

Determination of Facial References for Esthetic Restorative Treatment



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Although it is generally accepted that a prosthetic restoration must take into account the gingiva, smile, and patient's face, it is often difficult to determine precisely what facial references must be considered. The purpose of this study was to determine the correct vertical and horizontal facial reference planes in esthetic prosthetic treatment. Using photographic analysis of 160 individuals, the different facial reference planes (interpupillary, intermeatic, intercommissural, and incisal edge lines; facial midline; and Camper and Frankfort planes) were compared to the ideal prosthetic reconstruction axis. Additional measurements, including the human eye's ability to perceive parallelism, were recorded. Most participants (64%) exhibited facial asymmetry. Asymmetry was horizontal (difference between widths of the right and left sides; 52.4%), vertical (difference between heights of the right and left sides; 6.9%), or mixed (4.7%). The interpupillary line is the main horizontal reference in 88.4% of situations, with the intercommissural line the second most important. In the profile view, the horizontal plane was on average 6.5 degrees above the Camper plane and 9 degrees below the Frankfort plane. The human eye's ability to perceive parallelism between two lines was found to be limited to differences of approximately 1 degree. During anterior tooth reconstruction, it is necessary to take into account the right horizontal and vertical esthetic references. Knowledge of the biometric facial parameters in natural dentition is necessary to define the right reconstruction axes based on the facial symmetry or asymmetry. *Int J Periodontics Restorative Dent* 2021;41:113–119. doi: 10.11607/prd.4642

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The beauty of a smile is created by a global harmony between teeth, gingiva, lips, and the face. Certain universally known fundamental principles determine what is considered to be esthetically attractive.^{1–3} Health and esthetics are currently of particular importance. Patients are increasingly demanding, thus obliging the constant improvement of esthetic dentistry.⁴

Facial, dentolabial, dental, and gingival analyses are the obligatory starting points in all prosthetic treatment. Indeed, these analyses enable good treatment planning.^{5,6} Facial harmony can only be determined through detailed rational observation. However, the dental technician and the dentist must also consider the subjective perception of beauty.

Good communication between the dental technician and the dentist is essential to obtain a predictable result. Esthetic data communication enables the verification and predictability of the results, and therefore a good result and facial harmony.⁷ The aim of this study was to determine the standards concerning the use of the reference planes, which are essential in esthetic prosthetic treatment.

In esthetic dentistry, it is known that the prosthesis must be in harmony with the gingiva, the smile, and the patient's face in general.

Certain horizontal and vertical reference lines determine facial harmony.⁸ Numerous reports have shown that the interpupillary line must be used as the principal horizontal reference and that the sagittal midline must be the vertical reference.^{6,9-11} This facial analysis often reveals problems such as facial asymmetry.^{5,12-16} Meanwhile, it is known that symmetry is one of the principal factors in making a face attractive.

It is therefore paramount to determine the correct horizontal and vertical planes that should be used as reference planes. Some authors arbitrarily use the horizon as their esthetic reference.¹⁷ To date, no study has proven a link between the proposed facial references and the horizon. The principal objective of this study is to determine the correct horizontal reference for prosthetic treatment. In order to do this, it is important to determine whether there is perpendicularity between the sagittal midline and the interpupillary line, the intercommissural line, and the horizon. In the profile view, the esthetic plane is aligned with the horizon when the patient is looking straight ahead. This plane, located between the Frankfort and the Camper planes,¹⁷ helps to determine the correct inclination of the maxilla. During this study, the angle between the esthetic plane and the Frankfort and Camper planes was also measured.

Finally, the data collected during the study enables an analysis of the horizontal and vertical symmetry and asymmetry of a frontal face view. This analysis will demonstrate whether a face is symmetric and describe

the direction (vertical or horizontal) and degree of asymmetry. This part of the study is used to establish how to integrate notions of facial symmetry/asymmetry into treatment. In order to apply the abovementioned notions, the ability of the human eye to detect the absolute parallelism of two lines must be studied. This is to determine the level of accuracy required during esthetic treatment.

