



Maxillary Anterior Papilla Display During Smiling: A Clinical Study of the Interdental Smile Line



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The purpose of this research was to quantify the visual display (presence) or lack of display (absence) of interdental papillae during maximum smiling in a patient population aged 10 to 89 years. Four hundred twenty digital single-lens reflex photographs of patients were taken and examined for the visual display of interdental papillae between the maxillary anterior teeth during maximum smiling. Three digital photographs were taken per patient from the frontal, right frontal-lateral, and left frontal-lateral views. The data set of photographs was examined by two examiners for the presence or absence of the visual display of papillae. The visual display of interdental papillae during maximum smiling occurred in 380 of the 420 patients examined in this study, equivalent to a 91% occurrence rate. Eighty-seven percent of all patients categorized as having a low gingival smile line (n = 303) were found to display the interdental papillae upon smiling. Differences were noted for individual age groups according to the decade of life as well as a trend toward decreasing papillary display with increasing age. The importance of interdental papillae display during dynamic smiling should not be left undiagnosed since it is visible in over 91% of older patients and in 87% of patients with a low gingival smile line, representing a common and important esthetic element that needs to be assessed during smile analysis of the patient. (Int J Periodontics Restorative Dent 2012;32:375–383.)

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The smile has become the objective endpoint evaluation by which practitioners define esthetic treatment outcomes. Esthetics embraces and encompasses all specialties of dentistry; therefore, proper diagnosis of a patient's esthetic smile line before any treatment is undertaken is critical for success.

Previous studies on the smile line have focused on the visual amount and location of midfacial tooth and gingival display relative to the upper lip.¹⁻⁴ Tjan et al set smile guideline standards in the profession in the mid-1980s.² Their research classified smiles into three basic categories (high, average, and low) according to the exposure of the midfacial cervical margin of the clinical crown relative to the vermilion border of the upper lip. The majority of these patients (69%) fell within the category of the average smile line, with 75% to 100% tooth exposure (Fig 1). A total of 11% of subjects were found to reveal the entire clinical crown with a contiguous band of gingiva, hence categorized as a high smile line (Fig 2). The low smile line category, found



Fig 1 Average smile line where 75% to 100% tooth exposure is displayed.



Fig 2 High smile line where 100% tooth exposure plus some of the midfacial gingiva is displayed.



Fig 3 Low smile line where 75% tooth exposure or less is displayed.

in 20% of patients, represented a smile displaying less than 75% of the clinical crown (Fig 3).

A limited patient population between 20 to 30 years of age from both sexes was used in one such study.² Additionally, each subject was analyzed from a single frontal full-face posed photograph perspective. Gender differences were found for women versus men, who demonstrated greater tooth display during smiling, respectively.^{2,5} Of note, differentiation of smile categories was primarily based on the relative position of the vermilion border of the upper lip to the total clinical crown length. The relative position of the upper lip to the interdental papillae was not assessed independently for these groups.²⁻⁴

More recently, Van Der Geld et al demonstrated that patients reveal more tooth display during spontaneous versus posed smiling

using videography.³ The amount of midfacial tooth display could have been underestimated by previous studies since posed or static photographs have been shown to limit the display of maxillary anterior teeth during smiling. Of importance was the finding of a correlation between natural aging and the relationship between the soft tissue and dentition by Dickens et al.⁶ It was found that increased age results in a significant reduction of the exposed clinical crown to the border of the upper lip during smiling of age groups evaluated between the ages of 7 and 40 years; however, only subjects younger than 40 were evaluated in this study.⁶

Chu et al^{7,8} and Stappert et al⁹ recently published a series of studies in an attempt to more objectively diagnosis and treat the needs of the esthetic-restorative patient. They took a "biometric"

approach to the comprehensive analysis of tooth form and its surrounding gingival structures. This biometric approach uses determinants that are identified and can be measured objectively, allowing the clinician to more easily identify tooth and gingival abnormalities for the dentate patient. The clinical endpoint of treatment enables individual patient analysis to be quantified in relation to normative values that have been reported and confirmed by different research groups using various methods.¹⁰⁻¹² Several groups have established that objective measurements of width-to-length ratio of teeth or proportion result in a mean 80% of patients being judged to have pleasing dimensions for maxillary anterior teeth.¹³⁻¹⁵ In addition, recently published data demonstrate that the interdental papilla proportion (clinical tooth length to interdental

