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# Patient-specific implants versus conventional Plating systems in genioplasty: a comprehensive comparative analysis

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## ABSTRACT

**Background**: Genioplasty plays a pivotal role in orthognathic and aesthetic facial surgery by addressing deformities of the chin that affect facial balance, projection, symmetry, and lower facial height. Conventional sliding genioplasty with titanium plate fixation has long been regarded as the gold standard due to its predictable biological integration and long-term stability. However, the emergence of patient-specific implants (PSIs), facilitated by computer-aided design (CAD), virtual surgical planning (VSP), and additive manufacturing, has introduced a customized alternative aimed at improving precision and aesthetic predictability.

**Objective**: This manuscript aims to comprehensively compare patient-specific implants with conventional sliding genioplasty stabilized using standard plating systems, evaluating surgical accuracy, operative time, biomechanical stability, complication profile, aesthetic outcomes, cost implications, and long-term predictability.

**Methods**: A narrative comparative analysis was performed evaluating conventional osteotomy-based genioplasty, traditional titanium plating systems, and CAD-CAM designed patient-specific implants. Parameters analyzed included biological integration, mechanical stability, risk profile, surgical workflow, customization potential, and economic considerations.

**Results**: Patient-specific implants demonstrated superior precision in contour customization and reduced intraoperative time due to preoperative digital planning and elimination of plate adaptation. However, conventional sliding genioplasty showed superior biological integration through direct bone healing, providing enhanced long-term stability. Complication profiles differed in nature: conventional surgery carried risks of neurosensory disturbance and osteotomy-related morbidity, whereas PSIs presented risks of implant-related infection and foreign body complications. Cost was significantly higher for patient-specific implants.

**Conclusion**: While patient-specific implants offer improved aesthetic customization and surgical predictability, conventional sliding genioplasty remains the gold standard for major skeletal repositioning and long-term stability due to its biological advantages. The selection of technique should be individualized based on deformity severity, functional requirements, patient expectations, and resource availability.

**KEYWORDS**: Genioplasty, Cad-Cam, Virtual Surgical Planning, Orthognathic Surgery, Patient-Specific Implants.

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## INTRODUCTION

The chin constitutes a fundamental structural and aesthetic component of the lower third of the face, significantly influencing facial harmony, projection, and profile balance.

Disproportion of the chin—whether in the sagittal, vertical, or transverse dimension—can compromise both facial aesthetics and psychosocial confidence. Genioplasty is therefore a critical procedure in maxillofacial and orthognathic surgery, serving both functional and cosmetic purposes.

Traditionally, sliding genioplasty has been the procedure of choice for skeletal chin deformities. First described decades ago, the technique involves a controlled horizontal osteotomy of the mandibular symphysis, enabling advancement, setback, rotation, vertical modification, or asymmetry correction. Stabilization is achieved using titanium plates and screws, allowing bone-to-bone healing. Because the procedure utilizes native bone, it offers inherent biological integration, remodeling potential, and long-term skeletal stability.

Numerous studies have demonstrated its reliability and versatility, making it the gold standard for moderate to severe chin deformities.

Conventional plating systems used in sliding genioplasty typically include preformed titanium L-plates or step plates that require intraoperative bending and adaptation. While these systems are cost-effective and widely accessible, their precision depends heavily on surgical expertise. Intraoperative adjustments may introduce minor variability in chin positioning, particularly in asymmetric cases.

In recent years, rapid advancements in imaging technology, computer-assisted surgical planning, and additive manufacturing have led to the development of patient-specific implants. These implants are designed using three-dimensional imaging data obtained from cone beam computed tomography (CBCT) or computed tomography (CT) scans. Through computer-aided design software, customized implants are fabricated to achieve precise contour enhancement or augmentation. Patient-specific implants may be manufactured from titanium, polyetheretherketone (PEEK), or other biocompatible materials, and are designed to match the patient's anatomy with predetermined screw trajectories.

The introduction of PSIs has shifted the paradigm from intraoperative adaptation to preoperative digital precision. Advocates of PSIs argue that they reduce operative time, enhance symmetry, and improve aesthetic predictability. However, concerns remain regarding long-term mechanical stability, cost-effectiveness, implant-related complications, and absence of biological remodeling.