The purpose of the present study is to define the horizontal and vertical axes to be taken into account during esthetic prosthetic treatment. The first null hypothesis is that the interpupillary line and the facial midline are the horizontal and vertical references, respectively. The second null hypothesis is that the human eye's ability to detect non-parallelism starts at 1 degree.

Materials and Methods

The number of participants necessary for the study to find a difference of 1 degree between the interpupillary line and the horizontal line, which was taken as a reference (prosthetic plan reconstruction), was calculated for P values $\alpha = .05$ with a statistical power of $1 - \beta = .8$. The minimum number of participants necessary was 45; the study included 160 Caucasian students of the Marseille Dental University (89 women and 71 men) between 20 and 25 years of age. All participants provided informed consent in writing before the study was initiated and granted the right to use their images. Exclusion parameters were as follows: any sign of facial trauma, missing teeth

or prosthesis in the anterior area, or a history of orthodontic treatment. In order to evaluate the ability to detect parallelism between two lines, the selected participants needed to present a binocular vision of 20/20, possibly with correction.

The first experiment was designed to determine horizontal and vertical reference axes for esthetic prosthetic treatment. The photographic analysis was based on a frontal view (high smile) and a profile view made with a digital camera (D90, Nikon). A small mirror was placed just above and perpendicular to the objective to ensure good camera position. At the correct height and angle, the participant can see their eyes in the mirror.¹⁸

Each participant stood 3 m away from the camera and in front of a plain background, onto which two reference laser lines (one vertical and one horizontal; Laser Level, Black and Decker) were projected. Participants were asked to maintain a natural posture and to look straight into the objective (Fig 1).

First, it was necessary to identify the ideal horizontal and vertical prosthetic reconstruction axes on each image. Using Keynote software (Apple), a digital rectangular grid was placed vertically on the face. The photograph was then rotated clockwise or counterclockwise to obtain the best visual harmony between the face and the grid. This was validated by three dentists specialized in esthetics and by three nondentists. Next, the following lines were highlighted on the frontal-view photos: the interpupillary line (IP), which joins the centers of the

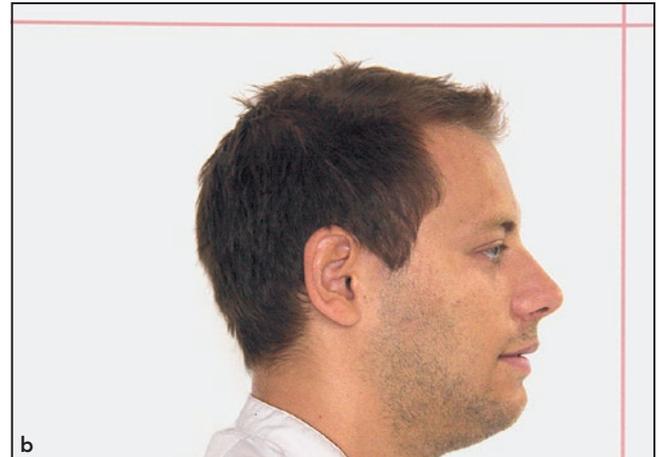


Fig 1 (a) Front and (b) profile views.

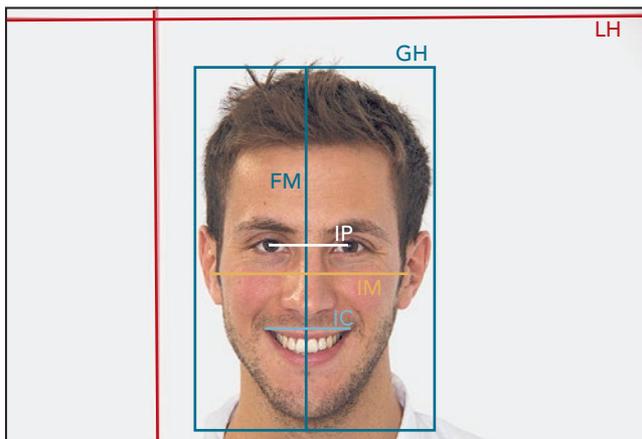


Fig 2 Reference lines in frontal view. LH = horizon line; GH = horizontal grid; IP = interpupillary line; IM = intermeatic line; IC = intercommissural line.

