

## Smile Esthetics: The Influence of Posterior Maxillary Gingival Margin Position

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#### Abstract

**Purpose:** Successful replacement of posterior teeth using contemporary prosthodontic techniques in esthetically demanding cases relies upon visual replication of the natural posterior dentition and surrounding gingival architecture. There is currently little in the way of guidance for creating ideal or acceptable gingival relationships for posterior teeth.

**Materials and Methods:** A cross-sectional study was conducted comparing perceptions of four groups of individuals to six digitally manipulated images with various posterior teeth gingival margin position configurations. A total of 120 volunteers aged 12 years to 80 years, comprising 30 patients diagnosed with hypodontia, 30 patients diagnosed with periodontal disease, 30 patients without either condition, and 30 qualified dentists were recruited from the Eastman Dental Institute & Hospital, London. A ranked order of preference for each set was obtained, and this was repeated after a minimum time interval of 10 minutes.

**Results:** Posterior gingival margin configurations from 0 mm to 2 mm (measured at the first premolar) were deemed most esthetic by the majority of the patient groups; dentists had a strong preference for the 1 mm configuration. Dentists appeared to be more perceptive to the alterations in gingival positions.

**Conclusions:** Posterior gingival margin configurations where the first premolar margins were 1 mm lower than the canine margins were deemed the most esthetically pleasing; however, it is likely that a range of acceptability of 1 mm deviations from this ideal exists.

Esthetic prosthodontic reconstruction/replacement of natural dentition and surrounding structures relies upon the reestablishment of harmonious relationships of smile components. Creating a natural esthetic smile is dependent upon the appearance, contour, and positioning of the teeth, gingiva, and lips. There is currently a lack of guidance for prosthodontists when considering replacement of natural posterior teeth. In esthetically demanding cases, where posterior teeth and gingiva are displayed when the patient is smiling, the importance of creating a natural appearance for the anterior and posterior teeth is critical. To date, the importance the population places on the esthetics of the posterior dentition is largely unknown. As contemporary prosthodontics strives to meet the expectations of patients, appropriate esthetic management of such cases demands an appreciation of what would be considered ideal and acceptable to patients.

The spatial relationship of the gingival margins (gingival configuration) to the teeth and lips, which frame the smile, is important in achieving smile harmony. While there is limited information regarding the optimal configuration of gingival relationships for anterior teeth,<sup>1,2</sup> there is currently no guidance relative to ideal gingival relationships for posterior teeth.

Ideally, the gingiva forms a parabolic contour around the clinical crowns of the teeth. Gingival margin positioning is influenced by cementoenamel junctions (CEJs), periodontal attachments, and morphology of the surrounding alveolus in the natural dentition. Proposals for ideal anterior gingival margin configurations have been made.<sup>1</sup> It has been proposed that the gingival levels on contralateral teeth should be symmetrical,<sup>1,2</sup> and that the heights of the gingival contours for maxillary lateral incisors should be at the same level or slightly lower than the central incisors and canines.<sup>1,2</sup> It has also been suggested that the gingival height of the maxillary central incisors and the canines should ideally be similar.<sup>1</sup>

A number of esthetic and unesthetic gingival arrangements for anterior teeth were proposed by Chiche and Pinault.<sup>2</sup> These concurred with the belief that the maxillary lateral incisor gingival margin should ideally be situated below or along a tangent drawn from the gingival margin of the central incisor to that of the canine. Asymmetries of the lateral incisor margins were still deemed esthetic, provided they were along or incisal to this line. Unesthetic gingival patterns included arrangements where the lateral incisor margins were superior to this tangent line, unilaterally or bilaterally, and asymmetries of the central incisor gingival margin heights. Recent investigations by Chu et al<sup>3</sup> of anterior sites in 20 healthy patients, confirmed that usually gingival margin positions of the maxillary lateral incisors were approximately 1 mm lower than the adjacent central incisor to canine gingival margin tangents. To the authors' knowledge, no specific studies relating to ideal posterior gingival contours have been conducted. It can be assumed from these findings relating to anterior teeth that asymmetries would be undesirable.

