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The Smile Esthetic Index (SEI): A method to measure the esthetics of the smile. An intra-rater and inter-rater agreement study

Key words *classification, diagnosis, esthetics, index, smile*

Purpose: To propose a method to measure the esthetics of the smile and to report its validation by means of an intra-rater and inter-rater agreement analysis.

Materials and methods: Ten variables were chosen as determinants for the esthetics of a smile: smile line and facial midline, tooth alignment, tooth deformity, tooth dischromy, gingival dischromy, gingival recession, gingival excess, gingival scars and diastema/missing papillae. One examiner consecutively selected seventy smile pictures, which were in the frontal view. Ten examiners, with different levels of clinical experience and specialties, applied the proposed assessment method twice on the selected pictures, independently and blindly. Intraclass correlation coefficient (ICC) and Fleiss' kappa) statistics were performed to analyse the intra-rater and inter-rater agreement.

Results: Considering the cumulative assessment of the Smile Esthetic Index (SEI), the ICC value for the inter-rater agreement of the 10 examiners was 0.62 (95% CI: 0.51 to 0.72), representing a substantial agreement. Intra-rater agreement ranged from 0.86 to 0.99. Inter-rater agreement (Fleiss' kappa statistics) calculated for each variable ranged from 0.17 to 0.75.

Conclusion: The SEI was a reproducible method, to assess the esthetic component of the smile, useful for the diagnostic phase and for setting appropriate treatment plans.

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Introduction

Facial attractiveness plays a key role in modern society and it can influence not only self-esteem, but also social opportunities, professional performance and employment prospects[1,2].

Data from the current literature showed that attractive people are judged and treated more positively than unattractive ones, and they exhibit more positive behaviours and traits[3]. In a face-to-face situation, a person's eyes primarily observe the other person's eyes and the area of the mouth, with little time spent observing other characteristics of the face[2,4]. This means that smile esthetics is becoming a dominant concern for patients, in particular when a dental treatment is required. A recent survey consisting of 659 interviews, conducted by the American Academy of Cosmetic Dentistry[5], confirmed this data, reporting that 89% of the patients decided to start cosmetic dental treatment in order to improve physical attractiveness and self-esteem. From the same survey, it appeared that the clinician mainly drives the initial dialogue with patients of new cosmetic dental treatments, even though the dental

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hygienist is also capable of contributing to this discussion. However, it is important to note that the entire dental team (dentist, dental hygienist, chair assistant, office employers) involved in the practice still remain fundamental in recommending esthetic procedures.

Several factors such as the facial midline, the smile line, the black spaces, the size, shape, position and colour of the teeth have been recognised as a determinant in the esthetics of the smile[6-10]. However, it has been assumed that all these factors should not be evaluated alone but in combination with each other. In fact, as suggested by Garber and Salama[11], the essentials of a smile involve the relationships between the three primary components: teeth, gingival scaffold and lip framework.

With regard to the teeth, the main relevant clinical characteristics could be identified in the shape, the colour and the position within the dental arch.

Factors associated with the gingival support are the position of the free gingival margins (i.e. the free gingival margins of the upper central incisors should be located at the same level of the canines, and the gingival margin of the lateral incisors about 1 mm lower than the central incisor-canine line; distally, the gingival margin of the premolars would be somewhat more coronally-positioned), the colour and the presence of scars and the amount of gingiva displayed during the smile[6,9].

The lips form the frame of a smile and define the esthetic zone. Three different levels of lip lines have been defined, based on the amount of tooth coverage by the upper lip; the exposure of 1 to 3 mm of the upper gingiva during smiling results in the most attractive smile[10].

Even if a lot of information is present in the literature, few data are available dealing with methods, which assess the esthetics of the smile. Frese et al[12] conducted a literature review to identify methods and clinical parameters adopted to evaluate the dentofacial esthetics. After the revision of 35 articles, a wide heterogeneity within the proposed methods was observed. From the same review, some clinical factors were identified as determinants for the dentofacial esthetics, in particular, the smile line, the lip line, the incisal offset, the location of the dental and facial midline, the incisor angulations and width to height ratios of the maxillary anterior teeth, the gingival contour, the root coverage and the papilla height.

However, even if all of these factors may be identified as determinants by the clinicians, little information is available about which variables are better perceived by the patients. In particular, whether the esthetic items identified by the clinicians could be associated with the subjective perceptions of similar factors identified by the patients, in order to allow proper quantification[13]. It appears very clear that esthetic ratings are based on a subjective assessment. An example of a subjective method of rating esthetics may be a questionnaire that solicits patient opinions. Measurements include ratings or indexes used by dental professionals to quantify the weight of several clinical factors, which influence the esthetics. For instance, an attempt to score the esthetics of prosthetic crowns supported by dental implants was provided by Meijer et al[14]. Other proposals focused their attention only on the integrity or quality of the natural non-prosthetic crowns[15-16].