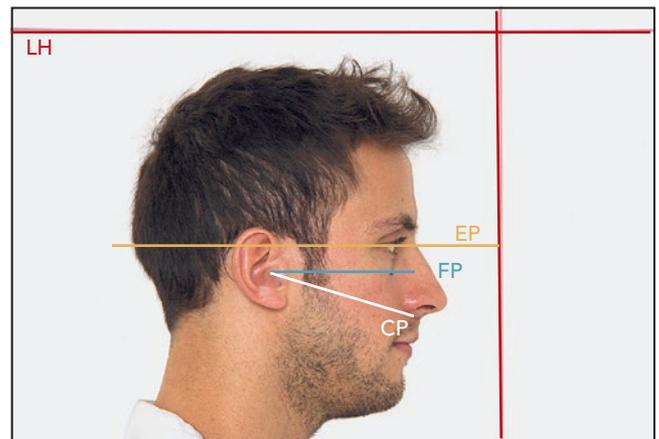


Fig 3 Reference lines in profile view. LH = horizon line; EP = esthetic plane; FP = Frankfort plane; CP = Camper plane.

two pupils; the intermeatic line (IM), which joins the two ear holes; the intercommissural line (IC), which joins the two corners of the mouth; the facial midline (FM), which joins the glabella and the middle of the philtrum; the incisal edge line (IL), which joins the points of the two canines; and the horizon line (LH) defined by the laser (Fig 2). All angles created by these lines and the horizontal grid (GH) were measured using the Keynote software package.

In the profile-view photographs, the Camper plane (CP; in-

ferior border of the nasal ala/superior border of the tragus) and the Frankfort plane (FP; lowest point on the margin of the auditory meatus) were drawn, and the angles between these lines and the laser LH, which is parallel to the esthetic plane (EP), were measured. To help locate the Frankfort plane, the infra-orbital point was marked on each face using a pen (Fig 3).

Finally, facial asymmetry was determined. Horizontal asymmetry was calculated by measuring the

distance between the left and right pupils and the facial midline. Vertical asymmetry was calculated by measuring the angles created by the IP, IM, and IC with respect to the GH (Fig 4).

The protocol reliability was tested by replacing the participant's face with a piece of paper that had two lines with specific angles drawn on it, ranging from -2 to $+2$ degrees in 0.5 -degree increments. A photograph of the paper was made and analyzed with the same digital protocol. Comparing the digital and

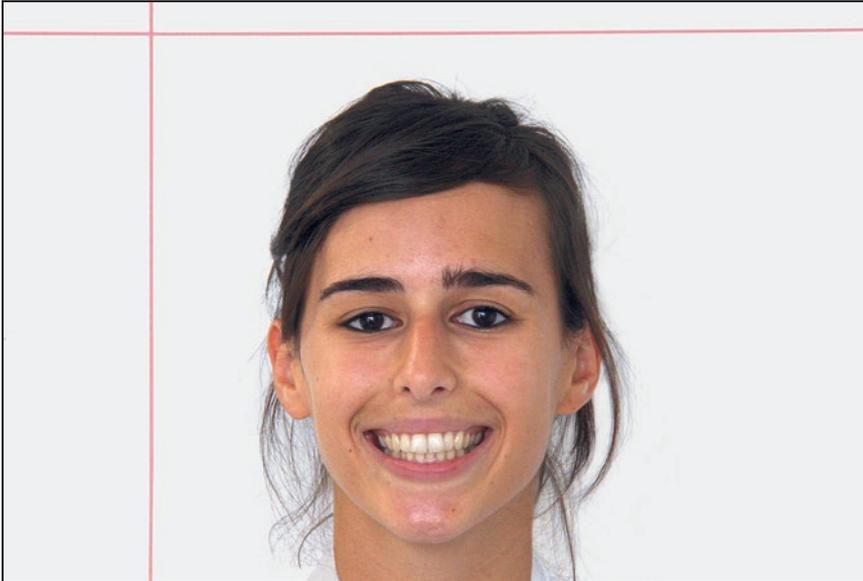


Fig 4 Vertically asymmetric face.

physical measurements led to a precision level of ± 0.2 degrees.

