Journal of
PERIODONTAL RESEARCH

J Periodont Res 2012; 47: 776–782

JOURNAL OF PERIODONTAL RESEARCH
doi:10.1111/j.1600-0765.2012.01495.x

Reliability of two measurement indices for gingival enlargement

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Miranda J, Brunet Ll, Roset P, Farré M, Mendieta C. Reliability of two measurement indices for gingival enlargement. J Periodont Res 2012; 47: 776–782.

Background and Objective: The objective of this study was to analyze the concordance of the vertical gingival overgrowth index (GOi) and the horizontal Miranda & Brunet index (MBi) and to compare their reliability and reproducibility for an early diagnosis of gingival enlargement. A wide range of methods has been employed to determine the severity of drug-induced gingival enlargement (DIGE) that has resulted in uncertainty with regard to the prevalence of this side effect. In recent studies, different indices have been used to grade DIGE. The large variability observed between studies and the differences between vertical and horizontal gingival-enlargement measurements could be the result of the use of nonreliable indices during the measurement process. Some indices involve invasive procedures that require many measurements, or even a data-processing system, while others are less convenient and technically expensive and complex. In previous studies we used two complementary indices – the vertical GOi and the horizontal MBi. The results of these studies found some differences between both indices, with the MBi rendering higher estimates of DIGE prevalence that was attributed to its greater sensitivity for the detection of minimal changes in gingival thickness. To our knowledge, there are no studies comparing different measurement indices for gingival enlargement that are supported by statistical concordance analysis.

Material and Methods: Twelve plaster casts from patients who had worn orthodontic brackets, and who had different degrees of chronic inflammatory gingival enlargement, were analyzed. Three previously trained examiners registered twice the degree of buccal overgrowth, using the GOi and MBi, in all cast models with a minimum interval of 7 d between the first and the second evaluation. In total, from each cast, measurements from 16 gingival sites were taken using the GOi, and from nine gingival units (mesial and distal sites measurements) using the MBi. Concordance analysis of the registered measurements (intra-examiner and among examiners) for each index and between indices was assessed using the nonweighted Kappa index with a confidence interval of 95%.

Results: We obtained 648 values for the GOi and the MBi. The overall score 0 (indicating absence of enlargement) was 32.7% and 19.8% for GOi and MBi, respectively, score 1 (light/moderate) was 39.7% and 48.1%, and score 2 (severe) was 27.6% and 32.1%. Concordance analysis for each index showed intra-examiner Kappa values of 0.820 for the GOi and 0.830 for the MBi. Interexaminer Kappa values were 0.720 for the GOi and 0.770 for the MBi. Concordance between indices showed Kappa values for the same examiner of 0.600, whereas

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Key words: gingival enlargement; gingival indices; screening; early diagnosis

Accepted for publication April 23, 2012

concordance among different examiners was 0.550. Discrepancies between indices indicated a systematic skew, with 79–82.1% of discrepancy associated with a higher value for the MBi compared with the GOi.

Conclusion: Both gingival enlargement indices analyzed are reliable, complementary and applicable for measuring gingival overgrowth. However, the MBi shows, with fewer measurements, a greater sensitivity than the GOi for the detection of the early stages of gingival enlargement, being adequate for the screening of large populations at risk.

Gingival enlargement or gingival overgrowth has been associated with inflammatory, pharmacological and neoplastic factors. Chronic inflammation, secondary to dental plaque accumulation, is the most common cause of gingival overgrowth. Drug-induced gingival enlargement (DIGE) is an adverse reaction associated with the use of phenytoin, cyclosporine A and calcium-channel blockers such as dihidropiridine, verapamil and diltiazem (1,2).

Evaluation of gingival enlargement needs reliable and reproducible indices. An ideal index should have clearly defined and simple criteria, with minimal measurements, to make the detection of early cases easy and should be suitable for the mass screening of populations at risk.

