

Effect of Labial-lingual Inclination of Maxillary Incisors on Aesthetic Assessment for Smile Profiles with Different Chin Positions

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Objective: To explore and visualise how different degrees of labio-lingual inclination of the maxillary incisors affect the aesthetic assessment of smiling profiles in people with various chin positions. Different perceptions from professionals and non-professionals are outlined in this study.

Methods: A profile photograph with a clear facial contour and a full smile was captured and then edited into a series of 49 smiling profile pictures, with seven variations in both chin position and maxillary incisor inclination. A MaxDiff survey was conducted to rank the photos according to the aesthetic preference of orthodontists and laypeople. The data were then evaluated using count analysis and hierarchical Bayes estimation.

Results: Upright and mild lingual inclination (0 to 5 degrees) of the maxillary incisors generally gained higher acceptance in both groups when chin protrusion was not taken into consideration, whereas the opposite was true for labial inclination. The acceptance of excessive lingual inclination (10 to 15 degrees) of the central incisor in laypeople was significantly higher than in orthodontists. Both groups suggested that as chin retrusion increases (6 mm), increasing maxillary incisor lingual inclination (10 degrees) is preferred. When chin retrusion was greater (6 mm), upright or mild lingual inclination (0 to 5 degrees) was considered acceptable by orthodontists, but greater lingual inclination (5 to 15 degrees) was also acceptable by laypeople.

Conclusion: Both labio-lingual inclination of maxillary incisors and chin position play an essential role in the aesthetic assessment of smile profiles. The ideal value for maxillary incisor inclination varies with chin position.

Keywords: chin prominence, facial profile, labio-lingual inclination, maxillary central incisors, smile aesthetics

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The smile is one of the most universally understood expressions. Besides serving as a bridge to connect individuals by expressing friendship, approval and appreciation, smiling also plays a major role in enhancing individuals' appearance.^{1,2} Improving smile aesthetics is a common request from patients seeking orthodontic treatment.^{3,4}

Positioning of the maxillary incisors in the antero-posterior (AP) dimension is crucial to achieve optimal dentofacial aesthetics. Numerous studies have been devoted to determining principles for assessing the positions and labio-lingual inclinations of maxillary

incisors. The patient's forehead has been used as a stable marker to confirm the location of the facial axis (FA) point of the maxillary incisor in the smiling profile most of the time.⁵ Cao et al⁶ proved that both the labio-lingual inclination and AP position of the maxillary incisors played an essential role in the aesthetics of the smiling profile. Naini et al⁷ indicated the ideal inclination of the maxillary incisors in profile view will be approximately parallel to the true vertical line. The lower bow-shaped curves (LBSCs) also could serve as a reference frame to determine the lateral limit of the anterior maxilla for the aesthetics of 45-degree angled smiles.⁸ Another study showed that patients who had completed orthodontic treatment were more likely to have the maxillary central incisor between the forehead FA and glabella.⁹ All these studies suggested both inclination and AP position of the maxillary incisors is vital for the full-facial harmony. However, no studies have been carried out to explore whether the optimal value of the maxillary incisors varies in patients with different facial types.

At the same time, chin position also played an important role in the aesthetic coordination of the profile and smile. The shape and position of the chin are important factors in evaluating the lower third of the face and smile aesthetics.^{10,11} Patients with an under- or overdeveloped chin or mild to moderate skeletal Class II or III (usually accompanied with chin retrusion or protrusion) require compensatory orthodontic treatment instead of orthognathic surgery. It is an important prerequisite to determine the appropriate target position of the maxillary incisors for the smiling profile and reconstruction of the lower facial third.¹² Li et al¹³ suggested the aesthetic and ideal anteroposterior position of the maxillary incisors was not only determined by the goal anterior limit line (GALL), but also involving the upper and midfacial soft tissue landmarks (glabella and subnasale (Sn) point). However, the aesthetic and ideal anteroposterior relationship between the maxillary incisors and the chin has not been reported yet. Furthermore, there is currently no conclusive evidence regarding whether there are distinct differences in aesthetic assessments and requirements between orthodontic professionals and non-professionals. When examining the current published literature, some studies emphasised the differences in perception of facial beauty between professionals and non-professionals,¹⁴ while others claimed that the overall aesthetic point of view is similar.¹⁵

The labio-lingual inclination of the maxillary central incisors and the degree of chin protrusion were adjusted by editing photographs of an Asian man with good

facial contour and smiling profile and the maximum difference (MaxDiff) questionnaire was designed and utilised in this study. The images were then ranked by orthodontic professionals and laypeople. The purpose of this study is to explore the effect of labio-lingual inclination of the maxillary central incisors on the aesthetic assessment of the smile in profile view with different chin positions and offer guidance when positioning the maxillary central incisors in orthodontic treatment with different chin positions to achieve a desirable aesthetic smiling profile, notably for patients with a protruding or retruding chin but who refused to have surgery. This study will also reveal the difference between orthodontists and laypeople from an aesthetic point of view, contributing to designing a better clinical treatment plan and achieving optimal treatment results.

Materials and methods

Ethical approval

This study was performed in line with the principles outlined in the Declaration of Helsinki. Approval was granted by the medical ethics committee at West China Hospital of Stomatology, Sichuan University (WCHSIRB-CT-D-2023-126).

Selection of standard smiling profile photos

A 27-year-old Asian man with a facial contour that met the following criteria was selected to capture a standard smiling profile photograph (Fig 1). His facial contour met the following criteria:^{5,16-18}

- Class I occlusion and Class I skeletal pattern;
- hard and soft tissue within the normal range on cephalometric analysis;
- facial angle and H angle within the normal range;
- conforming to Elements II in Andrews' Six Elements;¹³ that is, the ideal maxillary-forehead relationship: the maxillary central incisor's FA point is on the GALL and the labio-lingual inclination of the maxillary central incisor is normal;⁴
- the position of the soft tissue pogonion was normal: the true vertical line (TVL) was made from the subnasal point of natural head position, and the distance of the soft tissue pogonion was normal (2 to 4 mm behind the line).^{19,20}

Table 1 presents his cephalometric data.