Up to now, no data are available in the literature, with regard to reliable and statistically-validated methods aimed at measuring the esthetics of the smile, which is what patients or laypersons are commonly used to visualising during daily relationships. However, due to the influence of several factors (i.e. behavioural, emotional and psychological) which affect the patient's subjective judgment regarding the esthetics of the smile (able to vary the assessment of the patients when recorded at different moments), this type of evaluation cannot be useful as a reliable record relating to the esthetics of the smile. The objective assessment of a smile could not only provide an opportunity to measure the esthetic status of a patient, but also to facilitate the comparison between the preoperative and postoperative esthetical status of a treated clinical case and, therefore, the quality of a treatment outcome.

The aim of the present study is therefore to propose a method for measuring the esthetics of the smile, known as the Smile Esthetic Index (SEI), and to validate it by means of an intra-rater and inter-rater agreement analysis. The methodology adopted for this investigation is in accordance with the Guidelines for Reporting Reliability and Agreement Studies (GRRAS)[17].

Materials and methods

Description of the method

In order to assess the esthetics of a smile, 10 variables were identified as determinants for the esthetics of a smile: two variables (smile line and facial midline) deal with the facial traits, three variables (tooth alignment, tooth deformity and tooth dischromy) deal with the dental characteristics, and five variables (gingival dischromy, gingival recession, gingival excess, gingival scars and diastema/missing papillae) deal with the periodontal status. The present method is applicable only on smiles showing all teeth; the absence of teeth represents criteria which is not applicable for this method.

A specific assessment sheet was set up in order to simplify the collection of the data recorded after viewing a frontal natural smile of the considered patient. The scores 1 or 0 were attributed, depending on whether the considered variable is present or absent, respectively. In particular, score 1 would be assigned if the variable is correctly represented in the analysed smile or if the variable is not visible within the exposed smile. In this latter condition, the nondetection of the considered variable means that it would not influence the quality of the exposed smile. On the contrary, it would be assigned a score of 0 in case the considered variable was not correctly represented. The sum of the attributed score for each variable would represent the SEI of that patient. The worksheet adopted for the collection and analysis of the assessment is reported in Figure 1. Two clinical images analysed by means of SEI are represented in Figures 2 and 3.

Agreement of the method of assessment

The reliability and the agreement of the method of the Smile Esthetic Index was tested according to the Guidelines for Reporting Reliability and Agreement Studies (GRRAS)[17]. Smile pictures of male and female patients in the frontal view were consecutively selected and recorded by one examiner (RR). The only requested criterion of inclusion was the presence of teeth in the smile area. In order to establish the appropriate number of frontal smile pictures needed to verify the agreement, a priori

OBJECTIVE/EXTERNAL ASSESSMENT

1. **CORRECT SMILE LINE** (Do the incisal edges of the maxillary central incisors appear below the tips of the canines showing a convex appearance that can approximate and harmonise with the line of the lower lip?)
   ❑ yes (= 1) ❑ no (= 0)
2. **CORRECT FACIAL MIDLINE** (Does the facial midline correspond with the interincisive line, without any evident asymmetry between the right and left side of the upper dental arch?)
   ❑ yes ❑ no
3. **CORRECT TOOTH/CROWN ALIGNMENT** (Are the exposed teeth aligned correctly, without any malposition on the three dimensions of the space – i.e.: rotation, extrusion, inclination?)
   ❑ yes ❑ no
4. **ABSENCE OF VISIBLE TOOTH DEFORMITY** (Are the exposed teeth not abraded and not showing any crown form alteration?)
   ❑ yes ❑ no
5. **ABSENCE OF VISIBLE TOOTH DISCHROMY** (Do the exposed teeth show a homogeneous colour, without any dischromy?)
   ❑ yes ❑ no
6. **ABSENCE OF VISIBLE GINGIVAL DISCHROMY** (Does the gingiva of the exposed teeth show a homogeneous colour, without any dischromy, such as inflammation, amalgam tattoo, white spot/area from previous free gingival graft?)
   ❑ yes ❑ no
7. **ABSENCE OF VISIBLE GINGIVAL RECESSIONS** (Are the gingival margins of the exposed teeth correctly located and covering the cemento-enamel junction?)
   ❑ yes ❑ no
8. **ABSENCE OF VISIBLE GINGIVAL EXCESSES** (Is the gingival profile homogeneously integrated with the adjacent area on the bucco-lingual aspect, without any gingival excess – such as a bulky profile in correspondence with a gingival area treated using a very thick connective tissue graft?)
   ❑ yes ❑ no
9. **ABSENCE OF VISIBLE GINGIVAL SCARS** (Is the superficial texture of the mucogingival complex homogeneous, without any scars or superficial clefts?)
   ❑ yes ❑ no
10. **ABSENCE OF VISIBLE DIASTEMA AND/OR MISSING INTERDENTAL PAPILLAE** (Is an interdental diastema absent? Do the interdental papillae of the considered smile completely fill in the interdental spaces)
    ❑ yes ❑ no

