UNIVERSIDADE FERNANDO PESSOA

DESIGN OF MULTISAMPLING HOLDER PROTOTYPE FOR CONE BEAM COMPUTER TOMOGRAPHY APPLIED TO DENTAL RESEARCH

[Conceção de um protótipo de suporte de amostragem múltipla para tomografia computorizada de feixe cónico aplicada à investigação dentária]

Dissertação de Mestrado

[Master Integrado em Medicina Dentária]

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Orientador:

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I dedicate this work, first of all to my brother Doctor Selim Tekin who always believed in me and who always supported me in my choices and my projects. I dedicate this work to my brother Lawyer Serkan Tekin who helped me a lot during my years in Portugal. I dedicate this work to my father and mother who have made so many sacrifices for me and helped me to realise my dreams. I also dedicate this work to my cousin Yunus Tas for having been by my side and supported me over the years, and in particular for this work. I dedicate this work to my friend Aya Sabri, who has been by my side for 15 years.

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RESUMO

A tomografia computadorizada de feixe cônico foi introduzida no final da década de 1990 para atender a essas necessidades. A imagem da tomografia computadorizada de feixe cônico tornou-se parte integrante dos cuidados de saúde oral, particularmente da endodontia. É por isso que vários estudos têm sido realizados para avançar a odontologia com dentes sobre um suporte que incorpora as vantagens da tomografia computadorizada de feixe cônico. No entanto, nenhum estudo demonstrou a viabilidade de projetar um protótipo de suporte com um posicionador para ajudar a localizar os dentes de forma idêntica em uma posição única em cada tomografia computadorizada de feixe cônico ou mesmo como posicionar os dentes corretamente. O objetivo principal deste estudo é criar um protótipo de um suporte multiamostras para tomografia computadorizada de feixe cônico aplicado à pesquisa odontológica, para que os exames possam ser feitos de forma fácil e padronizada e constante. Assim, foi criado um suporte e posicionador em resina acrílica para colocação de 5 dentes naturais para a realização de 4 radiografias por tomografia computadorizada de feixe cônico. Duas radiografias foram realizadas por um dentista, a primeira no dia 1 e a segunda no dia 30. Outras duas radiografias foram realizadas da mesma maneira por uma recepcionista de clínica odontológica nos mesmos dias. Medições volumétricas e de superfície, bem como cálculos de contagem de voxels dos canais radiculares e de um dente, são realizadas utilizando o software 3D Slicer. Para cada radiografia foram feitas 2 segmentações utilizando o software 3D Slicer e os valores foram calculados para cada segmentação. A posição das estruturas de cada segmentação foram então analisadas no software Meshlab. Verificou-se que entre cada medição volumétrica e de superfície, bem como cálculo da contagem de voxels dos canais radiculares e de um dente utilizando o software 3D Slicer, não foram identificadas diferenças estatisticamente significativas de valores entre cada radiografia e cada segmentação, além disso, a posição das estruturas de todas as segmentações tiveram uma posição idêntica. Conclui-se que o suporte e o posicionador criados permitem que qualquer profissional seja guiado até o posicionador dentário para realizar uma ou mais radiografias utilizando uma tomografia computadorizada de feixe cônico em uma posição sempre idêntica. Nas radiografias, os cálculos podem ser feitos a qualquer momento. É um protótipo padrão que pode ser aplicado à pesquisa odontológica, eliminando o fator modificador ligado ao indivíduo e ao posicionamento.

Palavras chaves: radiografia, segmentação, posicionamento

ABSTRACT

Cone Beam Computer Tomography was introduced in the late 1990s to meet these needs. Cone Beam Computer Tomograph imaging has become an integral part of oral health care, particularly endodontics. This is why several studies have been carried out to advance dentistry with teeth on a support incorporating the advantages of Cone Beam Computer Tomograph. However, no study has demonstrated the feasibility of designing a prototype support with a positioner to help locate teeth identically in a unique position in each Cone Beam Computer Tomograph or even how to position teeth correctly. The main objective of this study is to create a prototype of a multi-sample support for cone beam computed tomography applied to dental research, in order to the scans can be easily done and in a standardized and constant way. Thus, A support and positioner made of acrylic resin is created to place 5 natural teeth for taking 4 radiographs using cone beam computed tomography. Two radiographs are taken by a dentist, the first on day 1 and the second on day 30. Another two radiographs are taken in the same manner by a dental clinic recepcionist on the same days. Volumetric and surface measurements, as well as voxel count calculations of the root canals and a tooth, are performed using the 3D Slicer software. For each radiograph, 2 segmentations were made using the 3D Slicer software and the values were calculated for each segmentation. The position of the structures of each segmentation was then analyzed on Meshlab software. It's verified that, Between each volumetric and surface measurement, as well as voxel count calculation of the root canals and a tooth using the 3D Slicer software, no differences in values were identified among each radiograph and each segmentation, moreover, the position of the structures of all the segmentations had an identical position. It's concluded that the support and positioner created enable any practitioner to be guided into the tooth positioner to take one or more radiographs using a cone beam computed tomography in a position that is always identical. On X-rays, calculations can be made at any time. It is a standard prototype that can be applied to dental research while eliminating the modifying factor linked to the individual and positioning.

Keywords: radiography, segmentation, positioning

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INDEX OF ABREVIATIONS

3D	3 Dimensions
ALARA	As Low as Reasonably Achievable
AMASSS	Archive of Motion Capture as Surface Shapes
cm	Centimeter
FOV	Field of View
kVp	Peak Kilovoltage
mA	MiliAmpere
Mac OS	Machintosh Operating System
mm	Milimeter
MMA	Methyl Methacrylate
nm	Nanometer
μm	Micrometer

I. INTRODUCTION

Endodontics is a fundamental and very important area of dentistry, involving the study and treatment of pathologies and lesions of the pulp and periradicular tissues and their relationship with systemic conditions. In order to achieve the prevention or treatment of pulp and periradicular pathologies in endodontics, it is essential for the dentist to have experience and knowledge of endodontics in a variety of research areas, including clinical, mechanical, biological and materials science topics (Bassam et al., 2021).Since the emergence of this dental field, there has been an increase in the number of publications due to the strong importance given by researchers to studies and projects with the aim of marking progress in dentistry. As a result, the number of researchers is also increasing year on year due to the increase in the number of academic institutions, academic promotion criteria and more accessible international databases (Özdemir et al., 2023).

This research has been fundamental in the discovery and application of new treatment techniques such as irrigation and root canal preparation to more recent concepts such as lasers and radiography such as periapical, bitewing, panoramic, teleradiography, cone beam computed tomography (De Almeida Decúrcio et al., 2021)

This is why we can say that endodontics is a dental field in which knowledge of tooth anatomy is essential for diagnosis, treatment and prognosis in order to overcome certain difficulties in organising decisions or avoiding root canal treatment failure (Pinto et al., 2023).

Consequently, in order to achieve successful treatment, an excellent diagnosis is essential, which is why the use of two-dimensional radiography is so widespread, which is why more than one quarter of medical radiographs in Europe are dental radiographs (Bromberg et al., 2023). However, they are very limited, which could lead professionals to make diagnostic errors that have been confirmed in in-vivo and ex-vivo studies (Alsaikhan et al. (2022).

It is true that the most common two-dimensional radiograph is the panoramic radiograph, which is widely used by dentists. This provides a view of the oral cavity in a single x-ray, unlike periapical x-rays, which need to be repeated several times to provide a comprehensive view of the dento-mandibular structures, thereby increasing the total radiation dose applied to the patient. Nevertheless, it is still possible to combine panoramic radiography with periapical radiography, the latter offering greater precision for a precise localization of the oral cavity (Berghuis et al., 2021).

It should be noted, however, that the choice of radiology made in the clinic is also based on the ALARA, as low as reasonably achievable principle, which is one of the most important criteria (Berghuis et al., 2021).

ALARA (as low as reasonably achievable) is a radiation protection concept that was introduced 20 years ago in the field of radiology in line with national and international guidelines. The aim of ALARA (as low as reasonably achievable) is to prescribe the lowest possible dose of radiation to the patient during the radiographic process, in order to reduce the risk of adverse effects from exposure while obtaining the necessary diagnostic information (Distefano et al., 2023).

At the same time, it should be added that these radiographs are limited in size and may include multiple positioning errors or distortion, unequal horizontal and vertical magnification, overlapping teeth or loss of image sharpness (Yeung & Wong, 2021).

Reflected images occurring as a result of an object or anatomical structure or few anatomical bone structures which can cause double superimposed real images, but also, any hair clips or accessories lead to apron artefacts which can lead to the appearance of ghost images, which are magnified in the panoramic radiographic image. These drawbacks can very easily lead to the dentist making a wrong diagnosis and causing irreversible errors that are harmful to the patient (Lingam et al., 2023).

Later, in the 1970s, it was discovered that it was possible to make a diagnosis using 3D images, so research, particularly in dentistry, was stepped up to limit errors and offer an alternative instrument to those already available for medical diagnosis. In the 1990s, an alternative had to be introduced: cone beam computed tomography. This is a three-dimensional radiography method with a low-radiation dose that offers greater sensitivity, specificity and excellent accuracy than two-dimensional radiography. It is an imaging scanner designed for imaging the head and neck. It emits X-rays in the form of a large cone covering the area of the head being examined (Bromberg et al., 2023).

This ionising radiation will pass through different structures of different densities. This difference in density will then be recorded by the X-ray sensor, and this data will be displayed on the computer, allowing structures to be viewed with shades of grey. High-density structures are displayed as white/light in the image and low-density structures that absorb very little of the X-ray beam, such as air, are displayed as black/dark (Hicks et al., 2019).

Each Cone beam computed tomography manufacturer will have a different amount of ionising radiation. During the acquisition process, the unit emits ionising radiation continuously during some Cone beam computed tomography machines. Others use pulsed or intermittent radiation, with less total radiation emitted. The radiation produced by Cone beam computed tomography depends on various machine parameters, such as field of view (FOV), peak kilovoltage (kVp), milliampere (mA) and a continuous or intermittent beam. These are all factors that will determine the amount of radiation absorbed by the patient. Some of these parameters are specific to each machine and others are linked to the clinician, in particular the field of view chosen. It is necessary to use a lead board to protect the patient (Bornstein et al., 2014).

In this way, Cone beam computed tomography consists of a beam emitting cone-shaped radiation and an alternating area detector that move synchronously around the patient's head, which is stabilised with a head support (MacLeod & Heath, 2008).

