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Radiographic Imaging Multidisciplinary Approach to Orthognathic Surgery: Integrating Orthodontic Planning, Oral Surgical Intervention, and Radiological Assessment

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ABSTRACT:

Background:

Orthognathic surgery requires accurate assessment of dentofacial skeletal discrepancies and precise coordination between orthodontic and surgical treatment objectives. Advances in three-dimensional (3D) imaging and virtual surgical planning (VSP) have provided improved opportunities for individualized treatment planning and prediction of postoperative skeletal outcomes.

Aim:

The present study aimed to evaluate the effectiveness and accuracy of integrated radiographic assessment and 3D VSP in patients undergoing orthognathic surgery.

Materials and Methods:

This observational study included 60 patients undergoing orthognathic surgical treatment. Comprehensive radiographic assessment was performed using panoramic radiographs, lateral and posteroanterior (PA) cephalograms, and cone-beam computed tomography (CBCT), as indicated. 3D VSP was used to determine the proposed skeletal movements and assist in multidisciplinary treatment planning. Presurgical cephalometric parameters were assessed before orthodontic treatment and immediately before surgery. Planned skeletal movements were subsequently compared with postoperative measurements. Clinical and radiological outcomes, treatment-plan modifications, multidisciplinary agreement, and planning confidence were also evaluated. Statistical analysis was performed using appropriate descriptive, comparative, and correlation-based methods.

Results:

Presurgical orthodontic preparation resulted in significant changes in the assessed skeletal and dental cephalometric parameters. Bimaxillary surgery was the most frequently performed surgical approach. Comparison of planned and postoperative skeletal movements demonstrated close correspondence across the evaluated maxillary and mandibular dimensions. Strong positive correlations were observed between virtually planned and postoperative skeletal movements. Postoperative assessment demonstrated generally favorable skeletal, occlusal, facial, and radiological outcomes, with stable positioning of the operated skeletal segments in most patients. Integration of orthodontic, surgical, and radiological assessments resulted in treatment-plan refinement in a proportion of cases and was associated with high multidisciplinary agreement and confidence in the finalized surgical plan.

Conclusion:

Integrated radiographic assessment combined with 3D VSP provides an effective and reliable approach to orthognathic surgical management. The multidisciplinary workflow facilitates comprehensive diagnosis, individualized treatment planning, accurate prediction of skeletal movements, and improved coordination between orthodontic and surgical objectives. This approach may enhance the precision, predictability, and overall quality of orthognathic surgical treatment.

INTRODUCTION

Orthognathic surgery is a multidisciplinary treatment modality used to correct dentofacial skeletal discrepancies that cannot be adequately managed through orthodontic treatment alone. Successful management of patients with dentofacial deformities requires close coordination among orthodontists, oral and maxillofacial surgeons, and radiologists. The integration of clinical findings, orthodontic records, and radiographic information allows accurate identification of skeletal and dental abnormalities and facilitates development of an individualized treatment strategy [1].

Radiographic imaging plays a central role in the diagnosis and planning of orthognathic procedures. Conventional two-dimensional (2D) modalities, including panoramic and lateral cephalometric radiographs, provide valuable information regarding dental relationships, skeletal proportions, and craniofacial morphology. However, their inherent limitations, including image distortion, superimposition of anatomical structures, and restricted visualization of three-dimensional (3D) relationships, may affect precise assessment in complex cases [2].

The increasing availability of cone-beam computed tomography (CBCT) has substantially improved 3D evaluation of the maxillofacial region. CBCT enables detailed visualization of skeletal structures, tooth position, root morphology, impacted teeth, airway dimensions, and important anatomical landmarks. These data can assist in determining the extent of skeletal discrepancy, identifying potential surgical risks, and improving the accuracy of osteotomy planning [3].

Orthodontic planning represents an essential component of orthognathic treatment because dental decompensation and appropriate presurgical tooth positioning influence the final skeletal correction. Digital cephalometric analysis and 3D imaging can be combined to evaluate occlusal relationships, facial proportions, and anticipated skeletal movements. Such integration helps orthodontists and surgeons establish a coordinated treatment objective before surgical intervention [4].

From the surgical perspective, 3D radiographic information facilitates assessment of the anatomical characteristics relevant to procedures such as Le Fort I osteotomy, bilateral sagittal split osteotomy, and genioplasty. Precise visualization of cortical boundaries, mandibular canals, tooth roots, and other critical structures may contribute to safer osteotomy design and reduce the likelihood of inadvertent injury [5].

The incorporation of computer-assisted virtual surgical planning (VSP) has further expanded the role of radiological assessment in orthognathic surgery. 3D datasets can be combined with digital dental models or intraoral scans to create a comprehensive representation of the patient's craniofacial anatomy. Virtual simulation permits assessment of proposed maxillary and mandibular movements before surgery and provides a basis for fabrication of patient-specific surgical splints or guides [6].

An important advantage of a multidisciplinary imaging-based workflow is the ability to establish communication between orthodontic and surgical teams using a common 3D treatment plan. Radiological findings can be correlated with clinical and dental information, allowing discrepancies between the intended and achievable surgical movements to be recognized during the planning stage. This coordinated approach may improve treatment predictability and postoperative occlusal and facial outcomes [7].