Fig 1 Worksheet adopted for the assessment of the smile.

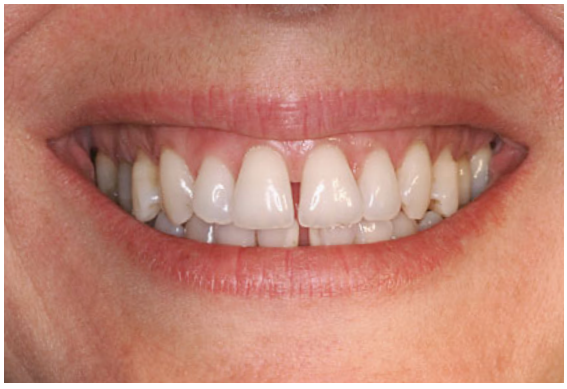

Fig 2 Smile of a 38-year-old female. Smile Esthetic Index = 2 (smile line: 0; facial midline: 0; tooth alignment: 0; tooth deformity: 1; tooth dischromy: 0; gingival dischromy: 0; gingival recession: 0; gingival excess: 1; gingival scars: 0; diastema/missing papillae: 0).

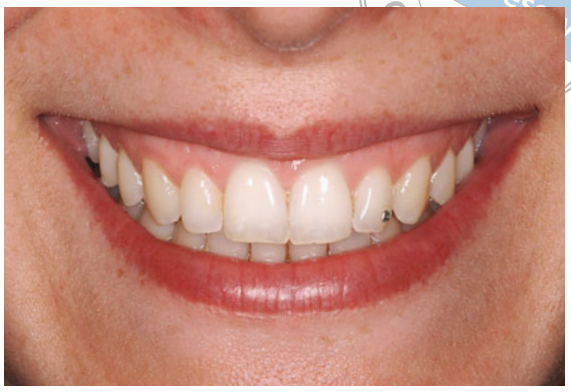

Fig 3 Smile of a 32-year-old female. Smile Esthetic Index = 9 (smile line:1; facial midline: 1; tooth alignment: 1; tooth deformity: 1; tooth dischromy: 1; gingival dischromy: 0; gingival recession: 1; gingival excess: 1; gingival scars: 1; diastema/missing papillae: 1).

Table 1 Assessment of level of agreement according to Landis and Koch[19].

Poor agreement	< 0.00
Slight agreement	0.00-0.20
Fair agreement	0.21-0.40
Moderate agreement	0.41-0.60
Substantial agreement	0.61-0.80
Almost perfect agreement	0.81-1.00

sample size calculation was performed. The sample size was calculated using a minimal acceptance level of the intra-class correlation coefficient (ICC) for the inter-rater agreement of 0.60, with an alternative hypothesis of 0.75, $\alpha = 0.05$ and $\beta = 0.05$[18]. Using these parameters, the minimal required number of subjects was 65, with six examiners. However, after a specific request made by the reviewers, the number of the examiners was increased to 10. The examiners had to show different levels of experience in clinical dentistry and different areas of specialty. Therefore, two general dentists, three periodontists, three prosthodontists, one specialist in restorative dentistry, and one in orthodontics were enrolled for the agreement assessment. The examiners applied the proposed worksheet twice on the selected pictures, independently and blindly, with the 10 variables, after an interval of 1 week.

Two way intra-class correlation coefficients were calculated for the inter-rater and intra-rater agreement amongst the 10 examiners for the global Smile Esthetic Index.

Agreement percentage and Fleiss' kappa statistics were calculated for the inter-rater agreement of each variable (or item) of the Smile Esthetic Index. The confidence intervals were calculated considering random patients and examiners.

The training results were evaluated according to the Landis and Koch assessment method[19] (Table 1).

MedCalc Statistical Software version 12.7.8 (MedCalc Software bvba, Ostend, Belgium) and AgreeStat version 2013.3 (Advanced Analytic, LLC, Maryland, USA) were used for the data computation.

