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**Sharath Kumar Shetty**
Professor& HOD, Department of Orthodontics and Dentofacial Orthopaedics, K. V. G. Dental College and Hospital, Sullia, Karnataka, India

**Mahesh Kumar Y**
Professor, Department of Orthodontics and Dentofacial Orthopaedics, K. V. G. Dental College and Hospital, Sullia, Karnataka, India

**Sony D**
Post Graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, K. V. G. Dental College and Hospital, Sullia, Karnataka, India

**Brigit Alphonsa Gervasis**
Reader, Department of Orthodontics and Dentofacial Orthopaedics, K. V. G. Dental College and Hospital, Sullia, Karnataka, India

**Corresponding Author:**
**Sony D**
Post Graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, K. V. G. Dental College and Hospital, Sullia, Karnataka, India

# Cephalometric prediction planning in orthognathic surgery

**Sharath Kumar Shetty, Mahesh Kumar Y, Sony D and Brigit Alphonsa Gervasis**

**Abstract**
Surgical prediction helps the orthodontist to predict the hard and soft tissue changes that may occur as a result of surgery and can be utilized to plan the orthognathic surgery and to communicate with patients and surgeons. Cephalometric prediction in orthognathic surgery allows direct evaluation of both dental and skeletal movements and can be accomplished manually or by computers, using several currently available software programs, alone or in combination with video images. This article describes the different methods of cephalometric predictions.

**Keywords:** Cephalometric prediction, orthognathic surgery, orthodontics

## Introduction
Orthognathic surgical cases require a combination of both orthodontics and orthognathic surgery to achieve a well-balanced occlusion, proper function, and harmonious facial aesthetics [1]. While occlusal goals, can be very objectively determined, definitions of ideal aesthetics are very subjective and may be viewed very differently by the clinician and the patient [2]. Therefore, it is essential to accurately predict the result of a proposed treatment plan for proper understanding and communication between the patient, the orthodontist and the oral surgeon involved [3].
Orthognathic prediction tracing is important for several reasons [4]:

1. The actual procedure and the required anteroposterior and vertical movements may be decided upon by the model surgery.
2. The change of soft tissue responding to hard tissue movement may be ascertained. To determine whether or not an adjunctive surgical procedure like genioplasty is necessary.
3. By superimposition of the photographs, patients may be given an idea of the surgical outcome.

Traditionally 'Mock surgical procedures' were carried out using cast sectioning technique using normal occlusion as the prime indicator. However, since the dental arch basal bone relationship maybe altered as a result of or in compensation for the underlying skeletal defect, the exclusive use of dental occlusion as treatment guide may produce a less satisfactory skeletal and facial profile result.

## Methods of planning and predicting surgical outcomes are
1. Manual acetate tracing "cut and paste" techniques.
2. Photo cephalometric method.
3. Computerized cephalometric prediction.
4. Video imaging.
5. Three-dimensional prediction.

## Prediction cephalometric tracing
### Manual methods
The first cephalometric treatment simulation was done manually [5]. An overlay prediction method of tracing was proposed by Holdaway (1983).

The surgical movements were simulated by manually repositioning the acetate tracings of skeletal structures over the original cephalometric tracing. The post treatment soft tissue outcome is established by using acceptable guidelines for the ratio of soft to hard tissue changes [3].

**Overlay method**

The overlay method[6] is the simplest prediction method for mandibular osteotomies. Its use is limited to surgeries that do not affect vertical maxillary position and the method is not time consuming. Procedure:

i. The initial cephalogram was traced and the surgical reference line was drawn.
ii. All structures that were not affected by the mandibular osteotomy were traced on a second paper placed over the original pre-surgical tracing, hence called the overlay tracing.
iii. The overlay tracing was held stable and the underlying pre-surgical tracing was moved backwards until desired overjet, overbite and proper occlusion were achieved. The mandible and lower teeth as well as the surgical reference line were drawn.
iv. The two tracings were superimposed on the cranial base and the distance of mandibular incisor backward movement was measured in mm. Data regarding ratios of soft tissue changes relative to respective skeletal movements was used to estimate the predicted lower lip position relative to surgical incisor movement. The distance between surgical references line was measured to determine the surgical movement in mm.
v. Tracings were superimposed on the mandible and lower lip outline and soft tissue chin are drawn.
vi. Superimposition was done on the cranial base and prediction soft tissue profile was completed.

**Advantages**

1. Simplest way of simulating the mandibular surgery.
2. Final tracing is produced without any intermediate tracing.

**Disadvantages**

1. This method is limited to surgery that does not affect the vertical position of the maxilla, that is the mandible does not rotate around the condylar axis.

**Template method**

The template method[3] was used in cases where vertical maxillary surgical movement was planned and it was useful when large dental movements were planned, as well as in chin repositioning. Typically, this method was used in maxillary osteotomies and in double surgeries (bi-maxillary surgery). During the prediction course, the mandible rotates around the condyle.

Procedure:

i. Maxillary anterior template and a posterior template were made.
ii. Two mandibular templates were prepared: one without extraction and the second one with the extraction (crowding resolved.) When mandibular template was prepared, the approximate centre of the condyle on the original tracing was marked, and this was transferred to the template. The mandibular template could be rotated around that point.
iii. The upper anterior template was placed in the desired position approximately 2mm below the lip line.
iv. The better fit of the mandibular teeth had to be checked by placing either of mandibular templates. It was clear that the prominence of the upper anterior teeth would be a function of how much the mandibular incisors were retracted and how far up the maxilla was moved.
v. Then the upper posterior template was positioned.
vi. The prediction tracing was completed on a fresh tracing paper.

