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RESEARCH ARTICLE OPEN ACCESS

ARTIFICIAL INTELLIGENCE OF COMPUTERIZED TOMOGRAPHY IMAGE RECONSTRUCTION BY BEAM AND MAGNETIC RESONANCE WITH THE USE OF THE INVESALIUS 3 SOFTWARE IN THE 3-D PRINTING OF BUCOMAXILLOFACIAL PROSTHESIS IN ORAL CANCER SURGERY

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ABSTRACT

Introduction: Ghost Cell Odontogenic Carcinoma is extremely rare, the etiology is unknown, and its diagnosis is only possible when the resected specimen is examined histologically. Radiographically, this Carcinoma is seen as a unicameral or multilocular radiolucent image without clear boundaries and is associated with varying degrees of bone destruction and infiltration into adjacent structures. ***Methodology:*** this is an integrative review, through bibliographic searches in the Pubmed, Scielo and Google Academic databases, based on articles published between 2017 and 2022, in English and Portuguese languages, where articles prior to 2017, that were unrelated to the theme, repeated and in other languages were excluded. ***Results:*** Facing the inclusion and exclusion criteria, 5903 articles were found, of these, 5883 were excluded after analysis and 20 selected to base the review. ***Discussion:*** The three-dimensional model is valuable for surgical planning and outcome prediction. InVesalius is an open source Software that allows 3-D reconstruction of human body structures and includes measurement volume of lesions. ***Conclusion:*** Invesalius offers valuable potential for low-cost virtual analysis that playsan important role in diagnosis as an intraoperative guide before surgeries.

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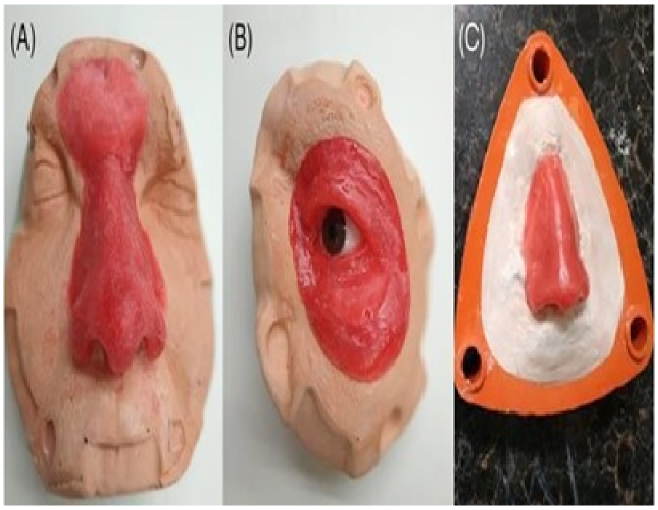
INTRODUCTION

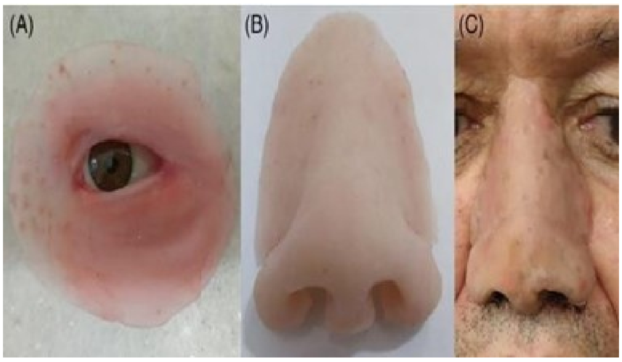
Ghost Cell Odontogenic Carcinoma (GCOC), a malignant counterpart of calcifying cystic odontogenic tumor, is extremely rare. It is characterized by ameloblastoma, as islands of epithelial cells with aberrant keratinization in the form of ghost cells with variable production of mineralized or dentin-like matrix. The etiology of GCOC is unknown, and its diagnosis is only possible when the resected specimen is examined histologically (GOMES et al., 2017). InVesaliusis an open source software tool for medical image visualization and analysis that works with the DICOM (Digital Imaging Communication in Medicine) file format. Itallows t h e user to create triangular mesh, manual or semi- automatic image segmentation, and volume rendering based on data obtained by scanning. In addition, InVesalius offers an ability to execute on different operations (PAKHOMOVA, Catherine et al., 2020). Maxillofacial prosthetics replace soft tissue that has been lost due to disease or trauma, providing restoration of the original anatomy and protecting the injured tissue. Silicone is the most commonly used material, but the cross-linking process usually takes 24 hours to complete. In another study, silicone and poly (methyl methacrylate) (PMMA) was prepared at room temperature and assisted by microwave irradiation. The sample was characterized by Raman confocal microscopy and scanning electron microscopy/ray-specification. X with trispectral energy scattering. Microwave-assisted crosslinking is completed in 10 minutes and leads to improved adhesion between silicone and PMMA than the ambient sample. The methodology was adapted for the fabrication of prostheses for 50 patients with an average life of 3 years (Dos Anjos, DSC, Revoredo, ECV et al., 2020).



