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# The gingival biotype revisited: transparency of the periodontal probe through the gingival margin as a method to discriminate thin from thick gingiva

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***Abstract***

**Aim:** To detect groups of subjects in a sample of 100 periodontally healthy volunteers with different combinations of morphometric data related to central maxillary incisors and surrounding soft tissues.

**Material and Methods:** Four clinical parameters were included in a cluster analysis: crown width/crown length ratio (CW/CL), gingival width (GW), papilla height (PH) and gingival thickness (GT). The latter was based on the transparency of the periodontal probe through the gingival margin while probing the buccal sulcus. Every first volunteer out of 10 was re-examined to evaluate intra-examiner repeatability for all variables.

**Results:** High agreement between duplicate recordings was found for all parameters, in particular for GT, pointing to 85% ($\kappa = 0.70$; $p = 0.002$). The partitioning method identified three clusters with specific features. Cluster A1 (nine males, 28 females) displayed a slender tooth form (CW/CL = 0.79), a GW of 4.92 mm, a PH of 4.29 mm and a thin gingiva (probe visible on one or both incisors in 100% of the subjects). Cluster A2 (29 males, five females) presented similar features (CW/CL = 0.77; GW = 5.2 mm; PH = 4.54 mm), except for GT. These subjects showed a clear thick gingiva (probe concealed on both incisors in 97% of the subjects). The third group (cluster B: 12 males, 17 females) differed substantially from the other clusters in many parameters. These subjects showed a more quadratic tooth form (CW/CL = 0.88), a broad zone of keratinized tissue (GW = 5.84 mm), low papillae (PH = 2.84 mm) and a thick gingiva (probe concealed on both incisors in 83% of the subjects).

**Conclusions:** The present analysis, using a simple and reproducible method for GT assessment, confirmed the existence of gingival biotypes. A clear thin gingiva was found in about one-third of the sample in mainly female subjects with slender teeth, a narrow zone of keratinized tissue and a highly scalloped gingival margin corresponding to the features of the previously introduced ''thin-scalloped biotype'' (cluster A1). A clear thick gingiva was found in about two-thirds of the sample in mainly male subjects. About half of them showed quadratic teeth, a broad zone of keratinized tissue and a flat gingival margin corresponding to the features of the previously introduced ''thick-flat biotype'' (cluster B). The other half could not be classified as such. These subjects showed a clear thick gingiva with slender teeth, a narrow zone of keratinized tissue and a high gingival scallop (cluster A2).

Key words: gingival biotype; gingival thickness; periodontal phenotype

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Earlier reports showed that the clinical appearance of healthy periodontal tissues differs from subject to subject (Olsson & Lindhe 1991). The bulky, slightly scalloped marginal gingiva with short and wide teeth on the one hand and the thin, highly scalloped marginal gingiva with slender teeth on the other may serve to illustrate the existence of markedly different periodontal entities or so-called ''gingival biotypes'' (Weisgold 1977, Seibert & Lindhe 1989). The identification of the gingival biotype may be important in clinical practice since differences in gingival and osseous architecture have been shown to exhibit a significant impact on the outcome of restorative therapy (Table 1). In natural teeth, Pontoriero & Carnevale (2001) showed more soft tissue regain following crown-lengthening procedures in patients with a so-called ''thick-flat biotype'' than in those with a ''thin-scalloped biotype''. This observation is in line with a higher prevalence of gingival recession in the latter as reported by Olsson & Lindhe (1991). Also at implant restorations, the gingival biotype has been described as one of the key elements decisive for a successful treatment outcome (Kois 2004). In particular, papilla presence between immediate single-tooth implants and adjacent teeth was significantly correlated with a thick-flat biotype (Romeo et al. 2008). In addition, a trend towards more gingival recession at immediate single-tooth implant restorations in patients with a thin-scalloped biotype was described (Evans & Chen 2008). Also, the outcome of regenerative surgery seems to be negatively influenced by the thickness of the soft tissues (Anderegg et al. 1995, Baldi et al. 1999). These observations illustrate that disparities in aesthetic treatment outcome could arise as a result of variability in tissue response to surgical trauma. The use of simple and reliable methods to identify the gingival biotype in clinical practice would be advantageous as this could help to tune the treatment for the individual and predict its specific outcome.

