CATÓLICA
FACULDADE DE MEDICINA DENTÁRIA

VISEU

DEVELOPMENT OF A THREE-DIMENSIONAL ANALYSIS TO LOCATE DENTAL ELEMENTS

Dissertação apresentada à Universidade Católica Portuguesa
para obtenção do grau de Mestre em Medicina Dentária

Por:
Joanna Almeida Binato

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Orientador: Profª Doutora Susana Paula Fernandes Machado da Silva

Coorientador: Profª Doutora Ana Maria Bolognese

Viseu, 2020

"É preciso, porém, deixar um pouco mais difícil essa conquista,

para que a vitória fácil demais não desmereça o preço".

William Shakespeare

Aos meus pais HEMERSON BASTOS BINATO e REGINA CÉLIA ALMEIDA BINATO que me permitiram uma vida de alegrias, me ensinaram a caminhar e me deram amor e tranquilidade para conquistar meus sonhos.

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> "Ser profundamente amado por alguém nos dá força; Amar alguém profundamente nos dá coragem".
>
> Lao Tsé

SINCERAMENTE DEDICO

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"Cada novo amigo que ganhamos no decorrer da vida, aperfeiçoa-nos e enriquece-nos, não tanto pelo que nos dá, mas pelo que nos revela de nós mesmos".

Miguel Unamuno

RESUMO

Introdução: A rotina de acompanhamento dos elementos dentários e a evolução da dentição incluem fotografias, radiografias e cefalometria lateral. Estes, no entanto, fornecem apenas uma representação bidimensional (2D) das estruturas dentárias e ósseas e podem levar à perda de dados, sem considerar as diferenças de largura, simetria e forma facial. A tecnologia tridimensional (3D) apresenta inúmeras vantagens, onde os aspectos referentes às estruturas dentárias podem ser visualizados em tamanho real, através de diferentes planos e angulações. **Objetivos** O objetivo deste estudo é apresentar uma análise tridimensional para localização dos elementos dentários, observando suas dimensões, angulações, posições espaciais e relação com o osso basal, em um estudo piloto utilizando o canino superior permanente em desenvolvimento. **Materiais e Métodos:** Os dados foram coletados por tomografia computadorizada de 30 crianças, de ambos os sexos, em dentição mista. O software utilizado permitiu a criação de uma análise individual e bilateral, onde as medidas propostas foram obtidas tridimensionalmente. **Resultados:** Esta análise cefalométrica foi composta por pontos, linhas e planos localizados nas estruturas anatômicas de interesse para a obtenção da posição exata do dente escolhido. Esta análise pode ser feita para qualquer elemento dental, esteja em erupção ou não na cavidade oral. Os pontos de referência localizados no canino superior permanente são comuns a todos os dentes. As linhas e planos dessa análise foram gerados por pontos de referência determinados nos ossos da face, completamente reprodutíveis em qualquer paciente. **Conclusões:** Como a tomografia substituiu as radiografias convencionais, o surgimento de novos pontos anatômicos e novas análises em 3D é natural, mais confiável e inevitável, com o objetivo de substituir as que foram utilizadas em 2D.

PALAVRAS-CHAVE Tomografia; análise cefalométrica; tridimensional; tecnologia.

ABSTRACT

Introduction Accompanying routine of the evolution of the dentition include photographs, radiographs, and lateral cephalogram. These, however, provide only a bidimensional representation of the dental and bone structures and it can lead to loss of data, not considering the differences of width, symmetry and facial form. The three-dimensional technology presents countless advantages, where dental structures can be visualised in real size, through different planes and angulations. **Objectives** The aim of this study is to present a three-dimensional analysis for locate the dental elements, observing their spatial positions and relation with the basal bone, in a pilot study using the developing upper permanent canine. **Materials and Methods** The data was collected through computerised tomography of 30 children, on mixed dentition. The software used allowed the creation of an individual and bilateral analysis where the proposed measures were obtained three-dimensionally. **Results** This cephalometric analysis was composed by points, lines and planes for the obtainment of the position of the chosen tooth. This can be done for any dental element, whether it is erupted or not into oral cavity. The landmarks located on the upper permanent canine are common to all teeth. The lines and planes on this analysis were generated by landmarks determined on facial bones completely reproducible on any patient. **Conclusions** As the tomography came to substitute the conventional radiographs, the appearance of new anatomic landmarks and new 3D analysis is natural, more reliable and inevitable with the aim to substitute the ones that have been used on 2D.

KEYWORDS Tomography; cephalometric analysis; three-dimensional; technology.

ÍNDICE

1 INTRODUÇÃO

O desenvolvimento da dentição humana é um processo biológico contínuo e extremamente complexo. O conhecimento da evolução da oclusão possibilita entender os desvios da normalidade e, assim, eliminar ou diminuir os fatores etiológicos que estejam impedindo o estabelecimento da boa oclusão dentária.

Durante a evolução ocorrem diversas mudanças significativas nos dentes e ossos faciais. Na supervisão deste desenvolvimento, podem-se identificar anormalidades e ausência de espaço, sendo necessárias interceptações para a prevenção de problemas futuros ou o delineamento de um plano de tratamento corretivo.

Os elementos dentomaxilofaciais se apresentam como estruturas tridimensionais (3D) localizadas em diferentes posições espaciais. A rotina de acompanhamento desses elementos e da evolução da dentição compreende fotografias e radiografias panorâmicas, periapicais, oclusais e cefalométricas laterais. Estas, entretanto, fornecem, exclusivamente, a representação bidimensional (2D: eixo X e Y) das estruturas ósseas e dentárias, podendo levar à perda de dados, não considerando as diferenças de profundidade, simetria e forma faciais.

Diferentemente das radiografias convencionais, que representam em 2D as estruturas obtidas pelos raios-X, a tomografia computadorizada (TC) é um método de diagnóstico por imagem que, apesar de também utilizar a radiação-X, permite obter a reprodução tridimensional de uma região do corpo humano representadas por um sistema de coordenadas XYZ: eixo X (dimensão horizontal ou transversa), o eixo Y (dimensão vertical) e o eixo Z (dimensão ântero-posterior ou “eixo de profundidade”) (1-9).

Programas computadorizados específicos permitem a reconstrução 3D do volume escaneado pela TC, além da reconstrução multiplanar, ou seja, a visualização de imagens axiais, coronais, sagitais e oblíquas, com alta definição e contraste, sem superposição de estruturas anatômicas, normalmente encontradas nas radiografias convencionais (6-9).

A análise 3D revela informações complementares impossíveis de serem obtidas por método diagnóstico convencional em duas dimensões (2D), como por exemplo cálculo volumétrico e análise individualizada de pontos cefalométricos bilaterais. A tecnologia 3D apresenta inúmeras vantagens onde aspectos referentes às estruturas dentárias e ósseas são observados em diferentes angulações e planos, apenas disponibilizados por aplicativos que são baseados no Sistema Cartesiano XYZ (1, 2, 10).

