Application of Multi-layer Spiral 3D Reconstruction Technique in Orthodontics

Mengyue Cai

Our Lady of Fatima University, Valenzuela City, 1441, Philippines

Abstract: In recent years, with the rapid development of computer technology and the improvement of Computed Tomography (CT) performance, 3D image reconstruction technology and equipment that can directly display the three-dimensional structure of objects have been introduced into the study of orthodontics and become an ideal tool for the study of dental anatomy. This article reviews the application of spiral CT 3D reconstruction in orthodontic treatment. The application of multi-slice spiral CT combined with 3D image reconstruction modeling technology to the process simulation of orthodontic treatment can intuitively diagnose and design correction plans, and allow patients and doctors to intuitively understand the correction results before the treatment starts, which has important practical application value. The application of spiral CT in the diagnosis of orthodontic micro-implant anchorage implantation can accurately observe the relationship between the implant location, micro-implant screws and their adjacent tissues, so as to more accurately judge the effect of micro-implant anchorage implantation, and then effectively point out the existing problems of implantation, so as to provide more reasonable guidance for orthodontic oral treatment.

1. Introduction

With the improvement of national economic level and people's living standards, people's requirements for health are gradually increasing. Oral malformations will not only affect patients' chewing function, but also affect patients' appearance to a certain extent, and then further affect patients' physical and mental health. At present, orthodontics has attracted wide attention. It has gradually become a focus of current stomatology research [1]. Before making the correction plan and treatment plan in orthodontics, ordinary X-ray plain film examination or panoramic film examination is usually taken to determine the patient's jaw position and tooth correction position through examination, and then formulate the corresponding treatment plan [2].

In recent years, with the rapid development of computer technology and the improvement of CT performance, 3D image reconstruction technology and equipment, which can directly display the three-dimensional structure of objects, have been introduced into the study of dental orthodontics and become an ideal tool for the study of dental anatomical morphology [3]. Three-dimensional image reconstruction technology refers to the application of special computer software on a specific computer workstation, the original volume data obtained from spiral CT, electron beam CT, multi-row CT, MRI and other scans are processed by computer programs, and the Z-axis is

projected onto the two-dimensional images of X and Y axes and the negative image is processed. An intuitive three-dimensional image is reconstructed. At present, CT scanner, maximum density projection (MRI) scanner, ultrasound and nuclear medicine imaging equipment are used to collect 3D image information. It is more ideal to use CT scanner to collect data, including spiral CT, electron beam CT, multi-dimensional CT, etc. [4]. Multi-slice spiral CT (MSCT) is currently a mainstream high-end device for obtaining clinical medical image information [5]. It uses multi-channel volume scanning data collection, which not only covers a wide range of scanning, but also reduces the X-ray radiation dose and saves operating costs. The image data acquired by continuous scanning without gap is accurately positioned and has a high resolution of reconstruction. The image will not be distorted due to the relationship between body position and projection Angle, and arbitrary retrospective 3D reconstruction can be performed according to diagnostic needs. With the advent of multi-slice spiral CT and the development of computer software, oral imaging diagnosis has made a leap forward. At present, multi-slice spiral CT has been widely used in the diagnosis of jaw fractures, tumors, malformations, ambushed teeth and implants and other oral and maxillofacial diseases [6]. In recent years, domestic and foreign scholars have successfully applied multi-slice spiral CT 3D reconstruction technology to the diagnosis and treatment of dental pulp diseases, so that difficult teeth that cannot be diagnosed by traditional methods can be treated, reduce tooth extraction, and improve the cure rate and preservation rate of affected teeth.

