27)	0.000	0.76 (±0.26)
31	0.81 (±0.29)	0.182	0.83 (±0.28)	0.60 (±0.19)	0.004	0.66 (±0.18)	0.71 (±0.26)	0.002	0.74 (±0.25)
32	0.86 (±0.35)	0.887	0.86 (±0.32)	0.69 (±0.31)	0.904	0.69 (±0.27)	0.77 (±0.34)	0.855	0.78 (±0.31)
33	0.86 (±0.26)	0.001	0.91 (±0.26)	0.53 (±0.26)	0.000	0.61 (±0.23)	0.69 (±0.31)	0.000	0.76 (±0.28)
34	0.88 (±0.22)	0.086	0.90 (±0.22)	0.60 (±0.23)	0.000	0.66 (±0.19)	0.74 (±0.27)	0.000	0.78 (±0.24)
35	0.87 (±0.25)	0.002	0.91 (±0.24)	0.63 (±0.21)	0.000	0.69 (±0.19)	0.75 (±0.26)	0.000	0.80 (±0.24)

N – non-invasive method, I – invasive method, p – level of statistical significance ($p \leq 0.05$).
N – metoda nieinwazyjna, I – metoda inwazyjna, p – poziom istotności statystycznej ($p \leq 0{,}05$).

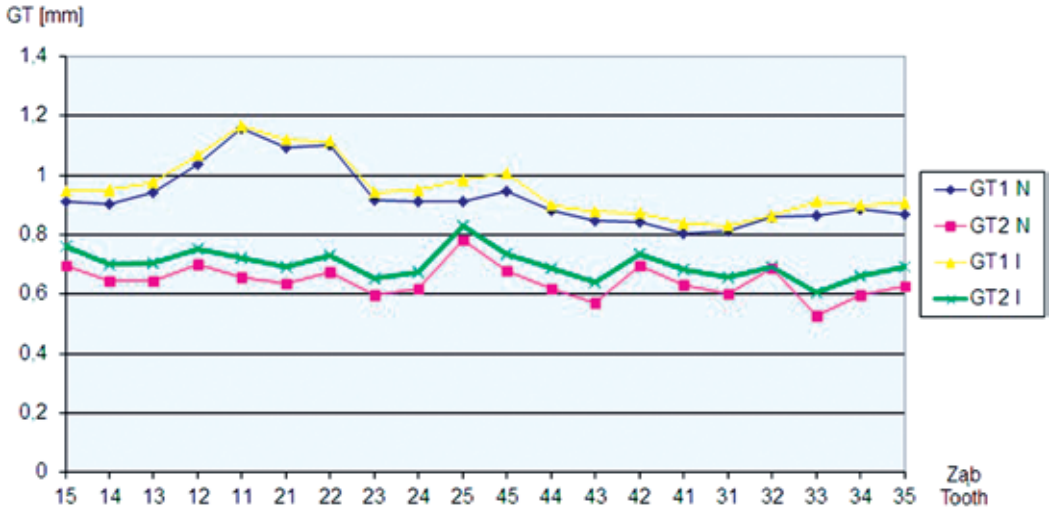

Fig. 5. Mean values of gingival thickness measurements (GT1, GT2) for individual teeth obtained with the non-invasive (N) and invasive (I) method

Ryc. 5. Średnie wartości pomiarów grubości dziąsła (GT1, GT2) dla poszczególnych zębów badane metodą nieinwazyjną (N) i inwazyjną (I)

