Stereolitography — a New Method of Implantological Operation Planning After Mandibular Reconstruction

Stereolitografija — nova metoda planiranja implantoloških zahvata nakon mandibulne rekonstrukcije

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Summary

Stereolithography (SLA) is used for treatment planning in reconstruction of severe defects after tumor resection, trauma, malformations of the skull, and for planning of dental implantology after mandibular reconstruction. In 16 patients, 1-mm CT scans and spiral CT scans of the reconstructed mandible were performed with image processing and stereolithography modeling of the mandible. Usual surgical drilling templates were manufactured for insertion of endosseous BONE-LOCK dental implants. After osseous integration, the supraconstruction was designed and prosthetic treatment completed with excellent functional and esthetic results. The accuracy of stereolithography models was very high, with a deviation of ± 0.5 mm. The method was found very reliable in severe implantological cases after bone reconstruction of the mandible.

Key words: *medical imaging, stereolithography, implantology*

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Introduction

A rapid development of powerful medical imaging systems during the last two decades has entailed the need of creating a link between computerized planning and modeling of anatomical structures. The first medical models based on CT data were created by a milling machine (3). After its invention in 1982 by Charles Hull (4), stereolithography found its medical use in 1987. It is based on the principle of polymerization of liquid photocurable resin monomer by a UV laser

beam, layer by layer (Fig. 1). As stereolithography is analogous to a three-dimensional printing technique, the platform is placed inside a tub

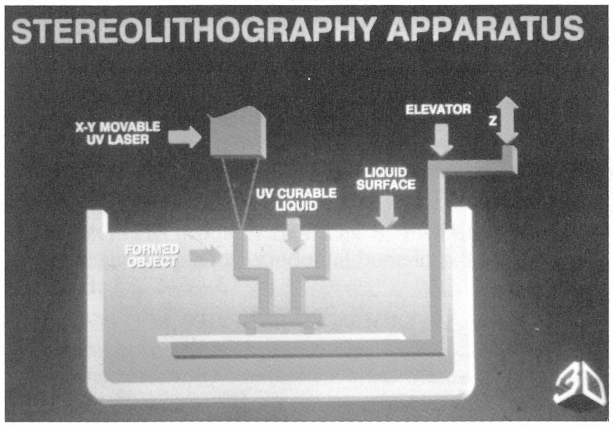


Figure 1. *Principle of stereolithography: after laser polymerization of liquid photocurable resin monomer, the first layer is submerged into the liquid monomer tank and the next layer is polymerized.*

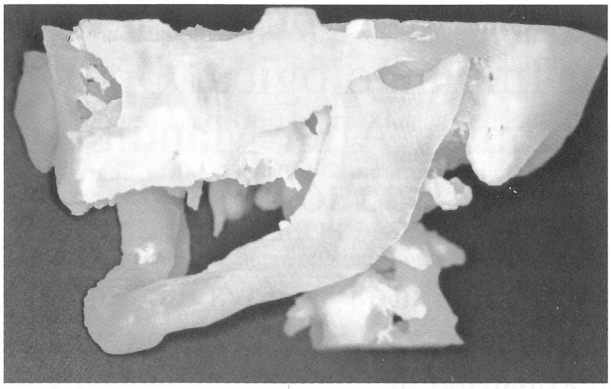
Slika 1. *Princip stereolitografije: nakon laserske polimerizacije tekućeg fotoosjetljivog akrilatnog monomera, prvi sloj se potopi u rezervoar tekućeg monomera, te se polimerizira drugi sloj*

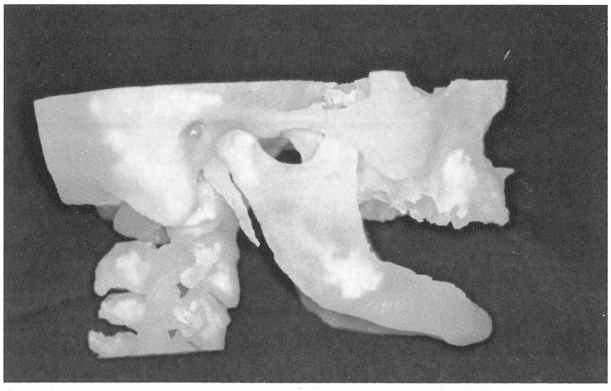
with liquid photocurable resin monomer. For curing of the first layer, the platform is placed directly below the monomer surface (0.1 — 0.25 mm). A horizontally driven He-Cd-Laserbeam (wavelength 345 nm, power 11.25 mW) polymerizes the monomer on the horizontal plane. After polymerization of one layer, the platform is submerged by one layer thickness, and the next monomer layer is polymerized.

