The Dimensions of the Human Dentogingival Junction

*James S. Vacek, DDS**
*Marlin E. Gher, DDS, MEd**
*Daniel A. Assad, DDS**
*A. Charles Richardson, DDS**
*Leo I. Giambarresi, PhD**

This study examined the naturally occurring dimensions of the dentogingival junction in 10 adult human cadaver jaws. The connective tissue attachment, epithelial attachment, loss of attachment, and sulcus depth were measured histomorphometrically for 171 tooth surfaces. Mean measurements were 1.34 ± 0.84 mm for sulcus depth; 1.14 ± 0.49 mm for epithelial attachment; 0.77 ± 0.32 mm for connective tissue attachment; and 2.92 ±1.69 mm for loss of attachment. These dimensions, as measured in this study, support the concept that the connective tissue attachment is a variable width within a more narrow distribution and range than the epithelial attachment, sulcus depth, or loss of attachment. The level of the loss of attachment was not predictive of the connective tissue attachment length. (Int J Periodont Rest Dent 1994;14:155–165.)

*Periodontics Department, Naval Dental School, National Naval Dental Center, Bethesda, Maryland.

Correspondence to: CAPT Marlin E. Gher, DC, USN, 2014 Subida Terrace, Carlsbad, California 92009.

Reprint requests to: Librarian, Naval Dental School, National Naval Dental Center, Bethesda, Maryland 20889-5077.

The dentogingival junction has been described as a functional unit composed of the connective tissue attachment of the gingiva and the epithelial attachment.[1] Gargiulo et al[2] reported that the connective tissue attachment varied in length from 0.0 to 6.84 mm with a mean of 1.07 mm; this measurement combined with the mean length of the epithelial attachment (0.97 mm) has been called the physiologic dentogingival junction,[2] or biologic width.[3,4] Although these individual measurements were found to vary greatly from tooth to tooth, the combined mean dimension has been used as a guideline for reestablishing the ideal attachment dimensions when performing clinical crown lengthening surgery.[3-11] The need to consider a variable supracrestal attachment area to allow for the range of epithelial and connective tissue attachments has also been discussed.[12,13]

The importance of the biologic width in relation to gingival health and as a guide for placing dental restorations has been studied.[14–19] Clinically, Newcomb[14] found that the greatest degree of gingival inflammation was seen when subgingival crown margins were placed near the base of the gingival crevice, while Richter and Ueno[15] noted no difference in gingival health when crown margins were placed subgingivally. From histologic observations on dog and human autopsy material, Waerhaug[16] concluded that pocket deepening in response to artificial crowns did not occur when the margin did not come closer than 0.4 mm to the bottom of the pocket and attached fibers were not severed. Than et al[17] found, however, that when the biologic width was violated by dental restorations there was a greater mean loss of connective tissue attachment adjacent to surfaces with a dental restoration than adjacent to those without.

In a clinical investigation, Tarnow et al[18] concluded that subgingival crown margin placement combined with injury to the gingival attachment resulted in rapid gingival repair in the form of recession with limited gingival inflammation. In a study in dogs, Tal et al[19] found that when amalgam restorations were placed at the osseous crest a biologic width was reestablished at 1 year, and that its dimension was 0.90 mm, compared to 4.47 mm on surgically operated control teeth without restorations. This finding suggests that the biologic width, if violated, may be reestablished at a minimal acceptable dimension for health. In humans the minimum dimension of biologic width for the maintenance of gingival health has not been established.

The purpose of this study is to provide additional information on the dimensions of the dentogingival junction and related structures using nondecalcified human block sections.

Method and materials

A pilot study was conducted to establish appropriate processing methods and sample size for the study. Block sections of dentulous mandibles were obtained from human cadavers preserved with phenol-formaldehyde, glycerin, and alcohol; one dentulous mandible was also obtained from a human fresh frozen cadaver. Results of the pilot study indicated that tissues from the fresh frozen cadavers were not suitable for histologic examination, because of the destruction of the epithelial layer resulting from the freezing process. The preserved cadaver tissues yielded sections with readily identifiable structures when stained histologically. Measurements from these sections were used to estimate the study sample size.

