Three-dimensional computed tomography cinematic rendering of mandibular odontogenic myxofibroma

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Three-dimensional (3D) methods for visualizing volumetric computed tomography (CT) data can aid in understanding the extent of a disease process and planning necessary surgical interventions. Recently, a new method of 3D image creation, known as cinematic rendering (CR), has been developed; it produces photorealistic images from standard CT acquisitions. We describe the CT appearance of a rare tumor type, odontogenic myxofibroma, in the mandible of a 33-year-old woman, and we focus on the potential applications of CR visualizations in this and similar scenarios. Although prospective data quantifying the advantages of CR relative to traditional methods of 3D visualization are still forthcoming, the photorealistic quality of CR images, nonetheless, suggests the important potential utility of this method. Realistic shadowing effects in the images create depth and show the relative positions of objects within a visualized volume in an advantageous manner. Furthermore, soft tissue details allow for visualization of structures that can otherwise be difficult to render with traditional methods. (Oral Surg Oral Med Oral Pathol Oral Radiol 2019;128:e122–e125)

Odontogenic myxofibroma is a rare benign tumor that is predominantly found in the mandible[1] and represents a subtype of odontogenic myxoma that contains a large amount of collagen.[2] The origin of these tumors is unknown, although it has been speculated that they arise from a mesenchymal source, such as the tooth pulp.[1] Patients often present with otherwise asymptomatic swelling and facial asymmetry, although the lesions can become painful when adjacent structures are involved.[1] The radiographic appearance of these lesions is nonspecific and consists of expansile unilocular or multilocular radiolucencies within the mandible or maxilla with varying amounts of soft tissue component. The differential diagnosis is broad and can include odontogenic fibroma, ameloblastoma, intraosseous hemangioma, odontogenic keratocyst, aneurysmal bone cyst, and simple bone cyst.[3]

That these tumors arise in a region of complex anatomy, such as the facial structures, suggests that imaging with use of three-dimensional (3D) visualization methodologies may assist in determining the extent of disease for surgical planning.[4-6] Recently, a new methodology for 3D visualization of volumetric imaging data has been developed, known as cinematic rendering (CR).[7-9] Although CR can be used with both magnetic resonance imaging and computed tomography (CT) data, it has been primarily explored in the context of CT evaluations of diseases in complex anatomy such as musculoskeletal trauma,[10] cardiovascular abnormalities,[11-13] and maxillofacial and skull base pathology.[6] CR maintains similarities to traditional 3D visualization methodologies, such as volume rendering. However, it makes use of a more complex global lighting model that uses path tracing algorithms to more realistically take into account the interactions of light with the materials within the imaged volume.[8] This creates 3D images with improved surface detail and shadowing, which add depth and relative spatial information.

The following case report details the findings from a patient we recently encountered at our institution who had presented with a mandibular odontogenic myxofibroma. We applied CR visualization to the CT scan volume.

CASE REPORT

A 33-year-old woman with a past medical history of obesity and asthma (well-controlled, no prior history of intubations) was referred from an outside dentist for evaluation of a left mandibular mass. The patient reported that she had noted the slow growth of the lesion for at least 2 years, with progressive medial displacement of her 2 posterior most left molar teeth. The lesion itself was not painful, and she had no trismus. A noncontrast maxillofacial CT scan was ordered.

The CT scan revealed a complex, multilocular, expansile, predominantly lytic mass involving much of the left mandibular body and extending posteriorly to approximately the left mandibular angle (Figures 1 and 2). Although predominantly lytic, the lesion did have some calcified internal architecture, including fine curvilinear calcifications surrounding multiple loculations (see Figure 1). The internal contents of the lesion consisted of tissue attenuation, and soft tissue components were noted growing outside of the expected location of the mandibular cortex, most prominently along the buccal/lateral margin of the lesion (see Figure 1). The lesion was believed most likely to represent an

