

Contribution of the mandible position to the facial profile perception of a female facial profile: An eye-tracking study

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Introduction: Studies concerning the visual attention of laypersons viewing the soft tissue facial profile of men and women with malocclusion are lacking. This study aimed to determine the visual attention to the facial profile of patients with different levels of mandibular protrusion and facial background attractiveness using an eye-tracking device. **Methods:** The scanning paths of 54 Chinese laypersons (50% female, 50% male, aged 18-23 years) were recorded by an eye-tracking device when they observed composite female facial profile images ($n = 24$), which were combinations of different degrees of mandibular protrusion (normal, slight, moderate, and severe) and different levels of facial background attractiveness (attractive, average, and unattractive). Dependent variables (fixation duration and first fixation time) were analyzed using repeated-measures factorial analysis of variance. **Results:** For normal mandibular profiles, the fixation duration of the eyes was significantly higher than that of other facial features ($P < 0.001$). The lower face and nose received the least attention. As the degree of protrusion increased from slight to moderate, more attention was drawn to the lower face accompanied by less attention to eyes in the unattractive group ($P < 0.05$). When protrusion degree increased from moderate to severe, attention shifted from nose to lower face significantly in the attractive group ($P < 0.05$). Attention shift from eyes to lower face was also found in the average group when protrusion degree rose to moderate protrusion from normal profile ($P < 0.05$). A significant interaction between facial attractiveness and mandibular protrusion was found in the lower face duration ($P = 0.020$). The threshold point (the point of mandibular protrusion degree that evoked attention to the lower face) of the attractive facial background was higher than that of the unattractive background. Once evoked, the effect of mandibular protrusion of the attractive group tended to be stronger than that of the unattractive group, though without statistical difference. **Conclusions:** Eyes are the most salient area. The increasing degree of mandibular protrusion tends to draw attention to the lower face from other facial features. Background attractiveness can modify this behavior. (Am J Orthod Dentofacial Orthop 2019;156:641-52)

Facial profile attractiveness plays an important role in orthodontic treatment, orthognathic surgery, and plastic surgery. Most studies concerning the facial profile have used subjective questionnaires as

the primary method. The region that people think they were focusing on may not be the place where their visual attention was fixed.¹⁻³ Other methods, such as near-infrared spectroscopy, functional magnetic resonance

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The eye tracker is an available resource in the Psychology Department of Sun Yat-sen University.

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imaging, and event-related potential technique, have been used as objective methods for facial preference research to explain the neuromechanics of facial perception and to provide an indication of the importance of different facial features in the facial cognition process.⁴⁻⁷ Eye trackers, which capture what patients see directly, can objectively and quantitatively characterize patients' attention distribution. As a result, eye tracking has been widely used in studies on facial perception, including those on faces with different emotions, genders, races, and facial deformities.

Orthodontic and orthognathic treatment are aimed at achieving better facial attractiveness through increased dental attractiveness. In recent years, eye-tracking methods are increasingly being used in dental research to examine how laypersons view patients with different classes of malocclusions and degrees of facial attractiveness. Hickman et al¹ investigated the visual pattern of frontal faces of posttreatment orthodontic patients and showed that the mouth received <10% of the visual attention for even a smiling face, indicating that the mouth may not be a visually salient area in well-balanced faces. However, other studies suggested that malocclusion could motivate an attention shift to the mouth from other facial features.^{2,3,8,9} Richard et al² found that as dental attractiveness decreased (corresponding to a higher score of Aesthetic Component of the Index of Orthodontic Treatment Need [IOTN]), the fixation density and fixation duration to the mouth increased, accompanied by a decrease in the eye area. This tendency can be amplified by facial background attractiveness in frontal female faces. However, for male faces, the facial background attractiveness was shown not to influence this effect.⁹ Wang X et al⁸ verified the same visual shift on frontal faces of patients with malocclusion. In addition, later attention capture on the eye and earlier attention capture on the mouth was revealed by the first fixation time, which indicated that eye tracking might be a suitable method to measure orthodontic treatment needs and results from the layperson's perspective. Johnson et al³ discovered a significant increase in mouth attention for attractive females with an IOTN-7 dental appearance, which is considered a borderline treatment need in orthodontics, indicating that eye-tracking data are consistent with traditional evaluation methods in judging orthodontic treatment need. This finding also verified the feasibility of using eye tracking as an evaluation method.

However, not all kinds of malocclusion provoke visual attention to the mouth. Meyer-Marcotty et al¹⁰ reported that patients with skeletal Class III malocclusion were viewed less on the center of the face in frontal photographs, especially around the mouth. Other

deformations, such as cleft lip and palatal deformity, facial paralysis, and abnormal lower facial height, received more attention in the lower third of the facial area.¹¹⁻¹³ Through these findings, many important dental factors that influence how laypersons view frontal faces have been uncovered. Studies that examined the profile with eye trackers¹⁴ have demonstrated that eyes and nose were viewed less by participants; participants viewed the outlines of the facial profile more intensely than the frontal face and half profile. Attention on the mouth or cheek was not dependent on the facial direction. Factors such as sex, race, facial emotion, and task can alter the visual pattern of the facial profile.¹⁴⁻¹⁷ However, there is a lack of literature on the visual attention of the malocclusion facial profile in the dental area.

