Scholastic Medical Sciences (ISSN: 3139-7352) Case Study

Volume 3 Issue 11 November 2026

Stereolithographic (STL) Models in Oral and Maxillofacial Surgery: Case Applications and Clinical Impact

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Received: September 25, 2026**; Published:** October 24, 2026

Abstract

Background: Stereolithographic (STL) models have emerged as a valuable adjunct in oral and maxillofacial surgery (OMFS), enabling three-dimensional visualization, accurate surgical planning, and improved operative outcomes. Their applications extend across trauma, pathology, implantology, temporomandibular joint (TMJ) surgery, orthognathic surgery, cleft reconstruction, and prosthetic rehabilitation. Information derived from article on STL.docx.

Objective: To demonstrate the clinical applications and impact of STL models in OMFS through a series of representative cases and to highlight their role in improving surgical precision, efficiency, and patient outcomes.

Methods: Seven clinical cases involving TMJ ankylosis, unicystic ameloblastoma, basal implantology, mandibular retrognathia, cleft lip and palate deformity, maxillofacial trauma, and TMJ reconstruction were analysed. In each case, patient-specific STL models were fabricated from computed tomography data and used for diagnostic assessment, preoperative planning, osteotomy marking, plate adaptation, mock surgeries, prosthesis selection, and patient education.

Results: STL models facilitated accurate visualization of anatomical structures and pathology, improved surgical planning, enabled pre-bending of fixation plates and customization of prostheses, and enhanced patient and clinician communication. Their use contributed to reduced intraoperative time, decreased anaesthesia and wound exposure duration, improved osteotomy accuracy, safer management of complex anatomical relationships, and predictable reconstructive outcomes across diverse OMFS procedures.

Conclusion: STL models represent a reliable and effective tool in contemporary oral and maxillofacial surgery. Their ability to enhance surgical precision, reduce operative time, and support individualized treatment planning makes them valuable in both routine and complex procedures. Continued advances in digital planning, artificial intelligence integration, and biocompatible manufacturing are expected to further expand their role in OMFS practice and education.

Keywords: Stereolithography; STL models; Oral and Maxillofacial Surgery; Surgical Planning; Three-Dimensional Printing; TMJ Reconstruction; Maxillofacial Trauma; Implantology.

Introduction

Any surgical procedure has its own goal. The first goal is to maintain pre-operative form and function. Followed by is to minimizing intra-operative time and postoperative complications. The last 30 years has seen emergence of abundant new technology in the field of OMFS. One of them was the emergence of 3-dimensional stereolithographic models which have been used to guide and assist surgical procedures.

Charles Hull in 1986 was the first to introduce 3-D technology and he used it in the automobile industry for the fabrication of polyurethane models and prototypes for various models, parts, and tools. In the 1990s, the use of 3-D models started in the medical and surgical field and have found a vast among of application since then.

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STL models have been in used in different clinical conditions like; craniofacial trauma, Implantology, TMJ reconstruction, orthognathic surgery, microvascular reconstruction, and cleft surgery[1-7].

3D models are widely used for diagnosis and treatment planning, surgical guides and templates, adaptation and pre-bending of plates, fabrication of custom-made prosthesis, and patient education.

The use of 3-D models leads to decreases the intra-operative time, wound exposure time, and time under general anesthesia.

Case 1: TMJ ankylosis

The 19-year-old male patient reported to our department with reduced mouth opening. A complete clinical and radiographic (OPG) examination in a diagnosis of left TMJ ankylosis; to further aid in patient education and treatment planning, an STL model in case of TMJ ankylosis can be used to evaluate the extent of ankylotic mass, relationship of various structure at the base of the skull with the ankylotic mass. It helps in assessing the possibility of complications and hence, prepares the surgeon to either avoid them or be prepared to handle them more efficiently. The various structures need to be evaluated and as can be seen in this care, the view from the medial aspect reveals a canal within the ankylotic mass which is an inferior alveolar artery passing through it.



a) b) c)

Figure 1: a) 3D CT showing complete bony fusion of left TMJ joint. b) preoperative osteotomy markings done on 3 D STL model. c) STL model showing inferior alveolar nerve passing through ankylotic mass.

