Current Status and Perspectives of Mucogingival Soft Tissue Measurement Methods

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ABSTRACT

The morphologic and metric assessment of mucogingival soft tissue dimensions is of great multidisciplinary clinical and academic interest, in order to quantify and monitor gingival changes while in treatment, e.g., during periodontal, restorative, prosthetic, orthodontic, or implant therapy. Pink esthetics play an increasingly important role in the overall treatment success, and therefore have to be monitored throughout therapy. The purpose of this article was to identify and summarize methods, which aim at quantifying gingival dimensions in terms of morphology, thickness, and volume, with respect to their accuracy and practicability. The introduced measurement methods should further facilitate personalized treatment planning and monitoring.

CLINICAL SIGNIFICANCE

Mucogingival esthetics play an increasingly important role whenever treatment results are evaluated. Several qualitative and (semi)quantitative methods for measuring soft tissue dimensions are available. New methods like CAD/CAM (computer-aided design and computer-aided manufacturing) technologies are emerging and allow practitioners to reliably monitor their patient's soft tissues throughout therapy. Future improvements may help to develop better treatment strategies in terms of optimized preservation and creation of gingival morphology, especially in the esthetic zone.

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INTRODUCTION

The clinical appearance of healthy gingiva depends on several factors such as tooth size, shape, and position,[1] the underlying bone anatomy as well as genetic influences and environmental factors.[2] Two basic types of gingival architecture have been described: the "pronounced scalloped" and the "flat" gingival biotype.[3] The pronounced scalloped biotype is associated with long, slender, and tapered teeth. Papillae are high and slim, the buccal marginal gingiva is delicate, and interdental contact areas are located close to the incisal edges. The flat biotype corresponds to more square teeth, to short papillae, and to comparatively thick buccal marginal gingiva.[4] It has been suggested that the severity of symptoms associated with periodontal disease may vary in different periodontal biotypes. Plaque associated inflammation in individuals with a flat-thick appearance may result in deep periodontal pockets, whereas patients with a scalloped thin biotype might respond with gingival recessions.[5] A thin gingival unit will not inevitably lead to recessions or a

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persistence of inflammation, but it can be assumed that the likelihood of these conditions is increased, especially if mechanical trauma, surgical injury, or irritants are present.[6]

According to several studies, the periodontal phenotype affects the thickness of other parts of the oral mucosa as well. Müller and Eger[7] described that individuals with thin and vulnerable gingival tissue often also present with thin palatal mucosa. In these patients, the mucosa of the hard palate might not be suitable for harvesting connective tissue of proper thickness for surgical root coverage in case of recessions. These authors also stated that the biologic width—namely the distance between the gingival sulcus and the alveolar crest—corresponds to the periodontal phenotype, and that it can be more easily violated in subjects with thicker and wider keratinized tissue.

There might also be a correlation between the gingival phenotype and the thickness of the Schneiderian membrane. Aimetti and colleagues described a statistically significant correlation between antral mucosal thickness in patients with different periodontal phenotypes.[8] It was concluded that gingival thickness measurements could be taken as a reliable parameter to predict sinus membrane thickness—a fact that may contribute to the choice of surgical intervention techniques during sinus augmentation procedures.

The morphologic and metric assessment of gingival soft tissue dimensions is of great multidisciplinary clinical interest in order to quantify and monitor gingival changes while in treatment, e.g., during periodontal, restorative, prosthetic, orthodontic, or implant therapy. Practitioners primarily bear their patient's health and restored function in mind. When judging the overall treatment success, gingival soft tissue dimensions play an increasingly important role, and therefore have to be monitored throughout therapy. In research, adequate methods to accurately quantify tissue changes are needed when evaluating new treatment modalities and materials affecting the gingival tissues. Different methods of determining periodontal soft tissue dimensions and their changes have been described in the literature. The purpose of this article was to identify, summarize, and discuss methods, which aim at quantifying gingival dimensions in terms of thickness, volume, and morphology. They were assessed with respect to their accuracy, practicability, and clinical indications.

METHODS OF MEASURING SOFT TISSUE DIMENSIONS

In the following section, the identified instruments, materials, and methods are described. Table 1 summarizes their accuracy, invasiveness, effort, and (dis)advantages.

