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Polylactic Acid-Based In-house Three-Dimensional-Printed Intraoperative Surgical Model is a Time- and Cost-efficient Approach for Mandibular Reconstruction

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Abstract

Background The advanced development of computer-assisted design/manufacturing (CAD/CAM) technology aids in the process of producing patient-specific template for intraoperative dissection and fixation guide. To date, CAD/CAM technology has been greatly used in reconstructive mandibular cases to enhance accuracy, reduce operation time, and minimize possible complications. However, this technology was believed to be cost- and time-inefficient, limiting widespread use in several institutions.

Methods This study displayed five case series incorporating in-house three-dimensional (3D)-printed models. 3D imaging was retrieved from computed tomography scan Digital Imaging and Communications in Medicine files, which was processed to STL (Stereolithography) format to recreate a symmetrical postoperative design. The rendered 3D file was then printed with the in-house printer using polylactic acid (PLA) material. A sterilized 3D-printed model was used as intraoperative guidance for plate bending and positioning. The process, time, and cost of each 3D model production were documented.

Results A total of 100% success rate was observed in processing 3D-printed model in all cases, with no fail in printing. The printing time on average took 7 hours, 39 minutes (ranging from 5 hours 59 minutes up to 9 hours 43 minutes) and cost spent on average was approximately $1.83 on each print (ranging from $1.69 up to $2.10). The in-house 3D printer costs approximately $750, which is compact and can be easily purchased online.

Conclusion CAD/CAM technology is a cost- and time-efficient approach, in addition to its renowned benefits in increasing surgical accuracy, reducing operation time, improving postoperative look, and minimizing complications. We suggest the implementation of in-house printed PLA-based 3D surgical guide for mandibular reconstructions.

Keywords
- 3D printing
- reconstructive surgery
- mandibular reconstruction

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Mandibular reconstruction is an attempt of reenacting the broken anatomical part of the mandible to preserve its function.[1] In 1989, this procedure was performed on cases such as jaw trauma or malignancies. Nowadays, mandibular reconstruction procedures are considered reliable to manage diseases like bone congenital defects, bone infection, and big vessels malformation surrounding the mandible.[2–4]

During the past 40 years, many surgeons had tried to improve the reconstruction technique, making it less perilous yet much more satisfactory in terms of patients' quality of life. One of the latest inventions regarding mandible reconstruction was incorporating the three-dimensional (3D) printing to create an accurate surgical template.[1,3] The use of 3D printing in craniofacial surgery has been promising. Furthermore, this newly developed 3D model template was proven to reduce operative time and blood loss with more predictable results.[4–6] Improved patient satisfaction can be achieved through a detailed visualization of the anatomy with the help of 3D-printed template.[7]

Patients with mandibular tumors often have a normal contralateral side to serve as a mirror template for preoperative 3D planning. 3D-printed models have been greatly utilized in mandibular reconstruction to aid visualization and surgical planning. The development of computer-assisted design/manufacturing (CAD/CAM) technology helps create accurate template for cutting, bending, and fixation guidance. This technology was also shown to minimize possible complications, dental malocclusion, intraoperative bleeding, and prolonged operation time.[8,9]

Our center recently implemented an in-house 3D printing to create 3D-printed models to aid mandibular reconstruction during preoperative and intraoperative planning. The goal of this study was to prove that in-house 3D printing technology is a safe, time- and cost-efficient approach to be implemented for all mandibular reconstructive cases.

Methods

In this retrospective case series, all 3D models were created from patients with mandibular tumor indicated for tumor resection and mandibular reconstructive surgery. The data were retrieved from multislice computed tomography (CT) scan and was processed in Digital Imaging and Communications in Medicine format. The file was transformed into a 3D model using 3D rendering Slicer Software V 4.11.20210226, then visually edited and checked with Autodesk MeshMixer V 3.5.474, as shown in ►**Fig. 1**. The STL (Stereo-lithography) file was created for printing purposes. The confirmed 3D design will then be sliced into a printable layer with the help of Ultimaker Cura software V.3.6.0–v4.1.0.

