REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 25, No. 1 (2024)
http://www.veterinaria.org
Article Received: Revised: Accepted:

Evaluation Of The Auto Surfacing Methods To Create A Surface Body Of The Mandible Model

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ABSTRACT
It's not easy to design an anatomical structure for a surgical treatment. This is particularly true for the craniofacial region, which is made up of bone tissues with extremely intricate geometries. To make the most of the tools that are currently accessible in connected procedures with the building of the craniofacial areas, CAD modelers need to possess the necessary knowledge and abilities in both technological sciences and medical. The four patients treated at the Department of Maxillofacial Surgery form the basis of the early investigations that are being presented. Using the ITK SNAP program, the mandible model's segmentation was completed. Two distinct approaches—organic and mechanical—were used in the Auto Surfacing module of the Geomagic software to generate surface body models. Next, evaluate the two approaches' accuracy in creating a CAD model of the mandible using the Focus Inspection and GOM Inspect tools based on a triangle mesh structure.

Introduction
The technique known as "reverse engineering" allows one to rebuild an existing object's geometry (Raja and Fernandes (2007), Bagci (2009)).It covers tasks associated with gathering data, reconstructing the geometry of objects that have been measured, and converting the data into a format that can be used with CAD software. Reverse engineering is frequently the sole method available for producing a digital representation of a physical object with a complex shape (Turek (2019), Ciocca et al. (2012)). As a result, reverse engineering is an extremely complicated procedure. The CAD modeler must possess the necessary abilities and knowledge about measuring technique (Raja and Fernandes, 2007), data processing (Urbanetal., 2008), and manufacturing technology (Boboulos, 2010; Gibbsonetal., 2021). This is necessary in order to correctly reconstruct the geometry of the object.Reverse engineering is being applied in numerous industries, such as the automotive and aviation industries (Marchetti and Stabili, 2018; Kumar et al., 2013). Medical applications for it include rebuilding anatomical structures' geometry (Stojkovicetal., 2018; Turek, 2019); designing implants (Milovanović et al., 2020); and creating surgical guides (Liu et al., 2014; Orabona et al., 2018).The three-dimensional representations of bone structures enable:

- Increasing the accuracy of the procedure
- Choosing the Right Surgical Instruments
- Talking with Other Physicians About the Case Carefully Before Proceeding
- Providing the Patient with a Full Rundown of the Procedure and Its Course
- Cutting Down on Blood Loss During Surgery
- Minimizing Intraoperative Complications.

Obtaining volumetric data is the first step in designing anatomical structures.Ultrasonography (Vaezi et al., 2012), magnetic resonance imaging (Huotilainenetal, 2014), and tomography systems (Cohenetal, 2009) can all be used to achieve this. After that, a three-dimensional model is created using the data that was obtained. For this, a variety of software types are employed.The commercial programs that are most frequently mentioned in the literature include Maxilin (Olszewski et al., 2014), Amira (Maret et al., 2012), 3D Doctor (Teeter et al., 2015), and Mimics (Figliuzzi et al., 2012).Researching the accuracy of the geometry reconstruction and the physical model's production is crucial (Budzik and Trueck, 2018; Trueck and Budzik, 2021).Research is now being conducted to increase the accuracy of triangulation methods (Manmadhachary et al., 2016), CAD modeling (Yoo, 2011), and segmentation of the anatomical structures (van Eijnatten et al., 2017 and 2018). This research is being done at the stage of reconstructing the model geometry. When creating additively manufactured models of anatomical structures, it's important to inspect the models saved in STL format for structural flaws (Manmadhachary, 2016).It is important to accurately produce a CAD model based on the STL model while taking machining procedures into account. The preparation time for the machining process can be greatly decreased by producing a correctly formed surface body based on a triangle mesh structure (Budzik et al., 2015).

The literature review demonstrates how CAD/CAM/RP systems are being used in medicine more and more. Understanding how to create anatomical models can be very beneficial in the future for the precise and controlled development of surgical guides and templates that meet the required level of precision. In addition, they can provide assistance with the treatment of certain skeletal system disorders as well as procedures aimed at maintaining the continuity of the mandible geometry.

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2. Materials and methods

The Siemens Somatom Sensation Open 40 tomograph provided models of the four mandibles. The Provincial Clinical Hospital No. 1 Frederic Chopin in Rzeszów donated the data for Digital Imaging and Communications in Medicine (DICOM). For the craniofacial scan, the conventional scanning procedure was used (Table 1).

Table1.The scanning protocol.

