SMILE ANALYSIS
— Converting digital designs into the final smile, Part 2

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Introduction

The fabrication of restorations has entered a new technological age, moving from 2-D to 3-D. Restoration design—whether it is a framework, full-mouth rehabilitation or all-ceramic—now can be completed on computer. This article, the second in a two-part series (the first part of which appeared in the first issue of the Clinical Masters™ magazine), addresses tooth anatomy, morphology and the various laboratory applications for digital design.

Teeth are very difficult to recreate. The way anterior and posterior teeth have been analyzed and characterized for the last 50 years has not been effective, as some of those methods have correlated the shape and morphology of the teeth to the shape and proportion of the head. However, individuals with a square head do not necessarily have square teeth; rounder-faced individuals do not necessarily have round teeth, etc. There are no sex-specific or ethnic differences between teeth.2

The American Academy of Cosmetic Dentistry has published guidelines4 on the artistic parameters of smile design, with the goal of esthetically replicating nature. Observation is fundamental to this endeavor, as is a true understanding of patient expectations.

In a very pleasing smile arrangement, the maxillary central incisors tilt in, the laterals tilt in slightly more, and the canines tilt in. In the mandibular arch, the anterior teeth tilt out slightly, while the canines tilt in (Fig. 1). There are three planes of a tooth and three shapes of the labial surfaces of the tooth: convex, flat and concave. There are different tooth shapes: round on the mesial, round on the distal, square on the mesial, square on the distal, and square on the mesial and distal.4 While the trend may be to create symmetrical inclinations between the teeth, tooth inclinations do not have to match to achieve natural esthetics. Tooth shape and proportion are controlled by root shape, root rotation, bone, and tissue preparation. The midline’s facial harmony significantly affects tooth esthetics. When the midline matches (e.g., height of contour to the mesial aspect, discrepancies regarding other esthetic aspects become insignificant. When two teeth are identical in length, angulation, midline, mesiodistal contour, and gingival sculpting, the irregularities of the surrounding teeth do not detract from the overall esthetics (Fig. 2). However, with some patients, a closer examination of the surrounding teeth shows one is more square and the contralateral is rounder; one tooth is tilted in and the other is not tilted (Fig. 2).5–7

Tooth anatomy

All tooth anatomy is imparted in the front of the tooth, but what constitutes the front of the tooth has to be clearly identified and defined. This is predicated on understanding where the contacts and embrasures should be positioned relative to proper tooth anatomy. Embrasures must be properly angled, as well as opened mesially or distally, depending upon the anatomical buildup that is required. Once
that has been identified, primary anatomy can be established, followed by secondary anatomy. It is important to note that characteristics of secondary anatomy, such as texture and luster, can change the perception of the tooth shape and value. Restorations that are smooth appear translucent and lower in value. Rougher restorations, because of the manner in which light reflects off the front, appear more brilliant but less translucent, despite possessing the same translucency. The various kinds of textures—broad, horizontal striations; narrow, horizontal striations; vertical striations; and a dimpled texture over the front of the tooth—create various visual characteristics.

**Digital dentistry**

Although basic dentistry has not changed a great deal in the past 20 years, innovative materials and equipment are continually enhancing the dental field. Owing to its state-of-the-art applications, allowing creation of strong and esthetic ceramic restorations in a single appointment utilizing computer software, CAD/CAM technology has become synonymous with digital dentistry. CAD/CAM is an innovative tool for creating a restoration designed on computer. Digital dentistry, however, encompasses communication, high- and low-resolution data, 3-D photography, and computer programs that provide dentists with the ability to create digital restorations and virtual patients through the collection of data and the utilization of various software programs. The compilation of conventional data for planning and treating patients, including demographic data, clinical measurements, observation, clinical analysis, thermal data, and color data, has been expanded to include digital data, intra-oral photographs, scan data, cone beam computed tomography data, and digital radiographs for digital planning and restorative treatment.

Conventionally, a digital restoration was a zirconia coping built up with modifiers, dentins, and enamels, sculpted by hand, ground down where necessary, baked, then stained and glazed. Today, a dentinal structure can be milled from a lithium disilicate block and enamel added, or from a block of ceramic prelayered with gingival dentin and incisal materials and milled using CAD/CAM technology, with no discernible differences evident among the three restorations (Fig. 3). The only difference is time. The first is labor-intensive, the second less so and, as expected, the machine-milled restoration is the quickest and easiest of all to produce.

**CAD/CAM**

The attainment of perfection in the duplication of natural dentition is the ultimate goal of contemporary esthetic dentistry. Understanding the complex relationship between tooth form and function, and how these relate and combine to create the esthetics of natural dentition is the basis of study for achieving predictable success in oral reconstruction. As patients become more educated about the advances of modern dentistry (as a result of television makeover shows and professional and over-the-counter whitening systems), their motivation and desire for natural-looking, esthetic restorative dentistry is increasing at a dramatic rate. Dentists and technicians are now fulfilling these patient demands, but still use dental laboratories.
and restorative techniques that do not always offer predictable efficiency and quality.

