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Facial, dental, periodontal, and tomographic characteristics of the etiology of excessive gingival display: a cross-sectional clinical study

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ABSTRACT

Purpose: In this study, we examined the facial, dental, periodontal, and tomographic features associated with excessive gingival display (EGD) when smiling in young adults self-reporting a "gummy smile," categorized by potential etiology.
Methods: The study included 25 healthy adults (18–42 years old; 23 women and 2 men) who self-reported EGD. Participants completed a health questionnaire and underwent a periodontal examination assessing probing depth, clinical attachment level, keratinized gingival width, and gingival thickness (GT). Extraoral and intraoral photographs were taken for smile analysis and to determine facial and dental characteristics. Cone-beam computed tomography (CBCT), performed with a lip retractor in place, was used to measure the distance from the gingival margin (GM) to the cementoenamel junction (CEJ), the distance from the CEJ to the alveolar crest, buccal bone thickness, and GT. The extent of EGD when smiling was quantified as the distance from the GM at the upper central incisor to the upper lip edge when smiling fully. The smile was categorized into 4 types based on gingival exposure characteristics observed during full smile.
Results: Most participants were female (92%), with a mean age of 28.77±6.56 years. The average EGD was 4.2±2.44 mm, extending bilaterally from the anterior to the posterior maxilla. Two primary etiological factors were identified, alone or in combination: vertical maxillary excess (VME), predominantly indicated by an anterior maxillary height greater than 29 mm and a large interlabial gap; and altered passive/active eruption (APE), primarily characterized by square teeth (64%), upper central incisor width-to-height ratio (CIW:CIH) exceeding 87.5%, and GM-CEJ distance on CBCT exceeding 2 mm.
Conclusions: These findings suggest a multifactorial etiology of EGD, primarily associated with VME and APE. Clinical periodontal examination, CBCT conducted with a lip retractor, CIW:CIH, and soft tissue facial cephalometric analysis may aid in identifying the etiological factors of EGD.

Keywords: Dental esthetics; Dental photography; Diagnosis; Gingiva; Smiling; Tomography

Conflict of Interest
No potential conflict of interest relevant to this article was reported.

Author Contributions
Conceptualization: Adriana Campos Passanezi Sant'Ana, Eduardo Sant'Ana, Mariana Schutzer Ragghianti Zangrando, Carla Andreotti Damante, Sebastião Luiz Aguiar Greghi; Formal analysis: Adriana Campos Passanezi Sant'Ana, Eduardo Sant'Ana; Investigation: Luciana Tanaka de Castro, Maria Carolina Candosin Sementille, Adriana Campos Passanezi Sant'Ana; Methodology: Luciana Tanaka de Castro, Maria Carolina Candosin Sementille, Eduardo Sant'Ana, Adriana Campos Passanezi Sant'Ana; Project administration: Adriana Campos Passanezi Sant'Ana; Writing - original draft: Luciana Tanaka de Castro, Maria Carolina Candosin Sementille, Adriana Campos Passanezi Sant'Ana; Writing - review & editing: Adriana Campos Passanezi Sant'Ana, Eduardo Sant'Ana, Mariana Schutzer Ragghianti Zangrando, Carla Andreotti Damante, Sebastião Luiz Aguiar Greghi.

INTRODUCTION

Excessive gingival display (EGD), commonly referred to as "gummy smile" (GS), is characterized by an excessive amount of gingiva visible when smiling. This can produce unattractive facial aesthetics, adversely affecting patients' quality of life and self-esteem [1]. A complete smile revealing more than 3 mm of gingiva is frequently deemed unaesthetic by patients, and dental professionals employ this measurement to diagnose EGD [2]. Approximately 10.5% of adults between 20 and 30 years old are affected by this condition, with women exhibiting around twice the prevalence of men [3-5].

GS can be attributed to various factors, including altered passive/active eruption (APE), short upper lip, hypermobility of the upper lip, vertical maxillary excess (VME), inflammatory gingival hyperplasia, and anterior dentoalveolar extrusion [5-11]. The treatment for EGD is tailored to the underlying cause and may involve a variety of approaches, such as aesthetic crown lengthening with or without osteotomy and osteoplasty [8,12,13], lip repositioning [11], orthognathic surgery [6,14-16], and the use of botulinum toxin [16]. Accurate diagnosis of the etiology of EGD is essential for effective treatment [17].

Although numerous studies have examined the causes of EGD [6-9,12,17,18], only a select few clinical studies have directly investigated the underlying parameters involved in its etiology [5,10,11]. VME is the primary extraoral cause of EGD. Consequently, the diagnosis of this dentofacial deformity, which is based on cephalometric analysis [19-21], should be straightforward for general clinicians and other specialists to facilitate the development of an appropriate treatment plan. According to Pavone et al. [9], the protocol to determine the etiology of EGD should encompass a medical history review, facial analysis using cephalometric X-ray images, evaluation of the lips and perioral muscles at rest and when smiling, analysis of the smile to ascertain whether EGD is confined to the anterior teeth, dynamic dental analysis to assess the exposure of the central incisors at rest, and periodontal examination to identify APE.

Recent years have seen a surge in the pursuit of treatment for GS driven by aesthetic concerns. This necessitates a deeper understanding of its diagnosis and treatment to promote optimal outcomes and patient satisfaction. Despite this need, a clinical protocol to investigate the causes of EGD has not yet been established and validated. The purpose of this study was to examine facial, dental, tomographic, and periodontal features that differentiate the various etiological factors of EGD in healthy, young adults self-reporting EGD at full smile.

MATERIALS AND METHODS

This cross-sectional observational study was approved by the Committee of Ethics in Research in Humans (CAAE # 63909617.4.0000.5417) and conducted in accordance with the Helsinki Declaration of 1975, as revised in 2013. All participants received both verbal and written information about the study's objectives, risks, and benefits and signed a consent form prior to inclusion. Participants were recruited from the Clinics of Periodontics at Bauru Dental School, University of São Paulo, from December 2017 to July 2018 through a public call. Eligible participants were required to be 18 to 45 years old and to self-report EGD when smiling fully. The exclusion criteria included smokers; individuals with chronic diseases necessitating the continuous use of medications known to have gingival side effects, such as calcium channel

blockers, cyclosporine, and anticonvulsants; those who had previously undergone surgical correction of GS; and pregnant or lactating women. All participants who met the inclusion criteria and fulfilled none of the exclusion criteria were included in the study.