To measure the reproducibility, the photographic protocol was repeated three times on three participants, and the data were compared. Reproducibility was estimated to be 99%, with an error margin of 0.3 degrees.

The second experiment was intended to evaluate the ability of the human eye to detect parallelism between two lines. Two parallel horizontal lines were drawn 7 cm apart (corresponding to the average distance between the ophryon and the incisal edges) on a piece of paper: an upper line 6 cm long (the average IP distance), and a lower line 6 cm long (the average IC distance). Several duplicate copies were made, and their lower line angle was modified from -2 degrees to $+2$ degrees in steps of 0.5 degrees. These lines were shown to the 160 participants in a randomized order at

a distance of 3 m, and then shown again at a distance of 1 m. Each participant expressed their impression as to whether the lines were parallel or not.

The statistical tests used in the parallelism study of the six horizontal lines were z test (to compare average and absolute values) and randomized block test (to compare two average values). Paired t test was used to study facial symmetry. All tests have *P*-value significance set at $\alpha = .05$ and a statistical power $1 - \beta = .8$.

Results

The following averages (SDs) were obtained from the statistical tests for reference line analysis. Using the GH as a reference: GH/IP = 0.51 (0.63) degrees; GH/IM = 6.69 (4.45) degrees; GH/IC = 0.68 (0.86) degrees; GH/IL = 0.94 (0.84) degrees; and GH/LH = 1.75 (1.77) degrees.

Using the IP as a reference: IP/GH = 0.51 (0.63) degrees; IP/IM = 1.97 (1.79) degrees; IP/IC = 0.67 (0.82) degrees; IP/IL = 0.96 (0.87) degrees; and IP/LH = 2.32 (1.69) degrees. See Appendix Tables 1 and 2 (available in the online version of this article at quintpub.com/journals) for the measurement repartition among the population.

Most participants (64%) exhibited facial asymmetry. Asymmetry was classified as horizontal (difference between widths of the right and left sides; 52.4%), vertical (difference between heights of the right and left sides; 6.9%), or mixed (4.7%; Fig 5).

Horizontal asymmetry was defined as a difference in width equal or superior to 2 mm. This represents a width difference of around 3.5%, which is approximately the mid-perception level. It was measured by the distance between the right and left pupils and the FM, and the mean (SD) difference was 2.21 (1.46) mm. Horizontal asymmetry was often substantial, with 31.1% of participants' faces revealing a difference in width of > 3 mm between the left and right sides.

Vertical asymmetry (difference between heights of the right and left sides) was measured by the angle between GH and IP and existed when the angle was > 1 degree. The mean (SD) vertical asymmetry angle was 1.84 (1.21) degrees.

In the profile view, the EP (parallel to the LH) was on average 6.5 degrees above the CP and 9 degrees below the FP. The average (SD) angle between the CP and FP was 15.5 (1.8) degrees.

Appendix Table 3 presents data concerning the ability to detect parallelism from distances of 1 and 3 m. Almost all participants (95%) did not detect an absence of parallelism from a 3-m distance when the angle difference was < 1 degree. The ability to detect parallelism increases slightly at the 1-m observation point.

Discussion

The results support the first null hypothesis and demonstrate that the IP and FM are horizontal and vertical references, respectively, in 88.4% of situations. The results also support the second null hypothesis, showing that the human eye is able to detect the absence of parallelism at ≥ 1 degree.

Facial analysis is a key step in every esthetic treatment. The empirical standard^{6,8,9} in esthetic treatment must be compared with biometric studies to confirm or reject these rules. Contrary to previous studies,^{10,14,15} the present study found it important to compare the vertical and horizontal anatomical reference lines of the face with the ideal prosthetic reconstruction axis (represented in the study by the GH axis on the rectangular grid).