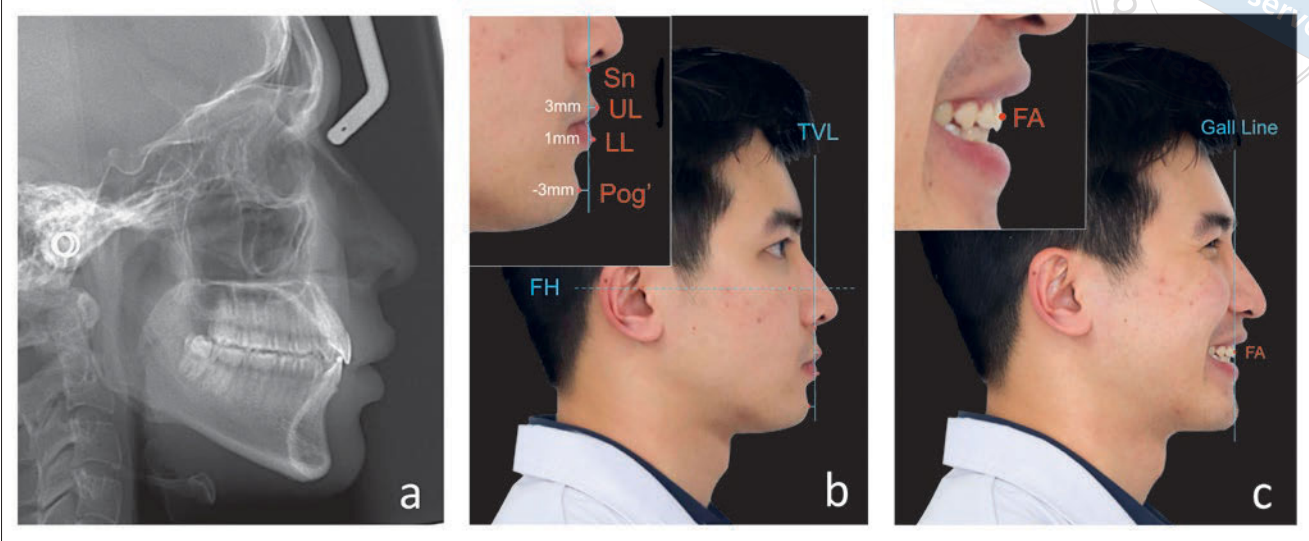


Fig 1a to c Lateral cephalometric radiograph (a), natural profile photograph (b) and smiling profile photograph showing the maxillary incisor FA lies on the GALL (c).

Table 1 Values for hard and soft tissue analysis.

Measurements	Normal	SD	Subject
SNA(°)	82.8	4.0	80.6
SNB(°)	80.1	3.9	76.7
ANB(°)	2.7	2.0	3.9
SN-MP(°)	32.5	5.2	37.7
SN-OP(°)	16.1	5.0	20.9
GoGn-SN(°)	32.5	5.2	36.2
U1-NA(°)	22.8	5.7	17.2
L1-NB(°)	30.3	5.8	30.0
U1-L1(°)	124.2	8.2	128.9
UL-EP(mm)	1.0	2.0	0.3
LL-EP(mm)	2.0	2.0	1.0
Z-Angle(°)	77.0	5.0	72.0
N-Sn-Pg(°)	168.0	4.0	164.0
Facial angle(°)	89.3	2.7	90.8
H angle(°)	15.3	3.3	11.3

SD, standard deviation.

Image modification

Photoshop CC2022 (Adobe, San Jose, CA, USA) was used to modify the chin position of the standard photograph and label them from A to G as follows: A, 4 mm retrusion (−4 mm); B, 2 mm retrusion (−2 mm); C, normal (0 mm); D, 2 mm protrusion (+2 mm); E, 4 mm protrusion (+4 mm); F, 6 mm retrusion (−6 mm); and G, 6 mm protrusion (+6 mm). The inclination of the maxillary central incisor in photographs A to G was then modified with the FA point as the centre, numbered from 1 to 7: 1, labial 5 degrees (+5 degrees); 2, labial 10 degrees (+10

degrees); 3, labial 15 degrees (+15 degrees); 4, upright (0 degrees); 5, lingual 5 degrees (−5 degrees); 6, lingual 10 degrees (−10 degrees); 7, lingual 15 degrees (−15 degrees). Finally, a total of 49 photographs numbered from A1 to G7 were generated, as shown in Fig 2.

Questionnaire design and survey

An online version of a MaxDiff questionnaire was created instead of using a traditional visual analogue scale (VAS) method to avoid visual and aesthetic fatigue.²¹ MaxDiff, also known as best-worst scaling, is a standard