Despite these advances, radiographic imaging should be selected according to the clinical requirements of each patient. Appropriate consideration of radiation exposure, image quality, anatomical coverage, and diagnostic necessity is essential, particularly when CBCT is used. Radiologists therefore have an important role in optimizing imaging protocols, interpreting anatomical findings, and communicating clinically relevant observations to the orthodontic and surgical teams [8], [9].

Overall, the integration of radiographic imaging with orthodontic analysis and oral surgical planning represents an increasingly important component of contemporary orthognathic care. A coordinated multidisciplinary approach can provide comprehensive anatomical assessment, improve visualization of planned skeletal movements, facilitate identification of surgical risks, and support more predictable treatment outcomes. Therefore, evaluating the contribution of radiographic imaging within an integrated orthodontic–surgical workflow is important for optimizing diagnosis, treatment planning, and surgical execution in patients undergoing orthognathic surgery.

MATERIALS & METHODS

Study Design and study population

The present study was conducted as a clinical observational study at a single tertiary care centre to evaluate the role of integrated radiographic assessment and 3D VSP in patients undergoing orthognathic surgery. A total of 60 patients requiring surgical correction of dentofacial skeletal discrepancies were included. The study population consisted predominantly of young adults with skeletal malocclusions requiring orthognathic intervention.

Patient Selection

Inclusion Criteria

- Patients diagnosed with skeletal malocclusion and planned for orthognathic surgical treatment
- Patients requiring corrective surgery involving the maxilla, mandible, or both jaws
- Patients with adequate preoperative clinical, radiographic, and cephalometric records
- Patients with appropriate CBCT and/or 3D VSP records where applicable
- Patients with sufficient postoperative clinical and radiological documentation for assessment of surgical outcomes
- Patients who underwent the planned orthognathic surgical procedure and had adequate records for comparison of planned and postoperative skeletal movements
- **Exclusion Criteria**
- Patients who were not considered suitable for orthognathic surgical treatment
- Patients with incomplete or inadequate diagnostic records
- Patients with missing or poor-quality preoperative or postoperative radiographic documentation
- Patients without sufficient information to compare virtually planned and postoperative skeletal movements
- Patients with incomplete cephalometric or clinical assessment records
- Patients whose treatment records were insufficient for evaluation of postoperative clinical or radiological outcomes
- Patients who underwent procedures unrelated to the correction of skeletal dentofacial discrepancies

Radiographic assessment

Each patient underwent comprehensive preoperative radiographic evaluation. Panoramic radiographs and lateral cephalograms were obtained routinely. Posteroanterior (PA) cephalometric imaging was performed when assessment of transverse skeletal relationships or facial asymmetry was required. Cone-beam computed tomography (CBCT) was used to provide 3D visualization of the craniofacial skeleton and relevant anatomical structures.

The radiographic records were assessed for skeletal relationships, dental inclination, facial asymmetry, and other parameters relevant to orthognathic treatment planning. Standardized cephalometric measurements were obtained before orthodontic treatment and immediately before surgery.

Presurgical orthodontic assessment

Patients underwent presurgical orthodontic preparation according to their individual skeletal and dental requirements. Cephalometric parameters, including the ANB angle, overjet, Wits appraisal, U1-SN angle, and mandibular incisor plane angle (IMPA), were evaluated at the relevant treatment stages. Changes in these measurements were used to assess dental decompensation and preparation of the dentition for surgical correction.

3D VSP

3D VSP was performed using the available CBCT-based craniofacial data. The digital assessment enabled visualization of the skeletal discrepancy and simulation of the intended surgical movements. The planned direction and magnitude of maxillary and mandibular movements were documented before surgery. The virtual plan was reviewed in conjunction with orthodontic and surgical findings. When necessary, modifications were made to the initial treatment plan with respect to the extent of maxillary or mandibular movement, the requirement for bimaxillary surgery, and the need for adjunctive procedures such as genioplasty.

Orthognathic surgical procedures

The surgical procedures were selected according to the underlying skeletal discrepancy and individualized treatment objectives. The procedures included Le Fort I osteotomy, bilateral sagittal split osteotomy (BSSO), combined bimaxillary surgery, bimaxillary surgery with genioplasty, and selected segmental or adjunctive procedures. Surgical movements were performed according to the finalized treatment plan.

Assessment of surgical accuracy

The accuracy of VSP was evaluated by comparing the skeletal movements predicted during preoperative planning with the corresponding postoperative measurements. Maxillary anteroposterior (AP) and vertical movements, as well as mandibular AP and transverse movements, were assessed. The absolute differences between planned and achieved movements were calculated to determine the degree of agreement.

Postoperative Evaluation

Postoperative clinical and radiological assessments were performed to evaluate treatment outcomes. Clinical parameters included skeletal correction, postoperative occlusion, and facial symmetry. Radiological evaluation included assessment of skeletal segment positioning and fixation stability. Any positional discrepancies or major postoperative complications were documented.

Multidisciplinary Assessment

Orthodontic, surgical, and radiological assessments were integrated throughout the treatment-planning process. The extent of agreement between orthodontic and surgical assessments and between radiological and surgical assessments was evaluated. The confidence of the multidisciplinary team in the finalized treatment plan was recorded using a 10-point planning confidence scale.