The second experiment was intended to determine the sensitivity of the human eye to perceive parallelism between two lines simulating the IP and IL. By digitally modifying the angle of the IL on each patient's photo, Behrend et al observed sensitivity of 1 degree among 21 observers.¹⁹ Another study shows the same

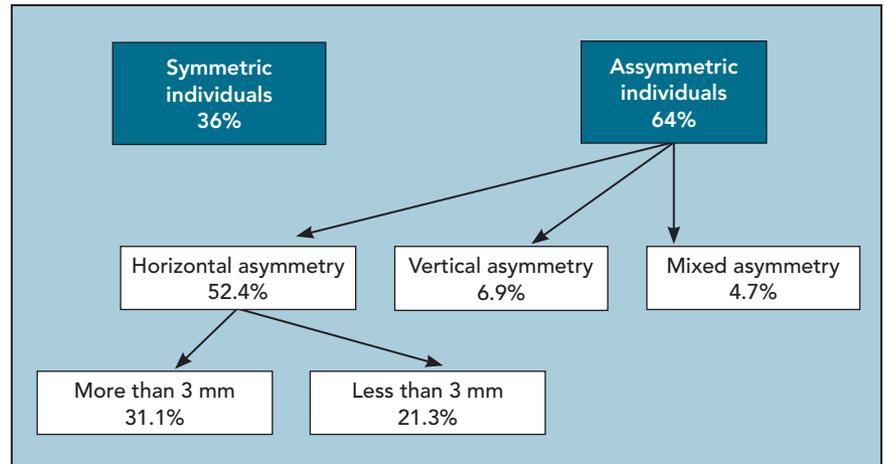


Fig 5 The study population comprised symmetric, asymmetric, and mixed subpopulations.

sensitivity for dentists and dental students, but it is lower for laypersons (3 degrees).²⁰ In the same way, Silva et al determined that the inclination of the occlusal plane must be less than 2 degrees for laypersons.²¹ In the present study, the test was limited to the observation of two lines in order to focus on the parallelism of the lines without any facial influence. The test was conducted with 160 initiated observers (dental students). A sensitivity of 0.5 degrees was observed among only 5% of the participants, and it started at 1 degree for the majority of participants.

The results shown in Appendix Table 1 conclude that the IP is the main horizontal reference in 88.4% of situations. A different horizontal reference axis must be chosen for the 11.6% of situations that exhibit vertical asymmetry. This axis is often the average of the IP, the IC, and the perpendicular of the FM. This finding confirms Behrend's results,¹² which demonstrate a significant influence of all these lines on the ideal prosthetic axis. The IC is the

second most important after the IP, because it is very close to the reconstruction zone. The FM is the third most important. The IM is covered by hair in the frontal view; therefore, it is certainly less important to the definition of the ideal prosthetic axis, and it shows a wide range of divergence with the GH axis. In the present study of 160 participants, the mean (SD) angle between the IM and the horizontal reference EP was 6.69 (4.45) degrees. Numerous authors^{6,16,22} have described the clinical consequences of a lack of parallelism between the IM (facebow references) and the horizontal EP. When in the mouth, a perfectly horizontal prosthesis on the articulator will exhibit a major esthetic alignment error and will therefore fail to guarantee good esthetic integration. Thus, it is very important to communicate the horizontal and EP precisely to the laboratory.^{7,12} The comparison of the ideal horizontal axis (GH) with the LH allowed differentiation of true vertical facial asymmetry from a simple head tilt.