Assim, a utilização de métodos 3D em pesquisas e na rotina da clínica odontológica, para observação do desenvolvimento da oclusão, se justifica pela necessidade da visualização do real volume e posição espacial das estruturas craniofaciais (5).

Portanto, o objetivo do estudo aqui descrito foi apresentar uma análise tridimensional para localização dos elementos dentários, observando suas dimensões, posições espaciais e relação com o osso basal, em um estudo piloto utilizando o canino superior permanente em desenvolvimento. O desenvolvimento desta análise foi descrita em um artigo de título: "**Development of a three-dimensional analysis to locate dental elements**”, submetido para publicação na revista *European Journal of Orthodontics.*

A escolha da revista para a submissão foi devido ao fato de ser o *European Journal of Orthodontics* um dos principais periódicos em seu campo, publicando artigos científicos destinados a todos os ortodontistas. A revista fornece um fórum para esses profissionais na Europa, onde muitos desenvolvimentos estão ocorrendo, mas também aceita artigos de todas as partes do mundo. Os documentos clínicos abrangem todas as técnicas, bem como diferentes abordagens para o planejamento do tratamento. Os trabalhos de pesquisa são de relevância direta para o clínico e ampliam a base científica da Ortodontia, possuindo também um relevante fator de impacto e classificação.

Artigo:

Title File

Development of a three-dimensional analysis to locate dental elements.

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Main File

Development of a three-dimensional analysis to locate dental elements.

SUMMARY

Background and objectives Accompanying routine of the evolution of the dentition include photographs, radiographs, and lateral cephalogram. These, however, provide only a bidimensional representation of the dental and bone structures and it can lead to loss of data, not considering the differences of width, symmetry and facial form. The three-dimensional technology presents countless advantages, where dental structures can be visualised in real size, through different planes and angulations. The aim of this study is to present a three-dimensional analysis for locate the dental elements, observing their spatial positions and relation with the basal bone, in a pilot study using the developing upper permanent canine. **Materials and Methods** The data was collected through computerised tomography of 30 children, on mixed dentition. The software used allowed the creation of an individual and bilateral analysis where the proposed measures were obtained three-dimensionally. **Results** This cephalometric analysis was composed by points, lines and planes for the obtainment of the position of the chosen tooth. This can be done for any dental element, whether it is erupted or not into oral cavity. The landmarks located on the upper permanent canine are common to all teeth. The lines and planes on this analysis were generated by landmarks determined on facial bones completely reproducible on any patient. **Conclusions** As the tomography came to substitute the conventional radiographs, the appearance of new anatomic landmarks and new 3D analysis is natural, more reliable and inevitable with the aim to substitute the ones that have been used on 2D.

KEYWORDS Tomography; cephalometric analysis; three-dimensional; technology.

INTRODUCTION

The dental and maxillofacial elements are three-dimensional (3D) structures, located in different spatial positions. The routine of accompanying these elements and the evolution of the dentition include photographs, radiographs and lateral cephalogram. These, however, provide only a bidimensional representation (2D: axis X and Y) of the dental and bone structures and it can lead to loss of data, not considering the differences of width, symmetry and facial form (1). In addition, can result in several limitations in 2D cephalometric analyses such as poor patient positioning, nonlinear magnification, limited parameters measured, distortion of most measurements with facial asymmetry, projected measurements and superimposition of anatomical structures (2-6). Three-dimensional cephalometric analysis has provided the ability to overcome the limitations of 2D cephalometric and has also enabled a more accurate analysis of asymmetric structures, segmental movements using 3D digital operations and comparisons of preoperative and postoperative facial profiles (4-5).

Cone Beam computerised tomography (CT) comparative to Spiral CT represents the development of a smaller and cheaper tomograph, with low radiation dose, especially indicated to the dental and maxillofacial region (7, 8). Differently from conventional radiographs, the CT is a diagnosis method by image that allows to obtain the 3D reproduction of a human body region represented by the coordinate system XYZ: the axis X, horizontal or transversal dimension; axis Y, vertical dimension and the axis Z, anterior-posterior dimension or depth’s axis (1, 7, 9).

The 3D analysis reveals additional information like the volumetric calculation and the individual analysis of bilateral cephalometric landmarks, due to uncountable advantages of this technology where aspects related to dental and bone structures are observed in different angulations and planes, only available on software based on this Cartesian System XYZ (1). This system also allows full visualisation of any differences between bilateral structures. For example, differences between the right and left absolute values of the *X*-coordinates may suggest an asymmetrical position in the transverse dimension. Differences between the right and left absolute values of the *Y*- and *Z*-coordinates will indicate asymmetries in the anteroposterior and vertical dimensions, respectively (2). The use of voxel-based 3D analyses in the quantification of surgical movements of the maxilla and mandible was more reliable and reproducible than the use of conventional landmark-based 3D analyses (10).

The most advantage for the clinician is the possibility of viewing facial anatomic structures and the dentition from different angles. This is even more enhanced with the help of different computer software programs, allowing the clinician measure area and volume of anatomical structures, such as the airway volume and facial outline (5). Specific software provide 3D reconstruction of the scanned volume by CT, and also allow secondary reconstructions, such as sagittal, coronal and axial views, with high definition and contrast. Therefore, these computerised programs can generate bidimensional images, substituting conventional radiographs used in clinical routine (6-9).

The use of 3D methods in research and clinical routine for the observation of the occlusion development is justified by the necessity of visualisation of the real volume and spatial position of the craniofacial structures. Additionally, cone beam computed tomography can provide more information than conventional radiographs in localising impacted and retained teeth, root formation and calcification, cleft lip and palate evaluation and third molar evaluations (5).

Therefore, the aim of this study is to present a three-dimensional analysis to locate dental elements, observing their dimensions, spatial positions and relation with the basal bone, in a pilot study using the location of the developing upper permanent canine during mixed dentition.

MATERIALS AND METHODS

Data of 30 CT was obtained under the same protocol and the same software was used to process the images. The 30 patients were of both genders, on mixed dentition and with good health. They are all inscribed in the Odontopediatric and Orthodontic Department of the Federal University of Rio de Janeiro, Brazil and this study has been independently reviewed and approved by the ethical committee of the same university.

Computerised Tomography and acquisition of the three-dimensional images

The tomography uses patterned protocols and presents itself as an advantage due to the fact that, anatomical details, on hard and soft tissues can be well detected and, all dimensions found correspond to the real size (1:1). They allow the study of an area at any location along the tridimensional model, comparisons of 3D distances and calculation of the volume (1).

Before collecting the images, the patient was asked to remove all jewellery from the face, neck and ears. The patient was instructed to sit upright and was positioned on the tomography according to the protocol established: head and chin sustained by the appropriated supports. After the initial adjustments, the patient was asked to stay still and look toward a specific spot until the end of the scanning process.

