J. Maxillofac. Oral Surg. (July–Sept 2019) 18(3):474–478
https://doi.org/10.1007/s12663-018-01181-x

ORIGINAL ARTICLE

Understanding Predictability Error in Orthognathic Surgery

Edlyn Rodrigues[1] · Vikas Dhupar[1] · Francis Akkara[1]

Received: 13 August 2018 / Accepted: 14 December 2018 / Published online: 18 January 2019

Abstract
Introduction Orthognathic surgery aims to improve the facial aesthetics while maintaining stable jaw form and function. Lateral cephalometry provides objective data used in pre-op mock surgery to predict movement of the maxilla and mandible during orthognathic procedures.
Patient and Methods A prospective cohort study was conducted on 30 adult orthognathic surgery patients. Mock jaw surgery predicted two-dimensional (horizontal and vertical) linear movement of maxilla and mandible. Operative procedures performed were bilateral sagittal split osteotomy and Le Fort I osteotomy. Seven-day pre-op cephalogram (T1) was compared to 7th day post-op cephalogram (T2) to assess hard tissue movement of point A (maxilla) and point B (mandible) using Cartesian (*X*–*Y*) plane.
Results The difference between predicted values to the 7th day post-op outcome results was statistically insignificant (p value less than 0.001).
Conclusion Planning in orthognathic surgery using digitized two-dimensional cephalometric tracings and mock jaw surgery produces predictable results.

Keywords Predictability error · Lateral cephalometry · Bilateral sagittal split osteotomy · Le Fort I osteotomy · Bijaw surgery · Hard tissue analysis

✉ Edlyn Rodrigues
edlynr@gmail.com

Vikas Dhupar
vikasdhupar@gmail.com

Francis Akkara
marcfrancis24@yahoo.com

[1] Department of Oral and Maxillofacial Surgery, Goa Dental College and Hospital, Bambolim, Goa 403-202, India

Introduction

Orthognathic surgery is a surgery designed to correct deformities in the mandible or maxilla. While orthodontics can correct minimal tooth positioning errors, surgery is required to correct significant functional and aesthetic problems. Movement of the jaw is simplified by use of lateral cephalometry. Cephalometry is a widely available, inexpensive, reliable and reproducible tool that can assess hard and soft tissue movement of jaws. Cephalometry-guided mock jaw surgery is the gold standard for diagnosis and treatment planning. There have been multiple evolutions including digitized cephalograms, CT scan and video cephalometry and three-dimensional software-guided prediction of jaw movement. In this study, we analysed a cohort of patients undergoing orthognathic surgery guided by digitized cephalogram and mock jaw surgery and compared their cephalometric prediction to post-surgical outcomes.

Patient and Methods

A prospective clinical study on 30 patients was conducted in the Department of Oral and Maxillofacial Surgery, Goa Dental College and Hospital commencing from November 2013 to October 2016. The aim was to compare the mock surgery prediction to the post-surgical outcome results in an orthognathic surgery. Ethical clearance was obtained from the institutional review board. Patient consent was taken for purpose of surgery and article publication. All the obtained data was analysed by a biomedical statistician.

Inclusion Criteria

Patients above 18 years of age.
ASA I and II on pre-anaesthesia check-up.

Exclusion Criteria

Craniofacial defect or syndrome.
Prior history of cranio-maxillofacial surgery.
Prior history of aesthetic facial surgery.
Prior cranio-maxillofacial trauma.
Unwilling for follow-up/noncompliant.
ASA III and above.

Methodology

Patients were enrolled after completing orthodontic decompensation. A lateral cephalogram was taken 1 week pre-operatively (T1) and 2 week post-operatively (T2). All radiographs were taken in the natural head position with teeth together and lips in repose, with a metric ruler in front of the mid-facial vertical line. The film distance to the X-ray tube was fixed at 150 cm and the film distance to the mid-sagittal plane of the patient's head at 18 cm. Lateral cephalogram was taken in occlusion under standardized conditions with a cephalostat by a single radiology technician.