Vertical modeling allows any kind of three-dimensional structures to be created (4).

After solving the problem of data transfer from complex medical imaging of CT and MR data (3,5,6,10), this technique has become available for use in medicine. The high diagnostic and therapeutic value of stereolithography lies in complete three-dimensional reconstruction of external and internal structures for better three-dimensional orientation (Fig. 2a, b), expression of tissue volumes, e.g., tumors, and most important, the possibility of direct operation planning.

Stereolithography models can be sterilized and used directly during the operation. In 1992, we used stereolithography for the first time in dental implantological treatment of patients who had undergone resection of squamous cell carcinoma of the oral cavity and mandibular reconstruction





Figures 2a and 2b: *Stereolithography model of a reconstructed mandible and midface region.*

Slike 2a i 2b: *Stereolitografska rekonstrukcija mandibule i srednje trećine lica*

with autologous iliac crest bone graft or with microvascular bone grafts of the scapula or fibula (1,2,7—9).

The most important facets of stereolithography-based implantation planning are dimensions of the bone as an implant layer, for exact positioning, direction, parallelism and size of implants.

Material and Methods

One-mm CT scans and spiral CT scans of the reconstructed mandible were performed in 16 patients after mandibular reconstruction with autologous bone graft, using a Siemens Somatom Plus S CT with a 512 pixel matrix (Siemens AG, Erlangen, Germany), image-processing by Konform Medical Modelling (KONFORM GmbH, Köln, Germany) on a Kontron Mipron

medical image device (Kontron, Eching, Germany) and stereolithography modeling on a SLA-250 stereolithography apparatus (3D-Systems, Darmstadt, Germany) (Fig. 2c).

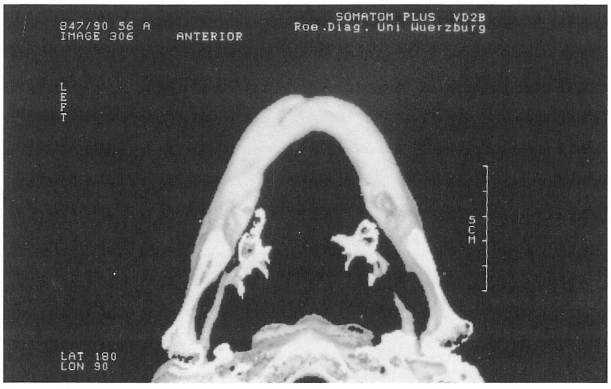


Figure 2c: *3D CT of a mandible with reconstruction of the left side of the mandibular arch*

Slika 2c: *3D CT mandibule s rekonstrukcijom lijeve strane mandibularnog kanala*

The created model was a copy of the patient's mandible, of accurate size and good visibility of every anatomical structure, including the bone graft inserted into the mandibular arch (Fig. 2d).