Some studies have indicated that the lateral face is not as important as the frontal face in terms of facial attractiveness.¹⁷⁻²⁰ An eye-tracking study showed that participants pay less attention to the facial profile relative to the frontal face and the half profile when rating or ranking the attractiveness of the subjects.¹⁷ Other studies have discovered that the facial profile is harder to detect in a large scene relative to other angles of faces.^{18,19} However, it is commonly agreed that the appearance of the facial profile should be considered in orthodontic and orthognathic treatment. Evaluation methods of orthodontic treatments (including the IOTN Index, Dental Aesthetic Index, and cephalometrics measurement) and theories used in orthodontic treatment (such as the Andrews 6 keys) contain sagittal standards.^{21,22} Furthermore, among patients who searched for orthognathic treatment, sagittal complaints were the highest, especially in patients with a Class III skeletal relationship who have been reported to be the least confident.²³⁻²⁵

Faces are viewed in 3 dimensions. Although the attractiveness of the frontal face is typically consistent with that of the lateral face, some distinctive characteristics (eg, thin upper lip, bulging nose, and blunt chin neck angle) may lead to significant differences between the attractiveness of the frontal and lateral faces.²⁶ The differences caused by the direction of the faces can exceed those associated with the attractiveness of different subjects.²⁷ Taking the facial profile into consideration is important when exploring facial attractiveness.

The purpose of this study was to determine the level of visual attention (first fixation time and fixation duration) of facial profiles with different degree of mandibular protrusion and to examine whether facial background attractiveness affects the view level of different facial profiles with protruded mandible.

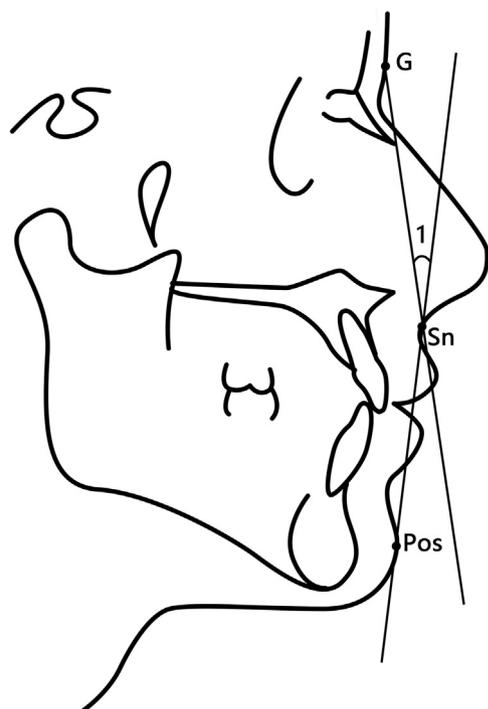


Fig 1. FCA. G, glabella; Sn, subnasale; Pos, pogonion of soft tissue.

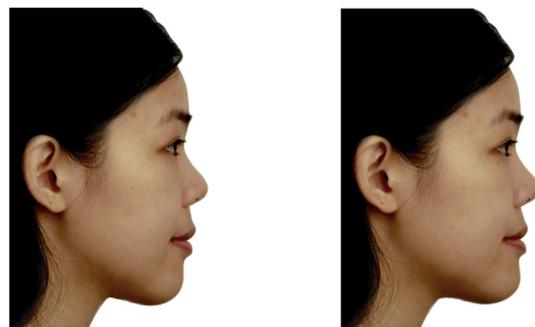
MATERIAL AND METHODS

This study was approved by the regulations of the Ethical Review Board at Sun Yat-sen University (approval number: ERC-[2016]-35).

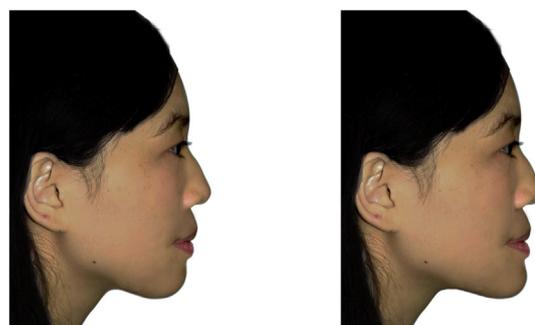
Female facial profile was obtained by seeking Chinese subjects (aged 18-25 years) with a normal facial contour angle (FCA; $7.3^\circ \pm 4.4^\circ$). FCA was measured by lateral cephalometric analysis (Fig 1). Subjects were excluded if evaluated as prompting prominent distraction by the researchers, such as a severe facial anomaly or unusual facial characteristics (eg, scars, unusual hairstyles, tattoos). A total of 200 subjects were selected. Facial profile photographs (in which the subjects were asked to relax the forehead and to look forward with neutral emotion) of each subject were taken using a digital single-lens reflex camera (D60; Canon, Tokyo, Japan). Images were standardized to a size of 2480 pixels \times 3508 pixels with a resolution of 300 pixels per inch (Adobe Photoshop CS4; Adobe Systems, San Jose, Calif).

These facial profiles were rated for attractiveness by 40 volunteers (20 males, 20 females) under the following inclusion criteria: (1) Chinese people aged 18-25 years, (2) no orthodontic and orthognathic treatment needs, (3) no orthodontic history, and (4) no professional dental expertise. Randomization was achieved using computer-

Before modification After modification



A



B



C

Fig 2. A, Modification of slight mandibular protrusion; B, modification of moderate mandibular protrusion; C, modification of severe mandibular protrusion.

generated randomization. The photographs were rated on a scale of 1-3 (1 = unattractive, 2 = average, or 3 = attractive), without time limitation or further definition. Forty photographs were repeated in a random order to determine reliability.² The intrarater kappa statistic was 0.76 with a 95% confidence interval (CI) of 0.70-0.82, and the interrater kappa statistic was 0.63 with a 95% CI of 0.56-0.70.