In the principal study, each of 10 jaws, from cadavers ranging in age from 54 to 78 years, were used to prepare seven block segments of two or three teeth each (Fig 1). These nondecalcified segments were sectioned first in a mesiodistal direction along the long axis and contacts of the teeth (Fig 2). The remaining facial and lingual portions were then sectioned buccolingually along the long axis of the teeth (Fig 3). All sectioning was done with an EXAKT I cutting/grinding device (Exakt) according to the manufacturer's instructions. The cutting/grinding device is capable of making 10- to 30-µm-thick serial sections of nondecalcified tissue approximately every 0.75 mm. The resulting thin nondecalcified sections contained structures, such as the enamel and dental restorations, for observation and reference. Figures 4a to 4d, a clinical series, demonstrate the sectioning of the specimens in preparation for histologic measurements.

The mesial (M), distal (D), facial (F), and lingual (L) surfaces of every tooth were each considered as individual surfaces for measurement of

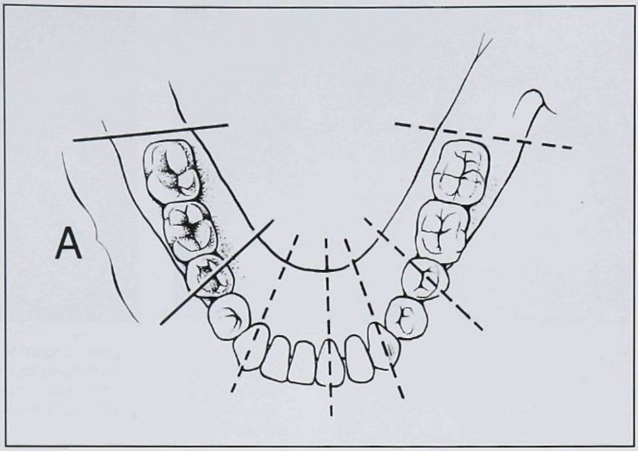

Fig 1 Schematic representation of a human mandible. Dashed lines represent the approximate initial sectioning planes. A = typical two- to three-tooth segment.

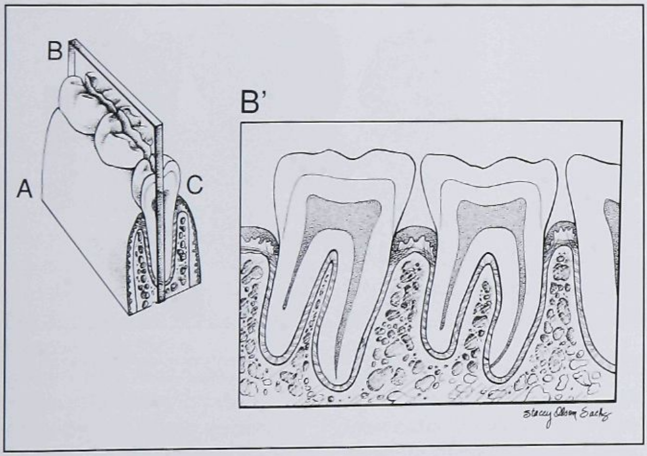

Fig 2 Nondecalcified segment A was first sectioned in a mesiodistal direction along the long axis and contacts of the teeth to produce block B. Block B′ was then histologically prepared to visualize the mesial and distal surfaces of the teeth for measurements. C = lingual portion that remained after sectioning.

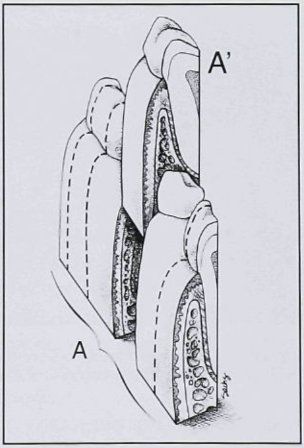

Fig 3 The facial and lingual portions (A and C from Fig 2) were sectioned buccolingually along the long axis of the teeth (dashed lines). Portion A′ was histologically prepared to visualize the buccal and lingual surfaces.

Fig 4a Nondecalcified sections are prepared for histologic analysis; posterior mandibular block segment is shown after initial sectioning.

Fig 4b Mesial-to-distal block sections were removed and used to prepare thin histologic sections. Residual buccal and lingual sections were then sectioned to permit measurements from those surfaces.

