S E L E C T E D R E A D I N G S

IN

ORAL AND

MAXILLOFACIAL SURGERY

STANDARDIZED DIGITAL PHOTOGRAPHY FOR VIRTUAL ORTHOGNATHIC SURGICAL PLANNING

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HISTORY OF ORTHOGNATHIC SURGERY

The historical development of orthognathic surgery has not been uniform and continuous, but instead followed a rather intermittent course. The early-phase was mainly limited to the mandible while maxillary surgical procedures came later. The first operation for the correction of malocclusion was Hullihen's procedures in 1849. The cradle of early orthognathic surgery, however, was in St. Louis where the orthodontist Edward Angle (1898) and the surgeon Vilary Blair (1906) worked together. They carried out the first described ostectomy of the horizontal ramus for the correction of a case of mandibular prognathism. Blair was also the pioneer who stressed the importance of orthodontics in dentofacial discrepancy treatment.[1]

Technology has been evolving over time, and optimizing it is a key factor for obtaining predictable results. Precision is required from the first analysis of the patient to be incorporated into treatment planning.

In this review, we describe a photographic protocol based on the principles of reliability and consistency in the photographs taken. A special technique, called Digital Smile Design (DSD)[2] is used for facial analysis, and it can make possible any other related intraoral or facial correlation or analysis (Figs. 1-3 on page 2).

PLANNING IN ORTHOGNATHIC SURGERY

An accurate diagnosis will lead to good surgical planning, thus favorable results. A systematic and full evaluation of the patient is of utmost importance. The orthodontist and the surgeon should take part and be responsible throughout the evaluation process, and there should be always a joint discussion between the surgeon, the orthodontist and the patient, before a definitive treatment plan is made. Full history such as medical and dental history should be obtained before the examination. Articulated dental models should be prepared for later evaluation. Understanding of the patient's socio-psychological profile will greatly reduce misunderstandings by knowing the patient's motives for surgery and expectations.

The differential diagnosis process generates a problem list and treatment planning options to discuss with the patient. The selection of the appropriate procedure must be based on the clinician's anticipated objectives with regard to esthetics, function, and stability,[3,4] but also on the patient's objectives, expectations, and perceived needs.[5] Important factors in the selection of orthognathic surgical procedures and treatment planning are the stability of the results, the predictabil-

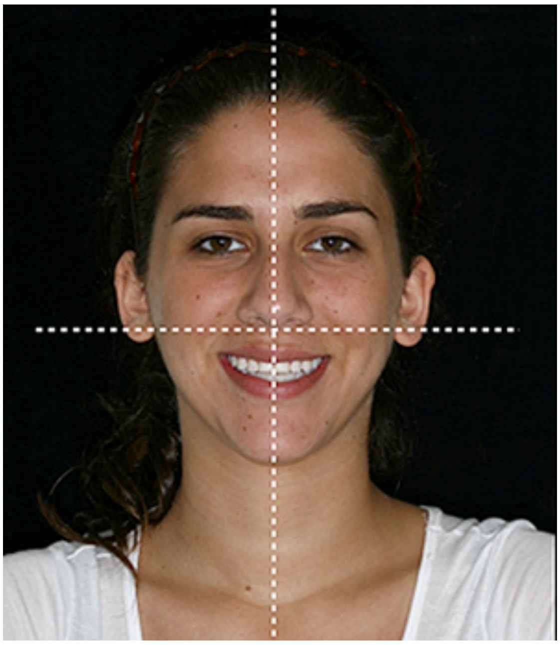

Figure 1. Frontal digital photograph with vertical and horizontal planes.

ity of hard and soft tissue changes to achieve facial balance and the patient's response.[6]

The analysis of soft tissue, alongside the study models and cephalometry, has become essential for the diagnosis of dentofacial deformities, because a treatment based only in cephalometrics can create undesirable results. Arnett and Bergman[7,8] presented "Facial keys to orthodontic and treatment planning." They used a three-dimensional clinical analysis of the face both in orthodontic diagnosis and in the planning of surgical cases.