Kimball (in 1939) and Harris & Ewalt (in 1942) were the first authors to describe an index for evaluation of gingival enlargement (3,4). In 1972, Angelopoulos & Goaz described an index to measure vertical enlargement, and this index divided the clinical crown in three-thirds (5). For many years, the literature reported only on the vertical component of gingival overgrowth (6,7). In 1985, Seymour and colleagues described a gingival overgrowth index (GOi), based on a study on plaster casts, that included the registration of horizontal and vertical overgrowth, the overgrowth score being the sum of both (8). This index allows a three-dimensional (3D) diagnosis and has been used by different authors (9–11). In 1992, Miller & Damm modified the original index of Angelopoulos & Goaz to enable the simultaneous measurement of vertical and horizontal overgrowth (12). In 1987, Barak *et al.* (13) reported the histopathologic findings in gingival biopsies of 34 cardiac patients treated with nifedipine. The most relevant feature was the tubular elongation of the rete pegs, consisting of a few layers of basal cells growing almost vertically into the lamina propria. The results were classified according to four grades of hyperplasia based on the length of the rete pegs (the width of epithelium). Only five patients showed clinical signs of gingival enlargement and they all fell histologically into the Grade 4 group (epithelium width ranging from 3.0 to 4.0 mm). Interestingly, of the 29 patients without clinical gingival hyperplasia, 11 biopsies showed Grade 3 hyperplasia (epithelium width ranging from 1.5 to 3.0 mm), stressing the need for a sensitive index to detect early cases of gingival enlargement. Inglés *et al.* (14) introduced a clinical index based on the Seymour index as guidance for the most appropriate time for surgical treatment of DIGE.

King *et al.* (15) stated that the clinical criteria to determine gingival enlargement were not universally well defined and were unsuitable for evaluating the prevalence reports from different studies. Moreover, many authors have published cases of gingival enlargement without using any index to quantify the overgrowth (16,17), while others have based their results on semiquantitative studies, which add a subjective value to the measurements (7,18).

A variety of methods have been employed to determine the severity of gingival enlargement, and this has resulted in uncertainty with regard to the prevalence of this side effect. Ellis *et al.* (19) reported that the photographic scoring of gingival overgrowth provided an objective, easy-to-use method for appraising gingival overgrowth severity. This method requires no specialized skills other than familiarity with the photographic equipment. The procedure is noninvasive and can be scored blinded. The technique is thus appropriate for large-scale population studies to determine the severity and prevalence of gingival enlargement in patients who are at risk from this unwanted effect. In addition, where more repeatable scoring on a small scale is required, the study method should be considered as the optimum technique of choice. Rosin *et al.* (20) quantified gingival edema using a new 3D laser. This scanning method investigated the suitability of measuring volume differences to monitor changes in the inflammatory status of the gingival tissues. Thomason *et al.* (21) described an elaborate method that allows 3D analysis of the changes in the contour and volume of the gingiva using a laser scanner and a data-processing system. These techniques should be ideal for assessing longitudinal changes in gingival contour, as seen in the progress of gingival overgrowth, its recurrence after surgery or changes in volume induced by surgery.

Although some authors have developed sophisticated methods to measure gingival enlargement, in our opinion there is no clinical gold standard index. In clinical practice, gingival enlargement is determined while examining gingival morphology. An index for mass population screening should be inexpensive, noninvasive and technically easy to reproduce.

In previous clinical studies we used two complementary indices to determine the prevalence of DIGE: the vertical GOi and the horizontal Miranda & Brunet index (MBi) (22–24). The GOi, originally described by Angelopoulos & Goaz and later modified by Miller & Damm, measures the height of the gingival tissue in the apex–crown direction from the cemento–enamel junction to the free gingival margin. The MBi, also named the nodullary-papilla index, measures horizontal enlargement of the papilla from the enamel surface at the interdental point of contact to the most external enlarged buccal papillary sur-

face. The results of these studies evidenced some differences between both indices, with the MBi rendering higher estimates of DIGE prevalence, which was attributed to its greater sensitivity to detect minimal changes in gingival thickness (Fig. 1).

Establishing as a predictive hypothesis that the MBi is an accurate method for the early diagnosis of gingival enlargement, the objective of this study was to analyze the concordance of both indices (GOi and MBi) and compare their reliability and reproducibility.

Material and methods

Twelve plaster casts (maxillary/mandibular) from patients who had worn orthodontic brackets, and who had been diagnosed with chronic inflammatory gingival enlargement associated with the accumulation of bacterial plaque, were analyzed.

Upon completion of the orthodontic treatments, and immediately after removing the orthodontic appliances, impressions of the dental arches were taken and study models were prepared. All showed different degrees of gingival enlargement in various buccal locations, which were measured using a standard periodontal probe (Michigan 8/11, Hu-Friedy, Chicago, IL, USA).