The mean attractive score for each image was used to group the profiles. The mean attractive score of all the

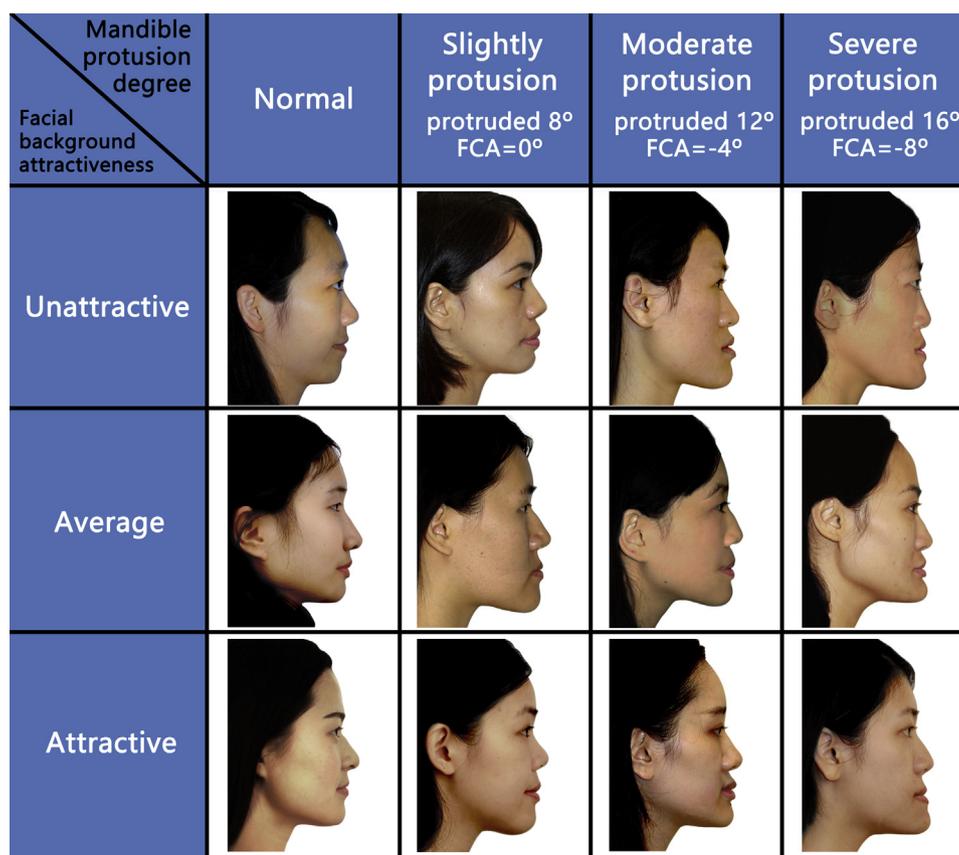


Fig 3. Examples of composite images (mandibular protrusion and facial background attractiveness) created for this study.

images was 1.96 with a standard deviation [SD], of 0.64. Photographs were grouped based on the following scores: <1.4 (unattractive group; $n = 45$), 1.7-2.3 (average group; $n = 79$), and >2.6 (attractive group; $n = 36$).²

Thereafter, the images were adjusted using image processing software (Adobe Photoshop CS4) by protruding the mandible while holding the height of the lower third of the face constant. Figure 2 shows examples of image modification. Eight images were randomly selected from each group: 2 were protruded 8° with a facial angle of 0°, 2 were protruded 12° with a facial angle of -4°, and 2 were protruded 16° with a facial angle of -8°. Thus, there were 2 normal profiles, 2 slightly protruded profiles, 2 moderately protruded profiles, and 2 severely protruded profiles in each attractiveness group. Normal profiles refer to profiles with normal FCA of Chinese people. Twelve kinds of profiles combined with different facial background attractiveness and mandibular protrusion were generated with 2 images for each, resulting in a total of 24 different images (Fig 3).

From September 2017 to October 2017, 55 participants were recruited via a recruitment advertisement in Sun Yat-sen University, Guangzhou. The inclusion criteria were as follows: (1) aged 18-25 years, (2) no visual impairment (eg, color blind, high degree of myopia), (3) no psychological problem (eg, autism, schizophrenia), (4) not a dental student or dentist, (5) no recent use of alcohol or other drugs, (6) not currently using any medication that might affect cognitive abilities, and (7) not wearing mascara or willing to remove it.^{2,8}

Before the experiment, the participants signed an informed consent form. A deception, informing participants that this research aimed to determine how laypersons view the lateral face, was used to reduce the bias caused by the mission factor. Participants were told the real purpose of the research after the completion of the study.

Eyelink 1000 Eye Tracker (SR Research, Ontario, Canada) was used in the research. Participants were positioned at a distance of 60 cm from the screen, with their heads settled by a chin support to eliminate head movement during the experiment. After a 9-point

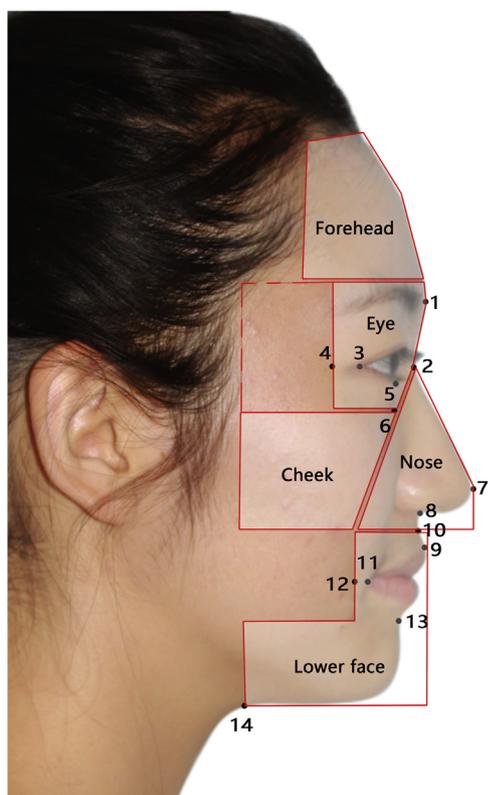


Fig 4. Example of AOI. 1, glabella; 2, nasion; 3, exocanthion; 4, 10 mm left to 3; 5, palpebrale inferius; 6, 10 mm below 5; 7, pronasale; 8, subnasale; 9, labrale inferius; 10 middle point between 8 and 9; 11, cheilion; 12, 5 mm left to 11; 13, mentolabial sulcus; 14, K point (point connecting neck and chin).