For dental implant restorations, peri-implant soft tissue positioning is determined by a number of factors: general shape of the teeth,<sup>4</sup> 3D implant positioning,<sup>5</sup> osseous morphology,<sup>6,7</sup> restoration contour,<sup>8-11</sup> proximity to adjacent teeth<sup>5</sup> or implants,<sup>12</sup> soft tissue thickness, and gingival biotype. There is thus the possibility of influencing the gingival margin positioning through modification of coronal restoration contours and emergence profiles,<sup>10,11</sup> osseous or soft tissue surgical procedures, or orthodontic tooth movement.<sup>1</sup>

The conditions for achieving optimal gingival esthetics may be compromised due to local anatomical constraints. Esthetic reconstruction is more challenging where significant deficiencies in alveolar bone and soft tissue exist. This is a common problem for those involved in dental implant reconstruction of patients who have lost teeth due to periodontal disease or patients who suffer from hypodontia. For patients affected by periodontal disease, the resultant compromises in dental esthetics, such as gingival recession and missing teeth, can affect the amount of teeth displayed, or cause patients to hide their mouth when smiling.<sup>13</sup> Oral-health-related quality of life studies have demonstrated a significant psychological impact by the disease process due to esthetic concerns.<sup>14</sup> Prosthodontic rehabilitation of patients with periodontally compromised teeth or teeth that failed to develop is often difficult without accepting a degree of esthetic compromise. This is true even with contemporary techniques, particularly with respect to replicating the gingival architecture.<sup>15</sup> Perceptions of periodontally compromised patients and hypodontia patients regarding compromised smile esthetics are largely unknown.

Although some proposals have been made for ideal gingival configurations of anterior teeth, to the authors' knowledge, no study of posterior gingival margin relationships has been reported. The aim of this study was to determine if the perceptions of smile esthetics by patients with hypodontia, patients with periodontal disease, patients without either condition, or dentists were influenced by variations in posterior gingival margin position.

## **Materials and methods**

Ethical approval was obtained by the Joint UCL/UCLH Committee on the Ethics of Human Research (REC 08/H0714/13). Digital manipulation of two photographic images of a woman with a naturally occurring high lip line was completed using Adobe Photoshop<sup>®</sup> (9.0 CS2 software; Adobe Systems Inc., San Jose, CA). A standardized baseline image was created by combining one lower facial extraoral and one intraoral image. It was constructed to adhere to many of the reported esthetic ideals with respect to dental, gingival, and facial soft tissue relationships.<sup>1–3,16–25</sup> Images were scaled to life size before the measurements and manipulations were completed.

Features of the standardized image included the following:

- 1. Coincident dental midlines bisecting the philtrum of the lip.
- Smile consisting of two symmetrical halves with the incisal edges and cusp tips in a smooth smile arc curving upward posteriorly, parallel to the upper border of the lower lip.<sup>16,17</sup>
- 3. Low smile index (3.4) giving the appearance of a youthful smile. The smile index is the width of the smile (intercommisure width) divided by the height of opening (interlabial distance on smiling).<sup>18</sup>
- Greater than or equal to 75% of the maxillary central incisors positioned below the lower border of the upper lip.<sup>19</sup>
- 5. Broad smile, where >98% of the width between the inner commissures was filled with visible maxillary dentition.<sup>20</sup>
- 6. Tooth width proportions of the anterior dentition when viewed from the front was within the acceptable proportional range (70%).<sup>21</sup>
- 7. Maxillary central incisor dominance, with an acceptable tooth proportion (80%).<sup>22</sup>
- 8. Slight upward curvature of the upper lip.<sup>23</sup>
- 9. An ideal gingival margin relationship<sup>2</sup> with the apical extent of maxillary central incisor and canine gingival margins (zenith points) higher than those of the lateral incisors and premolars. The lateral incisor gingival margins were positioned just incisal to a tangent line linking zenith points of the central incisor and canine teeth.<sup>1,3</sup>

