The Planning of Orthognathic Surgery - The Digital Era

Dr. Ben CHOW

BDS, FRACDS, FCDSHK(OMS), FHKAM(DS)
Specialist in Oral and Maxillofacial Surgery

Dr. Alfred LAU

BDS, MDS(OMS), Adv Dip(OMS), MOSRCS, FCDSHK(OMS), FHKAM(DS)
Specialist in Oral and Maxillofacial Surgery

Dr. Ben CHOW

Dr. Alfred LAU

Dentofacial deformity is defined as " the deviation from normal facial proportions and dental relationships that are severe enough to be handicapping". However the word "handicap" is not a pleasant word to use and the degree of deformity can vary from very mild to severe. Therefore this word has been seldomly used to describe this kind of patients. Although most of the time, treatments of dentofacial deformities are function restoring, a number of them are purely for cosmetic purposes. There is not a defined line between who needs and who does not need treatment. It all depends on the discussion between the patient and the surgeon, and sometimes, the patient's family members.

The word "handicapping malocclusion" was also used to describe dentofacial deformity in the 1975 report by the National Research Council of the United States of America, which focused attention on these problems. At of today, this term has largely been abandoned, because jaw function and facial esthetics, rather than dental occlusion, are the major problem. These patients almost always have severe malocclusion, but malocclusion is not the defining feature of their condition. Treatment almost always involves the co-operation between the orthodontist and the maxillofacial surgeon in different phases of treatment. Of course, a dentist is very important to be involved to maintain a healthy dental and oral condition before commencement of more complex treatment. The treatment process always starts with orthodontics for alignment, followed by surgical correction. It will then be followed by orthodontics again for fine alignment.

Classification of Dentofacial Deformities

Most of the dentofacial deformities are developmental problems, either hypoplasia or hyperplasia of the jaw(s) or part of them, in any direction. There is not a unique system to classify all the deformities; however, it can be basically categorised into several types, as shown in table 1. Dentofacial deformity can be a part of some syndromes, associated with cleft lip and palate or an isolated problem.

Orthognathic Surgeries

According to the diagnosis, orthognahtic surgeries can be performed to correct the deformities. Le Fort I osteotomy is the most commonly performed maxillary surgery; It can move the maxilla, basically, in all dimensions. Maxilla can also be segmentalised into two to five pieces to match the mandibular arch. If the nasal prominence or even the zygomatic buttresses are involved, Le Fort II or III osteotomy should be performed. Wunderer and Schuchardt osteotomies are performed when the correction of maxillary alveolar segment is needed. For the mandible, ramus surgeries such as sagittal split osteotomy and vertical subsigmoid osteotomy are performed to advance or set back the jaw and to correct asymmetry. Hofer osteotomy is performed when the angulation of the anterior mandibular alveolar segment needs to be corrected. Genioplasty is performed to correct deformed chin prominences in any direction, such as hyperplasia, hypoplasia and asymmetry. There are many other commonly performed procedures to correct dentofacial deformity in different situations; it all depends on the preference of the surgeon and the practice in different training centres.

Table 1. Different types of dentofacial deformities

Skeletal Deformity	Description	Underlying Skeletal Problem
Angle Class II	Short mandible in AP	1. Maxillary hyperplasia In AP
Angle Class III	Long mandible in AP / short maxilla in AP	1. Maxillary hypoplasia in AP or 2. Mandibular hyperplasia in AP or 3. Combination
Facial asymmetry	Deviated jaw / chin	1. Unilateral condylar hyperplasia or 2. Unilateral mandibular hyperplasia or 3. Chin deviation
Open Bite	Non-occluding anterior teeth	1. Reverse curve of Spee or 2. Posterior vertical maxillary excess 3. Short mandibular ramus or 4. Combination
Bimaxillary Protrusion	Proclined anterior bimaxillary alveolus	1. Bimaxillary dentoalveolar hyperplasia in AP
Vertical Maxillary Excess (VME)	Long maxilla in vertical	1. Maxillary hyperplasia in vertical

AP = anterior-posterior dimension

Patient Evaluvation

An accurate diagnosis will lead to good surgical planning, thus favourable 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 going into 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.

Frontal and Profile Analyses

Esthetic facial evaluation should be separated into frontal and profile analyses. For the frontal view, facial form should first be addressed. It is defined as the relationship between the facial width and vertical height. The general average of the height-to-width proportion is 1.3:1 for females and 1.35:1 for males. Short square facial types are usually associated with class II, deep bite, vertical maxillary deficiency and masseteric hypertrophy, while long narrow facial types are often associated with VME, narrow nose, high palatal vault and +/- anterior open bite. The "rule of fifths" is a commonly used method for analysing transverse facial proportion, where the face is divided into five equal parts as shown in Fig. 1.