Source: Dos Anjos, DSC, Revoredo, ECV et al., 2020.

Figure 1. A mold is initially carved in paraffin (Figure 1A,B) and inserted into a brass molding unit (Figure 1C) and pressed to give the desired shape

With the introduction of new computer technologies, the establishment of a set of standards for information exchange and storage, the development of complementary imaging in the modality (computed tomography (CT), magnetic resonance imaging (MRI), and digital ultrasound), and the advent of the three-dimensional (3D) printer, it is now possible to rapidly fabricate patient models (known as rapid prototyping). It is estimated that the savings (in terms of time and cost) provided by applying this rapid 3D prototyping technique is approximately 70%-90%. The 3D printed images produced from CT, called biomodels (Revoredo, ECV et al., 2020).



Source: Dos Anjos, DSC, Revoredo, ECV et al., 2020.

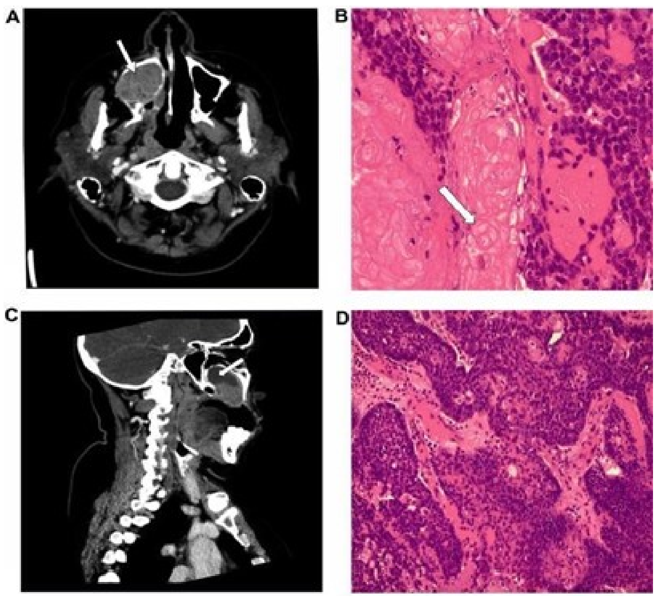
Figure 2. Facial prostheses made with silicone/PMMA blends. A, Hemifacial; B, Nose; C, Nose prosthesis delivered to a patient. PMMA, poly (methyl methacrylate)

METHODOLOGY

This study is an integrative review, through bibliographic searches in the databases Pubmed/Medline (Medical Literature Analysis and Retrieval System Online), Scielo (Scientific Electronic Library Online) and Google Scholar, with the descriptors "Oral Cancer", "Diagnosis", "Invesalius", "Artificial Intelligence" and "Dentistry", conducted in the period January 2022. As a result of the search, 5903 articles were found, which were read from the title and abstract to evaluate the eligibility criteria. The inclusion criteria for selection of articles were scientific studies available in full, in English and Portuguese, published from 2017 to 2022, and that met the theme. The exclusion criteria were publications prior to 2017, productions not related to the theme, repeated articles, articles in other languages, and articles that were not in their entirety. After the inclusion and exclusion criteria, the following results were obtained: 5883 articles were excluded, leaving 20 articles that were read in full and critically analyzed and included in the review.