The machine rotates only once around the patient's head from 180 to 360 degrees to collect imaging data, unlike Medical Computed Tomography Scanners which provide all the information needed to reconstruct the region of interest. These images are then reconstructed into tomographic images using a computer (Wang et al., 2023).

On the other hand, Cone beam computed tomography machines provide isotropic voxels, unlike the anisotropic voxels found in conventional Medical Computed Tomography Scanners. Medical Computed Tomography Scanners voxel areas can be as small as 0.625 mm square, and their depth is typically in the order of 1 to 2 mm, whereas Cone beam computed tomography produces sub-millimetre resolution ranging from 0.4 mm to 0.09 mm. As a result, the resolution of Cone beam computed tomography is sufficiently precise for measurements in oral and maxillofacial applications to meet the need for accuracy in dental assessment, since the resolution is sub-millimetre. Digital Imaging and Communications in Medicine format, which facilitates telecommunication and use with other third-party imaging software (Venkatesh & Elluru, 2017).

Cone beam computed tomography provides 360 images in a single scan. In addition, cone beam computed tomography is taken using a low dose of radiation compared with

Computer Tomography scans, for example. Thanks to the large number of images taken, it also offers a cost advantage (Bromberg et al., 2023).

Therefore, in terms of diagnosis, Cone beam computed tomography is of great benefit due to the sensitivity associated with hard and soft tissue distinction and accuracy and includes in a single scan data equivalent to approximately one complete oral periapical series or 3-10 standard dental panoramic tomograms (MacLeod & Heath, 2008).

As a result, since its discovery, its application in endodontics has been rapid thanks to its ability to provide precise information about the root canal, such as anatomy, volume, canal length and tooth area (Alsaikhan et al. 2022).

Nowadays, cone beam computed tomography has become an indispensable tool for many treatments in dentistry, since its precision, marked by the minute size of its voxels, increases the quality of its image, which is why many studies in endodontics have been carried out using cone beam computed tomography (Bueno et al., 2021). Consequently, The European Society of Endodontology recommends the use of cone beam computed tomography, particularly in the following cases, to obtain additional information and an objective diagnosis:

- Assessment and management of dentoalveolar trauma.
- Evaluation of complex root canal systems before endodontic therapy.
- Inspection of complex root canal anatomy.
- Evaluation of endodontic complications like post perforation.
- Evaluation of root resorption.
- Identification of obliterated root canals.
- Detection of periradicular bone changes that suggest root fractures.
- Presurgical review before endodontic surgery (Bromberg et al., 2023).

However, Cone beam computed tomography scans can still be affected by artefacts. Artefacts can be due to beam hardening (resulting in cupping artefacts, striae and dark bands), patient-related artefacts such as patient movement resulting in blurring of the reconstructed image, artefacts related to the type of scanner: circular or ring-shaped and conical beam. These limitations lead to strong tissue interactions, poor soft tissue contrast, increased image noise (Venkatesh & Elluru, 2017).

This may raise questions about the added difficulty and possible percentage of positioning errors, particularly in comparative studies, since a simple positioning error may lead the practitioner to repeat the cone beam computed tomography or even to the failure of the research (Yeung & Wong, 2021).

For most of the cases of certain researchers, a problem to be solved prior to the development of the study is to guarantee the stability of the natural teeth throughout the radiographic process and during the treatment of the tooth, for example. These practitioners are therefore led to consider the development of a support to guarantee a stable position during these manipulations (Altufayli et al., 2022).

These supports are often not used more than once, they are specific to a particular case and cannot be reused, as standardisation is not one of the conditions of this support, as no study to date has looked into the creation of a standard support and positioner for this type of study.

On the other hand, as no study to date has addressed the issue of guaranteeing the identical positioning of these teeth or telling us how to position natural teeth, or even providing a standardised support with a positioner on cone beam computed tomography to facilitate the latter, this could lead to a discussion on certain studies. So, it's also important to highlight this other major problem. We can illustrate this from the literature, because often as no research to date has demonstrated how to position the teeth in a model, practitioners have been led to specify that the natural teeth have been placed randomly in the support used (Zhang et al., 2022).

The aim of this study will beis to design a prototype multi-sampling support for cone-beam tomography applied to dental research, particularly comparative research, capable of guiding the researcher in the positioning of teeth during the research for the taking of radiographs with cone-beam tomography, thus allowing renewal of this radiography thanks to this standardised preparation.

The design of a prototype multi-sample support would eliminate the difficulties and margins of error that are questionable when taking cone beam computed tomography in relation to tooth positioning.

In the present work, a volumetric and surface study was carried out using several radiographs of natural teeth obtained with cone-beam tomography, taken with the developed prototype. These measurements was calculated using 3D slicer software by carrying out segmentations and the positioning of segmented structures on 3D Slicer was analysed with Meshlab software.

II. MATERIALS AND METHODS

Authorisation to carry out this study was obtained from the Ethics Committee of the Faculty of Health Sciences at the Fernando Pessoa University with authorisation number: FSC-MMED - 504/23-2 (Annex A)

For this study, single-rooted natural teeth were obtained in a dental clinic in Paris, extracted for reasons not related to the present study.

A total of 5 natural teeth were used. The natural teeth selected met the following criteria:

- teeth without restorations
- teeth without fractures
- Single root teeth

For each tooth, a periapical radiograph was taken to check the absence of any fracture or restoration.

1. Steps for making the support and positioner and taking the X-ray with cone beam computed tomography

1.1 Making the support and positioner

To make the support and positioner, a base was used as a reference model to form the shape of the support and positioner in self-curing acrylic resin. This base is a Mestra® (MESTRA,Biscaye, Spain) rubber base for making models in superior plaster. It acts as a container for the self-curing acrylic resin material of the Methax Ortho® (MakeVale Ltd, London, United Kingdom).

2 bases were used, one is used to make a base and the other for the positioner.

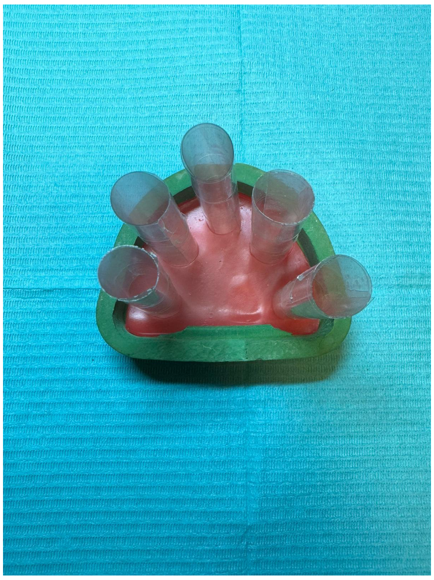
A Kemdent® (Kemdent Works, Swindon Wiltshire, United Kingdom) modelling wax was placed in each base at the bottom to make it easier to remove the acrylic resin model.

To make the positioner, 5 Mestra® (MESTRA,Biscaye, Spain) plastic tubes were installed in the base containing the modelling wax to form and keep empty the holes where the teeth will be positioned (Figure 1).

The plastic tubes were not placed in the base used to make the support.

Figure 1.

Positioning the plastic tubes in the upper plaster model base, containing a red modelling wax at the bottom of the component, before casting the acrylic resin.



In this study, a self-curing powder and liquid orthodontic base resin from Methax Ortho® (MakeVale Ltd, London, United Kingdom) was used to prepare the acrylic.

The components of the liquid and powder were

- The powder consists of a copolymer composed of methyl methacrylate.
- liquid: dimethacrylate, MMA

The liquid and powder must be mixed in a container following the manufacturer indications. The quantity of liquid required was 30 millilitres whereas the quantity of powder was 50 grams to obtain a viscous mixture of acrylic resin for making the positioner. The same quantities were needed to make the support (Figure 2). Mixing was carried out using a spatula for 2 minutes to obtain a firm, homogeneous consistency.

The self-curing acrylic resin produced by mixing the liquid and powder can be placed in a Kulzer® (Mitsui Chemicals, Hanau, Germany) brand acrylic resin press device (Figure 3).

Figure 2:

Plastic container from the Mestra® containing the quantity of acrylic resin liquid required before adding Methax Ortho (MakeVale Ltd, London, United Kingdom) acrylic resin powder

Figure 3.

Mixing stage between acrylic resin powder and polymerizable liquid

A weight was placed on the plastic tubes installed on the base to prevent the whole from moving until the end of the procedure.

The self-curing acrylic resin mixture was poured into the base to fill it completely (Figure 4). The curing time was approximately two hours.

Figure 4.

Acrylic resin curing in the upper plaster model base

The same protocol for obtaining the self-curing acrylic resin was used to make the support in the Mestra® (MESTRA,Biscaye, Spain) rubber base.

To finishing the positioner and support were adjusted and polished once they have completely hardened (Figure 5).

A Dentalfarm® plaster cutter and Edenta® prosthetic burs were used to cut the confections.

Figure 5.

Support and positioner after finishing by the prosthetists

1.2 Adaptation of the support and positioner to the Planmeca Oy Promax 3D Helsinki Finland cone-beam tomography

In order to adapt the holder to the Planmeca Oy Promax 3D Helsinki Finland cone-beam tomography, the support was cut and adjusted in order to be adjusted to the part of the cone-beam tomography and allows the patient's mandible to be positioned correctly when the cone-beam tomography is obtained (Figure 6.a and Figure 6.b).

Figure 6.a.

Measurement and marking of the support made from auto-polymerizable acrylic resin.

Figure 6.b.

Assembly of the tip used to position the mandible on the the cone-beam tomography with the support and the positioner

1.3 Preparation of natural teeth

The apical root section of the natural teeth was immersed in self-curing acrylic resin from Methax Ortho® (MakeVale Ltd, London, United Kingdom).

Self-curing acrylic resin was poured into the compartments, in a Mestra® (MESTRA,Biscaye, Spain) brand plastic box with several cubic compartments (Figure 7), and the teeth were positioned in them. Each tooth was placed in a cubic compartment filled with self-curing acrylic resin. The closed box is placed in a pressure polymerisation apparatus (Palamat practic ET from Kulzer® (Mitsui Chemicals, Hanau, Germany)) for 10 minutes at a temperature of 50°C and an air pressure of 2 bars, as suggested by the manufacturer.

Figure 7.

Plastic box from the Mestra® (MESTRA,Biscaye, Spain) brand used with cubic compartments for casting auto-polymerizable acrylic resin and positioning natural teeth.