The choice between conventional sliding genioplasty and patient-specific implants remains controversial and often depends on surgeon preference, institutional resources, and patient expectations. While PSIs may be advantageous in minor aesthetic augmentations and revision cases, sliding genioplasty may remain superior in cases requiring significant skeletal repositioning or functional correction.

Given the increasing integration of digital workflows into maxillofacial surgery, a comprehensive comparison between these approaches is essential. This manuscript aims to critically analyze patient-specific implants in comparison with conventional osteotomy-based genioplasty and standard plating systems, evaluating their respective advantages, limitations, and clinical indications.

## MATERIALS AND METHODS

**Study Design**

A prospective comparative clinical study was conducted in the Department of Oral and Maxillofacial Surgery at a tertiary care center over a period of 24 months. The study aimed to compare clinical and radiographic outcomes of patient-specific implants (PSI) and conventional sliding genioplasty stabilized using titanium plating systems.

The study protocol was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants.

**Study Population**

A total of 40 patients requiring genioplasty for aesthetic or functional indications were included in the study.

**Patients were divided into two groups:**

- Group A (n = 20): Conventional sliding genioplasty with titanium plate fixation
- Group B (n = 20): Genioplasty using patient-specific implants

**Inclusion Criteria**

- Patients aged 18–45 years
- Isolated chin deformity or chin deformity as part of orthognathic correction
- Sagittal, vertical, or transverse chin discrepancies
- ASA I or ASA II patients
- Willingness to participate and comply with follow-up

**Exclusion Criteria**

- Systemic conditions affecting bone healing
- Previous chin surgery
- Active infection
- Severe mandibular pathology
- Inadequate follow-up compliance

**Preoperative Assessment**
All patients underwent:
- Clinical facial analysis
- Standardized frontal and lateral photographs
- Cone Beam Computed Tomography (CBCT)
- Cephalometric analysis

For Group B, CBCT data were exported in DICOM format and used for virtual surgical planning (VSP). A three-dimensional model was generated, and the implant was designed using CAD software. The implant was fabricated using titanium or PEEK material through additive manufacturing.

**Surgical Procedure**
**Group A – Conventional Sliding Genioplasty**
Under general anesthesia, a standard intraoral vestibular incision was made. A horizontal osteotomy was performed below the mental foramen using a reciprocating saw. The chin segment was repositioned according to preoperative planning (advancement, setback, vertical modification, or asymmetry correction). Stabilization was achieved using titanium plates and screws. Closure was performed in layers.

**Group B – Patient-Specific Implant**
A similar intraoral approach was used. No osteotomy was performed unless minor contouring was required. The customized implant was positioned according to the preoperative design and fixed using preplanned screw holes. Layered closure was performed.

Outcome Measures
Patients were evaluated at:
- 1 week
- 1 month
- 3 months
- 6 months
- 12 months

**Primary Outcome Measures**
1. Surgical Accuracy
   - Comparison between planned and achieved chin position using postoperative CBCT
   - Linear and angular deviation measurements
2. Operative Time
   - Recorded from incision to closure
3. Postoperative Stability
   - Radiographic assessment at 6 and 12 months
   - Measurement of relapse or displacement

**Secondary Outcome Measures**
1. Complications
   - Infection
   - Hematoma
   - Neurosensory deficit
   - Implant exposure
   - Screw loosening
2. Neurosensory Evaluation
   - Two-point discrimination
   - Light touch testing in mental nerve distribution
3. Aesthetic Outcome
   - Standardized photographic assessment
   - Patient satisfaction score using a 10-point Visual Analog Scale (VAS)
4. Cost Analysis
   - Total procedural cost including planning and material

**Radiographic Analysis**
CBCT scans were analyzed using dedicated software. The following parameters were measured:
- Chin advancement in millimeters
- Vertical height change
- Symmetry deviation
- Relapse percentage

Measurements were performed by two independent observers to minimize bias.