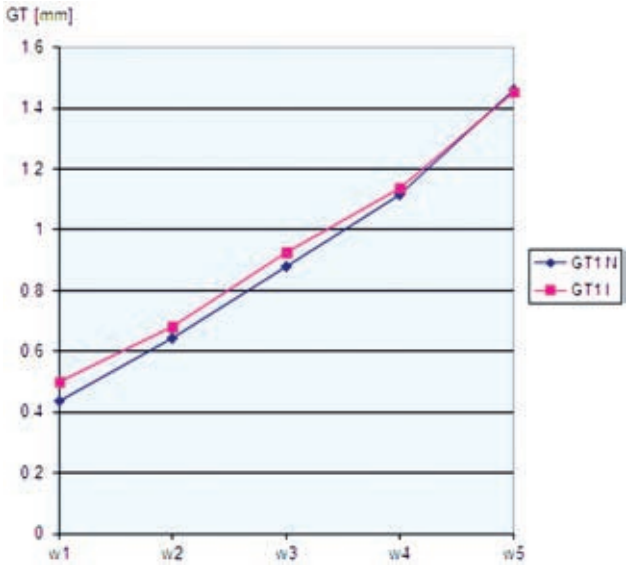

Fig. 6. Mean values of gingival thickness measurements (GT1) for fixed measurement ranges obtained with the non-invasive (N) and invasive (I) method

Ryc. 6. Średnie wartości pomiarów grubości dziąsła (GT1) dla określonych zakresów pomiarowych (w1, w2, w3, w4, w5) badane metodą nieinwazyjną (N) i inwazyjną (I)

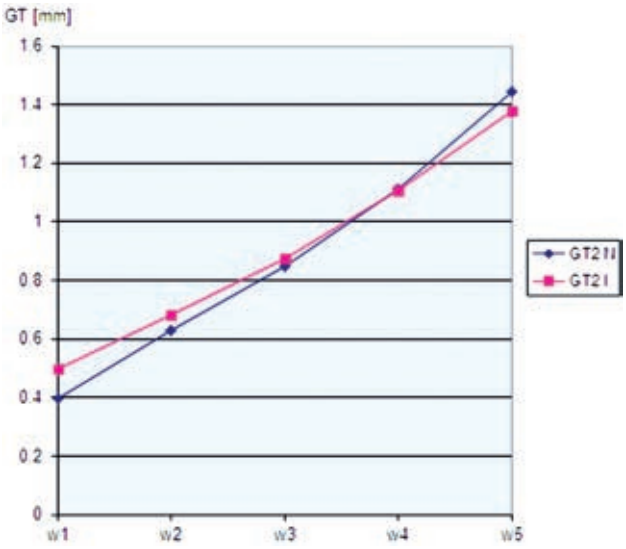

Fig. 7. Mean values of gingival thickness measurements (GT2) for fixed measurement ranges obtained with the non-invasive (N) and invasive (I) method

Ryc. 7. Średnie wartości pomiarów grubości dziąsła (GT2) dla określonych zakresów pomiarowych badane metodą nieinwazyjną (N) i inwazyjną (I)

the statistically significant differences in most instances, but in authors' opinion such results do not discredit the non-invasive method at all. According to Figure 1 there is a significant conformity of results from both methods. The bone sounding method is considered the most accurate method of gingival thickness evaluation [14], but it has disadvantages. In the published paper that assessed this measurement method, a periodontometer calibrated to 1 mm was used as a probe [18, 19]. It allowed to round results with accuracy up to 0.5 mm. The determination of gingival thickness in the measurement range below 1 mm is very dubious. Savitha and Vandana [19] compared gingival thickness in 338 sites near midbuccal part of incisive and canine teeth in the jaw and mandible, measured with transgingival probing and with ultrasonic method in 32 subjects between 16–38 years of age. The UNC-15 periodontal probe, calibrated to 1 mm, were used in the invasive exami-

Table 2. Mean values of gingival thickness measurements (GT1) for fixed measurement ranges (w1, w2, w3, w4, w5) obtained with the non-invasive (N) and invasive (I) method

Tabela 2. Średnie wartości pomiarów grubości dziąsła (GT1) dla określonych zakresów pomiarowych (w1, w2, w3, w4, w5) badane metodą nieinwazyjną (N) i inwazyjną (I)

GT1			
Wave-band (Zakres)	N (mm)	p	I (mm)
W1	0.44 (±0.05)	0.000	0.50 (±0.05)
W2	0.64 (±0.08)	0.000	0.68 (±0.09)
W3	0.88 (±0.07)	0.000	0.92 (±0.09)
W4	1.11 (±0.06)	0.004	1.13 (±0.10)
W5	1.46 (±0.15)	0.647	1.45 (±0.14)

W1 < 0.5 mm; W2 0.5–0.750 mm; W3 0.751–1 mm; W4 1.001–1.25 mm; W5 > 1.25 mm.