RESULTS

It was possible to reduce the bone transparency and observe the morphology of the mass, which was isolated from the other structures, allowed the size and position of the tumor to be confirmed (Figure 4A) and compared with the lesion ina fully hyperdense skull. In the 3-D model, after measuring the volume (21,989,409 mm³), the lateral margin of the tumor was shown to be more prominent, suggesting a higherprobability of tumor invasion in this area (Figure 4B). The area corresponding to the tumor on the CT image was manually segmented (Figure 4C), and in adding the tumor, the volume gave us a new perspective regarding the extentof the lesion in cubic millimeters, and also the analysis of morphological aspects of the tumor in panoramic view (Figure 4D). From two-dimensional (2D) images obtained by Computed Tomography (CT) or MRI equipment (D) Islands of ameloblast-like epithelial cells (hematoxylin and eosin x20). Magnetic Resonance Imaging (MRI), the program allows the creation of three-dimensional (3-D) virtual models corresponding to the anatomical structures of patients under medical follow-up. The Software allows the combination of a CT slice and the 3-D reconstruction of the neoplasm into a single image, as illustrated in Figure 5C. This makes it possible to combine a specific CT slice andthe 3-D reconstruction of the tumor (Figures 5C and 5D), allowing customization of surgical planning for the specific tumor (GOMES et al., 2017).



Source: GOMES et al., 2017.

Figure 3. (A) Computed tomography (CT) of the neck with intravenous contrast. An axial section shows an expansile lesion (arrow) infiltrating the maxillary sinus through the palate on the right side of the maxilla. (B) Hyperchromatic epithelial cells and enucleated, eosinophilic ghost cells (hematoxylin and eosin x40). (C) Lesion showing varying levels of density due to the presence of cystic area (arrow)

In this case, the volume of the cystic area was 5,224.335 mm³, representing 23.758% of the total. The software made it possible to combine a particular slice of the CT scan and the 3-D reconstruction of the tumor into a single image (Figure 5C), thus individualizing the tumor for further surgical planning (Figure 5D). The existence of a prominent region in the 3-D model near of the soft tissue, representing the right lateral margin, which was shown to be compromised by neoplastic cells after the first surgical procedure. The same method wasemployed with the cystic area; after manual segmentation (Figure 5A), it was possible to individualize the cystic area within the tumor, adjust the transparency level of the 3-D tumor model (Figure 5B) and to determine how much of the total volume lesion corresponds to the solid and cystic area, respectively (GOMES et al., 2017).

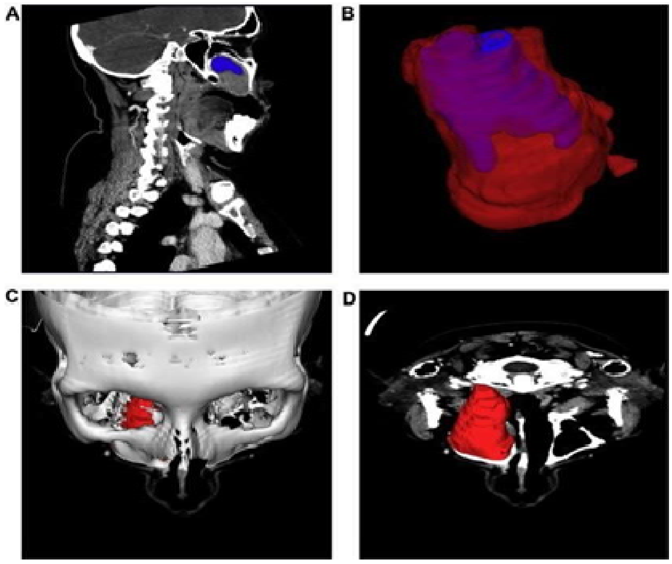
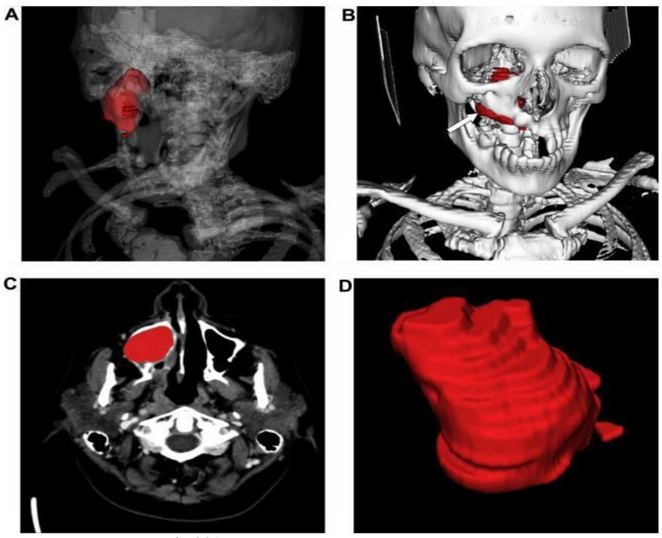


Figure 4. (A) Skeletal structure in isometric perspective with decreased transparency of the bone for better characterization of the neoplasm. (B) Volumetric reconstruction of the lesion within the bone structure after manual segmentation (volume measurement: 21.989.409 mm³) and automatically generated skeleton by pre- established boundaries. (C) Manual segmentation of the lesion infiltrating the maxillary sinus through the palate in an axial section of the CT scan of the neck. (D) Panoramic view of the individualized tumor after manual segmentation with volume measurement of 21,989.409 mm³.



