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EDUCATION & TRAINING

Application of PDF Software with 3D Functionalities in Radiological Models of the Skull Base: Characteristics, Experience and Solutions

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Abstract

A widely known alternative for reading and exchanging digital files is the PDF file, by Adobe. This type of file has become the most used for the electronic exchange of files. It is platform-independent, suitable for the exchange of medical data in electronic academic publication. PDF can support additional resources such image, media, even, three-dimensional surface mesh models. A three-dimensional model of the base of the skull is generated from computed tomography images to provide an overview of the PDF file format, with emphasis on biomedical images. Three-dimensional representation in PDF files offers many advantages, as these images have more information than two-dimensional images, therefore, we consider this tool (3D PDF) a good alternative for the visualization, interaction and distribution of 3D content.

Keywords 3D PDF · Tridimensional images · Interactive visualization · Skull base

Introduction

In the biomedical sphere, three-dimensional (3D) formulas are ubiquitous. However, data are usually presented in a two-dimensional form, or 3D models are projected in a two-dimensional (2.5D) plane. It entails an inherent loss of the information contained. The main reason is a technical problem [1]. Portable Document Format (PDF) is the most commonly used file format for the exchange of electronic documents [2]. It allows documents to be read while keeping their accuracy regardless of the device or operating system used to create the document [3]. It is the standard file format for communicating biomedical information over the Internet and for electronic academic publications [4]. It is platform-independent, suitable for the exchange of medical data.

However, the PDF file format offers more features. PDF can support additional resources (e.g. text, images or media) and open them easily with the free Acrobat Reader software. They also offer the possibility of being signed electronically [3, 5]. The latest versions of Adobe's PDF format allow the incorporation of three-dimensional (3D) surface mesh models, thus allowing an interactive visualization (e.g., zoom, panorama, rotation and component selection) of these objects with qualified reading software [5–7].

The first software capable of supporting 3D models was Adobe Reader 7. However, the software that really enabled more efficient use to work with 3D models in PDF Acrobat 8 was launched in early 2006. This version provides tools for importing and converting. Of many 3D formats and a 3D editor [3].

PDF has become an international ISO standard and is the electronic standard for most private and business documents. Therefore, we consider it useful to make an exhibition where the main functionalities offered by the PDF format with 3D content are discussed, taking as an example a radiological model of the skull base.

History:

The PDF file format started off on the dream of a paperless office, as the pet project of one of Adobe's founders, John Warnock. Initially it was an internal project in the company

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to create a file format so documents could be spread throughout the company and displayed on any computer using any operating system. Initially it was called the "Camelot project", which later became the Acrobat software {1–3].

The first time Adobe actually talked about this technology was at a Seybold conference in San Jose in 1991. At that time, it was referred to as 'IPS' which stood for 'Interchange PostScript.'

The PDF software has been developed by Adobe, incorporating improvements and add-ons in each of the updated versions.

Version 1.0 of PDF was announced at Comdex Fall in 1992. The tools to create and view PDF-files, Acrobat, were released in 1993. Acrobat 2 (November 1994) supported the new PDF 1.1 file format which added support for external links, notes… etc. Acrobat 2.1 added multimedia support with the possibility of adding audio or video data to a PDF document. PDF 1.2 was the first version of PDF that was really usable in a prepress environment. The release of a plug-in to view PDF files in the Netscape browser increased the popularity of PDF file on the booming Internet. The next version, Acrobat 4, (4.0) contained quite a lot of bugs that limited the usefulness of the software for prepress purposes. By the time Acrobat 4.05 was released, it could hardly be disputed that PDF had become an accepted file format for information exchange. More than 100 million copies of Acrobat Reader had been downloaded from the web. PDF 1.4 and Acrobat 5 appeared in May 2001. The file format itself had not changed that much. It was made easier to create PDF-files that could adapt themselves to the device they will be used upon, for the emerging market of ebooks, since it allows PDF files to be repurposed so they can be used on a wider variety of systems.

