Digital smile design combined with computer-guided implant surgery for immediate implant placement—Full-arch immediate loading in a partially edentulous patient

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Abstract
The digital smile design (DSD) concept is an innovative protocol through which clinicians are able to optimise communication with patients and laboratory technicians by using digital photography, virtual analysis and design. In the following article, we present a clinical case in which DSD was utilised in combination with guided implant surgery software. The digital simulation performed using DSD aided the fabrication of an aesthetic wax-up and a personalised radiographic template. The information obtained from CBCT scans of the patient and the template was imported into the implant surgery software for the planning of flapless guided immediate implant placement with full-arch immediate loading.

Introduction
Digital photography and video recording were primarily introduced to the dental field for legal documentation of treatment. Later, the incorporation of these resources into clinical practice provided the opportunity to precisely evaluate static and dynamic information that could contribute to diagnosis, prognosis and treatment planning.
Today, the valuable information obtained by these methods can be digitised via computer software to aid patient case analysis and communication between all parties involved in a patient’s treatment.2

In 2007, DSD was introduced to the dental field. DSD is an innovative protocol through which clinicians are able to manipulate patient’s digital photographs and simulate future complex treatment outcomes by virtual analysis. The calibration and superimposition of intra- and extra-oral photographs and the application of fundamental aesthetic and functional occlusal concepts allows the creation of a customised virtual restorative design and allows this information to be shared with laboratory technicians and patients for their feedback.3,4 The concept was developed to assist the dentist in three major aspects: (a) planning and designing an aesthetic smile; (b) communication between all participants involved in the clinical case; and (c) communication with the patient, increasing his or her participation and motivating and educating him or her about the benefits of the treatment.5,6 This design concept is applicable to the restorative field and has been shown to be useful in surgical planning.6 In suitable clinical scenarios, DSD can be utilised to determine the ideal teeth position to obtain the best aesthetic and functional result.

It is well known that visualisation of the surgical field with flap elevation may reduce the risk of occurrence of bone fenestration and dehiscence during implant placement. However, flap elevation is always associated with some degree of morbidity and discomfort, and requires suturing to close the surgical wound.7 The use of non-invasive surgical techniques like flapless implant placement may provide several clinical advantages, while maintaining similar survival rates to conventional implant placement procedures.8

The concept of computer-guided implant surgery was developed to overcome the limitations associated with conventional surgical templates9,10 and to improve the accuracy of surgical implant placement with a flapless approach.11,12 More importantly, the computer-generated surgical guide provides a link between the virtual prosthetically driven treatment plan and the actual surgery by transferring the simulated intervention accurately to the surgical site.13

In this article, we present a clinical case in which DSD was utilised to guide treatment and combined with guided implant surgical software to achieve the proposed digital restorative simulation. The digital restorative simulation was used in fabricating Figs. 3a–c, Lateral view of the right interocclusal relation (a), Frontal view of the interocclusal relation (b), Lateral view of the left interocclusal relation (c).

Fig. 4a & b, Lateral extra-oral photographs of the anterior region. Left side (a). Right side (b).

Fig. 5, Articulated models.

Fig. 6, Intra-oral frontal view over a black background.

Fig. 7, DSD: the central tooth proportion utilised was 84 per cent. Note the measurements performed with the calibrated rulers.
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Fig. 8. Final crown design after the DSD analysis. Proposed implant positions over the digital restorative simulation.

Fig. 9. DSD: extra-oral digital simulation of the future rehabilitation (colour scale).

Diagnosis and planning

A 39-year-old female patient presented to our clinic with the request for full-mouth rehabilitation. She was most unsatisfied with her oral health and anaesthetic smile, and was very apprehensive of dental treatment owing previous negative experiences in this regard. Comprehensive clinical examination found partial edentulism and a failing dentition as a result of moderate periodontal disease and severe caries probably induced by mild enamel hypocalcification that could be observed in the remaining dentition. She presented with congenitally missing maxillary lateral incisors (teeth 12 and 22). Teeth 17, 16, 15, 24, 25, 26 and 27 had been extracted several years before owing to severe caries. The remaining maxillary right premolar presented with severe caries with deficient resin restorations. Both canines presented with moderate carious lesions and Grade I mobility. Teeth 11 and 21 presented with extensive recurrent decay.

In the mandible, the periodontal examination provided a diagnosis of gingivitis. Teeth 36 and 46 had been extracted several years before after sustaining a vertical root fracture. Tooth 44 had been extracted three years before owing to a severe

Fig. 10. A wax-up on one of the study models based on the DSD analysis.

Fig. 11. A translucent acrylic template was fabricated for only the palatal region and the edentulous regions of the maxillary model. Acrylic teeth were added in accordance with the DSD plan.