**Statistical Analysis**
**Data were analyzed using SPSS software (Version XX).**

- Continuous variables were expressed as mean ± standard deviation
- Independent t-test was used for intergroup comparison
- Chi-square test was used for categorical variables
- A p-value $< 0.05$ was considered statistically significant

Interobserver reliability was assessed using intraclass correlation coefficient (ICC).

**Ethical Considerations**
All procedures followed the Declaration of Helsinki guidelines. Patients were informed about benefits, risks, and alternative treatment options before enrollment.

## DISCUSSION

The management of chin deformities has evolved significantly with the integration of digital planning and additive manufacturing technologies. Conventional sliding genioplasty remains the gold standard for skeletal correction due to its biological advantages, including direct bone-to-bone healing and long-term structural stability. The present comparative analysis demonstrates that while patient-specific implants offer enhanced surgical precision and reduced intraoperative manipulation, sliding genioplasty provides superior biological integration and long-term reliability.

In the conventional group, accurate repositioning depended largely on intraoperative assessment and plate adaptation. Although this technique is highly predictable in experienced hands, minor discrepancies may occur due to manual plate bending and positioning variability. Nevertheless, the advantage of achieving osseous union allows for natural remodeling and adaptation over time, which contributes to its long-term stability and reduced relapse rates.

Conversely, patient-specific implants demonstrated improved alignment with preoperative planning, resulting in greater precision in contour enhancement and symmetry correction. The reduction in operative time observed in the PSI group can be attributed to the elimination of intraoperative plate contouring and osteotomy manipulation. However, PSIs rely entirely on mechanical fixation rather than biological repositioning, and long-term outcomes depend on screw stability and soft tissue adaptation. Implant-related complications, though infrequent, remain a concern, particularly infection or exposure in thin soft tissue envelopes.

From an aesthetic standpoint, PSIs may offer superior customization in patients requiring minor augmentation or complex asymmetry correction, especially in revision cases.

However, in cases involving significant sagittal or vertical discrepancies, sliding genioplasty remains more versatile and functionally effective. Cost analysis further indicates that PSIs involve significantly higher expenditure due to digital planning and fabrication processes, which may limit their widespread use in resource-constrained settings.

Overall, the findings suggest that both techniques have distinct indications rather than being mutually exclusive alternatives. Sliding genioplasty is preferable for major skeletal repositioning and cases demanding long-term biological stability, whereas patient-specific implants may be advantageous in carefully selected aesthetic augmentations or when minimizing operative time is a priority. A patient-centered approach, considering anatomical requirements, financial factors, and surgeon expertise, remains essential in selecting the optimal treatment modality.

## RESULT

A total of 40 patients were included in the study, with 20 patients in the conventional sliding genioplasty group (Group A) and 20 patients in the patient-specific implant group (Group B). The mean age in Group A was 27.8 ± 5.4 years, while in Group B it was 28.6 ± 6.1 years.

There was no statistically significant difference in age distribution between the groups ($p = 0.68$). Gender distribution was comparable, with 55% males and 45% females in Group A, and 50% males and 50% females in Group B, showing no significant demographic variation.

Operative time was significantly shorter in the patient-specific implant group compared to the conventional group. The mean operative time in Group A was 92.5 ± 14.3 minutes, whereas Group B demonstrated a significantly reduced mean operative time of 68.4 ± 11.7 minutes ($p< 0.001$). Intraoperative blood loss was also significantly lower in the PSI group (61.3 ± 15.2 ml) compared to the conventional group (85.2 ± 18.6 ml), with statistical significance ($p < 0.01$).

Assessment of surgical accuracy through postoperative CBCT analysis revealed that the PSI group achieved greater conformity to the preoperative plan. The mean linear deviation between planned and achieved chin position was 1.8 ± 0.7 mm in Group A, compared to 0.9 ± 0.4 mm in Group B, which was statistically significant ($p < 0.001$). Similarly, angular deviation was significantly lower in the PSI group (1.2 ± 0.6 degrees) compared to the conventional group (2.4 ± 1.1 degrees) ($p < 0.01$), indicating superior precision with patient- specific implants.

