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Predictable Restorative Work Flow for Computer-Aided Design/ Computer-Aided Manufacture–Fabricated Ceramic Veneers Utilizing a Virtual Smile Design Principle

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Clinical Relevance

This clinical report demonstrates the use of a digital restorative work flow to achieve predictable esthetic clinical outcomes using computer-aided design/computer-aided manufacture–fabricated lithium disilicate ceramic veneers.

SUMMARY

The purpose of this case report was to present the use of a contemporary digital photograph–assisted virtual smile design principle, an intraoral digital impression, and computer-aided design/computer-aided manufacture–fabricated lithium disilicate ceramic veneers to treat a patient with esthetic needs in the maxillary anterior region. By using the proposed digital restorative work flow, this case report demonstrated an effective communication pathway between the patient, clinician, and dental laboratory technician. Effective communication can help to achieve a more predictable and satisfactory esthetic outcome.

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INTRODUCTION

Digital dentistry provides dental clinicians and technicians with a new perspective in their daily practice. However, the work flow involved in digital dentistry is significantly different when compared to the conventional treatment protocol in terms of prosthetic design and fabrication. Digital photograph–assisted virtual smile design (digital treatment planning/presentation process),[1-3] digital impression (digital data acquisition),[3,4] and computer-aided design/computer-aided manufacture (CAD/CAM) restorations[5-7] are all gaining popularity in modern clinical dentistry.

The original intent of standardized film-based clinical photographs was to provide the practitioner with a documentation tool to compare photographic records before and after treatment.[8] Modern digital photography eliminates the delay between image capturing and the development process of previous film-based photography.[9] Additionally, it has been proposed as an effective tool for diagnosis, treatment planning, and communication.[9-11] Presentation and computer design software can be used to evaluate a patient's esthetic needs and utilized to create a virtually designed esthetic treatment plan.[2,3] The smile analysis principles[12-14] are applied in the evaluation process, and the proposed virtually designed esthetic plan can be presented to the patient for immediate feedback and approval.[2,3] The approved virtually designed esthetic plan can serve as an effective communication tool between the patient, clinician, and dental technician throughout the course of treatment. Ideal communication of the entire restorative team can allow for a more predictable clinical outcome.[2,3,11]

The basic work flow for digital impression and CAD/CAM restoration includes the following: 1) capture the intraoral teeth geometry with a scanning device, 2) creation of a virtual definitive cast from captured data and/or optional physical definitive cast for subsequent computer-aided restorations design, and 3) computer-aided restoration manufactured chairside, in a dental laboratory, or at a centralized production center.[15-17] Machineable lithium disilicate ceramic block (IPS e.max CAD, Ivoclar Vivadent, Amherst, NY) became commercially available in 2006 with a partially crystallized blue-violet color. The partially crystallized state allows the block to be milled easier and more rapidly during the CAD/CAM process without excessive diamond bur wear or damage to the ceramic crystal.[18] Although lithium disilicate ceramic was initially available only as a substructure material, it had been suggested for fabrication of full-contour monolithic restorations and/or ceramic veneers. Extrinsic staining and glazing characterization is ideal because of its translucent properties, resin luting characteristics, and shade variabilty.[19-21] This report describes the work flow of a virtually designed esthetic plan, a digital impression, and CAD/CAM-fabricated lithium disilicate veneers to achieve a more predictable clinical esthetic outcome.

TECHNIQUE DESCRIPTION

A 45-year-old Caucasian female presented to the dental clinic (Dental Associates, School of Dentistry, University of Louisville, Louisville, KY) with concerns of her smile, including existing composite resin restorations on her maxillary anterior teeth. The patient reported that her maxillary anterior teeth had been restored with direct composite resin multiple times throughout the years. The patient consented to a comprehensive treatment plan to include lithium disilicate ceramic veneers for her maxillary anterior teeth (canine to canine) for a better esthetic outcome. A periodontal soft tissue recontouring surgery was proposed to the patient for the improvement of the soft tissue architecture; however, the patient declined the surgical proposal after full disclosure of the proposed esthetic benefits.