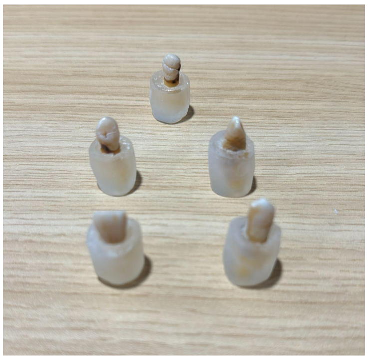
Once the acrylic was fully cured, the cubes with the teeth were removed from the box (Figure 8) and then using the prosthetic burs, the acrylic surrounding each tooth was adjusted so that they could be successfully placed on the support and positioner (Figure 9).

Figure 8.

The natural teeth in the hardened auto-polymerizable acrylic resin were removed from the box before being adjusted to fit the support and positioner.

Figure 9.

Natural teeth in hardened auto-polymerizable acrylic resin after fitting to the support and positioner.



1.4 Assembling and taking the X-ray with the cone beam computed tomography

Before the cone beam computed tomography radiograph was taken, a number of markings were made on the prototype with prosthetic burs, and these markings were covered with a black felt-tip pen to allow better visualisation. These markings allow the teeth to be placed in the same position as many times as required. By following and respecting the markings.

Two participants were chosen for the present study, one with dental practice, a dentist with 5 years of clinical experience and another with no dental practice, the dental clinic receptionist.

A simple explanation of how the prototype works was done to the participants by the main investigator.

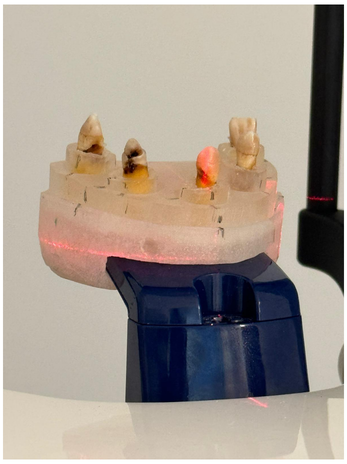
In sequence, each participant placed the teeth in the corresponding compartment within the fabricated prototype. Subsequently, each participant placed the assembled prototype on the cone beam computed tomography machine (Planmeca Oy Promax 3D Helsinki Finland) and took the radiograph. This assemblance was done in a blind way, which means that each participant realized the assemblance in the cone beam computed tomography room alone without the presence of the main investigator or of the other participant (Figure 10).

The constant parameters applied to all cone beam computed tomography scans (Planmeca Oy Promax 3D Helsinki Finland) were as follows: 90 kV, current of 10 mA, exposure time of 25 seconds, resolution of 400 µm, voxel dimension of 90 µm × 60 µm × 80 µm and with a resolution up to 0.075 mm voxel, and having a Focal spot: 0.5 mm with fixed anode, 8 x 8 cm FOV captures both dental arches, total filtration was 2,5mm AI + 0,5mm Cu.

Two more radiographies with cone beam computed tomography scans of the Planmeca Oy Promax 3D Helsinki Finland were done 30 days later, by the two participants.

Figure 10.

Image taken during the cone beam computed tomography radiographic process with this assembled prototype.



2. Explanation and measurement steps using 3D Slicer software

Four different measurement types were selected in this work to compare the different cone beam tomography radiographs taken

These 4 measurements are:

- the number of voxels
- the volume of the dental canal in Cubic millimetres
- the volume of a tooth in Cubic millimetres
- area in square millimetres

These are the measurements that can be provided by the 3D Slicer software following all the procedures best suited to this study created and applied by an expert computer engineer.

Each three-dimensional radiograph taken was downloaded in digital imaging and communications in medicine format so that they could be used on the 3D slicer software.

In order to adapt the software to this study, the expert in computer engineering made modifications to the software script and also to the "AMASSS" extension, and downloaded this extension that was added to 3D Slicer. These modifications to the software were made only once by the software engineer.

On the 3D Slicer software, there are 4 windows that appear allowing:

1. a three-dimensional window of the cone beam computed tomography radiograph, a window that belongs to the Visualization Toolkit and Start-TimeLapse format radiograph viewer
2. three-dimensional window of the sagittal position of the cone beam computed tomography radiograph in digital imaging and communications in medicine format
3. three-dimensional window of the frontal position of the cone beam computed tomography radiograph in digital imaging and communications in medicine format
4. three-dimensional window of transversal position of cone beam computed tomography radiograph in digital imaging and communications in medicine format

To obtain this window, converting the cone beam computed tomography radiographs taken into digital imaging and communications in medicine format can be done. These documents are then dragged onto the 3D Slicer software, which automatically provides a vision of the three-dimensional radiograph in each window, with the exception of the window displaying the radiograph in Visualization Toolkit or Start-TimeLapse format.

On a 3D slicer, it is also possible to view the three-dimensional radiograph taken by a cone beam computed tomography in Start-TimeLapse format. This can be viewed in the Visualization Toolkit window (Figure 11).

The other three windows allow visualisation after segmentation also in three-dimensional format but with sagittal, frontal and transversal views appearing (Figure 12).

Figure 11.

Visualization Toolkit window on the three-dimensional window that appears on 3D slicer with the three-dimensional radiograph taken by the cone beam computed tomography before segmentation in Start-TimeLapse format.

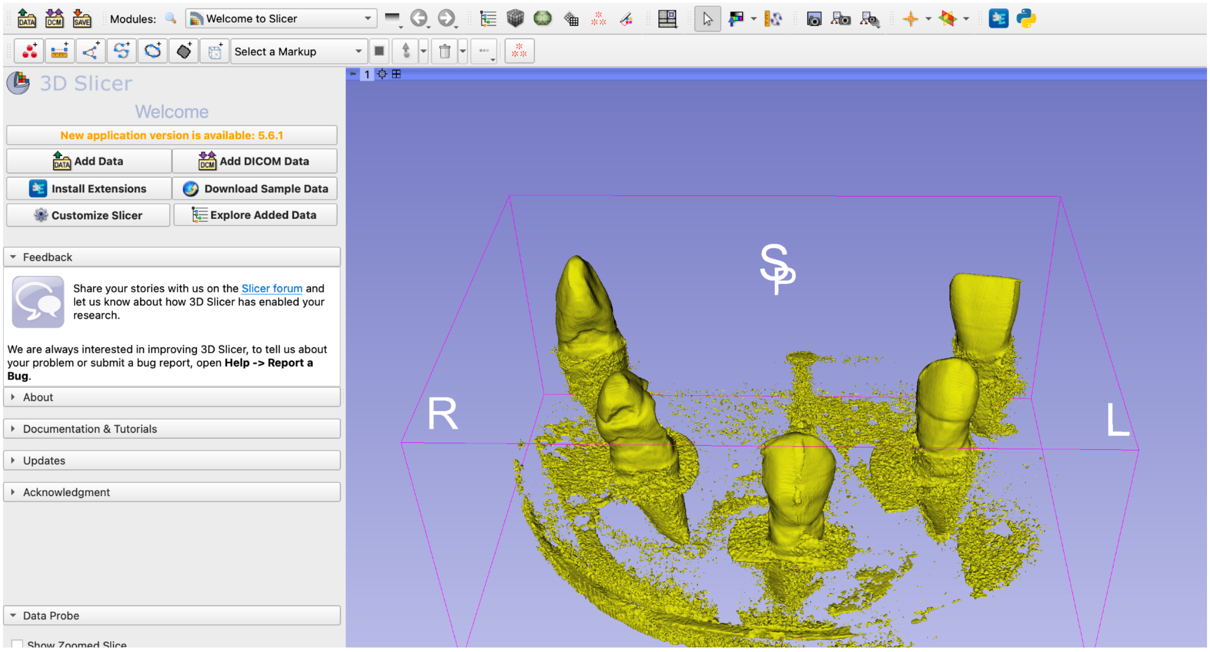
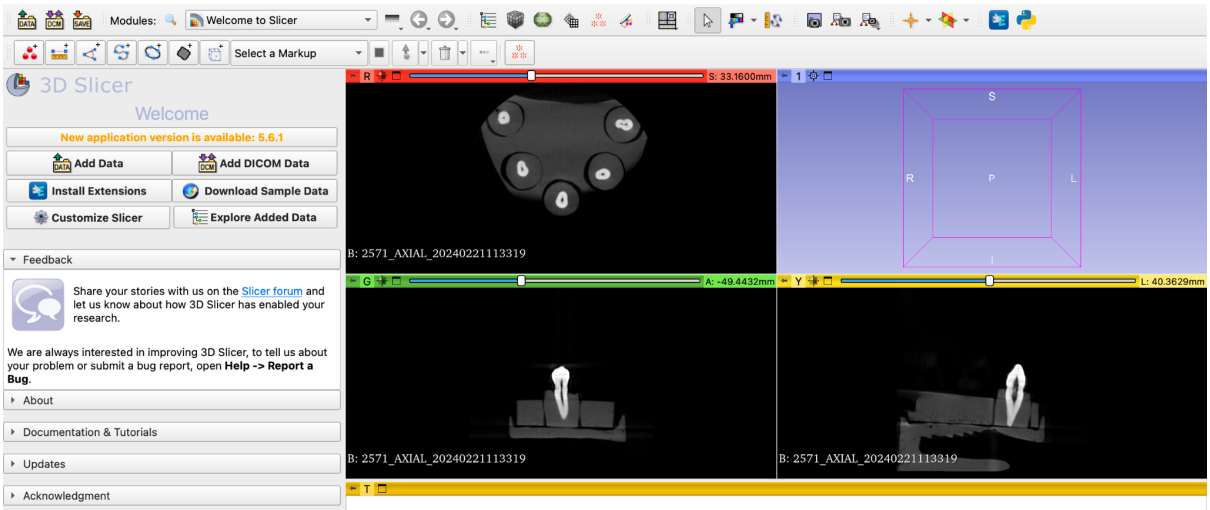


Figure 12.

The windows that appear on 3D slicer after dragging the three-dimensional radiograph in digital imaging and communications in medicine format



In order to obtain volumetric results for the canal, for a tooth and for the surface, it is essential to carry out a segmentation on a 3D slicer of each three-dimensional radiograph taken by participants on the cone beam computed tomography.

The segmentation lasts between 7 and 12 hours for each three-dimensional x-ray and for each x-ray the duration of the segmentation is different.

A total of 8 segmentations were carried out in this study as each segmentation was repeated twice to compare the data from the segmentations carried out on each radiograph in the same parameters. However, each segmentation was carried out at different times, to evaluate the fidelity of the segmentation.

In summary, the procedures were classified as follows:

A total 4 x-rays using cone beam computed tomography were taken:

- x-ray by the dentist on day 1
- x-ray by the dental clinic receptionist dental clinic receptionist on day 1
- x-ray by the dentist on day 30
- x-ray by the dental clinic receptionist dental clinic receptionist on day 30

Each radiograph underwent 2 segmentations at different times, resulting in a total of 8 segmentations.