N – non-invasive method, I – invasive method, p – level of statistical significance ($p \leq 0.05$).
N – metoda nieinwazyjna, I – metoda inwazyjna, p – poziom istotności statystycznej ($p \leq 0{,}05$).

Table 3. Mean values of gingival thickness measurements (GT2) for fixed measurement ranges (w1, w2, w3, w4, w5) obtained with the non-invasive (N) and invasive (I) method

Tabela 3. Średnie wartości pomiarów grubości dziąsła (GT2) dla określonych zakresów pomiarowych (w1, w2, w3, w4, w5) badane metodą nieinwazyjną (N) i inwazyjną (I)

GT2			
Wave-band (Zakres)	N (mm)	p	I (mm)
W1	0.40 (±0.07)	0.000	0.50 (±0.07)
W2	0.63 (±0.07)	0.000	0.68 (±0.10)
W3	0.85 (±0.07)	0.000	0.87 (±0.12)
W4	1.11 (±0.07)	0.690	1.11 (±0.13)
W5	1.45 (±0.15)	0.083	1.38 (±0.20)

W1 < 0.5 mm; W2 0.5–0.750 mm; W3 0.751–1 mm; W4 1.001–1.25 mm; W5 > 1.25 mm.
N – non-invasive method, I – invasive method, p – level of statistical significance ($p \leq 0.05$).

N – metoda nieinwazyjna, I – metoda inwazyjna, p – poziom istotności statystycznej ($p \leq 0{,}05$).

nation, and the A-scan 10 MHz ultrasonic instrument with the 13.5" × 7" probe in the non-invasive examination. The average thickness of a keratinized gingiva, measured with the invasive method, was 1.08 ± 0.42 (range 0.5 to 2.5 mm), and measured with the ultrasonic method was 0.86 ± 0.33 mm (range 0.4 to 1.6 mm). The authors indicated that all of the mean values of gingival thickness, determined with the ultrasonic method, were 0.22 mm smaller and statistically significant, and that is consistent with present findings.

According to the concept of da Silva et al. [9] an endodontic tool with a limiter is currently used for measurements, and a thickness gauge for prosthetic crowns as a caliper. This technique allows to assess gingival thickness with up to 0.1 mm accuracy. Although readout of measurement results are made in optical magnification, inaccuracies also have to be taken into account. There is a possibility of limiter displacement on the endodontic tool or its unintentional push with a tip of a caliper, imprecise application of a caliper between the needle tip and the limiter, visual readout of the result between caliper tips and on division at the other angle than 90 degrees. Inaccuracies occur also during the measurement itself. The most common error concerns directing the tip or needle of the endodontic tool not perpendicularly in relation to the underlying bone or tooth, or its bending because of excessive force application, no touch with the bone or tooth surface by the instrument tip, applying excessive pressure or the most often, moderate pressure with the limiter to the mucosa surface, lifting the limiter by rolling, movable mucosa on the GT2 measurement site. The authors think these are the main causes of the measurement values overestimation concerning soft tissues thickness in the periodontium, that are performed in the invasive fashion, especially in the range of the smallest distances. This is confirmed by the conducted analysis and results in the w1 subgroups (values ≤ 0.5 mm) between the I and N group. The mean value of the invasive examination results on the GT1 points was overestimated by 14.26%, and on the GT2 points by 25.12%. The difference in the w2 range (0.501–0.750 mm) was significantly smaller and was 5.99% on the GT1 points, and 8.54% on the GT2 points, with the mean overestimation of all invasive measurements 5.59%.

