Triple D: Dentofacial Digital Diagnostic

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Esthetic rehabilitations always start with a proper diagnostic effort,[1–5] traditionally a two-step approach including a diagnostic wax-up and the corresponding provisional restoration (to be evaluated in vivo). Anterior bonded restorations call for a specific approach. The additive diagnostic wax-up and the acrylic mock-up can be used as tools for molding direct restorations, to guide tooth preparation procedures, and to "biocopy" semi-(in)direct restorations.[6] This approach is intrinsically objective and simple and allows significant economy of tooth substrate while generating an invaluable amount of diagnostic information for design and prognosis of the final restoration. A close, interactive relationship with the dental laboratory is required for this approach, especially for the most complex indirect restorations.

In recent years, a new layer has been added to this process in the form of digital simulations to initiate the diagnostic approach. Original 2D digital designs were the logical evolution of previous analog tracings, and

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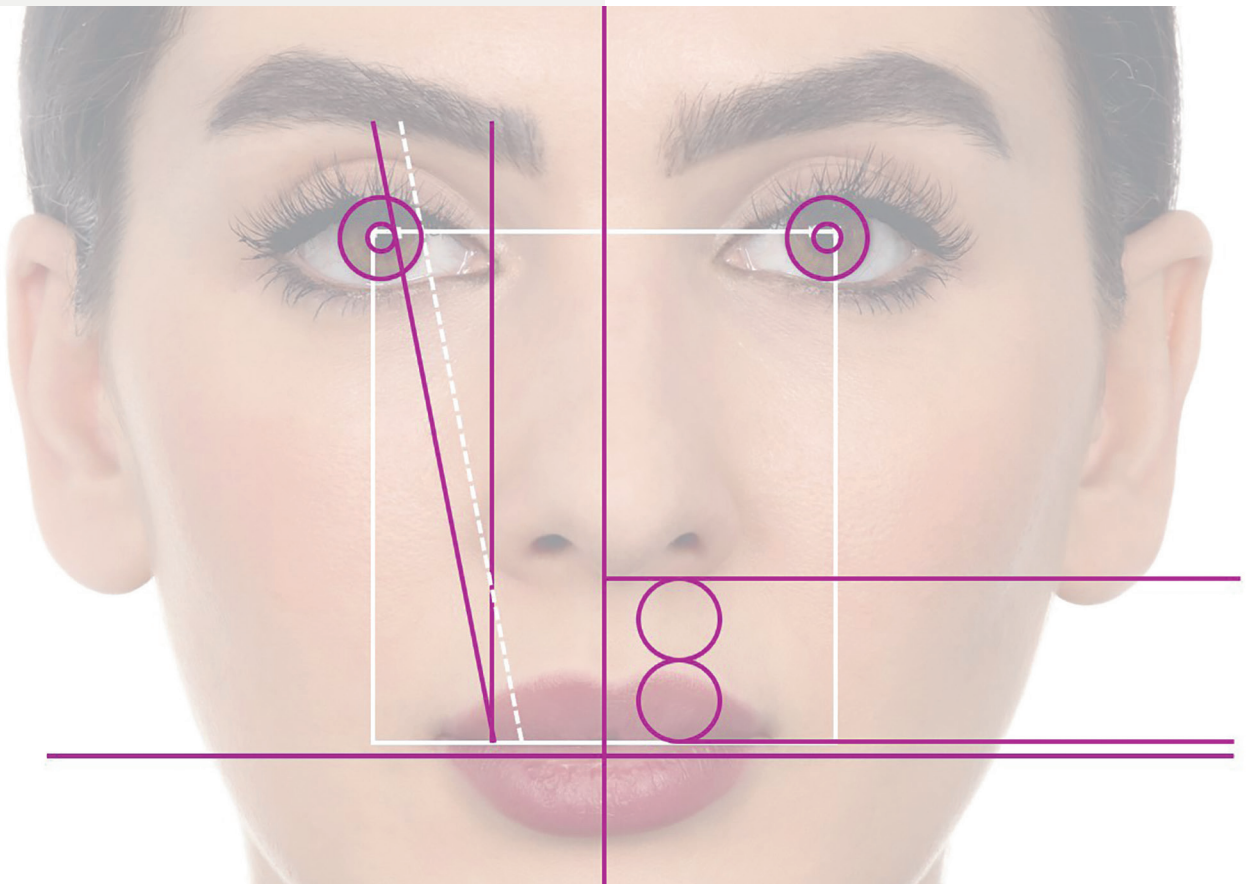


the exceptional computing power of today combined with the accessibility of digital photography and sophisticated photo editing software not only provide guidance in the treatment planning and diagnostic approach but also help to improve patient communication and motivate the patient.[7–9] Various forms of digital simulation are possible depending on the skills of the operator and the complexity of the software being used, ranging from comprehensive 3D approaches[7,10–12] such as Digital Smile Design (DSD),[7] which comprises specific steps, the use of online services, and printing of 3D models, to the more basic Photoshop Smile Design (PSD), which makes use of a few tools in Adobe Photoshop software.[8] While DSD uses 3D templates of existing dentitions, PSD is only 2D and relies on the existing knowledge of the operator. However, currently, the 2D approach provides a higher-quality image that appears more realistic for the patient to absorb.

This article presents an evolution of the PSD approach known as *Dentofacial Digital Diagnostic (Triple D)*. With this protocol, a limited number of high-resolution photos and standard imaging software are used to generate realistic images of the potential esthetic therapeutic outcomes. A specific head posture and novel dentofacial landmarks are proposed. The length and position of anterior teeth is first determined on a portrait photo in rest position and then transferred to a corresponding image showing the patient's smile (teeth visible but not touching lower lip) and then to the photo of the patient with lip retractors. Standardized images > 24 MP (megapixels) are necessary for use in the photo editing software. Depending on the case, the existing teeth are either corrected/modified or overlaid with teeth from a library of natural dentitions. The high resolution and standardization of the process allows fine editing of tooth details at high magnification while also enabling the operator to zoom out to evaluate edits and gestalt within the frame of the portrait. This allows a global representation of the esthetic treatment proposal with limited perceptual distortion. The patient's perception and desires can be assessed with different proposals to determine the most appropriate design. Additional retracted smile images can be used to provide detailed information about discrepancies in the soft tissue morphology and potential corrections by the periodontist. Preoperative and edited images are finally assembled, compared, and discussed with the patient using a presentation software. This whole process should prepare and help the operator read the patient's expectations and desires before starting the diagnostic wax-up/mock-up/provisional stage while significantly improving mutual confidence with the patient.