■ Results

After the enrolment phase, the frontal pictures of the smiles of 13 males and 57 females were used for the analysis. The age of the recruited patients ranged from 19 to 61 years old (44.2 ± 7.8 years). All descriptive statistics of the 10 examiners are reported in Table 2.

The intra-class coefficients (ICC) of the globally assessed SEI amongst the 10 examiners are reported in Table 2. The values of the intra-rater agreement were very high, ranging between 0.86 and 0.99.

The global inter-rater agreement (two-way intraclass correlation coefficient) was 0.62 (95% CI: 0.51 to 0.72), representing a substantial agreement, according to the interpretation presented by Landis and Koch[19]. The pairwise inter-rater agreement between the 10 examiners is reported in Table 3. The values ranged from 0.38 to 0.88.

Table 2 Descriptive statistics of the 10 examiners.

Rater	Mean	SD	ICC	95% CI
Examiner # 1 (general dentist)	5.2	1.8	0.96	0.94; 0.98
Examiner # 2 (general dentist)	5.2	1.9	0.98	0.97; 0.99
Examiner # 3 (periodontist)	5.7	1.8	0.98	0.97; 0.99
Examiner # 4 (restorative dentist)	5.8	1.3	0.86	0.79; 0.91
Examiner # 5 (prosthodontist)	5.7	1.9	0.99	0.98; 0.99
Examiner # 6 (prosthodontist)	6.2	1.7	0.98	0.97; 0.99
Examiner # 7 (orthodontist)	6.8	1.9	0.99	0.99; 1.00
Examiner # 8 (periodontist)	6.9	1.9	0.99	0.98; 0.99
Examiner # 9 (periodontist)	6.5	1.7	0.98	0.96; 0.99
Examiner # 10 (prosthodontist)	7.0	1.7	0.98	0.98; 0.99

SD: standard deviation; ICC: intra-class correlation coefficient; CI: confidence interval.

Table 3 Two-way intraclass coefficient (intra-rater and pairwise inter-rater agreement) obtained after application of the SEI method, with consideration for all 10 examiners.

	GD1	GD2	Perio1	Rest	Prosto1	Prostho2	Ortho	Perio2	Perio3	Prostho3
GD1	0.96	0.78	0.80	0.61	0.72	0.46	0.51	0.47	0.54	0.44
GD2		0.98	0.73	0.55	0.68	0.38	0.48	0.46	0.52	0.43
Perio1			0.98	0.61	0.76	0.55	0.63	0.62	0.64	0.53
Rest				0.86	0.65	0.62	0.51	0.50	0.57	0.50
Prostho1					0.99	0.55	0.60	0.60	0.61	0.54
Prostho2						0.98	0.54	0.51	0.56	0.48
Ortho							0.99	0.88	0.78	0.80
Perio2								0.99	0.73	0.82
Perio3									0.98	0.74
Prostho3										0.98

GD: general dentist; Perio: periodontist; Rest: restorative dentist; Prostho: prosthodontist.

Table 4 Frequencies and percentages of positive values, agreement percentages amongst the examiners, and related Fleiss' kappa inter-rater agreement of each item.

Item	Positive frequencies (%)	Agreement % (95% CI)	Fleiss' kappa (95% CI)
Item #1 (Smile line)	30.8 (44)	0.71 (0.65; 0.78)	0.42 (0.29; 0.55)
Item #2 (Midline)	30.9 (44)	0.70 (0.63; 0.77)	0.39 (0.23; 0.54)
Item #3 (Alignment)	22.4 (32)	0.74 (0.67; 0.81)	0.40 (0.23; 0.57)
Item #4 (Deformity)	34.0 (49)	0.71 (0.62; 0.80)	0.42 (0.24; 0.60)
Item #5 (Teeth dischromy)	31.2 (45)	0.74 (0.67; 0.81)	0.47 (0.32; 0.62)
Item #6 (Gingival dischromy)	63.3 (90)	0.92 (0.86; 0.98)	0.53 (0.22; 0.84)
Item #7 (Recession)	41.5 (59)	0.83 (0.74; 0.91)	0.64 (0.47; 0.81)
Item #8 (Excesses)	59.2 (85)	0.81 (0.69; 0.92)	0.26 (0.04; 0.48)
Item #9 (Scars)	67.2 (96)	0.94 (0.89; 0.98)	0.17 (-0.07; 0.42)
Item #10 (Diastema)	46.9 (67)	0.89 (0.83; 0.95)	0.75 (0.62; 0.88)

Regarding the 10 variables chosen for the SEI, frequencies and percentages of positive values, agreement percentages amongst the examiners, and related Fleiss' kappa statistics are reported in detail in Table 4.