Fig 4c Mesial-to-distal sections were then ground to a 10- to 30-µm thickness in preparation for staining.

Fig 4d Thin section stained to enhance identification of anatomic structures for measurement.

Fig 5a (left) *Stained thin section permits examination of dental restorations, enamel, and hard tissues in relation to soft tissues without distortion. Note the presence of calculus, which bridges the interproximal space immediately coronal to the gingival soft tissues.*

Fig 5b (right) *Photomicrograph of interproximal space demonstrates transeptal collagen fibers, epithelial attachment, which extends to the level of the transeptal fibers, and bacterial plaque and debris on the enamel surface of the teeth coronal to the interproximal soft tissues. Vacuoles noted within the gingival tissues are processing artifacts.*

the dentogingival junction. Each surface yielded two to four sections for histomorphometric measurement, depending on the width of the tooth and its location within the arch. Sections were stained with Masson's trichrome or hematoxylin and eosin stain and measured histomorphometrically by the same examiner with a Zeiss Interactive Digital Analysis System (ZIDAS; Zeiss) (Figs 5a and 5b). Each tissue section was viewed and measured through a Zeiss light microscope (Zeiss) at × 40 magnification, which was fitted with a drawing tube. Measurements of the following structures were recorded:

(1) Sulcus depth (SUL): the distance from the crest of the free gingiva to the most coronal extent of the epithelial attachment

(2) Epithelial attachment (EA): the distance from the most coronal extent of the epithelial attachment to the most coronal extent of the connective tissue attachment

(3) Connective tissue attachment (CTA): the distance from the most coronal extent of the connective tissue attachment to the most coronal extent of the periodontal ligament (The coronal extent of the periodontal ligament was defined as the level at which the PDL was first found to be of uniform thickness when compared with other areas of the PDL on the tooth being examined.)

(4) Loss of attachment (LOA): the distance from the cementoenamel junction (CEJ) to the most coronal extent of the connective tissue attachment

Also recorded were the subject's identification number, age, sex, tooth number, tooth surface (M = mesial; D = distal; B = buccal; L = lingual), the type of restoration present, if any, and the distance from the apical margin of the restoration to the coronal extent of the connective tissue attachment. Only teeth with subgingival restoration margins and a microscopically visible CEJ were included in the measurements for subgingival restorations. The mean dimensions of the dentogingival junction for each tooth surface were determined on 171 surfaces. Measurement error was calculated by making 124 replicate measurements on a total of 31 randomly selected sites. A period of at least 24 hours elapsed between replicate measurements. The two measurements were compared to determine the precision of the measurement technique.

Every effort was made to section the teeth parallel to the long axis of the tooth. However, due to variations in root contours, sectioning along the long axis resulted in tangential cuts across some isolated areas, such as furcation entrances, because of curvature of the root at the entrance into the furcation.[20-23] This precluded accurate dimensional measurements in these areas. These few areas were excluded from the data set.

The mean, standard deviation, range, and frequency distribution of the measurements of the EA, CTA, LOA, and SUL were determined. A one-way analysis of variance was used to compare measurements between surface locations (B, L, M, D), arch position (anterior, posterior), and surfaces with or without a subgingival dental restoration. Scheffe's method for multiple comparisons was used for discrimination. Regression analysis was used to correlate the CTA dimension to the corresponding LOA.

Results

Mean dentogingival dimensions for all surfaces are shown in Table 1. There were no significant differences between the measurements for the tooth surfaces (B, L, M, or D) for SUL, LOA, EA, or CTA (Fig 6). Regression analysis showed there was no significant correlation between the LOA and the CTA, EA+CTA (biologic width), or SUL+EA+CTA.

When tissue dimensions for the anterior and posterior teeth were compared, both the CTA and EA were significantly greater in the posterior sextants. When molars and premolars were analyzed separately, only the CTA was significantly greater in the posterior teeth (Table 2). When the dimensions of the EA and the corresponding CTA for that surface were combined (biologic width) the posterior teeth showed a significantly greater ($P < .004$) biologic width than the anterior teeth. When molars and premolars were analyzed separately, the biologic width of the molars was significantly greater ($P < .02$) than that of the anterior teeth, while the biologic width of the premolars was not significantly different from that of the molars or the anterior teeth (Table 3).