Nameofparameters	Valueofparameters
Tubevoltage	120 kV
Tubecurrent-timeproduct	115 mAs
Acquisition	40×0,6mm
Slicecollimation	0,6mm
Kernel	H60s
Matrixsize	512×512
Pixelsize	0,4×0,4mm

The ITK SNAP software was utilized to segment the mandible model based on the provided data. A threshold value of 200 HU was chosen as the bottom bound. The isosurface method, one of the surface rendering techniques, was applied to display the 3D model of the mandible. The marching cubes algorithm is the foundation of this technique. The method works by taking eight neighbor locations at a time from the scalar field, creating an imaginary cube. Next, it determines which polygon or polygons are required to represent the portion of the isosurface that crosses through this cube. The desired surface is then created by fusing the component polygons. The process involves treating each of the eight scalar values as a bit in an 8-bit integer, thereby generating an index to a recalculated array of 256 potential polygon configurations inside the cube. The appropriate bit is set to one if the scalar's value is higher than the iso-value (that is, inside the surface); if it is lower (outside), it is set to zero. The real index to the polygon in dices array is the final value obtained after all eight scalars have been validated. Ultimately, by linearly interpolating the two scalar values connected by the cube's edge, each vertex of the created polygons is positioned at the proper location along its edge. This algorithm ensures that all regions assigned to various materials are well separated from one another, that no triangles (a single surface formed on three nearest points) connect, and that the resulting surfaces are devoid of cracks and holes. The finished mandibular model was transferred into the Geomagic software after being saved as an STL (Stereo Lito graphy) file (Fig. 1). Numerous options are available in the Geomagic software for altering and modifying the data that is digitized. In an effort to maximize the accuracy of the physical model, this software's primary function is to transform the point cloud into a triangle mesh or free surfaces specified by NURBS (Non-Uniform Rational B-Spline) curves. The following basic errors in the triangular mesh were confirmed as a result of measurement mistakes:

- Inverted normal vectors,
- Surface deformities,
- Gaps between triangles defining the surface,
- Loss of the full surface and its fragments,
- Overlapping triangles,
- Assigning a single edge to many triangles are some examples of these phenomena.

There were no structural flaws in the mesh detected in the test results. The last step in the ready-made model preparation process involved establishing the cutting plane that the softened portions of the ready-made models were obtained against. The Auto Surfacing module handled the task of creating surface models. A surface body that can completely enclose a target mesh's geometric shape is produced by auto surfacing. It offers two distinct approaches:

• Mechanical: Create a surface body from a target mesh by building a curve network that adheres to the features; • Organic: Create a surface body from a target mesh by projecting an evenly dispersed curve network (Fig. 2).
The entire procedure for producing the surface model of the mandible parts involved applying the organic and then the mechanical methods to create spine approximation curves on the resulting triangle mesh. Consequently, an edge model was created and applied to disperse the panels across its full surface. Combining all of the produced surfaces into a cohesive whole was the last phase. For the purpose of accurately fitting the surface slices to the triangle mesh, the method uses default settings.