Six photographs were created with modifications applied bilaterally to the posterior gingival margins. No reported esthetic ideals relating to posterior gingival margin positioning could be found within the literature. It was assumed that the optimal gingival margin position would be just below the level of a zenith line linking the apical extent of the gingival margins of the canine and first molar teeth. From this line, gingival margins of the maxillary first premolar, second premolar, and first molar tooth were manipulated vertically in the direction of the long axis of each respective tooth. To maintain perspective, the magnitude of change decreased the more posterior the tooth. The maxillary first premolar gingival margin was moved vertically by 1 mm intervals, the second premolar by 0.75 mm intervals, and the first molar by 0.5 mm intervals in apical and occlusal directions (Figs 1 and 2).

The photographs were printed life size on high-quality gloss finish photographic paper using a photo-quality color inkjet printer (Canon<sup>®</sup> Pixma iP8500, Canon UK, Surrey, UK) on high quality settings and full Canon<sup>®</sup> ink cartridges. Each



Figure 1 Layer template used for gingival manipulation of the posterior teeth: 1 mm intervals (first premolar), 0.75 mm intervals (second premolar), and 0.5 mm intervals (first molar).



**Figure 2** Posterior gingival margin configurations (A-F): 1 mm intervals (first premolar), 0.75 mm intervals (second premolar), and 0.5 mm intervals (first molar). Measured from canine to the first molar zenith line in inferior direction, at first premolar – 1 mm (A) to +4 mm (F).

photograph was assigned an exclusive symbol on the reverse surface for identification purposes. Participants were asked to keep the photographs face-up during their evaluations.

Participants were asked to arrange the photographs in order of preferred smile esthetics. Thirty participants were recruited into each group: hypodontia group, periodontal group diagnosed with chronic or aggressive periodontitis and periodontal probing depths of 4 mm or greater (basic periodontal examination codes  $\geq$  3), a control group of patients undergoing dental treatment who, from their records, had no evidence of hypodontia or periodontitis (basic periodontal examination codes  $\leq$  2), and a dentist group.

Statistically it was recommended that 30 participants be recruited for each group. Sample size estimation was based on the results of a study with similar methodology by Buckhary et al.<sup>21</sup> Formal sample size calculations were not deemed appropriate in this instance, due to the use of a different set of photographs, where the clinical relevance of perceived differences were unknown.

Healthy participants (50 male, 70 female) aged between 12 years and 80 years were recruited to these groups from the Departments of Prosthodontics, Periodontology, Endodontics, and Orthodontics, of the Eastman Dental Hospital (please refer to Table 1 for a breakdown of age, gender, and ethnicity). Because this study required clear understanding and adequate visual acuity to perform the task and to ensure consistency of the information being provided, patients who did not speak English, patients with special communication needs, or patients with severe sight impairment were not recruited.

The participants were asked to complete a short questionnaire that included a 10 cm visual analog scale to record the level of concern with their own dental appearance, with the extreme endpoints of "no concern whatsoever" to "as concerned as it is possible to be." The life-sized smile photographs were then ranked by the participant from "most attractive" (best) to "least attractive" (worst). Participants were given a maximum of 2 minutes to complete the tasks. Participants viewed each series of photographs in similar ambient lighting conditions. Photographic ranking was repeated after a minimum time interval of 10 minutes.

Data were analyzed using SPSS for Windows (Version 12.0; SPSS Inc, Chicago, IL). The "best" selection for each participant was tested against participant group, gender, and ethnicity using Pearson's chi-square and participant age using one-way ANOVA. Cohen's Kappa and the associated 95% confidence intervals were calculated to assess the level of

