TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2018.17058

ORIGINAL ARTICLE

Comparison of the Accuracy of Manual and Digital Cephalometric Prediction Methods in Orthognathic Surgical Planning: A Pilot Study

Can Arslan[1], Ayşe Tuba Altuğ[1], Tülin Ufuk Toygar Memikoğlu[1], Elif Merve Arslan[1], Ensar Başpınar[2]

[1]Department of Orthodontics, Ankara University School of Dentistry, Ankara, Turkey
[2]Department of Biotechnology, Ankara University School of Agriculture, Ankara, Turkey

Cite this article as: Arslan C, Altuğ AT, Toygar Memikoğlu TU, Arslan EM, Başpınar E. Comparison of the Accuracy of Manual and Digital Cephalometric Prediction Methods in Orthognathic Surgical Planning: A Pilot Study. Turk J Orthod 2018; 31(4): 133-8.

ABSTRACT

Objective: To compare and evaluate the reliability of manual and digital cephalometric prediction methods in orthognathic surgical planning

Methods: Ten adults (5 females and 5 males) with skeletal class III malocclusion were included. The mean patient age was 21.97 years. Pre- to postoperative changes were evaluated using paired t-test. Manual surgical predictions made by tracing on acetate paper and digital predictions made using computer software were compared with actual postoperative values using intraclass correlation coefficient and root mean square.

Results: Statistically significant changes were observed in SNA, SNB, ANB, U1i-FH, and Nperp-A following bimaxillary orthognathic surgery ($p<0.001$). Postoperative changes in Co-A and Nperp-Pg were statistically significant ($p<0.05$). Comparison of manual and digital surgical predictions with actual postoperative values revealed that overbite and overjet showed the lowest agreements. Manual predictions were less accurate for points that were difficult to distinguish (Co and U6). Skeletal predictions were more accurate than dental predictions.

Conclusion: Parameters with low reproducibility (Co and U6) decrease the reliability of predictions. Dental predictions were inaccurate in both methods due to the effects of intermaxillary elastics, but both methods yielded similar predictions for skeletal parameters. The impact of applying strong elastics for postoperative intermaxillary fixation should be considered when making surgical predictions.

Keywords: Skeletal class III malocclusion, orthognathic surgery, surgical predictions

INTRODUCTION

Lateral cephalometric radiographic examination and analysis are a routine and important part of orthognathic surgeries. These procedures enable physicians to predict changes in the soft tissue and skeletal structure as a result of surgery and also help the patient to be informed about the planned surgery. Conventionally, orthognathic surgery is manually planned using acetate tracing paper. Today, however, these tracings can be performed digitally using computer software.

In the literature, Cohen (1) first described the degree of mandibular retraction required in mandibular surgeries to achieve satisfactory facial esthetic results. He marked reference points on patients' preoperative lateral cephalometric radiographs and used a compass to estimate postoperative changes. In another method developed by McNeill et al. (2), preoperative plaster models were created and an articulator was used to bring the maxilla and mandible into the ideal position. Henderson (3) developed a different method in which patients'

Address for Correspondence: Can Arslan, Department of Orthodontics, Ankara University School of Dentistry, Ankara, Turkey
E-mail: dt.canarslan@gmail.com

Received: 11 December 2017
Accepted: 2 July 2018

lateral cephalometric radiographs were superimposed on profile images in an attempt to predict the outcomes of osteotomy. The surgical procedure was performed virtually by applying LeFort 1 osteotomy incision lines on these superimposed images. Worms et al. (4) established a guide for use in orthognathic surgery planning, which specified the movement ratios between the soft and hard tissues. They used reference points, such as the incisor position on the jaw base and the hard tissue pogonion. Hohl et al. (5) made vertical and horizontal measurements using the nasion–pogonion line as a reference. Fish and Epker (6) developed another method of predicting postoperative changes in the skeletal and soft tissue structures following orthognathic surgery. They used the Ricketts' cephalometric analysis as well as growth estimation and objective parameters of visual treatment defined by Bench et al. to predict changes following mandibular advancement and combined maxillary and mandibular osteotomies (7). The Frankfort horizontal line and a vertical line drawn from the nasion were used as reference s to determine the optimal facial depth. In their study, the authors concluded that the repositioning of the posterior maxilla resulted in the autorotation of the mandible. In the mid-1980s, Wolford et al. (8) conducted a systematic review and developed an estimation table of hard and soft tissue changes after surgeries using different osteotomy techniques. Altuğ et al. (9) reported that favorable changes in the facial profile following bimaxillary orthognathic surgery were largely due to the posterior movement of the mandible and accompanying changes in the lower lip position.