Fig 4 Height of the interdental papillae measured from the gingival zenith incisally is roughly 40% of the length of the clinical crown.



papilla length) can be measured objectively in patients with esthetically pleasing smiles. This papilla proportion of tooth length/papilla length (Fig 4) was found to be, on average, 40% of the length of the tooth from the gingival zenith (highest point of the midfacial gingival margin) to the incisal edge.⁸

The authors have defined the term *interdental smile line* (ISL) as the position of the maxillary vermilion border relative to the interdental papillae. Two basic categories are defined: high interdental smile line (HISL) and low interdental smile line (LISL). ISL analysis is differentiated from traditional smile line analysis, which relates the postural position of the vermilion border of the upper lip to the clinical crown length of the maxillary anterior teeth. The ISL exclusively assesses the relative position of the labial tissues to the relative position of the interdental

papillary gingival tissues. It is believed that the visual display (presence) or lack of display (absence) of interdental papillae during smiling is a critical component to the diagnosis and treatment of the esthetic-restorative patient requiring either interdisciplinary reconstructive or conformational dental care.

The purposes of this study were to determine the following: the overall percentage of patients aged 10 to 89 years who display the interdental papillae of the maxillary anterior teeth during smiling to establish a normative value; any differences between age groups with respect to the display of the interdental papillae during smiling, thereby evaluating the effects of aging on the amount of interdental papillary display; and if gender differences affect the presence or absence of interdental papillae during smiling.



Figs 5a to 5c Digital single-lens reflex smile photographs were taken from the (a) right frontal-lateral, (b) frontal, and (c) left-frontal lateral perspectives to assess the presence vs absence of interdental papillae. Note that from the frontal perspective, it is not immediately apparent whether the interdental papillae are displayed.

Method and materials

Inclusion criteria were complete maxillary and mandibular arches up to and including the first molar. A total of 420 male and female patients were randomly selected, with ages ranging from their teens to 80s. Groupings of each age were divided into cohorts ranging from the second to the ninth decade of life. Two independent examiners evaluated digital photographic records providing a right frontal-lateral, frontal, and left frontal-lateral smile view of each patient (Figs 5a to 5c). Exclusion criteria consisted of patients with a previous history of periodontal disease, trauma, or iatrogenic dentistry resulting in an alteration of the attached gingival tissues. Additionally, patients with atypical conditions of the labial tissues, such as traumatized lips, cosmetic lip augmentation, or a history of previous surgery to the maxillary anterior region, were excluded as well. Each subject was compared,

analyzed, and carefully evaluated by visual examination for the presence or absence of display of interdental papillae and midfacial gingiva. Images were digitally enlarged to provide greater visual accuracy. The vermilion border of the upper lip was evaluated relative to the display or absence of the interdental papilla and midfacial gingiva of the maxillary teeth.

Two basic categories were defined: HISL and LISL. A third variant category, referred to as Cupid's bow smile line, was defined as when the upper lip displayed the interdental papillae distal to the central incisors while simultaneously covering the interdental papilla and/or midfacial gingiva of the maxillary central incisors upon smiling. The outline shape yields a double curve resembling an archer's bow, hence the term "Cupid's bow smile line." Two subclasses were noted: Cupid's bow interdental smile line (CB-ISL) and Cupid's bow gingival smile line (CB-GSL).

Definition of terms

Gingival smile line

A high gingival smile line (HGSL) displays the midfacial tissues of all maxillary anterior teeth upon smiling (Fig 6), whereas a low gingival smile line (LGSL) does not (Fig 7). CB-GSL does not display the midfacial gingiva of the maxillary central incisors but reveals the midfacial gingival tissues of the maxillary lateral incisors and/or those distal upon smiling (Fig 8).