2. Features of Multi-Slice Spiral CT

Multi-slice spiral CT is a new generation of CT products introduced at the North American Radiology Annual Meeting in 1998. It is an imaging system with a multi-row wide-body detector structure and a single exposure of the bulb tube to obtain multi-layer image data, representing the highest level and development direction of today's clinical CT machines [7]. Compared with traditional CT, multi-slice spiral CT obtains three-dimensional image information and has the following advantages. (1) Rapid scanning imaging can conduct a comprehensive scan of the skull and face in a few seconds, and obtain three-dimensional information from the soft tissue surface to the inside of the hard tissue through non-invasive means. CT scans can not only replace a series of traditional X-ray films necessary for orthodontic patients, such as the lateral head film and oral panoramic film, but also include three-dimensional information of the soft and hard tissues of the craniofacial. (2) Isotropic 3D voxel imaging to obtain volume data means that the same structure has the same image resolution in all directions. It can reconstruct high quality multi-axial plane image and three-dimensional image, avoiding image distortion and amplification. (3) The image post-processing function is powerful, which can meet the different needs of doctors. It can not only form oral curved fragments, lateral and anterior slices of skull positioning, but also form cross-sectional images of teeth and collar bones. Multi-axial plane 3D reconstruction, accurate 3D data measurement. (4) The development of computer hardware and software enables data to be presented interactively on personal computers, which brings great convenience to doctors. The application of multi-slice spiral CT in the three-dimensional reconstruction of teeth can accurately, quickly and simply obtain the tooth fault information with a high resolution, and the model established by the acquisition of image data has high reliability. However, the image quality of multi-slice spiral CT is affected by factors such as layer thickness, pitch and layer thickness overlap [8] : (1) Layer thickness; In order to obtain high-quality images, the layer thickness is more critical than other parameters, and the smaller the layer thickness, the better the image quality. (2) Pitch: A pitch of 1.0 indicates that the X-ray beam in the scan is connected end to end, with neither overlap nor spacing. Less than 1.0, the X-ray overlap, greater than 1.0 indicates that the X-ray spacing, the

image quality will be degraded. (3) Layer thickness overlap: the size of layer thickness overlap during reconstruction has a significant impact on the final reconstructed image, and the reconstructed image without overlap produces obvious stepped artifacts.

3. Reconstruction Methods Commonly Used in Spiral CT

The commonly used reconstruction methods of spiral CT include: surface hiding display (SSD), volume reconstruction (VR), multi-plane reconstruction (MPR), maximum density projection (MIP) and surface reconstruction (CPR). SSD is a surface quantity mode imaging that connects all relevant pixels whose surface of the object to be scanned is greater than a certain threshold through a computer. It sets a certain CT threshold and reopens the window along a certain diameter of pixels within the preset threshold range, which is the most commonly used 3D imaging method [9]. The key to the success of SSD technology is to select a good threshold, which is related to the density of the imaging structure. If the threshold is too high, information will be lost in the thin bone, resulting in "false pore sign", which is easy to cause illusion. If the threshold is too low, the hierarchy of some organizational structures is unclear and interferes with observation. On the premise of clearly displaying the imaging structure, a low threshold should be selected as far as possible, and the structure affecting the observation should be removed by cutting method. The biggest advantage of SSD is that it can accurately and intuitively display the lesion and its spatial relationship with adjacent structures in a stereoscopic manner. SSD of the mandible can not only well display the location of the mental foramen, but also accurately judge the relationship between bone destruction and the mental foramen and the changes of the mental foramen, which is of great help to surgical treatment. However, SSD has a large number of problems, such as loss of reconstructed volume data, lack of detail in image display, inability to observe internal bone morphology and density, inability to display internal tumour details and the extent of surrounding soft tissue invasion, lack of transparency effects, etc. Therefore, MSCT above 16 layers is rarely used and is gradually being replaced by VR. SSD images cannot be used for diagnosis alone and must be combined with 2D images.