Facial asymmetry is assessed through an imaginary line drawn from the soft tissue glabella, tip of nose, centre of filtrum and soft tissue pogonion. (Fig. 2) Assessment should be made not only on the chin midline, but also to facial balance, cheek and zygomatic prominence and level of the eyes. Vertical relationship can be assessed by dividing the face into upper, middle and lower thirds. Both skeleton and soft tissue should be evaluated in details, especially the symmetry. (Fig. 3)

For the profile view, similar to frontal assessment, we would evaluate the form, the upper, middle and lower thirds. However, special attention is made to the nose, cheeks, naso-labial angle, lip prominence, labial-mental fold and the chin prominence.

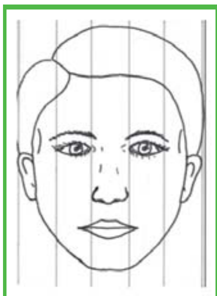
Fig.1

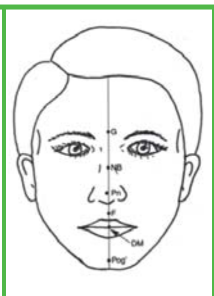
Fig.2

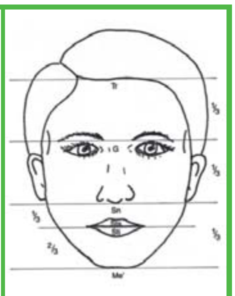
Fig.3

Lateral Cephalometric Analysis

Before 3-dimensional radiology became popular, lateral cephalometric analysis was the gold standard. It helps in assessing both the skeletal and soft tissue profiles, with a list of standard landmarks. (Fig. 4, 5) Angulations and distances between different landmarks are usually compared with the calculated average, using reference data of the same ethnic group. It is a very useful tool, as it indicates very clearly where are the problems and to what degree the deformities are. However, although cephalometric analysis is very import in both diagnosis and development of a treatment plan, it has several limitations. Firstly, errors could be created by a moving patient or in different head positions. Also, some individual's deformities have anatomic variations in the location of the cephalometric landmarks used as a baseline in many averages of the left and right skull analyses, thus resulting in incorrect conclusions. Cephalometry is still, a 2D image where the left and right sides of the skull cannot be analysed separately, whereas only a 3D image can give a full impression especially in an asymmetric case. It is very important that the clinician should always remember not to rely on a single cephalometric finding. Although cephalometric analysis forms an important part of the data base for diagnosis, it should not take precedence over the clinical evaluation of the patient.

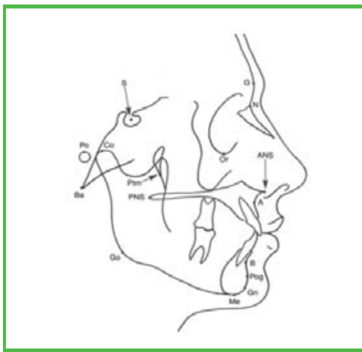
Fig.4

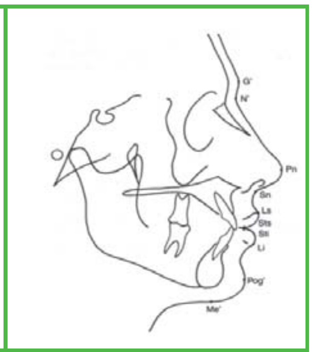
Fig.5

Protocol for 3D Orthognathic Workup

One of the objectives of orthognathic surgery is to produce a harmonious occlusion and facial appearance by normalising the position of the teeth as well as the jaw bones. As the surgical techniques mature over time, the expectation of our patients also rises tremendously. We have to plan more carefully, perform more safely and communicate better with our patients. Nowadays different 3D imaging modalities and more user-friendly computer software serve us well in this aspect. Gradually we develop our own protocol for 3D orthognathic workup for our patients utilising both 3D scan and 3D photography.

Cone beam CT (CBCT) has gained popularity over the recent years because it can provide 3D DICOM data of both soft and hard tissues with a relatively low radiation dose when compared with conventional medical CT. It has also the added advantage of having the scanned subject positioned in an upright position. Therefore the soft tissue of the face can be captured in the natural head position which is important when doing soft tissue analysis and soft tissue simulation of our planned virtual surgery.