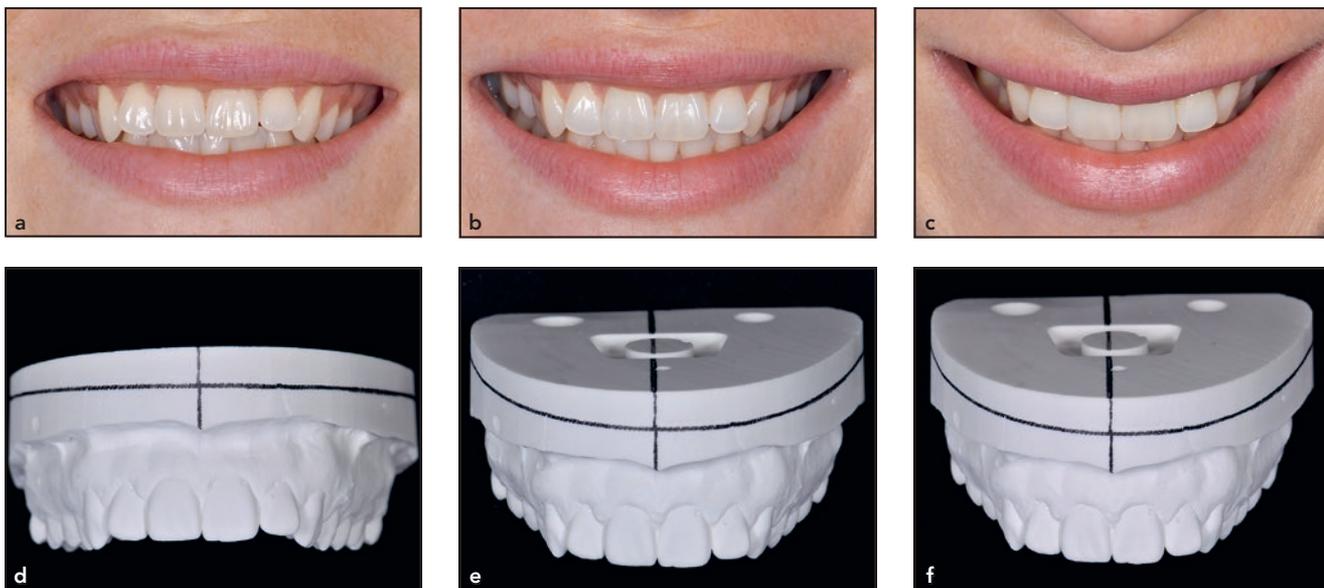


Fig 6 (a to c) Various perceptions of smile according to different vision angles or head tilting situations: (a) low-angle shot, (b) shot within the esthetic plan axis, and (c) high-angle shot. (d to f) Various images of the same arch cast: (d) low-angle shot, (e) shot within esthetic plan axis, and (f) high-angle shot. The view parallel to the Camper plane (the low-angle shot) gives the impression that teeth should be lengthened, whereas the high-angle view gives opposite impression (teeth should be shortened).

Contrary to Lee,¹⁷ the present study proved that the horizon cannot be used as a reference, owing to considerable divergence (approximately 2 degrees) and an SD of 1.55 degrees vs the ideal prosthetic horizontal reconstruction axis. Numerous authors have emphasized that the majority of faces are naturally asymmetric.^{5,12,16} A recent study shows that 51.6% of the selected population present a facial midline deviation, midline inclination, or occlusal plane inclination.²³ In the present study, 64% of participants had faces that were classified as asymmetric. It is therefore important to differentiate between vertical and horizontal asymmetry. In all, 52.4% of participants exhibited horizontal asymmetry, 6.9% exhibited vertical asymmetry, and 4.7% exhibited mixed horizontal and vertical asymmetry. Although left/right

horizontal asymmetry is frequent, it is not problematic from a clinical point of view because it does not affect the esthetic horizontal and vertical reconstruction axes. It usually manifests as an off-center dental midline, likely due to the difference in growth of the left and right sides of the face. However, vertical asymmetry has important clinical consequences that must be taken into account at the prosthetic stage. In the 11.6% of the vertical asymmetry population, the horizontal reconstruction axis used is the average of the IP, the IC, and the perpendicular of the FM.

In agreement with Lee's study, the EP in the profile view is centered between the FP and the CP at an angle of approximately 7.75 degrees from each of them.¹⁷ This plane provides the laboratory with the correct position of the IL and therefore

the correct incisal length. If the CP is used as a reference, it will tend to make the central incisors longer; inversely, there is a tendency to make the central incisors shorter if the FP is used (Fig 6). It is therefore important that the dental technician sees the cast in the same way as the dentist sees the maxillary teeth in the natural head position.⁷

Additional biometric studies with larger study populations are needed to confirm these results. Further studies will analyze the relationship between a facial asymmetry and the position of both head and body.