Case 2: Unicystic Ameloblastoma

A 38-year-old patient came to our department with a chief complaint of swelling in the anterior region of the lower jaw. Radiographic and histological Evaluation was done. The patient was diagnosed with unicystic ameloblastoma based on a histopathology report. STL model was obtained, and it reveals tumor extending from 34 to 44. Pre-operative osteotomy cuts were marked and plate bending was done. Osteotomy was done based on pre-operative markings. Reconstruction was done with pre-fabricated customized plates.



a) b) c)

Figure 2: a) Profile picture showing swelling in the lower anterior region. b) OPG showing bone resorption c) STL model d) Pre-operative plate adaptation was done on an STL model.

Case 3: Basal implantology

A 45-year-old patient has come to our hospital with a complaint of mobile teeth. The patient was clinically evaluated and a diagnosis of chronic generalized periodontitis was made. OPG revealed multiple teeth with generalized bone loss. STL model obtained based on CT scan and evaluation and planning was done for Basal implant. A total of 21 basal implant placement were done (maxilla 14 implants and mandible 7 implants). Immediate prosthesis placement was done on 1st postoperative day.

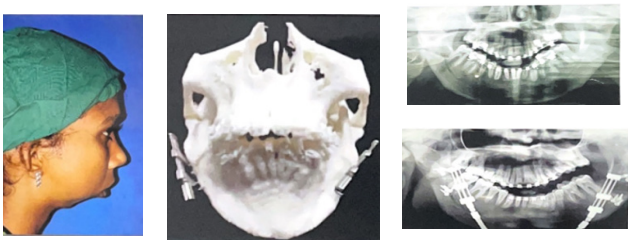


a) b) c)

Figure 3: a) Profile b) pre-operative marking done on STL model. c) Postoperative OPG. d) Post-operative occlusal photograph.

Case 4) Developmental deformity:

A 23-year-old female pt reported to our department with a complaint of a retrognathic mandible. Radiographic evaluation was done with CT scan OPG and the STL model was obtained for patient education and study the model for surgery, so that osteotomy cut can be planned and reduce the chances of error. Pre-operative osteotomy cuts were marked and plate bending Distractor adaptation was done. Osteotomy was done based on pre-operative markings.

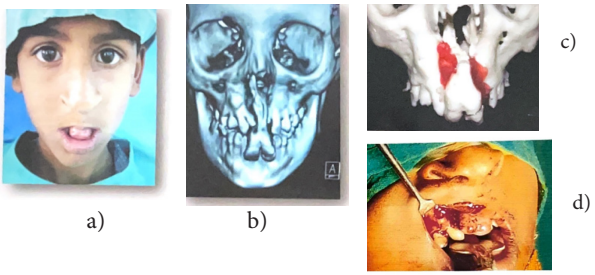


a) b) c)

Figure 5: a) Profile showing retrognathic mandible. b) Pre-operative osteotomy cuts marked on the STL model. c) pre-operative OPG. d) post-operative OPG.

Case 5) Cleft lip and cleft palate:

A 12-year-old pt reported to our department with a complaint of facial deformity. Clinical examination revealed a surgically corrected B/L cleft lip and B/L cleft alveolus and there was an excessive overgrowth of pre maxillary segment along with the erupted central incisors. CT scan confirmed the finding of an overgrown premaxillary (naso-alveolar segment) overhanging in the oral cavity. The STL model was prepared in study the attachment of the naso-alveolar segment so that osteotomy and reduction of the segment could be done without compromising blood supply to the osteotomized segment. A Mock was performed and segment was reduced on a model and a splint was fabricated on the model and was fixed as a guide for fixation intraoperatively.