The printing process was performed using the in-house Creality Ender 5 Plus printer, shown in ►**Fig. 2**, using polylactic acid (PLA) filaments acquired from e-Sun filaments, with resolution of 0.2 mm and a 0.4-mm printing nozzle. The printed

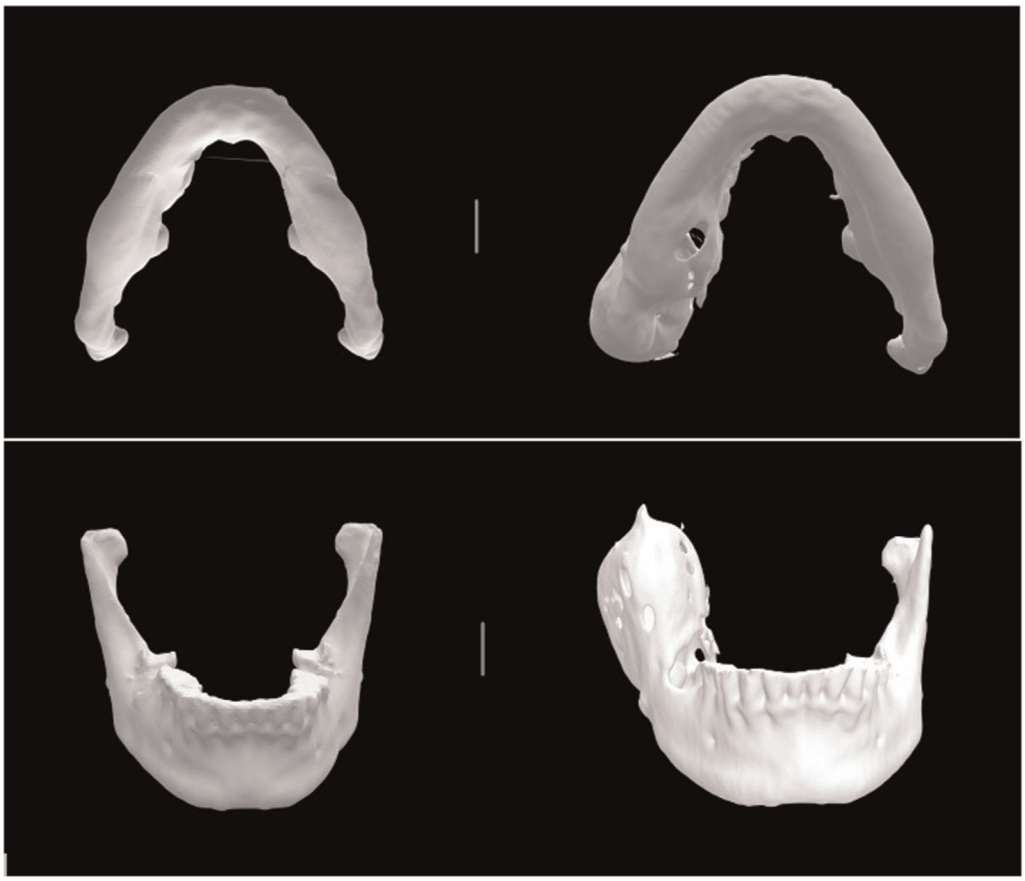

Fig. 1 AutoDesk MeshMixer rendering of three-dimensional (3D) model. *Left*: The mirrored 3D models. *Right*: Patient's raw 3D models with defects on the right mandible.

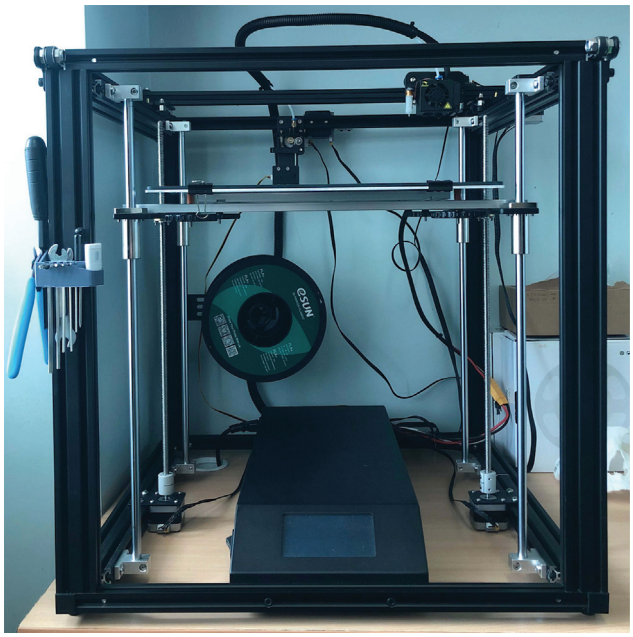

Fig. 2 Crealty Ender 5 Plus: In-house three-dimensional printer used in our center, Cipto Mangunkusumo National Reffered Hospital, Cleft and Craniofacial Center.