The computerised tomography was obtained at Odontological Radiography Center Dr. Murillo B. Torres, on the i-CAT Cone Beam 3-D Imaging System and archived on DICOM (Digital Imaging and Communications in Medicine) format.

Producing accurate anatomical 3D virtual models is important for the analysis. This procedure is necessary to segment the structures and remove undesired artefacts. From the information provided by the cross-sectional slices, the software builds 3D virtual models that allow visualisation and measurement of the cephalogram. The software used to build the 3D virtual models was SimPlant ® 12 (Materialise Dental Inc., Leuven, Bélgica) and it was operated by the same investigator.

Before the obtainment of the 3D image, the anatomical structures were segmented. This is the process used to outline the shape of structures visible in the cross-sections of a volumetric data set. Based upon the Hounsfield scale, hard and soft tissue can be identified separately. Moreover, through this scale, there is the possibility to separate the image related to dental elements from the other facial structures. Because the aim of the pilot study was the observation of the unerupted upper permanent canine this tool was extremely important.

After the data process, a 3D graphic representation of the anatomical structures allows the navigation through volumetric image, amplification, rotation and the creation of a cephalometric analysis.

Determination of landmarks and cephalometric analysis

Despite the use of tomography images on researches and, more recently, on clinical diagnosis, there is not a 3D landmark system that is able to indicate the precise location of the dental elements. The 3D cephalometric analysis allows the study of facial structures as found in the conventional method (2D), usually defined by lateral cephalometric and posterior-anterior radiographs (without superimposition or distortion) and even adding more detailed information.

Therefore, a 3D cephalometric analysis has been developed for this study. Landmarks, lines, cross section planes and cephalometric measures were based on anatomical landmarks already recognised in anthropology, anatomy and orthodontics. The upper permanent canine was used as the chosen dental element for the realisation of the pilot study of this analysis.

The measures developed and analysed in the location of the tooth in the pilot study are represented on Tables 1, 2, 3 e 4.

It is important to note that these measures, performed on the upper canine, are suggestions for the location of any tooth, correlating it to the plans and lines of the analysis. Sometimes, the definition of conventional 2D landmark must be modified due to the third dimension, or new landmarks can and must be added to the 3D cephalometric system. All the landmarks in this analysis are not static and were repositioned each time we changed the view and orientation plane in order to obtain the most accurate position of the proposed landmarks and measures.

Landmarks, lines, cross section planes and angles used on this analysis are represented on Figures 1 to 4.

Reliability of the measurements and Statistical analysis.

Investigation of the reliability of the measurements was performed. Measurement error was established by repetition of six randomly selected cases at three different times.

The Pearson Correlation was observed between the size of the root and the distance from the unerupted teeth to the border of the alveolar bone; between the transversal width of the nasal cavity and the perimeter of the superior arch; the facial asymmetry and the eruption of the upper permanent canine and between the transversal width of the nasal cavity and the labial-palatal and anterior-posterior angulations of the upper permanent canines. The mean observed was 0.99, with statistical significance of 95%. Therefore, the results of the present investigation suggest reliability of the measurements. Others measures also correlated were: the distance to the facial midline; the perimeter and resorption of the deciduous canine and the lateral and anterior-posterior angulations related to the sagittal plane.

Descriptive statistics including means and standard deviation for each measure was performed by analysis using the software SPSS 16 for Windows.

The paired *t*-test and the intraclass correlation coefficient were used to observe the agreement between the right and left canines of a same individual. Despite finding some differences on both right and left sides, when the paired *t*-test was done, those differences were not statistically significant. The intraclass correlation coefficient (ICC) confirmed these results showing the agreement and symmetry between both right and left sides.

The level of significance chosen for all tests was 95% of reliability.

RESULTS

The results were analysed observing the physiological development of the upper permanent canines as a model tooth and their spatial positions into the alveolar and maxillary bone. The measures that corresponded to the anatomical development of the canines were related to labial-palatal and mesio-distal dimensions and the length of the tooth. The 3D localisation of the model tooth were analysed observing the anterior-posterior and lateral angulations; the distance from the canine to facial midline; the distance between the canine and the border of the alveolar bone and the distance between the canine and the root of the deciduous teeth.

The first step to create the present analysis was to determinate the points that could isolate the canine as a single element and provide anatomical information such as length, thickness, diameter and size of root and crown (points 1 to 14 shown on Table 1). Other landmarks were created to spatially locate the canine into maxillary bone, so that we could correlate the position of this tooth to the limits of basal and alveolar bones and its relationship with the other teeth (points 15 to 26 shown on Table 1).

The determination of standardised planes for orientation that were defined by stable points was necessary to later reproduce this analysis in the same patient at another time, since the sample was composed by growing children, or in adult patients. The FHC plane, Sagittal and Anterior planes, associated to the long axis of the tooth, allowed the possibility to determinate the lateral and anterior-posterior angulations of the permanent canine and the symmetry with the homologous tooth. In this way the model tooth was observed through the three planes of space XYZ, including the width plane that is not obtained on a 2D study. These planes eliminate possible undesired effects of the patient’s head position during image acquisition for analysis, which can lead to measure error.

The measures made between points, lines and planes provide numerical information for the exact location of the unerupted canine and also the possibility to correlate its position to the size of the nasal cavity, arch perimeter, resorption of the deciduous tooth and with any landmark or craniofacial surface.

The accuracy of the measures showed that the main advantage of this real 3D analysis is that the anatomical landmarks can be placed on their right position, located through 3D views, individualising the right and left landmarks. The visualisation of the same point on different planes of observation by rotating the image in various angulations on the 3D and 2D windows of the software increased the accuracy and reliability of this study and the 3D analysis proposed, bringing out the maximum benefit of the technique. This combination of 2D and 3D information is the key to accurate indication of landmarks in a repeatable way.

DISCUSSION

Since the craniofacial structures are located at the 3 planes of space, the bidimensional images (2D) have limitations to perform the 3D cephalometric analysis. It has been stated that much information is lost when 3D structures are assessed with 2D methodologies (1-14, 16-23). The 3D analysis has been used through the combination of frontal and lateral cephalometric radiographs, but this method can't be considered 3D. Two-dimensional cephalometric, which is a projection image of 3D structures, has several weak points, such as non-homogenous enlargement and distortion, especially of lateral structures; overlapping structures, leading to inaccurate landmark locations; the landmarks that appear on the lateral radiograph may not appear on the frontal image or vice-versa and improper head position may lead to fault diagnosis (12-14). The standard cephalogram represents an average of left and right structures in 2D cephalometry. Although both sides of the face may seem to be symmetrical, this is not true since the human face is rarely symmetrical. Because 3D imaging shows each side separately, additional knowledge of the skull can be gained (2, 4, 5, 14-18). It is common for orthodontists and surgeons to use software packages to generate 2D cephalograms digitally from cone beam CT data rather than analysing the images three-dimensionally. This would seem to represent a decrease in the accuracy of the cephalometric analysis as you convert 3D data into 2D (1-14, 16-23).