Acrobat 6 (2003) and PDF 1.5 bring along a number of new features, that were not implemented in their entirety. In 2005 Adobe started shipping Acrobat 7. It offered support for a new PDF flavor; PDF 1.6 that can be used as a kind of 'container' file format by offering the possibility to embed files into a PDF. The major new feature is the ability to embed 3D data. PDF 1.7 was the most 'unexciting' PDF-version to ever be released, it contained improved support for commenting and security. Support for 3D also got improved, with the possibility to add comments to 3D-objects and more elaborate control over 3D animations [2]. One interesting development with PDF 1.7 is the fact that it became an official ISO-standard (ISO 32000-1:2008) in January 2008 [4].

Adobe Acrobat 8, (available in October 2006), introduced one interesting new feature: instead of using PDF 1.7 as its default file format, it sticks to PDF 1.6. It has also become easier to save documents as an older PDF version.

Since the ISO-organization now controls the PDF-standard, Adobe couldn't introduce a new PDF 1.8 file format with the release of Acrobat 9 (June 2008). However, the PDF file format is pretty flexible however and it allows for the use of extensions. This, can be used to embed geospatial data in a PDF file, something that is useful for maps.

The latest PDF project is PDF 2.0 released in 2018. This is the first major update in PDF post-Adobe. It is a refinement of the PDF format. Enhances document security, increased accessibility and allows a superior experience for managing and displaying graphically rich media: 3D, video, geospatial and printing. An important difference compared to previous versions of PDF, as ISO owns the copyright, the PDF 2.0 can not be freely downloaded [5–7].

Methodology

Instruments

A systematic search of the literature is carried out in the scientific database PUBMED. It is carried out by entering the words "Portable Document Format, 3D PDF" to find articles that apply 3D PDF technology for visualization purposes in the field of biomedical sciences.

Since PDF is a carrier for presenting data, rather than a research topic in itself, we selected the search for those articles that use PDF as a visualization medium.

It was limited to articles published after 2004, since, as mentioned above, 3D PDF was not available before 2005.

Several results ($n = 6$) should be discarded because there is no useful information or they are not related to the field of biosciences.

The rest of the articles obtained ($n = 13$) are analyzed to assess the applications in which they have used the PDF software with 3D functionalities.

Based on CT images (machine: CT Philips Brillance, 40 detectors), three-dimensional models are made.

The study protocol used is the so-called "boulders", with a cut thickness of 1 mm, and a pitch increase of 0,75. Parameters of the X-ray tube of 410 mA and 120 kV with collimation of 2 × 0.5mm and FOV of 200 mm are used. The studies have an average radiation dose of 432,4 mGy*cm. (Figs. 1 and 2).

The images are obtained from radiologic studies stored in the PACS archive of Radiology Department at the "Hospital Virgen de la Concha" (Zamora, Spain). Therefore, consent of the subjects of the studies is not necessary.

In this text we work with the PDF version of Acrobat reader DC version (15.016.20045).

Design and procedure

A three-dimensional model of the base of the skull is generated from computed tomography images obtained from studies carried out at the "Hospital Virgen de la Concha" (Zamora, Spain).