The ultrasonic examination is carried out with a contact method without local anesthesia. Underestimation of the measurement results can be avoided because patient reports pain while applying excessive pressure. The possibility of improper positioning of the instrument probe in relation to the underlying bone or teeth is also excluded. Results cannot be obtained with such positioning of the head. The measurement is impossible because sent ultrasonic pulse-wave do not return to the ul-

trasonic device. Similarly, the diameter of the Ultrasonic Biometer's head allows to a precise measurement at the site marked on the mucosa with a marker pen, and that was impossible with the other devices in this class, consisting of heads with the frontal surface two or three times bigger.

The mean values of gingival thickness measurements with the ultrasonic method at the labial/buccal side are similar to results from the other studies [16, 19]. The thinnest keratinized gingiva was found at the medial incisive teeth in the mandible: near teeth 41 – mean value was 0.80 ± 0.30 mm (range 0.40–1.55 mm), near teeth 31 – mean value was 0.81 ± 0.29 mm (range 0.30–1.29 mm). Gingival thickness measured at the GT2 point near these teeth was on average near teeth 41 – 0.63 ± 0.22 mm (range 0.25–1.15 mm), near teeth 31 – 0.60 ± 0.19 mm (range 0.29–1.13 mm). Müller et al. [16] have examined gingival thickness with an ultrasonic probe in 40 patients aged 19–30 and with normal periodontium, and demonstrated the thinnest gingiva on the buccal side has 0.65 ± 0.14 mm, and it was located also near the inferior incisive teeth. A horizontal diameter of the gingiva, near the canine and premolar teeth, has the value of 0.7–0.8 mm, and the thickest 2.3-milimeter gingiva was located near the wisdom teeth. They used the SDM instrument (Sonic Device Measurement) for measurements, with the A-scan head with 5 MHz frequency, an initial delay of 0.3 ± 0.2 ms and ultrasonic impulse velocity of 1514 m/s. The front of the head had 4 mm in diameter. When the authors were measuring thickness of the keratinized gingiva, they applied the head with its coronal margin aligned with a bottom of the gingival groove, about 1–2 mm below the marginal gingiva. The same authors have studied the mucosal thickness in another study, using the same instrument, but at the 3 measurement points near each examined tooth. On the first measurement point, the margin of the probe was located on the border of the free gingiva. On the second measurement point, the center of the probe was located on the mucogingival junction, and on the third measurement point, the upper margin of the head was located on the mucogingival junction. However, it seems that the measurement reproducibility is rather low with that size of the head, and the possibility of the comparison of obtained results with the bone sounding method could be simply unfeasible.

The results of measuring soft tissues thickness in the periodontium with the ultrasonic and invasive methods – bone sounding are very similar, but the differences among the values are statistically significant for most measurement points. The authors consider the ultrasonic method as more accurate than invasive method, especially in the lowest value range, taking into consideration the imperfection of the invasive examination. Also Müller et al. [20] shows that the most repeatable ultrasonic measurement was at certain tooth types with rather thin gingiva. Tsiolis et al. [21] were investigating ultrasonic scanner with a frequency 20 MHz in experimental soft tissue thickness measurement in pig jaws conclude that ultrasonography provides a highly accurate and repeatable technique for periodontal assessment.

In authors opinion the results presented in this paper should be considered as satisfactory and near to real values.