calibration and validation were conducted, 2 images were shown on the screen to familiarize the viewers with the procedure. Subsequently, 24 images used for the experiment were shown on the screen in a random order chosen by the computer program. Eye movement data were recorded at the same time. Each image was displayed for 4 seconds, with a randomly placed drift check dot shown for 1 second after that. The dot was used to eliminate the effect of the previous image and minimize the visual cuing of the observers. After all 24 images had been shown, the images were displayed in a new order to determine the intrarater and interrater reliability. The viewers were financially compensated after the completion of this experiment.

Statistical analysis

A sample size of 50 participants was used to obtain an α risk of 0.05, a CI of 0.2, and a predicted observed agreement of 0.88.¹ The lower face (mouth and mandible), eye, nose, cheek, and forehead were each

predetermined as an area of interest (AOI) according to the anthropometric landmarks (Fig 4).^{14,28}

Dependent variables (fixation duration, first fixation time) were analyzed using repeated-measures, factorial analysis of variance. Independent variables were as follows: AOI, grade of mandibular protrusion, and model facial background attractiveness. All the comparisons were analyzed using the Bonferroni test. The post-hoc testing was done using the GLMPower procedure in SAS (Cary, NC).

RESULTS

Of the 55 laypersons who entered the study, 54 completed the study; 1 layperson was disqualified after he failed to complete the validation and calibration steps. Among the participants, 50% ($n = 27$) were female, and 50% ($n = 27$) were male. Participant ages ranged from 18 to 23 years, with a mean of 20.3 years.

Heat maps of composite profiles are presented in Figure 5. Red color represents the visual salient area, and green color represents an area with less visual attention.

For the fixation duration and first fixation time, the intrarater viewer reliability ranged from interclass correlation values of 0.62-0.91, and interrater reliability ranged from 0.54-0.94. Because of the poor reliability for the forehead (interclass correlation, <0.10), this AOI was excluded from the study (Table I).

The fixation duration represents the total fixation time that viewers spent on each AOI during the observing time of an image. The first fixation time is the time from the beginning of observation to the location of the first fixation in each AOI for an image (ie, when the viewer first viewed this area of the image).

For both fixation duration and first fixation time, repeated-measures ANOVA showed a significant 3-way interaction between facial attractiveness, mandibular protrusion grade, and interest area (Table II). The fixation duration and first fixation time showed similar results but from a different perspective. However, because fixation duration had higher reliability than first fixation time, we subsequently focused on fixation duration. The differences between facial areas (eye, cheek, lower face, nose) and mandibular protrusion grades (normal, slight, moderate, severe) were examined within the context of this 3-way interaction. The level of significance was set at 0.05.

For normal profiles, eyes received greatest the most significant fixation and were higher than lower face and nose, which were the least-viewed areas (Fig 6). Slightly protruded profiles were viewed almost in the same way as normal profiles (Fig 7). However, for

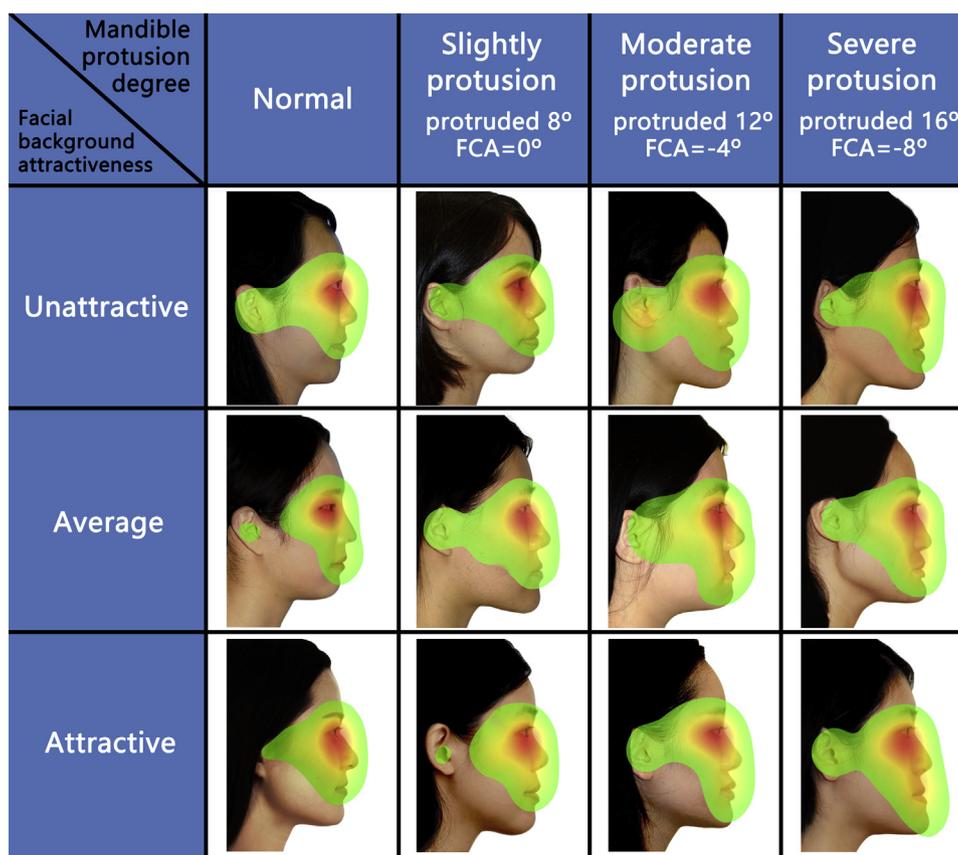


Fig 5. Examples of heat maps of composite profiles.