Step-by-Step Triple D

1. Personality patient portrait

It is important to capture the personality and social context of the patient. This will help in the definition of the project. An informal shot with the patient in a relaxed and casual stance using the setup described hereafter (studio conditions, camera settings, etc) can be used (Fig 1), but

FIG 1
Personality shot. The patient is encouraged to express a natural stance. Note the patient's subdued smile, revealing an introvert character.

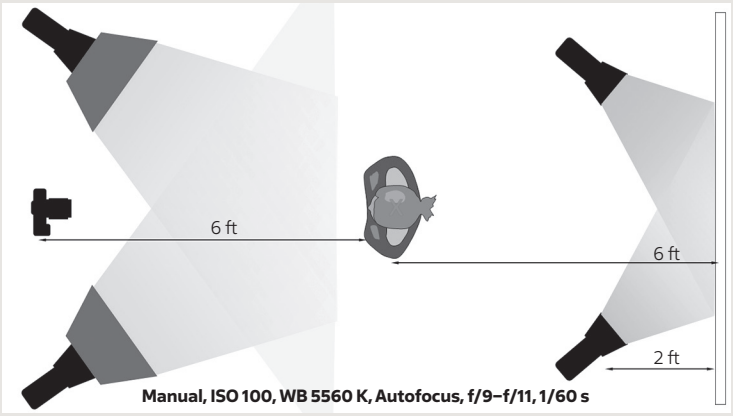


FIG 2 Two strobe lights are placed symmetrically 2 ft from the white matte wall and 5 ft apart and set at 70% power. The patient stands about 6 ft from the wall. Two additional strobe lights with softbox are placed 6 ft from the patient and set at 85% power.

FIG 3 Photograph showing studio setup. *A light-absorbing panel (black) was added to limit any reflections on the hair and increase contrast with the background (this is especially important in cases of light hair color).

the patient can also bring their own images to provide a glimpse of their social environment.

2. High-definition patient portraits

For these working shots, the patient is given the following instructions:

- The hair must be tied back so the ears are clearly visible.
- The skin and lips must not be too glossy (matte foundation and lip gloss) to avoid strong specular reflection, which could cause distraction.
- The neck must be visible all the way to the shoulder transition (ie, no turtleneck or halter tops should be worn).
- The patient must stand upright at a designated point marked on the floor (see Fig 2).

The setup for portrait photos includes the following:

- A white matte background wall or screen
- Two strobe lights (Hensel Integra Pro 500W monolight) directly illuminating the wall or screen
- Two strobe lights (same as above) with a diffusing softbox (minimum 1 × 2 ft) to illuminate the patient
- A dark ceiling above the patient's head if possible (see Fig 3)

If the suggested space between the object, operator, and the wall cannot be obtained, it is recommended to reduce the intensity of the back strobe lights and the direct lights until a satisfactory exposure is achieved. The camera settings may also need to be slightly altered. The strobe lights are paired with a transmitter to synchronize with the camera. It is recommended to set the power of indirect light (against the wall) at no more than 70% and the power of the direct light (with softbox) at 85%. A possible setup with the exact positioning of each element is depicted in Figs 2 and 3.

The camera settings must be as follows:

- Manual mode
- f-stop 9 to 11 (depending on skin tone, hair color, clothing, etc)
- Shutter speed 1/60 s
- White balance 5,560 K
- ISO 100
- Minimum resolution of 24 MP, preferably including RAW data for professional-level editing
- Lenses with 85 to 105 mm in focal length with full-frame sensors to avoid distortion of facial features
- Autofocus in single shot (AF-S) with the smallest area (pinpoint)

FIGS 4–7
The four raw images to be potentially used for the Digital Dentofacial Diagnostic. Note that Fig 6 will not be usable because of the contact between the teeth and the lower lip.

Finally, each portrait needs to be taken with a standardized head posture, framing, and focus point (see Figs 2 and 3), preferably in landscape format to facilitate horizontal alignment with the eyes:

- The patient's face and shoulders must be parallel to the camera sensor and strobe light planes.
- Both ears must be equally visible.
- The bipupillary line must be as horizontal as possible.
- The otobasion superior (soft tissue point on the upper outer rim of the ear where it unites with the skin of the head) must line up horizontally with the exocanthion (soft tissue point located at the outer commissure of each eye).
- For the at-rest photo, the focus point must be offset to the eye; for the smile and retracted views, it must be on the teeth (central incisors).
- The neck and shoulders must be visible.

A series of images (three to four per position) is generated as follows:

1. At-rest position, with lips closed or almost touching (Fig 4).
2. At various spontaneous smiles (Fig 5). Instruct or guide the patient to smile while avoiding contact of the central incisors with the lower lip. The images will not be usable if maxillary teeth are touching the lip or even hidden by the lower lip (Fig 6). For this reason, a series of images at various openings will provide a range to choose the best shot between a spontaneous smile and one with forced opening.
3. With lip retractors (Fig 7).

Each image is carefully verified for accuracy and to make sure that proper data has been collected.

3. Initial image enhancement

All images are transferred to the computer and archived in a folder labeled "original_raw" or something similar. The three most appropriate photos are selected (rest, smile, and retracted) and duplicated in a folder labeled "selected." Camera brands each have their own proprietary RAW format (eg, NEF for Nikon Electronic Format, CRW for Canon Raw Format) that requires conversion using a free converter (eg, Adobe Camera Raw for export to Adobe Photoshop). The RAW formats are uncompressed and unprocessed files that store the largest amount of information. After editing, RAW files can be converted and compressed to other formats like JPEG or PNG for use in other applications. At this stage, the RAW image will be enhanced in Adobe Photoshop in the following order:

1. **Crop tool:** Crop and rotate the image to obtain the horizontal bipupillary line and free space next to shoulders. Rotation is an essential tool and reveals a grid that can be used to align the reflections of the softboxes with one of the horizontal lines (Fig 8).
2. Optional: **Quick selection** of the white background can be made to increase the whiteness in case of shadows (especially in the corner of the image). There are various ways to blend the background. This additional step will allow smoother transitions when comparing subsequent images using the presentation software. Hair around the neck or other hair flashes can be easily removed with the Brush tool by selecting the shade of the background and using decreasing sizes and strength of brush strokes while approaching the neckline (Figs 9 and 10).