Table 1	Demographics and visua	I analog scale results f	or personal dental	appearance of participants
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		Hypodontia	Periodontal	Control	Dentists	All groups
Age (years)	Mean	20.56	49.25	37.41	33.57	35.20
	Median	16.53	47.14	34.26	31.73	33.03
	Min	12.08	27.01	18.55	26.70	12.00
	Max	41.48	73.82	77.04	61.06	77.04
Gender (frequency and percentage)	Male	12 (40%)	9 (30%)	10 (33%)	19 (63%)	50 (42%)
	Female	18 (60%)	21 (70%)	20 (67%)	11 (37%)	70 (58%)
Ethnic origin (frequency and percentage)	White	24 (80%)	23 (77%)	20 (67%)	16 (53%)	83 (69%)
	Nonwhite	6 (20%)	7 (23%)	10 (33%)	14 (47%)	37 (31%)
Personal dental appearance concern (VAS 0 mm to 100 mm)	Mean	63.83	74.50*	52.13*	63.73	63.55
	Median	67.5	86	44.5	74	72.5
	Min	2	9	0	1	0
	Max	99	100	100	100	100

\*Statistically significant difference p < 0.05 (one-way ANOVA).

agreement between initial and repeat assessments by the participants for the best and worst photographs in each set. Kappa with linear weightage ( $w\kappa$ ) was also calculated, allowing for recognition of close repeat measurements. A weightage of 0.5 was applied for a difference of one position, and 0.25 applied for a difference of two positions in cross-tabulations.

#### Results

#### **Descriptive statistics**

Demographic data collected from the four participant groups are displayed in Table 1. Female participants were more concerned about their dental appearance (mean 67%) than the males were (mean 52%); however, this difference was not statistically significant at the 5% level (p = 0.134).

# Effect of modifying posterior gingival margin positioning bilaterally

Figures 3–6 display the preferences for the six manipulated photographs (Fig 2) for the four participant groups. There was a general preference for the 1 mm (C) and 2 mm (D) photographs for the "most attractive" (best) selections. The 1 mm photograph was favored by the periodontal and dentist groups (36.7% and 63.3%, respectively). The 2 mm photograph was marginally preferred as the most esthetic by the hypodontia and control groups (26.7% and 33.3%, respectively, compared to 23.3% and 30% for the 1 mm photo). The two extremes of 4 mm and -1 mm were deemed least esthetic, with 4 mm least preferable across all groups (33.3% of the hypodontia, 33.3% of the periodontal, 43.3% of the control, and 60% of the dentist participants).

Analysis of the most- and least-favored selection distributions (Figs 7 and 8) confirmed a strong preference among dentists for the 1 mm arrangement; an almost normal distribution of preferences was apparent. The periodontal group demonstrated a similar preference but were less unified in their responses for the most attractive photograph. The hypodontia group was almost evenly divided between their preferences of 0 mm to 2 mm. The control group indicated a marginal preference for 2 mm over 1 mm posterior gingival arrangements. There was generally moderate-to-poor agreement when the task was repeated, reflected by the Kappa scores (Tables 2 and 3). The dentist and control groups exhibited the greatest repeatability, where weighted Kappa scores showed moderate agreement (w $\kappa = 0.21, 0.24$  for most and 0.32, 0.50, respectively, for least attractive).

#### **Statistical analysis**

Global statistical analysis revealed no statistically significant differences between the best selections for each of the participant groups (p = 0.398). No statistically significant differences were found between the best choices relating to gender, ethnicity, or age of the participants (p-values = 0.056, 0.893, and 0.429, respectively).

## Discussion

#### Photographs

The manipulated photographic images were created using a novel approach that enabled the creation of a baseline image adhering to as many of the previously reported concepts of smile esthetics as possible. This allowed standardization of the images so that the only differences between the images were the posterior gingival margin positions; unwanted distractions were minimized. It was important to create an esthetically demanding situation, where a broad smile with generalized gingival display existed.

Although full facial photographs have been previously used to investigate aspects of the smile,<sup>24-27</sup> this was avoided in this instance, as the facial features could detract from the assessment of the particular variables investigated. The use of life-sized photographs made the evaluation as realistic as possible.

When investigating altered gingival margin positions, it is unfortunately impossible to investigate this aspect alone, without affecting other aspects of the smile esthetics. Either the tooth proportions are maintained, and the tooth is moved bodily, or the gingival margin is moved, and incisal edges or cusp tips remain in the same positions. The former option significantly





**Figure 4** Overview of periodontal group perceptions of changes in posterior gingival margin vertical positions bilaterally (measured at the first premolar; second premolar 0.75 of value, first molar 0.5 of value).