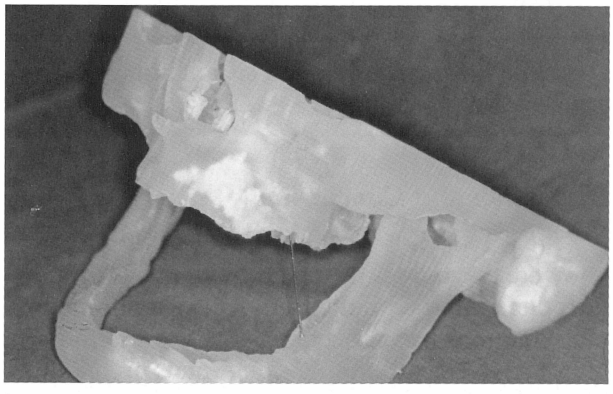
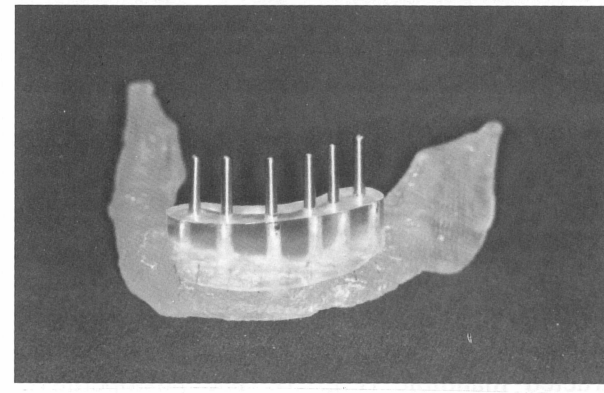
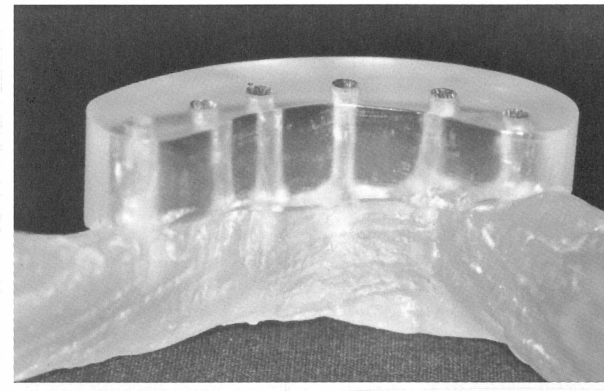


Figure 2d: *Stereolithography model with good visibility of mandibular bone and bony reconstruction.*

Slika 2d: *Stereolitografski model mandibule s dobro vidljivom koštanom strukturom*

The prosthetic treatment planning was performed with a provisional denture, which was transferred to the stereolithography-created mandible. According to the bone state and prosthetic treatment planned, the number, position and direction of the implants were marked on the model. After drilling parallel holes, a common individual surgical drilling template was made from autocurable methacrylate resin. It was placed exactly onto the alveolar ridge of the neomandible, showing the exact position and direction of the drilling (Fig. 3a, b).





Figures 3a and 3b: *The drilling template of autopolymerizing methylmethacrylate resin is exactly positioned onto the alveolar ridge of the model. It makes possible a precize preoperative positioning of the implant*

Slike 3a i 3b: *Individualna šablona načinjena od samopolimerizirajućeg metilmetakrilata postavljena na alveolarni greben. Time je omogućeno precizno preoperativno postavljanje implantata*

Intraoperatively, it was evident that an exact and reproducible position of the drilling template onto the patient's alveolar ridge was possible without any movement or malpositioning (Fig. 4).

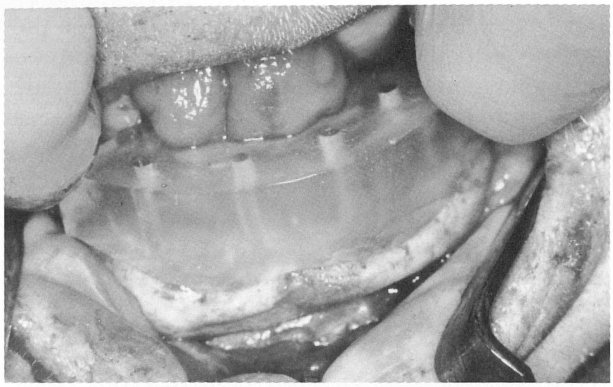


Figure 4. *The individual shape of the drilling template allows reproducible, exact positioning of the drilling--template onto the alveolar ridge of the patient*

Slika 4. *Individualna šablona omogućuje precizno i točno postavljanje na alveolarni greben bolesnika*

Using this technique, we placed endosseous BONE-LOCK dental implants into the reconstructed mandible (Fig. 5). The postoperative healing time was at least three months.