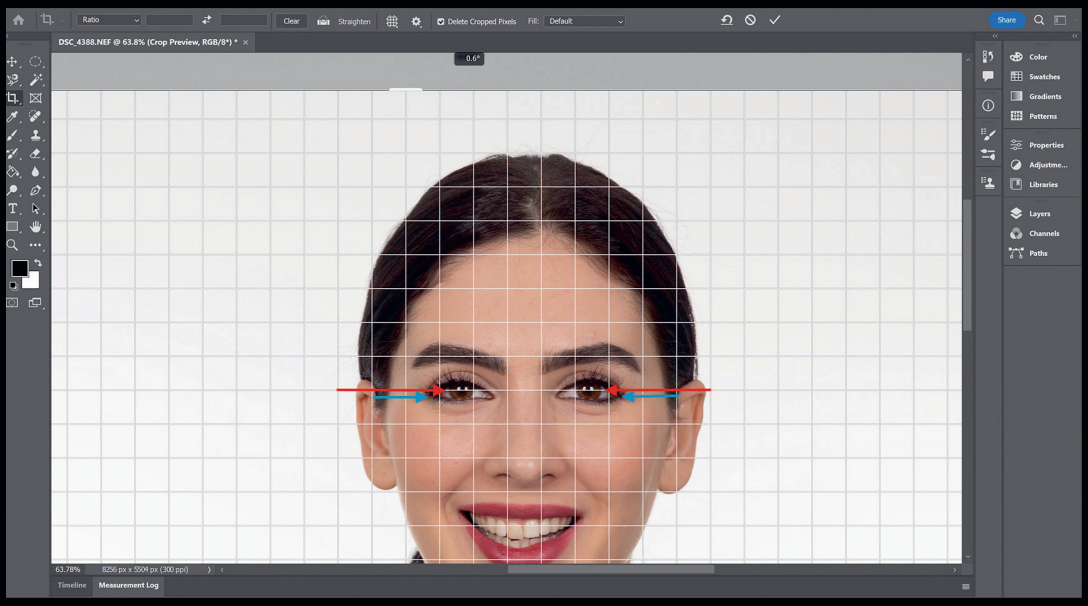


FIG 8 Horizontal alignment is facilitated by the reflection of the softboxes in the eyes *(red arrows)*. Note also otobasion superior is aligned with exocanthion *(blue arrows)*.

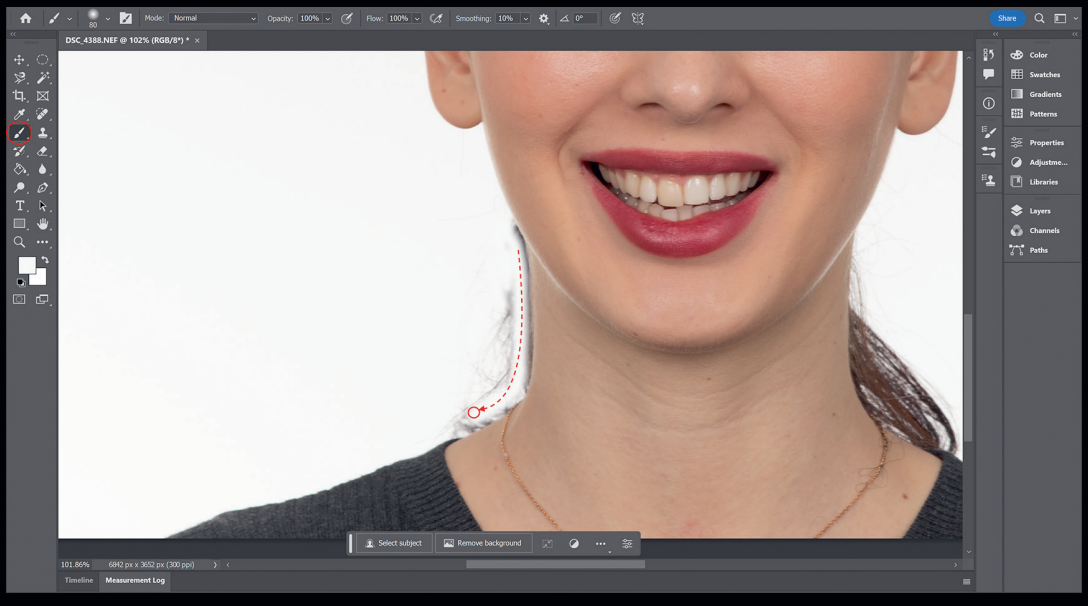


FIG 9 Painting the background (Brush tool) to eliminate hair flashes.

3. **Curves/sharpen:** Several adjustments are possible, but the all-in-one tool is the Curves adjustment (by moving some points in the tonal range graph; Fig 11). The goal is to improve the contrast, exposure, and color according to one's taste. The image can also be sharpened (increase of contrast at image edges) using the Sharpen filter, Unsharp Mask.
4. **Spot healing:** In this last step, dust from the camera sensor and undesired imperfections (acne, blemishes, pimples, etc) can be removed with the Spot Healing tool. The best results are obtained when using the smallest brush possible. The goal is to avoid the patient focusing on unpleasant features while evaluating the images.
5. **Save** in the photo editing software format (eg, PSD for Adobe Photoshop) and make an additional JPEG or PNG version to export the image for the next step (Fig 12).

FIG 10
Clean image with white background.