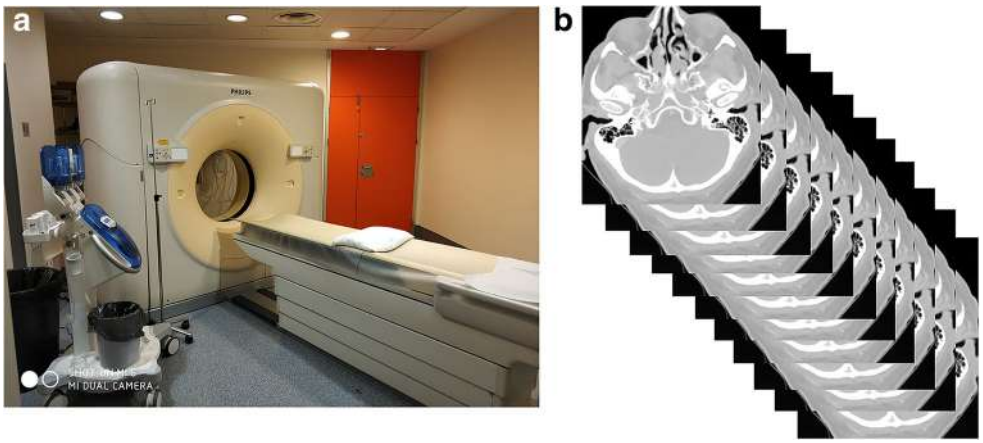

Fig. 1 **a** CT Philips Brillance, 40 detectors. Hospital Virgen de la Concha. **b** DICOM images of CT

The images are processed in the PHILIPS IntelliSpace PORTAL ® workstation, obtaining 3D surface models in 3D-PDF format.

Anatomical parts that are not to be included in the model are eliminated with the cutting tools. Afterwards, the regions of interest are selected (this is done automatically or manually depending on the definition of the images) and a surface mesh is created. They are then saved in the format of interest, in our case in 3D-PDF.

This model is used to show the functionalities of the 3D-PDF file format to show the anatomical models of biomedical use.

In our work, we handle the model created with Adobe Acrobat Document Cloud (version 2019.010.20064), free standard downloaded from the network, from the Adobe company website: "https://get.adobe.com/es/reader/".

Results

Bibliographic search

The bibliographic search in the PUBMED database when entering the words "3D PDF Portable Document Format" had

