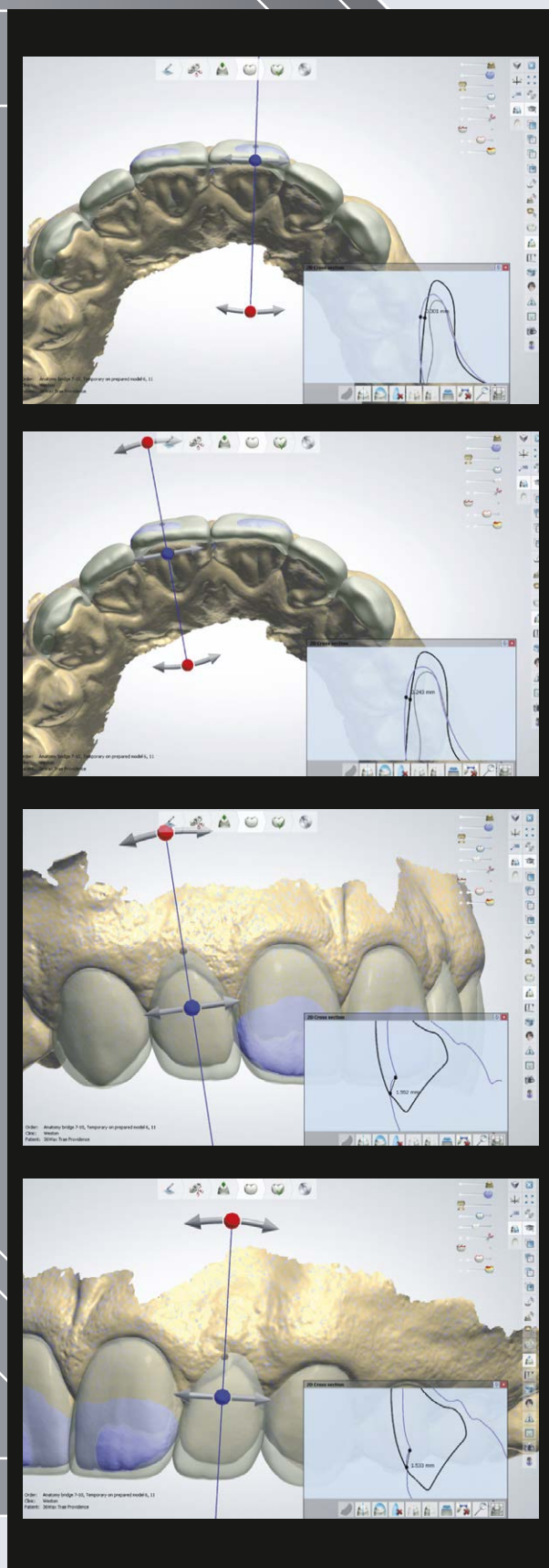# DIGITALLY GUIDED
Porcelain Veneer Smile Design

John F. Weston, DDS, FAACD

Abstract

Clinical principles guiding treatment planning and subsequent preparation/adhesive protocol have not significantly changed since veneers were introduced nearly 50 years ago. However, the technologies facilitating smile analysis and design, as well as laboratory communication and fabrication practices, have evolved, as have the materials available for digitally manufacturing esthetic veneers. This article illustrates a case in which effective communication among the patient, clinician, and ceramist was established throughout the planning and treatment process via 2D images, 3D design, and digitally printed and milled components to enhance collaboration and treatment accuracy, as well as ensure the predictability of the final esthetic outcome.

Key Words: digital smile design, 3D wax-up, digital wax-up, smile design, veneers

Introduction

As patients increasingly demand esthetic, conservative, and functional resolutions to their smile design concerns, all-ceramic veneers continue to represent a durable restorative option when adhesively bonded to enamel.[1,2] The smile design and clinical principles guiding treatment planning and subsequent preparation/adhesive protocols have not changed substantially since this restorative modality was introduced nearly 50 years ago.

Close examination of the components of the esthetic zone (i.e., relationship among the face, lips, gingivae, and teeth) is still required to determine the extent to which these individual and collective elements are attractive.[3,4] Likewise, diagnostic models, wax-ups, intraoral mock-ups, and silicone guides remain essential for designing and predictably delivering esthetic veneer restorations.