*Table 1.* Tissue response to inflammation, surgery and tooth extraction (Kao et al. 2008)

| | Thick gingival biotype | Thin gingival biotype |
|---|---|---|
| Inflammation | Soft tissues: marginal inflammation with pocket formation, bleeding on probing, oedema | Soft tissues: gingival recession without pocket formation |
| | Hard tissues: formation of infrabony defects | Hard tissues: loss of the thin vestibular bone plate |
| Surgery | Predictable hard and soft tissue healing | Delicate and unpredictable tissue healing (recession) |
| Tooth extraction | Minimal ridge resorption | Extensive ridge resorption in the apical and lingual direction |

Hitherto, a limited number of studies based on relatively small samples have been published using cluster analysis to identify subject groups with different combinations of morphometric data related to tooth and gingiva characteristics (Müller & Eger 1997, Müller et al. 2000a). In these studies, gingival thickness (GT) was determined using an ultrasonic device. Although this non-invasive method proved to be reproducible (Eger et al. 1996), drawbacks include difficulties in maintaining the directionality of the transducer (Daly & Wheeler 1971), unavailability of the device (Vandana & Savitha 2005) and high costs. These factors may be responsible for the fact that the device has not become part of the standard armamentarium of the clinician. Recently, a simple method has been proposed to discriminate thin from thick gingiva based on the transparency of the periodontal probe through the gingival margin (Kan et al. 2003). The objective of the present study was to identify the existence of gingival biotypes in a large sample of periodontally healthy volunteers using this visual method for GT assessment.

## Material and Methods

### Subjects

This study included clinical data on 100 medical students of the Free University in Brussels (VUB). Volunteers having all maxillary front teeth were included. The exclusion criteria were as follows:

(i) subjects with crown restorations or fillings involving the incisal edge on anterior maxillary teeth,
(ii) pregnant or lactating female volunteers,
(iii) subjects taking medication with any known effect on the periodontal soft tissues and
(iv) volunteers with clinical signs of periodontal disease defined as having pockets exceeding 3 mm.

All subjects were provided with oral hygiene instructions and tooth polishing. This was preceded by calculus removal, if necessary. All subjects consented to participate.

### Clinical parameters

Five clinical parameters were systematically recorded by one clinician at 1 week following oral hygiene instructions and dental cleaning:

(1) Crown width/crown length ratio (CW/CL) of the right central incisor was determined according to Olsson & Lindhe (1991). Assessments of width and length were recorded to the nearest 0.1 mm using a caliper. The crown length was measured between the incisal edge of the crown and the free gingival margin, or if discernible, the cemento-enamel junction. The length of the crown was divided into three equal portions of equal height. Crown width, i.e. the distance between the approximal tooth surfaces, was recorded at the border between the middle and the cervical portion.
(2) Gingiva width (GW) was measured midfacially with a periodontal probe (CPU 15 UNC, Hu-Friedy®, Chicago, IL, USA) to the nearest 0.5 mm. This parameter was defined as the distance from the free gingival margin to the mucogingival junction. Scores obtained from both central incisors were averaged.
(3) Papilla height (PH) was assessed to the nearest 0.5 mm using the same periodontal probe at the mesial and the distal aspect of both central incisors. This parameter was defined as the distance from the top of the papilla to a line connecting the

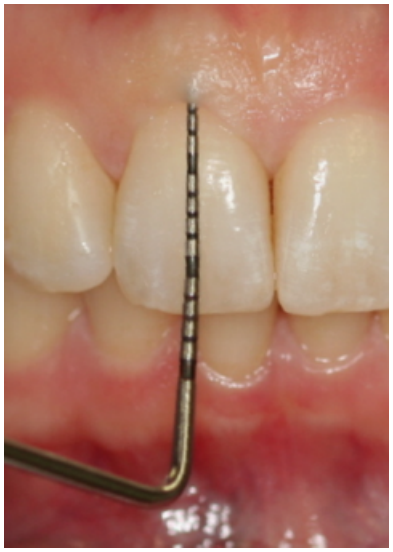

*Fig. 1.* Determination of gingival thickness using the periodontal probe.

midfacial soft tissue margin of the two adjacent teeth (Olsson et al. 1993). The mean value was calculated for the three papillae.