Tooth surfaces with subgingival restorations were found to have a significantly longer EA ($P < .04$) than nonrestored teeth, but no significant differences were found for the CTA, SUL, or LOA (Table 4). When the mean measurements for the combined dimensions of the EA and CTA (biologic width) for teeth that had restorations were compared to the biologic width for teeth without restorations there was a significantly greater ($P < .02$) biologic width in restored teeth. There was no significant difference in any of these dimensions when comparing types of restoration.

Analysis of the precision of replicate measurements demonstrated 95% confidence intervals of ± 0.08 mm for the CTA, ± 0.12 mm for the EA and LOA, and ± 0.14 mm for the sulcus depth.

Table 1 Dentogingival dimensions (mm) for the epithelial attachment (EA), connective tissue attachment (CTA), loss of attachment (LOA), and sulcus depth (SUL) for all surfaces

	Measurement (mean ± SD)	Range
EA	1.14 ± 0.49	0.32 - 3.27
CTA	0.77 ± 0.29	0.29 - 1.84
LOA	2.95 ± 1.70	0.60 - 8.73
SUL	1.32 ± 0.80	0.26 - 6.03

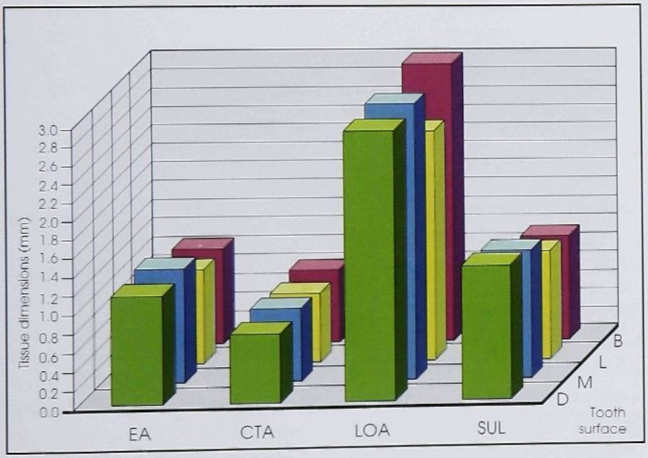

Fig 6 Graph displays mean tissue dimensions for the epithelial attachment (EA), connective tissue attachment (CTA), loss of attachment (LOA), and sulcus depth (SUL), for distal (D), mesial (M), lingual (L), and buccal (B) surfaces.

Table 2 Tissue dimension (mm) for the epithelial attachment (EA), connective tissue attachment (CTA), loss of attachment (LOA), and sulcus depth (SUL) for teeth grouped by arch position

	Measurement (mean ± SD)	Range
EA		
Anterior	1.03 ± 0.45	0.38 – 2.48
Premolar	1.20 ± 0.53	0.32 – 3.27
Molar	1.22 ± 0.46	0.44 – 2.30
CTA		
Anterior	0.71 ± 0.24*	0.35 – 1.34
Premolar	0.77 ± 0.31	0.29 – 1.84
Molar	0.89 ± 0.31*	0.40 – 1.77
LOA		
Anterior	3.33 ± 1.99	0.76 – 8.73
Premolar	2.73 ± 1.37	0.87 – 6.58
Molar	2.76 ± 1.65	0.60 – 6.50
SUL		
Anterior	1.19 ± 0.89	0.43 – 6.03
Premolar	1.30 ± 0.68	0.26 – 3.24
Molar	1.54 ± 0.80	0.56 – 4.04

*$P < .04$.

Table 3 Biologic width (epithelial attachment plus connective tissue attachment) (mm) for teeth grouped by arch position

Arch position	Measurement (mean ± SD)	Range
Anterior	1.75 ± 0.56*	0.75 – 3.29
Premolar	1.97 ± 0.67	0.78 – 4.33
Molar	2.08 ± 0.55*	0.84 – 3.29

*$P < .02$.