Based upon technology adopted from the aerospace, the automotive and even the watch-making industries, CAD/CAM is becoming widely accepted owing to its increased speed, accuracy and efficiency. Today’s CAD/CAM systems are being used to design and manufacture metal, alumina and zirconia frameworks, as well as all-ceramic full-contour crowns, inlays and veneers that are stronger, fit better and are more esthetic than restorations fabricated using traditional methods. As dentistry evolves in the digital world, the successful incorporation of computerization and new acquisition and manufacturing technologies will continue to provide more efficient methods of restoration fabrication and communication, while retaining the individual creativity and artistry of the skilled dentist and technician. The utilization of these new technologies—along with the evolution from hand design to digital design, with the addition of the latest developments in intra-oral laser scanning, materials, and computer milling and printing technology—will only enhance the close cooperation and working relationship of the dentist–laboratory team.

More than 20 different CAD/CAM systems have been released as solutions for restorative dentistry. The introduction of digital laboratory laser-scanning technology, along with its accompanying software, has allowed the dental laboratory to create a digital dental environment to present an accurate 3-D virtual model that automatically takes into consideration the occlusal effect of the opposing and adjacent dentition. With the model, the laboratory has the ability to design 32 individual full-contour anatomically correct teeth at the same time. These systems essentially take a complex occlusal scheme and its parameters, condense the information and display it in an intuitive format that allows dental professionals with basic knowledge of dental anatomy and occlusion to make modifications to the design, and then send it to the automated milling or printing unit. For the dental laboratory profession, the introduction of digital technology has effectively automated—and even eliminated—some of the more mechanical and labor-intensive procedures (waxing, investing, burnout, casting and/or pressing) involved in the conventional fabrication of a dental restoration, giving the dentist and technician the ability to create functional dental restorations with a consistent, precise method.

**Digital case**

The patient presented with a desire to have his anterior teeth restored and to have a more esthetic shape and color, while retaining the natural color nuances of his posterior teeth (Fig. 4). A comprehensive examination was performed to evaluate the patient’s periodontal and occlusal or functional needs, as well as his overall oral health. Despite extreme tooth discoloration, the basic tooth structure was found to be satisfactory for restoration. After esthetic and functional evaluation, it was deemed necessary to use full-coverage preparations and restorations to restore both esthetics and anterior guidance and function. As with any restorative process that will change tooth shape, position and function, a diagnostic workup (wax-up) was completed. After the patient, dentist and technician had all agreed to the proposed changes, the clinical preparations were completed, and a copy of the wax-up was created for the temporary PMMA restorations for the intra-oral evaluation. Once the provisional restorations had been approved, it became the technician’s responsibility to copy the temporary restorations in fabricating the final IPS e.max lithium disilicate (Ivoclar Vivadent) restorations (Figs. 5–23).
Fig. 5 Digital design for the diagnostic wax-up.

Fig. 6 Milled diagnostic wax-up.

Fig. 7 Completed digital diagnostic wax-up.

Fig. 8 Maxillary full-coverage crown preparations.

Fig. 9 Mandibular full-coverage crown preparations.

Fig. 10 Digital design for laboratory-milled PMMA provisional restorations.

Fig. 11 Milled PMMA provisional restorations, with light-cured stains and glaze applied.

Fig. 12 Intra-oral view of seated provisional restorations.

Fig. 13 Digital design for final milled maxillary all-ceramic IPS e.max CAD restorations.

Fig. 14 Digital design for final milled mandibular all-ceramic IPS e.max CAD restorations.

Fig. 15 Digital articulator with restorations, to check functional movements.

Fig. 16 Milled maxillary blue-stage IPS e.max CAD restorations.

Fig. 17 Milled mandibular blue-stage IPS e.max CAD restorations.

Fig. 18 IPS e.max CAD restorations after the crystallization process.

Fig. 19 Stain and glaze of IPS e.max CAD restorations.
Conclusion

This article has provided an overview of the possibilities of digital smile design, using computer design software, for the design of the milled diagnostic wax-up, the milled provisional restorations, and the final milled ceramic restorations.

CAD/CAM technology should not be regarded as mere machinery to fabricate full-contour ceramic restorations or frameworks; digital dentistry represents a new way to diagnose, plan treatment, and create functional, esthetic restorations for patients in a more productive and efficient manner. CAD/CAM dentistry will only further enhance the dentist–assistant–technician relationship as we move together into this new era of patient care.

Automation has been slow in coming to dentistry and although new equipment has been introduced to make our work easier, we still create complex dental prostheses using old techniques. Even though the lost-wax technique is still a tried-and-true method of fabrication, there will come a day in the near future when all frameworks and full anatomical crowns will be designed on computer. Only then will we truly realize the wonder and power of dental CAD/CAM technology that was introduced so long ago.

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Competing interests

Mr. Culp receives an honorarium from Ivoclar Vivadent. Prof. McLaren and Dr. Swann declare that they have no competing interests regarding this article.

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Fig. 20
Post-op image of cemented maxillary all-ceramic restorations.

Fig. 21
Post-op image of cemented mandibular all-ceramic restorations.

Figs. 22 & 23
Final view of digitally designed and milled IPS e.max CAD anterior restorations, showing excellent fit, form and natural-looking esthetics.

Editorial note: A list of references is available from the publisher.

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