Bhatia and Sowray (10) developed the first computer software for use in orthognathic surgical planning. This software could analyze reference points marked on patients' lateral cephalometric radiographs and import profile photographs to create animations of the possible postoperative changes. Moreover, programs with similar features were developed by Harradine and Burnie (11) and Walters and Walters (12). Currently, several computer programs are available to assist orthognathic surgical planning. One of these is Quick Ceph (Quick Ceph Systems, San Diego, California, USA), which was the first commercially available software developed for surgical planning. In this program, patient records are imported into the system, and surgeries can be simulated according to predefined normative values. In a similar program called Dolphin, various changes can be imposed on lateral cephalometric radiographs and profile images to facilitate a more accurate marking of reference points. In a 2009 study, Kaipatur et al. (13) showed that although surgical plans created using computer software may be clinically acceptable, they may yield misleading results, especially in the prediction of soft tissue movements involving the lower lip region. In a similar study conducted in 2007, Pektaş et al (14) found that computer software provided satisfactory results in the prediction of soft tissue changes after surgery. The authors reported that digital predictions were the most accurate toward the tip of the nose and least accurate in the lower lip area. They also noted that digital predictions were more accurate in the sagittal plane than in the vertical plane.

Table 1. Preoperative mean age of patients with skeletal Class III malocclusion, presented as mean with standard error (SE), minimum (min), and maximum (max) values

N	Chronological Age (years)			
	Mean	SE	Min	Max
10	21.97	2.01	18.58	25.00

Patients who have completed growth and development and have severe skeletal defects are managed using orthognathic surgical protocols incorporating both orthodontics and surgery. The success of these treatments is highly dependent on the pre- and postoperative orthodontic interventions used as well as presurgical planning. Changes in the skeletal and soft tissue structures after surgery can be predicted using conventional cephalometric tracings or computer software. Previous studies evaluating class III bimaxillary orthognathic surgical predictions have compared computer-generated predictions with surgical outcomes. However, no studies have compared conventional prediction using acetate tracing paper over lateral cephalometric radiographs, digital prediction using computer software, and actual postoperative results. Therefore, our objective in the present study was to determine which of these two prediction methods is more reliable by comparing them with each other and with postoperative outcomes.

METHODS

Ten patients (5 females and 5 males) with skeletal class III malocclusion were included in the study. All patients underwent presurgical orthodontic decompensation in the Orthodontics Department of the Ankara University School of Dentistry, followed by bimaxillary orthognathic surgery prepared and planned by the same surgical team in the Oral and Maxillofacial Surgery Department. The mean patient age is given in Table 1.

Patients Meeting the Following Criteria were Included in the Study

- Completed growth and development and skeletal class III malocclusion (ANB<0);
- Absence of any craniofacial syndrome;
- Skeletal class III malocclusion corrected through maxillary advancement (LeFort 1 osteotomy) and mandibular set-back (sagittal split osteotomy);
- Orthognathic surgery planned and performed by the same team;
- Absence of any additional treatment.

Patients Meeting Any of the Following Criteria were Excluded from the Study

- Incomplete growth and development, currently developing;
- Open or deep skeletal bites and severe hyperdivergent growth pattern;
- Any condition involving the craniofacial region;
- Inadequate or inaccessible radiographic records.

Cephalometric Evaluation

The study was conducted using pre- and postoperative lateral cephalometric radiographs, which were analyzed using the Steiner and McNamara normative values. All orthodontic radiographic records were collected using the same x-ray machine (Sirona Orthophos XG5, Sirona Dental Company, Long Island City, NY, USA). Postoperative lateral cephalometric radiographs were obtained 6 months after the surgery. Conventional surgical predictions (manual tracings on acetate paper) and computer-generated predictions (Dolphin Imaging 11.8, Dolphin Imaging & Management Solutions, Chatsworth, CA, USA) based on the same preoperative lateral cephalometric radiographs and the same surgical manipulations were compared with the actual postoperative values. The conventional method comprised manual tracing of the preoperative lateral cephalometric radiographs on acetate paper with a light box. Once the anatomical structures were traced, desired surgical movements were performed on the maxilla and mandible by cutting and repositioning the skeletal segments. The soft tissue structures were manipulated depending on the hard tissue changes, as described in literature (13).