To perform soft tissue cephalometric analysis, the patient should be examined clinically in natural head position (NHP), with the articular condyles seated in the fossa and

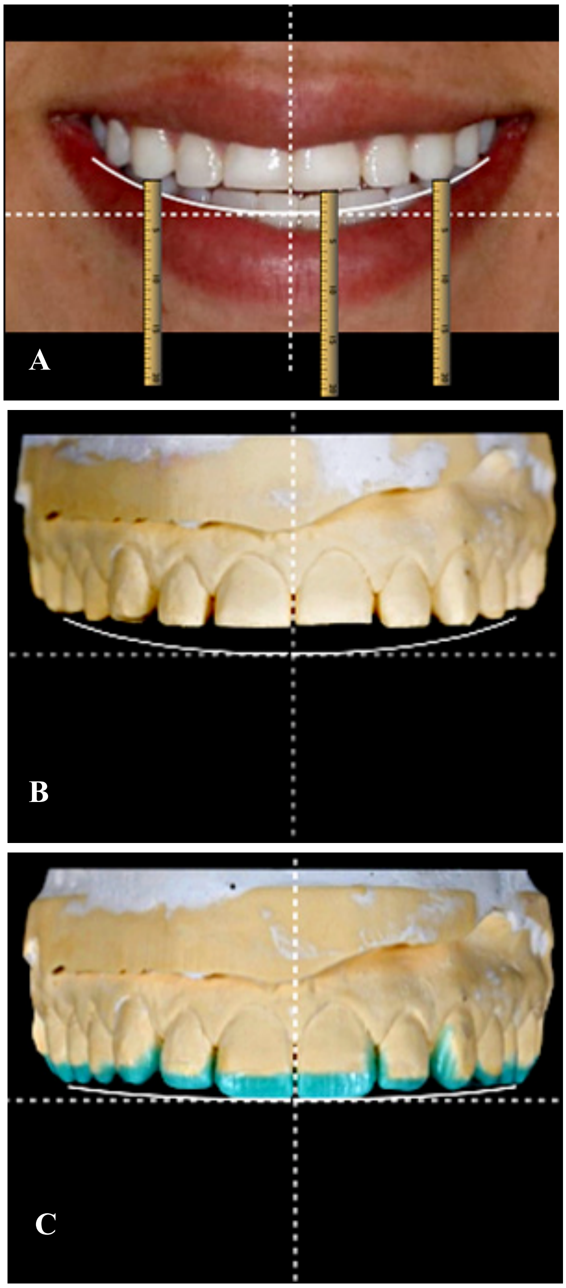

Figure 2. **A**. Digital Smile Design in the oral area followed by **B.** and **C**. casts planning the ideal smile design.

Figure 3. Composite reconstruction of the upper arch **A.** after Digital Smile Design treatment planning and **B.** prior to the jaw surgery.

the lips relaxed. This posture is imperative for reliability and standardization of cephalometric analysis. Cephalometric analysis cannot be used without facial analysis to complement and elucidate the cephalometric data. The analysis should emphasize midface facial structures not shown in a conventional cephalometric analysis, for example, the infraorbital rim and contour of the alar base, which are important indicators of the anteroposterior position of the maxilla.[9]

Surgery of the models is an important step in orthognathic surgery planning, being essential to the success of surgical procedures. Eliminating some stages of the treatment planning (e.g., facial analysis, predictive tracing or model block surgery) has been presented in the literature, but doing so introduces great risk of inaccuracy that could induce undesirable changes after surgery.[10] Errors in model surgery performed with an articulator have also been reported as a possible cause for discrepancies related to segment positioning.[11]

Cephalometric prediction in orthognathic surgery can be performed manually or by computer, using several currently available software programs, alone or in combination with video images. The manual methods of cephalometric prediction of the orthognathic outcome are time consuming, whereas, computerized methods facilitate and speed the visualized treatment objective. Both manual and computerized cephalometric prediction methods are two-dimensional and will always have limitations, because they are based on correlations between single cephalometric variables and cannot fully describe a three-dimensional biological phenomenon.[6]

Two basic problems are associated with traditional 2-dimensional cephalometry First, many important parameters cannot be measured on plain cephalograms, and second, most 2-D cephalometric measurements are distorted in the presence of facial asymmetry. Three-dimensional (3-D) cephalometry, which has been facilitated by the introduction of cone-beam computed tomography scans, can solve these problems, but only if the unreliability of internal reference systems and some 3-D measurements, along with the lack of tools to assess and measure symmetry, are resolved.[12]

Despite the promising capabilities of 3-D the technology is not yet reliable for orthognathic prediction.[6] However, the different methods of prediction are useful tools for orthognathic surgery planning and facilitate patient communication. We propose in this review the use of 2-D photographs for obtaining a 3-D analysis of the patient in presentation software.

