Aesthetic Digital Smile Design: Software-aided aesthetic dentistry—Part I

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Introduction

The concept of aesthetics has been explored by various authors and discussed by eminent philosophers. While their definitions are subjective, they all agree on the natural origin of the term. For this reason, I believe that the real objective of aesthetic dentistry must be imitating nature, which is so simple to perceive yet so difficult to copy, particularly as regards the aesthetics of the lower third of the face. The skill and visual perception of the dental team are essential in pursuing this goal, and the dentist acts as architect and artisan of the oral and periodontal tissue by moulding the physiology of the smile.

Smile designer: A new means of communication

Dental surgery is increasingly being forced to adopt a multidisciplinary approach to treating the face and smile, in which the dentist plays an influential if not primary role. A balance between the teeth, inter-oral and perioral tissue, face, smile and person creates an aesthetic ideal, and synergises the artistic capacities and the expertise necessary to see the design in the context of the face. Today aesthetics is increasingly linked to measure, proportion and symmetry, which were all already present in ancient civilisations but today have been considerably perfected by the digital age. Modern scientific knowledge puts at the disposal of professionals various therapeutic options. This along with collaboration between different specialists (orthodontists, implantologists, periodontologists, dental technicians, maxillofacial surgeons, plastic and cosmetic surgeons) and the above-mentioned goal enable a treatment plan to be
developed with ever-greater precision (Fig. 1). Furthermore, images captured at locations far away and viewed via video conferencing using Skype, for example, give the dentist the role of the conductor of an orchestra and provide him or her with a new way of working together with other professionals.

Digital dentistry requires that one follow precise protocols in order to obtain a standard, predictable result that corresponds to an optimal clinical result (virtual planning) in an ergonomic manner and with a high level of quality. Today, the use of 2-D and 3-D software for photograph editing and digital image editing allows us to process data and customise parameters for each specific clinical and aesthetic requirement of the smile makeover. Modern digital technology along with the experience and aesthetic sensitteness of the dentist, which are fundamental to the success of smile design, offers greater predictability for the patient, as regards both the final aesthetic results and the course of therapy agreed upon.

Figs. 4a–d. Front view and lateral views at 45 and 90 degrees.

Fig. 5a. Face Analogic Transfer Support.

Fig. 5b. Transfer of analogue measurements to digital calliper.
The combination of terms such as "aesthetic dentistry", "interdisciplinary vision", "digital dentistry" and "predictability" led me to consider that today a new professional figure might be created: the smile designer, whose fundamental role would be communicating with the patient and the aesthetics medical team, whose members are crucial in virtual planning.

My ideal would be to have at my disposal a single instrument that would serve the purpose of the smile designer.

Using various software platforms, I have pursued the development of a protocol for Aesthetic Digital Smile Design (ADSD) to be used alongside other important diagnostic elements useful for diagnosis and prognosis, ultimately to improve the health and well-being of the patient. Furthermore, it is advisable to obtain prior consent regarding the aesthetic treatment to be undertaken using real clinical models, such as a mock-up, since this is also a predictable method of simulating the aesthetic treatment plan. It is useful to recall here the forensic dentistry provides that the dentist is obliged to comply with three fundamental principles in carrying out his or her profession: prudence, diligence and technical expertise.

**ADSD method and protocol**

Further to what has been said above, ADSD should first be an instrument to improve communication with the patient by showing the patient detailed images. On the monitor, the before and after photographs allow an index of predictability and point of comparison with the patient himself or herself. A milestone is the innovation of aesthetic clinical planning in aesthetic dentistry and prosthetic dentistry relating to dental technical analysis and planning, which, among other things, can be integrated into diagnosis and planning for plastic and maxillo-facial surgery (Fig. 2).

The protocol first requires the acquisition of full-frame digital images and videos of the patient. Video especially is capable of capturing the dynamic phases of the smile linked to its physiology (mimicry, phonetics, relationship between the teeth and lips). Importing this vital data into the digital clinical file of the patient is complementary to the anamnesis because it is an integral part of the intra- and extra-oral objective examination, and will subsequently be the subject of aesthetic analysis according to the main guiding principles. Therefore, we could define this as the third part of the methodology, which we will call analytical processing, during which the aesthetic composition of the smile, the determining morphological features of the face and smile, including the fundamental points of reference to be...
obtained from software such as face makers, will be mapped and processed.

The next phase in digital data processing is virtual planning by means of digital image editing: wax-up, digital and analogue diagnosis, mock-up, and provisional and definitive restorations. The digital methodology used for photograph and image editing is very reliable, especially in communicating through images the ongoing clinical case to dental laboratories concerning functional and morphological adjustments, which is made even easier if accompanied by explanations and verbal comments. Compatibility with other digital systems is very important, for example being able to implement ADSD in digital orthodontic simulations, digitalisation of casts, CAD/CAM, etc., thus adding to the methodology.