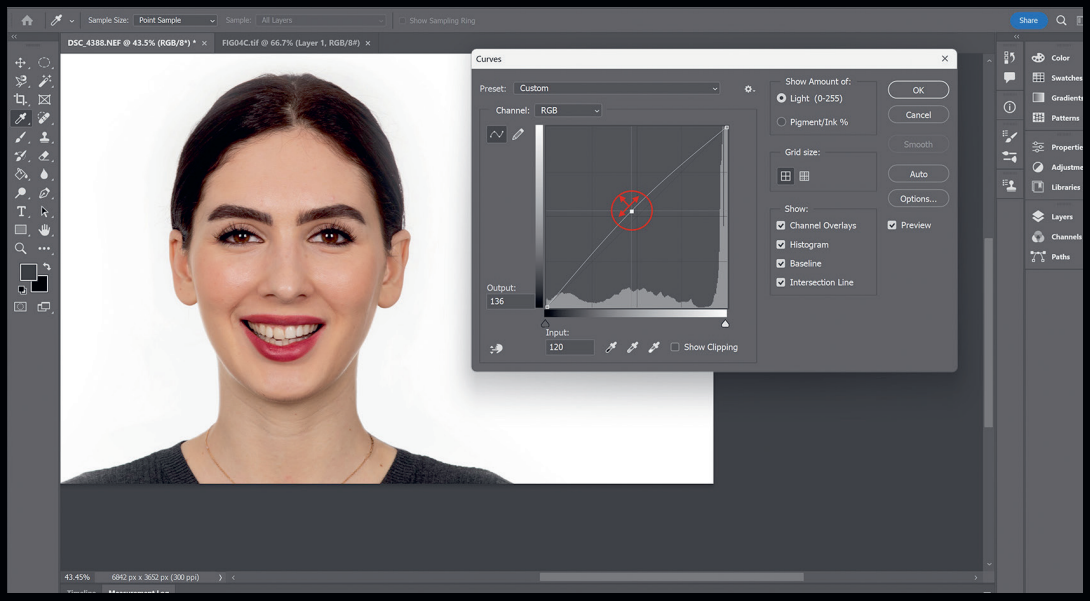


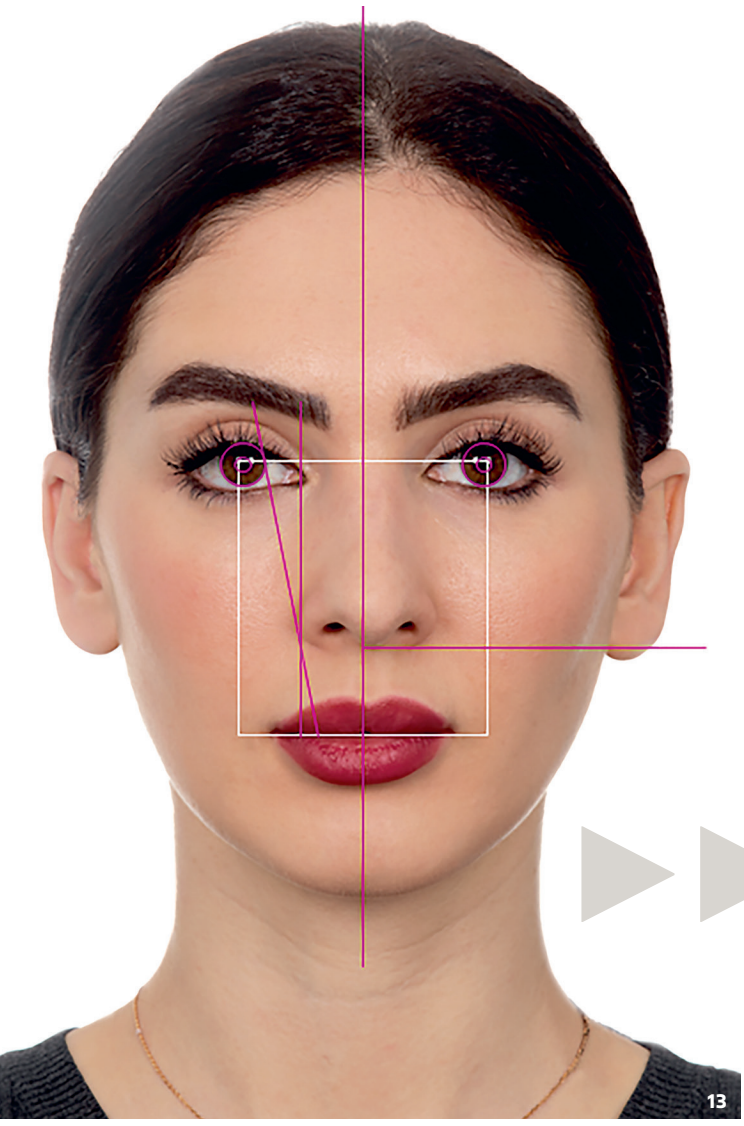
FIG 11
A wide range of adjustments of brightness and contrast can be made by slightly moving the central point of the tonal range graph, followed by increasing sharpness with the filter Unsharp Mask.

FIG 12
Clean high-resolution image saved as PSD and ready for export in presentation software. Preprocessing RAW image adjacent for comparison.

4. Dentofacial relationships and landmarks

The clean images (rest and smile) are now ready to start the dentofacial analysis. First, the rest image is imported into a presentation software (eg, Apple Keynote, Microsoft PowerPoint) to identify landmarks that will later be used to reveal facial characteristics and define the placement and position of anterior teeth. The following landmarks are obtained from the rest image (Fig 13):

- Median rectangle with upper corner at the center of the outer flash reflection in the iris and lower edge at the level of the labial commissures.
- Vertical midline at the center of the median rectangle. These first two landmarks provide facial centering and horizontal alignment.
- Vertical line through endocanthion. Where this line crosses the rectangle base is the mesiodistal position of the canine.
- Oblique line from the mesial outline of the iris to the ala naris. This is the inclination of the canines.