Table I. Intrarater reliability for total duration of fixations and first fixation time by area of the face

	Total duration			First fixation time		
	ICC	LCB	UCB	ICC	LCB	UCB
Fixation duration						
Eye	0.90	0.89	0.91	0.76	0.72	0.80
Cheek	0.82	0.81	0.83	0.55	0.53	0.58
Nose	0.78	0.76	0.80	0.58	0.55	0.62
Mouth and mandible	0.88	0.86	0.90	0.76	0.73	0.78
Forehead	0.80	0.79	0.81	0.06	0.00	0.12
First fixation time						
Eye	0.81	0.80	0.82	0.75	0.71	0.77
Cheek	0.91	0.90	0.92	0.94	0.89	0.98
Nose	0.68	0.66	0.70	0.54	0.52	0.57
Mouth and mandible	0.87	0.86	0.88	0.85	0.82	0.88
Forehead	0.62	0.58	0.66	-0.21	-0.26	-0.16

Intrarater reliability scoring: <0.20, poor; 0.21-0.40, fair; 0.41-0.60, moderate; 0.61-0.80, good; >0.80, very good.²
 ICC, Interclass correlation; LCB, lower confidence boundary (2.5%); UCB, upper confidence boundary (97.5%).

Table II. ANOVA summary for fixation duration and first fixation time

Effect	DF	F	P value
Fixation duration			
Attract	2	1.158	0.318
Angle	3	0.964	0.411
Area	3	4.906	0.003
Attract*Angle	6	2.011	0.064
Attract*Area	6	1.904	0.080
Angle*Area	9	4.351	<0.001
Attract*Angle*Area	18	3.212	<0.001
First fixation time			
Attract	2	7.783	0.001
Angle	3	2.788	0.042
Area	3	49.886	<0.001
Attract*Angle	6	3.164	0.005
Attract*Area	6	8.892	<0.001
Angle*Area	9	6.238	<0.001
Attract*Angle*Area	18	6.101	<0.001

DF, Degrees of freedom; F, test statistic; Angle, mandible protrusion grade; Area, facial area; Attract, facial attractiveness level.

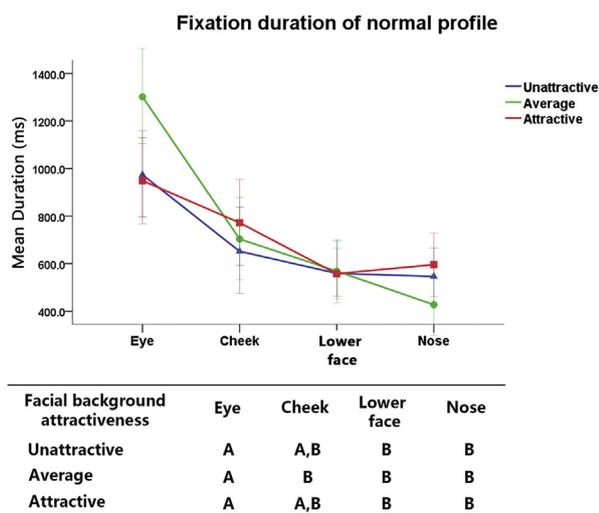


Fig 6. Mean duration of fixations for normal profiles received by facial background attractiveness by AOI. The graph is shown as mean ± SD. Significant differences ($P < 0.05$) are represented by discrepancies in the letters between each AOI for each facial attractiveness. Across a row, areas that differ significantly do not share the same letter.

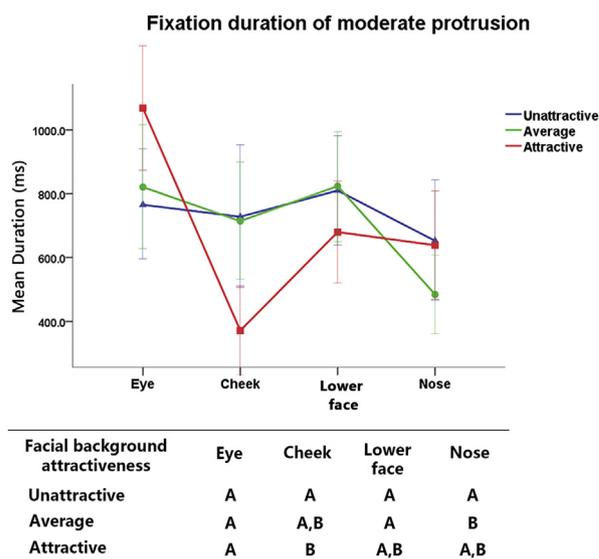


Fig 8. Mean duration of fixations for moderately protruded profiles received by facial background attractiveness by AOI. The graph is shown as mean ± SD. Significant differences ($P < 0.05$) are represented by discrepancies in the letters between each AOI for each facial attractiveness. Across a row, areas that differ significantly do not share the same letter.