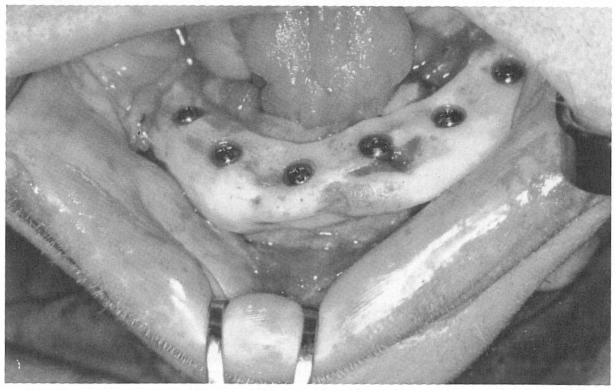


Figure 5. *State after implantation. The preoperatively determined direction of the implant was transferred exactly to the alveolar ridge of the patient's mandible*

Slika 5. *Stanje nakon implantacije. Preoperativno određen smjer implantata točno je prenesen na alveolarni greben mandibule bolesnika*

Results

No complications occurred in implant positioning. In 12 out of 16 patients, the prosthetic treatment was completed. Because of optimized implant positioning, the preoperatively created prostheses could be modified and used as definite prostheses with optimal functional and esthetic results (Fig. 6).

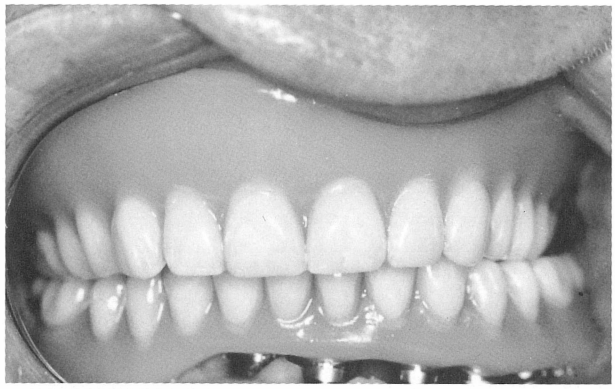


Figure 6. *State after completing prosthetic treatment with excellent functional and esthetic results*

Slika 6. *Stanje nakon protetske rehabilitacije s dobrim estetskim i funkcijskim rezultatom*

In the study of the accuracy of stereolithography models, intraoperative bone measurements were compared to stereolithography models, showing a deviation of $\pm$ 0.5 mm. Accuracy of the models created according to spiral CT and 1-mm CT scans was identical, but with the former the surface was considerably smoother and more convenient for planning and simulation of reconstructive surgery.

Discussion and Conclusion

The advent of the described methods has allowed the modeling techniques to be directly introduced in the implantological operation planning and surgical procedure. The stereolithography-based operation planning and preparation have also found use in reconstructive surgery, opening up new ways by their advantages. Model fabrication by a milling machine was first described in maxillofacial surgery in 1987 (3). In comparison to stereolithography, this method is characterized by several shortcomings, e.g., impossible creation of complex three-dimensional structures, lower accuracy, rough and porous surface structure, and impossibility of use within the operating theater. On the other hand, the cost of stereolithography models is almost two-fold

that of milling models. So, it appears that stereolithography models should be used when high anatomical precision or intraoperative change of the operative strategy are required, first of all in reconstructive surgery of the head and neck. In other cases, e.g., visualization of some deformed or malformed anatomical structures without use in the operating theater, milling models are generally adequate for proper operation planning.

STEREOLITOGRAFIJA — NOVA METODA PLANIRANJA IMPLANTOLOŠKIH ZAHVATA NAKON MANDIBULNE REKONSTRUKCIJE

Sažetak

Stereolitografija (SLA) se rabi kao pomagalo pri rekonstrukciji teških defekata nakon operacije tumora, traume, malformacije lubanje te za planiranje implantoloških zahvata u bolesnika nakon mandibulne rekonstrukcije. U 16 bolesnika provedeno je CT snimanje rekonstruirane donje čeljusti s debljinom sloja od 1 mm ili tehnikom spiralne CT, kompjutorska obrada podataka slojevnih snimaka i konstrukcija stereolitografskoga modela mandibule. Zatim je po modelu stvorena individualna šablona za umetanje BONE—LOCK implantata. Nakon oseointegracije konstruirana je suprakonstrukcija i završen protetski tretman s odličnim funkcijskim i estetskim rezultatima. Točnost dimenzija stereolitografskih modela izrazito je visoka, s odstupanjem od ± 0,5 mm. Metoda se pokazala veoma pouzdana u teškim implantološkim slučajevima nakon koštane rekonstrukcije donje čeljusti.

Ključne riječi: *medicinsko prikazivanje, stereolitografija, implantologija*

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