**Figure 5** Overview of control group perception of changes in posterior gingival margin vertical positions bilaterally (measured at the first premolar; second premolar 0.75 of value, first molar 0.5 of value).



**Figure 6** Overview of dentist group perception of change in posterior gingival margin vertical positions bilaterally (measured at the first premolar; second premolar 0.75 of value, first molar 0.5 of value).

**Figure 7** Perception of "most attractive" smile following modification of the posterior gingival margin levels (measured at the first premolar; second premolar 0.75 of value, first molar 0.5 of value).

**Figure 8** Perception of "least attractive" smile following modification of the posterior gingival margin levels (measured at the first premolar; second premolar 0.75 of value, first molar 0.5 of value).

affects smile esthetics by disrupting the harmony of incisal curvature and smile arc relation (parallelism of incisal edges and cusp tips to the lower lip curvature), considered important for smile esthetics.<sup>17</sup> The latter causes a degree of distortion of tooth proportions, but does not disturb the harmony of the smile arc. This has greater relevance to gingival esthetics and from

**Table 2** Cohen's Kappa ( $\kappa$ ) for initial-repeat recording agreement for most attractive (best) and least attractive (worst) choices for each participant group and collectively (overall). Key for interpreting Kappa<sup>28</sup>: Moderate agreement (0.21 $\leq \kappa \leq 0.40$ ) in bold; poor agreement ( $\kappa \leq 0.20$ ) not bold

	Hypodontia	Perio	Control	Dentists	Overall
Best	0.09 (0.00, 0.29)	0.01 (0.00, 0.19)	0.20 (0.00, 0.43)	0.02 (0.00, 0.29)	0.10 (0.00, 0.20)
Worst	0.26 (0.04, 0.47)	0.04 (0.00, 0.33)	0.36 (0.15, 0.58)	0.32 (0.04, 0.61)	0.25 (0.13, 0.36)

95% Confidence interval displayed in brackets.

**Table 3** Kappa with linear weighting (w $\kappa$ ) for initial-repeat recording agreement for most attractive (best) and least attractive (worst) choices for each participant group and collectively (overall). Key for interpreting Kappa<sup>28</sup>: reasonable agreement (0.41 $\leq\kappa\leq$ 0.60) *shaded*; moderate agreement (0.21 $\leq\kappa\leq$ 0.40) in bold; poor agreement ( $\kappa\leq$ 0.20) not bold

	Hypodontia	Perio	Control	Dentists	Overall
Best	0.10 (0.00, 0.38)	0.03 (0.00, 0.18)	0.24 (0.00, 0.47)	0.21 (0.00,0.53)	0.18 (0.00,0.51)
Worst	0.33 (0.08, 0.58)	0.13 (0.00, 0.38)	0.50 (0.24, 0.75)	0.32 (0.00, 0.64)	0.33 (0.15, 0.51)

95% Confidence interval displayed in brackets.

a clinical viewpoint is more relevant to prosthodontic or periodontal management. The authors accept that the effect of the manipulations on tooth proportions means that the results may not be purely attributable to the gingival margin discrepancies alone.

#### **Participant demographics**

Participant ages varied across the groups. As anticipated, the periodontal group was generally older (mean 49.3 years), and the hypodontia group younger (mean 20.6 years) than the control and dentist groups (mean 37.4 years and 33.6 years, respectively), reflecting the age at which these patients require restorative or orthodontic treatment. Younger participants may not be able to distinguish the subtle differences in the photographs and could be reflected in broader distribution of preferences observed within the hypodontia group. Patients undergoing dental treatment were selected as a control because they would more closely represent general dental patients; comparisons made between this and other groups would be more attributable to the presenting dental condition.