What have evolved, however, are the technologies facilitating well-accepted record-taking, diagnostics, smile analysis and design, and laboratory communication and fabrication practices, and the materials available for fabricating the anticipated veneers. Digital photography, digital design software, and computer-aided design/computer-aided manufacturing (CAD/CAM) have ushered in an era of virtual, almost instantaneous smile design in which printed photographs and stone models are practically obsolete. With smile design capabilities transitioning to chairside and/or any computer workstation or mobile device, there are unprecedented opportunities for patients' participation in—and understanding of—their esthetic smile transformation.

The application of these digital tools and technologies has also transformed how restorations are designed and fabricated in the laboratory. Stone models have given way to digital models, and wax-ups can be designed digitally, enabling 3D printing of prototypes and models for matrix fabrication for use in mock-up creation. With CAD/CAM, the combined digital design processes culminate in the manufactured production of predictable, definitive veneers. A machinable lithium disilicate material enables such fully digital fabrication processes (e.g., IPS e.max, Ivoclar Vivadent, Amherst, NY), yet simultaneously allows ceramists to exercise their artistry in imparting incisal effects, natural characteristics, surface morphology, and other nuances found in natural anterior teeth.[5]

However, these tools can help to ensure patient satisfaction with the definitive treatment outcome only when dentists and their laboratories consistently incorporate them into their diagnostic, smile design, and communication processes. By incorporating digital photography and 2D analysis, dentists can better determine patient expectations, enhance collaboration with their labora-tory, and establish a foundation for smile design communication among everyone involved (i.e., dentist, laboratory, patient). This article illustrates a case in which proper communication among the patient, clinician, and ceramist was established throughout the planning and treatment process using a combination of these digital tools to achieve exceptional esthetic results.

Capturing a Photographic Foundation

The minimum requirements for 2D smile analysis and design include:

1. Full-face image with patient smiling, looking straight at the camera, eyes level to the horizon; if necessary, this can be adjusted in smile design and/or photo-editing software (e.g., KeyNote, Apple; Cupertino, CA). The full-face image is the cornerstone of the entire case and must be oriented to the horizon if not exposed that way from the start. It is important that the eyes and teeth be in focus.
2. Smile image that includes the corners of the mouth.
3. Retracted view of the teeth with the same framing as the smile image, now with the upper and lower teeth slightly parted.
4. A "12 o'clock" view relating the incisal edges to the wet lip line. This photograph is best taken from above and behind the patient at the 12 o'clock position.
5. Image capturing central incisor length measurement.
6. Image capturing central incisor width measurement.

"Digital photography, digital design software, and CAD/CAM have ushered in an era of virtual, almost instantaneous smile design in which printed photographs and stone models are practically obsolete."

These images enable preoperative smile analysis and creation of a smile design for patient consultation, laboratory communication, and, ultimately, fabrication of a "motivational test smile" mock-up and definitive lithium disilicate veneers.

Case Presentation

This patient desired a "bigger," less gummy smile. He believed his front teeth were "too small and different sizes" and that his front four teeth needed veneers. During the consultation, the concept of a digitally guided 3D "smile try-in" was presented as a means to help ascertain the best treatment approach. The patient agreed, said he wanted the best clinical longevity possible, and that he had been told ceramic would last longer than composite. He consented to a six-unit smile try-in as a baseline to help determine whether to place four or six anterior veneers. We informed him that, based on initial examination, the case could be completed in an additive way with minimal to no tooth reduction. The results using a complete digital workflow are described below.

Analyzing What Is ▶ ▶ ▶

Digital Facebow

With the full-face photograph as the foundation, an analysis of the patient's preoperative condition can begin digitally in smile design or photo-editing software by first superimposing a pre-made template grid over the face and smile. This digital facebow illustrates the facial midline, drawn down through the smile zone, and includes horizontal lines through the pupils and across the teeth for evaluating the smile line, incisal edge, canting, and gingival display symmetry **(Fig 1)**.[6]

Zooming In

However, a more focused evaluation and comparison of the dental midline to the facial midline (as well as a targeted critique of the relationship between the incisal edges and gingival display to the lips, smile, and soft tissue) are best accomplished by zooming in from the full-face image to the smile, including the grid **(Fig 2)**.

Therefore, using the zoomed-in full-face view as a reference, a higher resolution smile and retracted images are added on top, properly oriented in relation to the face. In particular, the opacity can be reduced in the high-resolution smile photograph and its position adjusted to align the central incisors as closely as possible **(Fig 3)**.