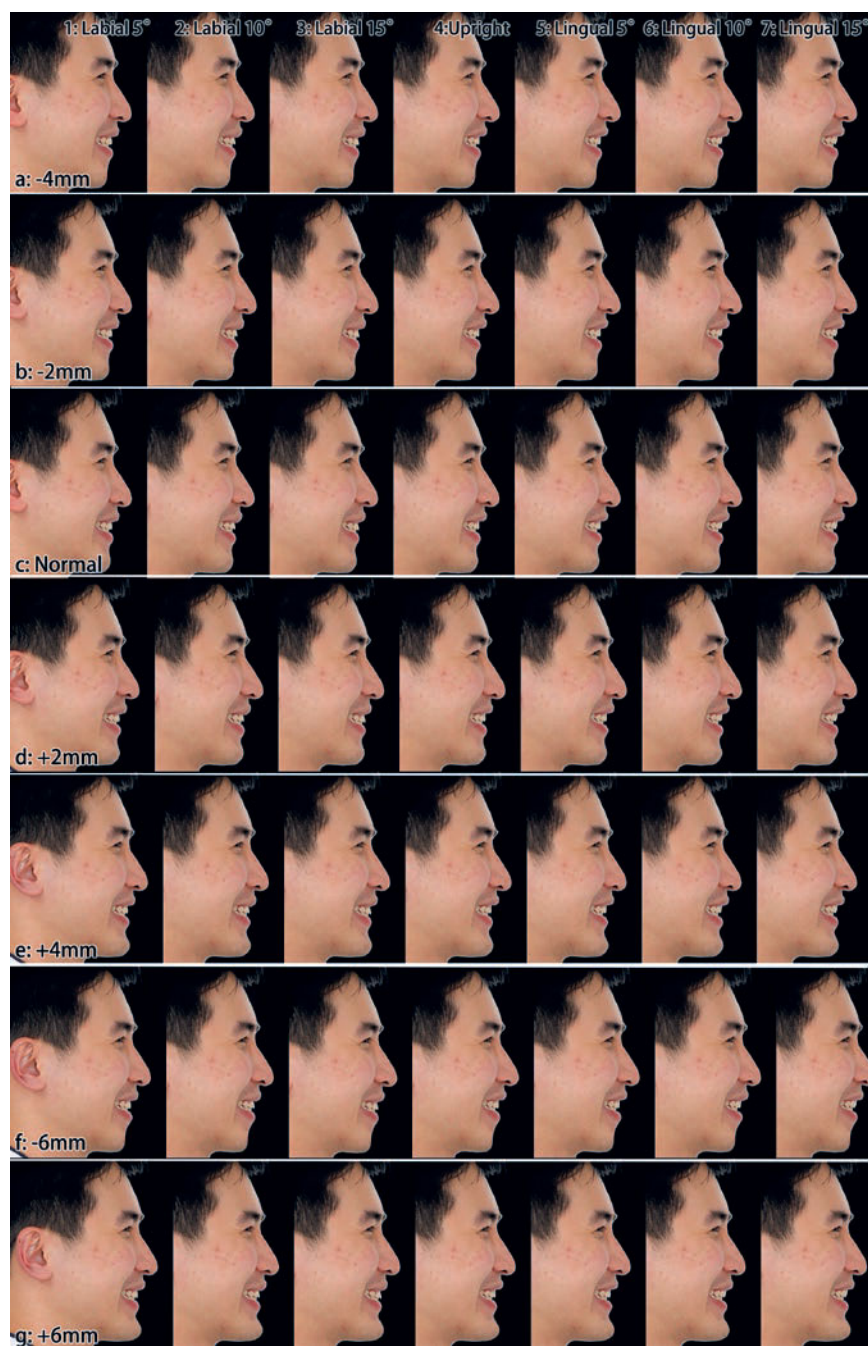


Fig 2a to g The 49 edited smiling photographs (A1 to G7); the maxillary incisors were inclined labially by 5, 10 and 15 degrees and lingually by 5, 10 and 15 degrees. Chin position was retruded or protruded by 2, 4 and 6 mm.

method used to analyse participants' preferences.²² It consists of choice tasks with a minimum of three options where participants need to choose the best and worst one for each task. As MaxDiff is considered to represent a low cognitive burden on study participants even when there are vast target options, it was chosen for this study. Rankers used computers to complete the questionnaire in which three photographs appeared randomly for each question and they were asked to rank them according to aesthetic appearance. Each photograph appeared

in at least three questions and was ranked at least three times. Only participants who completed the MaxDiff questionnaire and the demographics section in full were included in the analyses. The MaxDiff data were evaluated using count analysis and hierarchical Bayes (HB) estimation in Sawtooth Software (Provo, UT, USA).

The subjects included dental professionals and lay-people. The composite ranking of the photographs was generated by combining all the participants' answers. The sample size for the MaxDiff questionnaire was

Table 2 Overview of subjects participating in the survey.

Occupation	n	Sex		Age (y)		
		Female	Male	< 30	30–60	> 60
Orthodontists	83	41	42	27	56	0
Laypeople	240	168	72	205	29	6
Total	323	209	114	232	85	6

calculated in accordance with the recommendations from Sawtooth and resulted in a required sample size of 146. A group of orthodontists ($n = 83$; 41 women, 42 men; professional experience > 3 years) and laypeople ($n = 240$; 168 women, 72 men) were recruited as raters to evaluate the attractiveness of each image. The professional panel consisted of orthodontists who practiced in Chengdu, China. The lay panel consisted of college students from Sichuan University and their family members with no link to dentistry. To test intrasubject reproducibility, repeated assessments were made 3 weeks after the initial ratings. The order of the photographs was changed randomly between the first and second evaluations. Every image was examined twice by each judge, and the mean scores were used for statistical comparisons.

Data analysis

GraphPad Prism (GraphPad, La Jolla, CA, USA), SPSS (IBM, Armonk, NY, USA) and RStudio (Boston, MA, USA) were used to analysis and visualise the data. A t test was employed to analyse the difference in inclination score for the same central incisor between professional and non-professional groups for each chin position. All the photos were divided into three grades according to the scores, and a one-way analysis of variance (ANOVA) was used to calculate whether the grades had statistical differences. Intraobserver reliability of aesthetic evaluations was determined by intraclass correlation coefficient (ICC). Differences in aesthetic assessments between images within the series were detected by Sidak multiple comparisons. The significance level of all statistical tests was set at 0.05.

Results

Aesthetic differences between orthodontists and laypeople

A total of 323 participants took part in the ranking, including 83 orthodontists and 240 laypeople (209 women and 114 men; 232 younger than 30 years, 85 between

the ages of 30 and 60, and 6 older than 60 years. Table 2 summarises the participants who participated in the survey. Excellent intraobserver reliability was demonstrated for orthodontists (ICC 0.732 to 0.815) and laypeople (ICC 0.716 to 0.807).