Even when a modern software is used to measure the craniofacial structures on 3D, the misconception of the 3D measures is observed. That is because these measures can only be made through 2D windows as the axial, coronal, sagittal and oblique views in these computerised programs. The measure is done by the distance between two landmarks projected on a same plane on the computer screen rather than true spatial measurement, despite the fact that the image can be rotated and the different views of the slices. Only the X and the Y axis are considered. Most of angular and linear measurements on many 3D analyses are made as a projection, instead of being measured directly in the 3D space. For example, when the angle of the facial line of a patient with severe mandibular asymmetry is assessed, projected on the sagittal plane, the direct angular measurement actually shows a lower value than the projected measurement. This is because the direct measurement is affected by the transverse position of the asymmetric chin, while the angle of the facial line measure the anteroposterior mandibular position, regardless of the transverse mandibular asymmetry (2).

There is no difference in measurements from midline structures between both cephalometric systems because they were not located significantly away from the midsagittal plane in the 3D system such as the linear measurements. However, the 3D angular measurements from one midline point to two points outside the midsagittal plane, or between three points far from it, shows differences from the corresponding 2D measurements. The angle between two lines in 2D method might also be different from the angle between two planes in 3D method due to the different orientation of planes on a patient. Therefore, the measurement in 3D system cannot be interpreted in the same way as conventional 2D system (2, 20, 21).

Using 2D data for 3D simulation of orthognathic surgery experienced difficulty and inconvenience in the planning between the 2D and 3D systems (20). Favourable postoperative results have been obtained using 3D osteotomy and 3D soft tissue simulation on 3D-augmented virtual head models. The use of a voxel-based 3D cephalometric analysis for the quantification of maxillary and mandibular displacements after 3D virtually planned orthognathic surgery has proved to be more reliable than was landmark-based 3D cephalometric analyses because it is less observer-dependent, less time-consuming, and more accurate than conventional 3D cephalometric analyses (10).

The CT is based on the same principles as conventional radiograph. According to them, tissues with different composition absorb the X-radiation on different ways. By the time the X-rays penetrate these tissues, those with more density (ex. liver) or heavier (ex. calcium in bones) absorb more radiation than tissues with less density (ex. lungs). Thus, the CT indicates the quantity of radiation absorbed by each body part analysed (radio density) and translates these variations on a scale of gray color, producing an image. This scale is formed by a large variety of tonalities of white, gray and black. A gray scale was created especially for the CT and its unity was called Hounsfield Unity (HU), homage to the scientist that developed the CT (22).

Because of the poor contrast between the image of the root apex and the surrounding bone, the location of the apex is based more on the general knowledge of the length of the tooth than on actually observing the tip of the root. This supports the value of 3D imaging modalities and shows that when measuring dental structures, relying on the CT data is ideal (5).

Cone beam CT imaging has been demonstrated to provide clinical efficacy in altering treatment planning for impacted maxillary canines, unerupted teeth, presence of root formation and calcification and severe skeletal discrepancies. Relative to traditional radiographs, cone beam CT scans enable more sensitive and definitive diagnosis of root resorption associated or unassociated with impacted teeth. For orthodontic treatment, the conditions may be defined as the amount and morphology of the alveolar bone relative to tooth root dimensions, angulation, and spatial position. The complex anatomical boundary conditions may limit or determine the potential tooth movement as well as the final desired spatial position and angulation of the tooth (5).

The 3D analysis developed on this study allows the spatial location of the dental elements into the bone and their relationship with the other craniofacial structures. When applied, this analysis makes the observation of unerupted or impacted teeth possible and even the prevention of any deviation of eruption during the accompanying of the occlusion development. This exam can also be made at different times of observation allowing the visualisation of its path of eruption and the developing process.

Although more studies are using 3D cephalometry, there has been little standardisation of landmarks across them. While researchers have used the 3D equivalents of 2D cephalometric landmarks and occasionally proposed new 3D landmarks, we can now accurately examine structures that have been understudied due to the technical limitation of 2D radiographs (14). The main advantage of the CT is the possibility of the visualisation of a same anatomical landmark on different planes of observation by rotating the images through many angulations on the software's available windows increased the accuracy of the real 3D analysis, like the one presented on this study. However, it is necessary to provide specific training to individuals operating the software in order to identify anatomical structures, to explore the computerised programs and to convert data on biological concepts with clinical applicability (1, 23). Observe Figure 4.

The new 3D analysis presented has great clinical and scientific value for the observation of dental angulations, location of the teeth into their basal bone and its spatial relationship with the other craniofacial structures.

A sequence of this cephalometric analysis, made by taking the tomography exam at different times of observation, should lead to the visualisation of the path of eruption and the developing and evolution process.

This analysis can be done for any dental element, whether it is erupted or not into oral cavity. The landmarks located on the upper permanent canine are common to all teeth. The lines and planes on this analysis were generated by landmarks determined on facial bones completely reproducible on any patient.

The use of 3D image requires the applicability of various advanced mathematics techniques, computational science and statistics. Even so, modern software present tools of easy applicability and capacity of calculating distances and angulations through computational mathematics, making it easier for the operator to obtain the precise localisation of the craniofacial structures.

As the tomography came to substitute the conventional radiographs, the appearance of new cephalometric landmarks and new 3D analysis is natural and inevitable with the aim to substitute the ones that have been used on 2D.

CONCLUSION

When the 3D analysis presented is used, it is possible to locate the exact position of unerupted teeth; study the normal development of the occlusion in early stages, observing the position of the permanent dental germs and their path to eruption; relate them with their antecessors and also observe the relationship of these elements with the other craniofacial structures. Besides, it allows the precise determination of the distance to the border of the bone, to midline, to the other teeth, to the labial and palatine cortical, as well as their thickness and, especially, the real dental angulations on the 3 planes of space.

The software used on this study allowed that one landmark indicated by the investigator at the 3D image could also be visualised in other different windows of observation where the images could be moved through different angulations, which increased the accuracy of the research. The level of significance for all the results of the present investigation was 95%, which suggests reliability of the measurements.

Therefore, the great advantage of this 3D real analysis system is the fact that anatomical landmarks can be placed in their correct position or, any interesting spot can be found spatially located through 3D view, identified by its coordinate address X, Y or Z. Distances between landmarks, planes, angles and volume can be measured with accuracy and reliability.

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CONFLICTS OF INTEREST

No Conflicts

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LEGENDS

Table 1 Definition of anatomical landmarks used on the analysis of the upper permanent canines.

Table 2 Lines used on the analysis of the upper permanent canines.

Table 3 Planes used on the analysis of the upper permanent canines.

Table 4 Measures developed and observed for the analysis of the permanent maxillary canines.

Figure 1 Three-dimensional model image of the development of the dentition. A and B) location of the 3D cephalometric landmarks. Observe that the landmarks located into the bone structures can also be visualised, if desired. Structures of the model were selected through Hounsfield's scale; C) visualisation of the points AND e ANE for measuring the width of the nasal cavity and D) visualisation of the relationship between the dental elements and the cephalometric landmarks into maxillary and alveolar bones, buccal view.