models were inspected visually for defects, then sterilized in central sterilization unit in the hospital, as shown in ►**Fig. 3**. The sterilized 3D models were used in the operation theater to guide surgeons to: (1) visualize the reconstruction area in a detailed manner and (2) bend plates/meshes intraoperatively.

Results

We collected five patients with mandibular tumors and retrieved their CT scan files to be processed into 3D models for intraoperative guidance (►**Table 1**). The printing time ranged from 5 hours, 59 minutes up to 9 hours, 43 minutes (on average 7 hours, 39 minutes). The PLA material costs per printing was ranging from $1.69 up to $2.10, with average cost of $1.83 for each model. All 3D models in our center were produced using an in-house 3D printer (Creality Ender 5 plus, print dimension of 350 × 350 × 400 mm, approximately priced at $750 and available through e-commerce. A total of 100% printing was successful with no major defects on the 3D models.

Discussion

CAD/CAM technology has gained popularity in mandibular reconstruction as shown by previous successful studies. A study by Latief displayed the benefits of 3D printing implementation on mandibular reconstruction surgery, both preoperatively and intraoperatively, in improving surgical outcomes.[10] In this study, we highlighted other positive features of implementation of CAD/CAM technology and 3D printing models, including the efficient procedural process, time consumption, and production cost.

Our study revealed that the printing time needed for each model took 7 hours 39 minutes on average, depending on the complexity. Similar result was displayed by Bergeron et al