Importance of the Accuracy of the Data Collection

Elective operations are increasingly being done to correct skeletal discrepancies and severe malocclusion. This may be the result of a wider range of operations being available for treatment of complex dysgnathia, and older subjects being able to withstand such operations.[13] These developments have resulted in the need for a method that will rapidly and accurately predict the outcome of combined orthognathic and surgical treatment. The digitization of cephalograms have made their analysis much faster and easier, and the use of software for planning orthognathic operations is popular.[14]

Many studies of stability after orthognathic correction of dentofacial deformities have been published,[15] but only a few have attempted to evaluate orthognathic precision by comparing preoperative prediction with postoperative outcome.[13] For prediction of the results of orthognathic operations, planning devices usually involve clinical evaluation, photographs, and freehand surgical simulation based on cephalometric tracings and study model operations.[16] To evaluate the position of the maxilla and mandibula postoperatively, cephalometric analysis of the surgical result immediately after removing the intermaxillary splint should be considered.[12,16]

New methods of planning treatment have enabled correction of virtually any type of dentofacial deformity, but problems remain. As with all manual cephalometric tracing, digitization is prone to errors, including incorrect identification of landmarks and angles and errors in transfering of predicted data from digitized cephalograms to the study model operation and intraoperative sites.[17] If greater shifts in the transversal dimension are necessary, exact planning should be adapted with three-dimensional planning devices to avoid significant differences.[18]

Importance of the Accuracy of the Photographs

Complex clinical appearances of patients in craniomaxillo-facial surgery and facial plastic surgery are usually difficult to describe in words. Therefore, much of our professional time is spent in judging and discussing pictures and photographs. For that purpose standardized views and high-quality photographs are fundamental for pre- and postoperative documentation.

Clinical photographs are most commonly used to assist accurate planning of a surgical procedure and to illustrate the purpose of the surgical intervention for the patient. Consistent documentation of clinical diagnosis and treatment is also demanded in medico-legal cases. In addition, photo-documentation with reliable pre- and postoperative pictures are invaluable for scientific development, surgical education and staff training.[19] Some authors recommend that high-quality clinical photographs become an integral part of the patient's record, complimenting radiographs and other medical images.[20]

Clinical photographs taken before, during and after orthodontic treatment form an essential part of the patient's records. If correctly taken, they offer more useful information about the malocclusion and treatment than any other clinical record. There are, however, many potential sources of errors in obtaining these records. Photographs of inadequate quality may misrepresent the patients starting malocclusion, may inaccurately reflect progress with treatment or may inaccurately record dental anomalies and defects that may be present.

With both conventional and digital systems, errors related to use of mirrors and retractors and patient positioning are common. With digital equipment a whole new range of possible errors has been introduced and specific problems related to the digital system have been discussed in detail.[21] Thus, we highlight below a clinical protocol for photographs in order to minimize errors to achieve the highest possible quality of photographic records.

PHOTOGRAPHS AND FACIAL ANALYSIS

In orthognathic surgery, both the acquisitions of a harmonious profile and an improvement in occlusal function are important goals. Therefore, an objective and quantitative analysis of facial morphology before and after surgery is essential,[22] and it can be obtained by different methods. One such method is digital photography, which has the advantage of not exposing the patient to potentially harmful radiation while still providing a good assessment of the harmony and esthetics of external facial structures, including the influence of soft tissues.

Facial analysis is used as a diagnostic tool in orthodontics and orthognathic surgery to assist in directing treatment and to meet one of the patient's main motivations: facial aesthetics. Once these techniques are standardized, photographic analysis can be a useful complement to conventional radiographic and cephalometric analysis because orthodontics and orthognathic surgery require numerical data to understand the concept of beauty.