Statistical Analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA). Appropriate descriptive and inferential statistical methods were applied according to the type and distribution of the data. Continuous variables such as age were expressed as mean ± standard deviation (SD), while categorical variables were summarized as frequencies and percentages. Pre- and pre-surgical cephalometric measurements were compared using the paired t-test. The accuracy of planned versus postoperative skeletal movements was assessed by calculating absolute differences, while the relationship between planned and achieved movements was evaluated using Pearson's correlation coefficient (r). A p value <0.05 was considered statistically significant.

RESULTS

Table 1 & Figure 1 illustrate the demographic and clinical characteristics of the study population, which comprised 60 patients undergoing orthognathic surgery. The mean age of the participants was 24.9 ± 5.1 years. Most patients were in the 21–30-year age group (34; 56.7%), followed by those aged 18–20 years (14; 23.3%) and >30 years (12; 20.0%). A slight male predominance was observed, with 34 males (56.7%) and 26 females (43.3%). With respect to the underlying skeletal discrepancy, Skeletal Class III malocclusion was the most common presentation, accounting for 31 cases (51.7%). This was followed by Skeletal Class II malocclusion in 17 patients (28.3%), while vertical/transverse skeletal discrepancies were identified in 12 patients (20.0%). Overall, the study cohort primarily consisted of young adults, with Skeletal Class III malocclusion being the predominant indication for orthognathic surgical treatment.

Table 1: Study population and demographic characteristics

	Parameter	**n (%) / Mean ± SD**
	Age (years)	24.9 ± 5.1
Age Group	Age group 18–20 years	14 (23.3%)
	Age group 21–30 years	34 (56.7%)
	Age group >30 years	12 (20.0%)
Gender	Male	34 (56.7%)
	Female	26 (43.3%)
Type of Malocclusion	Skeletal Class II	17 (28.3%)
	Skeletal Class III	31 (51.7%)
	Vertical/transverse discrepancy	12 (20.0%)

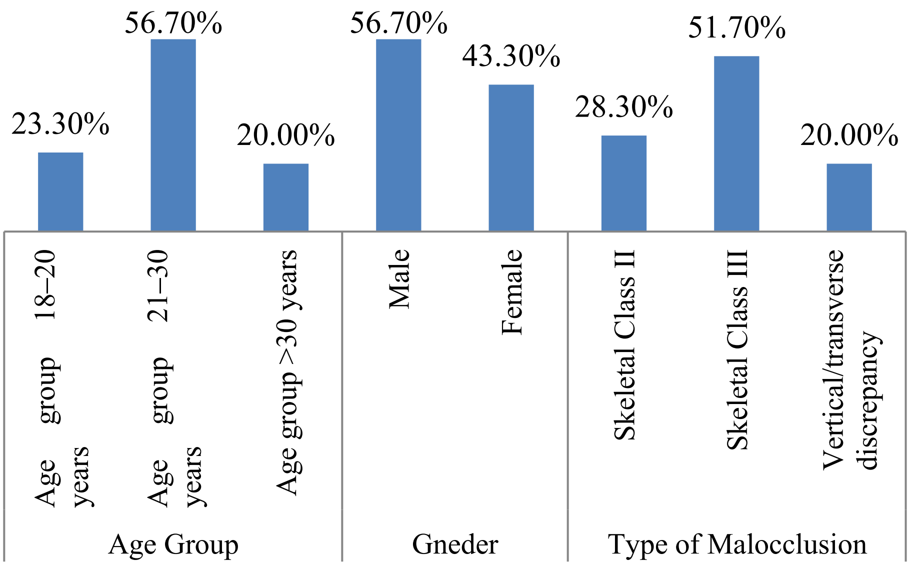

Figure 1: Distribution of study participants according to age group, sex, and type of skeletal discrepancy

Table 2 & Figure 2 illustrate the radiographic assessment performed in the study population using a combination of imaging modalities to support comprehensive evaluation and multidisciplinary treatment planning for orthognathic surgery. Panoramic radiographs and lateral cephalograms were obtained for all 60 patients (100.0%), providing routine evaluation of dental structures, skeletal relationships, and cephalometric parameters. Posteroanterior cephalometric radiographs were obtained in 42 patients (70.0%), primarily for assessment of transverse skeletal relationships and facial asymmetry. CBCT was performed in 48 patients (80.0%), enabling 3D evaluation of skeletal morphology and relevant anatomical structures. 3D VSP was utilized in 45 patients (75.0%), allowing precise visualization of the proposed skeletal movements and integration of orthodontic and surgical treatment objectives. Overall, the combined application of 2D and 3D imaging techniques provided comprehensive radiological assessment and supported individualized surgical planning.