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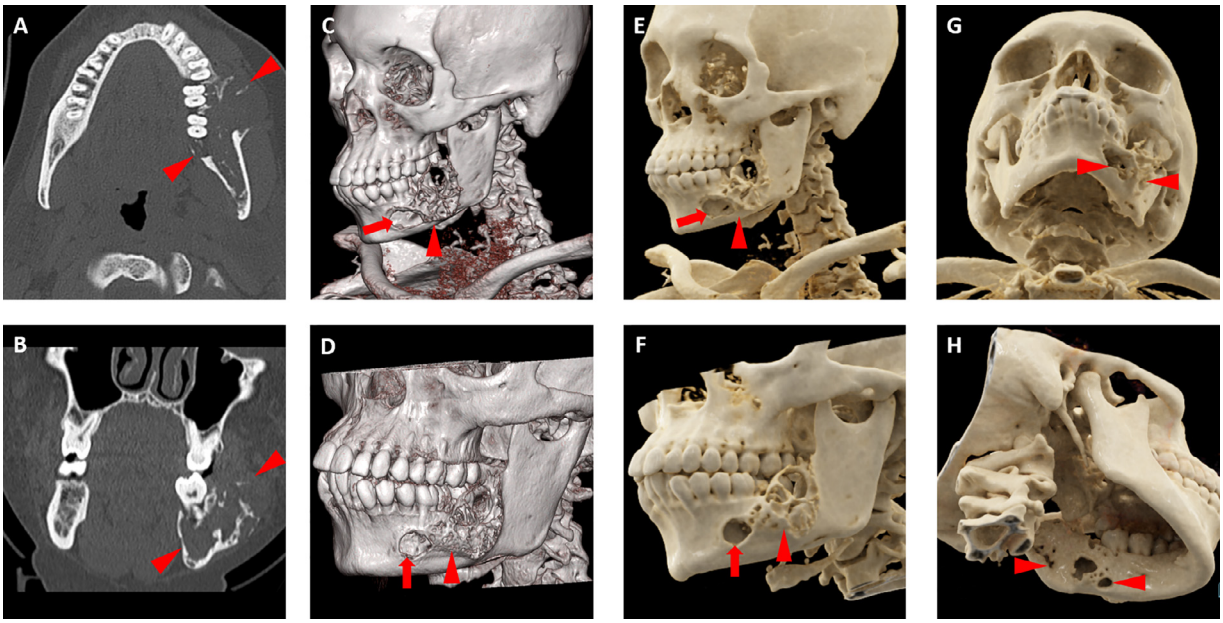

Fig. 1. **(A)** Axial non-contrast maxillofacial computed tomography (CT) image through the mandible demonstrates a radiolucent expansile lesion centered in the left body of the mandible and extending to the left angle *(red arrowheads)* with both buccal and lingual surface soft tissue components and with medial displacement of the adjacent left mandibular molars. This lesion was found to be an odontogenic myxofibroma following resection. **(B)** Coronal, noncontrast, maxillofacial CT image also demonstrates the lytic nature of the lesion with a significant associated soft tissue component (red arrowheads). **(C−D)** Volume rendered visualizations from a predominantly left anterior oblique orientation effectively demonstrate the odontogenic myxofibroma *(red arrowheads)* and allow for a superior visual overview of the lesion relative to the 2-dimensional (2D) images in **(A)** and **(B)**. The replacement of much of the left mandibular body by the lesion is readily apparent. **(E-F)** Cinematic-rendered (CR) visualizations of the odontogenic myxofibroma from similar left anterior oblique perspectives as in **(C)** and **(D)**. The photorealism of the cinematic rendered images can be noted; this is particularly apparent in some of the deeper mandibular radiolucencies, which are much more realistically shadowed in **(E)** and **(F)** then in **(C)** and **(D)** *(red arrows)*. **(G−H)** Additional CR images from a caudal perspective at the skull base **(G)** and from a caudal right posterior oblique projection **(H)** provide additional views of the odontogenic myxofibroma *(red arrowheads)*.

ameloblastoma, and the patient was scheduled to undergo resection with fibular free flap reconstruction.