Table 4 Tissue dimensions (mm) for surfaces with subgingival restorations (restored) and without subgingival restorations (nonrestored) for the epithelial attachment (EA), connective tissue attachment (CTA), loss of attachment (LOA), and sulcus depth (SUL)

	Measurement (mean ± SD)	Range
EA		
Restored	1.32 ± 0.47*	0.69 – 2.29
Nonrestored	1.11 ± 0.49*	0.32 – 3.27
CTA		
Restored	0.84 ± 0.26	0.42 – 1.47
Nonrestored	0.76 ± 0.29	0.29 – 1.84
LOA		
Restored	2.60 ± 1.53	0.60 – 8.73
Nonrestored	3.01 ± 1.73	0.74 – 8.73
SUL		
Restored	1.60 ± 0.80	0.64 – 4.04
Nonrestored	1.27 ± 0.79	0.26 – 6.03

*$P < .04$.
Restored (n = 27); nonrestored (n = 144).

Discussion

Nondecalcified sections were used in this study to minimize the error introduced by the dimensional changes inherent in decalcification and tissue preparation. The preservation of tissue with standard histologic methods has been shown to cause a measurable change (15% total shrinkage) in the dimension of the soft tissue; therefore, the dimensions of the sulcus would need to be adjusted for this factor.[24] The decalcification of the hard tissue also causes a dimensional change in the tissue.[25] These factors must be considered in all studies that use decalcified and histologically prepared tissue.

Because human cadaver material was used in this study, the duration of inflammation present at the time of tissue preparation could not be determined, and previous periodontal therapy on the sample population was not known. Within this sample population there was a wide range of loss of attachment. The sample population in the present study may represent a group of patients that had a low susceptibility to the development of periodontal disease,[26] because only subjects with few missing teeth were included in the study. As found in this study, the connective tissue attachment (CTA) varied in width, but with a more narrow range and variance than that for the EA, SUL, or LOA. The historical concept of allowing 1 mm for the CTA would adequately include the CTA dimensions reported here.

When the measurements for surfaces with subgingival restorations were compared to the dimensions for surfaces without restorations, there was a significantly longer EA for the restored teeth than for the nonrestored teeth. No significant difference was found for the other dimensions. These results are not in agreement with studies by Than et al[17] or Keszthelyi[27] that have shown a greater loss of attachment adjacent to restored surfaces; however, both of these studies used extracted teeth without attached adjacent structures.

In this sample population no correlation was found between the LOA and the corresponding length of the CTA or biologic width. This finding suggests that clinical determination of the LOA would not be useful in predicting the length of the CTA (or concomitant biologic width). Therefore the clinician could not use the attachment level as a guideline to determine the necessary requirements for the reestablishment of the EA and CTA.

The mean dimension of the CTA plus EA (biologic width) was 0.33 mm greater on molar teeth than anterior teeth. Although clinically small, this result suggests that on molar teeth a greater length of biologic width may have to be allowed when attempting to reestablish naturally occurring dimensions of the dentogingival junction. The range of biologic width that was observed was 0.75 mm to 4.33 mm. The ideal dimensions to use in a particular clinical situation cannot be determined by examining the results of this study.

The concept of a biologic width, as currently accepted (0.97 mm for the EA, and 1.07 mm for the CTA), requires a minimum of 2.04 mm of sound tooth structure above the osseous crest.[3-5,9,10] In the present study, 15% of the restorations violated these dimensions. In these samples the combined measurement of the EA and the CTA was less than 2.04 mm, and the restoration margin was less than 2 mm from the osseous crest. These findings suggest that a minimum dimension for the reestablishment of the biologic width may be less than previously reported.[3-5,9,10] This could be important when restoring teeth that have undergone root resective procedures that create tooth anatomy which does not allow for the establishment of acceptable dimensions of biologic width. For example, a recent article concluded that the biologic width, as currently perceived, is violated in 86% of distobuccal root resected maxillary first molars.[28] Further research is required to clearly establish the minimum dimensions of the dentogingival junction compatible with health in humans.

Conclusion

Within the limitations of this study and the use of individual teeth as the experimental units the following conclusions are presented:

(1) When comparing the dentogingival tissue dimensions between tooth surfaces (B, L, M, D), there were no significant differences for any of the tissue dimensions.

(2) No correlation was found between the LOA and the corresponding length of the CTA or biologic width (CTA+EA).

(3) While significant variation was noted in the length of the CTA, it was the least variable of the tissue dimensions evaluated.

(4) The epithelial attachment was significantly greater on tooth surfaces adjacent to subgingival restorations.

(5) Both the CTA and EA were significantly greater in the posterior sextants.

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