Table 2: Radiographic imaging modalities and diagnostic assessment

Imaging modality	Patients (n)	Percentage
Panoramic radiograph	60	100.0%
Lateral cephalogram	60	100.0%
Posteroanterior cephalogram	42	70.0%
CBCT	48	80.0%
3D VSP	45	75.0%

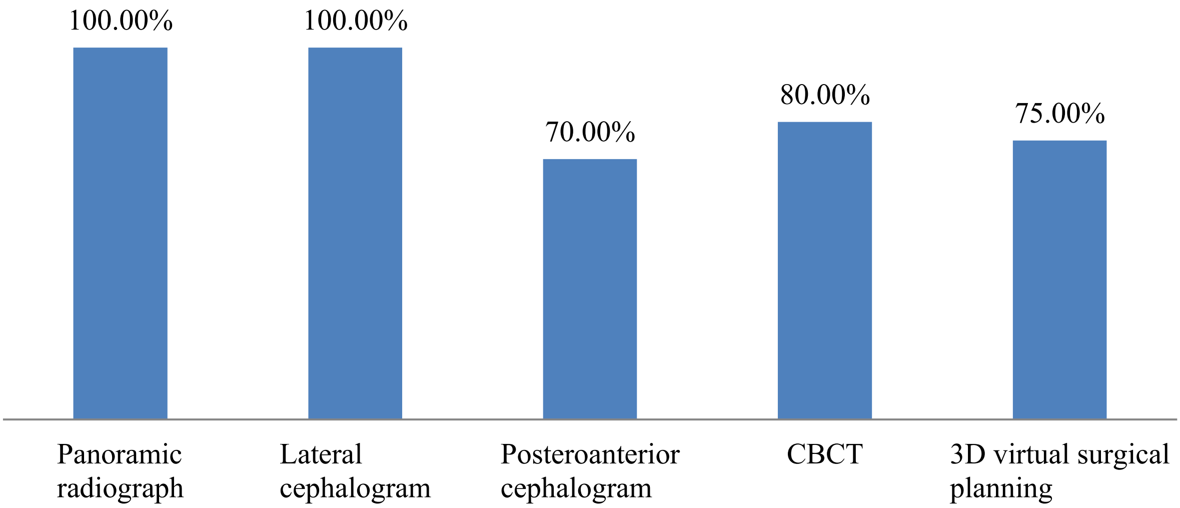

Figure 2: Distribution of patients according to the radiographic imaging modalities and 3D VSP used for orthognathic surgery

Table 3 & Figure 3 present the comparison of cephalometric parameters recorded before orthodontic treatment and immediately before orthognathic surgery. Significant changes were observed across all evaluated measurements following presurgical orthodontic preparation. The mean ANB angle increased from −3.8 ± 2.4° at baseline to −1.2 ± 1.9° before surgery, indicating a mean improvement of 2.6° ($p < 0.001$). Similarly, the mean overjet improved from −4.1 ± 2.0 mm to −1.0 ± 1.5 mm, corresponding to a mean change of 3.1 mm ($p < 0.001$). The Wits appraisal also showed significant improvement, changing from −7.0 ± 3.2 mm to −4.1 ± 2.7 mm, with a mean difference of 2.9 mm ($p < 0.001$). Regarding dental inclination, the mean U1-SN angle increased significantly from 106.4 ± 8.2° before orthodontic treatment to 111.1 ± 7.5° immediately before surgery, representing a mean increase of 4.7° ($p = 0.002$). Conversely, the mean IMPA decreased from 80.6 ± 7.4° to 76.8 ± 6.9°, corresponding to a mean reduction of 3.8° ($p = 0.004$). Overall, these findings demonstrate significant alterations in both skeletal and dental cephalometric parameters following presurgical orthodontic preparation. The observed changes are consistent with dental decompensation and optimization of the skeletal–dental relationship before orthognathic surgery

Table 3: Cephalometric parameters before and after orthodontic preparation

Cephalometric variable	Pre-orthodontic	Pre-surgical	Mean change	p value
ANB angle (°)	−3.8 ± 2.4	−1.2 ± 1.9	2.6°	<0.001
Overjet (mm)	−4.1 ± 2.0	−1.0 ± 1.5	3.1 mm	<0.001
Wits appraisal (mm)	−7.0 ± 3.2	−4.1 ± 2.7	2.9 mm	<0.001
U1-SN (°)	106.4 ± 8.2	111.1 ± 7.5	4.7°	0.002
IMPA (°)	80.6 ± 7.4	76.8 ± 6.9	−3.8°	0.004