To obtain consistent esthetic outcomes, the gathering of diagnostic data from questionnaires and checklists is important.[23] However, as in restorative dentistry, much of this information may be lost if it is not transferred adequately to the facial analysis.[24] The diagnostic data should guide the subsequent treatment phases, integrating all of the patient's needs and desires, as well as the patient's functional and biologic issues.[2]

The DSD is a multi-use conceptual tool that can reinforce diagnostic vision, increase communication, and enhance predictability throughout treatment. The DSD permits careful analysis of the patient's facial and dental characteristics along with any critical factors that may have been overlooked during clinical, photographic, or diagnostic cast-based evaluation procedures. The illustration of reference lines and shapes over extra- and intraoral digital photographs in a predetermined sequence can widen diagnostic visualization and help the restorative team evaluate the limitations and risk factors of a given case, including asymmetries, disharmonies, and violations of esthetic principles.[2] DSD sketches can be performed in presentation software such as Keynote™ (iWork, Apple, Cupertino, California, USA) or Microsoft PowerPoint™ (Microsoft Office, Microsoft, Redmond, Washington, USA). This improved visualization makes analysis of the patient easier.

The DSD protocol is characterized by effective communication within the interdisciplinary team. Team members can identify and highlight discrepancies in soft or hard tissue morphology and discuss the best available solutions using the amplified images. Each professional can add information directly onto the slides in writing or using voice-over, thus simplifying the process even more. All team members can access this material whenever necessary to analyze, alter, or add elements during the diagnostic and management phases.

The implementation of the DSD protocol can make diagnosis more effective and treatment planning more reliable. The efforts required to implement DSD are rewarded by more logical and straightforward treatment sequencing, leading to savings in time, materials and cost during treatment.

Digital Smile Design

According to Coachman and Calamita,[2] the DSD protocol offers advantages in the following areas: 1) Esthetic diagnosis, 2) Communication, 3) Feedback, 4) Patient management, and 5) Education.

Esthetic diagnosis

When the professional first evaluates a new patient with esthetic concerns, many critical factors could be overlooked. A digital photographic and analysis protocol enables the dentist to visualize and analyze issues that he or she may not notice clinically. Drawing of reference lines and shapes over extra- and intraoral digital photographs can easily be performed using presentation software

Figure 4. Suggested photographic layout for the Digital Smile Design protocol.

TABLE 1: TECHNICAL GUIDELINES FOR HIGH QUALITY DIGITAL PHOTOGRAPHS.

Nikon D90/D200/D300/D7000			Approximate References	
	Face with bouncers	Smile & Intraoral with bouncers	Smile & Intraoral without bouncers	XR Photography
ISO	400	200	200	
Flash Power	1/1	1/1	1/8	
“f”	around 13	22	22	
Focus	auto	Manual	Manual	
Speed	125	125	125	
Flash Control	Manual	Manual	Manual	
Image Quality	JPEG Fine	JPEG Fine	JPEG Fine	
White Balance	Kelvin “K” 5560	Kelvin “K” 5560	Kelvin “K” 5560	
Image Size	Large “L”	Large “L”	Large “L”	
Camera Mode	Aperture mode “m”	Aperture mode “m”	Aperture mode “m”	Auto
Color Space	/RGB	/RGB	/RGB	

DIGITAL PHOTOGRAPHIC PROTOCOL

Equipment Needed

The protocol requires a digital single-lens reflex camera (DSLR) body. For example, our protocol employs a Nikon D7000® (Nikon, Melville, New York, USA). A macro lens (105 mm) is also necessary, and arms for wireless flashes associated with bouncers are employed. Figure 4 illustrates the photographic layout.

Technical Guideline

To standardize the photographic procedure and obtain high quality photographs, a guideline is followed. The values and types of ISO, flash power, lens aperture (“f”),

Figure 5. Facial digital photographs. The black background helps define the patient’s features, and the presence of a mirror helps maintain natural head position.

Figure 6. **A.** The angle of the camera and the black background behind the upper arch produce the view in **B**. of the smile line and gingival margin levels.

focus, speed, flash control, image quality, white balance, image size, camera mode and color space for different photographs with or without bouncer are summarized in Table 1 (On page 7).

Patient's and Professional Positions

Face

Use a black background behind the patient's head and a mirror to help maintain Natural Head Position. Additionally, the camera must be in the same position, with the equipment stabilized vertically (Fig. 5 on page 7).