Diagnostic casts were made with irreversible hydrocolloid impression material (Jeltrate Alginate, Dentsply Caulk, Milford, DE) and poured with type III dental stone (Buff Stone, Whip Mix, Louisville, KY). A face-bow transfer and maxillomandibular relationship were obtained and used to articulate the diagnostic casts in a semiadjustable articulator (Hanau Modular Articulator System, Whip Mix). The length and width of the right maxillary central incisor were measured on the diagnostic cast. The measurements were recorded as 10.5 mm and 8 mm, respectively. The desired midline and incisal edge positions for central incisors were determined during the intraoral examination. After a thorough examination, the desired midline was determined to be shifted to the left by 0.5 mm, and the length of central incisors was determined to be increased by 1 mm. Digital photographs were taken showing the patient's frontal smile view (Figure 1A) and retracted intraoral view. The retracted intraoral digital photograph was taken with contraster (PhotoMed International, Van Nuys, CA) showing the maxillary anterior teeth (Figure 1B). The clinical digital photograph with intraoral frontal view was then imported into the presentation software (Keynote iWork, Apple, Cupertino, CA). A ruler was digitalized as an image file in JPEG format with a scanner (All-in-One Printer, Hewlett-Packard, Palo Alto, CA). The digital ruler file was then imported into the presentation software (Keynote iWork) on the same slide as the clinical digital photograph. The digital ruler was then resized, while maintaining the height-to-width ratio, until it matched the measurements obtained from the diagnostic cast. The calibrated digital ruler was then copied and positioned at the bottom and left side of the slide (Figure

Figure 1. *Pretreatment condition. (A): Smile, frontal view. (B): Intraoral facial view.*

2). The calibrated digital ruler served as an accurate representation of actual teeth dimensions and was used to transfer the virtually designed esthetic plan to the diagnostic casts during the wax-up procedure. The desired midline and incisal edge positions for central incisors were also transferred and marked in the presentation software (Keynote iWork; Figure 2).

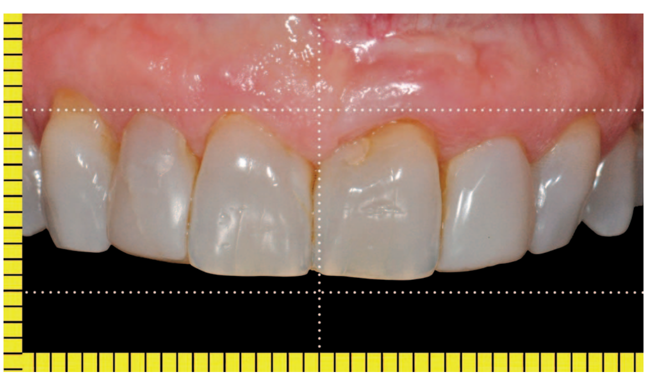

Figure 2. *The screen shot demonstrated the calibrated digital ruler (mm) placed at the bottom and the left-hand side of the screen. The apical horizontal dotted line represented the soft tissue zenith at the right maxillary central incisor. The incisal horizontal dotted line represented the desired positions of maxillary central incisors as determined during the clinical examination. The vertical dotted line represented the desired midline as determined during the clinical examination.*

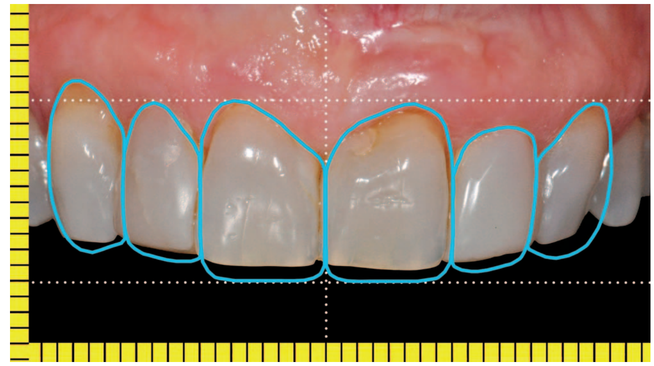

Figure 3. *The customized virtually designed esthetic plan was created in the presentation software.*