Figure 2 Sagittal and FHC Planes. A) right 45º lateral view of the skull, showing the relationship between the two planes and B) relationship between the planes and upper unerupted canines. The FHC and Sagittal planes associated to the long axis of the dental element, allowed the possibility to determinate the anterior-posterior and lateral angulations of the analysed tooth and the symmetry with the homologous tooth.

Figure 3 Anterior Plane. A) lateral view and B) relationship between the plane and upper unerupted canines. The Anterior plane, associated to the long axis of the tooth, allowed the possibility to determinate the anterior-posterior angulations of the analysed tooth.

Figure 4 Visualisation of the same landmark on different planes of observation by rotating the images through many angulations on the software's available windows. A) cuspid point of the canine marked on 3D model, B) the same point visualised on the axial slice, C) point visualised on coronal slice, D) point visualised on sagittal slice. The landmarks spot were only definitively determined, after having been repositioned every time we changed the orientation plane through the different windows in order to obtain the most accurate position of the proposed landmarks and measures.

Supplementary Material

Table 1

1	CCD	Cuspid’s point of the right upper permanent canine
2	CCE	Cuspid’s point of the left upper permanent canine
3	VCD	Most labial crown’s point of the right upper permanent canine
4	LCD	Most palatine crown’s point of the right upper permanent canine
5	VCE	Most labial crown’s point of the left upper permanent canine
6	LCE	Most palatine crown’s point of the left upper permanent canine
7	MCD	Mesial of the right upper permanent canine
8	MCE	Mesial of the left upper permanent canine
9	DCD	Distal of the right upper permanent canine
10	DCE	Distal of the left upper permanent canine
11	JACD	Amelocementary junction of the right upper permanent canine
12	JACE	Amelocementary junction of the left upper permanent canine
13	RzCPD	Most apical portion of the root of the right upper permanent canine
14	RzCPE	Most apical portion of the root of the left upper permanent canine
15	COVexD	Right external labial cortical bone
16	COLexD	Right external palatine cortical bone
17	COVexE	Left external labial cortical bone
18	COLexE	Left external palatine cortical bone
19	COVinD	Right internal labial cortical bone
20	COVinE	Left internal labial cortical bone
21	COLinD	Right internal palatine cortical bone
22	COLinE	Left internal palatine cortical bone
23	MargOD	Border of the alveolar bone below the right upper permanent canine
24	MargOE	Border of the alveolar bone below the left upper permanent canine
25	RCdD	Most apical portion of the root of the right upper deciduous canine
26	RCdE	Most apical portion of the root of the left upper deciduous canine

27	ENA	Anterior nasal spine
28	ENP	Posterior nasal spine
29	N	Nasion point
30	OD	Right orbit
31	OE	Left orbit
32	PoD	Right porium
33	PoE	Left porium
34	MxD	Right anterior maxillary point
35	MxE	Left anterior maxillary point
36	BorInc	Incisor border of the right upper incisor
37	II	Interincisal
38	AND	Right nasal cavity
39	ANE	Left nasal cavity

Table 2

ODOE	Line between point OD and point OE
NII	Line between point N and point II
LgECD	Line between point CCD and point RzCPD
LgECE	Line between point CCE and point RzCPE

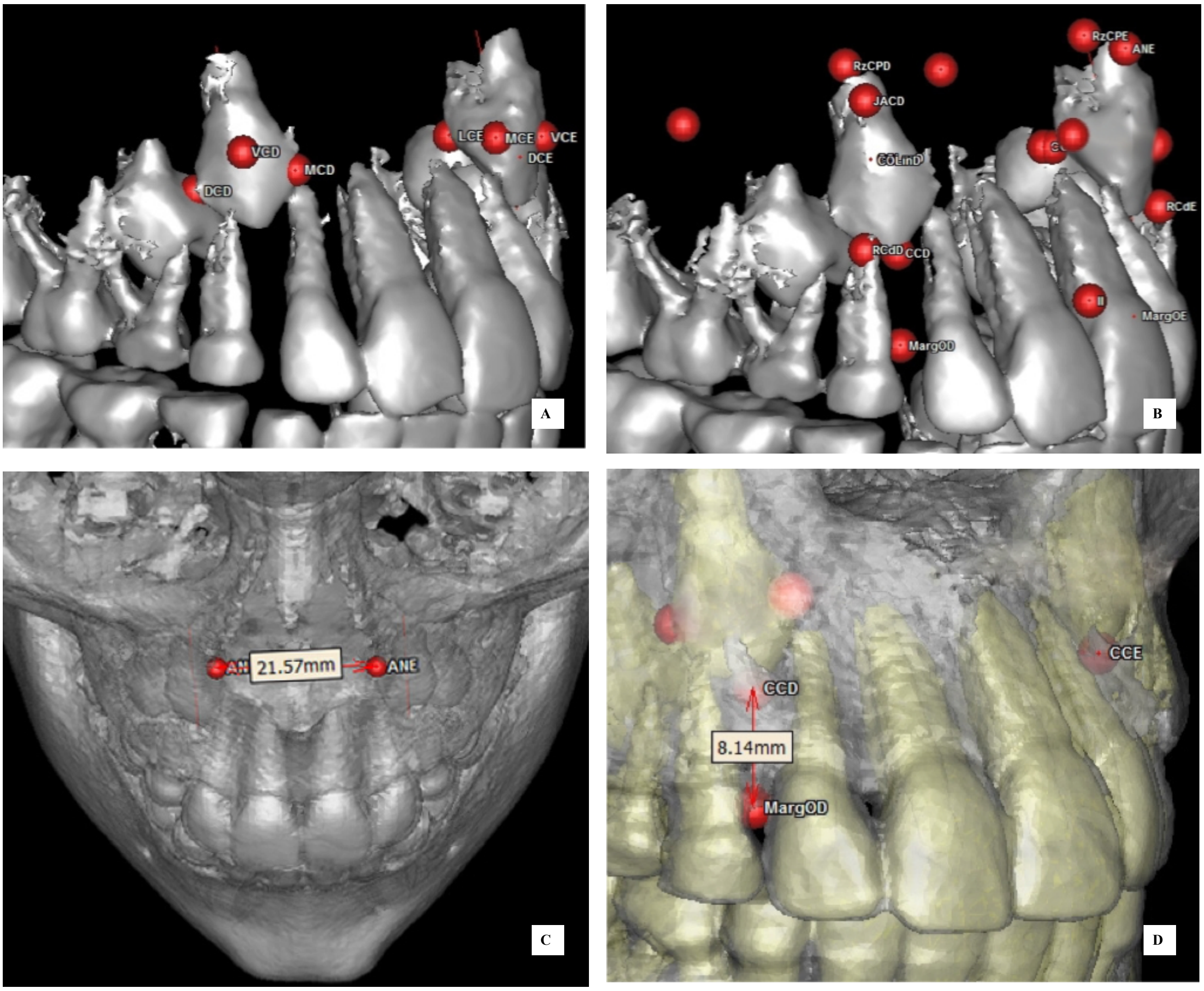
Table 3

Sagittal	Plane defined by point ENP, point N and point ENA
FHC	Plane defined by point PoD, point OD and point PoE
Anterior	Plane defined by point MxD, point MxE and point BorInc