Visual Determination of Gingival Contours and Morphology

Periodontal Probe

The periodontal probe represents an indispensable tool in daily practice to metrically measure different clinical parameters, such as *gingival recession* (distance between soft tissue margin and cementoenamel junction), *width of keratinized mucosa* (distance between soft tissue margin and mucogingival junction), s*oft tissue margin level* (distance between the most apical point of the soft tissue margin at the facial aspect of the crown and a line connecting the midfacial level of the soft tissue margin at the adjacent teeth[9]), and *papilla height* (distance between the top of the mesial and distal papilla to a line connecting the midfacial level of the soft tissue margin of two adjacent teeth[10]). It has also been suggested to use the periodontal probe for the determination of the biotype.[11,12] After insertion of the probe into the facial aspect of the sulcus, the periodontal/periimplant biotype can be categorized as thin (outline of the probe can be seen through the gingiva) or thick (outline cannot be seen).

Reproducible Oral Photography

Oral photography is used for soft tissue evaluation extensively, but most approaches are not standardized.[9,13] Weinländer and colleagues[14] evaluated

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the crown-mucogingival complex on standardized oral photographs. Mesial and distal papilla areas and heights, gingival recession, and some other soft-tissue-crown perimeters are measured and monitored by standardized patient-, camera-, and mirror-positioning. The acquired photographs are transferred into a medical image processing software, where reference lines were added as orientation for calculating the intended gingivomorphometrical measurements. Ricci[15] introduced a method for taking standardized photographs of study models that are positioned reproducibly with bite registration material. Dental casts made in the course of therapy are mounted for photography one after each other on the same day, using the same registration compound. A grid is laid over the images, they are superimposed and reference lines are used to take measurements after importation into graphical software.

Papilla Indices

Jemt[16] introduced the papilla index for visually determining the presence or absence of interproximal papillae adjacent to single implant restorations. Summarized, it consists of: index score 0: no papilla present; index score 1: less than half of the height of the papilla present; index score 2: at least half of the height of the papilla present, but not all the way up to the contact point between the teeth; index score 3: the papilla fills up the entire proximal space and is in good harmony with the adjacent papillae; index score 4: papillae are hyperplasic. Nordland and Tarnow[17] also described a classification system for loss of papillary height, using three identifiable anatomic landmarks: the interdental contact point (iCEJ), the facial apical extent of the cementoenamel junction (fCEJ), and the interproximal coronal extent of the CEJ (iCEJ). The four classes described are: normal—interdental papilla fills embrasure space to the apical extent of the interdental contact point/area; Class 1—interdental papilla lies between interdental contact point and the most coronal extent of the iCEJ; Class 2—tip of the interdental papilla lies at or apical to the iCEJ but coronal to the apical extent of the fCEJ; Class 3—tip of the interdental papilla lies level with or apical to the fCEJ. Cardaropoli and colleagues[18] had a similar approach with their Papilla Presence Index (PPI), which is based on the positional relationship of the papilla, the cementoenamel junction and adjacent teeth and consists of four scores as well.

Radiographic Soft Tissue Determination

Radiography has been extensively used to determine hard tissue anatomy, but can be applied for soft tissue examination as well. Alpiste-Illueca[19] introduced a radiographic exploration technique named parallel profile radiograph (PPRx) for measuring the dentogingival unit on the buccal surfaces of anterior teeth. A gutta-percha point cut to the known sulcus depth is inserted to the base of the sulcus; the apical end of the point marks the bottom of the sulcus, the coronal end depicts the gingival margin, and buccally it defines the inner surface of the free gingiva. Further, a self-sticking lead plate with fixed dimensions is positioned over the gingival surface, delimiting the gingival profile up to the gingival margin. Two radiographs are made using the long cone parallel technique; one in a frontal projection, the second (PPRx) in a lateral position. On these radiographs measurement of the distance between the CEJ/bottom of the gingival sulcus and the bone crest, the thickness of connective attachment and of the free gingiva, the thickness of the bone plate, the sulcus depth and the distance from the CEJ to the marginal limit of the gingiva is possible. Another possibility of radiographic soft tissue analysis is the placement of standardized ball bearings fixated on edentulous gingiva. In implant dentistry they are commonly used as reference structure for radiographic size calibration. Nevertheless, they also allow for estimation of soft tissue thickness of the site they are affixed to.