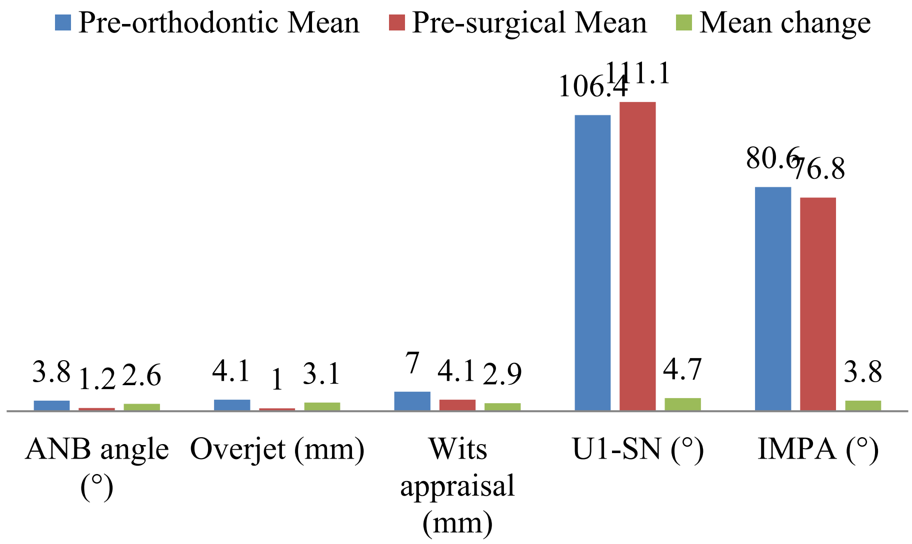

Table 4 & Figure 4 present the distribution of orthognathic surgical procedures performed among the 60 patients included in the study. Bimaxillary surgery consisting of Le Fort I osteotomy combined with bilateral sagittal split osteotomy (BSSO) was the most commonly performed procedure, accounting for 30 cases (50.0%). BSSO alone was performed in 12 patients (20.0%), while Le Fort I osteotomy alone was undertaken in 8 patients (13.3%). Bimaxillary surgery combined with genioplasty was performed in 6 patients (10.0%), whereas segmental and other adjunctive procedures accounted for 4 cases (6.7%). Overall, bimaxillary surgical correction was the predominant treatment approach, indicating that a substantial proportion of patients required coordinated maxillary and mandibular repositioning to address complex skeletal discrepancies and achieve comprehensive 3D correction.

Table 4: Orthognathic surgical procedures

Surgical procedure	n	%
Le Fort I osteotomy alone	8	13.3%
BSSO alone	12	20.0%
Le Fort I + BSSO (bimaxillary)	30	50.0%
Bimaxillary + genioplasty	6	10.0%
Segmental/other adjunctive procedure	4	6.7%
Total	60	100.0%

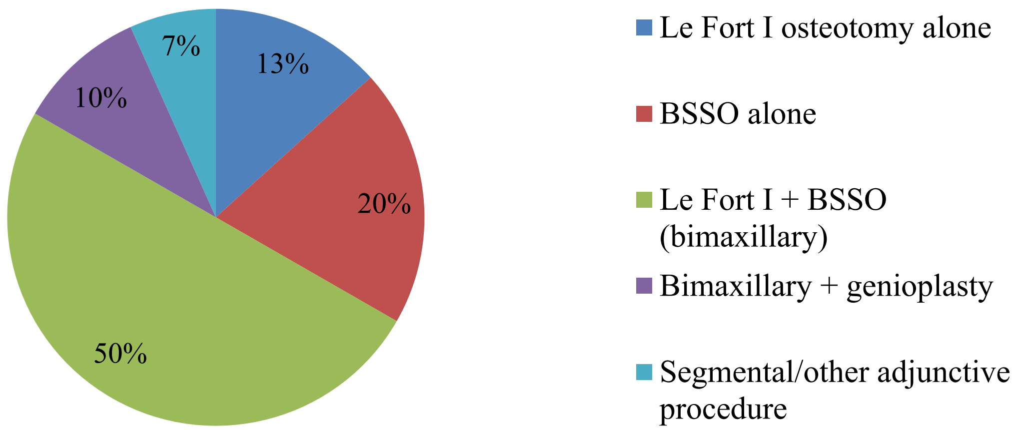

Figure 4: Distribution of patients according to the type of orthognathic surgical procedure performed

Table 5 & Figure 5 present a comparison between the skeletal movements planned during VSP and the corresponding postoperative measurements. Overall, the findings demonstrated a close agreement between the planned and achieved surgical movements, indicating a high degree of accuracy and predictability of the radiographic and 3D VSP approach. For the maxilla, the mean planned AP movement was 4.8 ± 2.1 mm, compared with 4.6 ± 2.0 mm postoperatively, yielding an absolute difference of 0.9 ± 0.7 mm. The planned vertical maxillary movement averaged 2.7 ± 1.4 mm, while the postoperative measurement was 2.6 ± 1.3 mm, with an absolute difference of 0.8 ± 0.6 mm. For the mandible, the mean planned AP movement was 6.1 ± 2.8 mm, compared with 5.9 ± 2.7 mm after surgery, resulting in an absolute difference of 1.2 ± 0.8 mm. The planned transverse mandibular correction was 2.4 ± 1.2 mm, compared with 2.3 ± 1.1 mm postoperatively, producing the smallest absolute difference of 0.7 ± 0.5 mm.

Taken together, the minimal differences between planned and postoperative measurements demonstrate good surgical accuracy and predictability of integrated radiographic and 3D VSP. Among the assessed movements, transverse mandibular correction showed the closest correspondence between the planned and achieved outcomes.

Table 5: Accuracy of radiographic and VSP

Measurement	**Planned movement (mm)**	**Postoperative movement (mm)**	**Absolute difference (mm)**
Maxillary AP movement	4.8 ± 2.1	4.6 ± 2.0	0.9 ± 0.7
Maxillary vertical movement	2.7 ± 1.4	2.6 ± 1.3	0.8 ± 0.6
Mandibular AP movement	6.1 ± 2.8	5.9 ± 2.7	1.2 ± 0.8
Mandibular transverse correction	2.4 ± 1.2	2.3 ± 1.1	0.7 ± 0.5