Table 4

VLCPD	Distance between point VCD and point LCD
VLCPE	Distance between point VCE and point LCE
QOVexD	Distance between point VCD and point COVexD
QOLexD	Distance between point LCD and point COLexD
QOVexE	Distance between point VCE and point COVexE
QOLexE	Distance between point LCE and point COLexE
CMargOD	Distance between point CCD and point MargOD
CMargOE	Distance between point CCE and point MargOE
CRzdD	Distance between point RCdD and point CCD
CRzdE	Distance between point RCdE and point CCE
CompCPD	Distance between point CCD and point RzCPD
CompCPE	Distance between point CCE and point RzCPE
QOVinD	Distance between point VCD and point COVinD
QOLinD	Distance between point LCD and point COLinD
QOVinE	Distance between point VCE and point COVinE
QOLinE	Distance between point LCE and point COLinE
MDCD	Distance between point MCD and point DCD
MDCE	Distance between point MCE and point DCE
CompRzD	Distance between point JACD and point RzCPD
CompRzE	Distance between point JACE and point RzCPE
AP	Distance between point AND and point ANE
LMCD	Distance between point MCD and plane Sagital
LMCE	Distance between point MCE and plane Sagital
RzCdMargOD	Distance between point RCdD and point MargOD
RzCdMargOE	Distance between point RCdE and point MargOE
InclinCD	Angle between line LgECD and Sagittal plane
InclinCE	Angle between line LgECE and Sagittal plane
FHCSagital	Angle between plane FHC and Sagittal plane
PoscCD	Angle between line LgECD and Anterior plane
PoscCE	Angle between line LgECE and Anterior plane

FIGURE 1


VCD
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DCD
LCE
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FIGURE 2

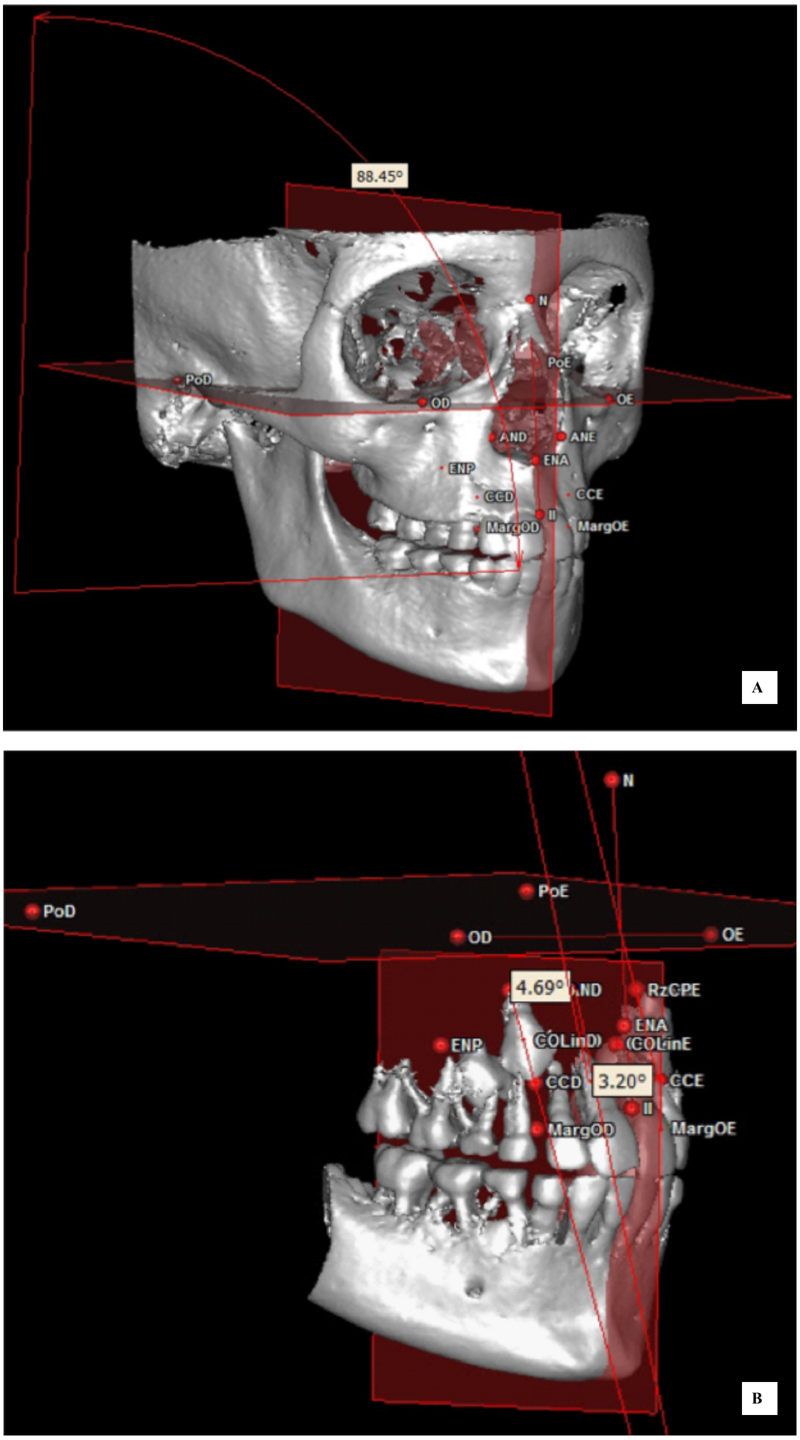
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FIGURE 3