Clinical and periodontal examination

Participants completed a health questionnaire and underwent professional prophylaxis and oral hygiene instruction prior to periodontal examination. Periodontal parameters were assessed by a single experienced examiner (LTC) and included probing depth (PD), clinical attachment loss, and bleeding on probing (BOP). These were measured using a UNC-15 periodontal probe at the mesial, buccal, and distal sites of the upper anterior teeth. The width of keratinized gingiva (WKG) was measured as the distance from the gingival margin (GM) to the mucogingival junction at the buccal sites [22]. Gingival thickness (GT) was assessed by inserting an anesthetic needle with a stop at 1.5 mm below the buccal GM until it reached the buccal bone, with the measurement taken using a digital caliper [22,23]. Based on these measurements, the gingival phenotype was classified as either thin (<1 mm) or thick (≥1 mm) [23].

Standardized photographs

Standardized photographs were taken of each participant following the Digital Smile Design (DSD) protocol (Nemotec, Madrid, Spain) [24,25]. A single operator (MCCS) captured the images, which included: full face with a complete smile and teeth apart; full face at rest; a retracted view of the full maxillary arch with teeth apart; 45° and profile views; and 12-o'clock and occlusal views. Additionally, intraoral photographs were taken with the teeth both occluded and apart. All images were captured at a consistent focus-to-object distance and calibrated using the DSD PowerPoint template to minimize distortions. DSD tools were then utilized to perform the measurements (**Figure 1**).

Facial analysis

Facial analysis was conducted using established parameters for soft tissue cephalometric analysis [19-21]. In summary, after image calibration, the following parameters were measured: the middle third (M_1/3), which is the distance from the glabella to the subnasale; the lower third (L_1/3), which is the distance from the subnasale to the soft tissue of the chin (**Figure 1A**); the length of the upper lip—from the subnasale to the inferior edge of the upper lip—both at rest (ULL_R) (**Figure 1B**) and at full smile (ULL_S) (**Figure 1C**); and the length of the lower lip, measured from the upper edge of the lower lip to the soft tissue of the chin (**Figure 1B**). Upper lip elevation was calculated as the difference between ULL_R and ULL_S [7,11,26]. The vermilion was measured from the peak of Cupid's bow to the lower edge of the upper lip (**Figure 1B**). The interlabial gap (ILG) was assessed as the distance between the edges of the upper and lower lips when at rest. Central incisor exposure at rest (CIE_r) was determined by measuring the vertical distance from the lower edge of the upper lip at rest to the edge of the upper central incisor. The anterior maxillary height (Mx_h) was measured from the subnasale to the edge of the upper central incisor (**Figure 1C**). Overbite was assessed in millimeters at the right central incisor, quantifying the extent of overlap of the upper right central incisor over the lower incisors. For each type of image, all measurements were taken by a single experienced examiner: ACPS for standardized digital photographs and ES for tomographic images.

Dental and smile characteristics

Dental characteristics were assessed using standardized intraoral photographs taken with a lip retractor. The upper right central incisor width (CIW) was measured at the tooth's

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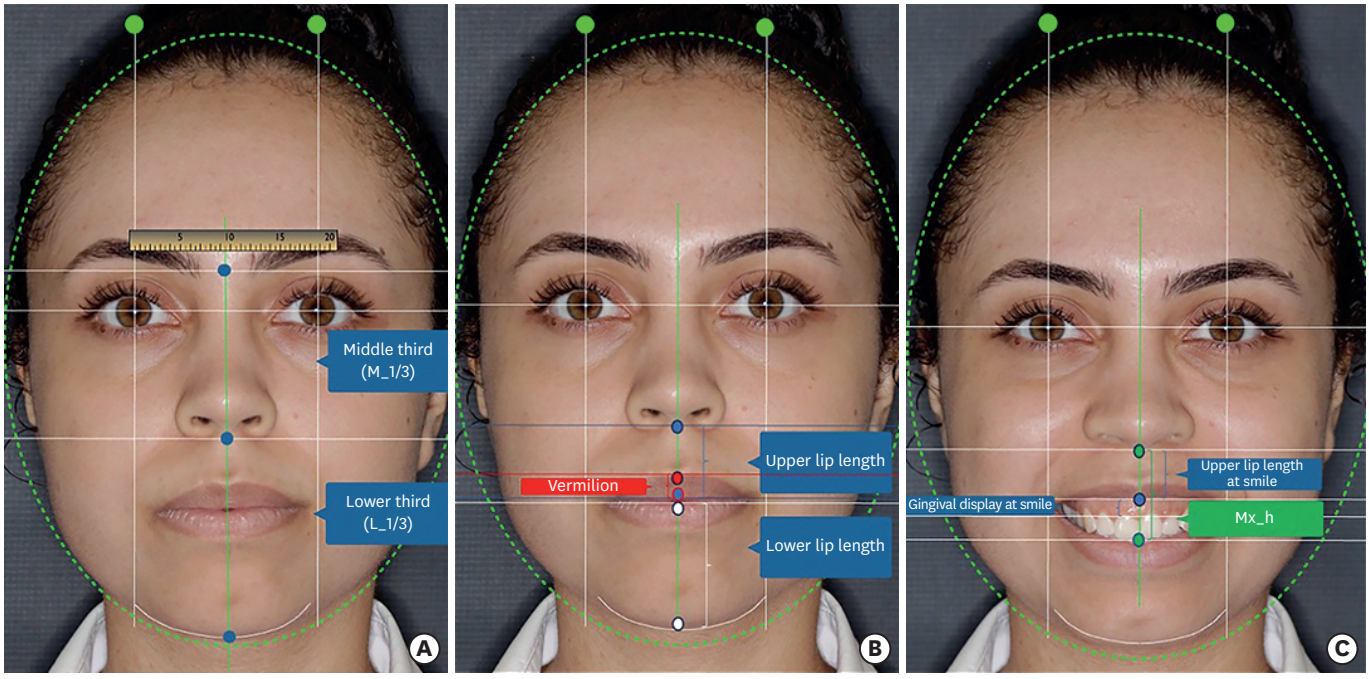

Figure 1. Facial analysis using standardized digital photographs. After calibration of the images using a DSD PowerPoint template, (A) the height of the middle third (M_1/3) was measured from the glabella to the subnasale, and the height of the lower third (L_1/3) was measured from the subnasale to the soft tissue of the chin. (B) The length of the upper lip was measured from the subnasale (blue dot) to the inferior edge of the upper lip (blue dot with a red line); the length of the lower lip was measured from the upper edge of the lower lip to the soft tissue of the chin (white dots); and the vermilion height was measured from the peak of Cupid's bow (red dot) to the lower edge of the upper lip (blue dot with a red line). (C) The length of the upper lip when smiling was measured from the subnasale (upper green dot) to the lower edge of the upper lip (blue dot); gingival exposure when smiling was measured from the lower edge of the upper lip (blue dot); and the Mx_h was measured from the subnasale to the edge of the upper central incisor (green dots).
M_1/3: middle facial third, L_1/3: lower facial third, Mx_h: anterior maxillary height.

greatest distance from the mesial to the distal edges, while its height (CIH) was measured at the greatest distance from the incisal edge to the GM (**Figure 2A and B**). The CIW:CIH ratio was calculated as a percentage (**Figure 2C**). The form of the tooth was documented as square (score 1), oval (score 2), or triangular (score 3).