To aid in surgical planning, 3D visualizations of the volumetric CT data were created and reviewed. These 3D images included both traditional volume rendering (see Figures 1C and 1D) and CR (see Figures 1E to 1H and Figure 2). Similar to the volume-rendered images, the CR images were created on a Siemens Syngo VB-30 workstation (Siemens, Erlangen, Germany); the rendering process involves interaction between the radiologist and the volumetric data so that appropriate window width and level, as well as necessary cut planes, are selected to produce visually diagnostic and appealing images. The creation of CR images takes

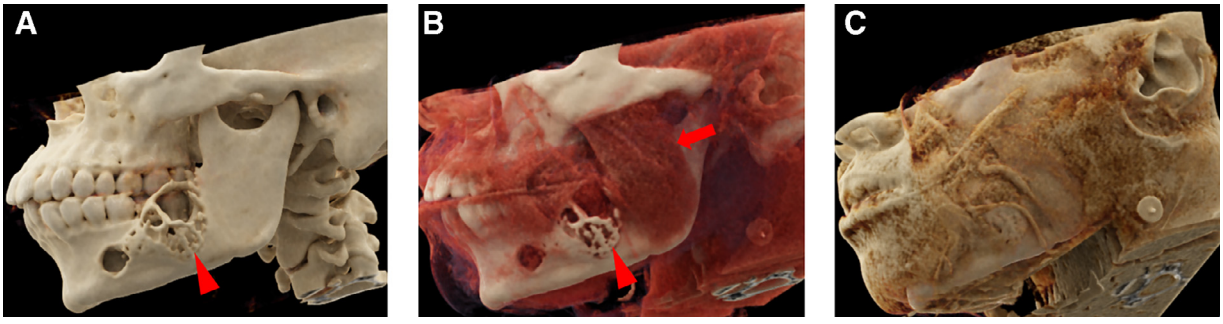

Fig. 2. **(A−C)** Cinematic-rendered (CR) images from the same patient as in Figure 1 with window width and level varied across the three panels to bring in more soft tissue overlay. The lesion can be seen in **(A)** and **(B)** *(red arrowheads)*. The high level of surface detail achievable with cinematic rendering provides the ability to see muscle texture, such as in the masseter muscle in **(B)** *(red arrow)*, as well as subtle superficial vascular structures and the cartilaginous folds in the ear in **(C)**.

approximately 5 minutes, allowing these images to be incorporated into typical clinical workflow. Furthermore, these images are created entirely from standard, volumetric CT data composed of isotropic voxels.

The overall extent of the lesion and its global architecture were well demonstrated on both the volume rendered and cinematic rendered images (see Figures 1C to 1H). However, a potential advantage inherent to the CR visualization algorithm includes the production of realistic shadowing effects that create depth in the images and allow for a more intuitive understanding of the relative positions of objects within the visualized volume (compare the large anterior radiolucency in the left mandibular body, as shown with volume rendering in Figures 1C and 1D with how the same finding is rendered with CR in Figures 1E to 1F, *red arrows*). In addition, the enhanced surface detail that is possible with CR allows for visualization of soft tissue structures that can be difficult to render with other methods (see Figure 2, where window width and level are adjusted to display varying amounts of soft tissue overlying the left mandibular lesion).

Shortly after imaging, the patient underwent the planned left hemi-mandibulectomy with right fibula free flap reconstruction. The patient suffered no significant complications in the perioperative or postoperative period. She rapidly progressed to full liquid diet with minimal pain medication requirement and was discharged on postoperative day 4. Gross pathology revealed a $6.0 \times 3.5 \times 3.5$ cm mass involving the left mandibular body as well as the overlying soft tissues. Final histologic diagnosis was odontogenic myxofibroma.

DISCUSSION

This case demonstrates the CT imaging appearance of the rare odontogenic myxofibroma in the left mandible of a 33-year-old woman. Additionally, both volume-rendered and cinematic-rendered 3D visualization methods were utilized to display the full extent of the disease and to contextualize the tumor within the complex anatomy of the facial structures and of the mandible. To date, prospective data that definitively identifies those features, if any, of CR that are quantitatively superior to volume rendering are not available. This is not surprising given the recent introduction of the CR technique. Nonetheless, the images provided in this article and other such images indicate potential advantages for CR that merit further study.

Perhaps the most prominent of those potential advantages in this case are the intrinsic realistic shadowing effects produced by the CR methodology (see Figure 1 for a comparison of CR with volume rendering in this regard). These shadows are a direct result of the global lighting model that underlies CR and derive from the complex path tracing that closely approximates the behavior of natural light when encountering the materials present in the imaged volume. The relative spatial relationships of objects are more intuitively displayed with CR, and this may have important implications for the use of these images in surgical planning.