The mean visual analog scale assessments of the level of concern with the participants' own dental appearance ranged from 52.1% (control group) to 74.5% (periodontal group): all groups resulted in wide-ranging values. Bearing in mind that extreme end-points of the scale were "no concern whatsoever" and "as concerned as it is possible to be," examination of the median scores indicated a high proportion of the periodontal and dentist groups were extremely concerned about their dental appearance. The results indicated that other dental conditions do not appear to affect the level of perceived esthetic compromise, that hypodontia, and to a greater degree, periodontal disease, brings. Statistical significance was found between the periodontal and control groups regarding levels of dental appearance (p = 0.036). This is consistent with the findings of quality of life studies,<sup>13,14</sup> which indicate a high oral esthetic awareness and negative impact of esthetic compromise by periodontal patients. Dentists' level of concern was surprisingly high and may be attributed to the interest and focus on their personal dental appearance as a result of their training and professional experience.

## Effect of modifying posterior gingival margin levels

Analysis of the distribution of ranked preferences (Figs 3–6) demonstrated a clear difference between the dentists, who were generally more unified in their preferences and possibly more perceptive to the subtle changes, and the three patient groups, where similar trends were apparent, but the distributions more dispersed. A general preference for the 1 mm arrangement was strongly advocated by the dentist group (63%) and to a lesser degree the periodontal group (37%). Opinion as to the most esthetic arrangement was split between 1 mm and 2 mm images for the control group and 0 mm, 1 mm, and 2 mm images for the hypodontia group. The level of dispersion of the selection frequencies was either a reflection of a true mixture of preferences within the groups, or an indication that the changes in appearance were not perceived by as many of the participants within the group.

Cohen's Kappa ( $\kappa$ ) and linear-weighted Kappa ( $w\kappa$ ) scores were both included, for comparison and clarity. The relatively low Kappa scores indicated that the 10-minute minimum time interval between assessments appeared to be adequate; they may also be a reflection of a low perceived magnitude of variation between the individual modifications made within each set of photographs.

Dentists seemed more perceptive to changes in posterior gingival positioning. Between the patient groups it was less clear cut. The periodontal group and the control group appeared collectively more in agreement about their perceived ideals. The results indicated that participant age and the degree of personal dental concern could be influential factors in the participants' ability to detect fine differences between dental photographs, but this is contradicted by the poor repeatability of the periodontal group.

It is likely that although dentists perceived a clear ideal relationship (1 mm), a range of acceptable relationships (0 mm



Figure 9 Zone of esthetically acceptable posterior gingival configurations.

to 2 mm), existed within the patient populations investigated. Accepting that a small number of configurations were investigated, but with no comparable ideals for posterior gingival margin arrangements available in the literature, the authors propose that a zone of esthetically pleasing arrangements exists. From the results of this study, the zone extends inferiorly from a tangent line between the apical extents of maxillary canine gingival margins to the lower border of the upper lip superior to the first molar. The zone of acceptable margin relationships extended 2 mm occlusally at the maxillary first premolar and 1 mm occlusally at the first molar (Figs 9 and 10).

#### Limitations

Intergroup comparison must be evaluated with caution, as the participant groups were not matched for age, gender, or ethnicity. Participants were recruited from a postgraduate dental teaching hospital; their opinions may not be representative of general dental patients or dentists. Identifying the point at which discrepancies were deemed to require operative intervention would be a useful modification to the study design and could be an aspect for investigation with future research. This



Figure 10 Zone of esthetically acceptable configurations (yellow zone) with configurations tested (green lines).

would give an indication to clinicians as to a threshold that a discrepancy is likely to be deemed unacceptable to patients, and treatment could be targeted accordingly.

## Conclusions

Within the limitations of this study, it was possible to draw the following conclusions:

- 1. A strong preference was indicated by the dentists for the 1 mm posterior gingival margin configuration.
- 2. Patients indicated that a zone of esthetically acceptable posterior gingival configurations existed. The superior border of this zone formed a line linking the apical extents of maxillary canine gingival margins to the lower border of the upper lip at the first molar. The inferior border of the zone of acceptable posterior configurations extended 2 mm apically at the maxillary first premolar and 1 mm apically at the first molar (Figs 9 and 10).

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