Two-Dimensional (2D) Measurement of Gingival Thickness and Contour

Transgingival Probing

After local anesthesia a periodontal probe or a needle is pierced vertically to the mucosal surface until resistance of the bone is felt. Optionally a silicone disc can be placed in contact with the mucosa to facilitate reading of the measurement[20,21] to determine tissue thickness to the nearest 0.5 mm.[22] For reproducible measurements of specific sites, a study model with an acrylic splint

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TABLE 1. Overview of measurement methods and some of their characteristics

Measurement	Accuracy of measurements	Discomfort/ invasiveness	Advantages (+)/ disadvantages (–)	Additional information/comments
Measurements made with a periodontal probe				
Gingival recession	• Results accurate to the nearest 0.5 mm • Low variability between examiners	• Non-invasive • No discomfort	+ Easy, uncomplicated – No three-dimensional (3D) information	• Part of routine record • Estimation necessary if cementoenamel junction (CEJ) obliterated
Width of keratinized gingiva				• If Schiller iodine solution is used: allergies and stains possible, bad taste
Soft tissue margin level				• A relative value (determined for a single tooth in comparison to the others)
Papilla height				• A relative value (determined for a single tooth in comparison to the others)
Two-dimensional assessment of soft tissue dimensions				
Reproducible oral photography	• Reproducibility for duplicate measurements accepted at a 95% confidence interval[14]	• Non-invasive • Slight discomfort if mirrors are used	+ Reproducible Intraoral photographs – Limited 3D information	• Intraoral photography should be part of routine diagnostic record if extensive reconstructions necessary • Standardized patient-, camera-, and mirror-positioning
Reproducible photography of dental casts[15]		• Non-invasive • Dental casts needed	– Only evaluation and comparison of casts possible – Additional imprecisions through dental casts possible	• Any tooth movement/new restoration makes reproducible cast positioning impossible; therefore indications are limited.
Papilla index[16] (originally designed to describe for papillae adjacent to implants)	• Visual index • Low variability between examiners	• Non-invasive • No discomfort	+ Easy, uncomplicated + Visual evaluation can also be made of photographs – Limited 3D information	• 5 index scores • Hyperplasia is taken into account • Can also be used chairside or applied to describe papillae adjacent to natural teeth
Classification system for loss of papillary height[17]				• 4 classes
Papilla Presence Index				• 4 index scores
Determination of gingival thickness				
Transgingival probing for determination of mucosal thickness	• Results accurate to the nearest 0.5 mm[22]	• Local anesthesia necessary • Unpleasant for patient	+ Time-effective + No special tool needed – Possible slipping of rubber – Possible volume changes through anesthesia	• This technique can be carried out fast without additional devices, suitable in clinical setting.
Ultrasonic determination of mucosal thickness	• Resolution of 0.1 mm[6]	• Mild discomfort • Diameter of device is 3mm • Non-invasive	+ Painless method – Special tool needed – Posterior regions less accessible for measurements	• Device cannot be used otherwise—limited practicability in clinical setting.

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TABLE 1. *Continued*

Measurement	Accuracy of measurements	Discomfort/ invasiveness	Advantages (+)/ disadvantages (–)	Additional information/comments
Gingival thickness measurement with a transformer probe	• Measurements accurate to 10 μm[25] • Difference in replicate measurements 150 μm	• Local anesthesia necessary • Invasive/painful	– Special tool needed – Posterior regions less accessible for measurements	• Device cannot be used otherwise—limited practicability in clinical setting.
Radiographic soft tissue determination	• Reproducibility for duplicate measurements showed equivalence at a 95% confidence interval[19]	• Slight discomfort: gutta-percha point in sulcus, lateral x-ray • Exposure to radiation	+ Simple method + X-ray apparatus widely available – Only in frontal region possible – Absolute parallelism of film and tooth necessary	• Not only gingival thickness, but also sulcus depth, distance CEJ/bone crest, thickness of connective attachment and bone plate, and the distance CEJ/marginal limit of gingiva can be measured. As only frontal regions can be measured, and absolute parallelism of film is necessary, practicability is limited.
3D determination of volume changes				
Measurements of 3D changes with the Projection Moiré method	• Relative error of measurements 2.2% or 50–600 mm^3 [28]	• Discomfort of impression-taking	+ 3D measurements possible – Dental cast necessary (additional imprecisions possible) – Moiré system cannot be used for other purpose	• Device usually not widely available in clinical setting.
3D laser scanning method	• Mean difference for replicas 7.75 μm or 6561 μm^3 [30]	• Discomfort of impression-taking	+ 3D measurements possible – Dental cast necessary (additional imprecision) – Laser scanner needed	• Very high accuracy. Device usually not widely available in clinical setting.
CAD/CAM device measurement	• Mean difference for replicas 0.01 mm^3 or 0.8%[39]	• Discomfort of impression-taking (direct or indirect) • Non-invasive	+ 3D measurements possible + Direct and indirect (cast) measurements possible – CAD/CAM device needed – Artifacts possible through scanning powder	• After a considerable initial investment, the CAD/CAM device is very suitable for capturing of digital intraoral 3D images.
Soft tissue cone-beam computed tomography (ST-CBCT)	• Measurement error depending on tomograph, up to 1.11 mm or 7%[26]	• Not painful • Exposure to radiation	+ 3D overview over anatomic structures—additional therapeutic information – Distinction of soft tissue types not possible yet	• In complex cases and special questions very helpful. Because of radiation exposure and cost repeated scans not recommended without strict indication setting.