(4) GT was evaluated and categorized into thick or thin on a site level. This evaluation was based on the transparancy of the same periodontal probe through the gingival margin while probing the sulcus at the midfacial aspect of both central maxillary incisors (Kan et al. 2003). If the outline of the underlying periodontal probe could be seen through the gingival, it was categorized as thin (score: 0); if not, it was categorized as thick (score: 1). This resulted in three possible scores on a patient level: 0 (both central incisors with score 0), 1 (one central incisor with score 1) or 2 (both central incisors with score 1) (Fig. 1).

(5) Probing depth (PD) was measured to the nearest 0.5 mm at the midfacial aspect of both central incisors.

#### Intra-examiner repeatability

The intra-examiner repeatability of the clinician who performed all clinical examinations was analysed. Therefore, every first volunteer out of 10 was re-examined 1 week after the first recording by the same clinician.

#### Statistical analysis

For all continuous variables (CW/CL, GW and PH) intra-examiner repeatability was evaluated using Pearson's correlation coefficient. For GW and PH percentile agreement within 1 mm deviation was also calculated. Categorical variables (GT) were analysed by means of percentile agreement and Cohen's $\kappa$ statistics.

As already described, mean values and standard deviations were calculated per subject for all continuous variables. Significant disparities between men and women were assessed using the independent-samples *t*-test. The Fisher's exact test was adopted to evaluate the impact of gender on GT.

Cluster analysis based on Euclidian distances of four clinical parameters was used to detect groups in the morphometric data. A division of 100 subjects into three clusters was iteratively improved by non-hierarchical disjunct cluster analysis using a *k*-mean algorithm in order to reduce the within-group sum of squares (Hartigan & Wong 1979). In the search for significant differences among the clusters, one-way analysis of variance (continuous variables) and the Kruskal–Wallis test (categorical variables) were applied. Post hoc tests included Scheffe's test; the Mann–Whitney test corrected for multiple comparisons.

## Results

The study population consisted out of 100 periodontally healthy medical students. Fifty male and 50 female Caucasian volunteers were examined, with a mean age of 28 years (SD 9; minimum 19; maximum 56). Sixteen per cent of the subjects were smokers.

*Table 2.* Clinical characteristics of tooth form and gingiva in 100 subjects [mean (SD)]

| | Male participants | Female participants | Total | Minimum–maximum |
|---|---|---|---|---|
| Crown width/Crown length ratio | 0.80 (0.11) | 0.82 (0.11) | 0.81 (0.11) | 0.54–1.10 |
| Gingival width (mm) | 5.28 (0.88) | 5.30 (0.93) | 5.29 (0.90) | 3.0–7.5 |
| Papilla height (mm) | 4.12 (0.95) | 3.80 (0.97) | 3.96 (0.97) | 1.2–6.0 |
| Pocket depth (mm) | 1.47 (0.40) | 1.32 (0.46) | 1.40 (0.44) | 0.50–2.75 |

SD, standard deviation.

*Table 3.* Frequency distribution for gingival thickness

| | Male participants | Female participants* | Total |
|---|---|---|---|
| Score 0 (%) | 10 | 46 | 28 |
| Score 1 (%) | 12 | 18 | 15 |
| Score 2 (%) | 78 | 36 | 57 |

*Significant difference between male and female participants.

The reproducibility of the measurements was evaluated in 10 volunteers. Pearson's correlation coefficients were 0.948 ($p<0.001$), 0.824 ($p<0.001$) and 0.723 ($p<0.001$) for, respectively, CW/CL, GW and PH. All but one measurement of the GW and 87% of the assessed PH showed agreement within 1 mm deviation. The method to evaluate GT proved to be highly reproducible, with 85% agreement between duplicate measurements and a corresponding $\kappa$ of 0.70 ($p = 0.002$).

#### Clinical parameters

Table 2 presents descriptive statistics of four clinical parameters. CW/CL was a reference for the crown form of the right central incisor and was on average 0.81. The mean GW was 5.29 mm, PH 3.96 mm and PD 1.40 mm. There were no significant differences between men and women for any of these parameters, although a trend was shown for PH ($p = 0.101$) and PD ($p = 0.097$).