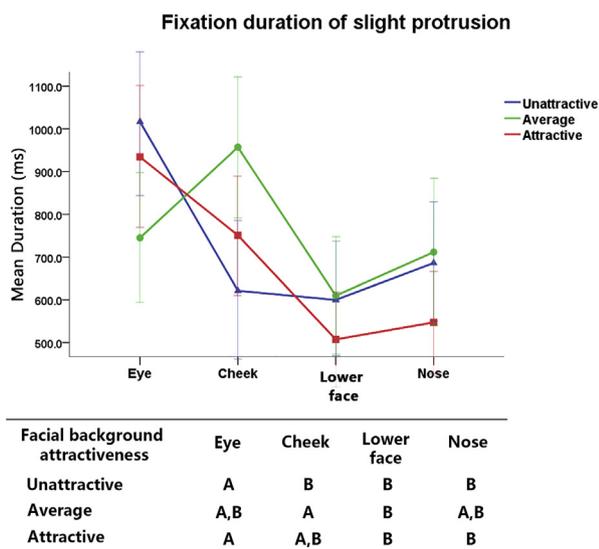


Fig 7. Mean duration of fixations for slightly protruded profiles received by facial background attractiveness by AOI. The graph is shown as mean ± SD. Significant differences ($P < 0.05$) are represented by discrepancies in the letters between each AOI for each facial attractiveness. Across a row, areas that differ significantly do not share the same letter.

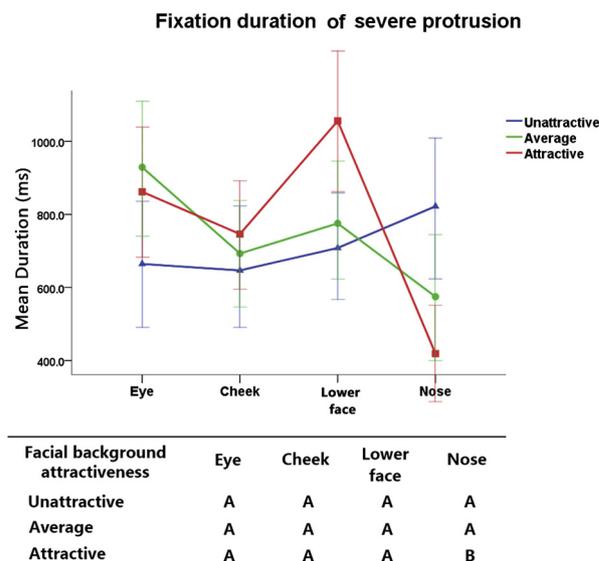


Fig 9. Mean duration of fixations for severely protruded profiles received by facial background attractiveness by AOI. The graph is shown as mean ± SD. Significant differences ($P < 0.05$) are represented by discrepancies in the letters between each AOI for each facial attractiveness. Across a row, areas that differ significantly do not share the same letter.

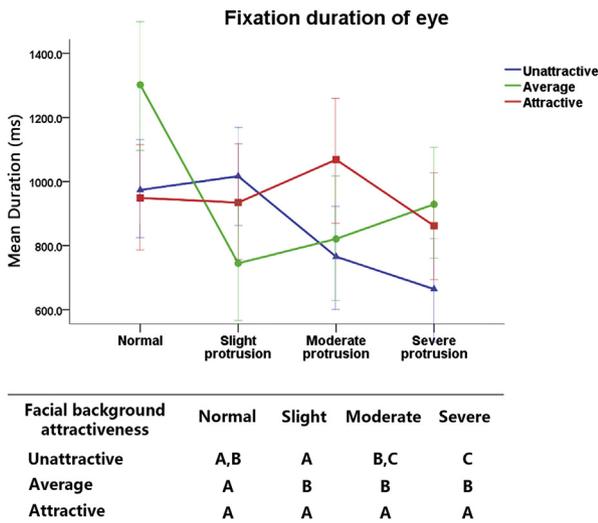


Fig 10. Mean duration of fixations for the eyes received by facial background attractiveness by the level of mandibular protrusion. The graph is shown as mean ± SD. Significant differences ($P < 0.05$) are represented by discrepancies in the letters between each mandibular protrusion level for each facial attractiveness. Across a row, levels that differ significantly do not share the same letter.

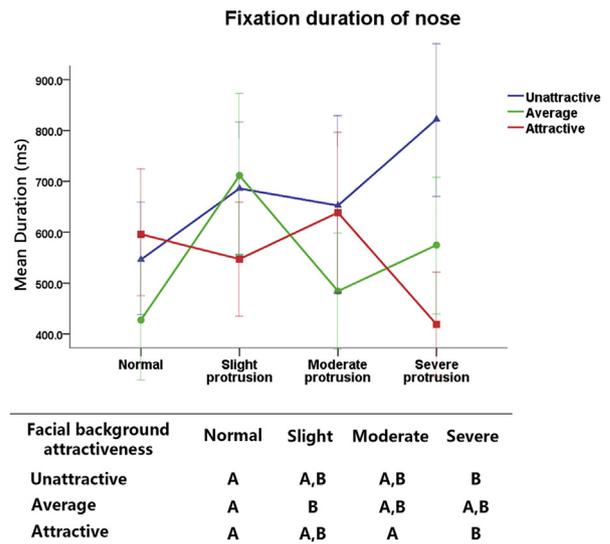


Fig 12. Mean duration of fixations for the nose received by facial background attractiveness by the level of mandibular protrusion. The graph is shown as mean ± SD. Significant differences ($P < 0.05$) are represented by discrepancies in the letters between each mandibular protrusion level for each facial attractiveness. Across a row, levels that differ significantly do not share the same letter.