To determine the degree of severity of overgrowth, measurements were made with the GOi and the MBi, used by the same authors in previous studies. Three previously trained examiners (J.M., Ll.B. and E.L.) registered both indices twice in all models with a minimum interval of 7 d between the first and the second evaluations. Eight anterior teeth in each arch (including the first premolars) from each plaster-cast model were evaluated and the gingival enlargement was graded and registered.

The GOi measures the overgrowth/height of the gingival tissue vertically in the apex–crown direction from the cemento–enamel line to the free gingival margin (5,12). The index grades, using a periodontal probe, the height of the enlarged gingiva covering the clinical crown and the nonvisible crown surface at six points around each tooth according to the following criteria: 0, normal gingiva; 1, slight, <2 mm increase and gingiva covered the cervical 1/3 or less of the anatomic crown; 2, moderate, 2–4 mm increase and/or gingiva extended into the middle third of the clinical crown; and 3, severe, >4 mm and/or gingiva covered more than 2/3 of the clinical crown (Fig. 2). The MBi measures the enlargement/thickness of the horizontal nodullary papilla at the level of the interproximal gaps, from the enamel surface at the interdental contact point to the outer papillary surface (22–24). Thickness was measured (in millimeters) using the periodontal probe and two scores were obtained – one for the buccal papilla and another for the lingual/palatal papilla – according to the following criteria: 0, papilla thickness $<$ 1 mm; 1, papilla thickness 1–2 mm; and 2, papilla thickness $>$ 2 mm (4). (Fig. 3). In this study we measured the degree of gingival enlargement in the cast models using both indices and only in the buccal surfaces. In total, from each cast, measurements from 16 gingival sites were taken with the GOi, and from nine gingival units (mesial and distal sites measurements) with the MBi.

To analyze the concordance of gingival enlargement between the two indices, gingival overgrowth scores were reduced to three levels, collapsing in one category the scores of gingival overgrowth = 2 (254/1152, 22%) and gingival overgrowth = 3 (31/1152, 2.7%). Moreover, the measurements of the GOi for each papilla (interproximal measurements from two adjacent teeth) were combined into one single score, and in the event of discordance the highest score was chosen (111/504, 22%).

Statistical analysis

The measurements from 12 different cast models, measured in duplicate by three examiners, were compared (n = 648). Concordance of the measurements was assessed using the nonweighted Kappa index with a 95% confidence interval (95% CI) using the PEPI program (Programs for Epidemiologists, Brixton Health, Wales, UK) Version 3.01 (25,26).

Conventional interpretation of the strength of agreement for Kappa values was adopted ($<$ 0.00 = poor concordance; 0.00–0.20 = slight concordance; 0.21–0.40 = fair concordance; 0.41–0.60 = moderate concordance; 0.61–0.80 = substantial concordance; and 0.81–1.00 = almost perfect concordance). Negative results were interpreted as 0.00 (27,28).

Concordance analysis was performed in steps in order to determine each of the sources of variability: index used, examiner and papilla were taken as systematic or fixed terms, whereas repetition and casts were random factors, as in the analysis of variance (27).

The following comparisons were analyzed.

- Intra-examiner concordance (IE) for each index, which corresponds to the repeatability of measurement of each index and demonstrates its reproducibility.

Fig. 1. Incipient gingival enlargement.

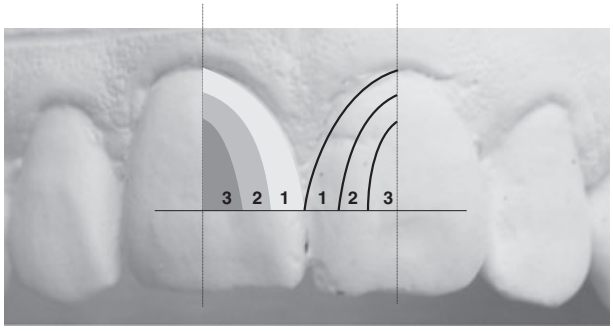

Fig. 2. Vertical gingival overgrowth index.