The smile line was classified as low (less than 75% exposure of the upper central incisors when smiling), average (75% to 100% exposure of the upper central incisors), or high (complete exposure of the upper central incisors plus an adjacent band of gingiva) [3]. Similarly based on the participant's appearance when smiling, EGD was categorized into 4 types according to the classification system proposed by Wu et al. [27]: type I referred to a continuous band of EGD visible from anterior to posterior; type II was characterized by EGD present in the upper posterior region; type III was marked by EGD affecting 1 upper hemi-arch; and type IV was defined as EGD in the upper anterior region.

Cone-beam computed tomography (CBCT)

CBCT images were obtained from the upper anterior region using a 3D Accuitomo 170 unit (J. Morita, Kyoto, Japan), following the manufacturer's recommendations (120 kVp, 3-8 mA, and a 0.3-mm voxel size). The image acquisition protocol aligned with the method described by Januário et al. [28]. In brief, patients held a lip retractor during imaging to eliminate the lip profile from the buccal soft tissue, thus enabling clear visualization of both hard and soft periodontal tissues on the axial reconstructed images. The images were reviewed using proprietary software from the scanner manufacturer (OneVolume Viewer, J. Morita).

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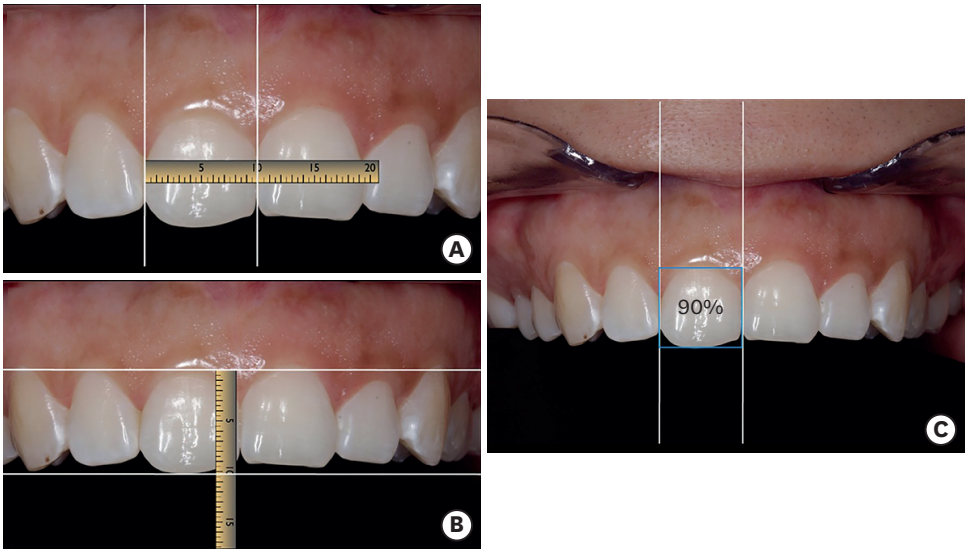

Figure 2. Digital analysis of dental characteristics. (A) The CIW was measured from the mesial to the distal edges using a previously calibrated digital ruler. (B) The CIH was measured at the greatest distance from the incisal edge to the gingival margin. (C) The CIW:CIH ratio was determined as a percentage.
CIW: central incisor width, CIH: central incisor height.

Measurements were taken at the left and right upper central incisors by a single examiner (ACPS). The following distances were measured: from the cementoenamel junction (CEJ) to the alveolar crest (AC) (CEJ-AC), from the GM to the CEJ (GM-CEJ), and from the GM to the AC (GM-AC), as well as the GT (CBCT_GT) and the bone thickness at 1 (EO1), 3 (EO3), and 5 (EO5) mm from the AC (**Figure 3**). The CEJ-AC and GM-AC measurements were taken parallel to the long axis of the tooth. The GM-AC distance was calculated by adding the CEJ-AC and GM-CEJ measurements. GT and BT1, BT3, and BT5 were measured at a 90° angle to the tooth's long axis.

Diagnosis of EGD etiology

To identify the primary factors contributing to EGD etiology, we referred to measurements documented in the literature. The EGD diagnostic protocol was conducted in a series of steps, as illustrated in **Figure 4**. First, the patient was evaluated for VME, indicated by an Mx_h greater than 29 mm [29] and/or a CIE_r of 4 mm or more [19,20]. Second, APE was assessed based on the presence of a short and square upper right central incisor, with a CIW:CIH ratio exceeding 87% [30]. The third step involved diagnosing upper lip hypermobility, which was identified when the upper lip movement from a resting position to a complete smile exceeded 8 mm [10,11]. Short upper lip was diagnosed when the length of the upper lip at rest measured between 10 and 15 mm [12]. Gingival inflammation (GI) was characterized based on a PD of 3 mm or more without attachment or bone loss, GM located more than 2 mm coronal to the CEJ, erythema and swelling of the GM, presence of dental biofilm, and BOP [31]. Lastly, overeruption of the upper anterior teeth was noted when an overbite of more than 2 mm was present and not associated with VME [9,19-21].

Statistical analysis

The overall characteristics of EGD in the sample were analyzed using descriptive statistics (mean ± standard deviation). The sample size calculation was based on a 1-mm difference in gingival display at full smile, with an alpha of 0.05 and a power of 80%. This calculation indicated that a minimum of 17 study participants was required. Following the establishment

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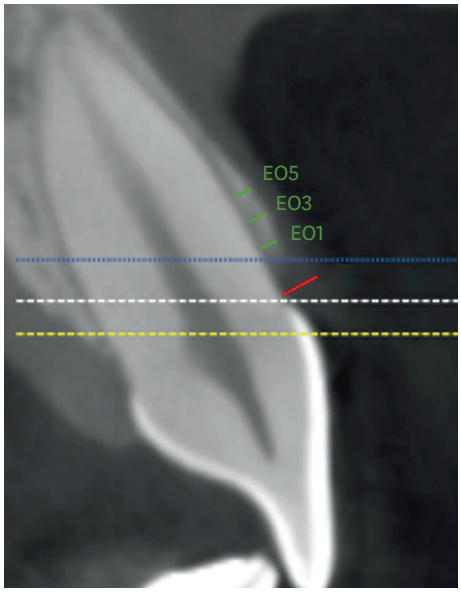

Figure 3. Axial CBCT image illustrating several measurements: GM-CEJ (the distance from the yellow to the white dotted line), CEJ-AC (the distance from the white to the blue dotted line), CBCT-GT (indicated by the red line), and EO1, EO3 and EO5 mm from the AC (shown by the green lines).
CBCT: cone-beam computed tomography, GM: gingival margin, CEJ: cementoenamel junction, AC: alveolar crest, GT: gingival thickness, EO: bone thickness.