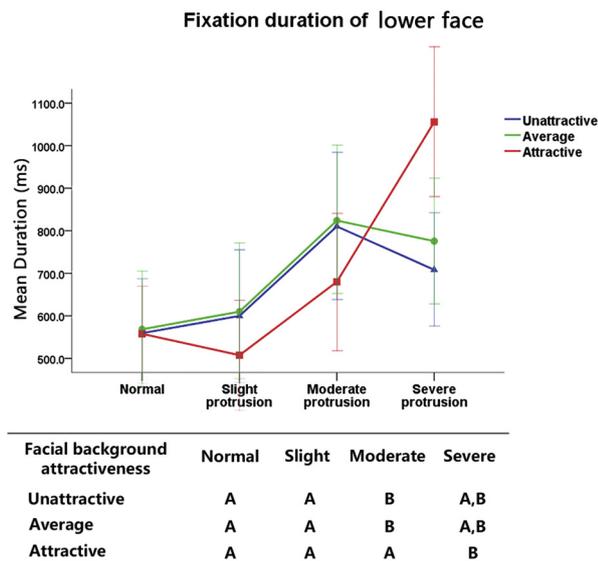


Fig 11. Mean duration of fixations and first fixation time for the lower face received by facial background attractiveness by level of mandibular protrusion. The graph is shown as mean ± SD. Significant differences ($P < 0.05$) are represented by discrepancies in the letters between each mandibular protrusion level for each facial attractiveness. Across a row, levels that differ significantly do not share the same letter.

moderately and severely protruded profiles, the lower face was viewed more than nose and cheek, with no significant differences when compared with eyes (Figs 8 and 9).

As the degree of protrusion increased from slight protrusion to moderate protrusion, more attention was drawn to the lower face accompanied by less attention to eyes in the unattractive group (Figs 10 and 11). When protrusion degree increased from moderate to severe, attention significantly shifted from nose to lower face in the attractive group (Figs 11 and 12). Attention shift from eyes to lower face was shown in the average group when protrusion degree shifted from normal to moderate protrusion (Figs 10 and 11). With more pronounced protrusion of the mandible, fixed duration demonstrated an uneven but gradual increase in attention to the lower face, an uneven decrease in attention to the eyes of unattractive and average models, and a decrease in attention to the nose of attractive models (Figs 10-12). Participants tended to shift visual attention from eyes to the lower face of unattractive and average subjects, and from nose to the lower face of attractive subjects with an increase in the severity of the mandibular protrusion grade, although this was not statistically significant.

Table III. ANOVA summary for fixation duration and first fixation time of mouth

Effect	DF	F	P value
Fixation duration			
Attract	2	0.176	0.839
Angle	3	9.972	<0.001
Attract*Angle	6	2.552	0.020
First fixation time			
Attract	2	0.612	0.544
Angle	3	7.407	<0.001
Attract*Angle	6	1.226	0.293

DF, Degrees of freedom; F, test statistic; Angle, mandible protrusion grade; Area, facial area; Attract, facial attractiveness level.

Interaction between facial background attractiveness and mandibular protrusion in lower face area was examined within the context of the 3-way interaction. Repeated-measures ANOVA showed a significant interaction for fixation duration (Table III).

The peak increase of lower face fixation duration appeared with slight (8°) and moderate (12°) protrusion for the unattractive and average group but between moderate (12°) and severe (16°) protrusion for the attractive group (Fig 11). The mean duration difference between moderate and severe protrusion in the attractive group was bigger than that between slight protrusion and moderate protrusion in the unattractive group (Fig 11); however, the differences were not statistically significant. We conclude that the evocation point (the mandibular protrusion degree that can evoke attention to the lower face) of the attractive facial background is higher than that of the unattractive background. Once evoked, the effect of mandibular protrusion of the attractive group was stronger than that of the unattractive group, although without statistical difference.

DISCUSSION

This study aimed to describe how laypersons view a normal facial profile, determine how the attention distribution and observation pattern (first fixation time, fixation duration) change with increasing mandibular protrusion, and explore whether facial background attractiveness affects the view level of profiles with varying extent of mandibular protrusion.

Previous studies have widely concluded that laypersons maintain a stable viewing pattern for frontal faces, including the initial and frequent viewing of the eye, with a later shift to the mouth.²⁹⁻³² Eye-tracking studies have also indicated that eyes are the most visual salient area of face.¹⁴⁻¹⁶ However, these studies assigned a task to the participants, such as to recognize the race or emotion of the face, which may have caused bias and

therefore may not be truly representative of the visual pattern identification procedures that participants used in their social life. In our study, similar to the case of the frontal faces, the eyes had the most extended attention duration on the facial profiles, which may be attributed to the highly informative characteristic of the eyes.

Psychological studies have reported that objects or contents with great information can catch the viewers' eye.^{33,34} People tend to perceive signals from eyes decoupled from language, such as emotional signals. One study showed that eye contact between mothers and infants had a positive effect on the babies' future social life,³⁵ which may explain the high prominence of the eyes in facial perception. Furthermore, the eyes may be used as an anchor when the face direction changes, which may also explain the consistent visual attention to the eye for both the frontal faces and facial profile.^{14,16}

In the present study, the viewing order of the facial profile was not the same as the frontal faces studied. Regardless of the mandibular protrusion, the cheek was always viewed earlier than other facial features, which may be because the cheek is located in the center of the face. There has been a lack of agreement in the fixation pattern of the first fixation. Some investigators have suggested a geometric theory as a determinant of the first fixation, which is most often directed toward the geometric center of the faces,^{15,36} and is consistent with the results of our study. Other researchers have shown that the first fixation always existed in a distinct facial feature, which may sometimes be located in the place of the geometric center, indicating that the main effect is the facial feature rather than the position.^{14,16} The remaining investigators have attributed the differences to the task that the viewer received.³²

Evidence collected from the most relevant studies implied that the main facial features (eyes, nose, and mouth) deliver less information in the face turned to the lateral side relative to the frontal orientation.¹⁴⁻²⁰ Viewers generally try to obtain more information by scanning the face. In our study, participants were not assigned a task, which may indicate why the cheek was viewed before the more distinctive facial features. However, it is commonly accepted that viewers begin by focusing on distinct features after the first fixation and throughout the whole observation, which coincides with the results of our study.