These 8 segmentations were divided into 4 groups:

- In the first group there are 2 radiographies taken with cone beam computed tomography on the first day. The first radiography was taken by the dentist and the second was taken by the dental clinic receptionist. In this group, the segmentation of the dentist's radiograph was done on day 1 and the segmentation of the dental clinic receptionist's radiograph was done on day 2.
- In the second group there are 2 radiographies taken with cone beam computed tomography on the first day, by the two participants, however, the segmentation of the dentist's radiograph was done on day 15 and the segmentation of the dental clinic receptionist radiograph was done on day 16.
- In the third group there are 2 radiographies taken with cone beam computed tomography on the thirtieth day. The first radiography was taken by the dentist and the second was taken by the dental clinic receptionist. In this group, the segmentation of the dentist's radiograph was done on day 30 and the segmentation of the dental clinic receptionist's radiograph was done on day 31.

- In the fourth group there are 2 radiographies taken with cone beam computed tomography on the thirtieth day by the two participants, however,, the segmentation of the dentist's radiograph was done on day 45 and the segmentation of the dental clinic receptionist's radiograph was done on day 46.

2.1 Parameters applied to 3D Slicer before launching segmentation.

On the 3D Slicer Software; a computer-modified extension named "AMASSS" is added.

Before launching the segmentation, it is imperative to indicate the desired parameters to carry out the segmentation process.

The segmentation of the root canal, a tooth and the surface were carried out, which is why in the indication window (Figure 14) appearing thanks to the "AMASSS" extension in the "Automated Dental tool" window (Figure 13) it must be checked:

- Root canal

- Maxilla

- Mandible

Figure 13.

AMASSS" icon appearing in the "Automated dental tool" window

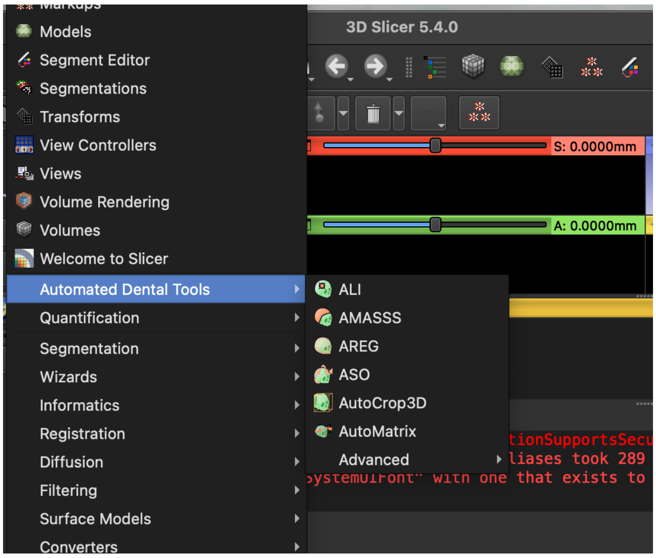
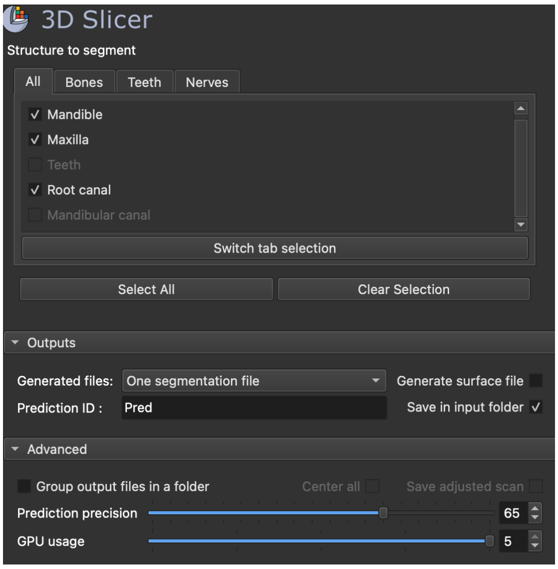


Figure 14.

Pre-segmentation indication window that appears and allows to tick the segmentation box



Note: the root canal as well as the mandible and maxilla have been selected to launch the segmentation, and a precision of 65% has been chosen.

The indication window includes the option to select the precision percentage. In this study, a percentage of 65% was chosen in order to successfully adapt the segmentation of the 3D Slicer software to the available computer (MacBook Pro 2021). The maximum precision for conducting this study was 65%. (Figure 14)

2.2 Parameters applied to 3D Slicer to obtain volumetric and surface calculations and to obtain the number of voxels for each segmented component.

Once the radiographs are segmented, 3D slicer generates Visualization Toolkit files so that the segmented portion could be viewed in the three-dimensional Visualization Toolkit window.

In this Visualization Toolkit window appears on a purple background with the segmented parts which are of different colors.

In order to distinguish the segmented parts, the software displays the segmented part in color. In this study, the respective colors of the segmented parts were as follows:

- the root canal segmented was in yellow

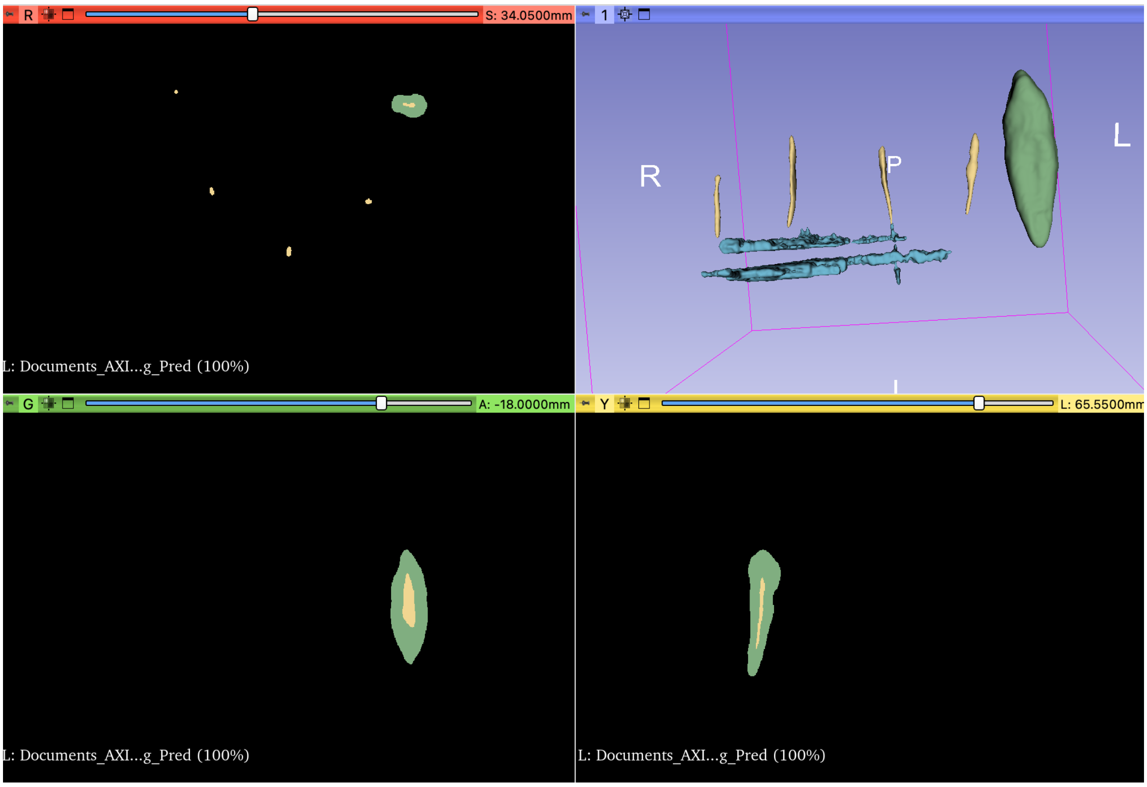
- the segmented tooth was in green

- part of the segmented support was in blue. (Figure 15)

However, this color code established by the software may differ depending on the radiographs in "Digital imaging and communications in medicine" format, that is to say there is no specific color assigned to each component.

Figure 15.

Three-dimensional radiograph taken with cone beam computed tomography which was undergone segmentation.



Note: The 3D slicer software showed a segmented tooth in green and the root canals in yellow in the Visualization Toolkit window and the part of the segmented support is in blue. In the sagittal, transverse and frontal view windows, the segmented canals appear in yellow and the segmented tooth in green and the part of the segmented support is in blue.

In order to distinguish the segmented documents, the software names the segmented documents "SegOut".

To obtain the measurements following the segmentation carried out, all the segmented documents established by 3D Slicer are loaded onto the platform.

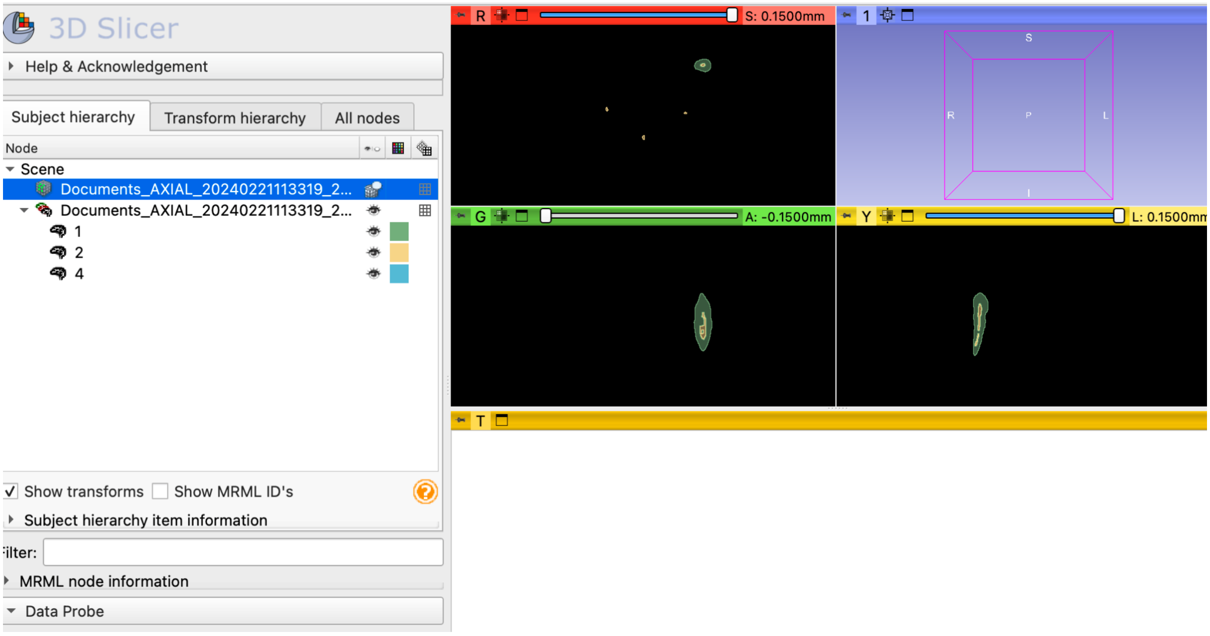
Then, in the Data window, the loaded document is converted by clicking on "Convert labelmap to segmentation node". 3 structures appear.