There was no significant difference between aesthetic assessments by men and women, but the orthodontists and laypeople differed significantly. According to the aesthetic assessments, the 30 images in each series were divided into three grades, “attractive”, “acceptable” and “unattractive”, according to Sidak multiple comparisons. Each image graded “attractive” had a significantly higher score than those graded “unattractive”. Images graded “acceptable” had scores that were neither significantly lower than those graded “attractive”, nor higher than those graded “unattractive”. A one-way ANOVA showed that there was a significant difference between the scores of the three groups ($P < 0.0001$), and Table 3 summarises the scores for all photographs. Figure 3 shows the difference in chin retrusion (Groups A, B, C and F) and chin protrusion (Groups C, D, E and G) scores between the professional and non-professional groups, respectively. The difference between the highest and lowest scores in the professional group was significantly greater than in the non-professional group regardless of chin position, indicating that orthodontists are more sensitive to subtle changes in the lower facial third as expected. In the chin retrusion group, the professional group had significantly lower scores than the non-professional group on photographs C7, B7, A7 and F7, which belonged to the group with -15 degrees inclination of the central incisor. The results showed that the acceptance of maxillary central incisor lingual inclination among laypeople was higher than that of orthodontists. Subsequently, the scores of seven photographs of the same chin protrusion were visualised to better compare the difference in acceptability of different central incisor inclinations under the same chin protrusion between the professional and non-professional groups (Fig 4). Firstly, for seven different chin prominences, the most acceptable central incisors were upright and -5 degrees inclination, and the lowest was 10 degrees and 15 degrees inclination in both the professional and

Table 3 Mean $\pm$ SD for the raw score of each photograph.

No.	Chin position, mm	Maxillary incisor inclination, degrees	Orthodontists Mean $\pm$ SD	Laypeople Mean $\pm$ SD
F1	-6	5	-0.08 $\pm$ 0.27	-0.04 $\pm$ 0.22
F2	-6	10	-0.55 $\pm$ 0.21	-0.27 $\pm$ 0.24
F3	-6	15	-0.67 $\pm$ 0.16	-0.36 $\pm$ 0.27
F4	-6	0	0.01 $\pm$ 0.24	-0.06 $\pm$ 0.19
F5	-6	-5	0.07 $\pm$ 0.24	0.09 $\pm$ 0.23
F6	-6	-10	-0.06 $\pm$ 0.18	0.12 $\pm$ 0.24
F7	-6	-15	-0.25 $\pm$ 0.21	0.03 $\pm$ 0.22
A1	-4	5	0.09 $\pm$ 0.20	0.01 $\pm$ 0.18
A2	-4	10	-0.57 $\pm$ 0.15	-0.25 $\pm$ 0.22
A3	-4	15	-0.72 $\pm$ 0.13	-0.29 $\pm$ 0.28
A4	-4	0	0.08 $\pm$ 0.24	0.05 $\pm$ 0.20
A5	-4	-5	0.31 $\pm$ 0.17	0.12 $\pm$ 0.22
A6	-4	-10	0.25 $\pm$ 0.26	0.10 $\pm$ 0.25
A7	-4	-15	-0.20 $\pm$ 0.17	0.05 $\pm$ 0.21
B1	-2	5	0.28 $\pm$ 0.17	0.05 $\pm$ 0.20
B2	-2	10	-0.31 $\pm$ 0.18	-0.17 $\pm$ 0.26
B3	-2	15	-0.52 $\pm$ 0.32	-0.24 $\pm$ 0.27
B4	-2	0	0.41 $\pm$ 0.20	0.06 $\pm$ 0.21
B5	-2	-5	0.63 $\pm$ 0.16	0.22 $\pm$ 0.21
B6	-2	-10	0.39 $\pm$ 0.25	0.17 $\pm$ 0.19
B7	-2	-15	0.03 $\pm$ 0.23	0.11 $\pm$ 0.19
C1	0	5	0.31 $\pm$ 0.21	0.11 $\pm$ 0.21
C2	0	10	-0.19 $\pm$ 0.22	-0.16 $\pm$ 0.28
C3	0	15	-0.33 $\pm$ 0.29	-0.19 $\pm$ 0.29
C4	0	0	0.40 $\pm$ 0.21	0.14 $\pm$ 0.21
C5	0	-5	0.66 $\pm$ 0.17	0.21 $\pm$ 0.21
C6	0	-10	0.43 $\pm$ 0.22	0.20 $\pm$ 0.18
C7	0	-15	0.10 $\pm$ 0.24	0.18 $\pm$ 0.22
D1	2	5	0.40 $\pm$ 0.20	0.15 $\pm$ 0.20
D2	2	10	-0.09 $\pm$ 0.27	-0.09 $\pm$ 0.25
D3	2	15	-0.36 $\pm$ 0.28	-0.16 $\pm$ 0.25
D4	2	0	0.42 $\pm$ 0.14	0.09 $\pm$ 0.18
D5	2	5	0.58 $\pm$ 0.15	0.23 $\pm$ 0.18
D6	2	10	0.29 $\pm$ 0.18	0.21 $\pm$ 0.17
D7	2	15	0.14 $\pm$ 0.22	0.15 $\pm$ 0.22
E1	4	5	-0.05 $\pm$ 0.20	-0.01 $\pm$ 0.19
E2	4	10	-0.40 $\pm$ 0.19	-0.24 $\pm$ 0.20
E3	4	15	-0.46 $\pm$ 0.20	-0.23 $\pm$ 0.23
E4	4	0	0.10 $\pm$ 0.19	-0.03 $\pm$ 0.20
E5	4	-5	0.20 $\pm$ 0.25	0.08 $\pm$ 0.25
E6	4	-10	0.12 $\pm$ 0.26	0.13 $\pm$ 0.23
E7	4	-15	-0.09 $\pm$ 0.22	0.05 $\pm$ 0.23
G1	6	5	-0.36 $\pm$ 0.30	-0.13 $\pm$ 0.22
G2	6	10	-0.65 $\pm$ 0.16	-0.36 $\pm$ 0.19
G3	6	15	-0.72 $\pm$ 0.12	-0.41 $\pm$ 0.27
G4	6	0	-0.16 $\pm$ 0.34	-0.15 $\pm$ 0.23
G5	6	-5	-0.14 $\pm$ 0.39	-0.07 $\pm$ 0.26
G6	6	-10	-0.23 $\pm$ 0.32	-0.06 $\pm$ 0.30
G7	6	-15	-0.47 $\pm$ 0.15	-0.10 $\pm$ 0.30