Previous eye-tracking studies of normal frontal faces have reported that the mouth occupies only a small part of the visual attention.^{1-3,8,9,37,38} Our study showed that the lower face occupies only a small part of the visual

attention for the normal facial profile, which suggests that the mouth may not be the most important feature in normal facial perception. However, questionnaire surveys showed that in contrast to the layperson, orthodontists focus more on the lower third of the face when viewing the full facial profile and that the lower third of the face is more sensitive to abnormality.^{25,39,40} This indicates that orthodontists may have a different facial preference pattern relative to the layperson. Orthodontists should communicate carefully with patients to reach an agreement on a treatment goal, as well as what can or should be improved by treatment. The difference in facial preferences between dentists and laypersons indicates that the perspective of the layperson should be considered in orthodontic treatment.

Although the eyes received most of the visual attention in facial perception, our findings demonstrate that the degree of mandibular protrusion significantly affected the fixation duration and first fixation time of the lower face. In cases of severe mandibular protrusion, visual attention shifted from other facial features to the lower face, which is consistent with studies concerning frontal faces of patients with malocclusion to some extent.^{2,3,9} The abnormal attention to the lower face may be caused by the viewer's identification of a deformity. Studies have discovered that facial inconsistencies, such as the cleft lip and palatal, abnormal lower facial height, and facial surgical defects, tend to induce greater visual attention to these areas.^{11,12,41} This phenomenon may be explained by the attentional chasing of an inconsistent object to determine its identity and ensure its placement.³

In our study, the protruded mandible may have been detected as inconsistent, thus leading to the shift in the attention from the eyes or the nose. Researchers have found that the head position in patients with skeletal Class III malocclusion varies from that of patients with Class I malocclusion. Patients with skeletal Class III malocclusion tend to lower their heads. However, this difference in head position gets resolved when the deformity is corrected by surgery or invasive treatment.⁴² We observed that in the clinic, some Class III patients preferred to wear masks when outside. This behavior can be explained by their desire to hide the protruded mandible to block visual attention directed to this area.

For the unattractive and average group, we found a significantly increased fixation duration on the lower face between the slightly protruded (8° protrusion) and moderately protruded (12° protrusion) profiles, corresponding to a threshold of significantly increased viewer

attention in this area. Consistent with our results, several studies on patients who searched for orthognathic treatment and underwent surgery in China have concluded that the facial angle of patients ranged between approximately -2° and -3°.^{43,44} Abnormally increased attention to the lower face from others may be the motivation of these patients to search for treatment. These patients desired to receive normal visual attention with a profile gained by orthognathic treatment. Most patients become more confident and experience increased social well-being after the surgery.^{45,46}

Facial background attractiveness was used as a factorial variable in this study and was defined as the attractiveness caused by facial factors other than mandibular protrusion. Such attractiveness was evaluated with a normal mandible position before image alteration. The results showed that facial background attractiveness and mandibular protrusion had an interaction effect on the lower face fixation duration.

When the mandible protruded <12°, higher facial background attractiveness weakened the effect of mandibular protrusion on lower face fixation. In other words, the same deviation of the mandible position is less likely to be noticed and studied with an attractive facial background, which is different from the interaction between dental attractiveness and facial attractiveness on the frontal faces.² This phenomenon can be explained by the strong ability of other facial features to draw attention and hold it for a long time. Previous studies have noted that an attractive face can be captured by the eyes earlier and can maintain visual attention for a longer time; thus, it is harder to divert attention from attractive objects.^{47,48} High attractiveness of other facial factors may override the slight abnormality of the lower face.

When the mandible protruded more than a certain threshold between 12° and 16°, a strong effect of mandibular protrusion occurred on the lower face fixation time in the attractive facial background, which might be attributed to the incongruity between the attractive facial background and the severely protruded mandible. The questionnaire survey showed that severe mandibular protrusion was considered to be least attractive in all kinds of facial profiles. The more the mandible protrudes, the less attractive is considered the profile.^{25,39,40} As a result, a severely protruded mandible is inconsistent with the attractive facial background. Studies have found that incongruous objects may act as a distinct region that is viewed most frequently.^{49,50} A study of female frontal faces with malocclusion reported a similar effect.²

Based on these results, we conclude that the appearance of the lower face draws the observer's attention but that facial background attractiveness can modify the effect of mandibular protrusion on lower face attention from the layperson. Patients with the same protruded mandible can be viewed differently depending on their facial background esthetic. Consequently, in patients with the same mandibular protrusion, some search for treatment urgently, whereas others are not affected by this characteristic or even unaware of any deformity. Patients with skeletal deformities may also consult orthodontic treatment only for alignment of the teeth, indicating that a discussion with patients about the complaint and the aim of the treatment is of vital importance.

The motivation drawing patients with Class III malocclusion to treatment may come from the observations they have received from social life, which is affected not only by mandibular protrusion but also by other facial features. Some patients may not require surgery because of other attractive facial factors. As a result, the perspective of the layperson should be considered when making treatment choices in patients with skeletal mandibular protrusion.

Although we chose a female facial profile and participants randomly within the criterion, geographic limitation still existed. Most of the participants and female subjects were from south China, which means the result of our study may not represent the entire Chinese population.

CONCLUSIONS

1. For normal and near-normal facial profiles, eyes are the most salient area; the lower face was observed less in terms of fixation duration.
2. The degree of mandibular protrusion tends to draw attention to the lower face from the eyes or nose. The visual attention allocated to the lower face may exceed the eyes in patients with severe mandibular protrusion, although without significant differences.
3. Visual attention of the facial profile is affected not only by mandibular protrusion but also by the background level of facial attractiveness, which can modify the effect that mandibular protrusion exerts on visual attention.
4. Taking the layperson's perspective into consideration when making treatment choices is of vital importance.
5. The result of this study may not be representative of the Chinese population in its entirety because of the geographic limitation of the study.

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