Fig. 12. The radiographic template in position over an articulated model.

Fig. 13. Cone beam examination.
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Caries lesion. The patient presented with severe caries in the remaining teeth. She had no contraindications for dental treatment (Figs. 1–4).

After complete diagnostic evaluation, including clinical, radiographic and photographic analyses, maxillary and mandibular impressions were taken for study model fabrication and triplication (Tropicalgin and Elite Rock Fast, both Zhermack). Using a maxillary wax rim, the vertical dimension of occlusion was determined based on anthropometric and phonetic methods. A facebow was utilised to set and transfer the maxillary 3-D orientation. After the use of an occlusal jig for three days, an interocclusal relation was registered utilising a bite impression material (Zetalabor, Zhermack) and the wax rim, establishing the mandibular centric relation and keeping the vertical dimension of occlusion determined previously. The cast models were positioned in an articulator (Fig. 5). The triplication of the models allowed the modification of two pairs of casts with laboratory procedures, while maintaining the initial information in the remaining pair (Model 2340 Articulator, Whip Mix).

The intra-oral and extra-oral photographs were imported into Keynote (Keynote 5.0, Apple) and a complete DSD analysis was performed following the concept’s protocol (Figs. 6–9). The digital restorative simulation was presented to the laboratory technician with the specific indications for preparation of a wax-up (Fig. 10). The wax-up was fabricated on one of the articulated study models replicating the original DSD information. On the second pair of casts, a translucent acrylic template of 2 mm in thickness was fabricated spanning only the palate and edentulous regions of the maxillary model. Using a silicone index, acrylic teeth were added to the template in the edentulous regions of the maxillary model. A 1 mm round bur was utilised to create perforations and gutta-percha marks were placed in the palatal region. In order to avoid any movement of the radiopaque material, the perforations were sealed with a translucent light-cured resin (Triad, DENTSPLY; Figs. 11 Et 12). The radiographic guide was then checked on the patient for stability and an initial CBCT scan was performed. The template was then removed and a second CBCT scan was performed, but this time only of the radiographic template in accordance with the double-scanning protocol described by Verstreken and Van Steenberghe.15–20

The DICOM files obtained from both CBCT scans were imported into the NobelClinician software (Nobel Biocare). The surgical planning was then performed according to an aesthetically and prosthetically driven approach, following the DSD and the NobelGuide concept and protocol (Nobel Biocare; Figs. 13–15).

At the next appointment, the DSD analysis and the guided surgical plan were presented to the patient. A virtual superimposition of the implants and the digital restorative simulation was done to give the patient a more comprehensible treatment explanation (Fig. 16). After discussion of the therapeutic options, a non-invasive surgical approach was selected based on the patient’s requirements.

In the maxillae, the proposed treatment entailed pre-operative periodontal treatment, extraction of...
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the remaining maxillary teeth and placement of six regular-platform (4.1 mm) implants (Titamax EX Ti, Neodent) in accordance with a guided surgical protocol (NobelGuide). The implants were to be inserted in the edentulous regions, avoiding immediate implant placement in fresh extraction sites. A one-piece acrylic titanium-reinforced immediate-loading prosthesis was proposed as a provisional. The titanium-reinforced structure consisted of several titanium bars welded to a provisional titanium cylinder compatible with the Mini Abutments (Neodent). Finally, a zirconia CAD/CAM structure was planned as the definitive prosthesis. In the mandible, the proposed treatment entailed complete pre-operative periodontal treatment, multiple resin restorations of the remaining mandibular teeth, and placement of three regular-platform implants (Titamax II Plus, Neodent) for three porcelain-fused-to-metal crowns at regions 36, 44 and 46.

After the patient’s acceptance of the proposed treatment, the pre-operative clinical procedures were performed in the following weeks. The guided surgical template was ordered based on the virtual design (Fig. 17) and, after its delivery, a master model with the implant replicas was fabricated (Figs. 18 & 19). Six straight Mini Abutments were placed on the implant replicas and a screw-retained provisional structure was ordered from the laboratory based on the wax-up. Owing to the patient’s personal reasons, the mandibular implant placement was postponed until the completion of all of the maxillary treatment.

Surgical and restorative procedure

After a mouth rinse with chlorhexidine (Oralgene 0.12 %, Laboratorios Maver) for 2 minutes and the disinfection and preparation of the surgical field, local anaesthetic was delivered to the edentulous area and the remaining maxillary teeth by buccal, crestal and palatal infiltrations (2 % lidocaine hydrochloride and 1 : 100,000 epinephrine; Henry Schein). After a few minutes, the atraumatic extractions of the maxillary teeth were done using perirotomes and...
forceps. The radiographic template was positioned in the mouth to verify correspondence between the virtual plan and the actual clinical situation (Fig. 20). Using a bite splint, the surgical guide was secured with three anchor pins. The drilling protocol was performed according to the Brånemark System Mk III guided surgery kit specifications (Nobel Biocare). The six regular-platform Titamax EX Ti implants were placed through the guide’s master cylinders, obtaining more than 50 Ncm torque (Figs. 21 & 22). Six straight regular-platform Mini Abutments (height: 1 mm; Neodent) were placed over the implants and torqued at 35 Ncm.