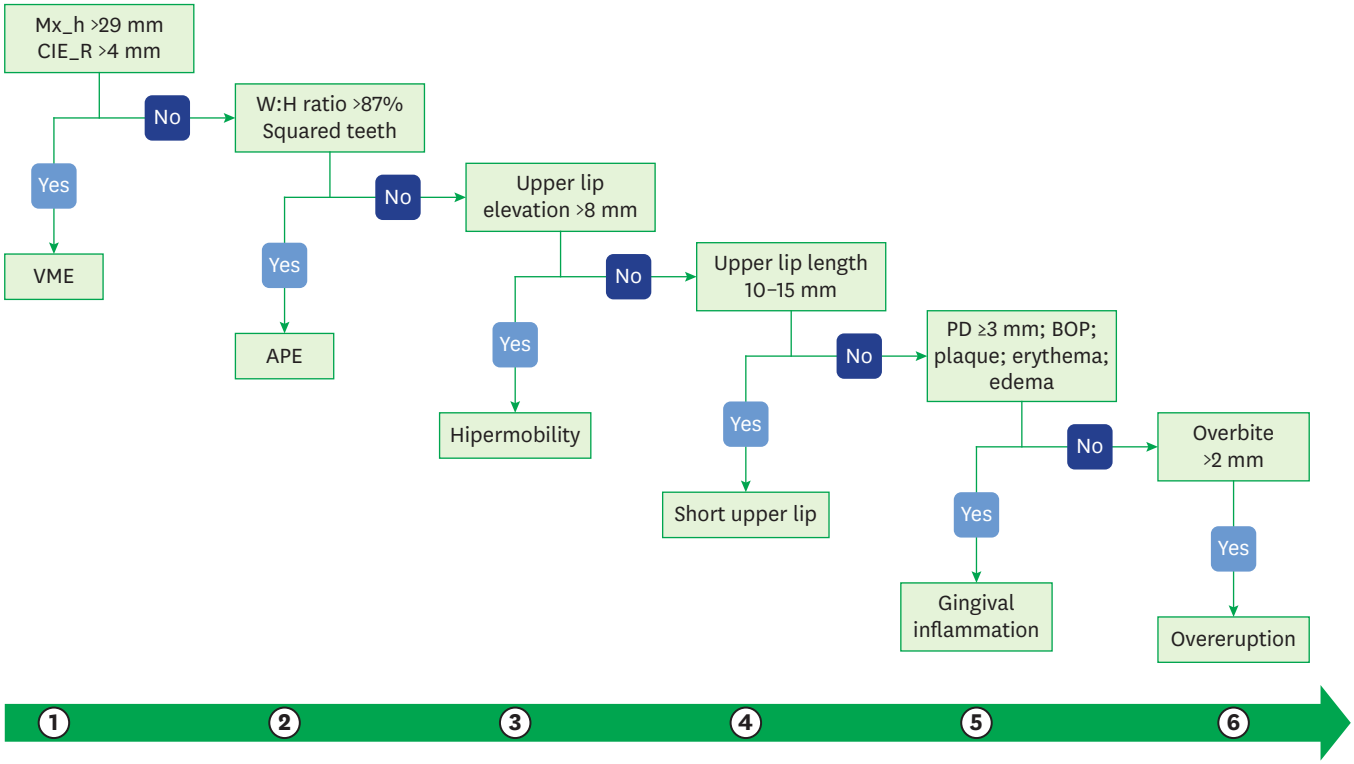

Figure 4. Clinical decision-making diagram for the sequential determination of the primary etiological factors of excessive gingival display.
Mx_h: anterior maxillary height, CIE_R: central incisor exposition at rest, VME: vertical maxillary excess, W:H: waist-to-hip, APE: altered passive eruption, PD: probing depth, BOP: bleeding on probing.

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of proper diagnosis of the etiologic factors of EGD, patients were categorized according to their primary etiologic factors. Since all cases in the sample exhibited VME, APE, or both, patients were divided into 3 groups: VME, APE, or VME+APE. The Kolmogorov-Smirnov test was applied to assess normality. Subsequently, data were analyzed using analysis of variance with *post hoc* Tukey test for the comparison of linear or parametric variables between groups, while the Kruskal-Wallis test with *post hoc* Dunn test was used for the comparison of non-linear or non-parametric variables between groups. The χ^2 test was employed to assess the prevalence of gingival phenotypes across the different groups. For all tests, a power of 80% and a significance level of 5% were adopted. Statistical analyses were conducted using GraphPad Prism 9 for Macintosh (GraphPad Software Inc., La Jolla, CA, USA).

RESULTS

Twenty-five consecutive participants who self-reported experiencing EGD responded to a public call and completed the study. The participants were predominantly female (92%), and most displayed more than 3 mm of gingiva when smiling (68%). EGD generally extended from the anterior to the posterior upper regions (88%). The overall characteristics of the sample are described in **Table 1** and illustrated in **Figure 5**.

All participants were diagnosed with VME (n=5), APE (n=12), or VME+APE (n=8), in accordance with the predefined diagnostic protocol (**Table 2**). Additional factors contributing to EGD were identified in conjunction with these categorizations, including hypermobility (32%), GI (12%), and overeruption (24%).

Facial analysis (**Table 3**) revealed that patients diagnosed with VME alone displayed greater ULL_R, ULL_S, ILG, and Mx_h than either those with APE only or controls (reference measures described in the literature). Similarly, patients with both VME and APE had greater ULL_R, ULL_S, ILG, and Mx_h values than those with APE only or controls.

Based on dental analysis (**Table 4**), the VME+APE group exhibited a higher CIW:CIH ratio than the VME-only group, with no significant differences from those with APE only. Additionally, a greater PD was observed in the VME+APE group than in the APE group (**Table 4**).

Table 1. Overall characteristics of the sample (n=25)

Characteristics	Value
Age (yr)	28.77±6.56
Sex	
Male	2/25 (8.0)
Female	23/25 (92.0)
Gingival display during smile	4.2±2.44
Prevalence of gingival display >3 mm during smile	17/25 (68)
Classification of the smile line	
High	25/25 (100.0)
Classification of EGD [27]	
Type I	22/25 (88.0)
Type II	1/25 (4.0)
Type III	1/25 (4.0)
Type IV	1/25 (4.0)

Values are presented as mean±standard deviation or number (%).
EGD: excessive gingival display.