Interdental smile line

An HISL displays any portion of the interdental papillae of the maxillary anterior teeth upon smiling (Fig 9), whereas an LISL does not (Fig 10). A CB-ISL does not display the interdental papillae of the maxillary central incisors but reveals that of the maxillary lateral incisors and/or those distal to these teeth upon smiling (Fig 11).

Figs 6 to 11 Gingival and interdental smile line classification.



Fig 6 High gingival smile line (HGSL). All of the midfacial gingival tissues are displayed during smiling.



Fig 7 Low gingival smile line (LGSL). None of the midfacial gingival tissues are displayed during smiling.



Fig 8 Cupid's bow gingival smile line (CB-GSL). Absence of display of the midfacial gingival tissues of the central incisors combined with the display of midfacial gingival tissues distal to those teeth during smiling.



Fig 9 High interdental smile line (HISL). All of the interdental papillae are displayed during smiling.



Fig 10 Low interdental smile line (LISL). None of the interdental papillae are displayed during smiling.



Fig 11 Cupid's bow interdental smile line (CB-ISL). Absence of display of the interdental papillae between the central incisors combined with the presence of interdental papillae distal to these teeth.

Results

Sex variability revealed that females had a higher percentage of HGSL compared to males (76% vs 24%).

When all ages were grouped together, 72% of patients (303 of 420) were classified as having an LGSL and 28% as having an HGSL. Ninety-one percent of patients were found to display the interdental papillae during smiling in both high and low gingival smile groups. Eighteen percent of all patients were found to display the interdental

papillae at or distal to the lateral incisors while simultaneously not revealing either the midfacial gingiva and/or the interdental papilla between the maxillary central incisors.

A greater number of subjects revealed both HGSL and HISL in the younger age cohorts compared to the older age cohorts (Fig 12).

The results of this study found that 87% of all patients classified as having an LGSL were found to have an HISL, which reveals all maxillary interdental papillae upon smiling (Fig 13).

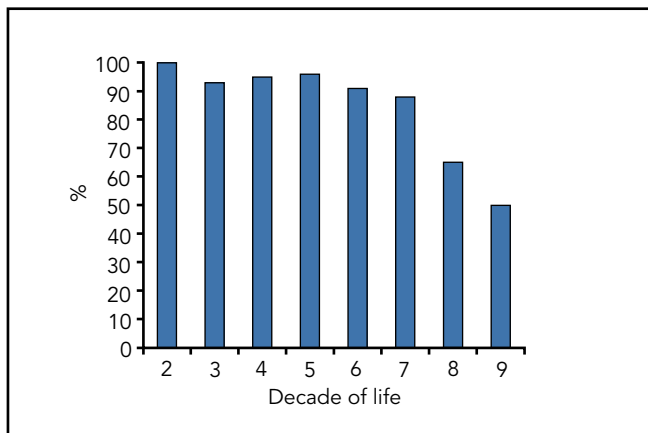


Fig 12 Percentage of subjects with a high interdental smile line (HISL) by decade of life.

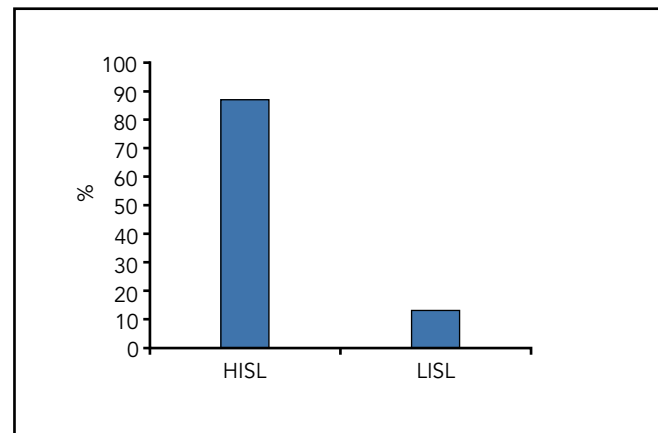


Fig 13 Subjects with a low gingival smile line (LGSL) according to whether the interdental papillae are displayed when smiling. High interdental smile line (HISL) = papillary display; low interdental smile line (LISL) = no papillary display.