A 3D stereophotogrammetrical camera set up is used to capture a 3D photograph of the face. The camera generates a 3D photograph from six 2D photographs taken simultaneously (four grey-scale photographs and two full colour photographs). A polygon pattern is projected into four of these six images. Based on this pattern and its deformed image, a 3D photograph is reconstructed. The 3D photographs are taken in the natural head position with the eyes open. Image fusion, i.e. registration of a 3D photograph upon a CBCT, results in an accurate and photorealistic digital 3D data set of a patient's face. (Fig. 6)


Fig. 6. High precision 3D surface image registered with CBCT data

3D Augmented or Composite Model

During CT scanning, artifacts generated due to metal fillings and orthodontic brackets are normally present at the teeth level causing inaccurate visualisation of the interocclusal relationship. There are different ways developed to set-up a 3D virtual augmented model of the skull with detailed dental surface. 3D virtual dental models can be obtained by using two different 3D image acquisition techniques: volumetric imaging techniques (e.g. computerised tomography) and surface acquisition systems (e.g. laser surface scanning, probe scanning). The digital image of the teeth surface can be combined with the skull model by registration techniques using special facial bow or occlusal wafer with radiographic markers. (Fig 7) For some difficult selected cases, we may produce a 3D stereolithographic model by the rapid-prototyping technique. We can physically perform surgical procedures on these models.

Fig. 7 CBCT of patient and dental casts for registration with special facebow

Digital Copy of the Patient

Data from the CBCT are exported in DICOM format. The skull and skin surfaces are segmented by thresholding. The soft tissue surface is textured with 3D photographs. The dentition is augmented with high resolution scan of the study models. Now we actually have a digital copy of our patient in front of us for all the analysis, diagnosis and planning in the virtual environment. (Fig. 8)

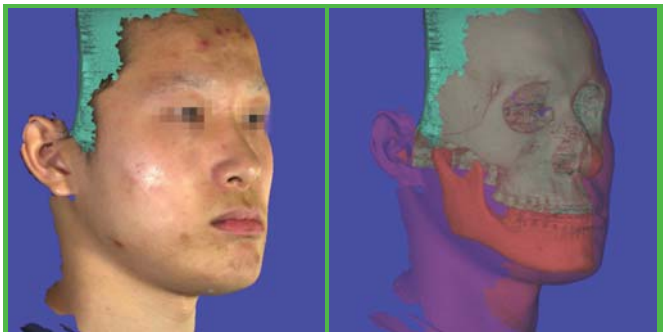

Fig. 8 Digital copy of patient comprising of CBCT data of skeletal and dental structures registered with photorealistic textured skin surface

Computer Planning Software

There are various commercially available software programmes on the market that provide platform for us to do our orthognathic workup from making the correct diagnosis to bringing the patient to the operating theatre.

3D Cephalometric Analysis

The traditional lateral cephalometric analysis has the difficulty of identifying the various anatomical landmarks projected onto a mid-sagittal plane as mentioned before. This limitation is even more noticeable when we are dealing with facial asymmetry. However location of anatomical landmarks on a 3D skull model is straight forward. Many research centres are coming up with 3D cephalometric data for normal population and individuals with various dentofacial deformities so that an accurate reference is available to make our diagnosis. (Fig. 9)

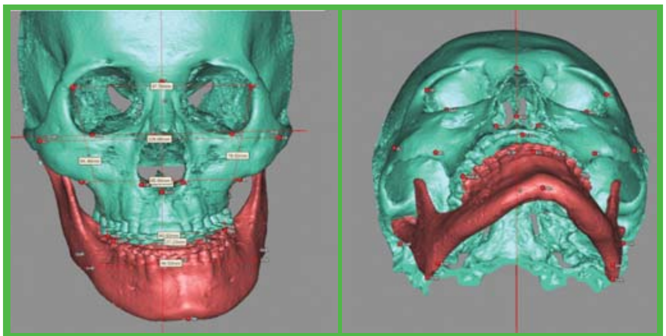

Fig. 9 Anatomical landmarks on 3D skull model and 3D cephalometric analysis

Virtual Surgery

Surgeries can be performed on the 3D virtual model. It is possible to visualise the relative movements of different bony segments and identify any potential obstacles to our surgical movements. Therefore different surgical plans can be tried out, so as to optimise the surgical procedures and to improve the surgical outcome. All these help to reduce the surgical time and the chance of facing surprises on the operating table. (Fig. 10)

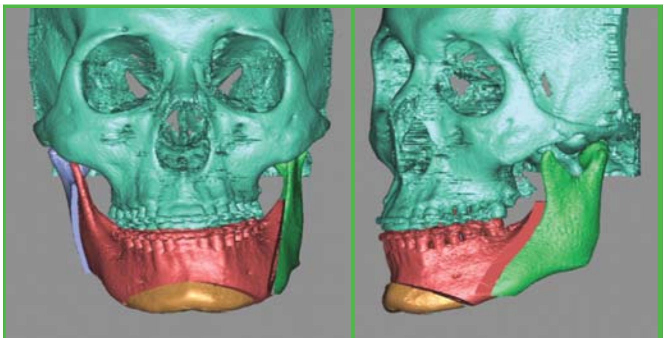

Fig. 10 3D virtual surgical plan

Soft Tissue Simulation

Photorealistic computer simulation of the soft tissue change as a result of the surgical movements is the area that patients show most concern. Of course proper guidance is required for the patients to interpret the result properly. We can also fine-tune our surgical movement based on the simulation result. (Fig. 11)