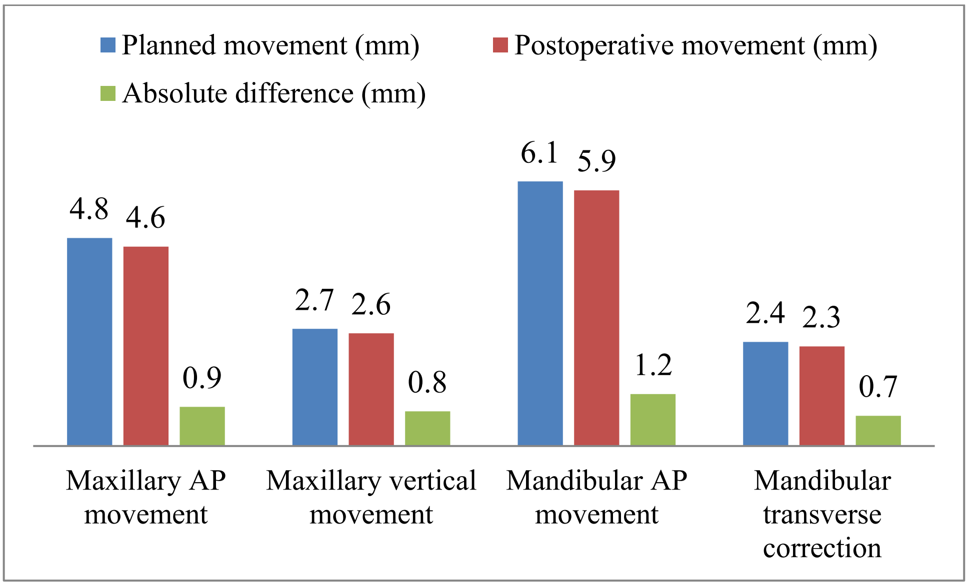

Table 6 & Figure 6 present the postoperative clinical and radiological outcomes observed among the 60 patients who underwent orthognathic surgery. Overall, the results indicated favorable treatment outcomes across the evaluated parameters. Satisfactory skeletal correction was achieved in 53 patients (88.3%), demonstrating effective correction of the underlying skeletal deformity. Satisfactory postoperative occlusion was observed in 55 patients (91.7%), representing the highest proportion of favorable clinical outcomes. Good facial symmetry was achieved in 52 patients (86.7%), indicating satisfactory improvement in facial proportions and skeletal alignment.

Postoperative radiographic assessment showed stable fixation with satisfactory positioning of the operated skeletal segments in 57 patients (95.0%). A minor positional discrepancy was detected in 3 patients (5.0%); however, these deviations were not associated with significant functional impairment. Major surgical complications occurred in 2 patients (3.3%). Overall, the findings demonstrate a high rate of favorable clinical and radiological outcomes following orthognathic surgery, with satisfactory skeletal correction, postoperative occlusion, and facial symmetry achieved in most patients. The high proportion of patients showing stable postoperative skeletal positioning further supports the effectiveness and predictability of the surgical approach.

Table 6: Clinical and radiological outcomes

Outcome	**n (%)**
Satisfactory skeletal correction	53 (88.3%)
Satisfactory postoperative occlusion	55 (91.7%)
Good facial symmetry	52 (86.7%)
Stable fixation on postoperative imaging	57 (95.0%)
Minor positional discrepancy	3 (5.0%)
Major surgical complication	2 (3.3%)

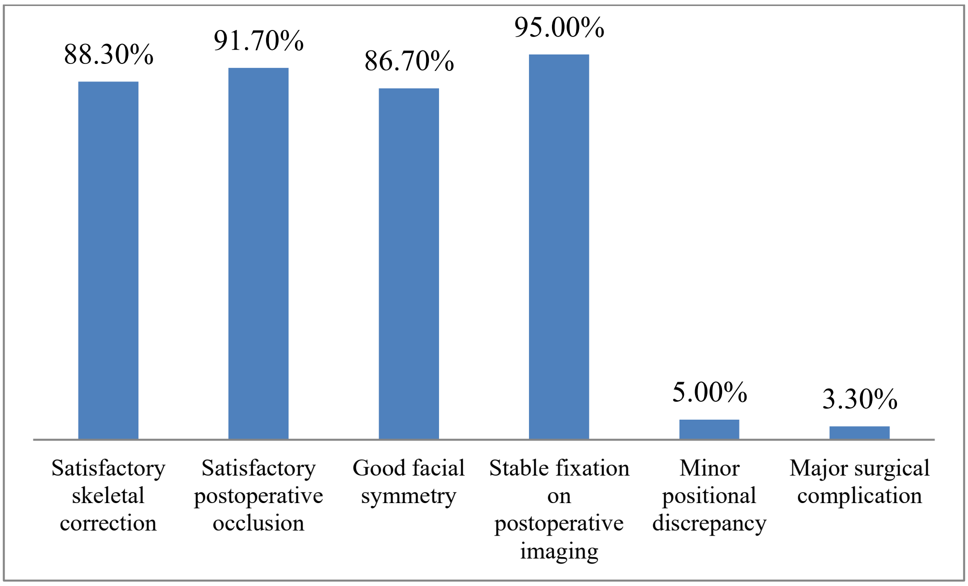

Figure 6: Distribution of patients according to postoperative clinical and radiological outcomes following orthognathic surgery