VR technology is developed on the basis of surface technology, it is along a beam through the volume data to display all pixels of the total image, that is, the use of all voxel CT value reconstruction, can display overlapping structure, less artifacts, can clearly reproduce the damaged fine structure, image more realistic; Combined with false color coding and varying degrees of transparency, it is easier to distinguish normal bone from lesions [10]. The image resolution of volume reconstruction technology is high, so the accuracy of length measurement is very high. VR can also clearly display blood vessel images, which is suitable for displaying overlapping blood vessels and the three-dimensional relationship between blood vessels and adjacent structures. VR can display real 3D display images. Because its volume data is not lost, the contrast is good, the level is clear, the display detail effect is good, and the spatial structure and density information can be displayed at the same time, VR is the best three-dimensional reconstruction method to replace SSD.

Multi-plane reconstruction (MPR) is one of the most important diagnostic methods for MSCT. It can perform any azimuth-oriented imaging according to the doctor's diagnostic requirements, including surface reconstruction, and can faithfully retain the density value of the original cross-sectional image to the resulting image, so it has the same density resolution and spatial resolution as the two-dimensional cross-sectional image. MPR reconstruction is especially suitable for maxillofacial neoplastic lesions. It can not only show the damage of bone, accurately show the changes of teeth and tooth roots in the lesion area, but also well show the relationship between soft tissue and bone. The scope, density and CT value of lesions in soft tissue can determine whether the

lesions originate from the jaw or from the surrounding soft tissue lesions invading the skull. It is particularly important to judge the nature of jaw lesions. Understanding whether the disease has invaded the cranial or pterygopalatine fossa can also help clinicians plan surgery and decide whether the tooth should be preserved.

Because the maxilla and mandible are irregular curved bones, neither axial nor MPR images can provide a complete panoramic image of the internal structure of the jaw. Surface reconstruction (CPR) is the application of dental software to reassemble the axial image into a curved panoramic image parallel to the jaw arch, which shows the entire internal structure of the jaw, and can truly, comprehensively and accurately show the location, size, shape and degree of infiltration of the lesions in the jaw. In particular, it can well show the relationship between the lesions and the teeth, alveolar bone and maxillary sinus and the degree of invasion. For example, odontogenic cysts near the root are displaced due to pressure, ameloblastoma near the root has irregular absorption, and malignant tumors show destruction, which can only be well displayed on CPR recombination. Therefore, the accurate display of tooth and root changes in the lesion area is conducive to the definitive diagnosis of jaw tumors, and can help clinicians make surgical plans and decide whether to preserve teeth.

4. Application of MSCT technology in oral orthodontics

4.1 Records of orthodontic patients

Instead of plaster memory model. For a long time, plaster memory models have been the main tool for orthodontic diagnosis, treatment planning and treatment evaluation. Their advantages are that they can be handmade, can correctly display the wrong he and some soft tissues, and are inexpensive. However, compared with the digital 3D dentition, the plaster memory model has the following disadvantages: (1) It takes time and energy to make the plaster memory model area through several steps such as mold extraction, mold filling, and model dressing, which takes about one hour. A CT scan and reconstruction takes less than three minutes. (2) Easy to damage: the texture of the gypsum memory model is relatively brittle, and it is easy to damage during use and storage, and the digital model avoids this defect. (3) Take up a lot of storage space: At present, orthodontists basically use digital photos and digital X-ray headshots, which are easy to save and occupy a small space. The use of plaster models requires a separate storage space. If you have a digital model, a computer can solve this problem. (4) Difficulty in remote consultation: Now orthodontic treatment requires more and more urgent multidisciplinary joint treatment. When the research model is digitized, all patient data can be transmitted through the network, so that remote consultation and multidisciplinary joint treatment can be realized.

With the development of technology, we can also improve the measurement analysis previously performed on plaster models on digital models, such as (1) line distance measurement: tooth size can be measured directly on the computer and Bolton analysis, arch width and length analysis. The analysis results can be attached to the notes next to the model. (2) Median line analysis. The virtual model can be "split" from the bone midline for comparative study. (3) Covering and overbite analysis: accurately measure covering and overbite to reduce the influence of ruler thickness.(4) Occlusion relationship record: Occlusion record is the analysis that determines the contact of the collar, and the occlusion record can be represented by color so that the orthodontist can visually evaluate the occlusion and determine the effectiveness of treatment.

