3D Volume Rendering and 3D Printing (Additive Manufacturing)

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KEYWORDS

• 3D printing • 3D volume rendering • Additive manufacturing • Rapid prototyping

KEY POINTS

- Three-dimensional (3D) volume rendering can be useful in volumetric assessment of bone defects; however, this still needs to be visualized on a computer monitor.
- 3D printing, additive manufacturing, and rapid prototyping techniques are being used in surgical planning with satisfactory accuracy.
- Categories of additive manufacturing techniques are discussed based on manufacturing process.
- 3D printing applications in dentistry and maxillofacial prosthetics are discussed.
- Limitations include time and cost; accuracy depends on type of 3D printer, material, and build thickness.

THREE-DIMENSIONAL VOLUME RENDERING

Volume rendering is a set of techniques used to display a 2-dimensional (D) projection of a 3D discretely sampled data set. These volume-rendered images can be sectioned in any plane and rotated in space, allowing 3D insight into the anatomy of craniofacial bones. 3D-rendered images provide additional information for surgical planning and teaching. Both multislice computed tomography and cone beam computed tomography (CBCT) have been shown as reliable techniques in the volumetric assessment of bone defects in alveolar and palatal regions.[1] With these techniques, accurate assessment of the size and extent of bone defects caused by oral clefts, for example, is possible. This is important not only in the treatment planning but also to establish

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the donor area and the volume of bone graft (Fig. 1). However, these volume-rendered images are still limited to viewing on a computer monitor and provide only additional visual cues. For a novice surgeon with limited experience with spatial perception, accurately evaluating the anatomy from visual cues alone may be cognitively and perceptually demanding. Consequently, 3D-rendered images may not provide a significant advantage over traditional visualization methods.[2]

3D PRINTING OR ADDITIVE MANUFACTURING

3D printing, also known as additive manufacturing and rapid prototyping, was first developed in late 1980s and was soon applied in medicine and surgery. The application of digital technology with 3D volumetric imaging was first introduced to the craniomaxillofacial region in 1983.[3] In the 1990s, computer-aided design and computer-aided manufacturing techniques began to be used in craniomaxillofacial surgery. Many reports have demonstrated satisfactory accuracy of 3D-printed models generated from DICOM® (Digital Imaging and Communications in Medicine) images and their use in surgical treatment planning.[4–10]

Additive manufacturing technologies have been categorized by the American Society for Testing and Materials Standards body (ASTM Active Standard F2792, June 2012) according to manufacturing process (Fig. 2):

- Vat polymerization: Based on the exposure of a light source to a vat of a light-sensitive resin in a layered fashion. Examples used in dentistry are stereolithography or directed light projection. This type of printing requires a fair amount of post processing to remove supports, remove unused material, and to complete the cure of the material. These types of printers have become popular in dentistry (Figs. 3–5).
- Materials extrusion: Use of a filament that is extruded through a heated extruder of a known diameter. This is the technology in most of the inexpensive desktop printers used by hobbyists; however, it does have some application in dental and medical use for models. This also has some necessary postprocessing.
- Material jetting: Use of a material that is jetted through multiple ports, the material is then cured layer by layer. This permits use of different materials that allow for color or different durometer (stiffness) within the same print. Supports are generally easily removed and the print is completed
- Binder jetting: A bed of powder, generally a gypsum material. A print head delivers color and a binder layer by layer. The powder supports the piece. The completed part generally needs some type of postprocessing because the part is rather fragile.

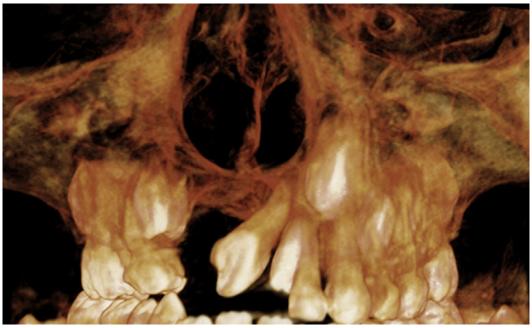

Fig. 1. Volume-rendered image from a CBCT dataset showing an alveolar cleft defect.

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