To obtain the volume, the segmentation of the document generated by 3D Slicer at the end of the computational process is blinded from the vision as shown in Figure 16.

These steps allow you to select the structure to measure in “Segment Editor”.

Figure 16:

Final view of the Data window before selecting the structure to be measured in the "Segment editor" window



In “Source volume”, the document currently being processed was selected.

Once these steps had been completed, in the "Segment Editor" window, it was necessary to hide the visualization of the structures appearing outside the desired structures to establish the correct measurement.

Then, using “Show 3D”, the structures appear in the Visualization Toolkit window.

In order to make the data that appear on 3D Slicer of segmentations and radiographies more understandable, each root canal and tooth is initially numbered according to the position of the teeth on the prepared model (Figure 17). The same numbering and designation were used to reference each segmented root canal as well as the segmented tooth on 3D Slicer (Figure 18).

Figure 17:

Numbering and visualization of teeth associated with segmented structures on the prototype

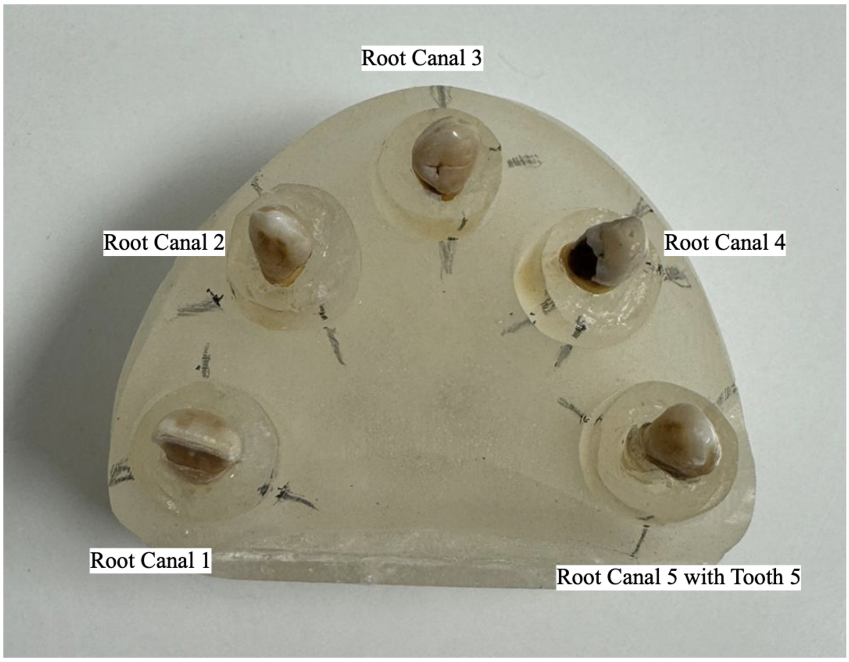
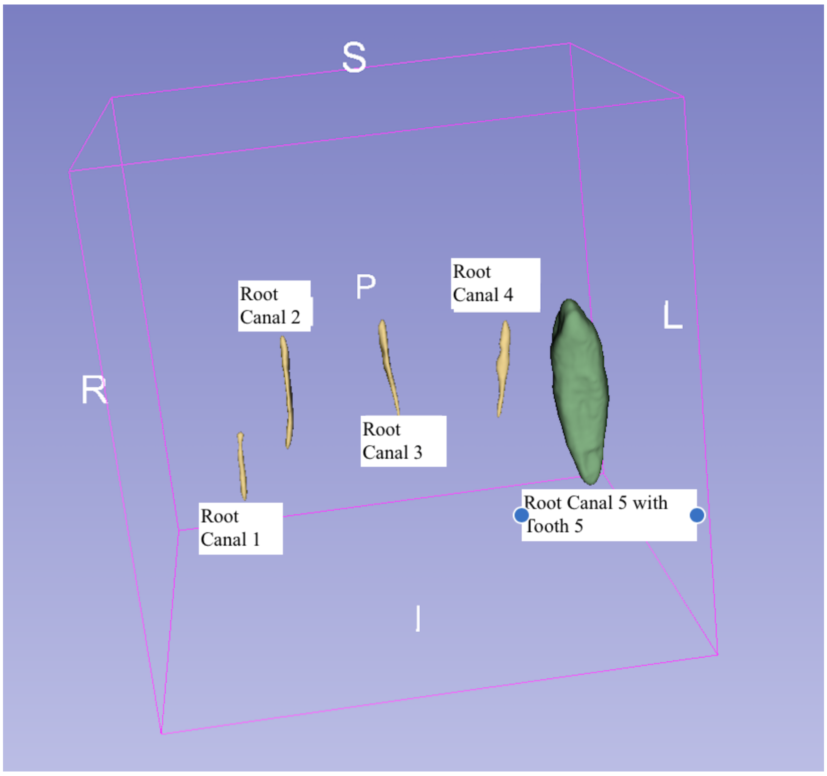


Figure 18:

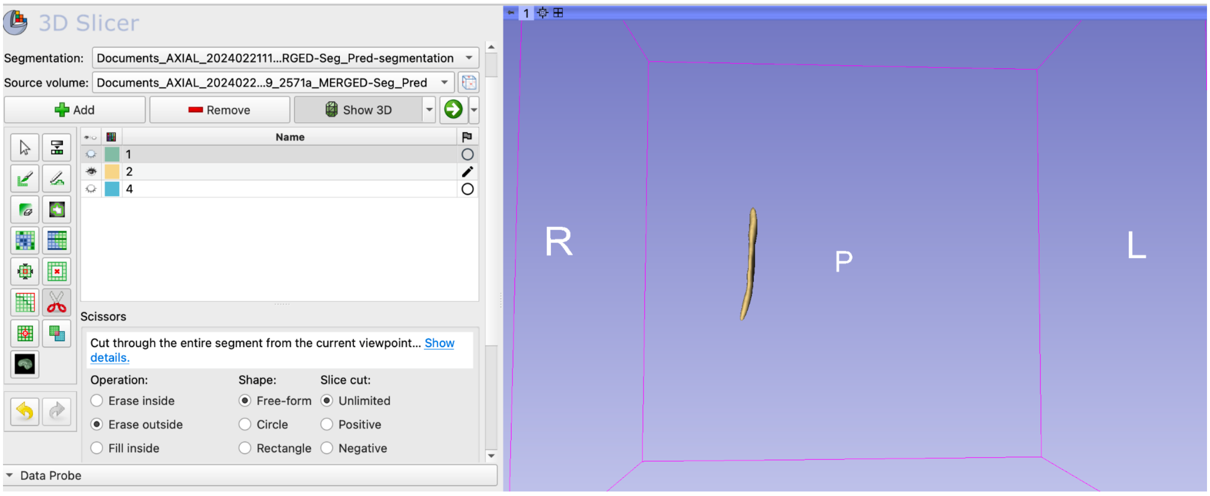
Tooth Numbering and visualization associated with segmented structures



After that, with the selection of scissors, the desired canal to be measured was circled and all other structures outside the selection automatically disappeared. This was explained by selecting "Erase outside" to remove other structures around the selected one and thus no other structures can interfere with the volume of the selected part (Figure 19).

Figure 19:

Final view of a canal measurement before switching to the "Segment Statistic" window

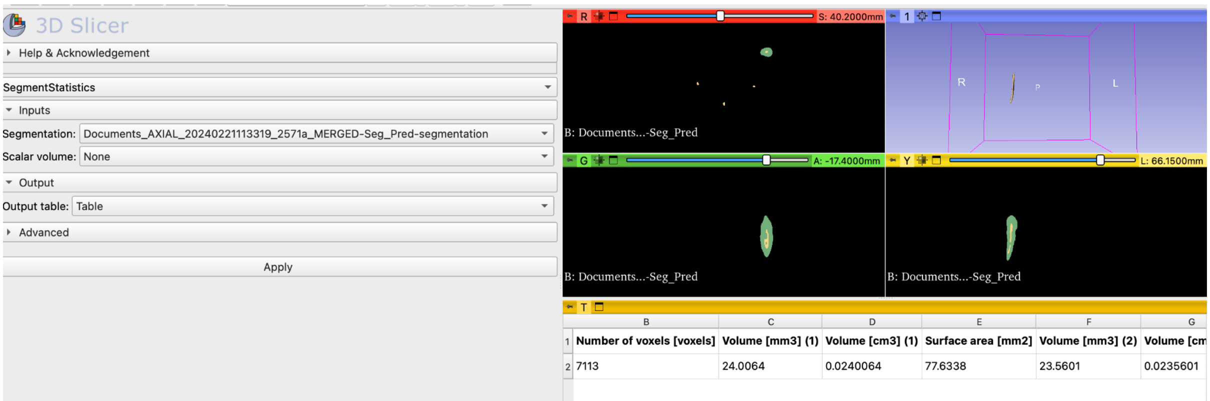


Note: Selecting the desired root canal to measure in the "Segment editor" window.

The last step to obtain the measurements for the selection of the surrounded structure in the “Segment Editor” window is to access the “Segment Statistics” window. In the “Segment Statistics” window, using “Apply”, the measurements of the selected structure appear. All measurements appear in an orange data window shown in Figure 20.

Figure 20:

Measurements obtained from the selected part to be measured



Note: These measurements are for the root canal selected and visualised in figure 16.

This process helps provide volumetric and surface measurements of each root canal and tooth. All the steps explained above were followed for each radiograph in order to obtain the desired calculations.