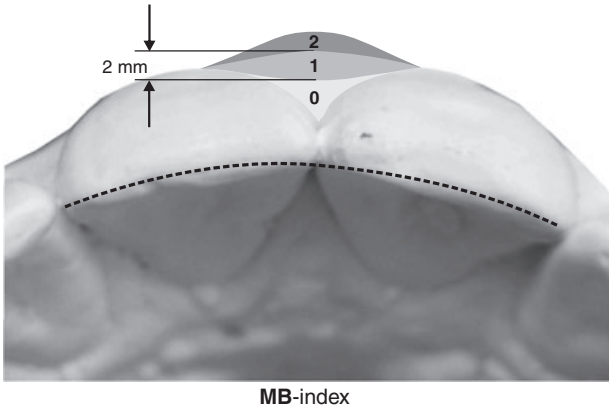

Fig. 3. Horizontal Miranda & Brunet index.

- Concordance among examiners (AE) for each index, which corresponds to the agreement of measurement among observers of each index and shows its consistency.
- IE between indices, which corresponds to the agreement of measurement between GOi and MBi when used by the same investigator and shows their intrinsic coincidence (true concordance).
- AE between indices, which corresponds to the global agreement of measurements between GOi and MBi when used by different investigators and would reflect their reliability in a clinical practice setting.

Finally, a descriptive analysis of the distribution of noncoincident scores was carried out to explore the compared performance of GOi and MBi.

Results

Overall, MBi overgrowth scores were higher than GOi scores, and the presence of gingival enlargement was more pronounced in the incisors area (Table 1).

Intra-index concordance

Global Kappa values for the intra-index concordance assessment, at IE level, were 0.820 and 0.830 for the GOi and the MBi, respectively, which shows almost perfect reproducibility for both. The IE Kappa values at each papilla ranged from 0.64 to 0.94 for the GOi and from 0.72 to 0.88 for the MBi, and were distributed without any particular pattern (Table 2).

The global Kappa values for AE were slightly lower – 0.720 and 0.770 – for the GOi and MBi, respectively, and indicated substantial consistency of each index when used by different observers. Again, the individual papillary values were tightly distributed around the global estimator and were randomly distributed among the different papilla.

Inter-index concordance

The global Kappa value for the inter-index concordance assessment at IE level was 0.600 (range, 0.43–0.75), which indicates a moderate concordance between both indices, and at the AE level was 0.550 (range, 0.28–0.70), denoting moderate reliability (Table 3).

Analysis of the discrepancies between both indices showed a systematic skew between the scores, given that

Table 1. Global distribution of scores for both gingival enlargement indices

	Papilla									
Index	5–4	4–3	3–2	2–1	1–1	1–2	2–3	3–4	4–5	Total
GOi score										
GOi = 0	44 (61.1)	29 (40.3)	16 (22.2)	10 (13.9)	13 (18.1)	12 (16.7)	13 (18.1)	27 (37.5)	48 (66.7)	212 (32.7)
GOi = 1	19 (26.4)	20 (27.8)	34 (47.2)	39 (54.2)	36 (50)	40 (55.6)	35 (48.6)	16 (22.2)	18 (25)	257 (39.7)
GOi = 2 + 3	9 (12.5)	23 (31.9)	22 (30.6)	23 (31.9)	23 (31.9)	20 (27.8)	24 (33.3)	29 (40.3)	6 (8.3)	179 (27.6)
MBi score										
MBi = 0	38 (52.8)	21 (29.2)	3 (4.2)	0 (0)	0 (0)	0 (0)	3 (4.2)	18 (25)	45 (62.5)	128 (19.8)
MBi = 1	20 (27.8)	17 (23.6)	48 (66.7)	39 (54.2)	52 (72.2)	51 (70.8)	49 (68.1)	20 (27.8)	16 (22.2)	312 (48.1)
MBi = 2	14 (19.4)	34 (47.2)	21 (29.2)	33 (45.8)	20 (27.8)	21 (29.2)	20 (27.8)	34 (47.2)	11 (15.3)	208 (32.1)

Values are given as *n* (%).
GOi, gingival overgrowth index; MBi, Miranda & Brunet index.