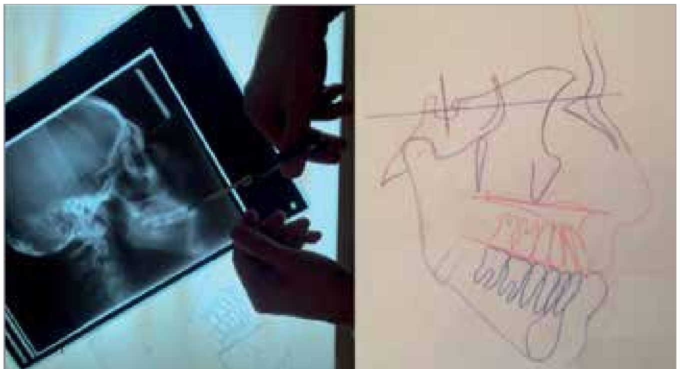
Figure 1. Manual prediction method

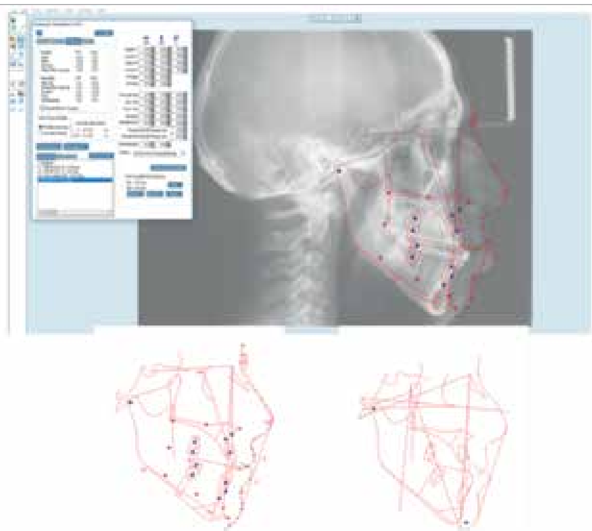
Figure 2. Digital prediction method

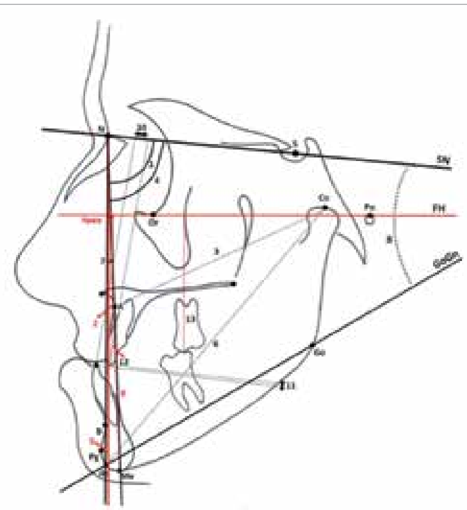
Figure 3. Reference points and planes used in lateral cephalometric radiographs

Cephalometric Points and Measurements

Reference points and planes used in lateral cephalometric radiographs (Figure 3).

Craniofacial Cephalometric Measurements

- SELLA-NASION PLANE (SN): The plane between the sella and nasion points
- FRANKFURT HORIZONTAL PLANE (FH): The plane passing through the porion and orbita points

Reference Points Used in Lateral Cephalometric Radiographs

The cephalometric landmarks used in our study are shown in Figure 1 and are as follows:

- S: Sella
- N: Nasion
- ANS: Anterior nasal spine
- PNS: Posterior nasal spine
- Point A: Subspinale
- U1i: Incisal edge of maxillary first incisor
- U6t: Tip of the mesiobuccal cusp of the maxillary first molar
- B Point: Supramentale
- Pg: Pogonion
- Gn: Gnathion
- Me: Menton
- Go: Gonion
- Co: Condylion
- Po: Porion
- Or: Orbita

Maxillary Measurements

- SNA: The angle between the SN and nasion-point A planes
- Nperp-A: Perpendicular distance between point A and nasion
- Co-A: Distance between condylion and point A
- U1i-FH: Distance between the Frankfurt Horizontal Plane and incisal edge of the maxillary first incisor
- U6t-FH: Distance between the FH plane and the tip of the mesiobuccal cusp of the maxillary first molar

Mandibular Measurements

- SNB: The angle between the SN and nasion-point B planes
- Nperp-Pg: Perpendicular distance between pogonion and nasion
- Co-Gn: Distance between condylion and gnathion

Maxillomandibular Measurements

- ANB: The angle between the nasion-point A and nasion-point B planes.