The frequency distribution for GT is depicted in Table 3. In more than half of the patients (57%), the gingiva was thick enough to conceal the periodontal probe at both incisors (score 2). The data on GT were significantly different between men and women ($p<0.001$): Seventy-eight per cent of the male participants displayed a score 2 corresponding to a clear thick gingiva, while only 36% of the female participants showed this score.

#### Cluster analysis

The partitioning method identified three groups using the morphometric data

*Table 4*. Clinical characteristics of tooth form and gingiva [mean (SD)] per cluster

| | Cluster A1 | Cluster A2 | Cluster B |
|---|---|---|---|
| Prevalence (%) | 37 | 34 | 29 |
| Crown width/Crown length ratio | 0.79 (0.09) | 0.77 (0.09) | 0.88 (0.13)†* |
| Gingival width (mm) | 4.92 (0.80) | 5.20 (0.89) | 5.84 (0.79)†* |
| Papilla height (mm) | 4.29 (0.70) | 4.54 (0.65) | 2.84 (0.58)†* |
| Pocket depth (mm) | 1.23 (0.40) | 1.45 (0.39) | 1.55 (0.47)* |

†Significant difference between clusters A2 & B.
*Significant difference between clusters A1 & B.
SD, standard deviation.

*Table 5*. Frequency distribution for gingival thickness per cluster

| | Cluster A1 | Cluster A2† | Cluster B* |
|---|---|---|---|
| Score 0 (%) | 73 | 0 | 3 |
| Score 1 (%) | 27 | 3 | 14 |
| Score 2 (%) | 0 | 97 | 83 |

†Significant difference between clusters A1 & A2.
*Significant difference between clusters A1 & B.

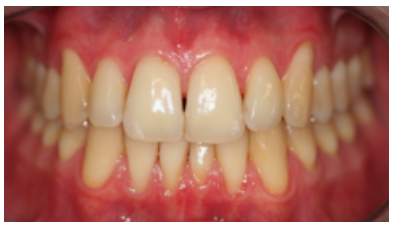

*Fig. 2*. Clinical example of a subject of cluster A1.

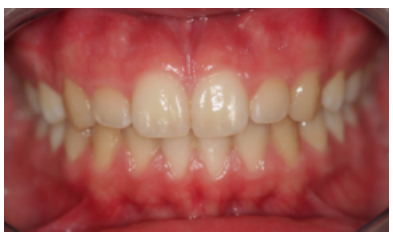

*Fig. 3*. Clinical example of a subject of cluster A2.

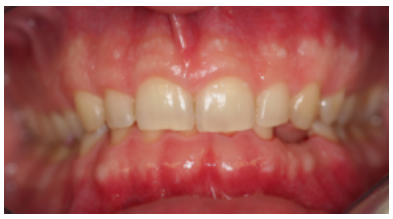

*Fig. 4*. Clinical example of a subject of cluster B.

obtained from the 100 participants. The specific features of each cluster are presented in Tables 4 and 5. Cluster A1 comprised 37 participants (nine men and 28 women), cluster A2 34 (29 men and five women) and cluster B 29 (12 men and 17 women).

Cluster A1 (Fig. 2) displayed a slender tooth form (CW/CL = 0.79), a GW of 4.92 mm, a PH of 4.29 mm and a thin gingiva (probe visible on one or both incisors in 100% of the subjects). Cluster A2 (Fig. 3) presented similar features (CW/CL = 0.77; GW = 5.2 mm; PH = 4.54 mm) with no significant differences for these parameters in comparison with cluster A1 ($p \geqslant 0.281$). However, subjects of cluster A2 showed a clear thick gingiva (probe concealed on both incisors in 97% of the subjects) ($p < 0.001$). A trend towards slightly deeper PD was also found in subjects of cluster A2 when compared with those of cluster A1 ($p = 0.095$).

Twenty-nine participants comprising cluster B (Fig. 4) had a more quadratic tooth form (CW/CL = 0.88) when compared with subjects of cluster A1 ($p = 0.003$) and A2 ($p < 0.001$). More apical contact areas and significantly lower papilla levels (PH = 2.84 mm) in comparison with cluster A1 ($p < 0.001$) and A2 ($p < 0.001$) were in line with this observation. The mean GW of 5.84 mm in cluster B was significantly higher when compared with clusters A1 ($p < 0.001$) and A2 ($p = 0.014$). A significant disparity between clusters B and A1 was also found in terms of GT ($p < 0.001$): 83% of the subjects of cluster B showed a clear thick gingiva. The mean PD of 1.55 mm for cluster B was significantly higher in comparison with cluster A1 ($p = 0.010$).