Instead of a linear shadow measuring piece. Since Broadbent invented cephalometry, orthodontists have used cephalometry to help diagnose the relationship between teeth, jaw and skull. Although technological developments have improved the resolution of radiographs and produced digital radiographs, radiographs themselves have the following disadvantages: (1) Overlap and

magnification: The use of two-dimensional radiographs to represent three-dimensional bone structures creates overlapping problems, which are unavoidable in both lateral and forward radiographs. Overlap will reduce the clarity of the X-ray film and make it difficult to determine the location of the landmarks. Especially when photographing the lateral film, the X-ray light source is on the side of the patient, so that the distance between the anatomical structure that exists symmetrically on both sides of the photographic film will be different, and the magnification will be different, resulting in fixed point and measurement errors. (2) X-ray film cannot show the three-dimensional anatomical structure: two-dimensional X-ray film cannot show the three-dimensional anatomical structure completely, many orthodontists have realized this point, so they combine the skull positioning side film and the forward film to obtain the three-dimensional information of the patient. However, because the two projection methods are different, the magnification is different, so it needs correction to be reasonable use. This method is cumbersome and prone to errors. It is MSCT volumetric imaging, which does not have the problem of distortion and amplification, but the true and complete presentation of craniofacial and dental collar shapes. In addition, MSCT three-dimensional imaging has the advantage that X-ray film cannot have - observation, evaluation and analysis from any direction.

4.2 Location of impacted teeth

It is concluded that full-mouth surface tomography is not an effective method to diagnose the location of impacted fangs [11]. The significance of CT in the location diagnosis of embedded teeth and redundant teeth lies in: (1) it can accurately show the number, size and shape of embedded redundant teeth. (2) It can be determined that the location of the ambushed multiple teeth is soft tissue obstruction or internal jaw obstruction. (3) The spatial position (elevation and tilt of the cheek and tongue sides) can be determined. (4) It can accurately show the distance or embedding relationship between the ambushed multiple teeth and the adjacent tooth embryo and tooth root. (5) It can show whether the adjacent tooth roots are absorbed and the degree of absorption. Therefore, MSCT is not only conducive to the treatment of orthodontics and retract-guided cutting, but also convenient for the surgical exposure of surgeons, which is of great help to shorten the treatment time and reduce the pain of patients.

4.3 Auxiliary diagnosis of implant anchorage

Implant anchorage has been introduced into orthodontic treatment as an important form of anchorage, but the implant is often limited by the implant site, which leads to the failure of implant surgery. By using the MSCT reconstruction and measurement function, detailed information about the implant site and surrounding structure can be obtained to determine the appropriate size and placement of the implant [12]. There are many types of implants. Currently, there are two types that are commonly used, namely intraosseous implants and microscrew implants. Here we will discuss them in two categories.
(1) Intraosseous implants
The implant location of the bone implant is mainly selected in the upper collar hard alligator area, which can be located in the congeal suture area or on both sides of the congeal suture behind the incisor foramen. However, in some patients, there are bony prominences or the bone cortex is not smooth, or the bone at the implant site is thin, which can cause the surgery to fail. Studies have shown that using traditional imaging methods, the vertical bone height in the central region varies greatly, making it difficult to determine the usable bone thickness. The actual bone thickness in the central region of the sternum is at least 2mm more than that indicated by the skull localization film. Andre used CT scan to prepare the upper collar bone of the patient for implant. After reconstruction,

he measured the height of the distal congeal bone of the incisor canal, and the bone height of the medial suture and the areas along the medial suture. It was concluded that the bone thickness should be at least 4mm in order to implant the implant in the palate, because the effective length of the implant was 3-6mm. In the distal incisive canal, the height of the palatine bone at 6mm was the largest, which was 6.17 and 2.81mm.