The preoperative and post-operative cephalometric radiographs were scanned using an Epson Perfection V33 Color Graphics Scanner, into a digital format at 600 dpi, in 16-bit greyscale, and an ABFO No. 2 scale was placed on the lower left corner of the X-ray. The scale incorporated both linear and circular graduations. Its L-shaped configuration ensured accurate scaling in both the vertical and horizontal directions and facilitated the gridding of lateral cephalogram to correct distortional errors (Fig. 1).

Movements of the skeletal units were calculated using cephalometry predictions. Impressions of the teeth were taken with alginate, and dental cast models were fabricated. A Facebow transfer permitted correct placement of cast models on Hanau articulator. A mock surgery was then carried out by the junior author (ER), and the osteotomy cuts were planned according to the cephalometry tracing. Fabrication of one final splint for single-jaw and intermediate and final splint for bi-jaw surgery was done. This splint allows the correct placement of the maxilla in relation to mandible thus transferring the preoperative surgical plan to the operation room. Surgical methods included Le Fort I osteotomy and segmental osteotomies for maxilla and bilateral sagittal split osteotomy for mandible performed by senior author (VD).

Fig. 1 Pre-surgical (T1) digitized cephalogram

All the scanned images of the radiographs were processed by a single investigator (ER), using Adobe Acrobat Pro Dc Software version 11. To enable optimal landmark identification digitally, all tracings and digitations were performed in a darkened room (Fig. 2).

Hard tissue landmarks of the cephalograms were traced using a modified version of the analysis of Legan and Burstone [1] and Lew et al. [2]. A horizontal reference line (*X*-axis) was constructed by raising a line 7° from sella-nasion, and a line perpendicular to this at nasion was used as the vertical reference line (*Y*-axis) (Fig. 3).

Movement of hard tissue point A (maxilla) and Point B (mandible) was measured in millimetres to the *X*- and *Y*-axes in the pre-surgical and post-surgical films. These movements are depicted in the graph as A-*X*, A-*Y*, B-*X*, and B-*Y* (Figs. 4, 5).

The difference in these movements in the pre- and post-surgical film of any patients was measured and tabulated. This difference was the predictability error for the particular movement (Fig. 6).

Statistics and Results

Data were tabulated in MS Excel and analysed by the Statistical Package for Social Sciences version 18 (SPSS version 18).

Fig. 2 Post-surgery (T2) digitized cephalogram

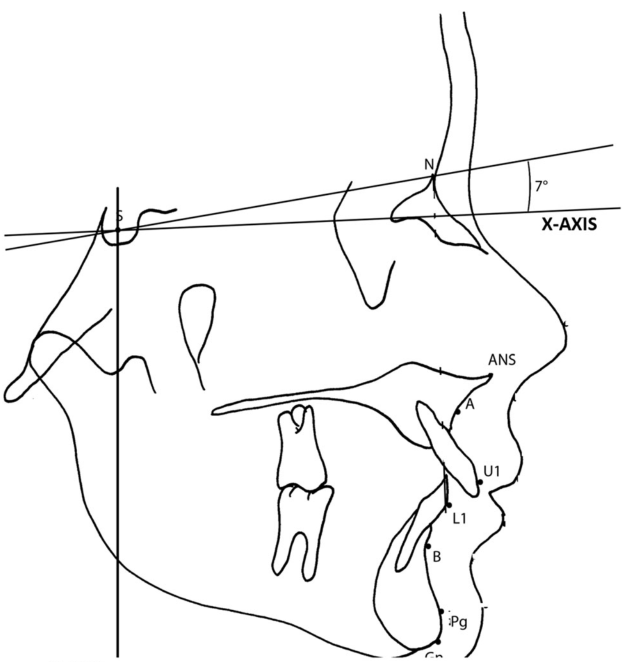

Fig. 3 Hard and soft tissue landmarks and reference lines for tracing cephalograms. (N) = nasion; (S) = sella; (A) = point A; (B) = point B; (L1) = lower incisor, (U1) = upper incisor; (Gn) = gnathion; (Pg) = pogonion); (ANS) = anterior nasal spine; *X*-axis = horizontal reference line; *Y*-axis = vertical reference line