3. Explanation and measurement steps using Meshlab software

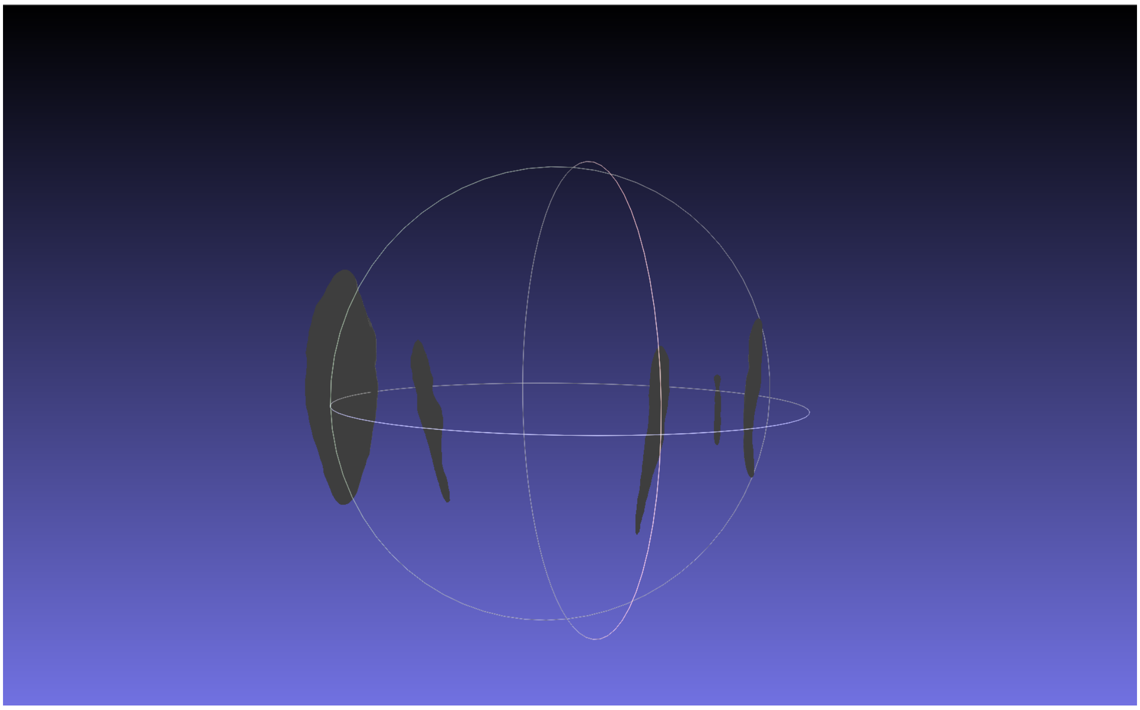
The positioning analysis performed using the Meshlab software requires the use of segmentations. It is the segmentations that allowed the determination of whether there was a difference in positioning between each segmentation as well as between each radiograph. In case of differences, these appear in a different color automatically and positioning offset in the window where the three-dimensional figures are displayed (Figure 23). This color is random and chosen by the software to distinguish them however it can be modified by the user.

For this purpose, the 8 segmentations in format Standard Triangulation Language performed were downloaded on Meshlab software.

Once all the segmentations were downloaded into the software one by one (Figure 21), they were all selected together.

Figure 21:

presentation of a single segmentation on Meshlab software



Next, select "Align" from the toolbar (Figures 22 and 23). This selection is used to choose reference points so that any differences in position between the different segments can be identified but also to be able to have a plan in space.

Figure 22:

"align" icon located in the toolbar

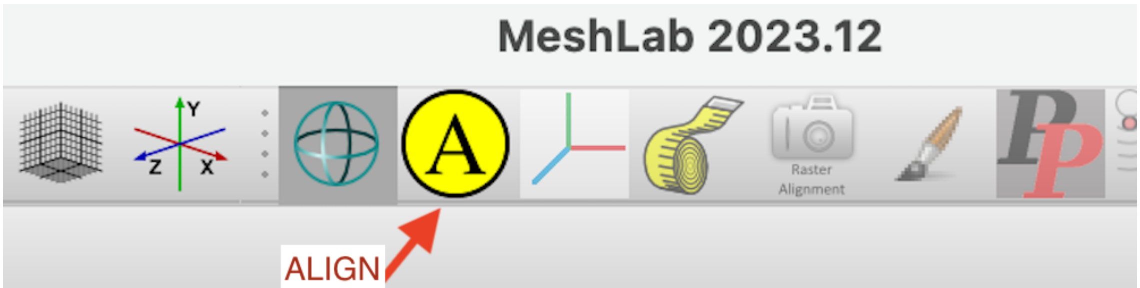
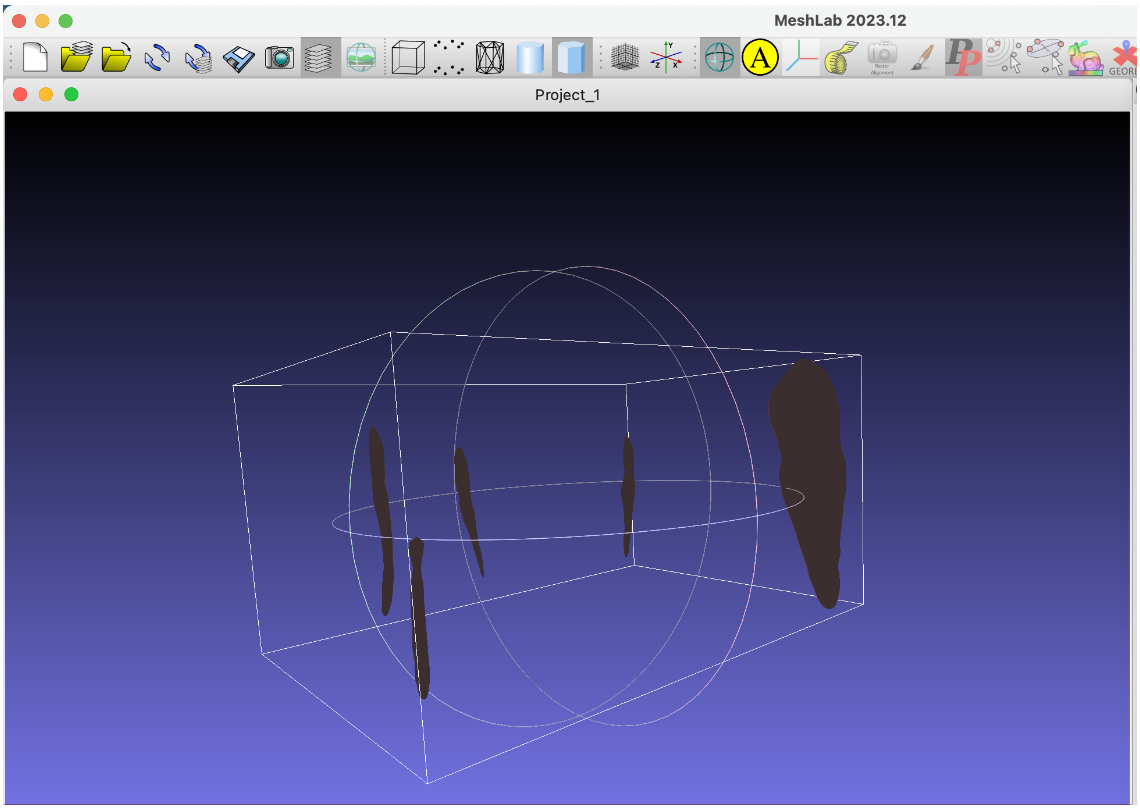


Figure 23:

Presentation of the structures after choosing the "Align" option and selecting the markers.

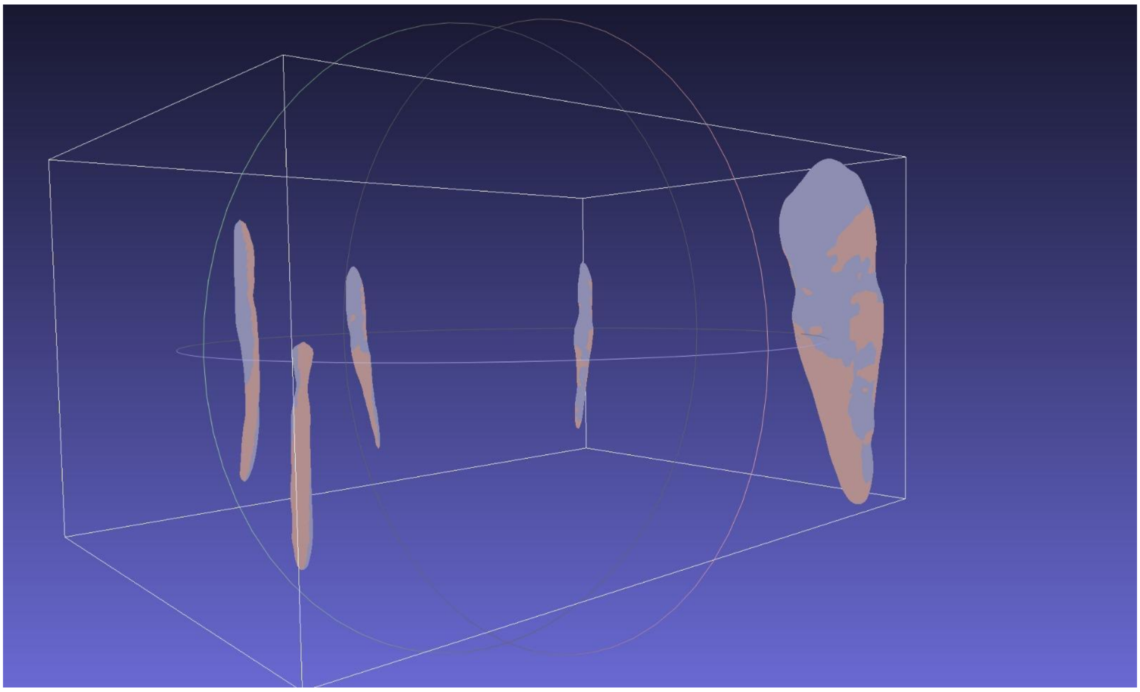


The software asks to choose strategic landmarks on the segmentations in order to continue the positioning differentiation process. The landmarks chosen are the root apices.

After confirming the marks on each segmentation, it is important to click on "process". Different colors can also be chosen in the MeshLab software (Figure 24).

Figure 24:

superposition carried out of the 8 segmentations on the Meshlab software



The positioning difference values between each superposition of segmentations appear in the Python console (Figure 25).