## Discussion

For a restoration to be a success, it should closely resemble what once existed in nature from a functional as from an aesthetic point of view. Complete harmony and symmetry of a restoration with the surrounding soft tissues may be most challenging and can therefore be considered the ultimate goal in terms of esthetics. Evidently, an insight into the morphological appearance of the periodontal structures and teeth is a prerequisite to accomplish this goal in a predictable way.

Previous studies have already shown considerable variation between individuals with regard to the morphological characteristics of the periodontium and teeth. Already in 1989 the existence of distinct morphotypes – so-called ''periodontal biotypes'' – was suggested (Seibert & Lindhe 1989). Later on, the specific features of these biotypes were well defined by Olsson et al. (1993). The objective of the present study was to evaluate whether groups of subjects with different morphometric combinations truly exist in a large sample using simple diagnostic methods. We decided only to include central maxillary incisors as reference teeth because differences between biotypes are most explicit for these teeth and because their specific features are easily found in other parts of the dentition (Olsson & Lindhe 1991, Olsson et al. 1993, Müller et al. 2000a).

Only one parameter, notably GT, presented a significant difference between male and female subjects. That is, 84% of all measured central incisors of male participants showed a gingiva that was thick enough to conceal the periodontal probe while probing the buccal sulcus. The equivalent value for females was only 45%. This disparity could be expected since previous reports had already demonstrated a generally thinner masticatory mucosa for females (Müller et al. 2000b, Vandana & Savitha 2005).

Cluster analysis encompasses a number of different algorithms and methods for grouping data of similar kind into respective categories. Theoretically, any number up to 100 partitions could be generated by this exploratory approach; yet, the identification of more than three clusters resulted in partitions of questionable clinical meaning. We applied cluster analysis to categorize subjects with similar morphometric characteristics and identified three groups (clusters A1, A2 and B) with a comparable number of individuals on the basis of four clinical parameters, i.e. CW/WL, GW, PH and GT. Our results indicated a high intra-examiner repeatability for GT assessment, substantiating the clinical usefulness of the simple method as

proposed by Kan et al. (2003). By and large, clusters A1 and A2 showed similar tooth and gingiva characteristics. Specific features included slender teeth, a relatively narrow zone of keratinized tissue and a highly scalloped gingival margin. In cluster A1, the vast majority of the subjects showed a clear thin gingiva. Because our results showed a higher prevalence of a thin gingiva in female volunteers, it should not be surprising that cluster A1 mainly consisted of females. Interestingly, the characteristics of this cluster seemed to correspond to the features of the previously introduced ''thin-scalloped biotype'' (Weisgold 1977, Seibert & Lindhe 1989).

In contrast to the subjects of cluster A1, those of cluster A2 were mostly male volunteers showing a clear thick gingiva. This observation failed to support the hypothesis that a slender tooth form always merges with a thin gingiva, which is in accordance with earlier reports. Olsson et al. (1993) described the lack of a significant relationship between CW/CL and GT. Also, Eger et al. (1996) failed to observe a meaningful association between these parameters. In addition, a relationship between tooth shape and bone morphology could not be confirmed (Becker et al. 1997).

In the present study a third cluster could be identified (cluster B), in which subjects mainly presented a thick gingiva as in cluster A2. However, the other clinical parameters of cluster B differed substantially from the other clusters. Specific features included short and wide teeth, a broad zone of keratinized tissue and a flat, slightly scalloped gingival margin. These characteristics seemed to correspond to the features of the previously introduced ''thick-flat biotype'' (Weisgold 1977, Seibert & Lindhe 1989). As a result, about two-thirds of our sample (clusters A1 and B) showed high similarity to earlier defined gingival biotypes, whereas one-third (cluster A2) with a clear thick gingiva could not be classified as such. This observation is imperative as it shows that a clear thick gingiva only comes in about half of the cases with quadratic teeth, a broad zone of keratinized tissue and a flat gingival margin.