Accurate Orientation

Although preoperative and diagnostic photographs are often hand-held or viewed on computer screens, they may not always be oriented correctly. In fact, it is important to note that this entire process could also be completed by drawing directly on a printed photograph if a computer and software are not readily available. However, when properly aligned with the
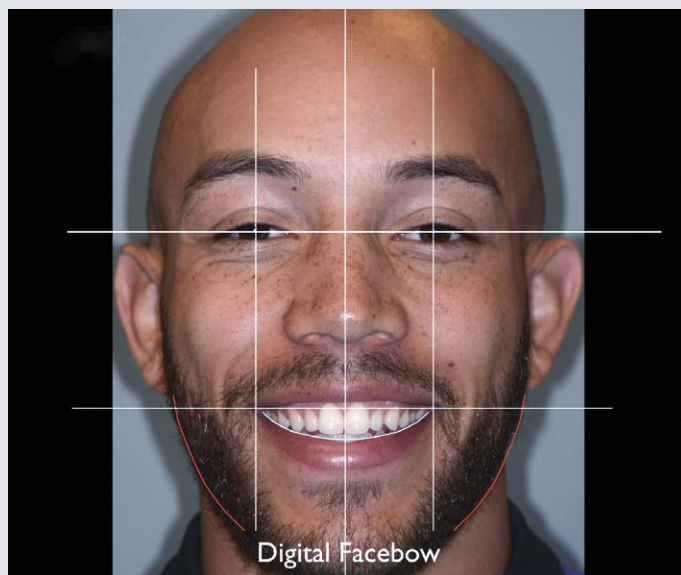

Figure 1: Full-face photograph superimposed with the "digital facebow."

horizon, these combined digital images more accurately represent how the teeth are oriented in the patient's face. This is significant in avoiding canted midlines, other associated problems, and enabling clinicians and laboratories to begin a successful 2D smile design process **(Figs 4 & 5)**.

Understanding existing anterior central incisor tooth lengths and widths, as measured with a caliper and in the context of ideal proportions and basic smile design principles, is of paramount importance to this undertaking. Width can be determined by measuring both incisors together and dividing in half; when the lateral edges are clearly established, measuring a single incisor is also reliable. The key is to always measure both length and width and take photographs.

Transferring Information

Photographing these measurements with the caliper in place facilitates information transfer into the digital smile design process **(Figs 6 & 7)**. It is not uncommon for clinicians to develop a 2D smile design at home or after hours, when a patient's chart or case notes may not be easily accessible. The measurement images, on the other hand, enable quick reference to existing incisor dimensions.

These dimensions are used with calibrated rulers on screen to determine the preoperative tooth proportions in the context of the average width/length ratio, which is 75% to 80% **(Fig 8)**.[3] In the case example, the patient's incisors were 9 mm wide and 11 mm long, with an 82% ratio (i.e., slightly short and wide compared to the ideal) **(Fig 9)**.

Figure 2: Zoomed-in view of the full face with superimposed grid in position.

Hi-res smile photo overlaid on full-face zoomed-in view

Full-face zoom with grid in place

Figure 3: View of the opacity-reduced, high-resolution smile photograph superimposed over the full-face view with central incisors aligned as closely as possible.

Smile photo orientation to face

Retracted photo orientation to face

Figures 4 & 5: Resulting high-resolution composite images of the close-up and retracted smile with teeth properly oriented to the horizon based on the full-face image.

Figure 6: Caliper in focus documenting preoperative central incisor length measurement.

Figure 7: Caliper in focus documenting preoperative central incisor width measurement.
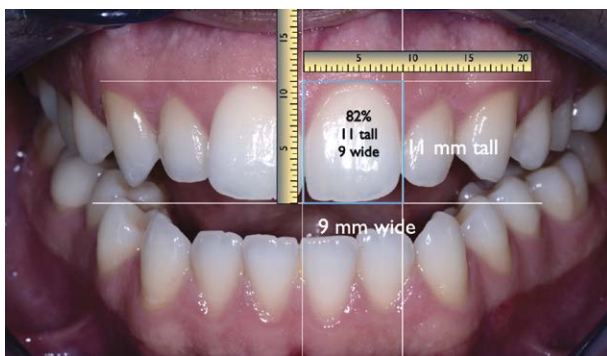

82%
11 tall
9 wide

11 mm tall

9 mm wide

Figure 8: On-screen calibrated rulers measure tooth proportions to establish the preoperative condition, which reveals a slightly higher percentage ratio or wider than ideal tooth proportion.