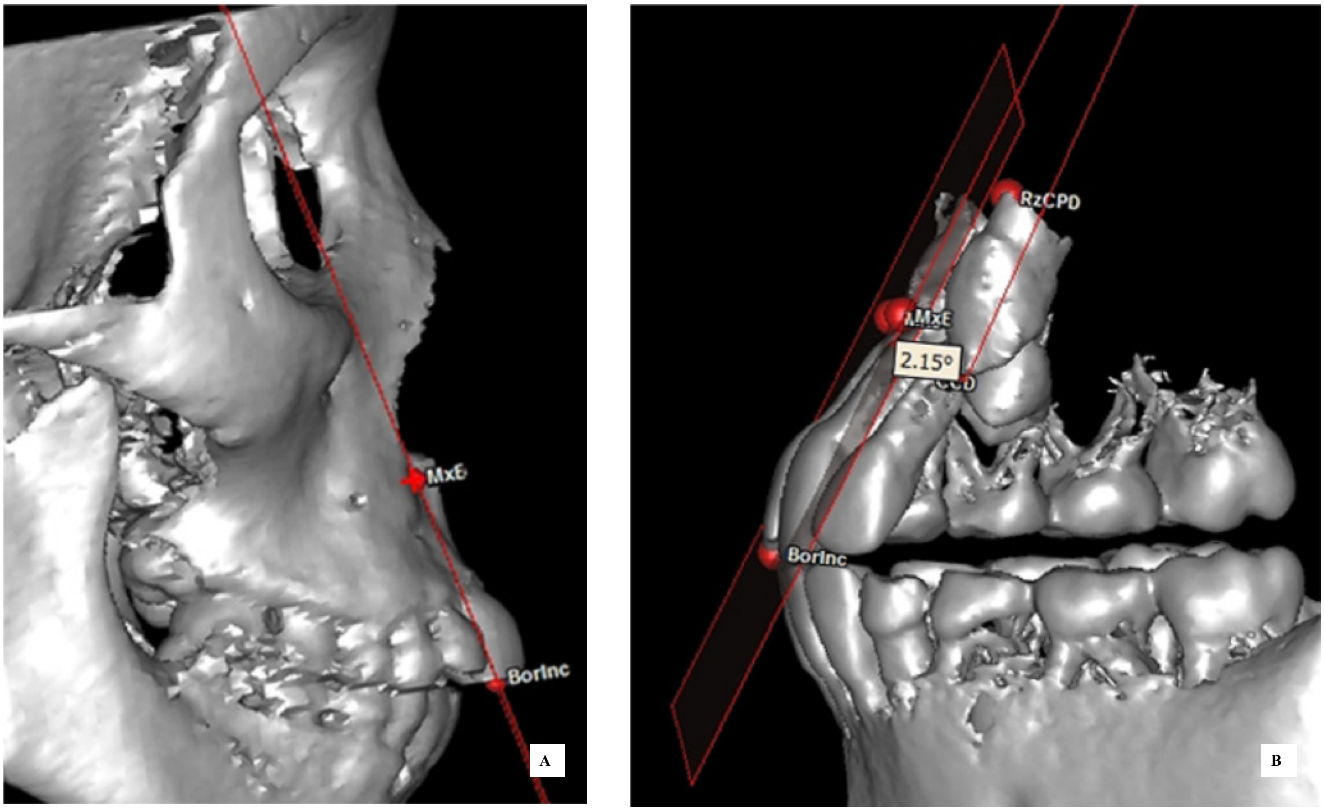
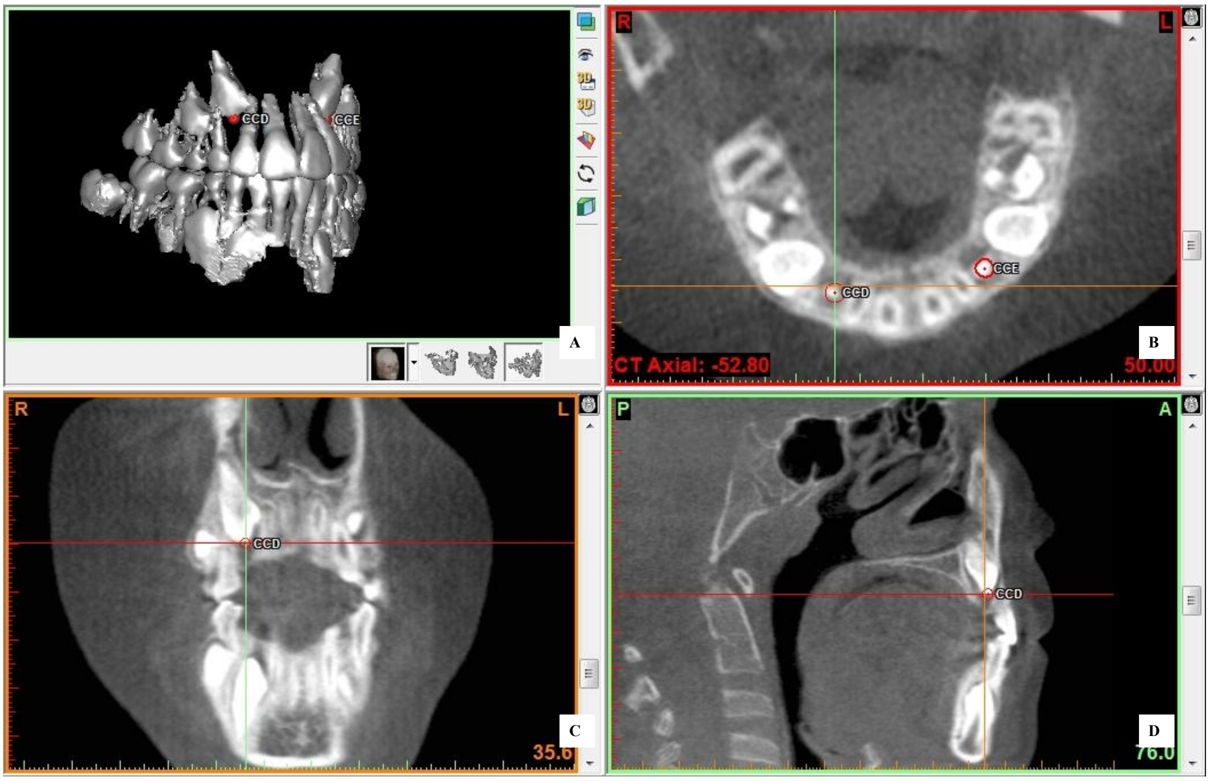
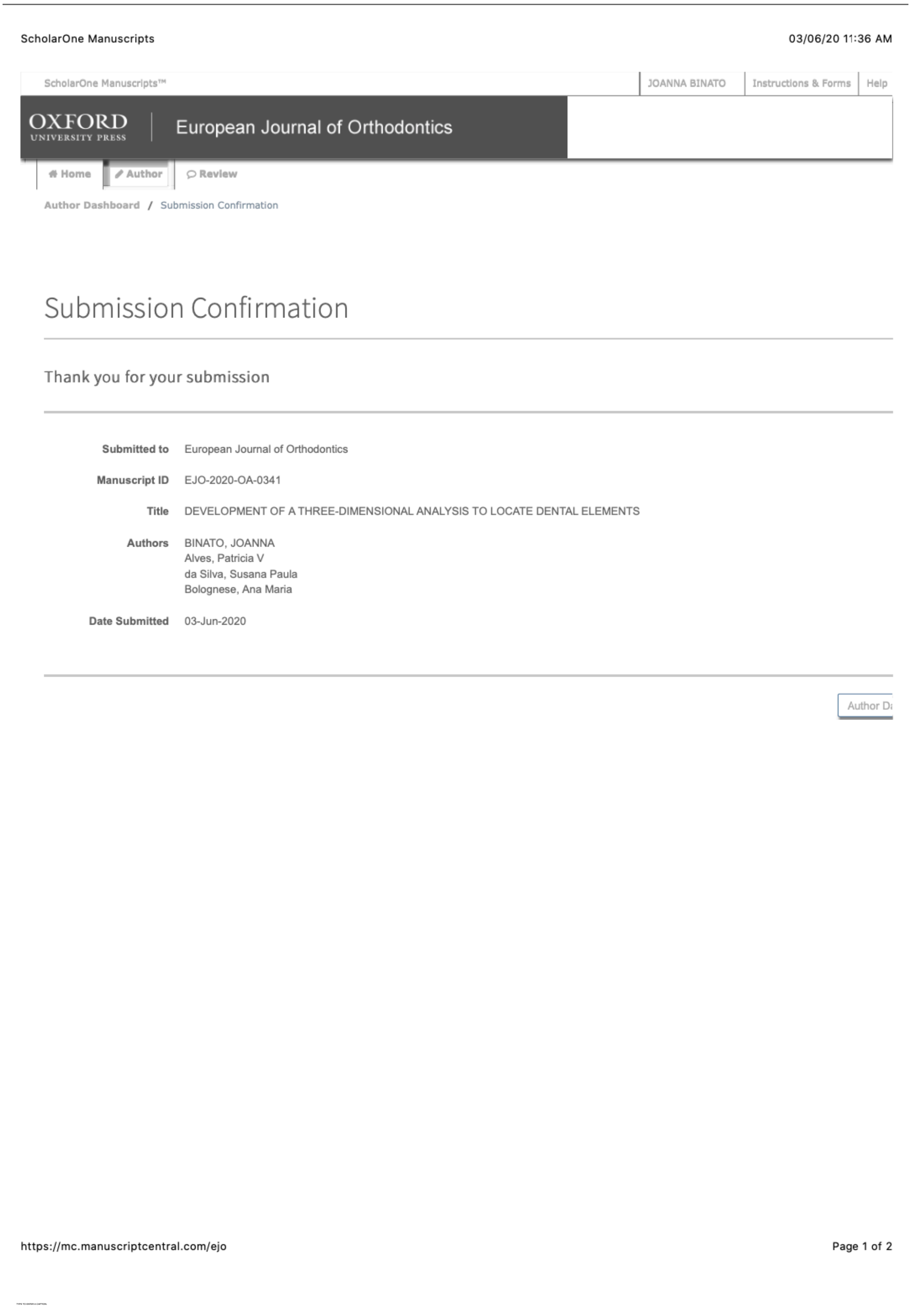