Source: GOMES et al., 2017.

Figure 5. (A) Manual segmentation of the cystic area in sagittal section of neck CT scan. (B) Individualization of the cystic area by adjusting the transparency levels of the 3-D tumor model, which makes it possible to determine the percentage of solid and cystic areas by their volume. (C and D) 3-D reconstruction model of the tumor from axial section of CT scan.

The pre-surgical planning was based on the biomodel. Using information about the best surgical approach for resection margins, previously discussed with the surgeon, the datawere transferred to the prototype to facilitate preoperative preparations (Fig 6). Modeling of the obturator in the prototype was completed upon removal of the viable prosthesis made prior to maxilectomy and on the basis of the pre-surgical CT (Fig. 7). It is important to observe the internal space that originates from a tumor resection, as well as the area that forms the external wall of the upper jaw, to reproduce a structure that will replace the area sectioned by a maxilectomy while promoting recovery (Fig. 8)(Revoredo, ECV et al., 2017).

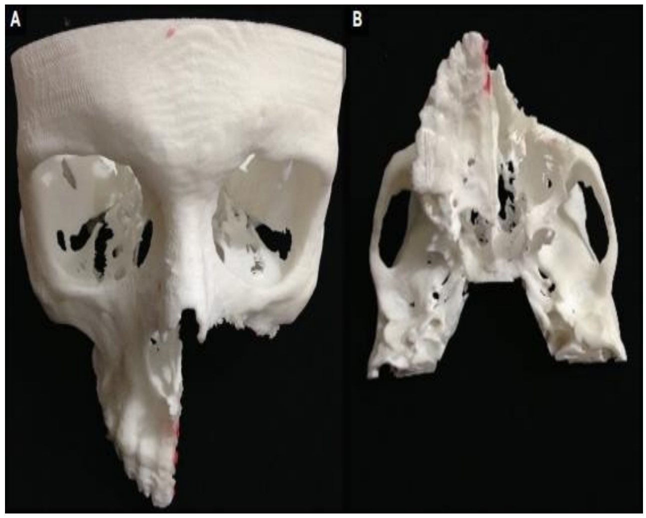


Figure 6. Bio-model of the resected maxilla. A. Coronal view. B. Axial view

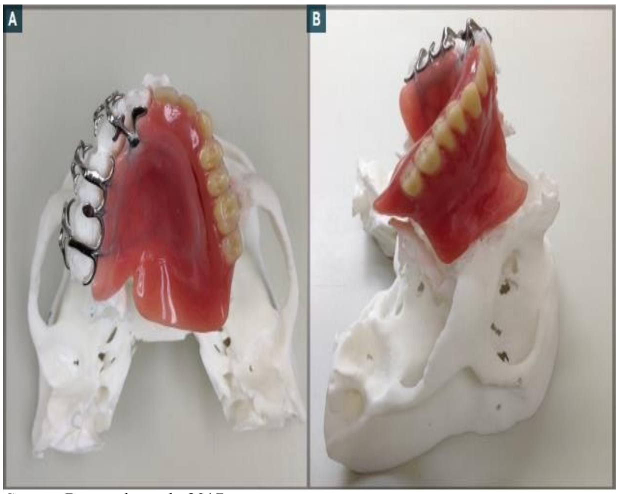
DISCUSSION

GCOC is a rare neoplasm that occurs mainly in the maxillary bone. It is essential that the procedure is precise inits surgical margins because the role of adjuvant therapies for this disease are controversial. A CT scan of the neck is a key element in determining the correct cancer staging and surgical planning.