Table 7 & Figure 7 present the influence of multidisciplinary integration of orthodontic, oral surgical and radiological assessments on the treatment-planning process. The initial treatment plan was refined in 18 patients (30.0%), while no major modification was considered necessary in 42 patients (70.0%). The principal changes involved adjustment of the magnitude or direction of maxillary and mandibular skeletal movements, reassessment of the requirement for bimaxillary surgery, and consideration of adjunctive genioplasty. A high level of concordance between orthodontic and surgical assessments was observed in 54 patients (90.0%), whereas agreement between radiological and surgical assessments was recorded in 55 patients (91.7%). The mean planning confidence score was 8.7 ± 1.1 on a 10-point scale, reflecting a high degree of confidence in the multidisciplinary approach to treatment planning. Overall, the findings indicate that integrating orthodontic, surgical, and radiological evaluations enhanced the accuracy, consistency, and confidence of orthognathic surgical planning. The multidisciplinary approach also facilitated identification of treatment modifications that might not have been recognized through assessment by a single discipline alone.

Table 7: Effect of multidisciplinary integration on treatment planning

Parameter	n (%) / Mean ± SD
Treatment plan modified after multidisciplinary review	18 (30.0%)
No major modification required	42 (70.0%)
High orthodontic–surgical agreement	54 (90.0%)
High radiological–surgical agreement	55 (91.7%)
Mean planning confidence score (0–10)	8.7 ± 1.1

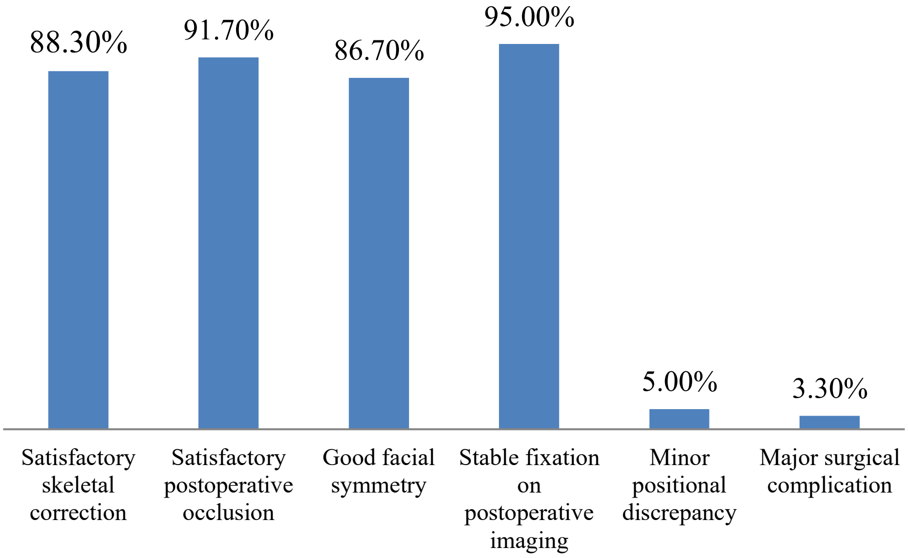

Figure 7: Impact of multidisciplinary orthodontic, surgical, and radiological assessment on treatment planning and planning confidence

Table 8 presents the correlation between the skeletal movements planned using VSP and the corresponding postoperative measurements. A strong positive correlation was observed for all evaluated skeletal parameters, indicating close agreement between the planned and achieved surgical movements. The strongest correlation was identified for maxillary AP movement ($r = 0.91$, $p < 0.001$), demonstrating a very high level of correspondence between the planned and postoperative measurements. Maxillary vertical movement also showed a strong positive correlation ($r = 0.86$, $p < 0.001$). For the mandible, mandibular AP movement demonstrated a strong positive correlation ($r = 0.89$, $p < 0.001$), while mandibular transverse movement showed a similarly strong association ($r = 0.82$, $p < 0.001$). All observed correlations were statistically significant. Overall, these findings demonstrate a strong relationship between virtually planned and postoperative skeletal movements, supporting the accuracy, reliability, and predictive value of integrated radiographic and 3D VSP.

Table 8: Correlation between planned and postoperative skeletal measurements

Variable	Correlation coefficient (r)	p value	Interpretation
Maxillary AP movement	0.91	<0.001	Strong positive correlation
Maxillary vertical movement	0.86	<0.001	Strong positive correlation
Mandibular AP movement	0.89	<0.001	Strong positive correlation
Mandibular transverse movement	0.82	<0.001	Strong positive correlation

DISCUSSION

The present discussion emphasizes the increasing importance of 3D radiographic imaging and VSP in orthognathic surgery, particularly in establishing a coordinated relationship between orthodontic preparation, surgical intervention, and radiological assessment. The transition from conventional 2D evaluation toward 3D imaging has improved visualization of complex dentofacial relationships and has provided clinicians with more comprehensive information for treatment planning.

Okumura et al. (1999) [10] demonstrated the usefulness of 3D VSP for evaluating the facial skeleton and dental morphology in patients undergoing orthognathic surgery. Their work highlighted the ability of 3D representations to overcome some of the limitations associated with conventional radiographs, particularly anatomical superimposition and difficulty in appreciating spatial relationships. These findings support the incorporation of 3D radiographic assessment into multidisciplinary treatment planning, where accurate visualization of skeletal and dental structures is essential for determining the appropriate surgical approach.