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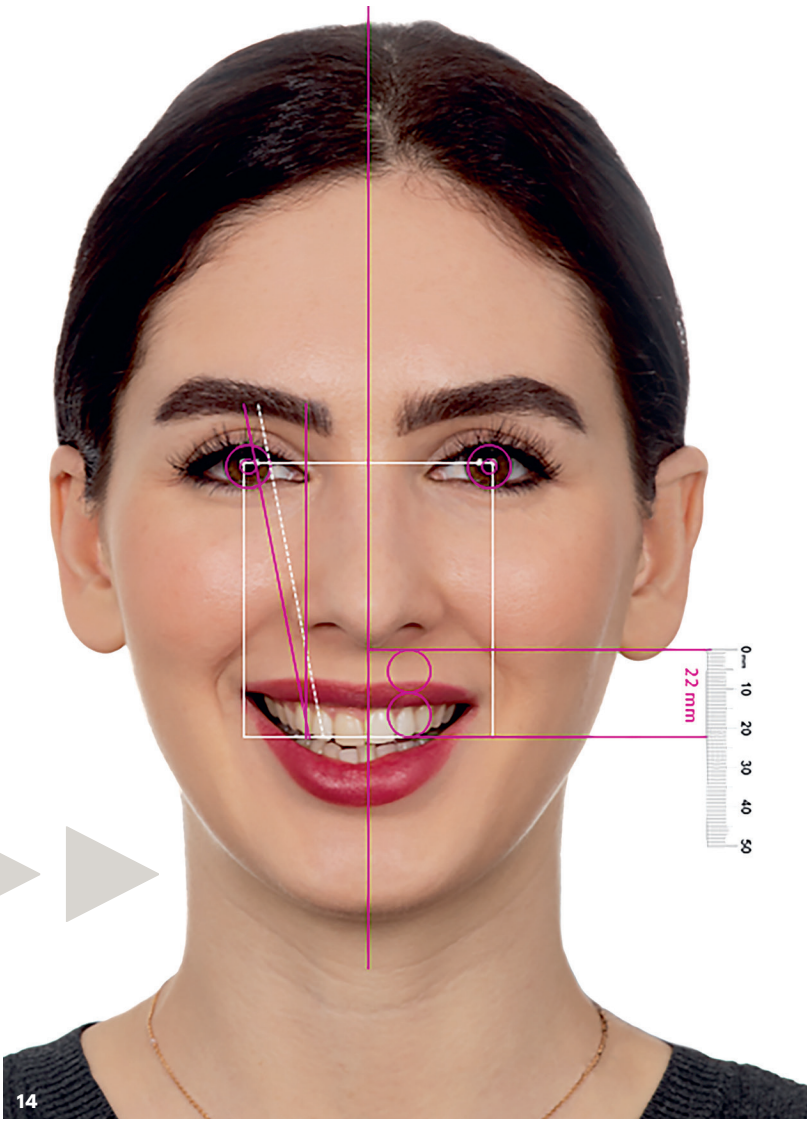

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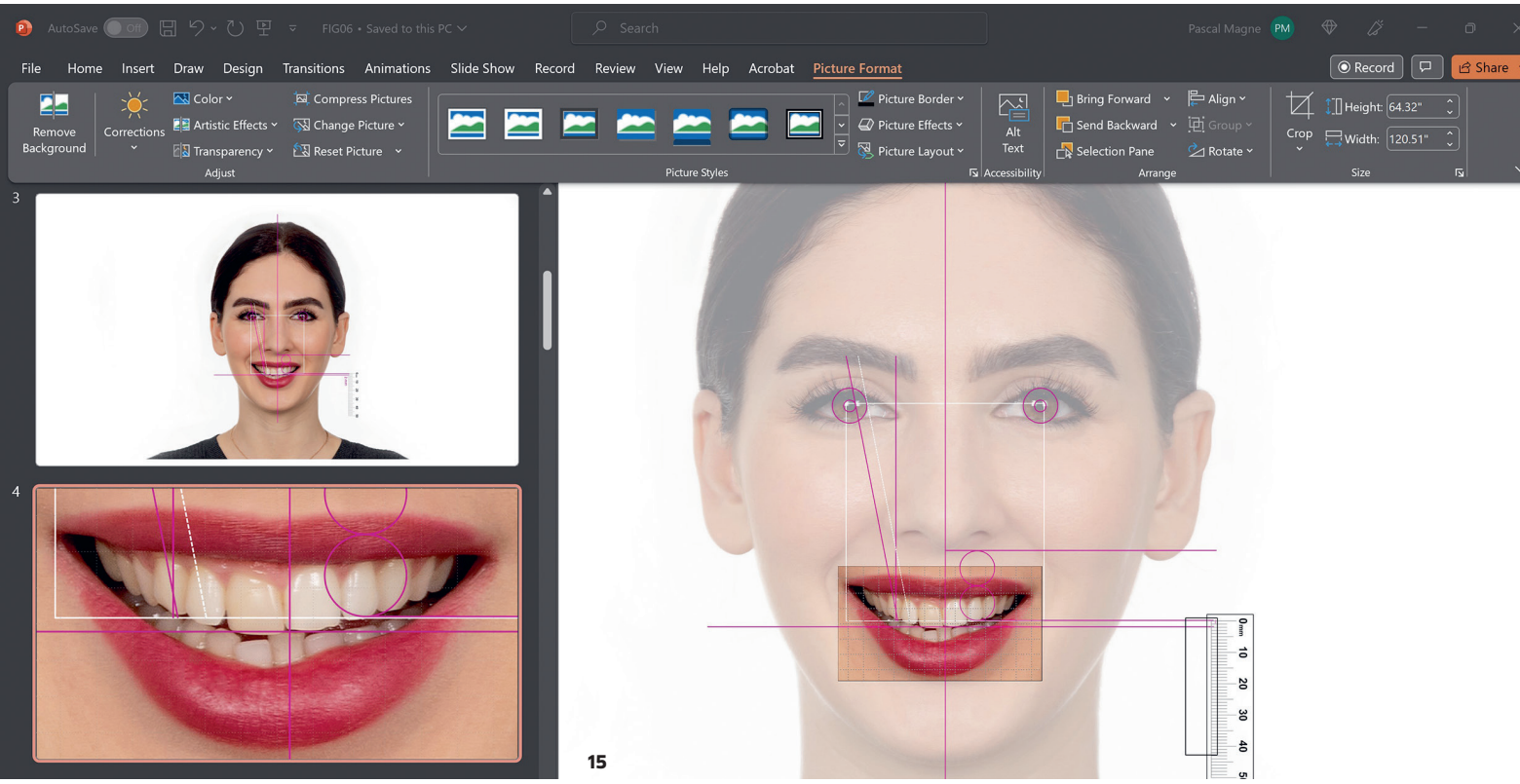
- A copy of the same oblique line is placed at the mesial outline of the pupil and should roughly meet the rectangle base at the same point as the endocanthion vertical line.
- Horizontal line at the level of the buccal vestibule, which can be approximated by the lower edge of the ala naris. This reference line cannot be established on the smile portrait due to the elevation of the soft tissue during smiling.