SD, standard deviation; a chin position of 0 mm indicates the normal pogonion position (unchanged on GALL).

non-professional group. This suggests that people tend to prefer the maxillary incisors to be upright or slightly lingually inclined rather than labially inclined regardless of the chin position. When the pogonion falls on the GALL (Group C), the acceptance of the central incisor 5 degrees, upright, -5 degrees and -10 degrees in the professional group was significantly higher than in the non-professional group. When the chin is retruded 2 mm (Group B) and protruded 2 mm (Group D), acceptance of the central incisor with 5 degrees, upright and -5 degrees in the professional group was significantly higher than that in the non-professional group, and the acceptability of 15 degrees was significantly lower than in the non-professional group. When the chin was retruded 4 mm (Group A) and protruded 4 mm (Group E), the acceptance of 15 degrees in the professional group was significantly lower than that in the non-professional group. The acceptance of -10 and -15 degrees in the professional group was significantly higher than in the non-professional group when the chin was retruded 4 mm (Group E). Under the extreme chin position (6 mm retrusion or protrusion: Groups F and G), the acceptance of 10, 15 and -15 degrees in the professional group was significantly lower than in the non-professional group. However, because of the small mean and large variance in the scores, no conclusions could be drawn regarding the difference between the professional and non-professional groups in their aesthetic perspective on these profiles.

Effect of chin position on aesthetic scores in various chin positions

The sum of all the scores for the four groups for chin retrusion resulted in an acceptable range of central incisor inclination for both professional and non-professional populations at each chin position. Table 4 summarises the results. When compared longitudinally, that is, whether the central incisor inclination score changes with different chin protrusions, the authors found that when chin prominence is normal, -15 degrees~+5 degrees (-15, 5, 0, -5, -10 degrees) are acceptable or attractive. As chin retrusion increases, however, different inclinations become acceptable or unattractive in both groups starting from -15 degrees, according to the above order (Fig 5). This paper highlighted whether the difference in the inclination of the central incisors was expressed as a compensation effect under same chin position when comparing the grade given by two different groups of participants. According to Table 4, -15 degrees is still considered acceptable under each amount of protrusion in the non-professional group,

Fig 3a and b The 49 images were divided into three groups according to Sidak multiple comparisons and least significant difference analyses, based on the idea that no significant difference exists between images within groups, but a significant difference ($P < 0.05$) exists between groups rated “attractive” and “unattractive”. The images in the “acceptable” group were not significantly different ($P > 0.05$) from the “attractive” and “unattractive” groups. Scores for chin retrusion images in orthodontists and laypeople (a); scores for chin protrusion images in orthodontists and laypeople (b).

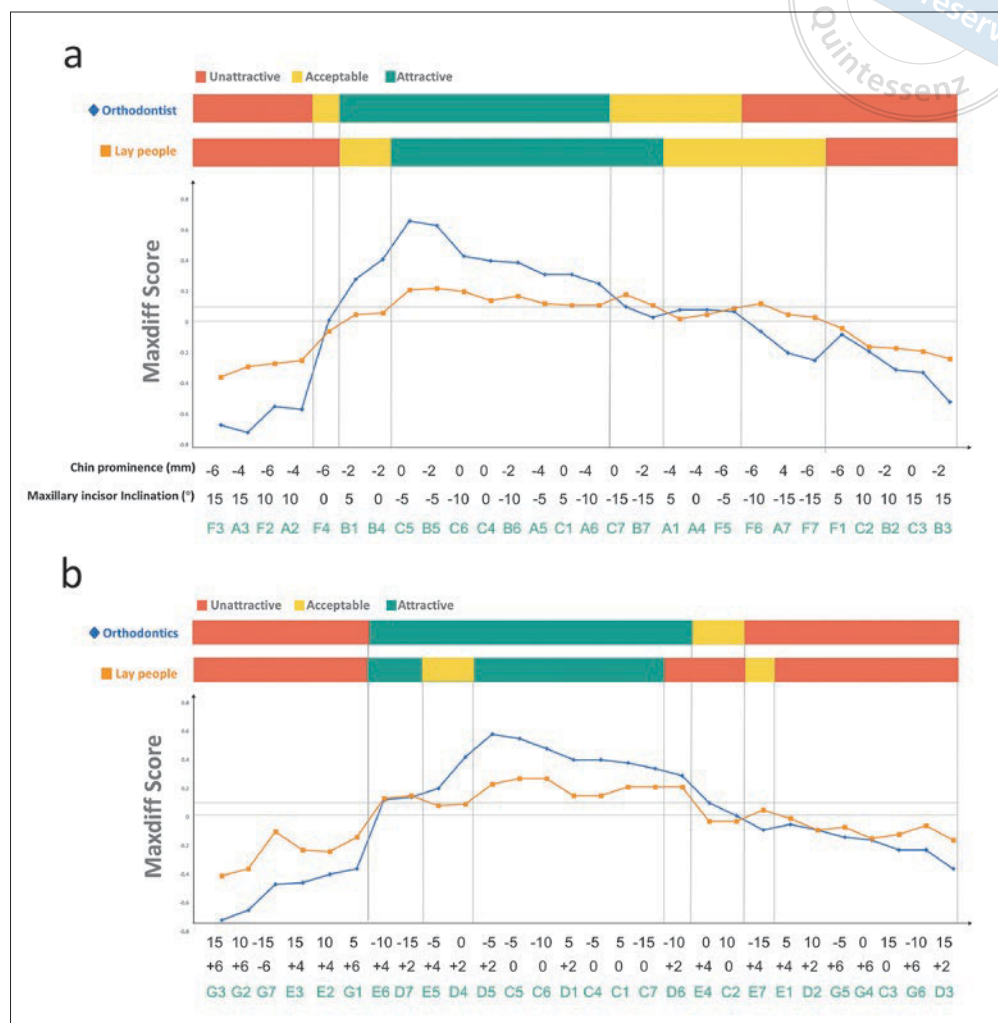


Table 4 Perception of acceptable and attractive maxillary incisor inclination with different degrees of chin retrusion by orthodontists and laypeople.