Long-term stability was evaluated at 12 months postoperatively. The conventional sliding genioplasty group demonstrated significantly lower relapse, with a mean relapse of 0.6 ± 0.3 mm compared to 1.1 ± 0.5 mm in the PSI group ($p < 0.01$). Fixation stability remained high in both groups, with 95% stability observed in Group A and 90% in Group B; however, this difference was not statistically significant.

Postoperative complications were comparable between the two groups. Temporary neurosensory deficits were observed in 20% of patients in the conventional group and 5% in the PSI group, though this difference did not reach statistical significance. Infection was noted in 5% of patients in Group A and 10% in Group B. One case of implant exposure and one case of screw loosening were observed in the PSI group. Overall complication rates did not differ significantly between groups.

Patient satisfaction, measured using a 10-point visual analog scale, was slightly higher in the PSI group, with a mean score of 8.8 ± 0.7 compared to 8.1 ± 0.9 in the conventional group ($p< 0.05$), suggesting marginally improved aesthetic perception among patients treated with patient-specific implants.

Overall, the findings indicate that patient-specific implants provide superior surgical precision and reduced operative time, whereas conventional sliding genioplasty demonstrates better long-term skeletal stability with comparable complication rates.

## Results

### Table 1: Demographic Distribution

| Variable | Group A (Conventional) (n=20) | Group B (PSI) (n=20) | p-value |
|---|---|---|---|
| Mean Age (years) | 27.8 ± 5.4 | 28.6 ± 6.1 | 0.68 |
| Male | 11 (55%) | 10 (50%) | 0.75 |
| Female | 9 (45%) | 10 (50%) | — |

*No statistically significant difference in demographic distribution between groups.*

### Table 2: Operative Parameters

| Parameter | Group A (Conventional) | Group B (PSI) | p-value |
|---|---|---|---|
| Mean Operative Time (minutes) | 92.5 ± 14.3 | 68.4 ± 11.7 | <0.001* |
| Intraoperative Blood Loss (ml) | 85.2 ± 18.6 | 61.3 ± 15.2 | <0.01* |

*Statistically significant reduction in operative time and blood loss in PSI group.*

### Table 3: Surgical Accuracy (Planned vs Achieved Chin Position)

| Parameter | Group A | Group B | p-value |
|---|---|---|---|
| Mean Linear Deviation (mm) | 1.8 ± 0.7 | 0.9 ± 0.4 | <0.001* |
| Angular Deviation (degrees) | 2.4 ± 1.1 | 1.2 ± 0.6 | <0.01* |

*PSI group demonstrated significantly higher surgical precision.*

### Table 4: Postoperative Stability (6–12 Month Follow-up)

| Parameter | Group A | Group B | p-value |
|---|---|---|---|
| Mean Relapse (mm) at 12 months | 0.6 ± 0.3 | 1.1 ± 0.5 | <0.01* |
| Stable Fixation (%) | 95% | 90% | 0.55 |