Using the bipupillary distance and outlines as a reference, all landmarks above are transferred to the smile image (Fig 14) and calibrated for size (using the pupils). Additional landmarks are then drawn in this image:

- The circle of the iris has an average 11-mm diameter (adult) and is duplicated to create a 22-mm reference, then aligned with the horizontal reference of the vestibule. A digital ruler is brought to the picture and calibrated using the 22-mm reference from the irises. Another more precise but less practical way of calibrating the ruler is to measure a fixed distance (eg, distal outline of the left central incisor to the distal outline of the right central incisor) on the patient or on casts.
- The 22-mm mark below the vestibule (using the lower edge of the ala naris from the rest photo) is the horizontal reference for placement of the lateral incisor edge (see Fig 14).
- The same ruler is then used to place a horizontal line 1.5 to 2.0 mm below the previous one, which is the reference for the length of the central incisor (Fig 15).

FIGS 13–15 Dentofacial references obtained from the rest portrait are transferred to the smile portrait using the irises as a reference. Additional references are drawn onto the smile portrait to find the incisal edge position of the lateral incisor (22 mm from estimated vestibule) and central incisor (2.0 to 2.5 mm below the lateral incisor). The image is then magnified within the presentation software to work on the tooth design.



Figures 16 and 17 show the detailed dentofacial mask performed in this case and the library of existing teeth selected for the digital design.

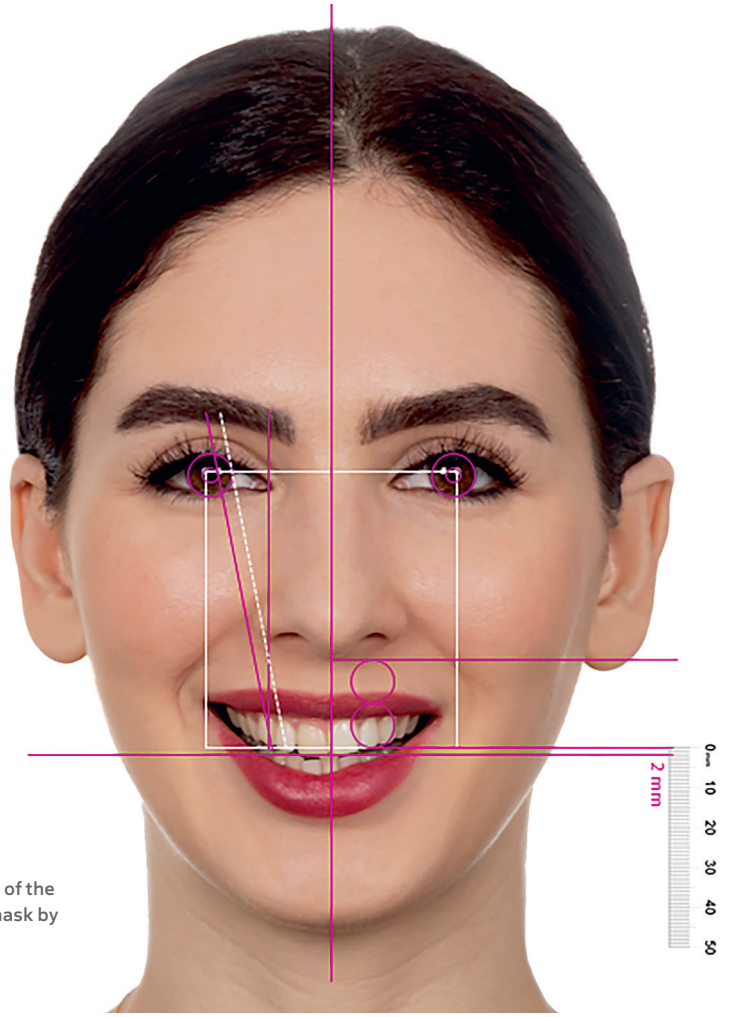


FIG 16 Detailed view of the dentofacial mask by author MM.

FIG 17 A library of existing teeth from a retracted smile was chosen according to the patient's desire/character/personality. Each tooth shape was saved as a separate file.

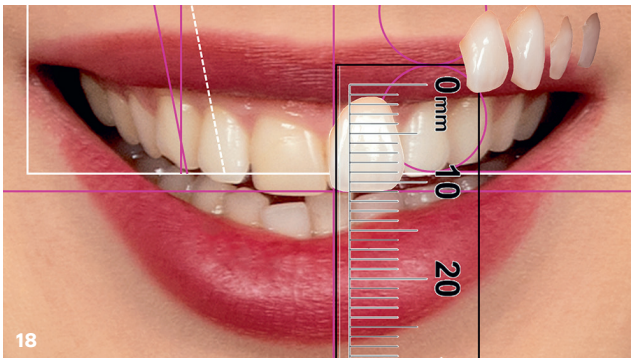


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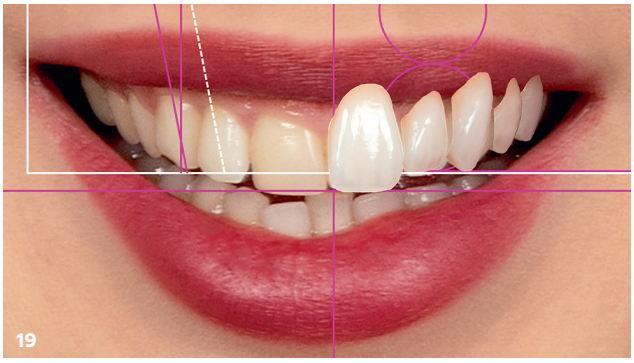
FIG 18 Magnified smile with all landmarks.

