ISSN 2618-1584 Vol. 5, Issue 2: 94-99, DOI: 10.25236/FMSR.2023.050216

CBCT evaluation of palatal alveolar protuberance in maxillary molars

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Abstract: *In recent years, the treatment goal of periodontal disease has developed from the single emphasis on the control of inflammation and improvement of function to the further shaping of oral"Whitening aesthetics", soft tissue transplantation is an important part of periodontal plastic and implant surgery. Periodontal ligament and gingival surgery based on autologous tissue transplantation has predictability and long-term stability, it has also been widely used in aesthetic prosthodontics of the oral cavity. However, the site of soft tissue defect and the donor site of the palate are different in clinical practice, which leads to the change of the operative procedure. Some patients have bony protrusions on the palatal alveolar ridge of their maxillary molars, which may affect periodontal surgery in these patients. CBCT has become a commonly used examination method in various oral clinical disciplines. It can be used to observe the skull from all angles and has a high clinical acceptance. In this article, we reviewed the research progress of CBCT in palatal measurement of maxillary molars and the feasibility of CBCT in evaluating palatal alveolar protuberance of maxillary molars.*

Keywords: *Palate mucosa; CBCT; Palate alveolar protuberance; Periodontal surgery*

1. Introduction

Cone Beam Computed Tomography (CBCT) . The basic principle of CBCT is to use a plane array detector and a Cone Beam x-ray source (about 10 ma current in a sphere tube) to perform a circular DR (digital projection) scan around the subject, using cone-beam CT reconstruction algorithm, the 3-d volume data of the object are obtained from the 2-D projection images of various angles obtained from the intersection of multiple (180-360 times, depending on the different products) digital projection[1]. Since 1990s, CBCT scanner has been used in the field of oral cavity, because of its high spatial resolution, short data acquisition time and high ray utilization efficiency, the CBCT technology has been widely used[2]. The preoperative diagnosis and treatment planning of CBCT has become an integral part of modern stomatology, especially in implant and periodontal surgery, jaw surgery, and prosthetics.

When it comes to oral health and gingival esthetics caused by soft tissue defect or absence, it is often recommended to perform periodontal ligament silver surgery, this kind of surgery refers to the periodontal plastic surgery which includes the relationship between the gingival tissue and the ligature attached to the gingiva, the muscles, the vestibular sulcus and the alveolar mucosa. Despite the proliferation of mucosal replacement materials, autologous tissue is still the gold standard for widening keratinized gums, improving gingival recession, and reconstructing the gingival papilla[3]. A key factor for surgical success is the quantity and quality of the graft tissue obtained, in addition to other factors such as blood supply and survival of the flap [4] . Maxillary nodules and the palatal side are the most commonly used donor sites for free gingival and subepithelial connective tissue grafting [5], and the area between the first premolar and the second molar is considered the most suitable donor area [6] ; Because of the high ratio of tissue thickness to keratinized gums, the thickness and histological composition of the gums vary from person to person, even within the same patient [7]. As a result, there is a growing interest in soft tissue assessment and measurement along with hard tissue assessment and measurement. For example, when free palatal flaps are used to repair the defect, the position and thickness of the flaps are not favorable for tissue healing and prognosis The thickness of palatal mucosa should not be neglected in the evaluation of bone mass of hard palate, because microanchorage is often

ISSN 2618-1584 Vol. 5, Issue 2: 94-99, DOI: 10.25236/FMSR.2023.050216

placed in the palatal side in orthodontic treatment In orthognathic surgery, in addition to accurately predicting important factors such as teeth and bones, the number of facial soft tissues must be assessed to achieve optimal aesthetic balance [8] .