The "Draw With Pen" tool under the "Shapes" menu toolbar in the presentation software (Keynote iWork) allows users to create custom-shaped objects. This tool was used in this clinical report to draw the desired tooth-shaped objects on the slide. Each tooth-shaped object was drawn and adjusted on the corresponding tooth to mimic the desired definitive restoration outline. The digital photograph–assisted virtually designed esthetic plan was completed with all tooth-shaped objects representing the desired posttreatment tooth contours and alignment (Figure 3). During the development of the esthetic plan, the desired incisal edge positions, midline position, and tooth proportions should be carefully considered. This proposal of a virtually designed esthetic plan was demonstrated to the patient and was modified according to direct feedback from the patient. The "Graphic Inspector" tool under the "Inspector" menu toolbar in the presentation software (Keynote iWork) allowed users to change the color, opacity, and style of the drawing line for the shape objects. The color, opacity, and drawing line of the superimposed tooth-shaped objects in digital photograph–assisted virtually designed esthetic plans can be altered using the "Graphic Inspector" tool to provide patients with different visual perceptions. Additionally, a virtually designed esthetic plan can facilitate communication between clinician and patient. In this clinical report, white color fills with 50% opacity and transparent drawing lines on all the tooth-shaped objects were used (Figure 4). The approved virtually designed esthetic plan was then used to communicate between the clinician and dental technician a virtual esthetic plan–guided diagnostic wax-up. Maxillary diagnostic wax-up was completed using tooth color wax (Diagnostic Wax, Blue Dolphin, Morgan Hill, GA; Figure 5) and then duplicated to fabricate a vacuum-formed preparation guide.

Figure 4. *The opacity of the drawings of the virtually designed esthetic plan can be increased to give the patient different visual perceptions during the decision-making process.*

Figure 6. *A preparation guide was fitted on the abutment teeth prior to the abutment preparation for additional visual confirmation of the clinical outcome of the virtual esthetic plan.*

For additional confirmation of the clinical outcome of the virtual esthetic plan–guided diagnostic wax-up, the preparation guide can be fitted onto the abutment teeth prior to the abutment preparation (Figure 6). Optional trial insertion (mock-up) can be achieved by using autopolymerizing composite resin material (Integrity, Dentsply Caulk) injected into the preparation guide and inserted into the patient's mouth. Maxillary abutment tooth preparations were completed with the use of the vacuum-formed preparation guide under local anesthesia (Xylocaine Dental, Dentsply Pharmaceutical, York, PA) with a diamond-cutting instrument (Fine Diamonds, Round End Parallel, Brasseler USA, Savannah, GA). The double-cord technique was used for soft tissue management during intraoral scanning procedures (Cadent iTero, Cadent Ltd, San Jose, CA). To facilitate the subsequent intraoral digital impression procedures, both cords were left in the soft tissue to retract the soft tissue away from the abutment tooth finish lines (Figure 7). The scanner software (Cadent iTero) prompted a guided scanning sequence with a series of scans at each abutment, followed by additional scans for recording the opposing dentition, and the interocclusal record registration (Figure 8). The interim veneers were fabricated with autopolymerizing composite resin material (Integrity A1, Dentsply Caulk) using the acrylic preparation guide. The interim veneers were luted with interim cement (TempBond Clear, Kerr Corp, Orange, CA).