needs to be prepared. Measurement holes in the splint are used as guiding path for the instrument once the splint is placed back on the patient's dentition.[20] Figure 1 schematically illustrates the proceeding. This method can also be applied to investigate alveolar bone levels (bone mapping or bone sounding).[23]

Ultrasonic Determination

Gingival thickness measurements utilizing ultrasound technology have been performed by a number of researchers.[6,21,24] Eger and colleagues[6] described gingival thickness measurements based on the ultrasonic pulse-echo principle. With a commercially available ultrasonic device (SDM, Krupp Corp., Essen, Germany) pulses were transmitted at 1,518 m/s through the mucous membrane and reflected at the surface of the tooth or jawbone. The thickness of the mucous membrane is determined by timing the received echo with a resolution of 0.1 mm.

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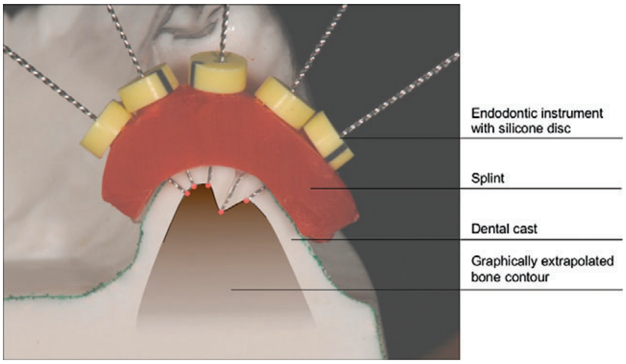

FIGURE 1. Transgingival probing schematically illustrated on a study cast. The holes in the splint guide the instruments and make their placing/measurement reproducible.

Transformer Probe

Goaslind and colleagues[25] used a differential transformer coupled to an oscillator and digital voltmeter for measuring facial gingival thickness of 10 subjects on selected teeth. The probe assembly (Hewlett-Packard, Palo Alto, CA, USA) has a reported accuracy of 0.01 mm, and the average range of difference in replicate measurements was below 0.15 mm.

Soft Tissue Cone-Beam Computed Tomography (CBCT)

Januario and colleagues[26] described a novel method based on CBCT technology called soft tissue CBCT (ST-CBCT) to visualize and measure the relationship between gingival margin, cementoenamel junction, and the facial bone crest, as well as the facial and lingual/palatal alveolar bone and the width of the facial and lingual/palatal gingival in CT-sections. For this study three patients with different biotypes underwent a conventional CBCT (iCAT, Imaging Sciences International Inc., Hatfield, PA, USA). Following this, a second scan called ST-CBCT was performed with the same settings, but this time the patient wore a plastic lip retractor and lowered his tongue toward the floor of the mouth. By retracting the soft tissue of the lips, cheeks, and tongue away from the gingiva in both facial and palatal aspects, a dark, air-filled space was created between the facial and lingual/palatinal soft tissues, which makes their distinction possible. This technique was also used to measure palatal masticatory mucosa.[27]

Three-Dimensional (3D) Determination of Gingival Soft Tissue Volume

Projection Moiré Method

Studer and colleagues[28] quantified 3D volume changes of single tooth pontic spaces after soft tissue augmentation surgery with the optical projection Moiré method. The system consists of a Moiré projector controlled by a Moiré driver (MP-1000A, Newport Corp., Irvine, CA, USA), a Moiré viewer (MV-1000A, Newport Corp.) with a video camera (CCD video camera, AVC, D7CE, Sony, Geneva, Switzerland) and a PC with graphic software to which the viewer was connected. Impressions were made before treatment and 1 and 3.5 months after surgery. For enhancement of visual contrast the dental casts were covered with white-colored spray, then a Moiré fringe image was captured and the image calculated. The relative error of measurement for volume differences was 2.2% in the range of 50 to 600 mm^3.[29] The duration of measurement for one series of casts was approximately 3 hours.