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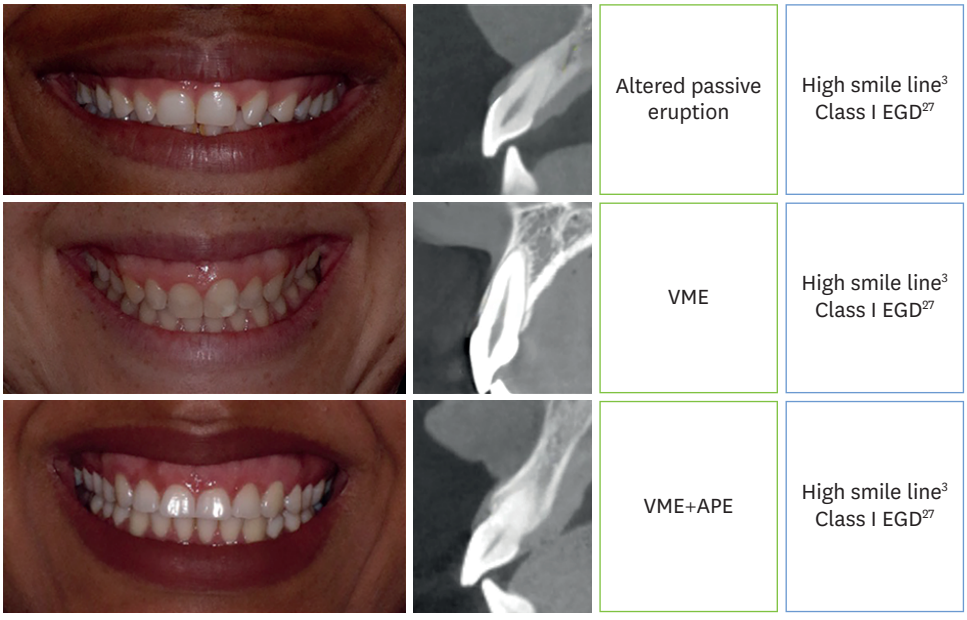

Figure 5. Types of gummy smile according to its etiology and classification. Notably, VME and/or APE were present in all participants, either in isolation or in combination with each other or with other etiological factors. EGD: excessive gingival display, VME: vertical maxillary excess, APE: altered passive/active eruption.

Table 2. Determination of excessive gingival display etiology based on facial, dental, and periodontal characteristics by participant

Characteristics	Mx_h	CIE_r	CIW:CIH	TF	UL_E	ULL_R	GI	OVE	Etiology
1	24	3	94.12	1	3.5	19.5	1	2	APE, GI
2	33	n/a	110.00	1	8.00	26.5	0	5.5	VME+APE
3	29	5	125	1	5	27	0	2	VME+APE
4	22	2	112.50	1	6.50	24.5	0	2	APE
5	32.5	4	105.56	1	4.50	24.5	0	1.5	VME+APE
6	25	2	94.12	2	6	24	1	3.5	APE, GI, OVE
7	27.5	4	88.89	1	1.50	20	0	2	APE
8	35.5	6	105.26	1	11	30.5	0	5	VME+APE, HPM
9	38.5	n/a	87.50	2	5.50	21	0	2.5	VME
10	34.5	1.5	90.00	2	9.50	27	0	3	VME+APE, HPM
11	25.5	7.5	94.74	1	9.00	22	0	2	APE, HPM
12	35	n/a	94.74	1	10	27.5	0	1	VME+APE, HPM
13	21	6.00	100	1	8.50	22.5	0	5	APE; HPM, OVE
14	26	4	100.00	1	5.50	22.5	1	2.5	APE, GI, OVE
15	24.5	3.00	100.00	3	7.50	22.5	0	3	APE, OVE
16	28	2.5	90.91	2	8.50	26	0	1.5	APE, HPM
17	21.5	1	87.50	3	7.50	18.5	0	1.5	APE
18	33	8.50	105.56	1	7.50	27.5	0	3	VME+APE
19	31	n/a	108.97	3	5	23.5	0	1.5	VME+APE
20	21.5	4.50	97.22	2	5.00	17.5	0	3	APE, OVE
21	26.5	6.5	90	1	10	24	0	2.5	APE, HPM, OVE
22	30.5	5	81.82	2	8.50	24.5	0	4	VME, HPM
23	27	8	81.82	1	7.50	23.5	0	5	VME, OVE
24	33	9.00	85.71	2	2.50	25	0	1	VME
25	33.5	6.00	85.71	1	8	28	0	5	VME
Mean ± SD	28.76±5.02	4.71±2.35	96.59±10.72	1.52±0.71	6.86±2.41	23.98±3.17	0.1±0.3	2.82±1.37	-

Mx_h, CIE_r; UL_E, and ULL_R values are shown in millimeters, CIW:CIH values are presented as percentages, and tooth form and GI values are displayed as scores. Mx_h: anterior maxillary height, CIE_r: central incisor exposure at rest, CIW:CIH: central incisor width-to-height ratio, TF: tooth form (where 1 indicates square, 2 indicates oval, and 3 refers to triangular), UL_E: upper lip elevation, ULL_R: upper lip length at rest, GI: gingival inflammation (where 0 refers to the absence of gingival inflammation and 1 indicates the presence of gingival inflammation, as determined by probing depth >3 mm, bleeding on probing, erythema, and edema), OVE: overeruption, VME: vertical maxillary excess, APE: altered passive/active eruption, HPM: hypermobility, SD: standard deviation.

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Table 3. Facial analysis according to primary etiology

Characteristics	APE (n=12)	VME (n=5)	VME+APE (n=8)	Reference (Control)	*P**
M_1/3	60.38±9.96[a)]	66.20±7.02[a)]	67±4.37[a)]	41.80±9.31[b)]	**<0.0001**
L_1/3	68.92±8.52[a)b)]	73.40±9.40[a)b)]	75.88±3.14[b)]	59.50±13.88[a)]	**0.005**
FH	130.1±15.85[a)]	141.6±19.41[a)]	142.9±6.21[a)]	126.4±5.10[a)]	0.06
ULL_R	21.96±2.58[a)]	24.88±2.26[a)b)]	27.40±2.13[b)]	21.91±1.95[a)]	**<0.0001**
ULL_S	15.1±2.40[a)]	18.20±2.92[a)b)]	18.69±1.03[b)]	15.14±0.30[a)b)]	**0.0032**
ULL_S:ULL_R	0.69±0.11[a)]	0.74±0.10[a)]	0.70±0.06[a)]	0.72±0.01[a)]	0.75
UL_E	6.58±2.44[a)]	6.40±2.46[a)]	7.56±2.51[a)]	5.0±2.16[a)]	0.25
LLL	47.08±6.44[a)]	50.30±6.76[a)]	51.56±4.81[a)]	47.52±2.83[a)]	0.30
LLL:ULL	2.14±0,19[a)]	2.06±0.23[a)]	1.93±0.19[a)]	2.20±0.00[a)]	0.08
Vml	6.13±0.71[a)]	6.70±0.57[a)]	8.25±0.75[b)]	NR	**<0.0001**
ILG	4.75±1.88[a)]	8.25±1.70[b)]	5.80±3.27[a)b)]	3.40±1.16[a)]	**0.009**
CIE_R	3.83±1.99[a)]	6.25±1.89[a)]	5.00±2.57[a)]	4.49±1.42[a)]	0.22
Mx_h	24.42±2.43[a)]	32.50±4.22[b)]	32.94±2.07[b)]	25.50±2.07[a)]	**<0.0001**
OVE	2.54±0.98[a)]	3.43±1.70[a)]	2.50±1.58[a)]	3.20±0.70[a)]	0.57