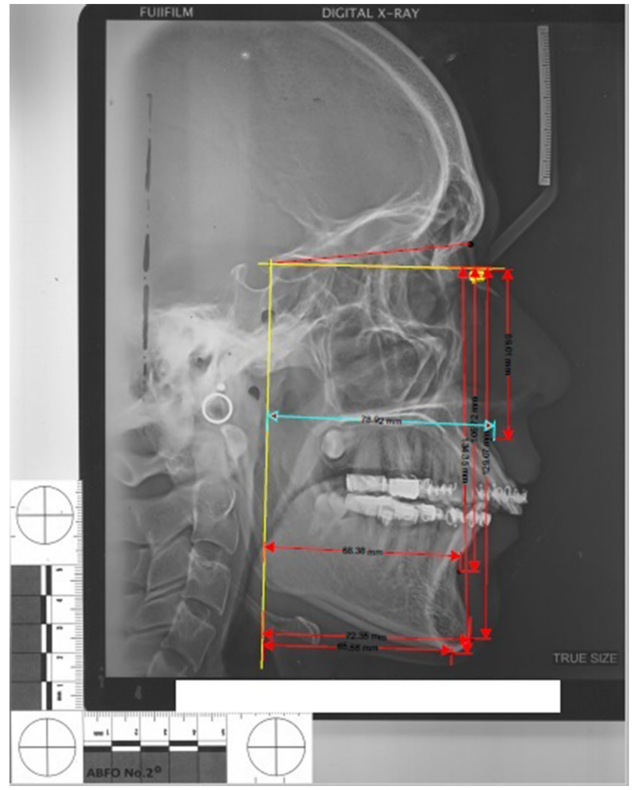

Fig. 4 Marking the pre-surgical hard tissue landmarks at point A (maxilla) and point B (mandible) to the *X*- and *Y*-axes

Descriptive statistics (mean and standard deviation) were calculated for all movements (A-*Y*, A-*X*, B-*Y*, B-*X*) between preoperative and post-operative groups. Statistics were analysed using unpaired T test for statistical significance. The difference between pre-op predicted movement and post-op measured distances (A-*X*, A-*Y*, B-*X*, B-*Y*) was statistically not significant ($p < 0.001$).

The predicted values were subtracted from the actual post-surgical results. The obtained statistic was the predictability error. If the difference was zero, it meant that the prediction was identical to the post-surgical result. Hence cephalometry prediction method was more accurate if the value was closer to zero.

In our study, the maximum predictable error in single-jaw and bi-jaw surgery was 0.7 mm suggestive of least predictability of point A to the horizontal followed by a predictable error of 0.6 mm associated with point B to the vertical. The least predictable error was 0.4 mm to point A to the vertical which makes this point, most predictable. Point B to horizontal not considered as no movements were included.