Table 2. Concordance values for gingival enlargement measures using either the gingival overgrowth index (GOi) or the Miranda & Brunet index (MBi)

	Papilla									
	5–4	4–3	3–2	2–1	1–1	1–2	2–3	3–4	4–5	Total
Intra-examiner concordance										
GOi (global)										
Kappa	0.850	0.840	0.640	0.860	0.944	0.910	0.750	0.660	0.770	0.820
(95% CI)	(0.68–1.00)	(0.65–1.00)	(0.43–0.86)	(0.71–1.00)	(0.79–1.00)	(0.78–1.00)	(0.57–0.93)	(0.49–0.83)	(0.56–0.98)	(0.76–0.87)
MBi (global)										
Kappa	0.810	0.780	0.780	0.830	0.720	0.830	0.820	0.820	0.790	0.830
(95% CI)	(0.65–0.98)	(0.62–0.95)	(0.60–0.97)	(0.66–1.00)	(0.49–0.96)	(0.69–0.97)	(0.62–1.00)	(0.67–0.97)	(0.62–0.97)	(0.78–0.89)
Concordance amongst examiners										
GOi (global)										
Kappa	0.770	0.620	0.570	0.740	0.780	0.810	0.640	0.620	0.710	0.720
(95% CI)	(0.68–0.86)	(0.52–0.73)	(0.45–0.68)	(0.65–0.84)	(0.69–0.87)	(0.73–0.90)	(0.55–0.74)	(0.52–0.72)	(0.60–0.83)	(0.69–0.75)
MBi (global)										
Kappa	0.710	0.670	0.600	0.920	0.830	0.810	0.790	0.590	0.730	0.770
(95% CI)	(0.61–0.81)	(0.58–0.77)	(0.48–0.72)	(0.85–0.98)	(0.72–0.93)	(0.71–0.91)	(0.69–0.89)	(0.50–0.69)	(0.63–0.83)	(0.74–0.80)

Intra-index concordance [Kappa (95% CI)].

approximately 79–82.1% of the discrepancies consisted of a higher value for the MBi than for the GOi (Table 4).

Discussion

Gingival enlargement is a gingival dimorphism associated with multiple factors. It is characterized by evident growth of the gingiva vertically towards the incisal edge of the clinical crown and horizontally towards the buccal-lingual area, and is more prevalent in the buccal surfaces of the anterior teeth. In the initial stages, gingival enlargement appears as a localized nodullary enlargement of the interdental papilla (horizontal growth) and with further progression extends to the dental crown (vertical growth). In severe cases, this overall volume increase may cover a large portion of the clinical crown. Csiszar *et al.* (29) found differences in the molecular composition of different parts of the gingiva. The molecular composition of the interdental papilla is distinct from that of the marginal gingiva, suggesting that the cells in the interdental papilla are in an activated state and/or inherently display a specific phenotype resembling wound healing. This finding could explain the increased susceptibility of the interdental papilla to nodullary enlargement compared with other parts of the gingiva, in the initial stages of gingival overgrowth.

An ever-increasing number of patients are using medications that induce gingival overgrowth. There has been a tremendous increase in the number of organ transplants, each requiring treatment with immunosuppressive drugs such as cyclosporine A, tacrolimus and sirolimus (30–34). Additionally, cyclosporine A-induced hypertension is frequently treated with calcium-channel blockers, such as nifedipine, with both drugs acting synergistically to induce gingival overgrowth (35–37).

Both clinical and experimental studies need indices for the quantification of the enlargement to ensure reproducibility by independent examiners. Criteria set for these clinical indices must take into account the progressive nature of this pathological process, and the value assignment for each criterion should be a reflection of the distinct clinical stages.

Previously to this study, we have reported the prevalence of drug-induced gingival enlargement using the criteria set for the GOi and the MBi (which measures growth horizontally at the interdental papilla) (22–24). Basically, the two main advantages of

Table 3. Concordance values for gingival enlargement measures of the gingival overgrowth index (GOi) compared with the Miranda & Brunet index (MBi)

	Papilla									
	5–4	4–3	3–2	2–1	1–1	1–2	2–3	3–4	4–5	Total
Intra-examiner concordance										
Kappa	0.720	0.580	0.440	0.430	0.460	0.610	0.340	0.590	0.750	0.600
(95% CI)	(0.62–0.81)	(0.48–0.68)	(0.32–0.55)	(0.31–0.55)	(0.34–0.57)	(0.50–0.71)	(0.21–0.47)	(0.49–0.69)	(0.66–0.85)	(0.56–0.63)
Concordance amongst examiners										
Kappa	0.700	0.440	0.380	0.430	0.460	0.590	0.280	0.460	0.660	0.550
(95% CI)	(0.63–0.77)	(0.36–0.51)	(0.29–0.47)	(0.35–0.52)	(0.38–0.55)	(0.52–0.67)	(0.19–0.37)	(0.39–0.54)	(0.58–0.74)	(0.52–0.57)

Inter-index concordance [Kappa (95% CI)].