2. Selection of donor site of palatal mucosa

The oral palate, the maxillary tubercle and the molar posterior pad are the main donor sites for the gingival flap transplantation[9], the hard palate is the most commonly used soft tissue donor site, and the maxillary hard palate is easy to operate, has a large range and can be taken repeatedly [10], it is the preferred region for the preparation of the graft. The location, size and thickness of the mucosa in the palatal donor site play an important role in the healing of the donor site, the healing of the transplanted flap and the prognosis. In clinic, because of the difference of the soft tissue and donor site of keratinized gingival defect, the operation plan is changed according to the condition of the patients. Long-term clinical practice has proved that free gingival transplantation is effective in increasing the width of attached gingiva and forming new attached gingiva, and it can also improve the abnormal position of strap attachment and shallow vestibular sulcus, the height and width of alveolar ridge were insufficient. The subepithelial connective tissue transplantation can not only cover the root surface, but also increase the tissue thickness and the reconstruction of gingival papilla, when the gingival thickness of the recipient site is less than 1 mm and the width of keratinized gingiva is less than 1mm, subepithelial connective tissue transplantation is the first choice[11]. Longitudinal studies have shown that free gingival grafts often require grafts of 1.5-2 mm thickness, whereas subepithelial connective tissue grafts typically require 0.8-1.5 mm thickness of non-epithelial connective tissue [12] .

2.1 Thickness of palatal mucosa

There are many factors affecting the thickness of palatal mucosa, including race, shape of palatal vault, periodontal biotype, and so on.

The mean thickness of palatal masticatory mucosa was (2.55 ± 0.49) mm, which was the largest in the second premolar region and the smallest in the first molar region [13]. Songl[14]measured the mean mucosal thickness of 100 Korean subjects by spiral CT, which was (3.83 ± 0.58) mm. The mucosa of the first and second molars was thinnest at the distance of 3 mm from the gingival margin, the second molar, especially at the point 12mm from the gingival margin, had the thickest mucosa. Cheng Xiaofan[15] analyzed the maxillary palatal masticatory mucosa of 32 Chinese young people by CBCT, and found that the mean thickness was (3.66 ± 1.15) mm. The thinnest area of palatal mucosa was at the level of 3 mm from the gingival margin of the first molar, and the thickest area of palatal mucosa was at the level of 12 mm from the gingival margin of the second molar. Although the molar region has a slightly smaller mucosal thickness than the premolar region[16] and a slightly increased number of submucosal glands in the second molar region[17] , because the periosteal connective tissue below the palatal side of the molar region is denser and more stable, showing less contraction and absorption during healing is still considered a good donor site for the graft [18] .

There was no significant correlation between the mucosal thickness of each tooth position and the sex of the subjects, but it was positively correlated with the age of the subjects [14,19,20,21]. The increase of mucosal thickness was mainly distributed in canine, first premolar, second premolar and first molar areas. Yilma[22]suggested that the thickening of the palatal mucosa with age in patients may be due to gingival retraction with age, leading to a shift of the reference measurement point on the palatal mucosa towards the palatal suture, thus rendering the measurement biased. In addition, age-related thickening of palatal mucosa may also be caused by the thickening of palatal epithelium or adipose tissue with age.

2.1.1 The effect of palatal fornix shape on palatal mucosa thickness

At present, there is no consistent conclusion about the effect of palatal fornix shape on palatal mucosa thickness. When Japanese scholar Uneo [23] evaluated the relationship between the palatal fornix morphology and the thickness of the hard palate mucosa, it was found that the palatal mucosa in the high fornix group was relatively thicker. Xue[17] measured the palatal fornix shape and found that the palatal fornix shape only had a significant difference in the thickness of the mucosa at the distance of 9 mm from the gingival margin of the second molars, and the mucosa of the high fornix group was thinner than that of the low fornix group. However, Song [14] did not find a correlation between palatal fornix morphology and palatal mucosal thickness. Cheng[15] showed that the shape of palatal fornix had

ISSN 2618-1584 Vol. 5, Issue 2: 94-99, DOI: 10.25236/FMSR.2023.050216

different effects on the mucosal thickness at different levels of different dental positions. At the level of 9 mm and 12 mm from the gingival margin of canine and second premolar, at the level of 12 mm from the gingival margin of first premolar, at the level of 3 mm from the gingival margin of second premolar, first molar and second molar, the mucosa of the high-palatal fornix group was thicker than that of the low-palatal fornix group, but the mucosa of the high-palatal fornix group was thinner than that of the low-palatal fornix group at the level of 9 and 12 mm from the gingival margin of the second molar area. Zhang Jianzhong[20] also found that the mucosal thickness of high palatal vault was greater than that of low palatal vault in maxillary anterior teeth.