77%
11 tall
8.5 wide

11 mm tall

8.5 mm wide

Figure 9: Based on the ideal average central incisor length of 11 mm, the patient's current length is acceptable, although it could be lengthened to 11.5 mm.

Digitally Designing What Will Be ▶ ▶ ▶

Based on conversations and consultations with their patients, clinicians usually have a clear understanding of patients' esthetic desires, as well as their own vision for how a case should proceed. However, the 2D digital design phase is imperative not only for allowing clinicians to evaluate their proposed esthetic modifications for a given case, but also for communicating their vision and specifications to the laboratory.

Two Options

In the case shown here, two options were possible to improve the patient's tooth width-to-length ratio: maintain the width and lengthen the incisors, or maintain the length and narrow the width (Fig 10). Since the accepted average central incisor length is 11 mm, the patient's current incisor length was acceptable.[7] This now limited the options to maintaining the length and narrowing the centrals from 9 mm to 8.5 mm, which would produce a more pleasing proportion of 77%. Further, narrowing the central incisors from the distal aspect to 8.5 mm would also enable widening of the laterals, while performing gingival contouring (i.e., tissue lift) at #7 and #10 and mesial of the canines would create better balance and harmony.

Communicating with the Laboratory and Patient

Once the clinician completes the 2D design, the information is shared with the laboratory for conversion into a 3D digital wax-up (Figs 11 & 12). Compared to an analog wax-up, the advantages of a digital wax-up include almost instantaneous screen-share capabilities between laboratory, clinician, and/or patient; easily made adjustments; and immediate evaluation of results, rather than the ceramist undertaking—and the dentist waiting for—the completion of a re-waxing series on a stone model.

These digital wax-up and information transfer capabilities are particularly helpful in communicating with patients about what is required to complete their esthetic smile transformation and why. In the case illustrated here, applying a transparent overlay of the digital wax-up onto the preoperative tooth forms facilitated visualization of areas where the smile design and natural tooth forms intersected (Fig 13). This intersection translated into specific areas of the patient's natural dentition that would require reduction during the preparation phase.

Without question, digital technology facilitates collaboration between the ceramist and clinician, enabling the wax-up to be fine-tuned before 3D printing the models that will be used to fabricate silicone templates for mock-up and provisionalization. Any necessary changes can be implemented digitally and shared easily in real time or by emailing images back and forth. An example is verifying the digital wax-up design in the context of the midline, smile line, and buccal corridors by overlaying the design on the full-face photograph (Fig 14).

When the smile design wax-up has been completed digitally, a wealth of information "outputs" can be generated to aid the dentist during clinical procedures. These include, but are not limited to, transparencies and cross-sectional views of the digital wax-up detailing the exact clearances required for the selected restorative material. This information provides the clinician with a clear reference guide during the preparation phase (Figs 15-18).

Figure 10: Digital smile design demonstrating how narrowing the centrals from the distal will enable widening the laterals for more pleasing proportions.