Conclusions

With the limitations linked to this biometric facial analysis, the following validation of the main rules used

in esthetic reconstruction was determined:

In 88.4% of situations, the IP can be used as the horizontal reference for esthetic dental reconstruction. The IC is the second most important after the IP. However, for the 11.6% of situations that exhibit vertical asymmetry, the reconstruction axis that should be used is the average of the IP, the IC, the perpendicular of the FM, and the horizon (in diminishing order of importance).

Because the human eye is capable of detecting parallelism with a level of sensitivity of approximately 1 degree, the dentist should not be concerned by deviations from absolute parallelism of lesser values.

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Appendices

Appendix Table 1 Distribution of Results: Angle Between the Horizontal Grid and All Other Reference Lines

	GH/IP	GH/IM	GH/IC	GH/IL	GH/LH
Angle range					
0.0–0.5 degrees	64.4%	16.8%	57.5%	36.3%	28.7%
0.5–1.0 degrees	23.9%	19.5%	22.5%	38.1%	19.5%
1.0–1.5 degrees	7.5%	38.2%	11.0%	19.2%	7.3%
> 1.5 degrees	4.2%	25.5%	9.0%	6.4%	44.5%
Mean	0.51	6.69	0.68	0.94	1.75
SD	0.63	4.45	0.86	0.84	1.77
95% CI	0.41, 0.61	5.19, 8.18	0.55, 0.82	0.75, 1.12	1.48, 2.02

GH/IP = angle between the horizontal grid (GH) and the interpupillary line; GH/IM = angle between GH and the intermeatic line; GH/IC = angle between GH and the intercommissural line; GH/IL = angle between GH and the incisal edge line; GH/LH = angle between GH and the horizon line.

Angle range values are shown as percentages of the total population. Mean, SD, and 95% CI values are measured in degrees.

Appendix Table 2 Distribution of Results: Angle Between the Interpupillary Line and All Other Reference Lines

	IP/GH	IP/IM	IP/IC	IP/IL	IP/LH
Angle range					
0.0–0.5 degrees	64.4%	14.2%	58.0%	38.4%	23.0%
0.5–1.0 degrees	23.9%	16.4%	17.7%	30.7%	17.7%
1.0–1.5 degrees	7.5%	39.6%	16.4%	22.0%	7.9%
> 1.5 degrees	4.2%	29.8%	7.9%	8.9%	51.4%
Mean	0.51	1.97	0.67	0.96	2.32
SD	0.63	1.79	0.82	0.87	1.69
95% CI	0.41, 0.61	1.70, 2.25	0.77, 1.16	0.77, 1.56	1.91, 2.73

IP/GH = angle between the interpupillary line (IP) and the horizontal grid; IP/IM = angle between IP and the intermeatic line; IP/IC = angle between IP and the intercommissural line; IP/IL = angle between IP and the incisal edge line; IP/LH = angle between IP and the horizon line.