Laser Scanner

Rosin and colleagues[30] described a method of quantifying gingival papillary edema from replicas of the clinical situation using a 3D laser scanner (Laserscan 3D Pro system, Willytec, Munich, Germany) working on the principle of optical triangulation.[31] Polyether impressions of the test quadrant were taken, plaster casts poured, and their buccal sides scanned with a 3D laser scanner. Papillary volume differences were determined between days 0 and 21, 0 and 28, 28 and 42, and 0 and 42 with reference free automated Match-3D software (Willytec). The intrinsic error of the Match-3D software resulted in a mean height difference of 0.47 μm. Thomason and colleagues[32] used a similar technique. They digitized stone dental casts of patients before and after gingivectomy procedures with a laser scanner (Laserscan 3D Pro system). A comparison of superimposed "before" and "after" surfaces was undertaken to assess changes in gingival contour to within 60 μm in one plane. Jemt and Lekholm[33,34] utilized the optical 3D scanning method (Atos®, GOM International AG, Braunschweig, Germany) for comparing changes in buccal and proximal tissue volume after local bone grafting and

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single-implant treatment. The setup had a calculated 3D accuracy of 150 to 200 µm. Henriksson and Jemt[35] used the same setup to measure changes in buccal tissue volume after placing restorations with single-implant crowns using two different abutment systems. Wälivaara and colleagues[36] made direct intraoral 3D measurements (PRIMOS optical 3D GF Messtechnik, Teltow, Germany) of the maxillary frontal contour before and after bone augmentation procedures. Shape alterations could be measured with an accuracy of 3 µm, but difficulties in using the device in posterior oral regions were reported.

CAD/CAM Cameras

Another option for soft tissue measurements is a commercially available CAD/CAM device (Cerec, Sirona Dental Systems, Bensheim, Germany) that was developed to digitally capture the 3D shape of teeth and their adjacent soft tissue structures applying the principle of active triangulation.[37] Windisch and colleagues[38] investigated this method by measuring geometrically complex forms; differences between test and control records amounted to 1.5%, and coefficients of variation ranged between 0.05 and 0.5%. Strebel and colleagues[39] used this device to measure small amounts of flowable composite resin material that was added to a papilla to mimic a soft tissue change. Two optical impressions—one with a thin layer of flowable composite resin material, the second without this layer—were taken chairside. Both situations were superimposed and the volume of the flowable composite resin layer added to the papilla was calculated. To assess the validity of this technique, the added composite material was also quantified by microcomputed tomography (µ-CT) and weight measurements. No difference was found when comparing µ-CT/weight measurements, but a difference of 7.5 and 5.8%, respectively, was found when comparing µ-CT/CAD/CAM and weight/CAD/CAM measurements. Fickl and colleagues[40] utilized this technique to assess volumetric changes of the buccal ridge contour of beagle dogs after treating extraction sites with socket preservation or buccal overbuilding. However, the optical impressions were not taken intraorally but indirectly from plaster casts produced at baseline, 2 weeks and 4 months postoperatively. The data obtained was analyzed regarding volume alterations in terms of different treatment modalities and time points.

Combination of Different Imaging Techniques

One of the future possibilities in 3D imaging is the integration of CAD/CAM information into CBCT-data.[41] The software (Galaxis software 1.7, Sirona Dental Systems) for this technique might bring valuable additional information, as quickly introduced at this point. Figure 2 shows the ST-CBCT scan (Galileos, Sirona Dental Systems), where the lower anterior teeth have been superimposed with a 3D model of the same patient's situation, which was obtained by a surface scan with an intraoral 3D camera of a CAD/CAM system (Bluecam, Cerec AC, Sirona Dental Systems). The patient presented with recessions, especially on tooth 31, which can also be noted on the clinical picture (Figure 3). Figure 4A depicts tooth 31 in the ST-CBCT image in the transversal aspect, with the yellow lines outlining the surface contour of the 3D model in the same position. In comparison, tooth 41 is displayed in Figure 4B. It can be seen that the soft tissue volume was considerably underestimated by the ST-CBCT scan, and additional information on the actual gingival thickness can be extracted from the superimposed 3D model.

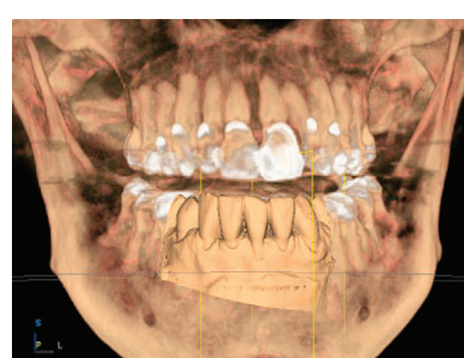

FIGURE 2. Cone-beam computed tomography scan superimposed by a three-dimensional model of the same situation in the lower anterior.