Figure 25:

Values between each superposition of the 8 segmentations on the Meshlab software

```
Starting Processing of 2 glued meshes out of 2 meshes
Computing Overlaps 2 glued meshes...
Arc with good overlap      1 (on       1)
       0 preserved 0 Recalc
(  1/  1)  0 ->  1 Aligned AvgErr dd=0.021983 -> dd=0.004315
Completed Mesh-Mesh Alignment: Avg Err 0.005; Median 0.005; 90% 0.005
Global Alignment...Completed Global Alignment (error bound 0.001000)
```

III. RESULTS

1. Value of measurements obtained with 3D Slicer

1.1 Value of measurements obtained in the first group

For this group, the dentist's radiograph was segmented on the first day (Table 1a), and the dental clinic receptionist’s radiograph on the second day (Table 1b) on 3D Slicer, no differences for all the variables evaluated were found.

Table 1a:

Measurements obtained by the segmentation using 3D Slicer of the Cone beam computed tomography radiograph taken by the dentist on the first day and segmented on the first day

Measured structure	Number of voxels	Volume (Cubic millimetres)	Area (Square millimetres)
Root Canal 1	1650	5.56875	25.6261
Root Canal 2	7113	24.0064	77.6338
Root Canal 3	6700	22.6125	67.6406
Root Canal 4	4895	16.5206	56.478
Root Canal 5	8751	29.5346	95.4571
Tooth 5	189561	639.768	599.077

Table 1b:

Measurements obtained by the segmentation using 3D Slicer of the Cone beam computed tomography radiograph taken by the dental clinic receptionist dental clinic receptionist on the first day and segmented on the day 2.

Measured structure	Number of voxels	Volume (Cubic millimetres)	Area (Square millimetres)
Root Canal 1	1650	5.56875	25.6261
Root Canal 2	7113	24.0064	77.6338
Root Canal 3	6700	22.6125	67.6406
Root Canal 4	4895	16.5206	56.478
Root Canal 5	8751	29.5346	95.4571
Tooth 5	189561	639.768	599.077

1.2 Value of measurements obtained in the second group

For this group, the dentist's radiograph was segmented on the day 15 (Table 2a), and the dental clinic receptionist's radiograph on the day 16 (Table 2b) on 3D Slicer, no differences for all the variables evaluated were found.

Table 2a:

Measurements obtained by the segmentation using 3D Slicer of the Cone beam computed tomography radiograph taken by the dentist on the first day and segmented on day 15

Measured structure	Number of voxels	Volume (Cubic millimetres)	Area (Square millimetres)
Root Canal 1	1650	5.56875	25.6261
Root Canal 2	7113	24.0064	77.6338
Root Canal 3	6700	22.6125	67.6406
Root Canal 4	4895	16.5206	56.478
Root Canal 5	8751	29.5346	95.4571
Tooth 5	189561	639.768	599.077

Table 2b:

Measurements obtained by the segmentation using 3D Slicer of the Cone beam computed tomography radiograph taken by the dental clinic receptionist on the first day and segmented on the day 16.

Measured structure	Number of voxels	Volume (Cubic millimetres)	Area (Square millimetres)
Root Canal 1	1650	5.56875	25.6261
Root Canal 2	7113	24.0064	77.6338
Root Canal 3	6700	22.6125	67.6406
Root Canal 4	4895	16.5206	56.478
Root Canal 5	8751	29.5346	95.4571
Tooth 5	189561	639.768	599.077

1.3 Value of measurements obtained in the third group

For this group, the dentist's radiograph was segmented on the day 30 (Table 3a), and the dental clinic recepcionist's radiograph on the day 31 (Table 3b) on 3D Slicer, no differences for all the variables evaluated were found.

Table 3a:

Measurements obtained by the segmentation using 3D Slicer of the Cone beam computed tomography radiograph taken by the dentist on the first day and segmented on day 30

Measured structure	Number of voxels	Volume (Cubic millimetres)	Area (Square millimetres)
Root Canal 1	1650	5.56875	25.6261
Root Canal 2	7113	24.0064	77.6338
Root Canal 3	6700	22.6125	67.6406
Root Canal 4	4895	16.5206	56.478
Root Canal 5	8751	29.5346	95.4571
Tooth 5	189561	639.768	599.077

Table 3b:

Measurements obtained by the segmentation using 3D Slicer of the Cone beam computed tomography radiograph taken by the dental clinic receptionist on the first day and segmented on the day 31.

Measured structure	Number of voxels	Volume (Cubic millimetres)	Area (Square millimetres)
Root Canal 1	1650	5.56875	25.6261
Root Canal 2	7113	24.0064	77.6338
Root Canal 3	6700	22.6125	67.6406
Root Canal 4	4895	16.5206	56.478
Root Canal 5	8751	29.5346	95.4571
Tooth 5	189561	639.768	599.077

1.4 Value of measurements obtained in the fourth group

For this group, the dentist's radiograph was segmented on the day 45 (Table 4a), and the dental clinic recepcionist's radiograph on the day 46 (Table 4b) on 3D Slicer, no differences for all the variables evaluated were found.

Table 4a:

Measurements obtained by the segmentation using 3D Slicer of the Cone beam computed tomography radiograph taken by the dentist on the thirtieth day and segmented on day 45.

Measured structure	Number of voxels	Volume (Cubic millimetres)	Area (Square millimetres)
Root Canal 1	1650	5.56875	25.6261
Root Canal 2	7113	24.0064	77.6338
Root Canal 3	6700	22.6125	67.6406
Root Canal 4	4895	16.5206	56.478
Root Canal 5	8751	29.5346	95.4571
Tooth 5	189561	639.768	599.077

Table 4b:

Measurements obtained by the segmentation using 3D Slicer of the Cone beam computed tomography radiograph taken by the dental clinic receptionist on the thirtieth day and segmented on day 46.

Measured structure	Number of voxels	Volume (Cubic millimetres)	Area (Square millimetres)
Root Canal 1	1650	5.56875	25.6261
Root Canal 2	7113	24.0064	77.6338
Root Canal 3	6700	22.6125	67.6406
Root Canal 4	4895	16.5206	56.478
Root Canal 5	8751	29.5346	95.4571
Tooth 5	189561	639.768	599.077

After calculating the number of voxels, the volume (cubic millimetres) and the surface area (square millimetres) on 3D Slicer, it can be seen that there is no difference between the values obtained between the four radiographs taken using cone-beam tomography, including 2 x-rays taken on day 1 and the other 2 on day 30 by the dentist and the dental clinic receptionist for root canal 1, root canal 2, root canal 3, root canal 4, root canal 5 and tooth 5.

Furthermore, there was no difference between the segmentation carried out on day 1, 2, 15 and 16 of the radiographs taken on the first day.

There was also no difference between the segmentation performed on days 30, 31, 45 and 56 and the X-rays performed on day 30.

Additionally, there is no difference between the values corresponding to the segmentations associated with days 1, 2, 15, 16, 30, 31, 45, 46.

2. Value of measurement obtained with Meshlab

In the Meshlab software, the 8 segmentations were superimposed. The software displays all the differences in a different colour as soon as they are distinguished and the positioning error detected and indicated in the Python console is 0.001 nm. This value is therefore negligible because such a small error will not have an impact on the operation and the technique of positioning the teeth on the support and positioner.

IV. DISCUSSION

In this study, a prototype of a reuseable multi-sample support for cone-beam tomography applied to dental research was designed.

In the absence of a prototype to guide the researcher in the positioning of teeth in a stable, standardised and, above all, reproducible manner, practitioners were led to position the teeth randomly on a support that had not been explored and analysed. In the literature, authors have reported that teeth are positioned randomly (Gambarini et al., 2020).

Acrylic resins were created in the 1930s and were first used in dentistry in the 1940s. They quickly replaced the materials that had previously been used to make dental prostheses. Their handling characteristics and mechanical properties are quite satisfactory for a variety of applications (Walker et al., 2020).

Furthermore, acrylic resin is made of combined methyl methacrylate molecules. Acrylic polymer plays a crucial role in the production of removable dental prostheses. More than 95% of dental coatings are made from acrylic resin (Wahyuni & Murwaningsih 2022).

The auto-polymerizable acrylic resin used MethxOrtho® (MakeVale Ltd, London, United Kingdom) is an acrylic resin for orthodontic use comprising:

- 5-50% by weight of a methacrylate with no urethane bond and an average molecular weight of 100-300 and containing at least one unsaturated double bond;
- 10-60% by weight of a methacrylate containing a urethane bond and having an average molecular weight of 300-5000 and containing at least one unsaturated double bond;
- 5-30% by weight of a cross-linked polyurethane powder;
- 10-50% by weight of a mineral filler;
- 0.03-3% by weight of photopolymerization initiator (Sugano, et al 2015).

The Methax Ortho® (MakeVale Ltd, London, United Kingdom) auto-polymerizable acrylic resin used in this thesis contains methyl methacrylate.

The residual concentration of methyl methacrylate monomer has been introduced into dentistry for various reasons, such as the efficiency of polymerisation conversion, and has an impact on various physical and mechanical properties due to the leaching of methyl methacrylate into resin materials. The amount of methyl methacrylate monomer that remains depends mainly on the efficiency of the degree and method of polymerisation (Tuna et al, 2013).

Methyl methacrylate, plays a key role in the manufacture of a variety of acrylics and plastics. In polymer chemistry, methyl methacrylate is a popular choice of monomer because of its ability to provide durability, thermal stability, optical clarity, impact resistance and scratch/abrasion resistance in polymers. It is a liquid with an odour that has the ability to polymerise itself, resulting in the generation of significant amounts of heat. Thus, commercially available methyl methacrylate (MMA) contains a small amount of inhibitor (around 0.1%) to ensure that it can be stored safely (Deka et al., 2022).

Thanks to the use of acrylic resin comprising methyl methacrylate copolymer and dimethacrylate in the manufacture of this prototype, cost savings and ease of material handling have been achieved, which is why the base of dental prostheses is often made from acrylic resin. In addition, it is mouldable and affordable (Lee et al., 2022).

In fact, auto-polymerizable acrylic resin is often used in many areas of dentistry. One of the main reasons for using this resin lies in the following benefits: the acrylic resin is able to hold the elements in a suitable and desired position, thus offering excellent retention (Lyros et al., 2023).

Furthermore, the integration of the Kulzer® (Mitsui Chemicals, Hanau, Germany) high-pressure polymerisation device enabled the optimisation of the polymerisation of the material; it is due to the fact that high pressure polymerisation technology was developed to produce high molecular weight polymers with well-defined structures. It has been observed that reversible addition fragmentation transfer polymerisation has an impact on polymerisation rates, resulting in polymers with a higher molecular weight and lower polydispersity. As a result, better stability and polishing will be favoured (Murakami et al., 2013).

On the other hand, acrylic resin is a very interesting material for the present study. In fact, in the 3D Slicer software, acrylic resin does not produce any interference between the natural teeth and the support and positioner. Furthermore, on the cone beam computed tomography thanks to the different levels of radiopacity, the components of the prototype are well distinguished.