Discussion

The evolution and advancement of esthetic dentistry is one of the more important changes to occur in the dental profession over the past 50 years. Esthetic dentistry, although not recognized as a formal specialty, is understood as a general approach to enhancing or establishing the ideals of beauty in combination with optimal health and function of the oral cavity. This may be accomplished through a variety of different treatment modalities using various disciplines within dentistry. Several of the recognized specialties of dentistry over the past two centuries have examined the characteristics of the patient smile to elucidate greater

understanding and meaning of this subjective topic. There have been two main approaches: subjective viewer testing to establish esthetic criteria to form specific parameters and measurable objective criteria to identify normative values establishing acceptable ideal esthetic outcomes. It is understood that through the combination of both of these approaches, essential traits have been identified to effectively establish a set of meaningful esthetic criteria for diagnosis and treatment.

The earliest studies performed on the topic of facial form, expression, and esthetics are found in the orthodontic and prosthodontic literature in which a formalized understanding of individual beauty

originated from an analysis of prior great artists and philosophers.^{16,17} The study of beauty in ancient Greece was documented through the writings of Plato (427 to 347 BC) and Aristotle (384 to 322 BC), who questioned the intrinsic meaning of beauty as a subjective discourse.¹⁸ The classic Greek artists of the fifth and fourth centuries BC established strict tenants for ideal bodily proportions, creating a subjective appreciation of beauty as well. Leonardo da Vinci is credited with introducing a mathematic model of the explanation of human facial form in the 15th century.¹⁹ The knowledge of past centuries established the foundation for our contemporary understanding of dental facial esthetics.

Contemporary smile analysis can be attributed to a series of publications appearing in the dental literature in the 1970s.^{4,20} These articles shifted the focus from general facial form toward identifying specific elements of an individual's smile. The basic components that were initially reviewed consisted of midline positioning, presence or absence of the buccal corridor, relationship of the maxillary incisal edges to the curvature of the lower lip, and the relationship of the amount of clinical crown length displayed upon smiling.²¹⁻²³ Hulseley reported findings from a randomized visual study using 40 subjects with the objective of analyzing the lip-to-teeth relationship in a frontal smile using photographs.²⁰ The evaluation was conducted using 10 independent reviewers providing subjective scoring for attractiveness of each subject. Hulseley noted that the majority of the highest scores for attractiveness were reported for those subjects in which the vermilion border of the upper lip was coincident with the free gingival margin of the maxillary central incisors. Lip positions deviating above or below the free gingival margin were scored with increasingly lower values with increasing distances, indicating that full display of the clinical crown is a desirable feature of a patient's smile.²⁰

Tjan et al defined three general categories of normalcy for smile type; high, average, and low smiles were defined based on the relative position of the vermilion border of the upper lip to the display of clinical

cal crown length and the associated gingiva.² A comparative analysis of 454 full-face photographs of subjects ranging from 20 to 30 years of age was performed. The survey reported that 48 (10.57%) subjects were classified as having a high smile, 313 (68.94%) as having an average smile, and 93 (20.48%) as having a low smile. Sex dimorphism with respect to smile lines was also provided. Low smile types were predominantly a male characteristic, while high smile types were a female characteristic. This study provided the normative distribution values of display of clinical crown length for subjects in their 20s.²

Peck et al conducted two studies that further examined the relationship of the maxillary central incisor clinical crown length, vermilion border of the upper lip, and the presence or absence of associated gingival tissue display of these teeth.^{24,25} A total of 115 subjects with a mean age of 15 years were clinically evaluated with direct measurements of the frontal soft tissue relationships to the maxillary incisors, and three sagittal radiographic cephalometric measurements were recorded.²⁴ Similar to previous studies, the position of the vermilion border of the upper lip was compared to the location of the gingival margin and the location of the maxillary incisal edge.^{25,26} The studies provided supporting data of normative values for patients in their 20s, in which sex dimorphism was a consistent finding with earlier studies. Female patients predominantly demonstrated that the