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Figure1

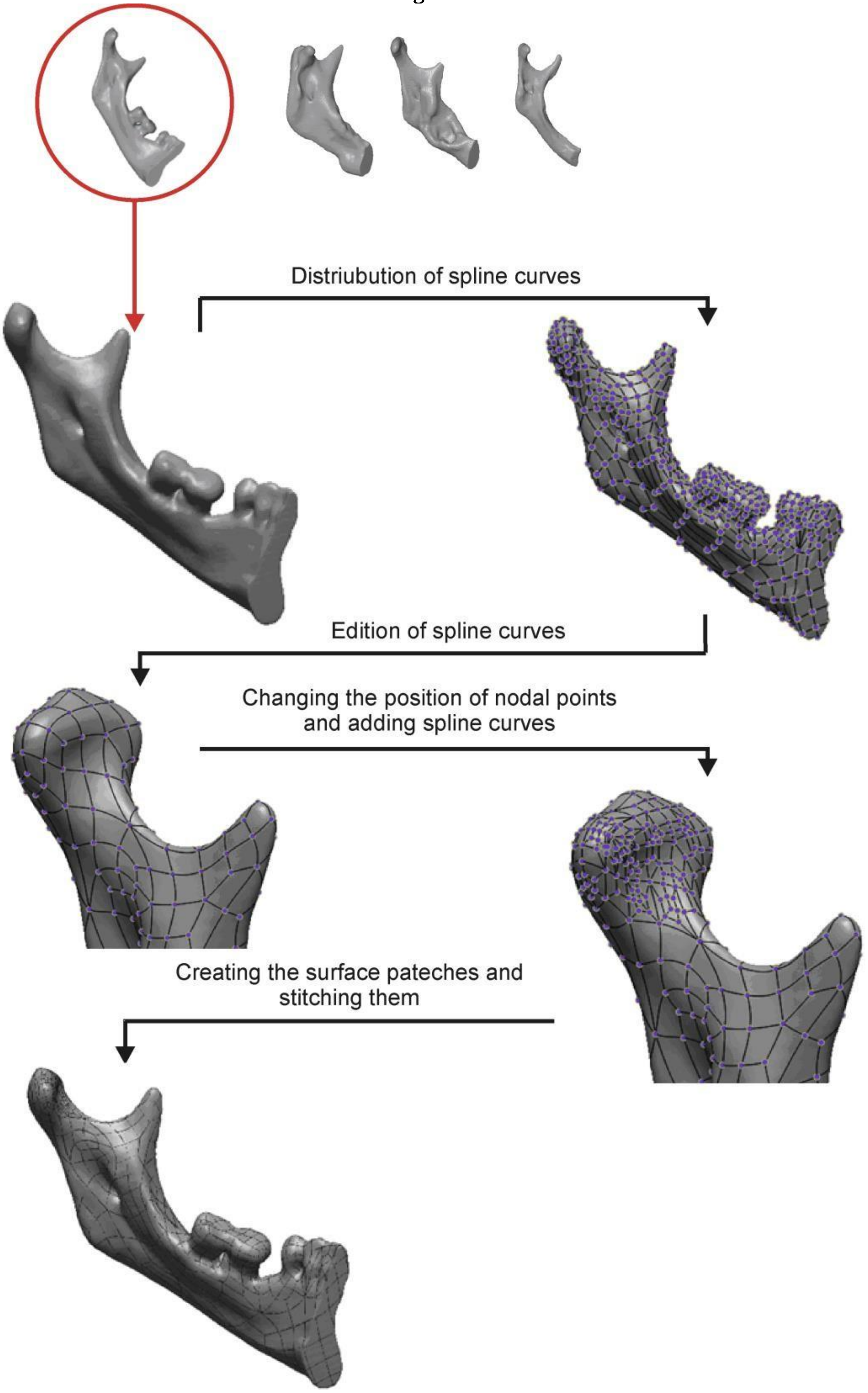

Figure2. The scheme of designing a mandible CAD model–organic method

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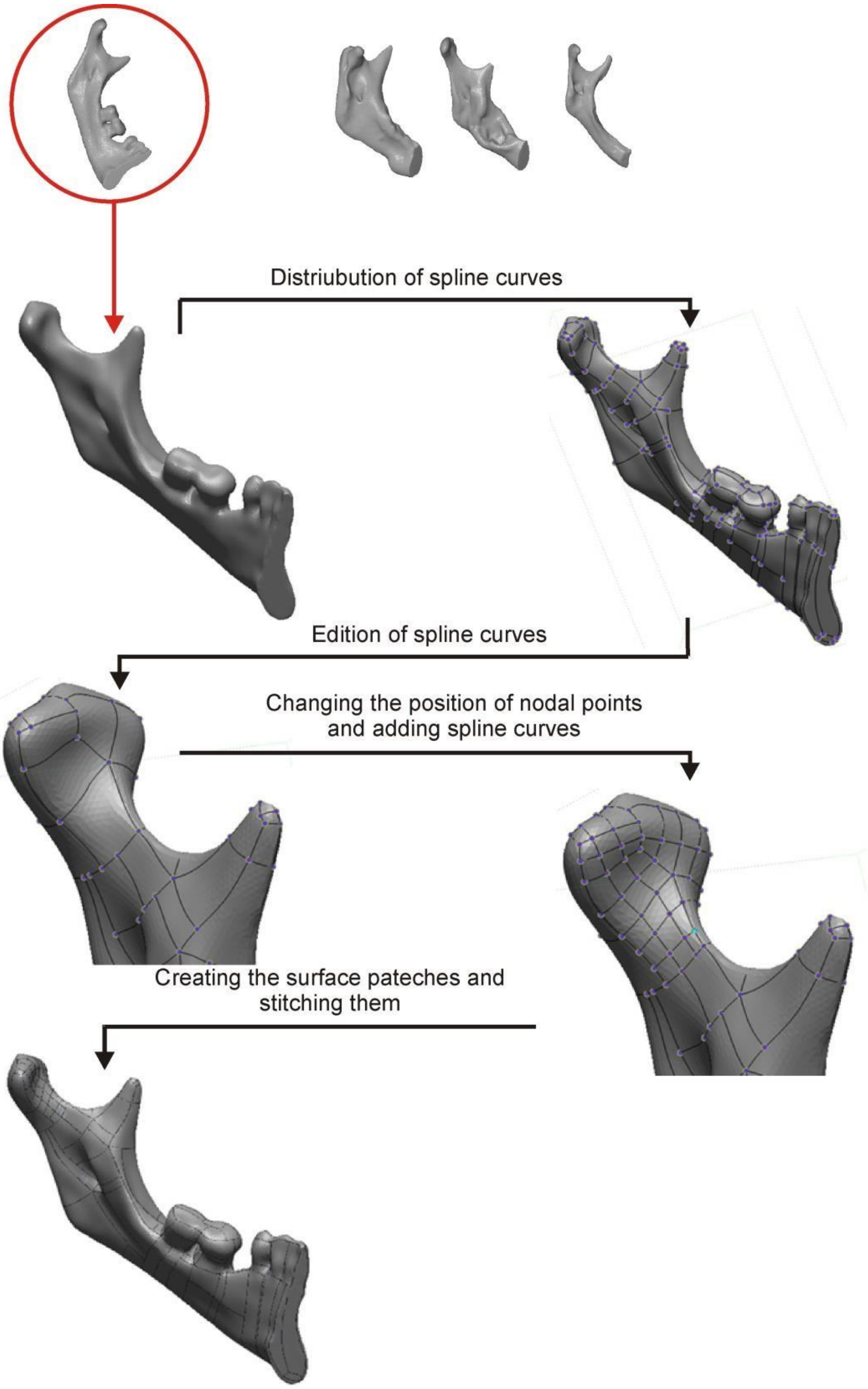