The high level of detail that can be achieved with the CR methodology allows for display of soft tissues that are not otherwise easily rendered. By adjusting the window width and level settings during the interactive process of CR image creation, the radiologist is able to add or subtract overlying layers of soft tissue so that various aspects of a pathologic process or complex anatomy can be displayed.[10] The interpreting radiologist must take care not to obscure the lesion when including overlapping structures in the rendered volume or when the CR image is viewed from an angle that causes shadows to hide a finding of interest.[12]

Beyond surgical planning, we expect that CR will find utility in patient engagement because the photorealism of the images makes them easier to understand—a fact that should be appreciated by both clinicians and their patients when a complex pathologic process must be explained. Additionally, in some cases where 3D printing is currently utilized, these images may be sufficient and preclude the need for the expensive 3D printing process. Finally, student and trainee education is likely to be facilitated by the more intuitive nature of these photorealistic quality images, which should be able to serve as useful adjuncts to anatomy laboratories, simulations, and other educational tools.

DISCLOSURE

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REFERENCES

1. Meleti M, Giovannacci I, Corradi D, et al. Odontogenic myxofibroma: a concise review of the literature with emphasis on surgical approach. *Med Oral Patol Oral Cir Bucal*. 2015;20:e1-e6.
2. Simon ENM, Merkx MAW, Vuhahula E, Ngassapa D, Stoelinga PJW. Odontogenic myxoma: a clinicopathological study of 33 cases. *Int J Oral Maxillofac Surg*. 2004;33:333-337.
3. Dietrich E-M, Papaemmanouil S, Koloutsos G, Antoniades H, Antoniades K. Odontogenic fibromyxoma of the maxilla: a case report and review of the literature. *Case Rep Med*. 2011;2011:238712.
4. Yu Y, Zhang WB, Liu XJ, Guo CB, Yu GY, Peng X. Three-dimensional image fusion of ^{18}F-fluorodeoxyglucose-positron emission tomography/computed tomography and contrast-enhanced computed tomography for computer-assisted planning of maxillectomy of recurrent maxillary squamous cell carcinoma and defect reconstruction. *J Oral Maxillofac Surg*. 2017;75:1301.e1-1301.e15.

5. Liebregts J, Baan F, de Koning M, et al. Achievability of 3D planned bimaxillary osteotomies: maxilla-first versus mandible-first surgery. *Sci Rep*. 2017;7:9314.
6. Rowe SP, Zinreich SJ, Fishman EK. 3D cinematic rendering of the calvarium, maxillofacial structures, and skull base: preliminary observations. *Br J Radiol*. 2018;91:20170826.
7. Dappa E, Higashigaito K, Fornaro J, Leschka S, Wildermuth S, Alkadhi H. Cinematic rendering—an alternative to volume rendering for 3D computed tomography imaging. *Insights Imaging*. 2016;7:849-856.
8. Johnson PT, Schneider R, Lugo-Fagundo C, Johnson MB, Fishman EK. MDCT angiography with 3D rendering: a novel cinematic rendering algorithm for enhanced anatomic detail. *AJR Am J Roentgenol*. 2017;209:309-312.
9. Eid M, De Cecco CN, Nance Jr., JW, et al. Cinematic rendering in CT: a novel, lifelike 3D visualization technique. *AJR Am J Roentgenol*. 2017;209:370-379.
10. Rowe SP, Fritz J, Fishman EK. CT evaluation of musculoskeletal trauma: initial experience with cinematic rendering. *Emerg Radiol*. 2018;25:93-101.
11. Rowe SP, Johnson PT, Fishman EK. Initial experience with cinematic rendering for chest cardiovascular imaging. *Br J Radiol*. 2018;91:20170558.
12. Rowe SP, Johnson PT, Fishman EK. Cinematic rendering of cardiac CT volumetric data: principles and initial observations. *J Cardiovasc Comput Tomogr*. 2018;12:56-59.
13. Rowe SP, Johnson PT, Fishman EK. MDCT of ductus diverticulum: 3D cinematic rendering to enhance understanding of anatomic configuration and avoid misinterpretation as traumatic aortic injury. *Emerg Radiol*. 2018;25:209-213.

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