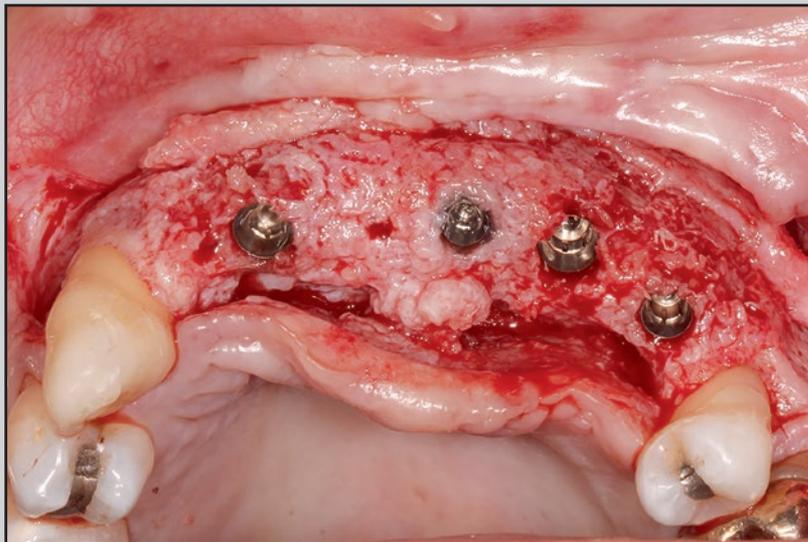
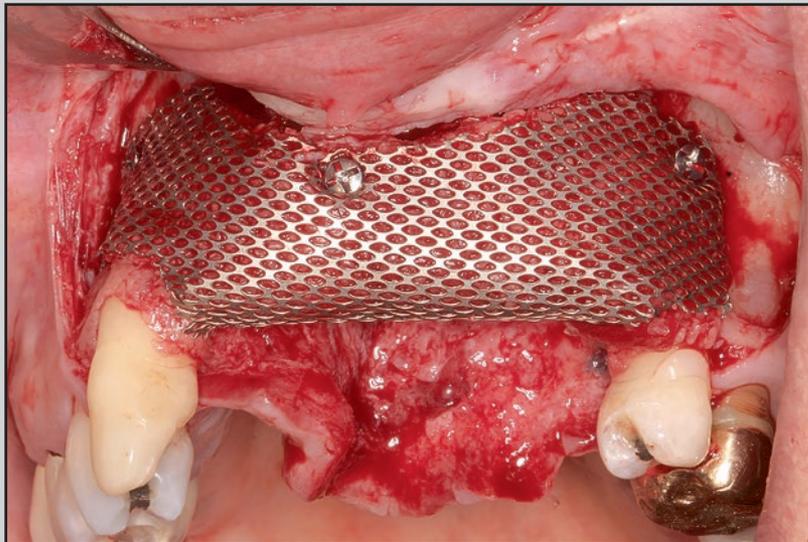
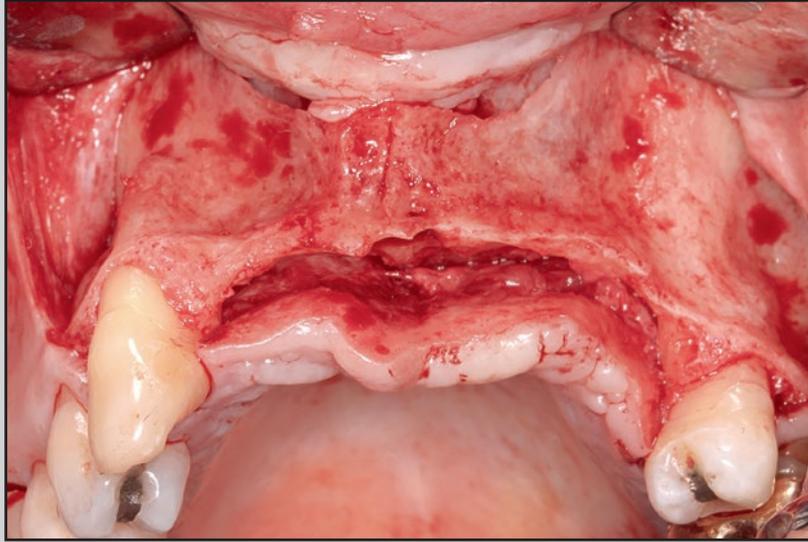
Angle range values are shown as percentages of the total population. Mean, SD, and 95% CI values are measured in degrees.

Appendix Table 3 Observation of Parallelism Between Two Lines According to Distance and Various Angles of Nonparallelism

Distance	Nonparallelism angle, degrees								
	–2.0	–1.5	–1.0	–0.5	0	+0.5	+1.0	+1.5	+2.0
3 m	13.0%	23.0%	71.0%	95.0%	100.0%	97.0%	75.0%	20.0%	5.0%
1 m	6.0%	11.0%	59.0%	92.0%	100.0%	94.0%	67.0%	13.0%	2.0%

0 degrees = parallel.

Values are shown as percentages of the total population.



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