Figure 11: Front view of the full-contour digital wax-up.
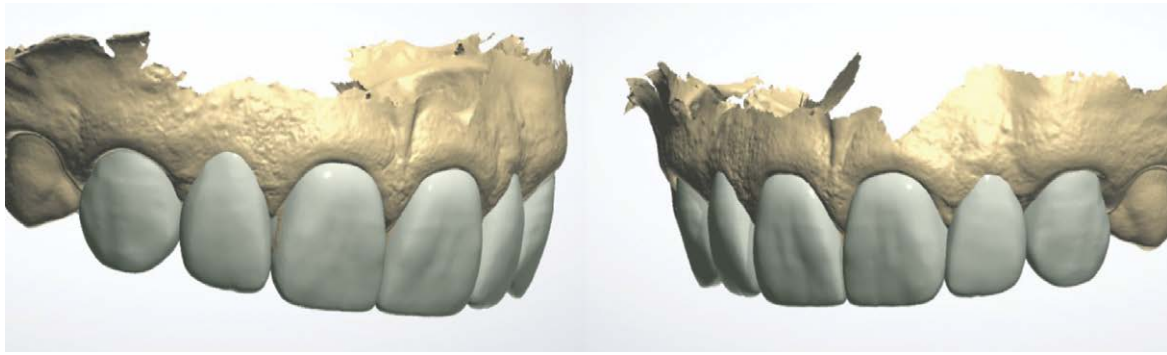
Figure 12: Lateral views of the full-contour digital wax-up illustrate incisal embrasures, cuspid forms, and length transition to premolars.
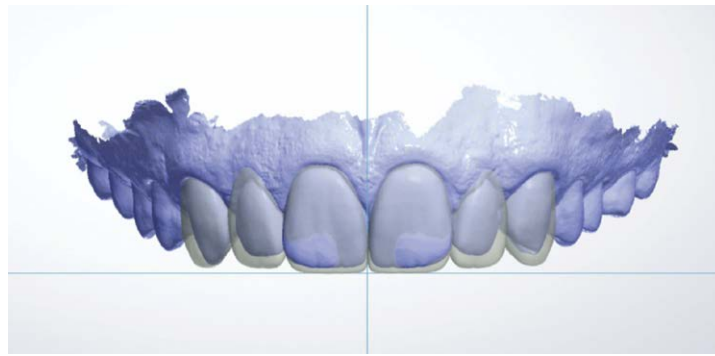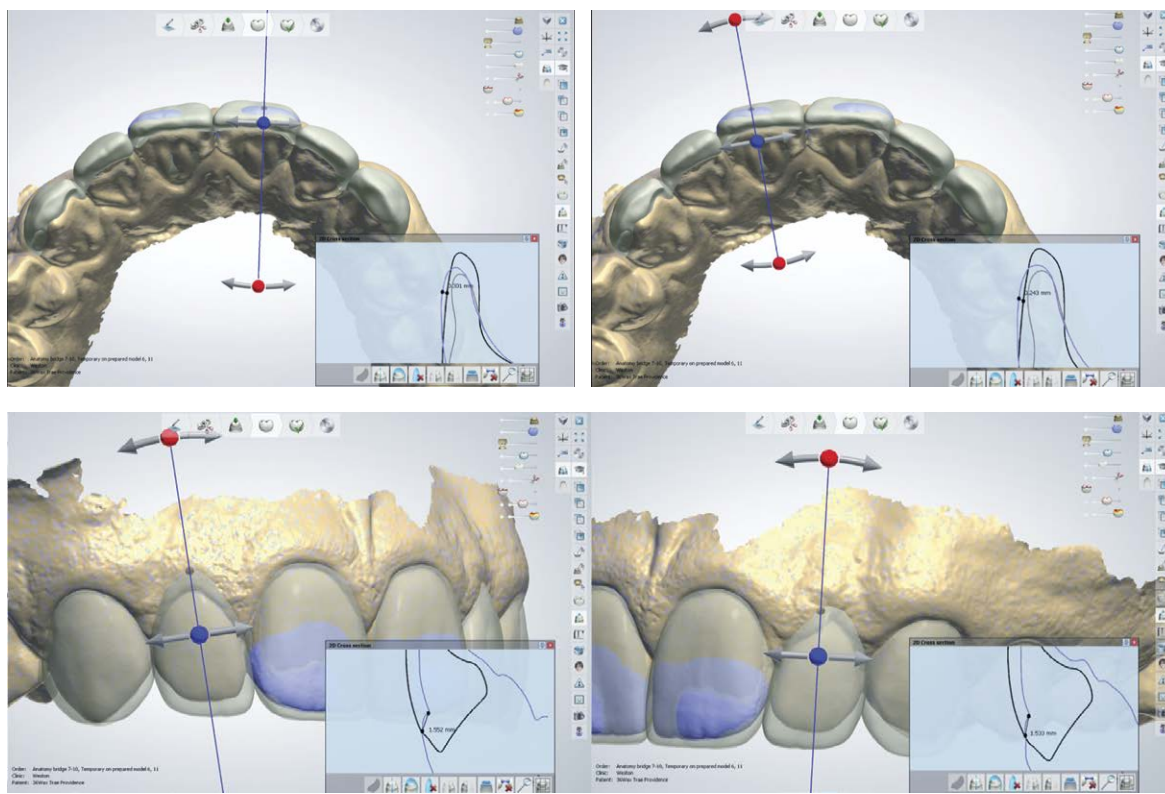

Figure 13: The dark purple areas of the digital transparency indicate where the smile design intersects with the natural tooth forms (i.e., areas requiring reduction during preparation).