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DISCUSSION

With literature emphasizing the importance of gingival dimensions for successful treatment planning and outcome, as well as rising patient expectations regarding the so called "pink esthetics," practitioners have to look into ways of conveniently and reliably monitoring soft tissue reactions to their therapy. For this purpose standardized measurement methods are preferred to avoid subjectivity to influence measurement results.

FIGURE 3. Clinical situation of the patient presenting with recessions in the lower anterior, especially on tooth 31.

Simple measurements performed with a periodontal probe, e.g., recessions or width of keratinized gingiva are fast and often part of routine diagnostics. Intraoral photography as well as visual papilla indices are helpful tools to monitor soft tissue changes, but provide limited 3D information. The same applies for the ultrasonic method assessing gingival thickness, where an overview of the gingival and periodontal structures and their relationship is not obtainable. Müller and colleagues[42] have extensively applied the described device and reported difficulties in obtaining reliable measurements of gingival thickness in different parts of the oral cavity, especially at molar sites. The diameter of the transducer probe is over 3 mm, resulting in difficulties in hardly accessible/posterior sites. Alternatively tissue thickness can be determined by transgingival probing, which is carried out quickly without special appliances or preparations. However, this technique must be performed under local anesthesia, which might induce an inadvertent volume increase and patient inconvenience.

Whenever opting for 3D information assessed with 3D laser scanners, CAD/CAM cameras or the Projection Moiré method, stone casts often are the basis for the tissue analysis. As study models frequently are part of the initial diagnostic package, no additional costs or chairside time is necessary. However, there is a risk of soft tissue displacement while impression taking, which may negatively influence measurement accuracy, as well

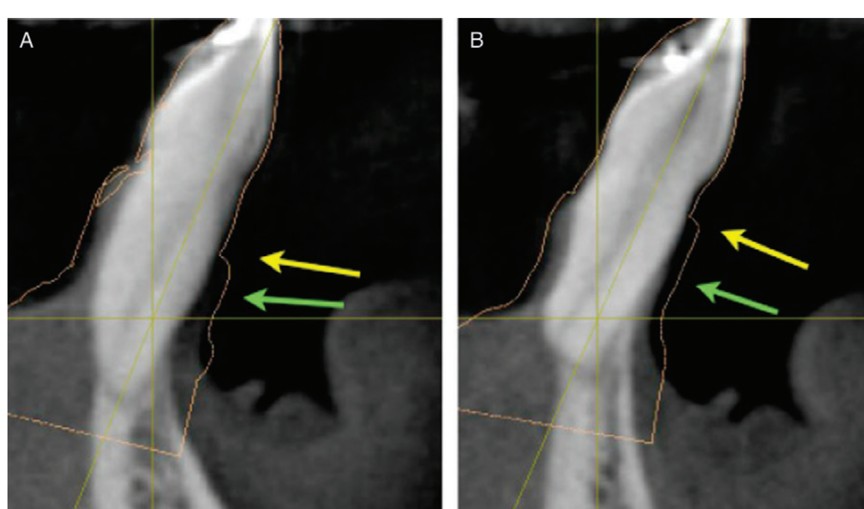

FIGURE 4. A, Transversal aspect of tooth 31 (soft tissue cone-beam computed tomography [ST-CBCT] and three-dimensional [3D] model superimposed). B, Transversal aspect of tooth 41 (ST-CBCT and 3D model superimposed). The yellow arrow marks the gingival margin as shown in the 3D model superimposition. The green arrow marks the gingival margin as revealed in the ST-CBCT scan.

as dimensional changes of impression or cast materials and artifacts. In addition, time that is needed for scanning the models, marking the areas of interest and calculating the changes in dimension should not be underestimated. Further, it can be challenging to obtain repeatable reference points in the oral cavity for superimposition of the two images. 3D laser scanners usually are more common in university and research settings, whereas more and more clinicians dispose of a CAD/CAM device. The latter additionally requires a pre-scan powdering procedure of the area of interest, which might influence measurement accuracy. Meyer and colleagues[43] looked at the thickness of powder layers in a MOD inlay-cavity using six different propellant methods. Depending on the location within the cavity as well as on the product used, layers were measured between 20 ± 7 μm and 85 ± 54 μm. However, if casts are used, material specially manufactured for the use in CAD/CAM technology can be utilized (esthetic base gold, Dentona, Dortmund, Germany), and the powdering step can be omitted in the procedure.