upper lip was either coincident to the gingival margin of the central incisors (ie, average smile type) or displayed 1 to 2 mm of direct gingival tissue (ie, high smile type) with the numeric mode of +1 mm. Male patients predominantly did not display gingival tissues (ie, low smile type) with the numeric mode of patients displaying -1 mm.²⁵ The authors concur that there is supporting evidence of an aging phenomenon that with increased age, subjects progressively display less maxillary incisor clinical crown length and/or gingival tissue during smiling, as was originally defined by Vig and Brundo in 1978.⁴

This article identifies a new characteristic of smile line analysis that has not been described previously in detail. The ISL is defined as the relationship of the vermilion border of the upper lip to the visual presence or absence of the interdental papillae during smiling. Three categories have been identified: the HISL, LISL, and a third variant referred to as CB-ISL and based on the unique shape of the maxillary lip relative to the soft tissues. The data herein represent normative values collected for males and females between the ages of 10 and 89.

Analysis of this data reveals that 91% of subjects evaluated displayed an HISL, revealing the interdental papillae for patients with high, average, or low smile lines as defined by Tjan and coworkers.² The high frequency noted in this study across all patient groups identifies a smile characteristic that should be expected in the



Fig 14 Excessively long contacts relative to the lack of interdental papillae display, which is not uncommon when the interdental papillae are not present because of interdental recession secondary to periodontal disease. It gives an unnatural form to the teeth that is visually displeasing.



Fig 15a Pretreatment digital photograph of a patient lacking visual display of the interdental papillae because of interproximal attachment loss. The contact areas were increased apically in an effort to eliminate the appearance of black triangles between the anterior teeth.



Fig 15b Adjunctive orthodontic therapy (forced eruption) was employed to bring the lost interdental papillae incisally into the smile view, thereby reestablishing the interdental smile line.

unaltered smile of the majority of populations across all age groups. Therefore, the display of the interdental papillae during smiling represents the most important smile characteristic that should be assessed for dental patients undergoing esthetic dentistry, especially since the frequency of a high smile line (HGSL) was relatively low.

Of particular significance is the high percentage of patients with a low smile line (LGSL) that display the interdental papillae during smiling

(87%). Therein lies a misconception by many dentists that the treatment of the LGSL patient represents a lesser esthetic challenge owing to the lack of visual midfacial tooth and gingival display. It is these authors' perspective that the presence of the interdental papillae in patients with low and average smile lines is the most important component to the maintenance and/or re-creation of an optimal esthetic outcome. Absence of the interdental papillae during smiling from patients with an

average or low smile line (LGSL) is often the difference between a visually pleasing and an unattractive artificial smile where the contact area dimensions are usually increased (Fig 14). Recognizing the importance of the ISL and having a classification that identifies this key esthetic element of a patient's smile provides the dentist with greater awareness of the treatment goals in the esthetic-restorative management of the dental patient (Figs 15a and 15b).

Conclusions

In a group of 420 patients between the ages of 10 and 89, the visual display of the interdental papillae during smiling was present 91% of the time. Even in those patients classified as having an LGSL, 87% were found to have visual display of the interdental papillae when smiling. Therefore, this study demonstrates that the visual display of interdental papillae is an important smile feature that is present in the overwhelming majority of patients receiving treatment. Preservation and maintenance of this anatomical structure should be given particular attention. The ISL should be considered an important esthetic parameter of smile analysis and should be given equal consideration to the traditional midfacial smile determinants previously defined for dentistry.