Figure 14: Digital wax-up design overlaid on the full-face photograph to verify the midline, smile line, buccal corridors, and other aspects.

Figures 15-18: Cross-sectional views confirm the additive nature of the case—except the central incisors due to rotations—and proper clearances for restorative material.

Moving from Virtual to Reality ▶ ▶ ▶

Combined Output Model

To bring the smile design vision to life, a 3D printed model of the digital wax-up is produced, along with a digital printed model of the patient's preoperative tooth form **(Fig 19)**. These models are united in a "combined output" model, which is used to create a silicone template as the basis for an intraoral "motivational test drive" of the planned smile design. This fosters patient engagement in the process and is a great starting point for explaining treatment requirements.

Note that in many cases, some areas of tooth structure will protrude beyond the smile design, which will allow the template to easily and fully seat in the patient's mouth, without altering any tooth structure. In this case, these areas were present on the combined output model on the facial incisal of #8 and #9 **(Figs 20 & 21)**. A final 3D digital design model is also printed and polished for presentation to the patient, as well as for use in chairside fabrication of provisional restorations **(Fig 22)**.

Motivational Test Smile

To create the "motivational test smile" try-in, a silicone template is first fabricated over the combined output model and formed in a pressure pot for increased accuracy **(Fig 23)**. The template is trimmed to just above the zenith on each anterior tooth, and the dental midline is marked for easy orientation in the mouth.

In this case, the motivational test smile mock-up was fabricated, then trimmed and the bite adjusted **(Fig 24)**. The test smile mock-up was then tried in to verify phonetics and function. The patient's overall reaction was positive, leading to approval to proceed with definitive veneer restorations **(Figs 25-27)**.

Although the mock-up demonstrated an improvement to buccal and incisal edge contours **(Fig 28)**, the possibility of potentially accentuating a deficient buccal corridor was noted. Therefore, feedback to the laboratory included directions to ensure the thinnest possible restorations on the canines (i.e., #6 and #11) to prevent such a deficiency.

Figure 19: Preoperative digitally printed model.

Figure 20: Combined output model of the new smile design contours and original tooth forms.

Figure 21: Areas marked in red on the combined output model indicating original tooth contours protruding beyond the planned design contours.

Figure 22: Final digitally designed and printed model, polished for presentation to the patient and provisional template fabrication.
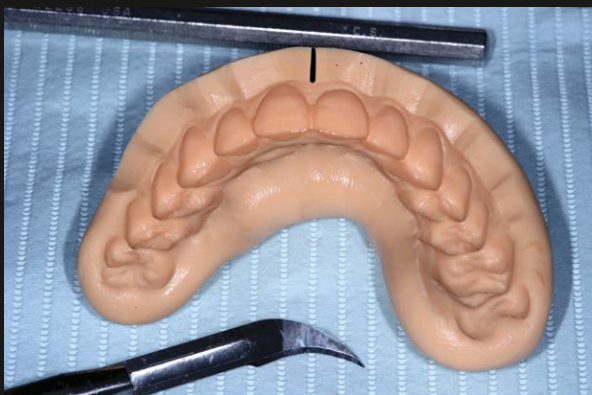

Figure 23: Silicone template fabricated over combined output model and formed in a pressure pot for increased accuracy.

Figure 24: Removal of silicone template from the mouth, revealing the resulting "motivational test smile" mock-up prior to trimming and polishing.

Figure 25: Full-facial comparison of the preoperative smile and the motivational mock-up in the mouth after trimming and bite adjustment.

Figure 26: Close-up preoperative and mock-up smile view comparison.

Figure 27: Retracted preoperative and mock-up comparison.

Figure 28: A 12 o'clock view showing the mock-up in relation to wet lip line and improved buccal and incisal edge contours.

Reduction Guide

Reduction guides based on the 3D printed full-contour smile design model are useful in ensuring that sufficient reduction and clearance are achieved in realizing a patient's requested tooth shade change. Increasing to a brighter shade from a very dark shade requires more space, so clinicians should confirm with the ceramist that the proper amount of space is available for the material being used.