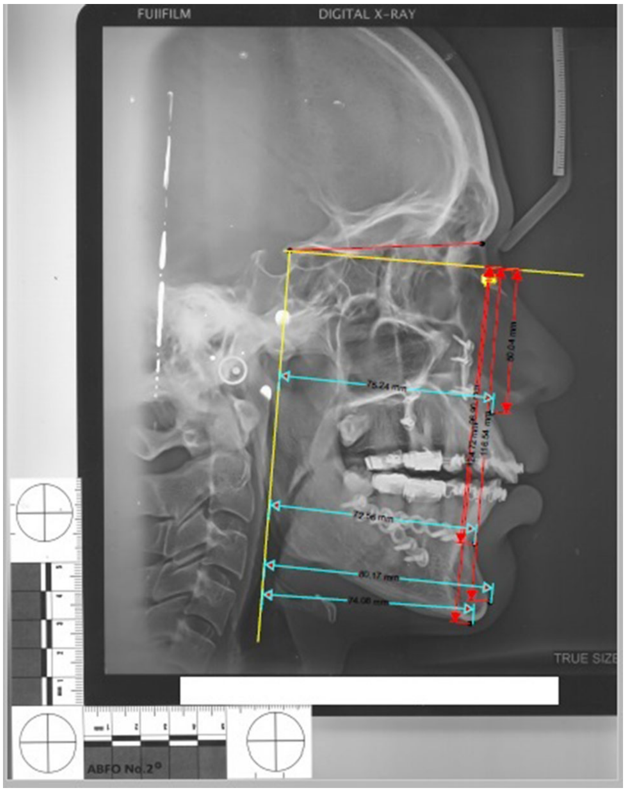

Fig. 5 Marking the post-surgical hard tissue landmarks at point A (maxilla) and point B (mandible) to the *X*- and *Y*-axes

Discussion

Orthognathic surgery is defined as the surgical correction of a dento-facial deformity [3] which aims to improve facial and dental aesthetics along with a stable functional occlusion [4]. Accurate planning is necessary to ensure ideal surgical outcomes. This warrants meticulous cephalometry evaluation, clinical assessment and mock surgery which serve as aids to surgical planning [5, 6].

Sample selection plays an important role to ascertain uniformity in the study, regular follow-up and patient compliance. In our study, individuals whose pre-existing surgery or deformity would alter the result after orthognathic surgery were excluded. A 7-day post-op OPG was taken so as to assess immediate skeletal movement. Since no soft tissue evaluation was done in this study, post-operative oedema was not in question.

The term ‘predictable error’ was coined by Maleiro. This value was the difference achieved by subtracting the scores of predicted values to the actual post-surgical outcomes and cephalometric measurements nearer to zero indicated a more accurate prediction error result [7]. Our predictability error of less than one millimetre is in accordance with other studies published [8–10].

Many authors claim that if the surgical outcome is as predicted by cephalometric analysis, the patient’s grievance would be resolved [11]. Underestimation of horizontal skeletal changes is attributed to errors in manual prediction tracings which give an estimated value rather than an absolute value. Other authors suggest that this error should be included in the pre-surgical planning [12]. Prediction error is greater in bi-jaw than single-jaw surgery. However, in the long-term analysis, relapse to pre-surgical skeletal position is less in bi-jaw surgery due to the redistribution of masticatory forces and decrease in tone of the musculature as compared to single-jaw procedure [13].

In this study, the sample consisted of patients who had undergone pre-surgical orthodontic decompensation treatment. A preoperative cephalometric tracing followed by a 7-day post-operative digitised cephalometric tracing was performed to analyse and document the immediate operative results. Pre-surgical mock surgery determined

Fig. 6 Predictability error in orthognathic surgery

	BIJAW SURGERY	LE FORT I	BILATERAL SAGITTAL SPLIT OSTEOTOMY
A-Y	0.57	0.36	0
A-X	0.72	0.675	0
B-Y	0.57	0	0.534
B-X	0	0	0

predicted values to estimate surgical movement required. The pre- and post-surgical digitised cephalograms were evaluated using Adobe Acrobat Pro Dc Software version 11. The maximum predictable error was measured for single-jaw and bi-jaw surgery was as follows: Point A to the horizontal—0.7 mm, Point B to the vertical—0.6 mm, point A to the vertical—0.4 mm. Hence, based on our study, the vertical movements are more predictable than those in horizontal plane which is in accordance with the previous studies.

In this study, we had similar treatment outcomes for single-jaw and bi-jaw surgery. Complexity, duration and cost were increased in bi-jaw surgery. In single-jaw surgery, there is no occlusal compromise, shorter duration of treatment, decrease cost, and decreased morbidity. However, the final decision of the surgical procedure to be carried out is dictated by the degree of deformity of the patient.