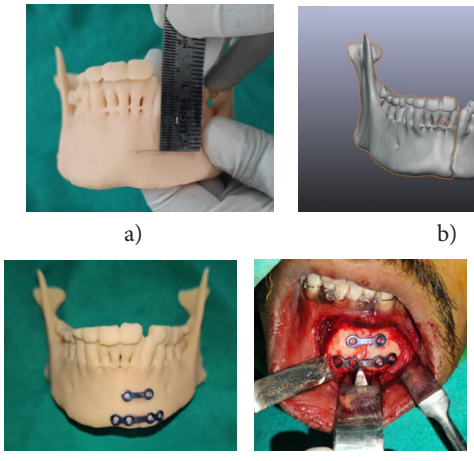


a) b) c) d)

Figure 6: a) Profile showing facial deformity b) 3D CT scan. c) STL model. d) vomerectomy and bone graft planning done on the STL model.

6) Maxillofacial Trauma:

A 32-year-old patient reported to our department with complaint of swelling in lower ant region. Clinical and radiographic evaluation was done on CT scan. STL model was obtained; it reveals Left Para symphysis fracture. Pre operative plate bending was done on STL Model. Open reduction and Internal fixation were done.



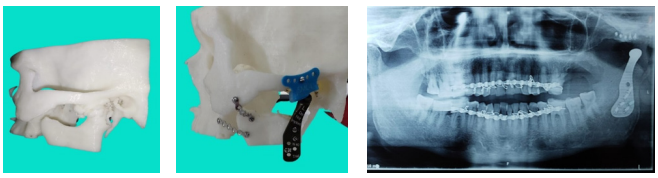
a) b) c) d)

Figure 7: a) 3D CT showing Para symphysis fracture. B) marking done on STL model. c) Plate adaptation done on STL model. d) Intraoperative plate adaptation.

7) TMJ reconstruction:

A male patient aged 62 yr presented to our department c/o reduced mouth opening. A thorough clinical and radiographic examination revealed a fusion of the condylar head to the mandibular fossa.

An STL model was prepared and study the extent of growth and the relation to the surrounding structure. (treatment plan included excision of a mass and total reconstruction of the joint) following which growth mass was excised on the model and the TMJ template was tried on the model to select the appropriate size of the template. The template size which best corresponds to the defect is selected for TMJ reconstruction during surgery, the condyle unit and fossa unit are available in different sizes and are sterile packed, so the most appropriate size must be selected preoperatively to avoid the mismatch during surgery. The STL model helps us in doing this.



a) b) c)

Figure 8: a) STL model b) condylar and fossa unit adaptation done on STL. c) OPG showing condylar and fossa units.

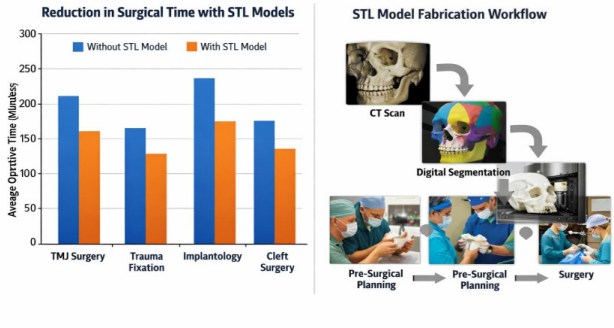
Discussion

Table 1. Clinical Applications of STL Models

Case	Condition	STL Utility	Outcome
1	TMJ Ankylosis	Visualization of ankylotic mass, nerve canal	Safe osteotomy
2	Ameloblastoma	Osteotomy markings, plate bending	Accurate resection
3	Implantology	Implant planning	21 implants placed
4	Retrognathia	Osteotomy planning, distractor adaptation	Reduced error
5	Cleft deformity	Mock surgery, splint fabrication	Preserved blood supply
6	Trauma	Plate pre-bending	Stable fixation
7	TMJ Reconstruction	Prosthesis sizing	Avoided mismatch

Table 2. Comparative Advantages of STL Models

Parameter	Conventional Approach	STL-Assisted Approach
Intra-operative time	Longer	Reduced
Wound exposure	Prolonged	Shortened
Accuracy	Variable	High precision
Patient education	Limited	Enhanced
Prosthesis adaptation	Manual	Pre-bent/customized



Manufacture Process and Types of Models

The process of fabrication begins with a tank of ultraviolet (UV)-curable photopolymerize resin and a UV laser. The model is fabricated in a series of layers, each that correspond to the equivalent of a slice of an axial image on a CT scan. ‘‘A platform is immersed in the liquid plastic, then raised to a level just below the surface of the photopolymerize. A software-guided beam from a helium-cadmium laser strikes the surface of the liquid and draws each layer of the object onto the surface of the liquid. This causes the plastic to solidify. After the first layer is built, the platform lowers slightly and the laser once again strikes the liquid for sequential polymerization’’ 1.