Chin position	Grade	Orthodontists	Laypeople
Normal	Acceptable	-15°~-10°	NA
	Attractive	-10°~5°	-15°~5°
2 mm retrusion	Acceptable	-15°~-10°	-5°~5°
	Attractive	-10°~5°	-15°~-5°
4 mm retrusion	Acceptable	0°~5°	-15°~5°
	Attractive	-10°~-5°	-10°~-5°
6 mm retrusion	Acceptable	-5°~0°	-5°~0°
	Attractive	NA	-10°~-5°

while other incisor inclinations did not significantly differ from the professional group. This indicates that the acceptance of central incisor lingual inclination (-10~-15 degrees) is higher in the non-professional group compared to the professional group. Moreover, when the chin was severely retruded (-6 mm), upright or mild

lingual inclination was acceptable in the professional group, whereas a greater degree of lingual inclination was considered acceptable in the non-professional group, which indicates that compensatory lingual inclination of the central incisors is acceptable to achieve a better smiling profile when there is significant chin

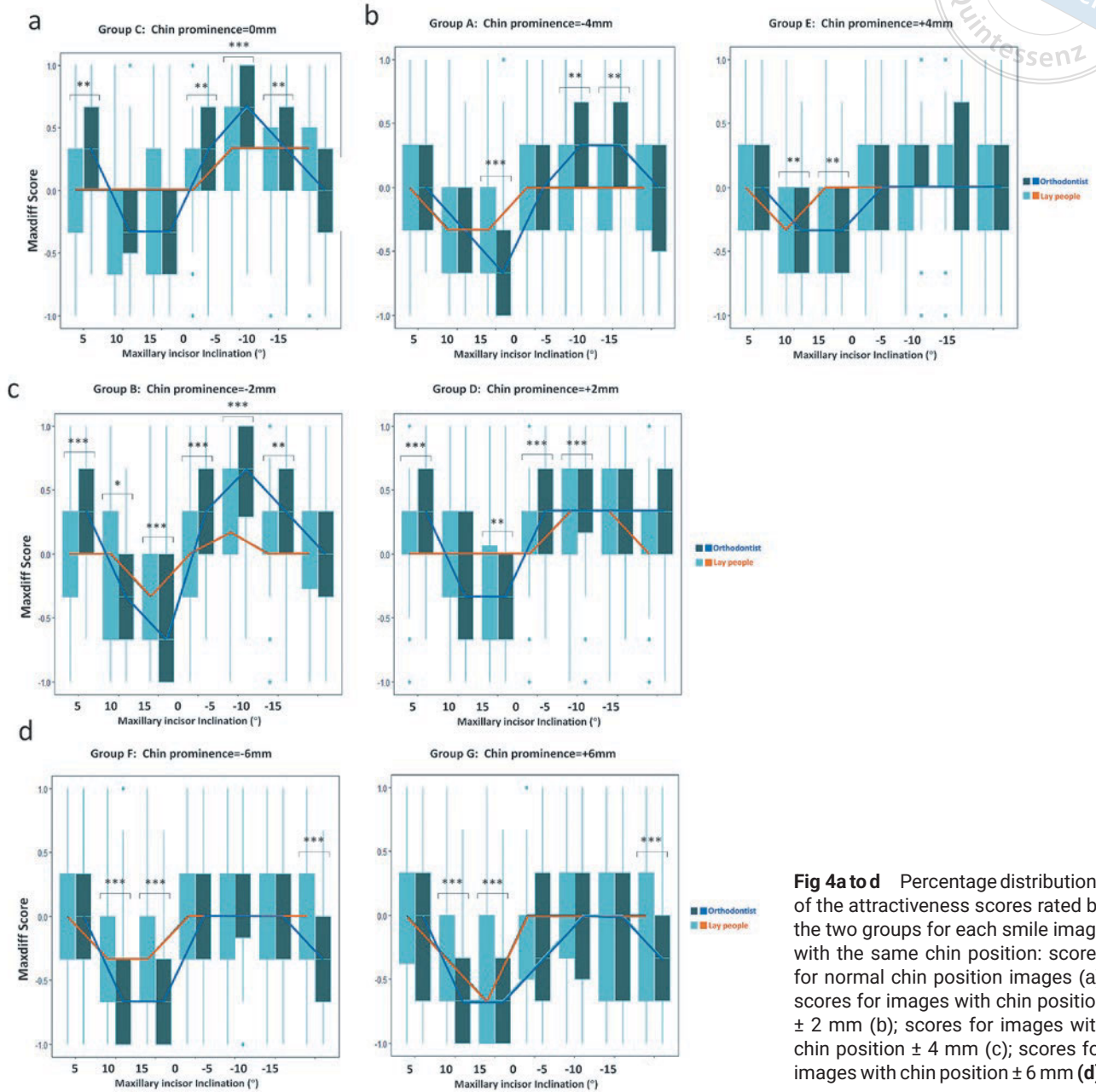


Fig 4a to d Percentage distributions of the attractiveness scores rated by the two groups for each smile image with the same chin position: scores for normal chin position images (a); scores for images with chin position ± 2 mm (b); scores for images with chin position ± 4 mm (c); scores for images with chin position ± 6 mm (d).

Table 5 Perception of acceptable and attractive maxillary incisor inclination with different degrees of chin protrusion by orthodontists and laypeople.

Chin position	Grade	Orthodontists	Laypersons
Normal	Acceptable	5°~10°	NA
	Attractive	-15°~5°	-15°~5°
2 mm protrusion	Acceptable	NA	0°~5°
	Attractive	-15°~5°	-5°~-15°
4 mm protrusion	Acceptable	-5°~0°	-5°~-15°
	Attractive	-5°~-10°	-10°
6 mm protrusion	Acceptable	NA	NA
	Attractive	NA	NA

Fig 5 Tendency toward attractive and acceptable maxillary incisor inclination changes with chin retrusion.