Orthognathic jaw surgery involves three major surgeries, that is Le for I, BSSO or bi-jaw surgery. All these three methods move the maxilla and mandible in two directions, namely horizontally (i.e. forward and backward) or vertically (upward and downward). The third dimension of medial and lateral movement of jaw is rarely attempted in standard orthognathic surgery. Hence, the maxillofacial surgeon in collaboration with orthodontist needs a reliable and simple method for predicting 2D movement of jaw. This has been ably fulfilled by our method which is simple, does not require videography or CT scans and is inexpensive. 3D software analysis for orthognathic should be utilized in complex craniofacial syndromes and facial skeletal asymmetries.

Conclusion

This study was performed to test a method for planning orthognathic surgery, pre-op cephalogram and digitization of the cephalogram using Adobe Acrobat Pro Dc Software version 11™. Based upon 2D movement of maxilla (point A) and mandible (point B) on *X*- and *Y*-axes, mock jaw surgery with splint fabrication was done. Surgical osteotomies and movements were executed based on mock surgery. Using this method the differences between predicted values to the outcome results were insignificant statistically which makes the outcomes of our method predictable. The prediction does not only aid in surgical plan, but it also motivates the patient and is an important prognosticating tool.

The limitation of our study was the inability to compare our results with those obtained using licensed 3D softwares. The sample size was limited due to our inclusion criteria and shorter sampling period.

Beauty lies in the eyes of the beholder and even the most beautiful person need not have ideal cephalometric values. However, cephalometric evaluation of orthognathic surgery is a guide to excellence in achieving consistently predictable results.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interests.

References

1. Legan HL, Burstone CJ (1980) Soft tissue cephalometric analysis for orthognathic surgery. J Oral Surg 38(10):744–751
2. Lew KK, Low FC, Yeo JF, Loh HS (1990) Evaluation of soft tissue profile following intraoral ramus osteotomy in Chinese adults with mandibular prognathism. Int J Adult Orthodon Orthognath Surg 5:189–197
3. Proffit WR, White RP (1990) Jr Who needs surgical-orthodontic treatment? Int J Adult Orthodon Orthognath Surg 5:81–89
4. Barnard D, Birnie D (1990) Scope and limitations of orthognathic surgery. Dental Update 17:63–69
5. Friede H, Kahnberg KE, Adell R, Ridell A (1987) Accuracy of cephalometric prediction in orthognathic Surgery. J Oral Maxillofac Surg 45:754–760
6. Hack GA, Mol van Otterloo JJ, Nanda R. Long term stability and prediction of soft tissue changes after Le Fort I surgery. *Am J Orthod Dentofacial Orthop*. 1993; 104(6): 544-55
7. Gimenez CMM, Bertoz FA, Gabrielli MAC, Magro Filho O, Garcia I, Pereira Filho VA (2013) Cephalometric evaluation of the predictability of bimaxillary surgical-orthodontic treatment outcomes in long face pattern patients: a retrospective study. Dental Press J Orthod 18(5):53–58
8. Bryan DC, Hunt NP (1993) Surgical accuracy in orthognathic surgery. Br J Oral Maxillofac Surg 31:343–349
9. Csaszar GR, Niederdellmann H (2000) Reliability of bimaxillary surgical planning with the 3-D orthognathic surgery simulator. Int J Adult Orthodon Orthognath Surg 15:51–58
10. Gil JN, Claus JD, Manfro R, Lima SM (2007) Predictability of maxillary repositioning during bimaxillary surgery: accuracy of a new technique. Int J Oral Maxillofac Surg 36:296–300
11. Kiyak HA, Vitaliano PP, Crinean J (1988) Patients' expectations as predictors of orthognathic surgery outcomes. Health Psychol 7(3):251–268
12. Thallita PQ, Gulinelli GL, Souza FA, da Silva LS (2010) Assessment of the accuracy of cephalometric prediction tracings in patients subjected to orthognathic surgery in the mandible. Dental Press J Orthod 15(4):117–123
13. Pospisil OA (1987) Reliability and feasibility of prediction tracing in orthognathic surgery. J Craniomaxillofac Surg 15(2):79–83