The completed scan data were then transmitted to the manufacturing company (Cadent iTero), undergoing a modeling process. Milled polyurethane definitive casts were fabricated and articulated on a specifically designed hinge articulator (iTero Articulator, Cadent; Figure 9). The milled polyurethane definitive casts and diagnostic wax-up were digitalized with a laboratory-based scanner (Straumann CARES, CS2 scanner, Institut Straumann AG, Basel, Switzerland), and all the scanned data were then imported into the CAD/CAM software (Straumann CARES). The scanned diagnostic wax-up was used as a design template for the definitive veneer restorations (Figure 10). The digital ruler in the CAD/CAM software was used to confirm the dimensions of the designed CAD/CAM restorations

Figure 5. *Completed virtual esthetic plan–guided diagnostic wax-up.*

Figure 7. *Completed maxillary abutment tooth preparations. Both cords were left in the periodontal sulcus to complete the soft tissue management for the intraoral scanning procedures.*

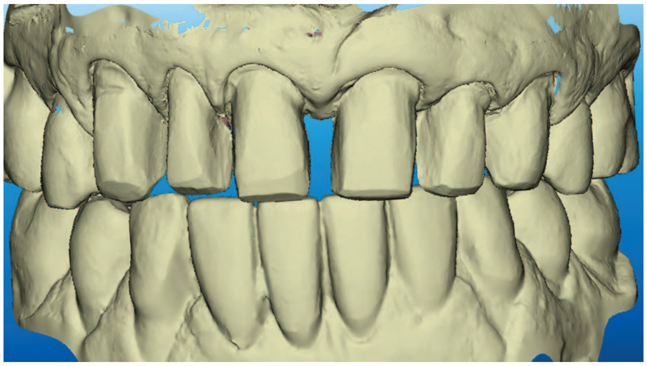

Figure 8. *Completed maxillary definitive impression, mandibular impression for the opposing dentition, and the interocclusal record.*

Figure 10. *The scanned data of diagnostic wax-up (blue color) were used as a design template for the designs of CAD definitive restorations (light gray color).*

to ensure that the definitive restorations shared the same dimensional specifications as the virtual esthetic plan–guided diagnostic wax-up (Figure 11). The approved design was sent to a centralized production center, and anatomic full-contour veneers were milled from machineable lithium disilicate ceramic blocks (IPS e.max CAD, LT, Ivoclar Vivadent). Cutback of the milled veneers was performed, and low-fusing nanofluorapatite glass-ceramic veneering porcelain (IPS e.max Ceram, Ivoclar Vivadent) was used to complete the layering process. Additional characterization and a glazing process for the layered definitive lithium disilicate ceramic veneers was completed with low-fusing nanofluorapatite glass ceramic (IPS e.max Ceram Shades and Essences, Ivoclar Vivadent; Figure 12).

During the insertion appointment, the intaglio surfaces of veneers were etched with 5% hydrofluoric acid gel (IPS Ceramic Etching Ge, Ivoclar Vivadent) for 20 seconds. The etched surfaces were rinsed and dried with oil-free air. Ceramic primer (Monobond Plus, Ivoclar Vivadent) was applied on all treated lithium disilicate surfaces for 60 seconds and then dried with oil-free air. The abutment teeth were etched with 37% phosphoric acid (Scotchbond Etchant; 3M ESPE, St Paul, MN) for 30 seconds and rinsed with water. The teeth were dried with oil-free air, and a single-component bonding agent (Adper Single Bond Plus Adhesive, 3M ESPE) was applied on the etched surface. The CAD/CAM-fabricated, layered lithium disilicate veneers were adhesively luted with dual-polymerizing resin cement (Transparent Variolink II, Ivoclar Vivadent). The excess luting agent was removed, and the patient was given home care instructions (Figure 13A,B).

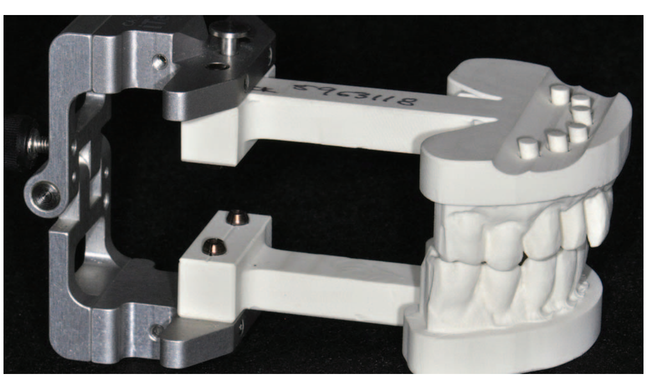

Figure 9. *Milled polyurethane definitive casts articulated on a specifically designed hinge articulator.*