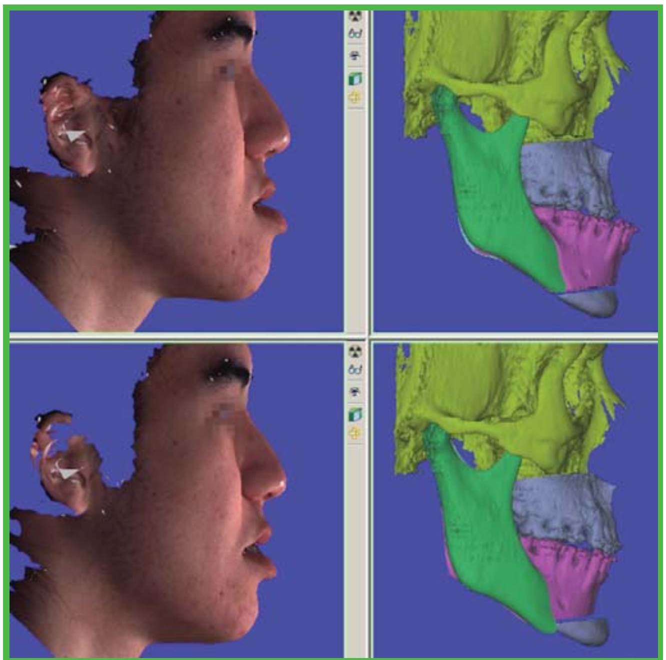

Fig. 11 Soft tissue simulation

CAD/CAM Construction of Surgical Wafer

Time has arrived when physical model surgery is no longer necessary for the fabrication of surgical wafers. The virtual surgical plan can be transferred to the operating table through the CAD/CAM construction of surgical wafers. (Fig. 12)

Fig. 12 CAD/CAM construction of surgical wafer

Clinical Audit of the Surgery

It is possible to superimpose the pre and post-operative 3D data sets, so enabling accurate 3D cephalometric comparison of the hard tissue changes after osteotomies. A study by Joanneke on sagittal split osteotomy, besides the expected AP movement of the distal segments of the mandible, unexpected rotational and translational movements of the proximal segments of the mandible were visualised, resulting in obviously changed positions of the condyles in the fossae. Furthermore, wide variations of the lingual fracture were observed. We can also make direct comparison of the pre and post-operative soft tissue 3D surfaces. (Fig. 13) A colour histogram is a convenient way to visualise the actual change in a glance. (Fig. 14)

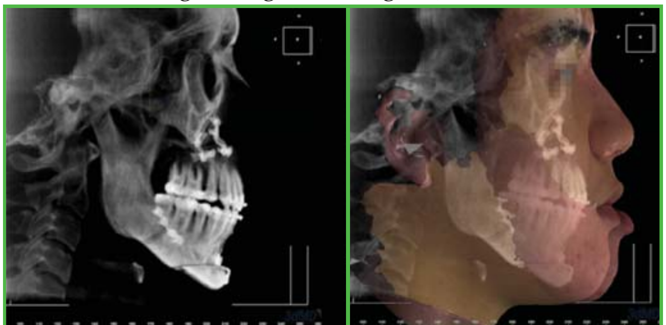

Fig. 13 Post-operative CBCT registered with pre- and post-operative soft tissue surfaces

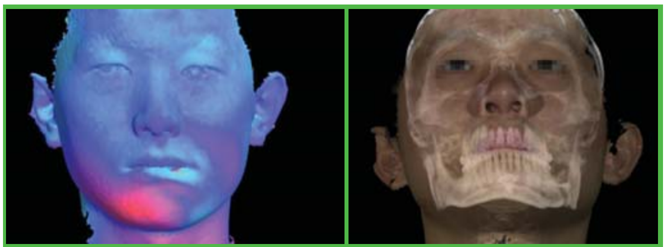

Fig. 14 Colour Histogram showing the difference between pre- and post-operative soft tissue surfaces

The application of 3D imaging modalities and computer planning software has helped a lot in our orthognathic workup making the surgery more acceptable and predictable. It is also a useful tool of communication with the patients so that they can understand their problems better and have more realistic expectation of the surgical outcome. It also opens up a totally new territory for clinical research leading to better understanding of the surgery and improved surgical techniques. In the end we will have more happy patients.

Future

We still need to make a dental impression now. However the first intra-oral scanner that can capture the image of our dentition quickly and accurately will become available commercially very soon. We are just a tiny step away from having all our 3D orthognathic workup performed digitally.