Figure 7. Frontal facial photographs. **A**. At rest; **B**. Smiling; **C.** Open smile with teeth apart.

Figure 8. 3/4 facial photogrpahs. **A**. Right side at rest. **B**. Left side at rest; **C.** Right side when smiling, **D**. Left side when smiling. All photographbs were taken at 45 degrees.

Figure 9. Lateral facial photographs. **A.** Profile smile; **B**. Profile rest.

Intraoral

Use a black background behind the upper arch to display the smile line and the levels of the gingival margin. Additionally, the camera must be in an approximate angle of 45º with the maxilla (Fig. 6, facing page).

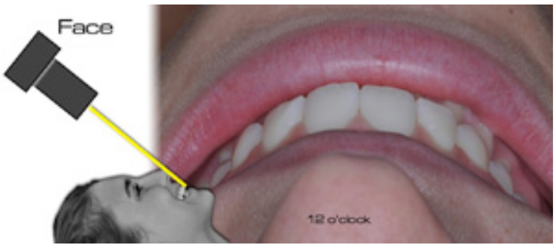

Figure 10. 12 O'clock special photograph.

Type of Photographs

Face

Three photographs for frontal facial analysis are taken: at rest, while smiling and during an open smile with teeth apart (Fig. 7, facing page). Four 3/4 facial photographs (at 45º) are taken at rest and while smiling (Fig. 8). Two photographs in profile are taken at rest and while smiling (Fig. 9).

A special 12 O'clock photograph is taken with the patient in supine position and the camera lens aligned to make a straight line with the nasal apex, to obtain a photograph of the relationship of the teeth and lips while smiling (Fig. 10).

Three photographs for frontal intraoral analysis are taken: with the teeth apart, in maximum intercuspation (MIC) and during protrusion (Fig. 11 on page 10). Images of the teeth apart and in protrusion allow

Figure 11. Intraoral frontal photographs. **A**. Teeth apart, **B**. Maximum intercuspation; **C**. Protrusion. Teeth apart and protrusion allow analysis of the plane of occlusion.

Figure 12. Intraoral occlsual photographs. **A**. Upper oclussal; **B.** Lower occlusal.

analysis of the occlusion plane. Two occlusal photographs are taken of the upper jaw and lower jaw (Fig. 12).

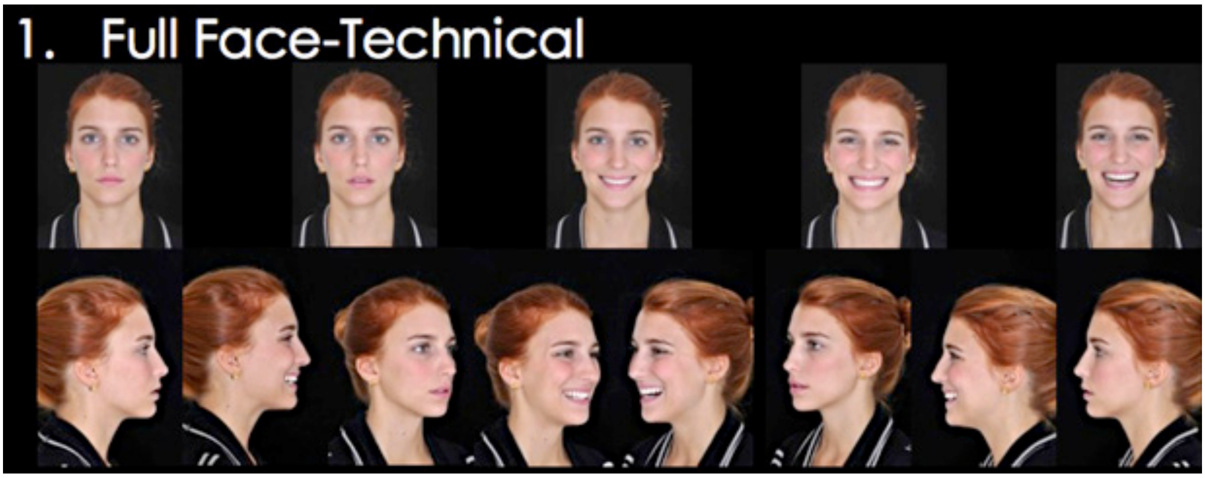

Figure 13. Clinical Case 1: Full face protocol for facial treatment planning.