References

[1] Ronay V., Sahrmann P., Bindl A., Attin T., Schmidlin P.R..: Current status and perspectives of mucogingival soft tissue measurement methods. J. Esthet. Restor. Dent. 2011, 23, 146–156.
[2] Bednarz W., Pakuszyńska-Błaszczyk J.: Augmentacja cienkiej błony śluzowej podniebienia twardego w potencjalnych miejscach dawczych tkanki łącznej. Czas. Stomatol. 2008, 61, 8, 525–537.
[3] Hwang D., Wang H.L.: Flap thickness as a predictor of root coverage: a systematic review. J. Periodontol. 2006, 77, 1625–1634.
[4] Fagan M. C., Owens H., Smaha J., Kao R.T.: Simultaneous hard and soft tissue augmentation for implants in the esthetic zone: Report of 37 consecutive cases. J. Periodontol. 2008, 79, 1782–1788.
[5] Yared K.F.G., Zenobio E.G., Pacheco W.: Periodontal status of mandibular central incisors after orthodontic proclination in adults. Am. J. Orthodont. Dentofac. Orthop. 2006, 130, 6.e1–6.e8.
[6] Olsson M., Lindhe J.: Periodontal characteristics in individuals with varying form of the upper central incisors. J. Clin. Periodontol. 1991, 18, 78–82.
[7] De Rouck T., Eghbali R., Collys K., De Bruyn H., Cosyn J.: The gingival biotype revisited: transparency of the periodontal probe through the gingival margin as a method to discriminate thin from thick gingiva. J. Clin. Periodontol. 2009, 36, 428–433.
[8] Kan J.Y., Morimoto T., Rungcharassaeng K., Roe P., Smith D.H..: Gingival biotype assessment in the esthetic zone: visual versus direct measurement. Int. J. Periodontics Restorat. Dent. 2010, 30, 237–243.
[9] Da Silva S.C., Joly J.C., de Lima A.F.M., Tatakis D.N.: Root coverage using the coronally positioned flap with or without a subepithelial connective tissue graft. J. Periodontol. 2004, 75, 413–419.
[10] Fu J-H., Yeh Ch-Y., Chan H-L., Tatarakis N., Leong D.J.M., Wang H.-M.: Tissue biotype and its relation to the underlying bone morphology. J. Periodontol. 2010, 81, 569–574.

[11] Ueno D., Sato J., Igarashi C., Ikeda S., Morita M, Shimoda S., Udagawa T., Shiozaki K., Kobayashi M., Kobayashi K.: Accuracy of oral mucosal thickness measurements using spiral computed tomography. J. Periodontol. 2011, 82, 829–836.
[12] Terakura T.: Non-invasive thickness measurement of the oral soft tissue. J. Clin. Prosthodont. Soc. 986, 30, 1402–1411.
[13] Uchinda H, Kobayashi K, Nagao M.: Measurement *in vivo* of masticatory mucosal thickness with 20 MHz B-mode ultrasonic diagnostic equipment. J. Dent. Res. 1989, 68, 95–100.
[14] Schulze R K. W., Curić D., d'Hoedt B.: B-mode versus A-mode ultrasonographic measurements of mucosal thickness *in vivo*. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod. 2002, 93, 110–117.
[15] Müller H.P., Schaller N. Eger T.: Ultrasonic determination of thickness of masticatory mucosa: a methodologic study. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod. 1999, 88, 248–253.
[16] Müller H.P., Schaller N., Eger T., Heinecke A.: Thickness of masticatory mucosa. J. Clin. Periodontol. 2000, 27, 431–436.
[17] Bednarz W.: The thickness of periodontal soft tissue ultrasonic examination – current possibilities and perspectives. Dent. Med. Probl. 2011, 48, 3, 303–310.
[18] Vandana K.L., Savitha B.: Thickness of gingiva in association with age, gender and dental arch location. J. Clin. Periodontol. 2005, 32, 828–830.
[19] Savitha B., Vandana K.L.: Comparative assesment of gingival thickness using transgingival probing and ultrasonographic method. Indian J. Dent. Res. 2005, 16, 135.
[20] Müller H. P., Nusair K. M. B., Könönen E.: Repeatability of ultrasonic determination of gingival thickness. Clin. Oral. Invest. 2007, 11, 439–442.
[21] Tsiolis F.I., Needleman I.G., Griffiths G.: Periodontal ultrasonography. J. Clin. Periodontol. 2003, 30, 849–854.

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