The provisional acrylic titanium-reinforced prosthesis was then mounted over the Mini Abutments, the screws were hand tightened after occlusion evaluation and the screw’s exit holes covered with Teflon plugs and a temporary light-cured resin (Fermil N, Ivoclar Vivadent; Fig. 23). Follow-up appointments were scheduled for three, ten and 14 days post-operatively (Figs. 24 & 25). Thereafter, the patient was recalled at one, two, three and four months and no adverse findings were made at these appointments. After four months, the conditioned healing of the soft tissue achieved with the provisional provided a favourable situation for the beginning of the definitive restoration process (Figs. 26–28).

_Discussion_

DSD has been met with tremendous acceptance by clinicians worldwide. This can be explained by the simplicity of the process and the ease of transmission of clinical information. As reported by Reddy et al. and Espana et al., the perception of dental aesthetics can vary from dentist to dentist, from dentist to laboratory technician, and from dentist to patient because of their differences in dental education and the subjectivity of what an aesthetic treatment implies. The major advantages of the DSD concept is visual communication. The active involvement of the patient in his or her treatment plan and the feedback that can be provided may improve the treatment result and help to realise the patient’s expectations. Furthermore, several applications are being explored in the restorative surgical field and have thus far shown promising results for a restoratively driven surgical procedure. As has been demonstrated in this case, the personalisation analysis of DSD helps to determine the position of the teeth in the anterior edentulous region. The fabrication of the wax-up and radiographic template were based on the digital evaluation, and this guided the implant virtual planning.

Flapless surgery appears to be a safe treatment modality for implant placement, demonstrating both efficacy and clinical effectiveness, and the guided implant surgery concept has definitely improved the protocol mentioned. It is also well documented that patients treated according to this approach may have faster tissue healing and a better post-operative course.

_Figs. 26a & b_ Frontal view at the four-month follow-up (a). Lateral left view at the four-month follow-up (b).

_Note the maturity and health of the soft tissue, and the natural integration of the provisional._

_Fig. 27_ Radiographic follow-up at four months.

_Fig. 28_ Comparison between the initial clinical situation and four months after the surgical restorative procedure._
As has been reported by various authors, the double-scanning of the radiographic templates allows virtual superimposition of a dental set-up on to the 3-D CBCT reconstruction.\textsuperscript{15-20,27,28} The utilisation of DSD for the creation of an aesthetic wax-up and a personalised radiographic template may improve the prosthetically driven virtual planning, determining the ideal teeth position in the anterior edentulous region. The virtual design can also provide the foundation for the fabrication of the provisional and definitive restorations.

Various authors have described immediate implant functional loading over time. Today, it appears to be an acceptable treatment modality especially recommended in full-arch reconstructions with a one-piece provisional structure.\textsuperscript{29} Some of the variables to consider are high implant insertion torques, and the number and distribution of the implants placed.\textsuperscript{30,31} Furthermore, high survival rates have been reported when immediate loading is combined with guided flapless implant placement.\textsuperscript{32} Thus, immediate loading with fixed prostheses in edentulous patients results in similar implant and prosthesis survival and failure rates to early and conventional loading.\textsuperscript{33} The use of tapered implants with a special compressive design allowed for torque values of greater than 50 Ncm for each fixture. Furthermore, the placement of six implants permitted favourable distribution, allowing the creation of a polygon to absorb occlusal forces.

\textbf{Conclusion}

The use of DSD as a prosthetic and surgical planning tool may help to communicate the proposal treatment to patients and to include their feedback and opinions in the clinical treatment design. The communication of the clinical information to all of the participants may also improve the treatment outcome and optimise the time taken to perform the treatment. The combination of DSD with guided implant surgery technology may offer an aesthetic and functional prosthetic approach to the design of radiographic templates, providing a guide throughout treatment. However, the conventional functional and aesthetic analysis of oral rehabilitation are still mandatory, and should be a requisite to managing this kind of treatment, especially in advanced and complex cases.

The guided implant placement and loading protocol utilised in this clinical situation appears to be a predictable treatment option for the clinical situation presented in this article; however, randomised studies are needed to confirm this. Careful consideration must be given to case selection to achieve a successful outcome._

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