Values are presented in millimeters as mean ± standard deviation.
APE: altered passive eruption, VME: vertical maxillary excess, M_1/3: middle facial third, L_1/3: lower facial third, FH: facial height, ULL_R: upper lip length at rest, ULL_S: upper lip length at full smile, UL_E: upper lip elevation, LLL: lower lip length, Vml: vermilion, ILG: interlabial gap, CIE_R: central incisor exposition at rest, Mx_h: anterior maxillary height, OVE: overbite, NR: not reported.
*Analysis of variance with *post hoc* Tukey test. $P<0.05$ (in bold) indicates statistical significance.
[a)b)]Different lowercase letters in a row represent significant differences between groups in *post hoc* tests, while the same lowercase letter in a row indicates no significant differences between groups.

Table 4. Dental and periodontal parameters according to primary etiology

Characteristics	APE (n=12)	VME (n=5)	VME+APE (n=8)	*P*
Dental parameters				
CIW*	8.41±0.90[a)]	8.93±1.08[a)]	9.60±0.41[a)]	0.06
CIH*	8.8±1.02[a)]	9.87±1.21[a)]	9±0.61[a)]	0.09
CIW:CIH**	95.83±6.84[a)b)]	91.44±11.47[a)]	107.2±10.97[b)]	0.03
Tooth form**	1	2	1	0.11
Periodontal parameters				
WKG*	6.47±1.42[a)]	6.81±1.37[a)]	7.70±1.56[a)]	0.08
GT*	1.65±0.26[a)]	1.66±0.45[a)]	1.72±0.57[a)]	0.89
PD*	2.04±0.55[a)]	2.25±0.44[a)b)]	2.60±0.51[b)]	0.02
CAL*	0.16±0.38[a)]	0.12±0.34[a)]	0.40±0.51[a)]	0.20
Phenotype***				0.10
Thin	0 (0.0)	2 (12.5)	2 (20.0)	
Thick	24 (100.0)	14 (87.5)	8 (80.0)	

CIW, CIH, WKG, GT, PD, and CAL values are shown in millimeters (mean ± SD), CIW:CIH values are presented as percentages (mean ± SD), tooth form is displayed as scores (median), and thin and thick phenotypes are presented as numbers (percentages).
APE: altered passive/active eruption, VME: vertical maxillary excess, CIW: central incisor width, CIH: central incisor height, CIW:CIH: central incisor width-to-height ratio, WKG: width of keratinized gingiva, GT: gingival thickness, PD: probing depth, CAL: clinical attachment loss, SD: standard deviation.
*Analysis of variance with *post hoc* Tukey test; **Kruskal-Wallis test with *post hoc* Dunn test; ***Chi-square test. For all tests.
[a)b)]Different lowercase letters in a row represent significant differences between groups in *post hoc* tests, while the same lowercase letter in a row indicates no significant differences between groups.

On CBCT images, greater GM-CEJ and EO5 measurements were observed in conjunction with APE, with no significant differences noted compared to VME+APE (**Table 5**). Additionally, a significantly greater GT_CBCT was found in those with VME alone compared to VME+APE, but this value displayed no significant differences when compared to APE alone.

DISCUSSION

In this cross-sectional study, we examined the facial, dental, periodontal, and tomographic characteristics associated with EGD and proposed a diagnostic protocol to determine its

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Table 5. CBCT parameters according to primary etiology

Characteristics	APE (n=12)	VME (n=5)	VME+APE (n=8)	*P**
GM-CEJ	2.91±1.08[a)]	1.83±0.74[b)]	2.63±0.82[a)b)]	**0.01**
CEJ-AC	1.60±0.82	2.00±0.81	1.33±0.48	0.08
BT1	0.86±0.25	1.01±0.30	0.91±0.27	0.33
BT3	0.80±0.29	1.03±0.45	0.97±0.36	0.15
BT5	0.66±0.26[a)]	1.02±0.25[b)]	0.87±0.32[a)b)]	**0.004**
GT_CBCT	1.05±0.22[a)b)]	1.21±0.19[a)]	0.88±0.23[b)]	**0.002**

Values are presented in millimeters as mean ± standard deviation.
APE: altered passive/active eruption, GM-CEJ: distance from the gingival margin to the cementoenamel junction, CEJ-CA: distance from the cementoenamel junction to the alveolar crest, BT1: bone thickness at 1 mm apical to the margin, BT3: bone thickness at 3 mm apical to the margin, BT5: bone thickness at 5 mm apical to the margin, GT-CBCT: gingival thickness on cone-beam computed tomography.
*Analysis of variance with *post hoc* Tukey test; $P<0.05$ (in bold) indicates statistical significance.
[a)b)]Different lowercase letters in a row represent significant differences between groups in *post hoc* tests, while the same lowercase letter in a row indicates no significant differences between groups.

etiology. The findings indicate that the etiology of EGD is multifactorial and is primarily linked to VME and APE, either individually or in combination. Additional contributing factors to EGD were identified in conjunction with VME, APE, or the combination of the 2. These included upper lip hypermobility, greater overbite due to overeruption, and GI. Notably, no cases of short upper lip were observed in this sample. These insights are valuable for guiding clinicians in making accurate diagnoses and formulating suitable treatment plans to enhance clinical outcomes [6-12,17,32-35].

Of our patients with EGD, more were women (who comprised 92% of the study sample) than men (8%), aligning with findings from previous studies [3-5]. The mean gingival display when smiling was 4.2±2.44 mm, featuring the exposure of a continuous band of keratinized gingiva from anterior to the posterior regions (class I) [27]. This supports earlier research indicating that the exposure of 3 mm or more of gingiva is perceived as unaesthetic by patients [2] and is accordingly utilized to define GS [36,37].

To our knowledge, this is the first study to explore the etiology of GS by integrating facial, dental, periodontal, and CBCT features. Digital analysis of standardized extraoral and intraoral photographs was used to assess facial and dental characteristics. The proposed methodology enabled the determination of EGD etiology based on reference measurements. However, further research is required to validate this methodology. The suggested protocol adopts a stepwise approach to ascertain the cause of EGD, beginning with facial analysis to detect the presence of VME. This is followed by the assessment of dental, periodontal, and CBCT parameters to identify APE. Subsequent steps involve examining upper lip hypermobility or short length, GI, and overbite. Although other staged diagnostic processes have been proposed [9,11,32], they differ in methodology and do not incorporate CBCT images into the diagnostic framework.