(2) Microscrew implants

Microscrew implants are generally implanted on the crest of the buccal alveolar of the posterior tooth, located between the roots of two neighboring teeth, and cannot touch the adjacent root structure. The best way to prevent root injury is accurate interroot localization. In 2004, Marissa A. Schenelle evaluated implant placement with total oral curvature, showing that there were horizontal and vertical magnification problems with total oral curvature, and the image deformation rate increased in some areas. However, MSCT 3D imaging can avoid these problems.

4.4 Clinical application results of three-dimensional reconstruction of multi-slice spiral CT

Multi-slice spiral CT volume scan, only about 9 seconds to obtain the patient's dental dentition image information, the obtained data location is accurate. Combined with the three-dimensional model reconstructed by professional software and the multi-plane reconstructed image, the interference of overlapping of the surrounding bone tissue and the tooth itself in the X-ray film can be removed, and the morphological characteristics of the tooth and the location, degree and scope of the lesion can be observed more carefully from multiple planes and angles such as sagittal, coronal and axial positions. For example, the results of a case showed that the root of the patient's right maxillary cusp had a lesion. In the hidden distal and proximal palatine wall, the root appeared localized external absorption at about 1/3 of the root tip and was communicated with the root canal. There was a large semicircular bone destruction area around the root, but no root line (see Figure 1).
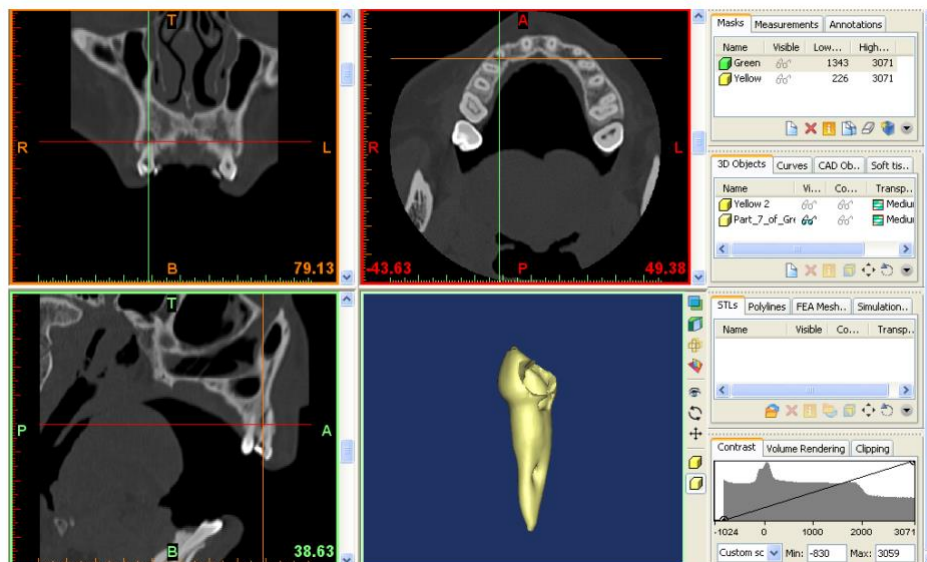

Figure 1: 3D and multi-plane reconstruction images of the tooth in a case

5. Conclusion

Because of the rapid development of information technology, spiral CT 3D reconstruction technology is more and more widely used in stomatology. Spiral technology and multi-functional three-dimensional reconstruction technology change the spatial dimension of imaging observation,

and observe from multiple angles in three-dimensional space, providing three-dimensional multi-directional image information, and making it easier to fully control the patient's collar structure. It can establish the three-dimensional morphological image of teeth, present the three-dimensional relationship of different teeth, accurately present the specific position, morphological structure and number of the ambushed teeth, and carry out comprehensive and effective evaluation and examination for orthodontic patients before orthodontic treatment. Although multi-slice spiral CT has been widely used in clinical practice, it is mainly used in other fields besides orthodontics. With the rapid development of computer technology, multi-slice spiral CT technology will certainly be further improved to help clinicians obtain more diagnostic information in orthodontic treatment and make reasonable treatment plans.

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