The ST-CBCT is the most suitable tool for getting an overall anatomic overview and a painless way for obtaining images of the teeth and surrounding periodontal structures. The maintained image aspect ratio of 1:1 allows measurements to be made directly on the scan print.[26] Obvious disadvantages are the high dose of radiation exposure, the cost of the scan, and frequently the need of a separate appointment. Also, it is not possible to distinguish different types of soft tissues. Inflamed gingiva has a similar appearance on the ST-CBCT scan as healthy gingiva; gingival epithelium looks similar to gingival connective tissue.[26] Further, depending on the scan-settings, soft tissue dimensions can be considerably underestimated. Nevertheless, in more complicated cases or in situations with special questions it is part of the standard diagnostic record for treatment planning. As soft tissue dimensions are closely related to bone anatomy, the CBCT technique and its developments, e.g., lower dose of radiation, higher resolution, and further software applications will play a more and more important role in future dentistry.

CONCLUSION

Different methods for assessing and monitoring soft tissue dimensions are summarized and discussed. Clinicians can choose the individually appropriate measurement approach for determining their patient's gingival situation, which should further facilitate personalized treatment planning and become an integral part of good clinical practice. In research, these methods may also help to develop better treatment strategies in terms of optimized preservation and creation of gingival morphology, especially in the esthetic zone in the future.

DISCLOSURE

The authors do not have any financial interest in the companies whose materials are included in this article.

REFERENCES

1. Müller HP, Eger T. Gingival phenotypes in young male adults. J Clin Periodontol 1997;24:65–71.
2. Schröder HE. The periodontium. In: Oksche A, Vollrath L, editors. Handbook of microscopic anatomy. 5th ed. Berlin: Springer; 1986, pp. 233–47.
3. Ochsenbein C, Ross S. A reevaluation of osseous surgery. Dent Clin North Am 1969;13:87–102.
4. Lindhe J, Lang NP, Karring T, editors. Clinical periodontology and implant dentistry. 5th ed. Oxford: Blackwell Munksgaard; 2008.
5. Olsson M, Lindhe J. Periodontal characteristics in individuals with varying form of the upper central incisors. J Clin Periodontol 1991;18:78–82.
6. Eger T, Muller HP, Heinecke A. Ultrasonic determination of gingival thickness. Subject variation and influence of tooth type and clinical features. J Clin Periodontol 1996;23:839–45.
7. Müller HP, Eger T. Masticatory mucosa and periodontal phenotype: a review. Int J Periodontics Restorative Dent 2002;22:172–83.
8. Aimetti M, Massei G, Morra M, et al. Correlation between gingival phenotype and Schneiderian membrane thickness. Int J Oral Maxillofac Implants 2008;23:1128–32.
9. Chang M, Wennstrom JL, Odman P, Andersson B. Implant supported single-tooth replacements compared