FIGURE 4



ANEXOS

ANEXO 1: SUBMISSÃO DO ARTIGO À REVISTA *EUROPEAN JOURNAL OF ORTHODONTICS*



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ANEXO 2: REGRAS PARA A SUBMISSÃO DE ARTIGOS À REVISTA *EUROPEAN JOURNAL OF ORTHODONTICS*

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Details of all funding sources for the work in question should be given in a separate section entitled 'Funding'. This should appear before the 'References' section.

The following rules should be followed:

- The sentence should begin: ‘This work was supported by …’
- The full official funding agency name should be given, i.e. ‘the National Cancer Institute at the National Institutes of Health’ or simply ‘National Institutes of Health' not ‘NCI’ (one of the 27 subinstitutions) or ‘NCI at NIH’ (full RIN-approved list of UK funding agencies) . Grant numbers should be given in brackets as follows: ‘[grant number xxxx]’
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- Where individuals need to be specified for certain sources of funding the following text should be added after the relevant agency or grant number 'to [author initials]'.

An example is given here: ‘This work was supported by the National Institutes of Health [AA123456 to C.S., BB765432 to M.H.]; and the Alcohol & Education Research Council [hfygr667789].’

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Systematic reviews and meta-analyses

Systematic reviews and meta-analysis submitted to the EJO are screened for compliance of PRISMA (preferred reporting items for systematic reviews and meta-analyses) guidelines. Therefore, systematic reviews and meta-analyses should be prepared according to PRISMA guidelines. Please download the PRISMA checklist and flow diagram and submit with your article. When submitting your manuscript, click the appropriate box ‘systematic review’.

Summaries for systematic reviews and meta-analyses should be in a structured format and should follow the PRISMA guidelines; when applicable the summary should contain the following subtitles: Background, Objectives, Search methods, Selection criteria, Data collection and analysis, Results, Conclusions, Registration and Conflict of interest. Summaries for systematic reviews should not exceed 330 words.

Author names, trial reg numbers and ethics committee details can be included in the main file without blinding it, as SRs are single-blinded.

Randomized controlled trials

Randomized controlled trials should be prepared according to the CONSORT (consolidated standards of reporting trials) guidelines. Download the CONSORT checklist and flow diagram and submit with your article. When submitting your manuscript, click the appropriate box ‘RCT’.

Summaries for RCTs should be in a structured format and should follow CONSORT guidelines. The summary should include information on Background, Objectives, Trial design, Methods (Participants, Interventions, Objective, Outcome, Randomization, Blinding), Results (Numbers randomized, Recruitment, Numbers analysed, Outcome, Harms), Conclusions, Trial registration, Funding.

Examples of summaries for RCTs can be found on the CONSORT website, as well as in Figure 3 of Fleming PS, Buckley N, Seehra J, Polychronopoulou A, Pandis N. 2012 Reporting quality of abstracts of randomized controlled trials published in leading orthodontic journals from 2006 to 2011. American Journal of Orthodontics and Dentofacial Orthopedics 142: 451-458.

Summaries for RCTs should not exceed 330 words.

Author names, trial reg numbers and ethics committee details can be included in the main file without blinding it, as RCTs are single-blinded.

Clinical trials registry

The EJO supports the registration of clinical trials in a clinical trials registry such as ClinicalTrialsRegister or ClinicalTrials. A list of national and international registries can be found on Wikipedia. Clinical trials registries usually provide an official catalogue for registering clinical trials which can be accessed by the public free of charge. Clinical trials registries usually provide information on the design of each trial, the sponsor (company or institution), the therapy investigated and the status of the trial. The registration number should be provided in the manuscript methods section.

Commentaries

Commentaries are short review reports about original articles published in the EJO. Leading experts are asked to write commentaries after the reviewers of the manuscript have highlighted the high quality of the original article. Commentaries are reserved for articles of particular merit. The original articles are thought to be ground breaking, possibly seminal and are predicted to strongly influence future developments. The commentary will be published together with and will be linked to the original article.

A commentary is a short review of the paper and a short review of the subject. It should state why the subject is important, what are the important recent developments in the field, why the article is noteworthy and give a perspective of where the article fits into the field. Commentaries should have a punchy title and a very short abstract (2-4 sentences). Commentaries should be a maximum 2 printed pages i.e. 500–1200 words and can include one figure (image, schematic diagram or table). References should be kept to a minimum. Commentaries should be submitted with 2–3 months so that they can be published in a timely manner. Commentaries are subject to peer review.

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