Former studies using cluster analysis also revealed three groups of subjects with different combinations of morphometric data related to maxillary front teeth and surrounding soft tissues (Müller & Eger 1997, Müller et al. 2000a). Both studies described groups that could be identified with some of the clusters in the present study. The subjects comprising clusters A and B in the study of Müller & Eger (1997) resembled those of, respectively, clusters A1 and B in this report. In the same manner we could identify clusters A1 and B in a subsequent report by Müller et al. (2000a), which presented features comparable to the similarly labelled clusters of the current study including their prevalence (A1: 35% and B: 28% in the study by Müller et al. (2000a); A1: 37% and B: 29% in this study). Interestingly, the remaining third cluster in the studies showed little resemblance. In particular, cluster C in the report by Müller & Eger (1997), characterized by a thin and narrow gingiva at the maxillary front teeth in conjunction with a quadratic tooth form, could neither be identified with cluster A2 in their subsequent report (Müller et al. 2000a), nor with the features of cluster A2 in the present study. The fact that the conditions of two groups of the current study (clusters A1 and B) can be compared with those of two groups in earlier studies may confirm the existence of two biotypes within a population. At the same time, it is clear that about one-third of the population cannot be classified in a uniform way, given the observed inconsistencies. This observation highlights a possible impact of racial and genetic variation on the morphology of teeth and soft tissues (Vandana & Savitha 2005). In addition, the influence of the bucco-lingual tooth position within the alveolar process should not be underestimated. In fact, Müller & Könönen (2005) showed that most of the variation in GT was related to this position and only to a minor extent to subject variability (i.e. thin-scalloped and thick-flat biotype).

In the present study, a low midfacial pocket depth was systematically recorded, which should not be surprising because only periodontally healthy patients were included. Still, the observed disparity in pocket depth between the clusters remained noteworthy. At buccal surfaces, the mean value increased gradually from 1.23 mm (cluster A1) over 1.45 mm (cluster A2) to 1.55 mm (cluster B). A statistically significant difference between clusters A1 and B was found, which may have been the result of a high sample size. The clinical relevance of this difference, however, seems negligible, and the proximity of the mean data suggests closely overlapping pocket depth distributions, making this parameter inappropriate to predict the gingival biotype in a patient. Still, a comparable distinction in pocket depth was noticed by Olsson et al. (1993). These and our data confirm that shallower pockets may be expected in patients with a thin-scalloped biotype and that deeper pockets coincide with a thick-flat biotype. An explanation for this observation has been provided earlier: patients with a quadratic crown form have a thicker periodontium and may respond to gingival inflammation by means of pocket formation. In contrast, individuals with a tapered crown form and a comparatively thinner periodontium may be more susceptible to gingival recession (Weisgold 1977, Seibert & Lindhe 1989, Olsson & Lindhe 1991).

In conclusion, the present analysis, using a simple and reproducible method for GT assessment, confirmed the existence of gingival biotypes. A clear thin gingiva was found in about one-third of the sample in mainly female subjects with slender teeth, a narrow zone of keratinized tissue and a highly scalloped gingival margin corresponding to the features of the previously introduced ''thin-scalloped biotype'' (cluster A1). A clear thick gingiva was found in about two-thirds of the sample in mainly male subjects. About half of them showed quadratic teeth, a broad zone of keratinized tissue and a flat gingival margin corresponding to the features of the previously introduced ''thick-flat biotype'' (cluster B). The other half could not be classified as such. These subjects showed a clear thick gingiva with slender teeth, a narrow zone of keratinized tissue and a high gingival scallop (cluster A2).

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**Clinical Relevance**

*Scientific rationale for the study*: The identification of groups of subjects with different combinations of morphometric data related to tooth and gingiva characteristics needs documentation in a large study sample. Furthermore, the use of simple methods to produce these data has not yet been described.

*Principal findings*: Two-thirds of the subject sample corresponded well with the features of previously described ''thin-scalloped'' and ''thick-flat'' biotypes. However, one-third with a clear thick gingiva could not be classified as such.

*Practical implications*: A clear thick gingiva only comes in about half of the cases with quadratic teeth, a broad zone of keratinized tissue and a flat gingival margin.