**Acquisition and import of digital images**

As stated earlier, the first phase of ADSD entails the acquisition and import of photographs of the patient. If possible, these photographs should be taken with a digital SLR camera with semi-professional features and with a good illumination system (nowadays there are a number of basic dental photography courses and books available dealing with this fascinating subject). We must remember that in the analytical phase the photograph is a clinical and aesthetic diagnostic element that will form part of the patient’s clinical history, which can be consulted by other specialists to establish an interdisciplinary vision. In view of this, the dentist/photographer must capture the photographs with the patient's head in a position that can be replicated in the future to verify topography in relation to smile design. The
most reliable position in which to photograph the patient’s face is that relative to the aesthetic plan (Fig. 3), that is the plane perpendicular (frontal) to the plane that runs at the centre of the angle formed between the Frankfort horizontal plane and Camper’s plane. The same position must be projected orthogonally at 45 and 90 degrees (Figs. 4a–d) because photographs of the profile are of great importance in the aesthetic dental and facial analysis of the profile in relation to occlusal class, the relationship between the lips, and aesthetic angles, according to studies in orthodontics, maxillofacial surgery and cosmetic plastic surgery.

ADSD imports the measurements of the photographed subject standardised and configured to the scale of values expressed in pixels, the ordinary unit of measurement of a digital photograph. In order to do this, it is possible to use technical drawing tools, such as set squares and rulers (made of metal if possible and thus easily cleaned and capable of being sterilised, or other similar material). I have personally built a measuring tool called Face Analogic Transfer Support (Fig. 5a), which consists of a ruler with graduated millimetre and centimetre scales, which the patient can wear like a pair of glasses. Furthermore, for new photographs for the fabrication of mock-ups and PMMA models etc., it is useful to use a device such as a craniostat fixed to the headrest, which is integrated into our dental chair. If more accurate and detailed measurements of the teeth and gingival parameters are required, one can use digital callipers whose tips are placed at the cervical margin and incisal edge (the length of the tooth) or at the mesial and distal margins relative to the dental line (width of the tooth; Fig. 5b). These measurements when transmitted can be very effective in communication between the dentist and dental technician, whose manufacturing skills and expertise will be the most important to the end-result of this innovative method (Fig. 5c). It is necessary to bear in mind that the measurements expressed in millimetres in relation to the digital image produced by the digital processing, as well as the design of the dental contours, are not of much interest to patients, who desire a photograph of the first phase simulation, but
the measurements represented as 3-D wax models and mock-ups tried in and analysed in the patient's mouth will give you an idea of the delicate psycho-aesthetic approach to the clinical case very important for aesthetic dentistry.

_Aesthetic analysis of a face and a smile_

In relation to the manner in which to portray the patient in a photograph, we should reflect on the aesthetic component of the face and the smile. For the objective aesthetic analysis, the focal length is modified, starting from the first photograph (Fig. 6). For this parameter, the following classification criteria could be applied:

- macro-aesthetics (extra-oral analysis of the face);
- mini-aesthetics (extra-oral analysis of the mouth); and
- micro-aesthetics (intra-oral analysis of teeth and gingiva).

As regards the aesthetic analysis of the smile, the specific areas of the objective analysis that are pertinent to dentistry are as follows, based on that provided by a number of many authors:

- Facial analysis: Frontal/lateral, determining morphological features, horizontal/vertical reference lines, vertical/horizontal facial proportions, golden ratio, horizontal/vertical dimensions, analysis of the facial profile, and analysis of the lips, nose and eyes as regards position and size (Fig. 7).
- Dental analysis: Dental composition, dental arrangement and position, dimensions, proportions, shapes, contours, margins, textures, surfaces, axial inclinations, inter-incisal angles, interproximal contacts and colour (Fig. 8).
- Dento-labial analysis: Labial dynamics, smile line, width of smile, labial corridors, occlusal plane, mid-line, and inter-incisal and commissural lines (Fig. 9).
- Phonetic analysis: This is complementary to the dento-labial analysis and involves the recording

Figs. 13a–f Virtual modelling of dental forms with DDID.
of the phonetics with particular attention to consonants and their combinations. In addition, the analysis of the phonemes "/m/" and "/i/" (sometimes also the phoneme "/e/"") is of great importance for detecting and determining the position of the lips and the maxillary incisors relative to the age and sex of the subject being analysed. Furthermore, it is important to bear in mind the extent to which the central incisors are the visual focal point of the smile architecture.

Gingival analysis: Architecture, shape parallelism, symmetry, zenith, papillae, biotype and colour (Fig. 10).

In general, it can be stated that considering all of these very important values and parameters in detail requires comprehensive planning and competence that cannot be contained in only a few lines. These have been scientifically established by a number of authors and further information can be found in books and scientific articles.

Dental digital image editing

Digital image editing can be performed in various ways (Fig. 2) according to the requirements of the smile designer and with various software packages (both freeware and for purchase) easily obtained from the Web. Their main use includes generic image and photograph editing for both amateur and professional graphic designers. Some of the packages available have been developed by dentists. An important contribution to these packages is offered by some authors, who through the use of Keynote (a presentation application developed by Apple for Mac OS X and iOS) have made smile design easier with results that provide a schematised dental design with real outlines.