Minimal Preparation

In this case, the shade change was subtle, resulting in almost no preparation except for a slight reduction on the distal facial aspect of #8 and #9, as noted on the combined output model and transparencies **(Fig 29)**. When placed intraorally, the reduction guide demonstrated the proper clearance required for the lithium disilicate veneers **(Fig 30)**.

Aside from slight preparations on #8 and #9, all other areas of enamel were lightly textured using a medium diamond bur. The incisal edges were rounded and smoothed in a facial-to-lingual direction to accommodate a porcelain "wrap" of the incisal edge. Note that all digital outputs should verify the same information and serve as redundant tools during the clinical process. Gingival contouring on #7 and #10 **(Fig 31)** was accomplished with a diode laser.

Once the preparations were complete, a moist dentin shade was taken and photographed for the laboratory, since dry dentin always appears lighter than moist dentin **(Fig 32)**.

In this case, immediate "shrink-to-fit" direct provisionals were then created, the margins trimmed and surfaces polished, and the occlusion verified **(Fig 33)**. The provisionals were spot-bonded and splinted together for ease of fabrication and greater strength.
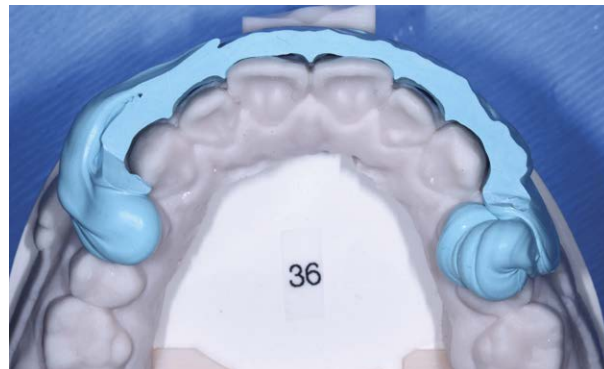
Delivering the Digitally Designed Smile ▶

Based on the 3D digital smile design and all feedback provided, the lithium disilicate veneers for this case were digitally manufactured (i.e., milled) to achieve the desired contour and anatomical detail **(Figs 34 & 35)**. As with most all-ceramic restorations, the laboratory acid-etched the intaglio surface of the restorations prior to delivery.

As in this case, the definitive restorations can be verified on a carbon-printed model, which provides an extremely accurate way to confirm margins, maintain tissue contours, and avoid black triangle issues **(Figs 36 & 37)**. A trough is printed just below the margin to allow for complete seating of the restoration.

Figure 29: Reduction guide made from the full design model seated over the preoperative model to verify areas requiring reduction.

Figure 30: The same reduction guide intraorally showing proper clearance required for ceramic restorations.

"The advantages of applying digital technology to esthetic treatments extend beyond mere planning, communication, and fabrication."

Figure 31: Completed conservative preparations and tissue contouring. Note "all-in-enamel" surfaces for all treated teeth.

Figure 32: A moist dentin shade was taken for proper shade building.

Figure 33: Immediate post-placement view of the "shrink-to-fit" direct provisional restorations.

►►►*Tips*

Beginner

- When taking photographs, ensure the patient is standing up straight.
- Keep in mind that a solid and non-distracting background achieves ideal contrast between the patient and the background.
- Remember the camera should be directly in front of the patient.

Intermediate

- When taking smile images, focus on the central incisors, but be sure the corners of the mouth are also included to capture the full smile.
- When taking smile photographs, avoid including the nose and chin in the shot.
- Use the photography time to engage patients in a discussion about what they like and don't like about their smile.

Advanced

- The vividness of the teeth is best captured when the camera's white balance is calibrated.
- To calibrate a camera's white balance, first take a photograph of a gray card, then calibrate the white balance to the gray color.

Final Procedures

At the delivery appointment, standard-of-care procedures were followed for anesthesia, removing the provisionals, establishing isolation, and cleaning the preparations.[8] Meticulous adhesive protocols were also undertaken (i.e., total-etch fourth-generation adhesive bonding system, light-cure adhesive cement) for definitive seating of the veneers.

After delivery of the final restorations, the patient's new smile demonstrated balance and harmony with his natural teeth **(Fig 38)**. The buccal corridor did not appear deficient, which is common in six-unit anterior cases. Instead, the thinness of the veneers on the canines, combined with their proper axial inclination, achieved an ideal esthetic effect. Tissue response was excellent **(Fig 39)**.[9] Overall, the combination of proper line angles, primary and secondary anatomy, and ideal gingival chroma and incisal translucency contributed to a very natural-looking result that pleased the patient **(Fig 40)**.