Different clinical guidelines have been proposed in the literature, with these recommendations based on narrative reviews rather than clinical studies [6,8-11,17,18]. Notably, facial analysis can be useful in determining whether a patient presents with VME, which is the most common extraoral cause of EGD [9]. Patients diagnosed with VME not associated with an open bite typically exhibit Angle class II malocclusion, an increased lower third of the face, a retracted chin, excessive CIE_r, an extended ILG, and EGD at rest or when smiling [14,15]. In our sample, patients diagnosed with VME, regardless of whether it was associated with APE, displayed longer middle and lower third facial heights than the standard values reported in

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the literature. However, no significant differences were observed among the VME, APE, and VME+APE groups. Consequently, these measurements did not help differentiate between the conditions. Similarly, no significant differences were found between groups in CIE_r. In contrast, significantly greater ILG and Mx_h measurements were observed in patients with VME (with or without APE) compared to those with APE only or to normal values reported in the literature, as previously suggested [10]. Therefore, these dimensions can assist in distinguishing VME from APE as a cause of EGD when smiling. The primary treatment for VME-related EGD is a combined orthodontic-surgical approach [19-21].

APE is defined as a failure in the apical migration of the dentogingival junction toward the CEJ after the tooth erupts and reaches the occlusal plane. This positions the GM at the enamel, coronal to the tooth's cervical convexity [38,39]. The causes of APE are not fully understood, but 2 mechanisms appear to be at play [39]. The first is a failure of the apical migration of the GM, while the second is a failure in the active phase, where the tooth does not emerge sufficiently from the alveolar bone. This latter insufficient emergence results in a proximity of <1 mm between the CEJ and the AC, preventing the apical dislodgement of the dentogingival junction. The first condition has been classified as APE type I [40] or simply APE [13] and is primarily treated with gingivectomy or internal bevel incision procedures. The second condition is classified as APE type II [40] or APE associated with altered active eruption (AAE) [13]. This form is treated with internal bevel incision, osteotomy, and apical flap repositioning. APE associated with AAE may be linked to early orthodontic movement, as it is slightly more prevalent in orthodontic than in non-orthodontic patients [41].

In our study, an elevated CIW:CIH ratio (>95%) was observed in cases of APE alone or when combined with VME. This finding may be triggered by factors such as incisal tooth wear, fractures, an excess of gingival volume, or a combination of these [9,19,30]. Among our participants, 3 exhibited minor signs of occlusal wear, and 1 had a mesial angle fracture that did not interfere with the measurement of the clinical crown (data not shown). Additionally, a shallow sulcus depth has frequently been noted in cases of APE associated with AAE [13,39,40]. When comparing VME in combination with APE to APE alone, the former was associated with a significantly greater PD, indicating that a high CIW:CIH ratio without occlusal/incisal wear may distinguish APE from other etiological factors contributing to EGD. However, further research is required to explore this observation, as no significant differences were found between APE and VME alone. GM inflammation can also impact the CIW:CIH ratio and is frequently observed in patients with excessive and thick gingiva, which exacerbates the hyperplastic condition [13,39]. In our study, this condition was identified in 3 participants, all of whom were diagnosed with APE.

On CBCT images, the GM-CEJ distance was greater in the APE than the VME group, whereas those with VME exhibited increased EO5 mm from the AC compared to patients with APE. This thicker bone could be associated with a greater GT [42], which may account for the higher GT_CBCT observed in patients with VME. Previous research has explored the dimensions of the dentogingival junction using CBCT, facilitating the appropriate planning of crown lengthening procedures [28,43].

Overall, our findings indicate that VME and APE, either individually or in combination, are primary etiological factors in EGD. This aligns with some earlier research [6], yet contrasts with more recent findings identifying APE and upper lip elevation as the primary causes of GS [5,37,44]. The main characteristics that differentiate VME, which are based on facial

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analysis, include an Mx_h measurement exceeding 29 mm and a large ILG (approximately 2 times greater than in APE). In comparison, the primary features that characterize APE are a high CIW:CIH ratio (>87.5%) and a greater GM-CEJ on CBCT images obtained with a lip retractor. The combination of VME and APE seems to accentuate these characteristics, aggravating EGD when smiling fully. The use of facial analysis as well as dental, periodontal, and tomographic parameters may be valuable in determining the key etiologic factor of a given EGD case, enabling the establishment of a proper treatment plan.

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REFERENCES

1. Allen EP. Use of mucogingival surgical procedures to enhance esthetics. Dent Clin North Am 1988;32:307-30. PUBMED | CROSSREF
2. Kokich VO Jr, Kiyak HA, Shapiro PA. Comparing the perception of dentists and lay people to altered dental esthetics. J Esthet Dent 1999;11:311-24. PUBMED | CROSSREF
3. Tjan AH, Miller GD, The JG. Some esthetic factors in a smile. J Prosthet Dent 1984;51:24-8. PUBMED | CROSSREF
4. Peck S, Peck L, Kataja M. Some vertical lineaments of lip position. Am J Orthod Dentofacial Orthop 1992;101:519-24. PUBMED | CROSSREF
5. Andijani RI, Tatakis DN. Hypermobile upper lip is highly prevalent among patients seeking treatment for gummy smile. J Periodontol 2019;90:256-62. PUBMED | CROSSREF
6. Garber DA, Salama MA. The aesthetic smile: diagnosis and treatment. Periodontol 2000 1996;11:18-28. PUBMED | CROSSREF
7. Sabri R. The eight components of a balanced smile. J Clin Orthod 2005;39:155-67. PUBMED
8. Silberberg N, Goldstein M, Smidt A. Excessive gingival display--etiology, diagnosis, and treatment modalities. Quintessence Int 2009;40:809-18. PUBMED
9. Pavone AF, Ghassemian M, Verardi S. Gummy smile and short tooth syndrome--part 1: etiopathogenesis, classification, and diagnostic guidelines. Compend Contin Educ Dent 2016;37:102-7. PUBMED
10. Miron H, Calderon S, Allon D. Upper lip changes and gingival exposure on smiling: vertical dimension analysis. Am J Orthod Dentofacial Orthop 2012;141:87-93. PUBMED | CROSSREF
11. Bhola M, Fairbairn PJ, Kolhatkar S, Chu SJ, Morris T, de Campos M. LipStaT: The Lip Stabilization Technique- indications and guidelines for case selection and classification of excessive gingival display. Int J Periodont Restor Dent 2015;35:549-59. PUBMED | CROSSREF
12. Ahmad I. Anterior dental aesthetics: dentofacial perspective. Br Dent J 2005;199:81-8. PUBMED | CROSSREF
13. Zangrando MS, Veronesi GF, Cardoso MV, Michel RC, Damante CA, Sant'Ana AC, et al. Altered active and passive eruption: a modified classification. Clin Adv Periodontics 2017;7:51-6. CROSSREF
14. Bell WH, Creekmore TD, Alexander RG. Surgical correction of the long face syndrome. Am J Orthod 1977;71:40-67. PUBMED | CROSSREF
15. Fish LC, Wolford LM, Epker BN. Surgical-orthodontic correction of vertical maxillary excess. Am J Orthod 1978;73:241-57. PUBMED | CROSSREF
16. Indra AS, Biswas PP, Vineet VT, Yeshaswini T. Botox as an adjunct to orthognathic surgery for a case of severe vertical maxillary excess. J Maxillofac Oral Surg 2011;10:266-70. PUBMED | CROSSREF
17. Bynum J. Treatment of a "gummy smile": understanding etiology is key to success. Compend Contin Educ Dent 2016;37:114-22. PUBMED
18. Chu SJ, Karabin S, Mistry S. Short tooth syndrome: diagnosis, etiology, and treatment management. J Calif Dent Assoc 2004;32:143-52. PUBMED | CROSSREF