Each layer is polymerized at a thickness of typically 0.05–0.15 mm. This process is continued until each corresponding slice of the CT image is duplicated in the resin model. The final step is curing the entire model after fabrication. The final product is a solid and accurate 3-D representation of the patient. 3-DP models are sequentially fabricated in a similar way. An inkjet printer utilizes images that are transformed from a CT scan to sequentially fuse separate layers in formation of the 3-D product. Layers of a powder or plaster are bonded following injection of an adhesive in the shape of the axial CT image from the inkjet printer. Once the model is completed, the excess plaster is removed and the final model is cleaned and refined4.

SLA models are showing higher strength, higher temperature resistance, lower moisture absorption, and lower shrinkage. They can be sterilized for surgical use, and literature has shown superior accuracy1.

The STL model helps in Diagnosis and treatment planning, Direct visualization of anatomic structures, Surgical guides/templates Surgical practice/rehearsal, Designing precise incisions, Surgical resections, Assessment of bony defects for grafting, Adaptation/pre-bending of reconstruction plates Fabrication of custom prostheses TMJ prostheses, distraction devices, and fixation devices. it decreases surgical time, Anesthesia time, and Wound exposure duration. it helps as an educational tool for patients.

Future Scope of STL Models in OMFS Surgery

The integration of STL models into OMFS is poised for significant expansion, driven by technological advancements and evolving clinical demands. The following areas represent key directions for future development:

1. AI-Driven Surgical Planning

Integration of artificial intelligence with STL data for predictive modeling of surgical outcomes.Automated segmentation and virtual simulation of complex procedures.

2. Biocompatible and Functional Printing

Development of STL models using biocompatible materials for intraoperative use.Exploration of functional STL models embedded with sensors for real-time feedback.

3. Tele-Surgical Collaboration

STL models shared across institutions for remote surgical planning and expert consultation.

Enhanced doctor-to-doctor communication in complex craniofacial cases.

4. Curriculum Integration

Inclusion of STL modeling in postgraduate OMFS training programs. Hands-on workshops for STL fabrication, virtual planning, and mock surgeries.

5. Research and Innovation

Clinical trials comparing STL-guided vs. conventional outcomes in trauma, TMJ, and cleft surgeries. Cost-effectiveness studies in low-resource settings.

6. Patient-Centric Applications

Personalized STL models for patient education and consent.

STL-based prosthesis customization for improved functional and aesthetic outcomes.

Conclusion

STL models show lots of advantages like; decreased intraoperative time and the ability to perform more precise and accurate surgical procedures. STL has an important role in oral and maxillofacial surgery. As described in the abovementioned cases, they can be utilized in multiple surgical areas. They are useful for in-patient education and doctor-to-doctor communication. It is a very important tool to plane TMJ reconstruction, microvascular reconstruction, surgical pathology, Implantology, maxillofacial trauma, and cleft lip and palate surgery function.

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2. Chow L, Cheung L (2007). The usefulness of stereomodels in maxillofacial surgical management. *J Oral Maxillofac Surg* 65:2260–2268 Fig. 6 a 3-D model has been waxed up to mimic normal bone contour of a mandibular ramus which has been destroyed multiple reconstructive surgical procedures in a patient affected with rheumatoid-induced TMJ disease. b Intraoperative view showing fixation of a patientfitted, customized TMJ total joint replacement with an inlay cranial bone graft strut for simultaneous mandibular ramus reconstruction 12 *J. Maxillofac. Oral Surg*. (Jan-Mar 2011) 10(1):6–13 123
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