Figures 34 & 35: Facial and intaglio surface views of the lithium disilicate veneers showing margin, contour, and anatomy details. The four anterior restorations were layered for increased depth and incisal effects.

Figure 36: The definitive full-contour lithium disilicate veneers seated on a carbon-printed model.

Figure 37: Incisal view of the restorations on the model, highlighting proper line angles and facial anatomy achieved via digital milling.

Figure 38: After light-curing, the definitive restorations achieve balance and harmony with—and are difficult to distinguish from—the adjacent natural dentition.

Figure 39: At one-week postoperative, excellent tissue response is demonstrated.

Figure 40: Close-up post-treatment view showcasing proper line angles and excellent primary and secondary anatomy.

Summary ▶ ▶ ▶

The advantages of applying digital technology to esthetic treatments extend beyond mere planning, communication, and fabrication. They also enable clinicians and laboratory ceramists to transform 2D smile concepts into virtual and ultimately tangible 3D smile designs. Capable of illustrating and verifying patient desires, clinical requirements, and necessary modifications before the virtual becomes reality (e.g., tooth reduction, restoration fabrication), the combination of digital photography and 3D smile design software also reduces the likelihood of remakes while simultaneously making the process more efficient and productive for all involved.[10]

Despite the straightforward nature of the case described in this article, the beautiful results achieved could be accomplished only through detailed visual planning and engaged communication among the patient, clinician, and ceramist **(Figs 41-43)**. Utilizing 2D images, 3D design, and digitally printed and milled components throughout the planning and treatment process enhanced collaboration and treatment accuracy, in addition to ensuring the predictability of the final esthetic outcome **(Fig 44)**.

Figures 41-43 (above): Side-by-side pre- and postoperative views provide excellent documentation for clinical record-keeping and highlight case accomplishments.

Figure 44 (left): Close-up left lateral view highlighting the micro anatomy of the surfaces achieved in these digitally milled restorations.

Acknowledgement

Dr. Weston is an AACD Accredited Fellow. He practices at Scripps Center for Dental Care, a multispecialty group in La Jolla, California.

Disclosure: The author did not report any disclosures.

References

1. Belser UC, Magne P, Magne M. Ceramic laminate veneers: continuous evolution of indications. J Esthet Dent. 1997;9(4):197-207.

2. Da Cunha LF, Reis R, Santana L, Romanini JC, Carvalho RM, Furuse AY. Ceramic veneers with minimum preparation. Eur J Dent. 2013 Oct;7(4):492-6.

3. McLaren EA, Tran Coa P. Smile analysis and esthetic design: "in the zone." Inside Dent. Jul/Aug 2009;5(7):44-8.

4. McLaren EA, Rifkin R. Macroesthetics: facial and dentofacial analysis. J Calif Dent Assoc. 2002 Nov;30(11):839-46.

5. Zandinejad A, Lin WS, Atarodi M, Abdel-Azim T, Metz MJ, Morton D. Digital workflow for virtually designing and milling ceramic lithium disilicate veneers: a clinical report. Oper Dent. 2015 May-Jun;40(3):241-6.

6. McLaren EA, Culp L. Smile analysis: the Photoshop® smile design technique: part I. J Cosmetic Dent. 2013 Spring;29(1):94-108.

7. Magne P, Gallucci GO, Belser UC. Anatomic crown width/length ratios of unworn and worn maxillary teeth in white subjects. J Prosthet Dent. 2003 May;89(5):453-61.

8. Calamia JR. Clinical evaluation of etched porcelain veneers. Am J Dent. 1989 Feb;2(1):9-15.

9. Rigolin Ferreira FJ, de Vasconcellos AA, Miranda ME, Santini E, Bocabella L. Conservative restorations combined with gingival zenith contour technique. Quintessence Int. 2014 Nov-Dec;45(10):813-8.

10. Meereis CT, de Souza GB, Albino LG, Ogliari FA, Lima GS. Digital smile design for computer-assisted esthetic rehabilitation: two-year follow-up. Oper Dent. 2016 Jan-Feb;41(1):E13-22. **jCD**