**Advantages**

1. The template method could be used in any case where vertical maxillary surgical movement was planned and it was very useful when large dental movements were planned, as well as in chin repositioning.

**Disadvantages**

1. Time consuming.
2. Use of intermediate tracing is mandatory between the original and final tracing when the maxilla is repositioned vertically.

**Photo cephalometric technique**

A photo cephalometric technique for the prediction and evaluation of skeletal and soft tissue changes following dentofacial and craniofacial surgery was advocated by Hohl *et al*. [7] Manipulation of the patient photographs (cut and paste) was done to illustrate treatment goals.

Procedure:

i. The lateral cephalogram was traced and superimposed onto a profile picture in a ratio of 1:1; this has been called a "photometric plan".
ii. The photograph, with the hard tissue points marked, was then cut-up to simulate the pre-surgical orthodontic phase of incisor decompensation.
iii. The necessary surgical movements were then undertaken; followed by the soft tissue response to the hard tissue movements.

**Advantages**

1. It gives the patient better visualization of the profile changes than acetate tracing does.

**Disadvantages**

1. No changes in the soft tissue contours that occurs with treatment.
2. Gaps in the photographs that give an unnatural appearance.
3. An experienced clinician with artistic skill is essential.

**Computerized Methods**

Computer-based analysis were introduced in the 1980s, where cephalometric landmarks could be digitized and their positioning could be monitored. This has facilitated the prediction, shortened the time and was more practical and accurate than the manual techniques [8, 9]. With these programs, measurements, calculations and analyses were performed by the computer. Prediction of the orthognathic surgery outcome could also be done by using various available software programs, alone or in combination with video images.

**Video imaging**

It is a computerised diagnostic and planning software that integrates video images with the patient's lateral cephalogram that aids in planning and predicting surgical orthodontic

procedures. Video imaging technology used computer graphics and video camera [10]. The patient's video image was superimposed over the soft tissue line of a digitized cephalogram. Then, every part of the digitized video image could be modified according to average ratios of the hard and soft tissue changes based on reported data.

In the treatment planning process with video imaging, calibration of the patient's cephalogram to the patient's profile video image was automatically accomplished by the computer. The cephalogram was superimposed over the profile image. An ''auto-treatment'' function adjusted the video image to the limits of the profile prediction and projects the predicted outcome in video graphics form. The movements on the video screen were in terms of ''real size''.

Two major aspects of treatment planning process with video imaging were counselling (communication) and video cephalometric treatment planning. The counselling phase is a graphic way of communicating concepts that are difficult to present to the patient verbally [11].

The planning phase permits a quantification of the treatment plan for the surgery. The superimposition of the cephalogram to the profile video image, along with the predictions, permits the clinician to plan the surgery to closely match the desired outcome [11, 12]. However, there are inherent errors in all the component parts of the superimposition of facial images and cephalometric radiographs [13].

**Computerized cephalometric prediction**

Computerized interactive treatment planning allows orthodontists and surgeons to evaluate treatment goal feasibility, and also enables better education of patients regarding their treatment plan as a part of the informed consent.[25] Computerized tracing could be accomplished either by direct digitization of the cephalogram or a previously traced image, or by indirect digitization of the image. The photographs of patients' profile were superimposed on the digitized cephalometric tracings and the computer-based estimation displayed both the line drawing tracings and the corresponding facial images [14, 15].

Various computer software programs allow the orthodontists and oral surgeons to manipulate the digital representations of hard and soft tissue profile tracings and subsequently morph the pre-treatment profile to produce a predicted treatment simulation. Prediction of the patient's soft tissue profile was performed by the program automatically using selected hard to soft tissue ratios.

**Three-Dimensional Prediction Methods**

Computer methodology integrating cephalometric data with three-dimensional (3D) computerized tomographic (CT) data has been found to aid in the clinical planning of orthognathic surgery, especially in craniofacial anomalies cases. Three-dimensional data were derived from conventional anatomic landmarks which could be identified on both lateral and posteroanterior cephalometric films by converting two-dimensional representation into a three-dimensional representation by a variant of a ray intersection method commonly used in stereophotogrammetry [16].

A patient's 3D tracing is compared to a similarly generated ''ideal'' for every age and sex corresponding Bolton tracing. After the type and number of osteotomies to be performed have been selected, the program calculates the postoperative movements of all osteotomy fragments required to have the surgical outcome most closely approximate the Bolton ''ideal'' form. The user can modify the orientation and position of each osteotomy fragment, if needed. The surgical planning cephalometric treatment may be performed on 3DCT scan reconstructions for superior visualization of the planned surgical changes.

Nowadays software systems fuse the 3D image with the CT/cone-beam CT image, and/or digitized dental study model, to assess, plan, monitor, evaluate and simulate possible patient treatments. The principle of image fusion is the development of a single data set that contains all three structures such as bone volume, soft tissue surface and dentition [17]. 3D data can be fused using point-based matching with or without a reference frame, surface based matching [18-20], and vomex based matching [21-23].

**Advantages**

1. 3D digital model is a valuable aid to clinicians in order to communicate with an interdisciplinary team, the patients and their parents.

**Disadvantages**

1. The lack of reference and normative data [24].
2. All currently available fusion models are expensive and in order to meet the demands of prediction and simulation, need improvement.

**Conclusion**

Accurate prediction is highly critical, as it is related to proper treatment decision-making, appropriate treatment planning and post-treatment facial appearance anticipated by the patient. Nevertheless, these predictions will always have limitations and the patients should be informed that predictions are only a guide and not the actual result of the surgical outcome and as such, they should be implemented.

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