Figure 14. Clincial Case 1: Informal facial photographs.

Figure 15.Clinical Case 1: Close-up photographs for smile and tooth-lip relations analysis.


Figure 16. Clinical Case 1: Intraoral photographs.


Figure 17. Clinical Case 1: Special intraoral photographs.

DEMONSTRATION OF CLINICAL CASES

The first clinical case demonstrates full face photographs taken for facial treatment planning. It is worth noting that this protocol gives the sensation of tri-dimensionality (3-D) even when using two-dimensional photographs (Fig. 13, facing page). Furthermore, full-face informal photographs are employed to permit a less structured and natural analysis (Fig. 14, facing page). Close-up photographs allow analysis of the smile and tooth-lip relations (Fig. 15). Intraoral and special intraoral photographs are shown in figures 16 and 17, respectively.

The second clinical case reinforces the indication of DSD for a standardized

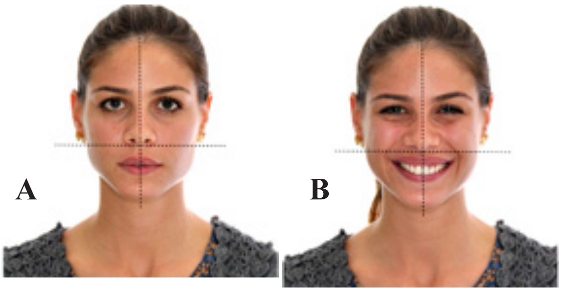

Figure 18. Clinical Case 2: Standardized facial photographs with vertical and horizontal planes. **A** At rest; **B.** While smiliing.

analysis of patients undergoing orthognathic surgery. Figure 18A illustrates the DSD analysis in a frontal facial photograph; figure 18B shows the DSD during smiling. Figure 19 displays the full face photographs at rest and during smiling, respectively. Figure 20 (on page 13) combines three facial photographs: 3/4 at rest and frontal during smiling. Figure 21 (on page 13) shows the final occlusion at maximum intercuspation in frontal, right and

Figure 19. Clinical Case 2: Suggested facial layout. **A.** with profiles at rest; **B**. With profiles while smiling.

Figure 20. Clinical Case 2: Facial 3/4 views with frontal smile with teeth apart (center), that shows better facial contour.

Figure 21.Clinical Case 2: Intraoral regular photographs of final occlusion at maximum intercuspation.

Figure 22. Clinical Case 2: Frontal facial photograph during smiling, with relationship of maxillary and mandibular central incisors (insert).

left occlusion views, which is the most commom protocol for the evaluation of the occlusion and intercuspation. Figure 22 displays a frontal facial photograph during smiling associated with the final occlusion to demonstrate the relation of the maxillary central incisors and the mandibular central incisors (i.e., overjet and overbite).

The final two cases demonstrate the standardization of the present protocol, with the photographs being practically identical. Figures 23 and 24 (on page 14) give the sensation of tri-dimensionality in the facial and intraoral photographs, respectively. The case illustrated by Figures 25-27(on pages 14 & 15)

Figure 23. Clinical Case 3: Facial layout giving the sensation of tri-dimensionality.

Figure 24. Clinical Case 3: Preoperative (top row) and postoperative (bottom row) intraoral photographs.

Figure 25. Clinical Case 4: Facial layout giving the sensation of tri-dimensionality.

Figure 26. Clinical Case 4: Facial smile layout.

Figure 27. Clinical Case 4: Preoperative (upper row) and postoperative (lower row) intraoral photographs.

includes frontal facial analysis and intraoral analysis. Note that this protocol allows a better juxtaposition of preoperative and postoperative intraoral photographs, making differentiation easier for professionals and patients.

CONCLUSION

The DSD protocol enables the oral and maxillofacial surgeon to work together with orthodontists and other dental professionals in a practical and reliable way of communication. Moreover, a digital photographic and analysis protocol using presentation software permits visualization and analysis of issues that might not be noticed clinically without the additional cost of a special software analysis prior to orthognathic surgery.

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