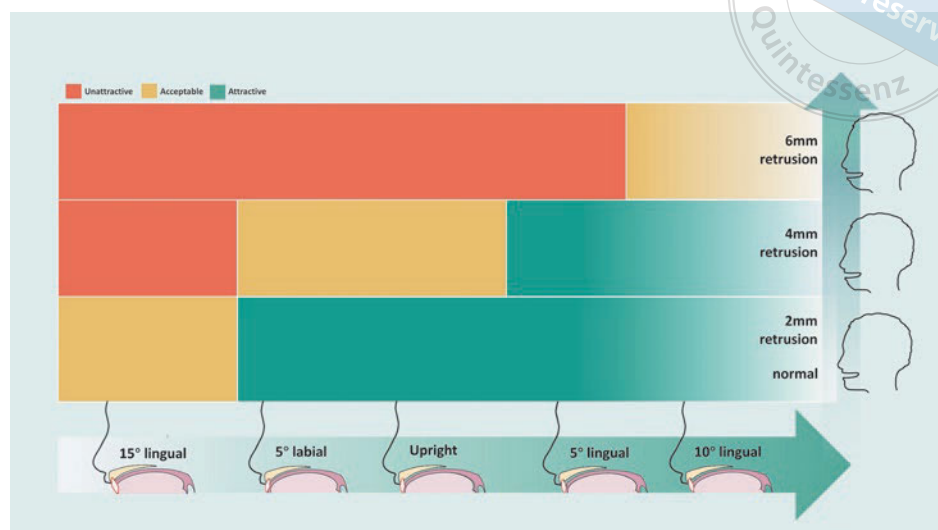
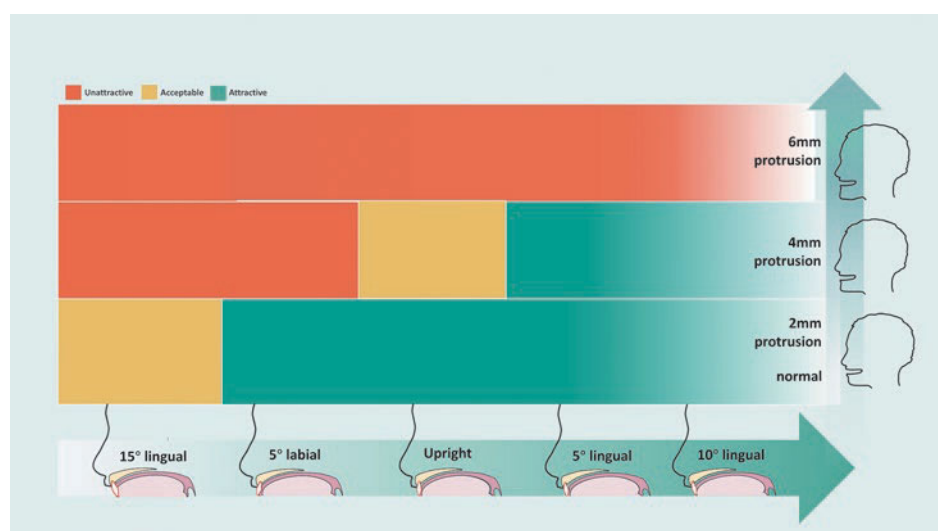


Fig 6 Tendency toward attractive and acceptable maxillary incisor inclination changes with chin protrusion.



retrusion. Table 5 shows the data for the chin protrusion group summarised by the same method as described above. The trend in longitudinal comparison is similar to that of the chin retrusion group, that is, -15, 5, 0, -5, and -10 degrees successively become acceptable or unattractive with the extent of chin protrusion increasing (Fig 6). Interestingly, some central incisor inclination professionals considered attractive are only graded acceptable in the non-professional group when the result is being compared across the group of participants, while this phenomenon is absent in the chin retrusion group. It indicated that laypeople's acceptance of chin protrusion is lower than that of chin retrusion. In contrast to the chin retrusion group, when the chin was significantly protruded (6 mm), all degrees of central in-

cisor inclination were aesthetically unacceptable, indicating that it was not possible to achieve an acceptable smiling profile by inclining central incisors when there is significant chin protrusion.

Discussion

General preference for U1 inclination of orthodontists and laypeople

Previous studies have shown that chin protrusion and central incisor inclination are both important factors that contribute to the assessment of smile aesthetics,^{6,23} revealing that 4 mm chin retrusion is generally accept-

able and can be compensated by labio-lingual inclining the incisors. Concurrently, mild lingual inclination of the maxillary incisors showed a higher acceptance compared to labial inclination.

In an orthodontic treatment, labio-lingual inclination of the maxillary incisors can be easily manipulated and controlled by the orthodontists. The present study demonstrated that mild lingual inclination of the maxillary incisor was preferred by both professionals and laypeople regardless of the chin position, while excessive labial inclination (≥ 10 degrees) was deemed unacceptable. This indicates that the increase of labial inclination will be disastrous to achieve an ideal and aesthetic smile. In addition, the decrease in smile aesthetics caused by the increase of the labial inclination of the maxillary incisors results in flattening of the smile curve and the reduction in incisor exposure.^{24,25} Therefore, labial inclination of the maxillary incisor, such as in patients with crowded anterior teeth treated by non-extraction treatment or patients with Class III malocclusion treated with an compensated treatment plan showed poorer treatment outcomes. Thus, adequate and clear doctor-patient communication before orthodontic treatment is crucial to ensure patients understand and accept possible risk and outcomes, such as an increase in the labial inclination of the upper incisors lead to a more protruded profile.