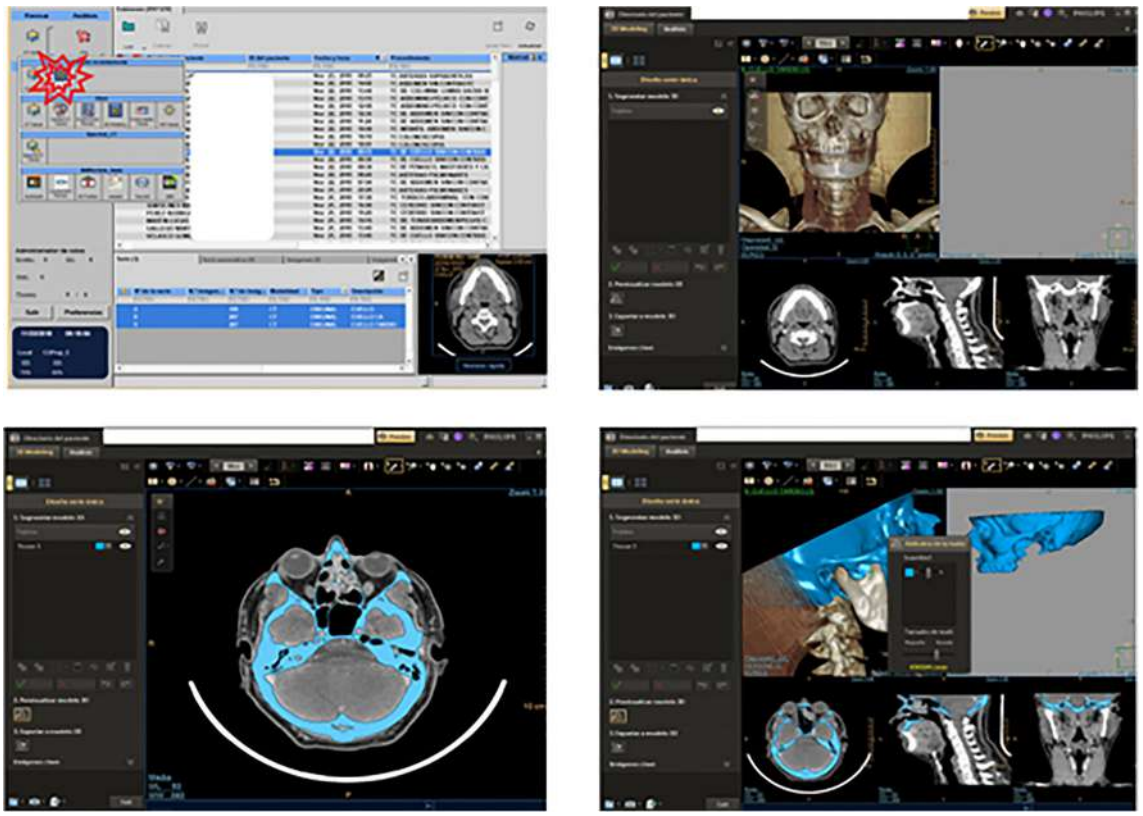

Fig. 2 Screenchot of Portal IntelliSpace Philips, creating 3D model

Table 1 Results from PubMed Database

Article (n = 13)	Journal	Year	Field	Aplication
The Role of Portable Documentation Format in Three-Dimensional Interactive Visualization in Maxillofacial Prosthetics.	International Journal Prosthodont.	2018	Odont	Visualization
A Novel and Freely Available Interactive 3d Model of the Internal Carotid Artery.	J M Systems	2018	Neurol	Visualization
Using Interactive 3D PDF for Exploring Complex Biomedical Data: Experiences and Solutions.	Stud Health Technol Inform	2016	Anatom	Visualization
Interactive 3D-PDFPresentations for the Simulation and Quantification of Extended Endoscopic Endonasal Surgical Approaches.	J M Systems	2015	Surgic	Clinical App
Software for browsing sectioned images of a dog body and generating a 3D model.	Anac Rec	2016	Animal	Visualization
Towards an easier creation of three-dimensional data for embedding into scholarly 3D PDF (Portable Document Format) files.	Peer J	2015	Inform	Teaching
Application and evaluation of interactive 3D PDF for presenting and sharing planning results for liver surgery in clinical routine.	PLos one	2014	Surgic	Clinical App
3D interactive model of lumbar spinal structures of anesthetic interest.	Clin anat	2015	Anest	Visualization
Simplified generation of biomedical 3D surface model data for embedding in to 3D portable document format (PDF) files for publication and education.	Plos one	2013	Educ	Teaching
Embedding 3D radiology models in portable document format.	AJR Am	2012	Radiol	Teaching
Portable document format file showing the surface models of cadaver whole body.	J Korean Med	2012	Educ	Teaching
Three-dimensional portable document format: a simple way to present 3-dimensional data in an electronic publication.	Am J Orthod Dentofacial Orthop	2011	Educ	Visualization
The interactive presentation of 3D information obtained from reconstructed datasets and 3Dplacement of single histological sections with the 3D portable document format.	Development	2011	Educ	Teaching

19 results. The temporary filter was applied from 2004 to 2018.

Several results ($n = 6$) should be discarded because there is no useful information or they are not related to the field of biosciences.

The rest of the articles obtained ($n = 13$) contained information on 3D PDF technology in the field of research (Table 1; Fig. 3).

Most of the results are related to teaching ($n = 7$). Results were also obtained for the demonstration of the 3D PDF tool in data visualization ($n = 4$) and for use in clinical applications ($n = 2$).

The functionality of the 3D PDF model

In the initial view of the PDF document, an interface of the projected 3D model is displayed as a two-dimensional view image (2.5-dimensional image) (Fig. 4).

By selecting the model with the mouse pointer, the model is selected for the different functions.