Figure3. The scheme of designing a mandible CAD model–mechanical method

3. Results

As part of the presented research, the CAD modeling methods were assessed to match the surface patches to the triangle mesh structure. The process of verifying the procedures was carried out on the Focus Inspection and GOM Inspect software. The fitting of the nominal model (triangle mesh) and the reference model (CAD model) was performed using the best fit method with an accuracy of 0.001 mm.

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4. Discussion

Two methods were used in the 3D modeling process - CAD of the mandible models - Organic and Mechanical. Both methods allowed for the creation of approximation splain curves on the obtained triangle mesh. As a result, an edge model was created on which the surface patches were spread. The great advantage ofthemethodsusedistheabilitytocontrolthecourseofthegeneratedcurves.The difference between them is how they are generated.

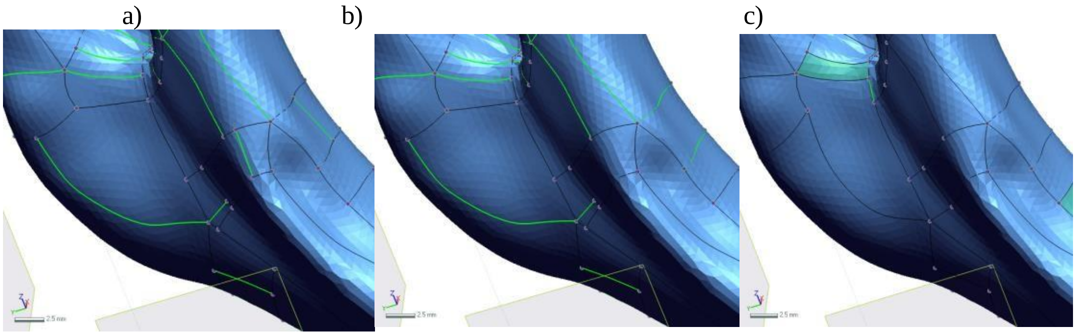

Figure3. Process of editing curves :(a) View before editing; (b) After removing curves; (c)after joining

The surface patches produced by the first approach had more uniform forms. The second approach is primarily concerned with reducing the quantity of patches on the 3D CAD model's surface. The condylar process's geometry and the most accurate portrayal of the mandible's lateral surface were carefully considered during the modeling process. These fields are mostly utilized in the design of implants and instruments to enhance the surgical procedure and post-operative care of patients in the mandibular region. There were issues with approach one, including lengthier data processing times and frequent non-closing of surface patches. Furthermore, evaluations evaluating how well the patches fit the model surface primarily point to an increase in the first method's standard deviation. The findings demonstrate that increasing the number of surface patches in a surface model of anatomical objects does not always improve the surface model generation's accuracy. The mapping of sharp edges in models presents a challenge for both approaches. When comparing the two processes, the mechanical approach is the most effective at simulating the mandibular lateral portions.

5. Conclusion

It is not an easy process to design an anatomical structural model for surgery. This is particularly true for the craniofacial region, which is made up of bone tissues with extremely intricate geometries. To make the most of the instruments currently accessible in linked processes, such as store and construct the craniofacial areas, CAD modelers need to possess the necessary knowledge and abilities in medicine and technical sciences. This is particularly true for the lower jaw, the sole moveable bone in this region. The findings of the initial study on the accuracy of creating a computer-aided design (CAD) model using a triangle mesh serve as a foundation for future work that will concentrate on creating a process for creating surgical templates and implants in the mandibular region.

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