Compensation effect in chin retrusion and protrusion group

After aggregating the total scores for the four types of chin retrusion in this study, the maxillary incisor with -15 , 5 , upright, -5 , and -10 degrees inclination was found to be acceptable or attractive when chin protrusion was normal. The orthodontist and laypeople groups rated 15 degrees as acceptable and unattractive respectively as chin retrusion increased, and the aesthetic score of -10 degrees was higher than that of -5 degrees when the chin was retruded by 6 mm. For patients with chin retrusion, increasing the inclination of the maxillary incisor lingually helps to camouflage the mandibular hypoplasia. Besides, -15 degrees inclination of the maxillary incisor was attractive or acceptable in the non-professional group but not acceptable in the professional group under all degrees of chin retrusion. The results showed that the acceptance of excessive lingual inclination of the central incisor (-10 ~ -15 degrees) in the non-professional group was higher than in the professional group. In addition, maxillary incisors with upright or mild lingual inclination (0 ~ -5 degrees) were still acceptable in the professional group when chin

retrusion was greater (-6 mm), whereas greater lingual inclination (-5 ~ -15 degrees) was considered acceptable in the non-professional group. This indicates that an acceptable smiling profile can be achieved even when chin retrusion is significant by lingual inclination of the central incisors as a camouflage treatment.

Meanwhile, in cases with chin protrusion, orthodontists considered some of them (such as -5 ~ $+5$ degrees with 2 mm chin protrusion, -10 ~ -5 degrees with 4 mm chin protrusion) attractive while laypeople only graded them acceptable, but no such phenomenon was observed in chin retrusion groups. In patients with chin protrusion, the maxillary incisor with compensatory inclination was less aesthetically pleasing than cases with chin retrusion, which indicated that the acceptance of chin protrusion was lower than chin retrusion in the general population. Especially when the chin is more noticeably protruded (6 mm), all degrees of inclination of central incisors were not helpful in camouflaging the protrusion and were unacceptable in general. This indicates that an acceptable smiling profile cannot be achieved by compensatory inclination of the central incisors when there is significant chin protrusion. These findings are in line with the study by Arnett et al¹⁹ in which chin protrusion greater than 6 mm requires surgery, and that the greater the chin protrusion, the poorer the aesthetic evaluation and the greater the indication for surgical correction.

Differences between professionals and laypeople

The hypothesis that professionals and non-professionals have distinct aesthetic standards remains inconclusive, like the results in various published studies.^{15,26} In this study, professional and non-professional evaluation of the most attractive maxillary incisor inclination and chin position was similar, but there were also differences across the groups. Firstly, the scores from non-professional group had a significantly smaller range than the professional group, indicating that trained orthodontists do have a more sensitive aesthetic observation than the general population. Secondly, the non-professional group was generally more accepting of excessive lingual inclination (-10 ~ -15 degrees) of the central incisor compared to the professional group, indicating that Class II patients who refused to undergo surgery could be treated in a satisfactory manner by lingually adjusting the inclination of the maxillary incisor after active communication. Lastly, some central incisor inclinations in the chin protrusion group that professionals considered attractive were only graded as acceptable in the non-professional group, which did not happen in the

chin retrusion group. This phenomenon suggested that compared to patients with chin retrusion, patients with chin protrusion are less likely to achieve an aesthetic smiling profile through compensatory inclination of the maxillary central incisors and hence having lower satisfaction after camouflage treatment. In summary, orthodontists and laypeople share a similar general aesthetic appreciation trend for the smiling profile, but there are also subtle differences. Summarising these differences will help to achieve more satisfactory clinical treatment outcomes and smoother doctor-patient communication.

However, this study used only the smiling profile photographs of one male volunteer, and whether the same factors had different effects on female facial aesthetics was not explored. In addition, whether other aspects of the volunteer's appearance and features, such as the shape of the forehead and nose, affect the perceptions of smiling profile aesthetics still requires further exploration. Also, this study only focused on the influence of maxillary anterior tooth inclination and did not account for the impact of angular changes in the maxillary anterior teeth on the upper lip soft tissue, nor the effect of upper lip soft tissue thickness on the lateral smile profile. The factors of soft tissue changes are relatively complex, and the regularity of changes with tooth movement is not clear. Thus, this study did not specifically change the position of the upper lip. To derive more rigorous recommendations, future studies should employ methods such as 3D facial reconstruction to simulate the influence of soft tissue and obtain more precise conclusions through 3D facial scans.

Conclusion

Both labio-lingual inclination of the maxillary incisors and chin position play essential roles in the aesthetic profile view of the smile. The ideal value of maxillary incisor inclination varies as the chin position changes, and the acceptance of excessive lingual inclination of maxillary incisors is higher in laypeople than orthodontists. According to the study results, several conclusions can be drawn. Regardless of chin position ($-6\sim+6$ mm), when the FA point falls on the GALL, an upright or mild lingual inclination of the maxillary central incisor is generally more preferred in both groups; in contrast, labial inclination of the maxillary incisor often results in aesthetic problems in the smile in profile view. The acceptance of excessive lingual inclination ($-15\sim -10$ degrees) of the maxillary central incisor in laypeople was generally higher than in orthodontists. When significant chin retrusion (-6 mm) is present, orthodon-

tists consider upright or mild lingual inclination (0 to 5 degrees) of the maxillary incisors to be acceptable, while laypeople also considered a larger lingual inclination ($-15\sim -5$ degrees) to be acceptable. These results indicate that chin retrusion can be compensated by lingual inclination of the maxillary central incisors. Finally, compensatory labio-lingual inclination of the maxillary central incisor demonstrated a lower degree of aesthetic acceptability in profile view with a protruding chin compared to a retruding chin with similar magnitude. Hence, when significant chin protrusion (6 mm) is present, it is considered extremely challenging to achieve an aesthetic profile view of the smile through labio-lingual inclination of the maxillary incisors alone.

Conflicts of interest

The authors declare no conflicts of interest related to this study.

Author contribution

Dr Rui Ying HAN contributed to the investigation, data analysis and original draft preparation; Drs Yong Wen GUO and Ding BAI contributed to the conceptualisation, methodology and manuscript review and editing; Dr Fu Shuang LIU contributed to the image modification and questionnaire making; Drs Eunice Chan Jie YU, Bin LI, Yi Kai HE, Wan Xi CHEN and Tian Yi WANG contributed to the original draft preparation.

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