Table 4. Distribution of measurement discrepancies

	GOi = 0	GOi = 1	GOi = 2 + 3				
Intra-examiner concordance between indices (global)							
MBi = 0	252	4	0	Agreement:	955	(73.7)	
MBi = 1	165	402	57	GOi > MBi	61	(4.7)	(17.9)[a]
MBi = 2	7	108	301	GOi < MBi	280	(21.6)	(82.1)[b]
Concordance amongst examiners between indices (global)							
MBi = 0	465	43	0	Agreement:	1822	(70.3)	
MBi = 1	369	760	119	GOi > MBi	162	(6.3)	(21.0)[a]
MBi = 2	14	225	597	GOi < MBi	608	(23.5)	(79.0)[b]

Values are given as *n* (%).
[a]Percentage measurements in which GOi values were higher than MBi values.
[b]Percentage measurements in which MBi values were higher than GOi values.
GOi, gingival overgrowth index; MBi, Miranda & Brunet index.

the MBi are: (i) it allows direct clinical measurement of horizontal growth at the interdental papilla level (the area where the enlargement first develops); and (ii) it discriminates the two components of gingival enlargement for any localization, sorting out the degree of overgrowth in the vertical and horizontal registers. In these studies on the prevalence of DIGE (phenytoin, nifedipine, verapamil and diltiazem) we reported significant differences in the frequency of gingival enlargement between the two indices. The MBi detected early overgrowth, in the initial stages, which was not diagnosed by the GOi. Nevertheless, once the degree of concordance (Kappa values) was established, both indices showed reliability. Because the MBi enables a simple, early diagnosis of gingival enlargement, with minimal measurements, it is useful for the mass screening of populations at risk.

The GOi suggested by Seymour *et al*. (8) and performed on plaster casts, leads to a final score value that is the result of the registration and summation of the vertical and horizontal overgrowth. This index gives us an adequate general value, but it cannot discriminate between vertical and horizontal overgrowth. In recent prevalence studies, different indices have been used to grade gingival enlargement induced by drugs. The large variability observed between studies may be a consequence of the use of unreliable indices during the measurement process (38,39). Other authors have also drawn attention to the frequency differences between vertical and horizontal gingival enlargement measurements (40,41).

To find out whether a new index can replace an existing one, the diagnostic accuracy of both indices has to be compared. (42) As the sensitivity and specificity of an index can vary across subgroups, the indices must be evaluated in comparable groups or, preferably, in the same patients (43). In our current study we decided to perform the repeated measurements on plaster casts of the same patients, to fulfill this criteria and to guarantee that the severity of the overgrowth would remain unchanged, at each location, for the enlargement assessment between different intra-examiner and interexaminer measurement periods. To our knowledge, there are no studies comparing the accuracy of different measurement indices for gingival enlargement that are supported by statistical analysis.

To determine the validity of a given index with respect to another it is necessary to work from a Gold Standard model. As currently no model is available with these qualities, it must be assumed that the ideal method should be simple, reliable, easy to use and reproducible by different examiners, with a high sensitivity in the incipient gingival overgrowth (42–46). In our opinion, the GOi, described by Miller & Damm, and the MBi are complementary in the screening and diagnosis of patients with gingival overgrowth. Our study shows that there is a high level of concordance between the GOi and the MBi, and between different examiners, which proves its high reproducibility status. When we register initial gingival enlargement, the level of concordance diminishes as a result of the high sensitivity of the MBi with respect to the GOi.

In conclusion, both gingival enlargement indices analyzed (the vertical GOi and the horizontal MBi) are reliable, complementary and applicable for the measurement of gingival overgrowth. However, the MBi shows greater sensitivity than the GOi at the initial stages of gingival enlargement. Additionally the MBi shows greater reliability in the initial phases of gingival enlargement with fewer measurements, thus being more applicable for the early diagnosis of this dimorphism and appropriate for the mass screening of populations at risk.

Acknowledgements

The authors thank Eduard Lahor, DDS (Associate Professor of Dental Pathology and Therapeutics at the University of Barcelona), for his contribution.

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