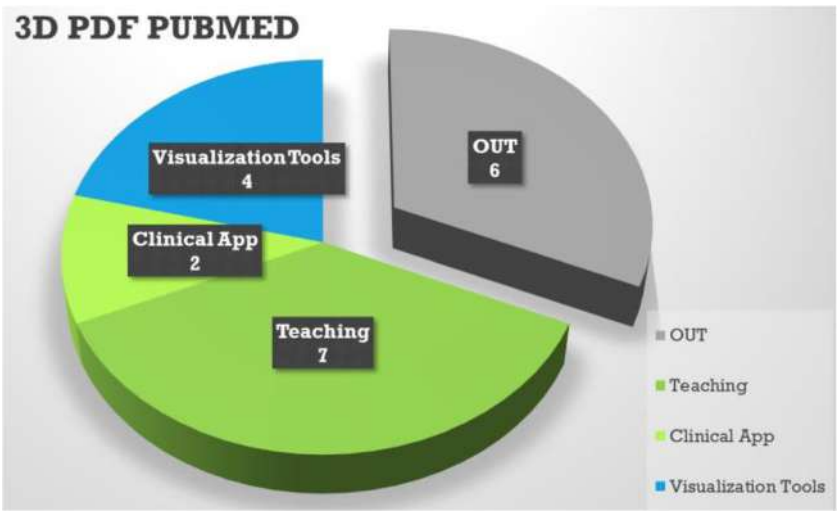

Fig. 3 Graphic results bibliography search

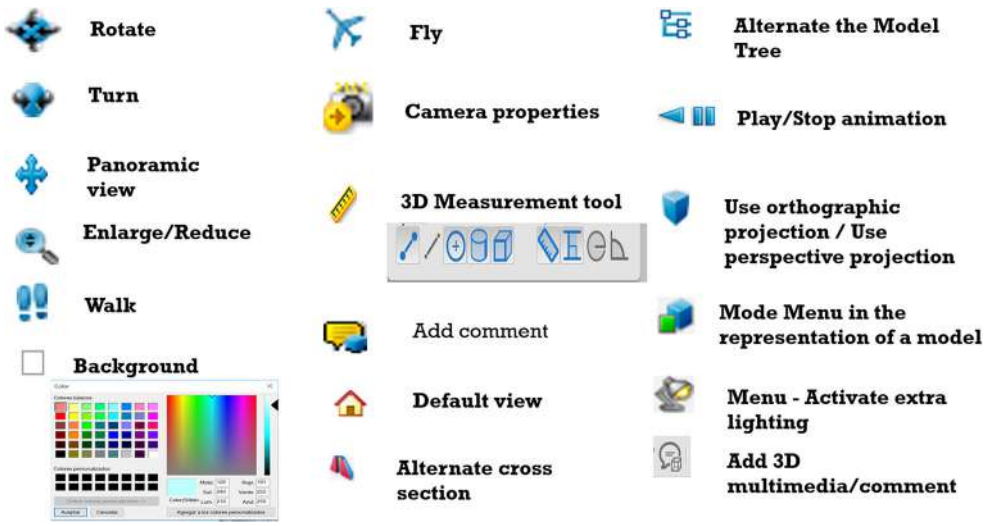

Fig. 4 3D toolbar buttons

Once the 3D content is enabled, a 3D toolbar opens and the animation is played (if the model we are using has this one).

The PDF file allows you to customize the basic functions, according to the preferences of each user. It is possible to hide or incorporate buttons of common use according to the interests of the user [8, 9].

The 3D toolbar allows you to manage the different functions to interact with the surface model.

With the different tools included in the toolbar, you can enlarge a part of the model, rotate it, navigate… The model tree allows you to hide or isolate parts, or make parts transparent.

3D navigation tools

The PDF has a series of tools to work with the models (Fig. 5).

Rotate the 3D model, move a 3D model, panoramic view, zoom, walk on models, surface flight function, set camera properties; to define camera angle, alignment and other properties that define the lens through which a 3D model is viewed.

In addition, it allows measurements to be made on the 3D model. Different units and types of measurements can be configured; distances, angles, etc.