Source: Revoredo et al., 2017

Figure 7. Waxed palatal obturator in the model

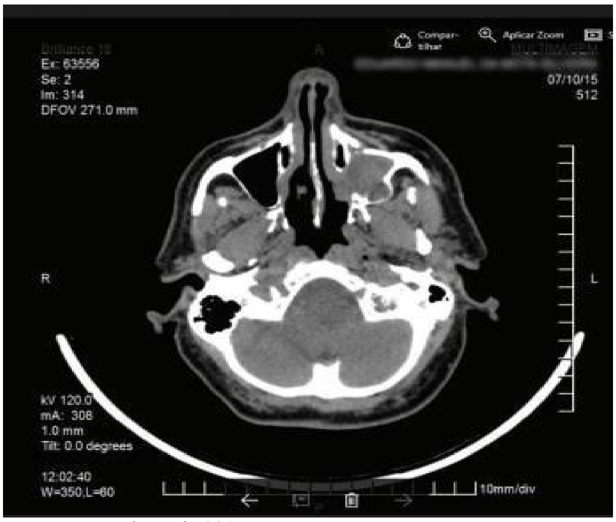
Targeting of the neoplastic structure is performed manually using the brush for axial, coronal or sagittal sections of the CT data and provides a representative 3-D image of thetumor, which appears automatically. It is also possible to rotate and magnify the targeted structures, and changing their transparency individually allows the analysis of the relationship between the pathological condition and the bone structure surroundingthe tumor. The volume of a GCOC area can be determined by 3-D reconstruction of the lesion using Invesalius. The 3- D reconstruction aspect of the tumor emphasizes more enlarged areas and their proximity to soft tissue surrounding the tumor, a factor that can assist the surgeon in deciding which areas should be selected for freezing and section analysis (GOMES et al., 2017).



Source: Revoredo et al., 2017.

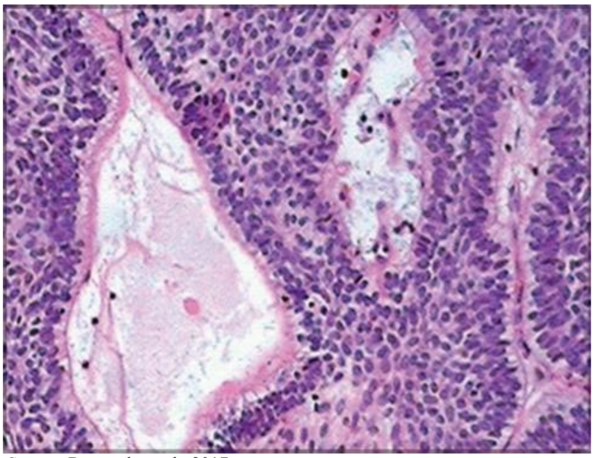
Figure 8. Palatal obturator adapted to the biomodel. A. Axial view. B. Sagittal view

CT scan showed a solid mass with soft tissue density in the inferior portion of the left maxillary sinus (Fig. 9).



Source: Revoredo et al., 2017.

Figure 9. CT scan showing lesion in the left maxillary sinus



Source: Revoredo et al., 2017.

Figure 10. Solid, cystic lesion exhibiting a proliferation of ameloblastic epithelial cell islands (hematoxylin and eosin stain; original magnification 100x)

The lesion ruptured the posterior cortex of the paranasal sinuses and obliterated the fat pad of the masticatory space. Microscopic analysis revealed a solid, cystic lesion comprising ameloblastic epithelial islands, separated by areas of stellate cells with loose connective tissue and a peripheral area composed of columnar cells (Fig. 10). These columnar cells demonstrated a hyperchromatic nucleus oriented away from the membrane, i.e., reverse polarity. Immunohistochemistry also revealed diffuse positivity for 34βE12 and p63 protein. The finding was consistent with themarker typically found in a multicystic solid ameloblastoma and correlated with clinical and radiographic evidence (Revoredo, ECV et al., 2017).

CONCLUSION

The 3-D image provided by the InVesalius software was presented, which avoided the risk of a second surgery. Therefore, regarding the GCOC, this study shows the importance of 3-D reconstruction in the planning stage because the use of this feature can provide the surgical team with clear information about the shape and location of the lesion, as they may not be clearly seen on 2-D images or individualized by CT images. The volume of the tumor, asprojected on the biomodel, can aid in planning of possible surgical margins, the resulting defect and, consequently, the extent of the reconstructive prosthesis. An immediate palatal obturator prosthesis made of this 3D technology with head and neck neoplasms, allows the possibility of immediate rehabilitation. Thus, choosing a workflow in 3D reconstruction, the Software, the type of 3D printer, the mechanical characteristic, provides the gain of time and accuracy of the printing material.

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