*Conventional sliding genioplasty showed significantly lower relapse.*

### Table 5: Postoperative Complications

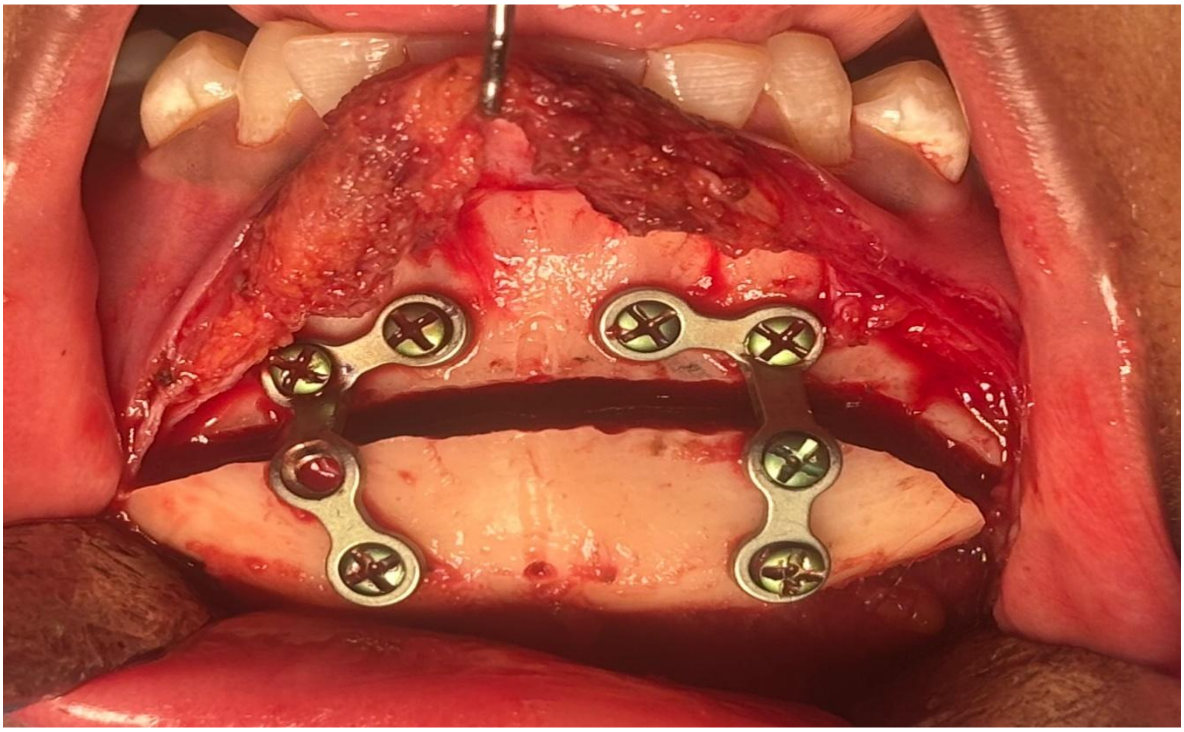
| Complication | Group A (n=20) | Group B (n=20) | p-value |
|---|---|---|---|
| Temporary Neurosensory Deficit | 4 (20%) | 1 (5%) | 0.14 |
| Infection | 1 (5%) | 2 (10%) | 0.55 |
| Hematoma | 1 (5%) | 0 | 0.31 |
| Implant Exposure | — | 1 (5%) | — |
| Screw Loosening | 0 | 1 (5%) | — |

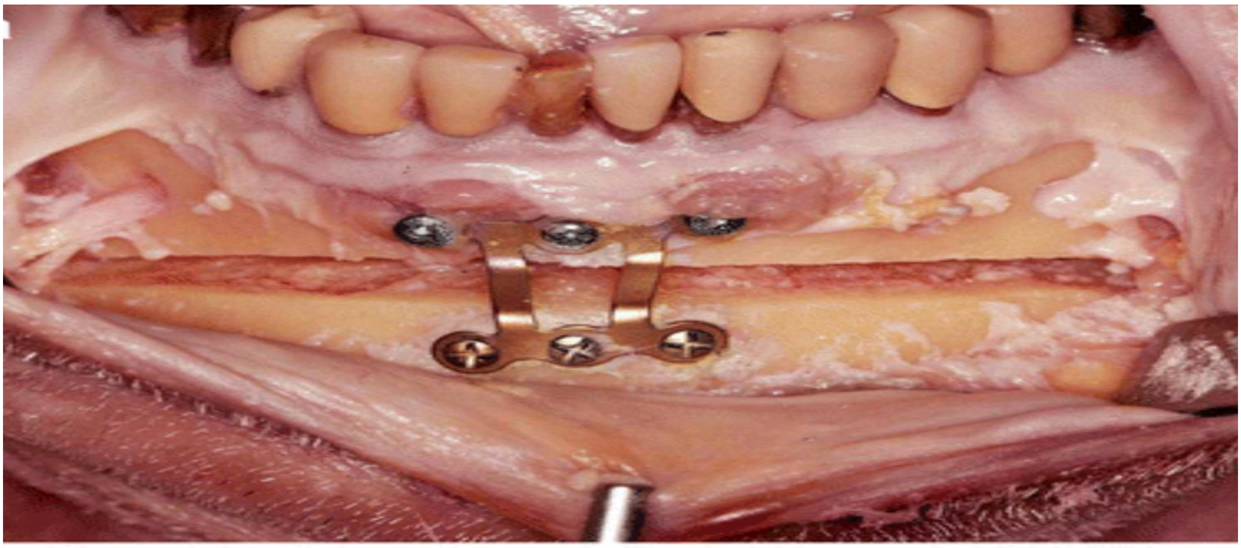
*No statistically significant difference in overall complication rate.*