Controls in the 3D toolbar

Default view It recovers the zoom, panoramic, rotation and projection mode of the 3D model (Figs. 6 and 7).

View menu This second part of the toolbar offers the possibility to make changes to the appearance of the model.

The Play/Stop animation alternates the perspective viewing and orthographic projection of the 3D object, provides different appearances of the model, outlines the content, activates additional lighting (it provides a drop-down list of the various lighting effects available to improve the illumination of the 3D object).

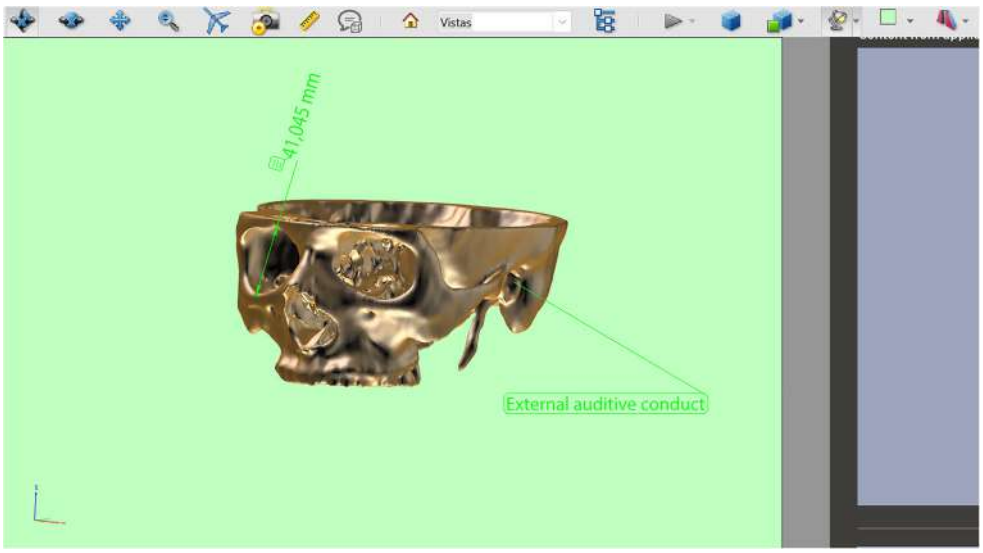

Fig. 5 Screenshot of a model with a measure and annotation

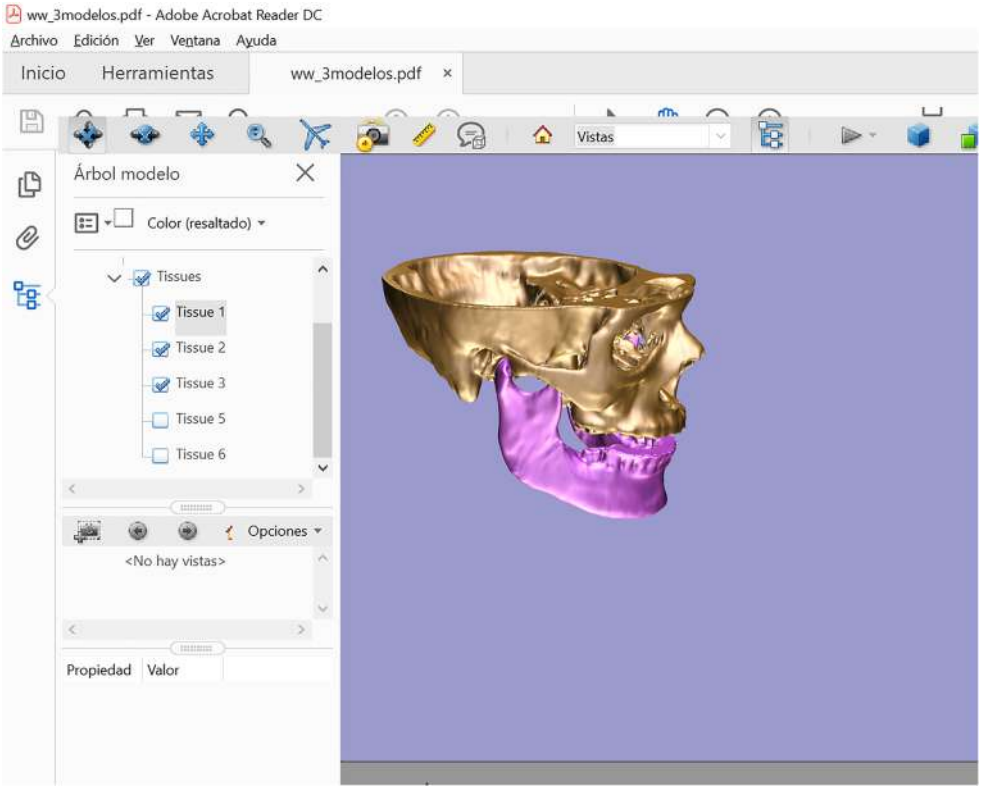

Fig. 6 Screenshot of a model with a cross-section plane in sagittal plane

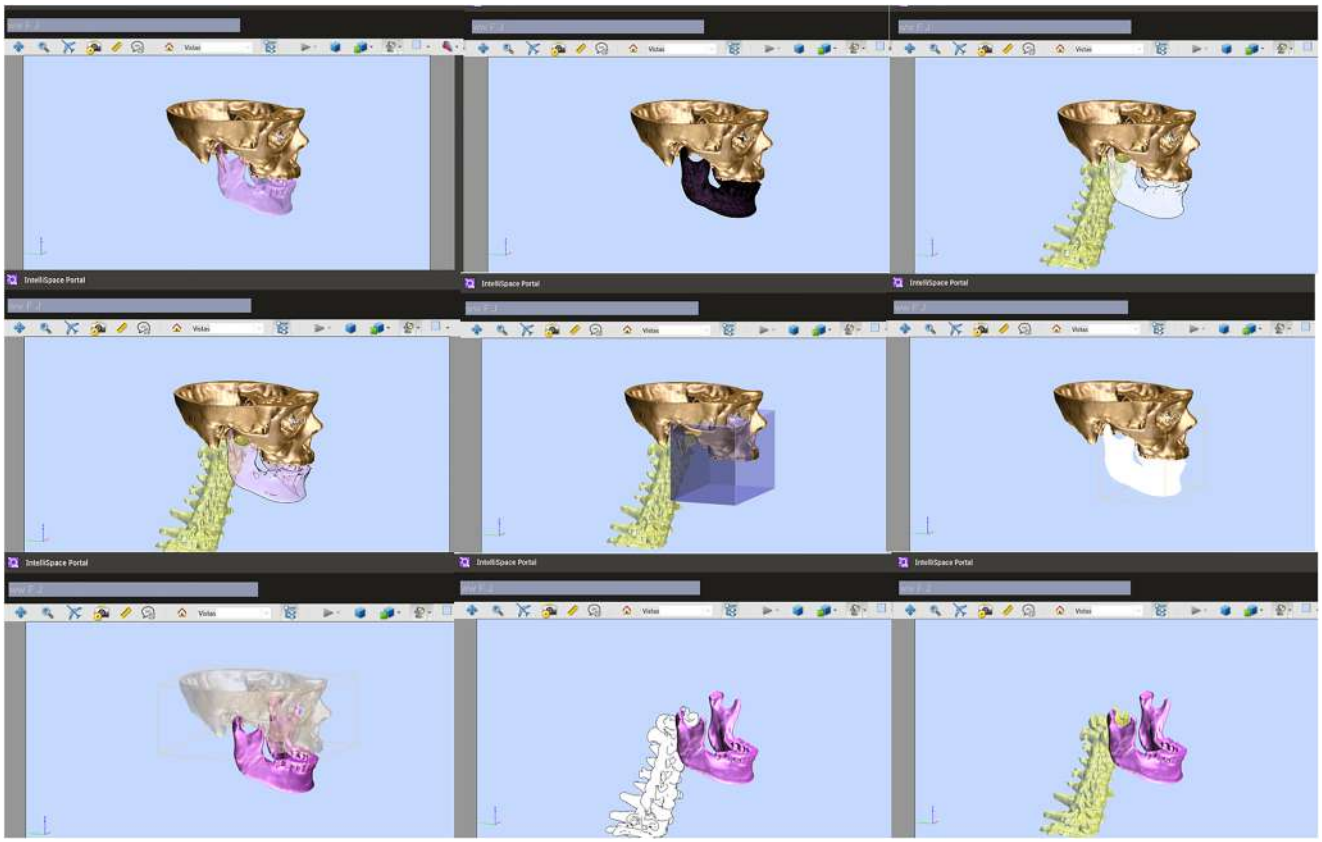

Fig. 7 Multiple model parts visualizations in the PDF program

Change the background colour, cross section (it shows/hides the cross planes of the object. A pop-up menu opens and you can choose the parameters and the axis of the cross-section).

Add multimedia content / 3D comments (it allows you to add notes or comments with arrows pointing to any part of the 3D model).

Some tools are more useful in a biomedical environment, others for teaching (such as annotations), some available tools would be of interest in the clinical field and for planning (such as measurement functions). Other functions have almost no use in the biomedical field, such as the function of flying or walking. This tool is considered especially useful for architectural models [6]).