2.2 The position of the foramen magnum

The distribution of the great palatal nerve and blood vessel bundles is the main consideration in the gingival surgery with the palate as the donor site, the accurate assessment of palatal vessels and nerves by the location of the greater palatal foramen is key to preoperative planning, postoperative healing, and revascularization of the periodontal ligament and gingiva [24] . Multiple studies have shown that there is some racial specificity in the location of the greater palatal foramen[25,26], and that the greater palatal neurovascular bundles can be distributed in the palatal sulcus of a variety of morphologies in the maxillary molar region [27] .

In a systematic retrospective analysis in 2018, Tavelli[28]clarified the location of the palatal foramen, with 91.87% of the palatal foramen located between the palatal sides of the second and third molars and more distantly, and 6.21% of the palatal foramen located on the palatal side of the second molars, 0.84% of the palatal foramen were located between the palatal sides of the first and second molars. Furthermore, when Tavelli[28]measured the distance from the great palatal artery to the maxillary enamel cementum boundary, they found that its mean distance at the second molar position was (13.9 ± 1.0) mm, with a decrease in the forward walking diameter as it approached the enamel cementum boundary more closely; The mean distance from the canine was only (9.9 ± 2.9) mm. The literature also suggests a safe area for the acquisition of soft tissue, that is, the mean distance from each enamel cementum boundary to the great palatal artery minus the distance obtained by standard deviation and 2 mm thickness of the gingival margin is the safe area. In addition, other literature has shown that the location of the great palatal artery correlates with the height of the palatal vault, with the lower the palatal vault, the greater the proximity of the great palatal artery to the gingival margin [29].

3. Alveolar ridge of palate is bony process

Japanese scholar Ueno [23] found that some patients with maxillary molars have bony protrusions on the palatal alveolar ridge. Xue [29] measured the distribution of alveolar ridge processes in 66(56.89%) of 116 male subjects and 77(59.69%) of 129 female subjects, respectively, and detected at least one palatal alveolar ridge process, of which, the positive rate of palatal process was the highest in maxillary second molars (32.76%) and the lowest in maxillary first molars (29.84%) , the palatal bone processes were found in 23.71% and 18.99% of the maxillary third molars, respectively. In all the subjects with palatal bone processes, at least one tooth and at most five teeth were found to have palatal bone processes, the mean number of teeth was (1.97 ± 1.06) . Periodontal surgery in the maxillary molar region of these patients may be affected by the prominence of the alveolar ridge in the palate. For example, the primary donor site for oral soft tissue transplantation is the maxillary palatal masticatory mucosa, and bony protrusions of the alveolar ridge should be avoided when obtaining connective tissue to ensure graft quality and good healing of the donor site. In flap-based or flap-based periodontal regeneration surgery, gingival clefts due to improper flap manipulation or perforation due to bony protrusions on the palatal side of the tooth should be avoided.

4. Clinical application of CBCT in the measurement of palatal mucosa

4.1 The thickness of palatal mucosa was measured

At present, most researches focus on the measurement of palatal soft tissue thickness and the localization of the greater palatal nerve and vascular bundle, the commonly used method for clinical measurement of mucosal thickness is the invasive measurement by means of periodontal probe or sharp instrument penetrating tissue to bone surface. Although there are many methods to measure the thickness of soft tissue, the common direct puncture measurement under local anesthesia has obvious