The development of computer-assisted planning has subsequently strengthened the integration of radiological information with surgical simulation. Haas et al. (2015) [11] reviewed computer-aided planning in orthognathic surgery and emphasized the growing role of digital technologies in treatment planning. Computer-assisted workflows allow radiographic datasets to be incorporated into virtual simulations, enabling clinicians to evaluate planned skeletal movements before surgery. Such an approach may improve communication between orthodontists and surgeons by providing a common digital platform for evaluating occlusion, skeletal discrepancies, and anticipated surgical changes.

The accuracy of transferring virtual plans into the surgical setting has also been investigated. Chin et al. (2017) [12] evaluated VSP combined with CAD/CAM-fabricated surgical splints and demonstrated the potential of this workflow for achieving accurate postoperative skeletal positioning. The use of patient-specific surgical splints can facilitate transfer of the digitally planned movements to the operating room. This is particularly relevant in multidisciplinary practice because the orthodontic treatment objective can be incorporated into the surgical plan and subsequently translated into a clinically applicable surgical guide.

Otranto de Britto Teixeira et al. (2020) [13] further investigated the 3D accuracy of VSP in orthognathic surgery. Their findings provided evidence that VSP can achieve a high degree of correspondence between planned and postoperative skeletal positions. 3D assessment is particularly valuable because orthognathic movements occur simultaneously in multiple spatial planes. Consequently, radiological evaluation based exclusively on 2D projections may not adequately demonstrate rotational or translational discrepancies. 3D imaging therefore provides a more comprehensive framework for evaluating surgical accuracy.

Accurate postoperative assessment also depends on appropriate radiological registration and superimposition methods. Andriola et al. (2022) [14] systematically evaluated computed tomography (CT) imaging superimposition protocols for assessing orthognathic surgical outcomes and provided recommendations for standardized evaluation. Their work emphasizes that postoperative assessment should not rely solely on visual comparison of preoperative and postoperative images. Standardized 3D superimposition can provide objective information regarding skeletal displacement and the relationship between the planned and achieved surgical positions. This strengthens the radiologist's role in outcome assessment and facilitates meaningful communication with the orthodontic and surgical teams.

More recently, Starch-Jensen et al. (2023) [15] systematically compared 3D VSP with conventional 2D planning and reported that the available evidence generally supports the increasing role of VSP, although results regarding hard- and soft-tissue accuracy remain somewhat inconsistent. Their review also identified advantages related to intraoperative efficiency, while recognizing increased financial expenditure associated with 3D VSP. These findings indicate that digital planning should be viewed as an evolving multidisciplinary technology rather than simply a replacement for conventional methods. Continued improvements in imaging, virtual simulation, surgical guides, and patient-specific fixation systems may further enhance the precision and clinical efficiency of orthognathic surgery.

Overall, the evidence from these studies demonstrates a progressive transition from conventional radiographic planning toward integrated 3D workflows. Radiographic imaging provides the anatomical foundation, orthodontic analysis establishes the desired dental and occlusal relationships, and VSP translates these objectives into a simulated surgical procedure. Close collaboration among orthodontists, oral and maxillofacial surgeons, and radiologists is therefore essential for maximizing the diagnostic and therapeutic value of modern imaging technologies. The integration of these disciplines may ultimately improve surgical predictability, facilitate objective postoperative assessment, and support individualized management of patients with complex dentofacial deformities.

LIMITATIONS

The present study has certain limitations that should be considered when interpreting the findings. The relatively small sample size of 60 patients and the single-center study setting may limit the generalizability of the results to larger and more diverse populations. The study included patients undergoing different types of orthognathic procedures, and variations in skeletal deformity, surgical technique, and treatment complexity may have influenced the observed outcomes. In addition, postoperative assessment was performed at a limited follow-up interval, which may not adequately reflect long-term skeletal stability, relapse, or changes in facial aesthetics and occlusion. The accuracy of VSP may also be influenced by factors such as patient positioning, image quality, registration errors, intraoperative variations, and differences between the planned and actual surgical execution. Furthermore, the assessment of certain clinical outcomes, including facial symmetry and overall treatment satisfaction, may involve a degree of subjectivity. The study also did not incorporate a direct comparison with patients managed using conventional surgical planning alone. Future multicenter studies with larger sample sizes, standardized assessment protocols, longer follow-up periods, and direct comparison of conventional and 3D VSP approaches are recommended to further validate the findings.

CONCLUSION

The present study concludes that an integrated approach combining orthodontic, surgical, and radiological assessment can effectively support the planning and execution of orthognathic surgery. The use of comprehensive imaging and 3D VSP facilitates detailed evaluation of skeletal discrepancies, improves visualization of the proposed surgical movements, and enables individualized treatment planning. The close correspondence between planned and postoperative skeletal outcomes further supports the usefulness of VSP in achieving predictable surgical results. Multidisciplinary collaboration also contributes to better coordination of treatment objectives and allows potential modifications to be identified before surgery. Overall, the findings support the incorporation of integrated radiographic and 3D VSP into contemporary orthognathic treatment protocols to enhance surgical precision, predictability, and clinical decision-making.

Conflicts of Interest: Nil

Financial Support: None

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