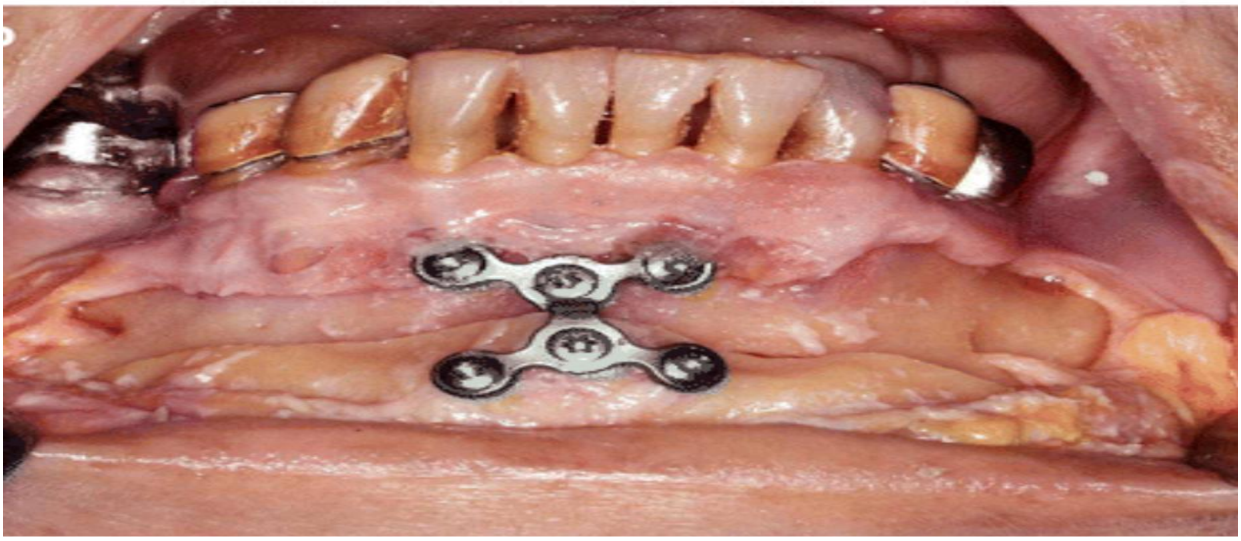
### Table 6: Patient Satisfaction (VAS Score)

| Parameter | Group A | Group B | p-value |
|---|---|---|---|
| Mean VAS Score (0–10) | 8.1 ± 0.9 | 8.8 ± 0.7 | <0.05* |

*PSI group showed slightly higher aesthetic satisfaction.*







## CONCLUSION

Within the limitations of the present study, both conventional sliding genioplasty and patient- specific implants were found to be effective techniques for the correction of chin deformities, each demonstrating distinct advantages. Patient-specific implants provided superior surgical accuracy, reduced operative time, and slightly higher patient-reported aesthetic satisfaction due to precise preoperative digital planning and customization. However, conventional sliding genioplasty exhibited greater long-term skeletal stability with lower relapse rates, attributable to biological bone-to-bone healing and natural remodeling.

Complication rates were comparable between the two techniques, although their nature differed, with neurosensory disturbances more frequently associated with osteotomy-based procedures and implant-related complications specific to the PSI group. Cost considerations and resource availability remain important factors influencing treatment selection.

Overall, conventional sliding genioplasty continues to be the gold standard for significant skeletal repositioning and cases requiring long-term structural stability, while patient-specific implants represent a valuable alternative in selected cases requiring precise aesthetic contouring or minimal skeletal manipulation. A patient-centered, case-specific approach integrating anatomical requirements, functional needs, aesthetic goals, and economic considerations is recommended for optimal clinical outcomes.

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