ISSN 2618-1584 Vol. 5, Issue 2: 94-99, DOI: 10.25236/FMSR.2023.050216

defects such as trauma, easy to be disturbed by anesthesia, and low patient acceptance. However, various imaging methods also have limitations: for example, the accuracy of ultrasonic instruments depends on the ease of site detection and the technical proficiency of the operator; the slice thickness of spiral CT [30] affects its accuracy, that is, the smaller the slice width, the more accurate the numerical results are, and the higher the radiation dose, MRI has the advantage of no radiation damage and high resolution of soft tissue [21] , however, CBCT is expensive, time-consuming, has many contraindications and complex interpretation of signal changes, and is limited by equipment, it can be used to observe the skull from many angles and has a high clinical acceptance. CBCT can clearly show the soft and hard tissues of the oral cavity, but the low contrast and resolution of CBCT cannot distinguish the soft tissues. Thus, Barriviera[19] proposed that palatal mucosa could be distinguished on CBCT by using an ostium and a tongue depressor to avoid contact of the tongue body with the palatal mucosa. Recently, it has been proposed that the boundary of the palatal mucosal soft tissue surface can be better identified by fusing CBCT and oral digital impression data [31]. The data of palatal mucosa thickness can be obtained by CBCT in a non-invasive way before operation, and the operation plan can be designed in advance to improve the accuracy of operation.

4.2 Measurement of the vascular groove and foramen magnum of the greater palatine nerve

The anatomical location and distribution of the vascular groove and foramen magnum of the greater palatine nerve can not only ensure the effectiveness of anesthesia, but also ensure the safety of the operation, it is also helpful to judge the trend of the vascular bundle of the greater palatine nerve, and to guide the acquisition of the palatal tissue transplantation flap, palatal operation and maxillary implant implantation, to reduce the possibility of bleeding, tissue necrosis or paresthesia caused by the injury of the greater palatine nerve and blood vessel bundle [6] , and to provide reference for the establishment, implementation and accurate evaluation of the prognosis of the operation.

By analyzing the skull specimens of different races or CBCT images, some scholars draw a broad conclusion that when the occlusal reconstruction is completed and the third molar erupts the palatal foramen magnum, it corresponds to the palatal side of the third molar Incomplete reconstruction or congenital absence of the third molar is more common on the palatal side of the last molar [33] , and the location of the palatal foramen magnum is considered to be racially specific. Whereas Yusk [10] and Ling[34]both found polymorphic palatal great palatal neurovascular sulcus structures in cadaveric specimens, Zhang Rui[17]sought to determine the palatal great palatal neurovascular sulcus by photographing imaging data, and were unable to determine the palatal great arteries and branch misalignment by palpation during clinical diagnosis, therefore, by determining the bony reference point of the vascular groove of the greater palatal nerve, the greater palatal artery has a predictable process, and the palatal sides of the second and first molars, bone cristae, concave or tubular structures can be observed in most people.

5. Limitation of palatal mucosa related indexes

At present, the study on the optimal donor area of palatal flap is based on the mucosal thickness and the distribution of the greater palatal nerve and blood vessel bundle. However, clinical practice has demonstrated that successful flap design has a direct impact on tissue healing and revascularization after surgery [35] .

The use of CBCT to assess the presence of palatal alveolar process and the mucosal thickness of the surface of the process before palatal-related surgery involving the maxillary molar region contributes to a more accurate preoperative assessment and more appropriate surgical planning, reduce the occurrence of surgical complications and improve the prognosis. At present, there are few reports about palatal alveolar ridge process of maxillary molars in China, and there may be racial difference in the cases of patients in China. Therefore, more research and discussion on the domestic population are needed.

6. Conclusion

The success and long-term outcome of soft-tissue transplantation can be improved by careful preoperative planning. The location, size and quantity of the transplanted tissue should be determined and the potential surgical risks should be avoided. CBCT can be used to measure the palatal alveolar process of adult maxillary molars with different sex, age and tooth position before operation, in order to promote the establishment of CBCT image database, the thickness of mucosa at the thinnest surface

ISSN 2618-1584 Vol. 5, Issue 2: 94-99, DOI: 10.25236/FMSR.2023.050216

was analyzed, further use of the database to compare palatal alveolar processes and delineate bone levels of maxillary molars between different regions and ethnic groups would allow for advance consideration of anatomical variation and identification of potential preventive measures, in order to ensure that the risk of patients to the minimum, in order to provide a reference for clinical periodontal and implant work.

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