FIGS 19/20 Libraries of tooth surfaces are imported and placed one by one (mirror replicas can be used to complete the contralateral side).

FIGS 21/22 A facial mask obtained by deleting the teeth from within the lips is then overlaid to hide the cervical excess from imported shapes.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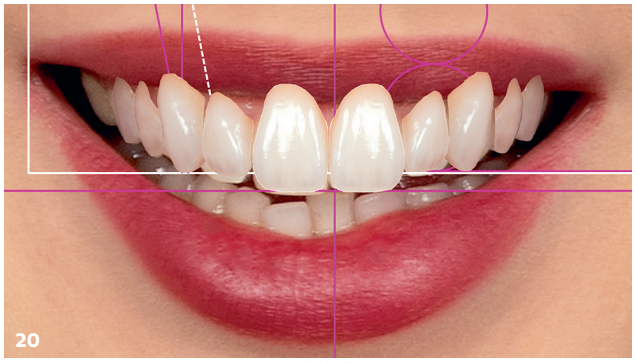
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5. Image editing

The smile image with all lines completed is magnified within the presentation software to start the new design (Fig 18), which can be achieved using three different techniques, depending on the case complexity as well as the skills of the operator with Photoshop software and especially their knowledge of morphology and esthetic principles.

Library approach

The library method is chosen when multiple existing teeth need major modifications (large unesthetic restorations, severe wear, etc). Tooth surfaces from a database of natural teeth (see Fig 17) are imported from retracted smiles, ideally natural dentitions provided by family peers or other dentitions preferred by the patient. A realistic simulation is only possible with a library originally photographed with the same setting used for the portrait images of the patient (lens, strobe light arrangement, distances, etc). Within the presentation software, the landmarks are used to place each tooth surface (Figs 19 and 20). Mirror copies of the shapes are used on the contralateral side, and an arrangement can be easily obtained. Finally, all landmarks are removed, and a facial mask without teeth (Fig 21) is imported to cover the surfaces with the lips (Fig 22).


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22

FIGS 23–25 The magnified file with the new tooth shapes and lips is exported to Adobe Photoshop to refine the incisal edges and blend and integrate the outline of each tooth (interdental and gingival transitions). A more natural appearance is obtained by painting a light shadow of the upper lip onto the teeth and gingiva.

FIG 26
The final portrait is obtained by replacing the original smile with the edited one within the presentation software.

The resulting smile image is saved as a TIFF and finally exported to Photoshop to be refined with various tools, mostly the Brush tool to outline the incisal edges (Fig 23) and blend interdental spaces and gingiva (Fig 24). The outline of each surface can be blended using the Smudge tool to soften the transitions. The final image is finally completed by brushing the shadow of the upper lip at the cervical aspect of each tooth (Fig 25). This file can be imported in the presentation software and overlapped with the initial portrait to generate the final design (Fig 26).

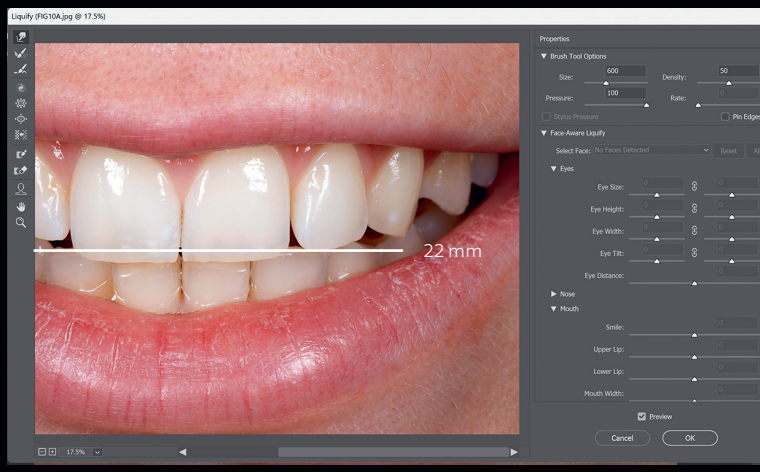
Using again the irises as a reference, it is also possible to reposition the new shapes on the portrait with retracted smile. This will provide preliminary guidelines

FIGS 27–30
Repositioning of the modified library tooth shapes within the retracted smile revealed significant discrepancies of the gingival contours.

for periodontal surgery (Figs 27 to 30). These markings can be meticulously utilized by a periodontist to delineate the gingival line during surgery. Each modification can be calibrated using a digital ruler to provide precise measurements of the discrepancies between the current gingival line and the intended outcome of the Triple D. This case was planned and restored accordingly using 12 bonded porcelain restorations (Figs 31 to 34).

FIGS 31/32
The treatment of this specific case required periodontal surgery, which was calibrated by the Triple D and consecutive wax-up/mock-up. Bonded porcelain restorations were used for final restoration (Creation CC on refractory die technique).

FIGS 33/34 The final restoration is well integrated within the face and the soft tissues.



FIGS 35/36 The lateral incisor edge was identified at 22 mm from the ala naris (rest image), and the Liquify tool (in Filters menu, Forward Wrap tool) was used to edit the lateral incisors.

FIG 37 Duplicate Layer in Layer menu is then applied to fill the background before further transformations.

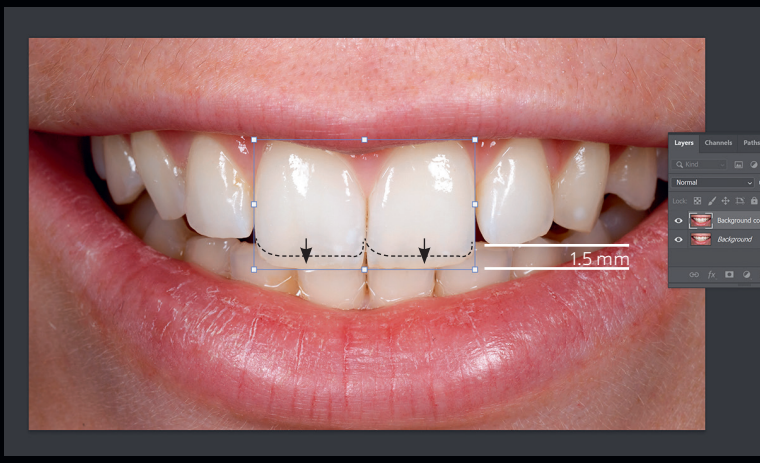


FIG 38 The central incisor outlines are selected (Magnetic Lasso tool), and Free Transform (in Edit menu) is used to obtain an average of 1.5 mm of length difference with the lateral incisor.