19. Arnett GW, Bergman RT. Facial keys to orthodontic diagnosis and treatment planning--part II. Am J Orthod Dentofacial Orthop 1993;103:395-411. PUBMED | CROSSREF
20. Arnett GW, Jelic JS, Kim J, Cummings DR, Beress A, Worley CM Jr, et al. Soft tissue cephalometric analysis: diagnosis and treatment planning of dentofacial deformity. Am J Orthod Dentofacial Orthop 1999;116:239-53. PUBMED | CROSSREF
21. Arnett GW, McLaughlin R. Facial and dental planning for orthodontists and oral surgeons. Philadelphia (PA): Mosby-Elsevier; 2004.
22. Cortellini P, Bissada NF. Mucogingival conditions in the natural dentition: Narrative review, case definitions, and diagnostic considerations. J Periodontol 2018;89 Suppl 1:S204-13. PUBMED | CROSSREF
23. Kan JY, Morimoto T, Rungcharassaeng K, Roe P, Smith DH. Gingival biotype assessment in the esthetic zone: visual versus direct measurement. Int J Periodontics Restorative Dent 2010;30:237-43. PUBMED
24. Arias DM, Trushkowsky RD, Brea LM, David SB. Treatment of the patient with gummy smile in conjunction with digital smile approach. Dent Clin North Am 2015;59:703-16. PUBMED | CROSSREF
25. Coachman C, Calamita M. Digital smile design: a tool for treatment planning and communication in esthetic dentistry. Quintessence Dent Technol 2012;35:103-11.
26. Zachrisson BU. Esthetic factors involved in anterior tooth display and the smile: vertical dimension. J Clin Orthod 1998;32:432-45.
27. Wu H, Lin J, Zhou L, Bai D. Classification and craniofacial features of gummy smile in adolescents. J Craniofac Surg 2010;21:1474-9. PUBMED | CROSSREF
28. Januário AL, Barriviera M, Duarte WR. Soft tissue cone-beam computed tomography: a novel method for the measurement of gingival tissue and the dimensions of the dentogingival unit. J Esthet Restor Dent 2008;20:366-73. PUBMED | CROSSREF
29. Sant'Ana E, Kuriki EU, Arnett W, Lautenschläger GA, Yaedu RY. Comparative evaluation of the normal profile pattern in leucoderma Brazilians and North Americans. Rev Dent Press Ortodon Ortop Facial 2009;14:80-9. CROSSREF
30. Magne P, Gallucci GO, Belser UC. Anatomic crown width/length ratios of unworn and worn maxillary teeth in white subjects. J Prosthet Dent 2003;89:453-61. PUBMED | CROSSREF
31. Chapple IL, Mealey BL, Van Dyke TE, Bartold PM, Dommisch H, Eickholz P, et al. Periodontal health and gingival diseases and conditions on an intact and a reduced periodontium: consensus report of workgroup 1 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. J Periodontol 2018;89 Suppl 1:S74-84. PUBMED | CROSSREF
32. Dym H, Pierre R 2nd. Diagnosis and treatment approaches to a "gummy smile". Dent Clin North Am 2020;64:341-9. PUBMED | CROSSREF
33. Milutinovic J, Zelic K, Nedeljkovic N. Evaluation of facial beauty using anthropometric proportions. Sci World J 2014;2014:428250. PUBMED | CROSSREF
34. Kerns LL, Silveira AM, Kerns DG, Regennitter FJ. Esthetic preference of the frontal and profile views of the same smile. J Esthet Dent 1997;9:76-85. PUBMED | CROSSREF
35. Chiche GJ, Pinault A. Esthetics of anterior fixed prosthodontics. Chicago (IL): Quintessence Publishing; 1994.
36. Al Sayed AA, Alshammari BZ, Alshammari AR, Aldajani MB, Alshammari FR. Gummy smile prevalence among ha'il city female young adults and its impact on quality of life: a cross-sectional study. Cureus 2023;15:e51302. PUBMED | CROSSREF
37. Tatakis DN, Silva CO. Contemporary treatment techniques for excessive gingival display caused by altered passive eruption or lip hypermobility. J Dent 2023;138:104711. PUBMED | CROSSREF
38. Goldman HD, Cohen D. Periodontal therapy. Philadelphia (PA): Mosby; 1968.
39. Mele M, Felice P, Sharma P, Mazzotti C, Bellone P, Zucchelli G. Esthetic treatment of altered passive eruption. Periodontol 2000 2018;77:65-83. PUBMED | CROSSREF
40. Coslet JG, Vanarsdall R, Weisgold A. Diagnosis and classification of delayed passive eruption of the dentogingival junction in the adult. Alpha Omegan 1977;70:24-8. PUBMED
41. Nart J, Carrió N, Valles C, Solís-Moreno C, Nart M, Reñé R, et al. Prevalence of altered passive eruption in orthodontically treated and untreated patients. J Periodontol 2014;85:e348-53. PUBMED | CROSSREF
42. Zucchelli G. Mucogingival esthetic surgery. Berlin: Quintessence Publishing; 2013.
43. Batista EL Jr, Moreira CC, Batista FC, de Oliveira RR, Pereira KK. Altered passive eruption diagnosis and treatment: a cone beam computed tomography-based reappraisal of the condition. J Clin Periodontol 2012;39:1089-96. PUBMED | CROSSREF
44. Tatakis DN, Paramitha V, Lu WE, Guo X. Upper lip characteristics and associated excessive gingival display etiologies in adults: race and sex differences. J Periodontol 2024;95:74-83. PUBMED | CROSSREF