With respect to each variable selected for the assessment, the lowest inter-rater agreement was obtained for the scars variable (kappa = 0.17) (even if only 5% of pictures showed the presence of scars), while the highest value (kappa = 0.75) was obtained for the variable absence of visible diastema and/or missing interdental papillae.

■ Discussion

The aim of the present study was to propose and validate a method to measure the esthetics of a smile. In order to consider external factors involved in a smile exposition, 10 different variables have been identified and included in a specific worksheet to rate a smile. The presence/absence of the aforementioned variables corresponded to a number (0 or 1), and the sum of the attributed numbers represent the SEI of that subject (from 0 – very bad, to 10 – very good).

In addition, in order to provide a statistical validation of the method, 10 different examiners applied SEI on spontaneous smile photographs, recorded from 70 consecutive subjects. The inter-rater agreement revealed substantial agreement between the examiners. Overall, the obtained results indicated that the proposed method is reproducible and reliable.

The choice to adopt specific clinical variables in the assessment of the smile is supported by the current literature. In fact, several studies have attempted to investigate potential factors and their influence on a person's preference regarding the esthetics of a smile. For instance, Witt and Flores-Mir[20] reviewed the literature evaluating the magnitude of esthetic impairment that the layperson is capable of understanding, in particular with regard to periodontal factors. Results showed that facial midline and smile line were mainly perceived by most of the participants enrolled in the different analysed articles. In a second review[21], the same authors selected articles in which investigators explored anterior dental esthetics from a layperson's perspective, and assigned methodological scores to the studies. The main findings showed that the layperson was capable of discerning tooth shape, tooth deformity (absence of abrasions), tooth alignment and absence of diastema.

More recently, Nold et al[22] examined esthetic parameters in natural smiles and dentitions, to establish guidelines useful for clinicians in esthetic analysis, treatment planning and restoration fabrication. The analysis of standardised intraoral and extraoral photographs of 106 adults with a healthy dentition revealed that usually a dental midline coincides with the facial midline, an average smile line is present, and a straight upper lip curvature is most prevalent. During a smile, the maxillary anterior teeth should not touch but should follow the curvature of the lower lip. In addition, the second premolars should be considered part of the esthetic zone, and the most common tooth shape is oval.

Nevertheless, in order to quantify the esthetic value of a smile, some proposals regarding smile assessment have been reported in the literature[23], but no statistical validation has been provided for any models.

A possible limitation of the present method may be recognised in the quality of the images adopted for the evaluation. Photographs of posed smiles are today routinely used to perform diagnosis and treatment planning but the alternative use of dynamic (video) smiles has been proposed and tested. Walder et al[24] tested whether a posed smile is a reproducible method and compared the videography and photography in evaluating the patient's smile. Twenty-two subjects were simultaneously photographed and videotaped twice. A panel of four people (one layperson, one oral surgeon, one orthodontist and one prosthodontist) assessed the reproducibility of the smile, posed versus spontaneous smiles, and the diagnostic value of video versus still images. In particular, they compared still photographs of day 1 with day 2, still photography versus videography, cropped and uncropped posed versus spontaneous smiles. Results showed that objective measurements of the posed smile were reliable and reproducible, whether captured by video or photography. However, the panel members identified differences between the posed smiles observed at different periods 80% of the time. In addition, the professional members of the panel showed stronger preference

for videography than photography, and for spontaneous rather than the posed smile. Therefore, for future investigation and practice, the use of videography, instead of photography, should be taken into consideration as a more reliable method for the smile assessment.

Another limitation of the proposed method is the absence within the analysed clinical variables of the lip frame. This is justified by the limited knowledge and competence of the general practitioner to assess and, eventually, manage this area. The present method of assessment is to support dental practitioners (general dentists, prosthodontists, periodontists etc) in their daily practice routine. This was the main reason to identify and suggest a dichotomic method of assessment, even if more intermediate scores might be possible in nature.

However, the point of strength of the SEI is the potential it offers for numerically measuring the esthetics of a smile and to use it, for instance, in order to compare the preoperative and postoperative esthetical status of a treated clinical case and, therefore, the esthetical quality of a treatment outcome. In addition, the present investigation was able to demonstrate, through a validation session, that the suggested method can lead to reliable and reproducible results with a substantial rate of agreement.

Conclusions

The SEI is a reproducible method to assess the esthetic component of a smile, which could be used for comparing the pre-treatment and post-treatment esthetics in clinical research and in routine clinical practice.

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