Modification approach

The modification method is best for cases that require minor modifications, especially when the existing teeth already have adequate structure, color, and surface texture. Figures 35 to 44 illustrate the sequencing of this approach:

1. It always starts with the lateral incisor edge based on the 22-mm rule described previously. If only slight modifications are needed, just the Liquify tool (in Filters menu, Forward Wrap tool) is necessary (Figs 35 and 36).
2. A duplicate background layer is created (Duplicate Layer in Layer menu; Fig 37) before doing further transformations. This will ensure that no blank negative spaces appear after transforming the teeth.
3. Continuing with the central incisors, tooth outlines are selected with the Magnetic Lasso tool and then edited with Free Transform (in Edit menu; Fig 38) to increase length and obtain ~1.5 mm of difference in length with the lateral incisor (up to 2 mm depending on the wear status). If no further Free Transform is needed, layers can be merged by using the Layer menu, Flatten Image.

FIGS 39/40 The most appealing central incisor is selected as a rectangle before opening the Liquify tool and optimizing the shape with the Forward Wrap tool.

FIG 41 The Magnetic Lasso tool is used to copy and paste the edited central incisor and mirror the selection (Flip Horizontal in Edit, Transform menu).

FIG 42 Once in position, the image is flattened again and cleaned with the usual tools (Brush tool, Spot Healing Brush, etc) to blend the edges of the copied tooth.

FIG 43 The left canine is modified and then copied and mirrored to obtain the right canine.

FIG 44 Final clean image (blended, shapes refined, and symmetric elements removed).

4. One central incisor outline is first modified using the rectangle selection before opening the Liquify tool (Fig 39) in order to close the contact with the lateral incisors without modifying the latter. Further use of the Liquify tool allows refinement of the cervical shape (Fig 40).
5. The other central incisor is made by selecting the first one (Magnetic Lasso tool), copying and pasting it, then mirroring the selection with Flip Horizontal (in Edit, Transform menu; Fig 41). It is moved into the ideal position with the Move tool. Once in place, the image is flattened again and cleaned with the Brush and Spot Healing Brush tools in order to blend the edges of the copied tooth (Fig 42).
6. Finally, the canines are treated exactly as the central incisors. The left canine is modified, copied, and pasted using mirroring to obtain the right canine (Fig 43).
7. The final image is cleaned using previously mentioned tools to improve blending, refine the shapes, and remove symmetric elements created by the mirroring steps (Fig 44).

FIG 45 Direct comparison of the so-called "classic" *(left)* and "natural" *(right)* smile designs. Both images were generated digitally.

Mixed approach

While this article illustrated two cases using the library approach and the modification approach individually, these approaches can certainly be combined whenever necessary to maximize the esthetic potential.

Expressions of the Smile

For optimal interaction with the patient, it is fundamental to understand the two major types of smile expression and all the variations in between (Fig 45).

The stereotypical smile expression

The stereotypical smile (see Fig 45, left) is perfectly symmetric, static, dull, and lacks natural character. Some call it the "classic Hollywood smile" or the "perfect smile." It is characterized by the following:

- Smaller, more regular, and similar groups of teeth (central incisor, lateral incisor, canine)
- Maximally reduced incisal embrasures
- Limited or absent length shift between central and lateral incisors
- Buccal alignment without steps between tooth groups
- Flat smile line (compared to the lower lip line)

The general feeling associated with this design is a heavy visual weight ultimately justifying a reduced tooth size with an aged/worn connotation.

The natural smile expression

The natural smile (see Fig 45, right) is more animated, dynamic, and associated with character. Some call it the "European smile." Such a smile displays teeth firmly rooted in their alveolar ridge, with dynamism but stability. It is characterized by the following:

- Distinct groups of teeth with contrasts similar to the different but complementary elements of a symphony
- Sharp but delicate incisal embrasures
- Length shift between central and lateral incisors
- Often buccally inset or rotated lateral incisors
- Incisal edges and canine tips following the lower lip line

The general feeling associated with this design is harmony, youth/health, and light visual weight, ultimately justifying, especially in women, predominant central incisors and a voluptuous connotation. In this design, each tooth provides a specific expression/meaning: patient personality (central incisors), fantasy/joviality (lateral incisors), and masculinity/potency (canines).

Presentation and Discussion with the Patient

All media created during the Triple D can be imported into a presentation software (Keynote, PowerPoint, etc). Because all images can be superimposed, the patient

can browse through consecutive images and watch them like a "movie" of the steps involved. Looking at the simulation, an individual is more prone to explore surgical and orthodontic options when it appears that teeth are extremely out of position or the gingival display requires adjustment.

When patients have difficulty expressing their desire and mental image of the expected smile, it is useful to present simultaneously two different designs—one natural and one more artificial. The individual response will ultimately guide the designer toward the most appropriate type of design. For optimal communication, it is best to avoid any intermediaries between the designer and the patient.

Conclusion

The Dentofacial Digital Diagnostic (Triple D) uses a maximum of three high-resolution photos, specific head posture, and novel dentofacial landmarks in an image editing software to provide realistic images of the potential esthetic therapeutic outcomes. Because the modified images include the whole face, all edits and gestalt can be evaluated within the frame of the portrait as well as detailed information about discrepancies in the soft tissue morphology. Different proposals can be used to determine the most appropriate design, and all documents, once assembled, can be compared and discussed with the patient using a presentation software. Through this 2D blueprint, a unified target is created for the dentist, involved specialists, and the technician to be able to understand the patient's expectations and desires before starting the 3D process (diagnostic wax-up/mock-up/provisionals).

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