References

- Frush JP, Fisher RD. The dynesthetic interpretation of the dentogenic concept. *J Prosthet Dent* 1958;8:558–581.
- Tjan AH, Miller GD, The JG. Some esthetic factors in a smile. *J Prosthet Dent* 1984; 51:24–28.
- Van Der Geld P, Oosterveld P, Bergé SJ, Kuijpers-Jagtman AM. Tooth display and lip position during spontaneous and posed smiling in adults. *Acta Odontol Scand* 2008;66:207–213.
- Vig RG, Brundo GC. The kinetics of anterior tooth display. *J Prosthet Dent* 1978;39: 502–504.
- Al-Jabrah O, Al-Shammout R, El-Naji W, Al-Ajarmeh M, Al-Quran AH. Gender differences in the amount of gingival display during smiling using two intraoral dental biometric measurements. *J Prosthodont* 2010;19:286–293.
- Dickens ST, Sarver DM, Proffit WR. Changes in frontal soft tissue dimensions of the lower face by age and gender. *World J Orthod* 2002;3:313–320.
- Chu SJ, Tan JHP, Stappert CFJ, Tarnow DP. Gingival zenith positions and levels of the maxillary anterior dentition. *J Esthet Restor Dent* 2009;21:113–120.
- Chu SJ, Tarnow DP, Tan JHP, Stappert CFJ. Papilla proportions in the maxillary anterior dentition. *Int J Periodontics Restorative Dent* 2009;29:385–393.
- Stappert C, Tarnow DP, Tan JHP, Chu SJ. Proximal contact areas of the maxillary anterior dentition. *Int J Periodontics Restorative Dent* 2010;30:471–477.
- Chu SJ. A biometric approach to predictable treatment of clinical crown discrepancies. *Pract Proced Aesthet Dent* 2007; 19:401–409.
- Sterrett JD, Oliver T, Robinson F, Fortson W, Knaak B, Russell CM. Width/length ratios of normal clinical crowns of the maxillary anterior dentition in man. *J Clin Periodontol* 1999;26:153–157.
- Ali Fayyad MA, Jamani KD, Agrabawi J. Geometric and mathematical proportions and their relations to maxillary anterior teeth. *J Contemp Dent Pract* 2006;7: 62–70.
- Magne P, Gallucci GO, Belser UC. Anatomic crown width/length ratios of unworn and worn maxillary teeth in white subjects. *J Prosthet Dent* 2003;89:453–461.
- Hasanreisoglu U, Berksun S, Aras K, Arslan I. An analysis of maxillary anterior teeth: Facial and dental proportions. *J Prosthet Dent* 2005;94:530–538.
- Zagar M, Knezović Zlatarić DK. Influence of esthetic dental and facial measurements on the Caucasian patients' satisfaction. *J Esthet Restor Dent* 2011;23:12–20.
- Angle EH. *The Treatment of Malocclusion of the Teeth and Fractures of the Maxillae*, ed 6. Philadelphia: SS White, 1900.
- Boucher CO, Hickey JC, Zarb GA. *Prosthodontic Treatment for Edentulous Patients*, ed 7. St Louis: Mosby, 1975.
- Beardsley MC. *Aesthetics from Classical Greece to the Present*. New York: Macmillan, 1966.
- Huntley HE. *The Divine Proportion: A Study in Mathematical Beauty*. New York: Dover, 1970.
- Hulsey CM. An esthetic evaluation of lip-teeth relationships present in the smile. *Am J Orthod* 1970;57:132–144.
- Kokich VO Jr, Kiyak HA, Shapiro PA. Comparing the perception of dentists and lay people to altered dental esthetics. *J Esthet Dent* 1999;11:311–324.
- Zachrisson BU. Esthetic factors involved in anterior tooth display and the smile: Vertical dimension. *J Clin Orthod* 1998; 23:432–445.
- Janson G, Branco NC, Fernandes TM, Sathler R, Garib D, Lauris JR. Influence of orthodontic treatment, midline position, buccal corridor and smile arc on smile attractiveness. *Angle Orthod* 2011;81: 153–161.
- Peck S, Peck L, Kataja M. The gingival smile line. *Angle Orthod* 1992;62:91–100.
- Peck S, Peck L, Kataja M. Some vertical lineaments of lip position. *Am J Orthod Dentofacial Orthop* 1992;101:519–524.
- Passia N, Blatz M, Strub J. Is the smile line a valid parameter for esthetic evaluation? A systematic literature review. *Eur J Esthet Dent* 2011;6:314–327.