 DOI 10.1111/j.1708-8240.2011.00424.x

to contralateral natural teeth. Crown and soft tissue dimensions. Clin Oral Implants Res 1999;10:185–94.
10. Olsson M, Lindhe J, Marinello CP. On the relationship between crown form and clinical features of the gingiva in adolescents. J Clin Periodontol 1993;20:570–7.
11. Kan JY, Rungcharassaeng K, Umezu K, Kois JC. Dimensions of peri-implant mucosa: an evaluation of maxillary anterior single implants in humans. J Periodontol 2003;74:557–62.
12. De Rouck T, Eghbali R, Collys K, et al. 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;36:428–33.
13. Furhauser R, Florescu D, Benesch T, et al. Evaluation of soft tissue around single-tooth implant crowns: the pink esthetic score. Clin Oral Implants Res 2005;16:639–44.
14. Weinländer M, Lekovic V, Spadijer-Gostovic S, et al. Gingivomorphometry—esthetic evaluation of the crown-mucogingival complex: a new method for collection and measurement of standardized and reproducible data in oral photography. Clin Oral Implants Res 2009;20:526–30.
15. Ricci A. An objective method to measure soft tissue behavior around single-tooth implants. Part 1: vertical measurements. Eur J Esthet Dent 2007;2:434–46.
16. Jemt T. Regeneration of gingival papillae after single-implant treatment. Int J Periodontics Restorative Dent 1997;17:326–33.
17. Nordland WP, Tarnow DP. A classification system for loss of papillary height. J Periodontol 1998;69:1124–6.
18. Cardaropoli D, Re S, Corrente G. The Papilla Presence Index (PPI): a new system to assess interproximal papillary levels. Int J Periodontics Restorative Dent 2004;24:488–92.
19. Alpiste-Illueca F. Dimensions of the dentogingival unit in maxillary anterior teeth: a new exploration technique (parallel profile radiograph). Int J Periodontics Restorative Dent 2004;24:386–96.
20. Wara-aswapati N, Pitiphat W, Chandrapho N, et al. Thickness of palatal masticatory mucosa associated with age. J Periodontol 2001;72:1407–12.
21. Savitha B, Vandana KL. Comparative assesment of gingival thickness using transgingival probing and ultrasonographic method. Indian J Dent Res 2005;16:135–9.
22. Studer SP, Allen EP, Rees TC, Kouba A. The thickness of masticatory mucosa in the human hard palate and tuberosity as potential donor sites for ridge augmentation procedures. J Periodontol 1997;68:145–51.
23. Ursell MJ. Relationships between alveolar bone levels measured at surgery, estimated by transgingival probing and clinical attachment level measurements. J Clin Periodontol 1989;16:81–6.
24. Tsiolis FI, Needleman IG, Griffiths GS. Periodontal ultrasonography. J Clin Periodontol 2003;30:849–54.
25. Goaslind GD, Robertson PB, Mahan CJ, et al. Thickness of facial gingiva. J Periodontol 1977;48:768–71.
26. Januario AL, Barriviera M, Duarte WR. Soft tissue cone-beam computed tomography: a novel method for the measurement of gingival tissue and the dimensions of the dentogingival unit. J Esthet Restor Dent 2008;20: 366–73; discussion 374.
27. Barriviera M, Duarte WR, Januario AL, et al. A new method to assess and measure palatal masticatory mucosa by cone-beam computerized tomography. J Clin Periodontol 2009;36:564–8.
28. Studer SP, Lehner C, Bucher A, Scharer P. Soft tissue correction of a single-tooth pontic space: a comparative quantitative volume assessment. J Prosthet Dent 2000; 83:402–11.
29. Studer SP, Sourlier D, Wegmann U, et al. Quantitative measurement of volume changes induced by oral plastic surgery: validation of an optical method using different geometrically-formed specimens. J Periodontol 1997;68: 950–62.
30. Rosin M, Splieth C, Hessler M, et al. Quantification of gingival edema using a new 3-D laser scanning method. J Clin Periodontol 2002;29:240–6.
31. Mehl A, Gloger W, Kunzelmann KH, Hickel R. A new optical 3-D device for the detection of wear. J Dent Res 1997;76:1799–807.
32. Thomason JM, Ellis JS, Jovanovski V, et al. Analysis of changes in gingival contour from three-dimensional co-ordinate data in subjects with drug-induced gingival overgrowth. J Clin Periodontol 2005;32:1069–75.
33. Jemt T, Lekholm U. Measurements of buccal tissue volumes at single-implant restorations after local bone grafting in maxillas: a 3-year clinical prospective study case series. Clin Implant Dent Relat Res 2003;5:63–70.
34. Jemt T, Lekholm U. Single implants and buccal bone grafts in the anterior maxilla: measurements of buccal crestal contours in a 6-year prospective clinical study. Clin Implant Dent Relat Res 2005;7:127–35.
35. Henriksson K, Jemt T. Measurements of soft tissue volume in association with single-implant restorations: a 1-year comparative study after abutment connection surgery. Clin Implant Dent Relat Res 2004;6:181–9.
36. Wälivaara DA, Isaksson S, Rosen S. Description of a technique for evaluation of three-dimensional shape alterations in soft tissue after intra oral bone reconstruction. Br J Oral Maxillofac Surg 2007;45:382–6.
37. Mörmann WH, Bindl A. All-ceramic, chair-side computer-aided design/computer-aided machining restorations. Dent Clin North Am 2002;46:405–26.
38. Windisch SI, Jung RE, Sailer I, et al. A new optical method to evaluate three-dimensional volume changes

of alveolar contours: a methodological in vitro study. Clin Oral Implants Res 2007;18:545–51.

39. Strebel J, Ender A, Paque F, et al. In vivo validation of a three-dimensional optical method to document volumetric soft tissue changes of the interdental papilla. J Periodontol 2009;80:56–61.
40. Fickl S, Schneider D, Zuhr O, et al. Dimensional changes of the ridge contour after socket preservation and buccal overbuilding: an animal study. J Clin Periodontol 2009;36:442–8.
41. Ritter L, Neugebauer J, Dreiseidler T, et al. 3D X-ray meets CAD/CAM dentistry: a novel procedure for virtual dental implant planning. Int J Comput Dent 2009;12: 29–40.
42. Müller HP, Barrieshi-Nusair KM, Kononen E. Repeatability of ultrasonic determination of gingival thickness. Clin Oral Investig 2007;11:439–42.
43. Meyer BJ, Mörmann WH, Lutz F. Optimization of the powder application in the Cerec method with environment-friendly propellant systems [in German]. Schweiz Monatsschr Zahnmed 1990;100:1462–8.

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