Table 2. Preoperative (pre-op) to postoperative (post-op) changes in skeletal class III anomalies treated by bimaxillary orthognathic surgery were evaluated using paired t-test (SE: Standard error, Sig.: Level of significance *p<0.05, **p<0.01, ***p<0.001)

Measurements	Pre-op		Post-op		Difference		
	Mean	±SE	Mean	± SE	Mean	± SE	Sig.
Maxillary Measurements							
1. SNA (°)	79.05	0.99	83.22	0.85	4.17	0.85	***
2. Nperp-A (mm)	-0.18	0.99	4.17	1.0	4.35	0.76	***
3. Co-A (mm)	80.60	1.1	85.59	1.4	4.99	1.73	*
Mandibular Measurements							
4. SNB (°)	83.24	1.2	80.92	1.2	-2.32	0.46	***
5. Nperp-Pg (mm)	6.39	2.0	3.02	1.7	-3.37	1.06	*
6. Co-Gn (mm)	119.70	1.3	117.43	2.3	-2.27	1.68	
Maxillomandibular Measurements							
7. ANB (°)	-4.23	0.96	2.33	0.70	6.56	0.99	***
8. SN/GoGn (°)	36.27	2.1	34.68	1.9	-1.59	1.08	
9. N-Me (mm)	126.40	2.8	123.50	2.9	-2.90	0.67	
Dental Measurements							
10. Overjet (mm)	-7.40	0.85	2.40	0.21	9.80	0.80	***
11. Overbite (mm)	1.60	0.16	1.50	0.15	-0.10	0.22	
12. U1i-FH (mm)	55.45	1.5	51.80	2.0	-3.65	0.80	***
13. U6t-FH (mm)	50.30	1.1	49.15	1.6	-1.15	1.10	

Table 3. Comparison of conventional surgical predictions based on lateral cephalometric radiographs with actual postoperative results using intraclass correlation coefficient (ICC) and root mean square

Parameter	Standard Deviation	ICC
SNA (°)	0.714	0.9613
Nperp-A (mm)	1.017	0.9492
Co-A (mm)	4.508	0.6278
SNB (°)	1.409	0.9209
Nperp-Pg (mm)	2.439	0.8968
Co-Gn (mm)	4.094	0.8460
ANB (°)	1.388	0.7879
SN/GoGn (°)	2.205	0.9212
N-Me (mm)	1.466	0.9829
Overjet (mm)	0.716	0.6920
Overbite (mm)	0.612	0.5000
U1i-FH (mm)	1.984	0.9306
U6t-FH (mm)	2.695	0.7893

Table 4. Comparison of digital surgical predictions based on lateral cephalometric radiographs with actual postoperative results using intraclass correlation coefficient (ICC) and root mean square

Parameter	Standard Deviation	ICC
SNA (°)	1.581	0.8626
Nperp-A (mm)	1.308	0.9121
Co-A (mm)	1.525	0.9312
SNB (°)	1.392	0.9187
Nperp-Pg (mm)	2.282	0.9136
Co-Gn (mm)	2.795	0.9194
ANB (°)	1.598	0.6450
SN/GoGn (°)	2.368	0.9088
N-Me (mm)	2.127	0.9676
Overjet (mm)	0.680	0.3944
Overbite (mm)	0.316	0.7500
U1i-FH (mm)	2.550	0.9178
U6t-FH (mm)	2.188	0.8957

- GoGnSN: The angle between the gonion-gnathion and SN planes.
- N-Me: The distance between the nasion and menton.

Dental Measurements

- Overjet
- Overbite

Statistical Analysis

Paired t-test was used to analyze the mean pre- and postoperative values of the treatment group and to evaluate changes that occurred as a result of surgery. Variation between manual predictions and actual postoperative values as well as that between digital predictions and actual postoperative values was assessed using the intraclass correlation coefficient (ICC) (reproducibility) and square root of the mean square (root mean square).