In addition to Digital Dental Design (Figs. 11a & b), ADSO offers important processing functions: the import, conversion and editing of dental shapes and types of dentition in the form of real images. In order to carry out these important functions, it is necessary to create a real dental library, which we shall call the Digital Dental Photos Database (DDPD). This might include:

Dental shape library, which might be the best form of database, in which five types of dentition could be captured relative to anatomical form and possibly colour according to the quality and amount of light in the photograph as observed by the operator. The photographs of the teeth in this library should be taken at a frontal projection, and at 45 and 90 degrees laterally, that is a profile, so that they can be
special digital smile design

incorporated into the photographs and images of the patient in ADSD. The dental shapes contained in the library must correspond to nature itself, such as triangular, oval or rectangular with variables, like square or trapezoidal (Fig. 13f).

Libraries of dentition containing aligned and aesthetically ideal complete mouths: There are some libraries, such as that of Digident, in which the teeth are already preformed according to the morphology of the incisal edges (flat, square and round).

Personal case reports database, that is the collection of our clinical cases concerning the fabrication of prostheses, aesthetic dentistry, virtual wax-ups, mock-ups and the healthy dentition of patients (with their permission). Dental technicians in laboratories could also exchange data thanks to the goodwill of colleagues who supply them with images. An ADSD images community would be of great scientific advantage. This library should consist of images of complete and partial dental arches (eight anterior teeth, six anterior teeth). These might be single maxillary arches, the primary object of smile design, or maxillary and mandibular arches with normal occlusion (useful for partially or totally edentulous patients). The images might also contain the gingiva according to photographic requirements; indeed, they may be integrated as a whole into the virtual oral cavity or else one might isolate single teeth (Fig. 12) in order to be able to adapt them according to shape, alignment, emergence, ideal contour and contact points respecting the aesthetics.

Dental libraries of removable prostheses: These are available on the Web from leading companies in the industry, such as Ivoclar Vivadent, Heraeus Kulzer and Candulor.

Smile library, consisting of photographs with faces of models smiling, which can be useful if in high resolution. The teeth can be selected and extrapolated from the face of the subject, generally photographed by professional photographers. These images can be downloaded from stock photography sites at a fee (such as 123RF.com, Fotolia.com, Shutterstock.com and Fotosearch.com).

Another very important feature of this method of smile design is Digital Dental Image Distortion (DDID; Figs. 13a–f), which allows the modification of the morphology of the teeth to be processed. This function is of great utility for the formation of the teeth in the DDPD. It must be applied to length and width (Figs. 14a–c), as well as in every direction both along the contours and on the dental surfaces, and especially along the lines of transition. This processing is often very useful for light reflected on the dental surfaces characterised by micro- and macro-textures, and is effective in the analysis and processing of the interproximal contact points and inter-incisal angles. Moreover, it is effective in the morphological classification of the incisal edges, transitional lines, etc., often reference points specific to the age, sex and personality of the patient (morphopsychology). From my point of view, this part of dental digital image editing is the most important because it is not possible to give a prefabricated smile to a patient; while such a smile might be made up of teeth that are in themselves perfect, it is necessary to know how to modify, model, shape, deform, increase, diminish or eliminate everything in contrast with the harmony of form (Figs. 15a–e).
In many aesthetic clinical cases, it is useful to perform Digital Dental Calibrated Transposition (DDCT), a transposition of the teeth necessary for the simulation of orthodontic movements, some of which apply to the situation prior to aesthetic treatment, prosthetic treatment, implants, etc. (Figs. 16a & b). The transposition must be calibrated, that is must move the teeth into the desired position and maintain the measurements and anatomical dimensions. This makes it easier to calculate more predictably the future dental composition, not only aesthetically but also functionally, as well as the relative spacing (mesialisation/distalisation) necessary for the insertion of the prosthetic implant. It gives important feedback for the implantologist, prosthodontist, and orthodontist, with all of whom it is necessary to communicate radiological findings (DICOM and Tac3D—the latter is compatible with ADSD). Only after having decided on the final positioning of the teeth can the smile designer pay greater attention to the improvement of the aesthetic aspects by further modifying the images with DDID. The same is true for the integration of the orthodontic simulation data from sophisticated applications such as ClinCheck (Align Technology), which can be implemented in the virtual planning towards an integrated aesthetic and prosthetic solution to an orthodontic problem (Figs. 17a–d).

Editorial note: This is the first of a two-part article based on a paper presented by Dr Valerio Bini to the 15th International Congress of Aesthetic Medicine in Milan in October 2013 during the session titled “Aesthetic dental surgery of the lower third of the face.” Part II of the article will appear in CAD/CAM 2/2014.

Figs. 17a–d Implementation in ClinCheck, ADSD.

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