DISCUSSION

The use of feldspathic porcelain veneers was introduced into dentistry in the early 1980s and has steadily increased in popularity for the conservative restoration of unesthetic anterior teeth.[22] When adhesively bonded to enamel, the evidence suggests that the estimated cumulative survival for feldspath-

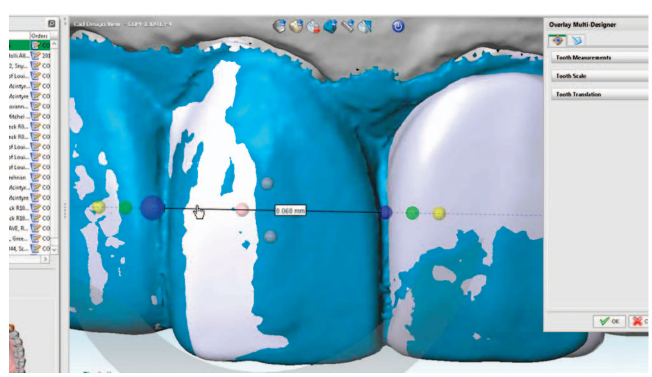

Figure 11. *The digital ruler was used to ensure the dimensions of the designs for the future CAD/CAM-fabricated lithium disilicate ceramic veneers. The three-dimensional measurements on the CAD should have a close resemblance to the virtual esthetic plan–guided diagnostic wax-up.*

Figure 12. *CAD/CAM-fabricated lithium disilicate ceramic veneers after layering and characterization.*

ic porcelain veneers is 95.7% at five years and ranges from 64% to 95% at 10 years across three studies.[23] Other nonfeldspathic ceramics were also used to fabricate veneers; however, the clinical evidence of these veneers is very limited. A systematic review and meta-analysis suggested that the long-term outcome (more than five years) of nonfeldspathic porcelain veneers is only sparsely reported in the literature, and most studies have focused on pressed leucite-reinforced glass ceramic (IPS Empress, Ivoclar Vivadent) with a five-year pooled cumulative estimated survival at 92.4%.[24] Recently, CAD/CAM-fabricated lithium disilicate ceramic veneer has been proposed in various clinical case reports[21,25] and is the choice of treatment in this report.

Although the clinical outcome can be satisfactory, clinicians should utilize this treatment modality with caution. The digital design of definitive restorations was used in the report, where the CAD software was chosen over the conventional wax-up procedure produced by a dental technician. Dental laboratory technicians will require additional training and production experience in digital restorative dentistry to provide consistent definitive restorations. There are also some limitations facing the clinician with this digital work flow as well. The success in utilizing this new treatment protocol depends on the clinician's capacity to operate and maintain the presentation software and intraoral scanning machinery.

SUMMARY

In this case report, the clinician used presentation software (Keynote iWork) to design a virtual esthetic plan during the treatment planning and presentation process. A digital photograph–assisted virtual esthetic plan can serve as an effective communication tool. The patient can provide direct feedback, and the virtual esthetic treatment plan can be immediately modified to satisfy the patient's esthetic expectations. The approved virtual esthetic plan can be transferred to a calibrated dental laboratory along with the diagnostic casts. The esthetic plan then becomes a tool to relay the patient's personal preferences to the dental laboratory technician while performing the diagnostic wax-up. The resulting diagnostic wax-up can then be scanned with the laboratory-based scanner and serve as a design template for the definitive restorations. This helps ensure that the CAD/CAM-fabricated definitive restorations will follow the initial esthetic plan to achieve a predictable clinical result.

Figure 13. *Posttreatment condition. (A): Smile, frontal view. (B): Intraoral facial view.*

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Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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