RESULTS

The patient's cephalometric values before and after the orthognathic surgery and the differences between these measurements are presented in Table 2.

Following bimaxillary orthognathic surgery, significant increases were observed in the maxillary parameters SNA (4.17°, p<0.001), Nperp-A (4.35 mm, p<0.001), and Co-A (4.99 mm, p<0.05).

Significant decreases were noted in the mandibular parameters SNB (2.32°, p<0.001) and Nperp-Pg (3.37 mm, p<0.05).

Of the maxillomandibular measurements, there was a significant increase of 6.56° in ANB (p<0.001).

Dental measurements showed a statistically significant increase of 9.80 mm in overjet and significant decrease of 3.65 mm in U1i-FH (p<0.001).

When conventional surgical predictions were compared with actual postoperative values using ICC and root mean square, overbite measurement was the most unpredictable parameter (0.5000). Following overbite, manual predictions of Co-A, overjet, ANB, and U6t-HF were less accurate (0.6278, 0.6920, 0.7879, and 0.7893, respectively; Table 3).

Comparison of digital predictions with actual postoperative values revealed that overjet was the most unpredictable parameter (0.3944). Moreover, digital predictions of ANB and overbite were less accurate (0.6450 and 0.7500, respectively).

Comparisons of manual and digital orthognathic surgical predictions with actual postoperative results are presented in Tables 3 and 4, respectively.

DISCUSSION

Severe skeletal defects are managed using orthognathic surgical protocols incorporating both orthodontics and surgery. Pre- and postoperative orthodontic interventions and surgical planning based on preoperative lateral cephalometric radiographs are important factors for the success of these treatments. Changes in the skeletal and soft tissue structures after surgery can be predicted using conventional cephalometric tracings or computer software. Several previous studies evaluating class III bimaxillary orthognathic surgical predictions have compared computer-generated predictions with surgical outcomes (15-17). However, no studies have compared conventional prediction using acetate tracing paper over lateral cephalometric radiographs, digital prediction using computer software, and actual postoperative results. Therefore, we aimed to compare these two commonly used prediction methods (manual and digital) with each other and with postoperative values.

Ten patients (5 females and 5 females) with similar skeletal class III malocclusion characteristics and who had completed growth and development were included. Ensuring that all orthodontic treatments and orthognathic surgical preparations, planning, and procedures are performed by the same team is important for the reliability of the study.

In the present study, the same researcher made conventional surgical predictions based on preoperative lateral cephalometric radiographs (manual tracings on acetate paper), obtained computer-generated predictions (Dolphin Imaging 11.8, Dolphin Imaging & Management Solutions, Chatsworth, CA, USA), and measured actual postoperative values.

In both manual and digital predictions, the mean impaction, advancement, and set-back were 2.4, 4.9, and 4.45 mm. Predicted impaction and advancement values were similar to actual postoperative values (N-Me: -2.90 mm and Nperp-A: 4.35 mm), while actual set-back values were different (Nperp-Pg: -3.37 mm).

Manual predictions of Co-A, Co-Gn, and U6t-FH were less accurate compared with digital predictions. This may be attributed to the ability to adjust the contrast values of cephalometric images in computer software, thus allowing a clear visualization of points, which may be difficult to distinguish otherwise.

Overjet and overbite predictions showed poor agreement with postoperative values in both methods. Postoperative radiographs of the study subjects were obtained after a period of intermaxillary fixation. Therefore, strong elastics used in the anterior region during this phase may have affected the measurements. Moreover, unpredictable dental movement may occur because of the low anchorage value of the incisors.

Limitations

Being a pilot study, there are certain limitations in this research. First, the sample size is small (5 females and 5 males), but a more detailed study with 30 subjects is ongoing. Second, this study did not include the assessment and comparison of soft tissue changes after orthognathic surgery. Soft tissue parameters were intentionally excluded while designing the pilot study as the complete healing of soft tissues following orthognathic surgeries requires a long time. As mentioned before, a more detailed study is ongoing to specifically address these limitations. Nevertheless, this pilot study provides valuable initial data regarding the accuracy of manual and digital cephalometric prediction methods.