Planmeca Oy ProMax is the first machine to combine three modes of three-dimensional data capture in a single unit. It is possible to make a cone beam computed tomography image, a three-dimensional facial photo and a three-dimensional dental model scan with this machine. It can measure, record and analyse jaw movement in three-dimensional in real time. The same machine can be used to create two-dimensional radiographic images, including orthopantomography, without changing sensors (Bashir et al., 2023).

On the other hand, it has been shown that the use of Planmeca Oy Promax three-dimensional Helsinki Finland cone beam computed tomography, with high or low resolution increases the detection and ability to make an excellent objective diagnosis in endodontics such as root fracture detection since the accuracy is improved (Almeshari et al., 2023).

In the present study, four cone beam computed tomography radiographs were taken at different times by the two participants. On day one, two radiographs were taken, one by the dentist and the other by the dental clinic receptionist. On the thirtieth day, the two participants took a new radiograph in the same manner.

The results show that all variables evaluated for each tooth were the same in both operators and in both acquisitions.

These results show that it is possible to perform several cone beam computed tomography radiographs at different times while maintaining the same position of the teeth, and by different operators. In this way, not only is the possible temporal modification factor rejected, but also the operator-related modification factor is eliminated in the same manner.

Cone beam computed tomography allows downloading radiographs in various formats, including the digital imaging and communications in medicine and Standard Tessellation Language or Standard Triangulation Language formats, which are necessary for associating the radiographs with the 3D Slicer software. The digital imaging and communications in medicine image file format is widely accepted as the standard format for the transmission of radiological images and medical information. It is particularly relevant for computed tomography, as it allows different file formats from different brands of machines to be standardised and a single viewing software to be created (Miranda-Viana et al., 2023).

This Standard Tessellation Language or Standard Triangulation Language is a great advantage in dentistry today. It allows the visualisation of dental parts in three-dimensional format, and also has other advantages, such as the three-dimensional printing of different types of dental restorations, since it is highly accurate, using units for intensity values (luminosity) as well as voxels (Kamio & Kawai, 2023).

Indeed, 3D Slicer is the software used in this thesis to carry out all the measurements on the various X-ray images.3D slicer is a platform created in 1990 by the Surgical Planning Laboratory, led by Ron Kikinis based on the experience of previous research groups at the Massachusetts Institute of Technology and the Surgical Planning Laboratory at Brigham and Women's Hospital in Boston (You et al., 2022).

At the same time, it is important to note that the 3D slicer is a very powerful platform that is used in many medical fields such as dentistry. The integration of three-dimensional technologies into dental treatments has become increasingly widespread since the discovery of Cone beam computed tomography. This platform has made it possible to meet the image analysis needs of a number of researchers and dentists, thanks to its potential clinical and preclinical application, since it was originally designed as a guided treatment system (Borowska et al., 2023).

3D Slicer software does not have any specific components for a particular operating system. Versions of 3D Slicer can be used on Windows, Mac OS X or Linux that allows free distribution of derived software for academic and commercial use. Industry collaborators can use the image analysis tools developed in 3D Slicer directly (Fedorov et al., 2012).

Also, many advantages accompany the use of this platform since it allows the visualization of the anatomy of the organs through the integration of medical imaging techniques such as cone beam computed tomography (Sendyk et al., 2021).

It is also important to emphasize that this software is free, it is very often used in medical research because it is equipped with several functionalities which give reason to practitioners in its choice of use, for example such as segmentation, taking into account versatile viewing load. 3D slicer will allow the evaluation of our quantitative methods which are advantageous opportunities, particularly in the notion of comparison (Connolly et al., 2022).

Furthermore, it presents another significant advantage, which allows interacting with the software using Python code and other programming languages, enabling users to create extensions or make modifications to the software's code to integrate it, modify it, and consequently apply it according to current studies conducted by practitioners worldwide.

It is also possible to continuously enhance the capabilities of 3D Slicer without cost by integrating extensions and modifications in the interest of a study (Lassó et al., 2022).

In the present study, an extension named "AMASSS" was modified and integrated into 3D Slicer. The modifications made to the platform allowed integrating the software into our study to obtain volumetric and surface results and calculate the number of voxels on the different radiographs taken using cone beam computed tomography.

The main reason for using 3D Slicer is its ability to perform three-dimensional radiographic segmentation using our cone-beam volume tomography, enabling us to obtain a volumetric and surface measurement of our natural teeth radiographed using our support and positioner.

It is also necessary to know that 3D slicer is a valid platform for the data delivered so far. Indeed, in the literature 3D slicer has been compared to other platforms such as ITK-snap or OsiriX MD, which has allowed its fidelity to be approved (Shetty et al., 2021).

So, the calculated data obtained from this platform helps us approve the standardization and functionality of our prototype.

In order to obtain measurements, it is always necessary to segment the radiographs. Image segmentation is considered one of the most fundamental tasks in image processing applications (Khorram & Yazdi, 2018).

The image segmentation technique is widely used in the field of image processing due to its suitability for multiple uses. It is also possible to use image segmentation to separate objects from background (Mustafa et al., 2020).

Traditional image segmentation uses artificial techniques to extract and select features such as edges, colours and textures from the image. In addition to requiring a large amount of energy and work time, it also requires a great deal of skill to extract relevant information, which no longer meets the requirements of practical applications in medical image segmentation and recognition (Chen et al., 2023).

At the end of each segmentation, the software provided four documents, including a Visualization Toolkit (Visualization Toolkit). The Visualization Toolkit (Visualization Toolkit) document allows the visualization and manipulation of the data obtained from the radiograph as well as the segmentation of the prototype with the teeth positioned in a three-dimensional format. Visualization Toolkit is a format that is increasingly used in medicine. It contains vectors, algorithms, tensors and textures, as well as excellent visualisation (Wang et al., 2022).

At the end of all computer manipulations, the volumetric and surface results, as well as the number of voxels for each root canal (root canal 1, root canal 2, root canal 3, root canal 4, root canal 5) and for the segmented tooth (Tooth 5), are provided by the 3D Slicer software and presented in tabular form.

It is thus noted that:

- Table 1a and 1b show the measurements obtained from segmentations performed on day 1 and day 15 respectively using 3D Slicer from cone beam computed tomography radiographs taken by the dentist on the first day, and Table 1b and 2b show the measurements obtained from segmentations performed on day 2 and day 16 respectively using 3D Slicer from cone beam computed tomography radiographs taken by the dental clinic receptionist on the first day, were identical.
- Furthermore, the comparison of Table 3a and 4a, showing the measurements obtained from segmentations performed on day 30 and day 45 respectively using 3D Slicer from cone beam computed tomography radiographs taken by the dentist on the thirtieth day, and Table 3b and 4b, showing the measurements obtained from segmentations performed on day 31 and day 46 respectively using 3D Slicer from cone beam computed tomography radiographs taken by the dental clinic receptionist on the thirtieth day, are also identical.

It is important to specify that each measured radiograph underwent 2 segmentations but at different times. This approach demonstrates that the 3D Slicer software is a valid method and validates the reliability of the 3D Slicer software.

Moreover, the comparison of all tables also demonstrates identical measured values for each component. This observation highlights that the crafted prototype can guide any user in positioning the teeth for taking a radiograph using cone beam computed tomography. Therefore, it is a standardized and accessible reusable prototype that has the ability to facilitate the researcher's work by eliminating the modifying factor related to tooth positioning.

However, a limitation can be observed in this study. Indeed, 5 single-rooted teeth without restoration or fractures were selected to facilitate the various evaluations conducted using the 3D Slicer software. However, it would be relevant to conduct the same research in future studies with multi-rooted teeth.

Meshlab is software that is very easy to use and accessible for free. In dentistry, this software is widely used, particularly for three-dimensional reconstructions (Pan et al., 2022).

In dentistry, Meshlab is of great interest, particularly in examining patterns of dental wear. Assists in non-parametric statistical evaluation of standard deviations and mean percentages, as well as detection of multiple variables, distances, areas and angles using 3D visualization (Jablonski et al., 2018).

To determine the positioning of each tooth in each radiograph taken using the cone beam computed tomography with the support and positioner, 8 segmentations were used, namely those of the dentist and the assistant for teeth 1, 2, 15, 16, 30, 31, 45, and 46. Each segmentation was downloaded and superimposed using Meshlab software. The software identified difference in positioning between each segmentation, this value is indicated by the Completed global alignment which indicates an error bound of 0.001 nm. This computationally difference in positioning proves the fact that the segmentations are different and this difference is computationally negligible. So, no positioning error that could have an impact on searches is detected. This method also validates the reliability of tooth positioning using the prototype.

The creation of the support and positioner in this study represents an advantageous opportunity for future research. However, it is possible to carry out other studies on this creation, for example:

- Carrying out the same study but with multiradicular teeth
- This study could be carried out with artificial teeth
- Improve the image analysis protocol to make it more practical and faster
- Create a 3D printed positioner and evaluate its possible commercialization.

V. CONCLUSION

Taking into account the limitations of the present study, the acrylic resin prototype fabricated includes a support and positioner, thus providing assistance to all users in positioning the teeth for cone beam computed tomography radiography.

This standardized model has demonstrated its reliability by ensuring precise positioning of the teeth in an identical location when performing one or multiple radiographs using cone beam computed tomography. What's more, the desired measurements can be taken at different times and as many times as required.

In this way, the developed support and positioner help eliminate variations in positioning

VI. BIBLIOGRAPHY

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VII. ANNEXES

Annex A - Opinion of the UFP Ethics Committee on the proposed project to obtain a Master's degree in Dental Medicine.

UNIVERSIDADE FERNANDO PESSOA

Exma. Senhora
Prof. Doutora Sandra Gavinha
Diretora da FCS

Nº	Data
FCS/MMED – 504/23-2	01 de fevereiro de 2024

Exma. Senhora Professor Doutora,

A Comissão de Ética apreciou a resubmissão do projeto de investigação apresentado por Selma Cidem Tekin, intitulado "Design of a multisampling holder prototype for Cone Beam Computer Tomography applied to dental research", a realizar no âmbito do Mestrado Integrado em Medicina Dentária.

Todos os esclarecimentos/alterações solicitados foram feitos.

Deste modo, a Comissão de Ética considera nada haver a opor quanto à realização deste projeto.

Com os melhores cumprimentos.

A Presidente da
Comissão de Ética da UFP
Inês Lopes Cardoso
Inês Lopes Cardoso

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* (chamada para a rede fixa nacional)

Autorizo