Discussion

Three-dimensional representation in PDF files offers many advantages, as these images have more information than two-dimensional images. This information can never be presented in classic 2D images and therefore there is an inherent loss of information in these images [9, 10].

3D PDF offers an interactive visualization of the image, allowing its manipulation to highlight the features that most interest users.

These 3D files can be managed from any personal computer containing a qualified Adobe reader (version 7 or higher) that can be obtained free of charge, without expensive software packages [11, 12].

This mode of presentation is also useful in multiple biomedical areas, as we can accurately represent structures such as a complex anatomical region, orthopaedic templates, chemical formula structures, etc.) [9, 12–17].

In the scientific field, the representation of information by means of the 3D PDF tool could increase the information presented in courses and congresses, as it offers the possibility of manipulating virtual objects with real 3D qualities. This would increase realism and improve the experience offered to users [11, 12, 18].

The possibility of interactive manipulation offered by 3D PDF can encourage the user to “explore the image” in great detail individually. In addition to the new information obtained, this stimulating action can also increase curiosity and help long-term memorization [11, 15, 19].

Another important interesting feature offered by the PDF software since its inception in the first versions is the ability to make prints with great security and accuracy. The latest versions with 3D models also share this important feature (depending on the compatibility and 3D printer material). There are a lot of examples regarding this feature. For surgical planning, medical-surgical training, generation of orthopaedic prostheses and other uses of printed models [13, 20, 21].

Conclusions

A PDF document with inserted 3D objects (3D PDF) offers the possibility of interactive visualization, more dynamic and with greater detail than in a 2D image.

This work describes the experience of using PDF files with 3D images, as a means to study and exchange digital information (biomedical models) in a fast and secure way.

We consider this tool (3D PDF) a good alternative for the visualization, interaction and distribution of 3D content, since it offers the known advantages of the classic PDF files that have made this file format a reference, incorporating new advantages and tools for the interaction and exchange of 3D models in a safe way.

3D PDF offers a good alternative to share files with 3D structures through small workgroups, or even in the scientific community, in a digital format.

Compliance with ethical standards

Human and animal rights This article does not contain any studies with human participants or animals performed by any of the authors.

Conflict of interest The author declare that they have no conflict of interest.

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