CONCLUSION

Cephalometric points and their associated parameters (Co and U6) with low reproducibility reduce the reliability of prediction.

Cephalometric points that are difficult to distinguish using the manual method can be visualized through digital images by adjusting contrast settings.

Dental predictions were inaccurate in both methods due to the effects of intermaxillary elastics.

Both methods yielded similar predictions for skeletal parameters. Skeletal predictions were more accurate than dental predictions.

The effect of applying strong elastics for postoperative intermaxillary fixation should be considered in manual or digital predictions.

Mechanisms that enhance anchorage, such as skeletal anchorage units, can be used to reduce unwanted dental movement caused by strong elastics.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethical Committee of Ankara University School of Dentistry (24.04.2017).

Informed Consent: Written informed consent was obtained from the volunteers who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - C.A., A.T.A.; Design - C.A., A.T.A.; Supervision - A.T.A., T.U.T.M; Data Collection and/or Processing - E.M.A., E.B.; Analysis and/or Interpretation - A.T.A., T.U.T.M.; Writing Manuscript - C.A., A.T.A.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Cohen MI. Mandibular prognathism. Am J Orthod 1965; 51: 368-79. [CrossRef]
2. McNeill RW, Proffit WR, White RP. Cephalometric prediction for orthodontic surgery. Angle Orthod 1972; 42: 154-64.
3. Henderson D. The assessment, management of bony deformities of the middle, lower face. Br J Plast Surg 1974; 66: 378-96. [CrossRef]
4. Worms FW, Isaacson RJ, Spiedel TM. Surgical orthodontic treatment planning: Profile analysis and mandibular surgery. Angle Orthod 1976; 46: 1-25.
5. Hohl TH, Wolford LM, Epker BN, Fonseca RJ. Craniofacial osteotomies: A photocephalometric technique for the prediction and evaluation of tissue changes. Angle Orthod 1978; 48: 114-25.
6. Fish LC, Epker BN. Surgical-orthodontic cephalometric prediction tracing. J Clin Orthod 1980; 14: 36-52.
7. Bench RW, Gugino CF, Hilgers JJ. Bioprogressive therapy: Part 2-principles of the therapy. J Clin Ortodod 1977; 11: 661-8.
8. Wolford LM, Hilliard FW, Dugan DJ. Surgical treatment objective. A systematic approach to the prediction tracing. 1985. Mosby Year Book, St Louis, pp 54-74.
9. Altug AT, Bolatoglu H, Toygar Memikoglu U. Facial soft tissue profile following bimaxillary orthognathic surgery. Angle Orthod 2008; 78: 50-7. [CrossRef]
10. Bhatia SN, Sowray JH. A computer-aided design for orthognathic surgery. Br J Oral Maxillofac Surg 1984; 22: 237-53. [CrossRef]
11. Harradine NWT, Burnie DJ. Computerized prediction of the results of orthognathic surgery. J Maxillofac Surg 1985; 13: 245-9. [CrossRef]
12. Walters H, Walters HD. Computerized planning of maxillofacial osteotomies: The program and its clinical applications. Br J Oral Maxillofac Surg 1989; 24: 178-89. [CrossRef]
13. Kaipatur N, Al-Thomali Y, Flores-Mir C. Accuracy of computer programs in predicting orthognathic surgery hard tissue response. J Oral Maxillofac Surg 2009; 67: 1628-39. [CrossRef]
14. Pektas ZO, Kircelli BH, Cilasun U, Uckan S. The accuracy of computer-assisted surgical planning in soft tissue prediction following orthognathic surgery. Int J Med Robot 2007; 3: 64-71. [CrossRef]
15. Sinclair PM, Kilpelainen P, Phillips C, White RP Jr, Rogers L, Sarver DM. The accuracy of video imaging in orthognathic surgery. Am J Orthod Dentofac Orthop 1995; 107: 177-85. [CrossRef]
16. Harradine NW, Birnie DJ. Computerized prediction of the results of orthognathic surgery. J Maxillofac Surg 1985; 13: 245-9. [CrossRef]
17. Loh S, Heng JK, Ward-Booth P, Winchester L, McDonald F. A radiographic analysis of computer prediction in junction with orthognathic surgery. Int J Oral Maxillofac Surg 2001; 30: 259-63. [CrossRef]