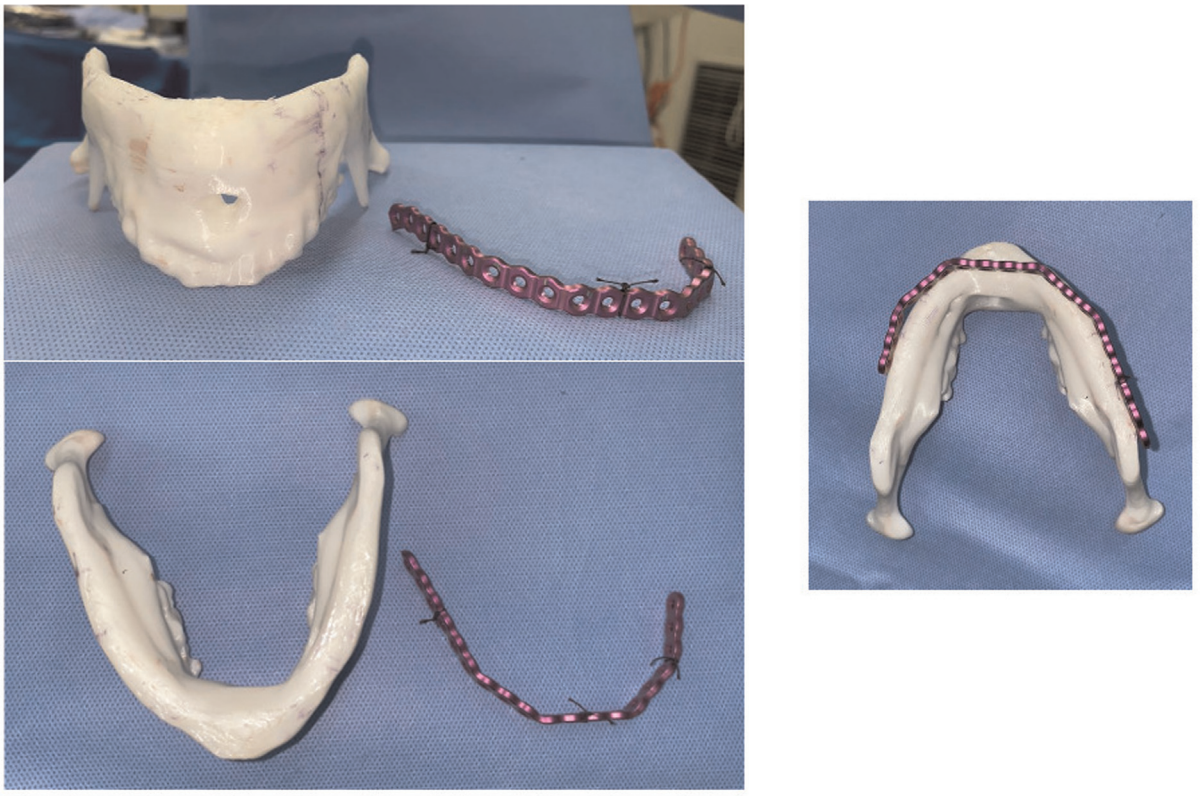

Fig. 3 Intraoperative use of the three-dimensional printed model to aid the prebending of mandibular reconstruction.

Table 1 The details of cases that have been using three-dimensional-printed model to aid the surgeries, inclusive the time and cost of each prints

Case number	Diagnosis	Model printed	Time of printing (h:mm)	In-house cost
1	Squamous cell carcinoma of oral cavity with involvement of mandible	Mandible	7:30	$1.69
2	Ameloblastoma on mandible Dextra	Mandible	5:59	$1.72
3	Ameloblastoma on mandible Dextra	Mandible	9:43	$2.10
4	Ameloblastoma on mandible Dextra	Mandible	6:59	$1.76
5	Ameloblastoma on mandible Sinistra	Mandible	8:06	$1.90
Average			7:39	$1.83

who noted an average of 7 hours and 55 minutes for each model printing. However, his study included printing time of multiple areas of craniofacial other than the mandible, such as orbital, frontal, and maxilla, ranging from approximately 2 to 26 hours, which made it not directly comparable with our study.[11] Bergeron and colleagues have detailed the costs of each print, which on average costed about $0.95. We found that our in-house printed mandibular model using PLA material approximately costed $1.55, which is relatively affordable.

Several studies reported various benefits following CAD/CAM technology implementation. Mahendru et al mentioned that CAD/CAM group reported no flap failures compared with the conventionally approached groups.[12] Furthermore, a study by Zhang et al showed a reduction of dental malocclusion postoperatively in this CAD/CAM-guided group, with 2.5% occurrences compared with 15% in conventional approach.[13] They also documented 95% success rate of flap transfer following CAD/CAM implementation. Overall, the use of 3D printing was well known to significantly reduce complications by providing better precision.[12–15] By reducing the time needed for surgery, the operational costs of the surgery would also be suppressed, which will in turn benefit the hospital.[14,16] Kurlander et al and Latief pointed that 3D printing technology also helped to minimize operator mistakes during the operation up to 60%.[10,16]

Our study used PLA filaments to create the templates for reconstruction guide. PLA is a synthetic, biodegradable polymers that has been utilized for many medical applications. Some previous studies used this material as reconstruction template considering its properties; readily available, high strength, cheaper option, and easy to print.[10] Adhitya et al stated that PLA materials had more durable structure compared with other materials such as acetyl butane stearate or high-impact polystyrene.[17] In general, PLA is still an acceptable biomaterial choice for reconstructive surgery. Therefore, this material is also considered cost-effective.[14]

We are one of the pioneers to claim that CAD/CAM technology is an affordable approach for mandibular reconstruction, incorporating in-house 3D printer and PLA-based 3D printing material. This technology should be widely implemented in reconstruction centers to improve intraoperative accuracy and postoperative outcomes while promoting economic benefits. Our study is limited with small number of involved cases with limited outcome parameters. Moreover, all cases were collected from single surgery center with advanced technology and resources. This may not be able to represent other centers with more limited resources across Indonesia. Bigger study involving multicenter participation and incorporating more comprehensive parameter such as operation time, postoperative complications, and qualitative rating of patient's satisfaction should be conducted.[8]

Conclusion

In conclusion, 3D printing method using CAD/CAM technology is a time- and cost-efficient approach in mandibular reconstruction procedures. The use of in-house 3D printer using PLA material to produce 3D template guides should be popularized to acquire a more accurate, aesthetically pleasing outcome.[16,18]

Conflict of Interest

None declared.

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