Original Article
Measurement for natural dental neck data of normal adults and its clinical significance on guiding implant restoration

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Abstract: Objective: Provide reference basis for the clinical implant restoration to select implant diameter through measuring each data of 7 teeth in the dental neck of bilateral upper and lower jaws of the young volunteers with normal dentition. Methods: Select 30 healthy young volunteers with complete dentition but no malocclusion, take cone beam CT (CBCT), measure the mesiodistal and buccolingual distance of the tooth root at 1.5 mm from 14 teeth (bilateral upper and lower jaws) to alveolar crest, trace out the outline of each tooth neck in this layer, calculate the cross sectional area and roundness of each tooth neck according to pixel value calibration, and then carry out statistical processing. Results: Complete the data collection and processing of mesiodistal length, buccolingual width, cross sectional area, and cross sectional roundness of the dental neck at 1.5 mm from these seven teeth of the bilateral upper and lower jaws to the alveolar crest of 30 volunteers, and calculate the mean value, variance, and reference value range of medical science of each index. Conclusion: CBCT can effectively obtain the image information of the dental neck. Through mimos 10.0 and Photoshop CS3, it is possible to accurately calculate the dental neck length and width, and cross sectional area of each tooth according to CBCT image information. This result can provide reference basis for the implant restoration of the clinical teeth.

Keywords: Natural tooth, cone beam computed tomography, measurement, dental implant

Introduction

The tooth is an important organ of human body with function of chewing, pronouncing, beauty, etc. After the loss of tooth, how to better select the restoration method to restore its function is the work emphasis and pursuit target of the dentists all along. At present, with the constant deepening of the implant-support false tooth basis and clinical research, its simulation and long-term effect have aroused great concern in this circle. The natural teeth can be divided into incisor, canine, premolar and molar based on the function. Their form and function is uniform. Therefore, with regard to restoring the lost implant-support false teeth, it is necessary to take the crest, neck and root form of the teeth in different parts into full account. With regard to selecting the implant and restoration abutment, it is important to refer to the form and size of the natural dental neck. To discuss the dental neck form of different tooth position and its relation with the tooth aesthetics, the author designs this research subject. It is aimed at guiding the clinic to rationally select implant and restoration base through the data from this research, and realizing the ideal and perfect restoration of the implant-support false tooth.

Material and method

Select healthy young volunteers with complete dentition, no malocclusion, no endodontics, and periodontal disease, at the age from 18 to 25. 15 males and 15 females. When taking CBCT, they adopted erect position and made the Ala-tragus line parallel to the horizon. Besides, the teeth of upper and lower jaws were in intercuspal occlusion. The scanning range is from the Frankfort plane to the superior border.
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of the thyroid cartilage. The thickness of the scanning layer is set into 0.3 mm. Each volunteer gained 255 images, and copied the data into the disc.

Data measurement and processing

Measurement for mesiodistal distance and buccolingual diameter: Through NNT Viewer built in NewTom VGG CBCT, directly transform into DICOM format data of international standard of medical image, export and lead in mimics 10.0, select the image of the horizontal scanning layer in the operation window, magnify and position to the plane as the plane of the alveolar ridge crest that the mesiodistal part of the target dental neck is just surrounded by the alveolar ridge (Figure 1); regard this plane as the standard, and move five planes towards the root, i.e. gain the plane that is 1.5 mm away from the root of the alveolar ridge crest (Figure 2), apply Measure Distance function in Tools menu of mimics, select proper amplification factor in Zoom Factor, and measure the buccolingual distance and mesiodistal distance of each tooth according to the form of the dental arch and tooth.

Measurement for sectional area and roundness: Transform the selected dental neck plane image into JPEG format, lead in Photoshop CS3 and open it, apply the function of setting measurement proportion in the analysis menu, calibrate the pixel value of the corresponding length according to the length data measured by mimics. In this way, it is feasible to get the actual length of the pixel per unit (Figure 3), and then use the polygon lasso tool in the toolbar to trace out point-by-point outline of the dental neck of each tooth according to 15-25 points of the outline tracing, establish selection area, and record the cross section selection data of each tooth through the recording measurement function in the analysis menu. This function is favorable for calculating the area, perimeter and roundness of the corresponding selection area according to the pixel quantity in the area (Figure 4).

Statistical analysis

Depict, measure and calculate CBCT images of 30 volunteers; carry out statistics on the mesiodistal and buccolingual distance, cross sectional area and roundness of 840 teeth in 14 tooth positions (the tooth on the right and left with the same name is regarded as a tooth position) of the upper and lower jaws. The statistical magnitude of each tooth position is 60. Sort out the data, lead in SPSS17.0, describe the statistical magnitude, and get the statistics information of the mesiodistal and buccolingual distance, roundness and cross sectional area where the dental neck of the upper and lower jaws is 1.5 mm away from the alveolar ridge crest root.

Results

Through the statistics, get the mean value and standard deviation of mesiodistal diameter, buccolingual diameter, cross sectional area and roundness where 14 dental neck parts of the upper and lower jaws is 1.5 mm away from the alveolar ridge crest root (Table 1).

Discussion

According to the function, the teeth are divided into incisor, canine, premolar and molar. Their
function differs from the forms. The external form of each tooth is composed of dental crown, dental root, and dental neck. The dental neck is to connect the dental crown and dental root. It can uniformly transmit the occlusal force undertaken by the dental crown to the tooth root and jaw. The normal natural dental neck can support the radian and fullness of the

Figure 3. Calibrate the length of the corresponding pixel in Photoshop through the measured length data.

Figure 4. Depict the outline of the dental neck and calculate the parameters.
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Table 1. Most trails and natural tooth implant diameter recommendations

<table>
<thead>
<tr>
<th>Mesiodistal diameter</th>
<th>Buccolingual diameter</th>
<th>Cross sectional area</th>
<th>Roundness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper 7</td>
<td>7.31±0.57</td>
<td>10.62±0.42</td>
<td>82.11±5.24</td>
</tr>
<tr>
<td>Upper 6</td>
<td>6.96±0.32</td>
<td>10.51±0.59</td>
<td>76.50±4.74</td>
</tr>
<tr>
<td>Upper 5</td>
<td>4.35±0.26</td>
<td>7.95±0.35</td>
<td>35.34±2.53</td>
</tr>
<tr>
<td>Upper 4</td>
<td>4.37±0.25</td>
<td>8.45±0.47</td>
<td>36.15±2.84</td>
</tr>
<tr>
<td>Upper 3</td>
<td>5.36±0.36</td>
<td>7.85±0.39</td>
<td>44.59±4.00</td>
</tr>
<tr>
<td>Upper 2</td>
<td>4.31±0.23</td>
<td>6.10±0.64</td>
<td>28.22±3.06</td>
</tr>
<tr>
<td>Upper 1</td>
<td>5.03±0.34</td>
<td>6.71±0.58</td>
<td>40.75±3.38</td>
</tr>
<tr>
<td>Lower 7</td>
<td>9.09±0.52</td>
<td>7.69±0.50</td>
<td>65.95±12.98</td>
</tr>
<tr>
<td>Lower 6</td>
<td>8.85±0.41</td>
<td>7.64±0.49</td>
<td>72.70±6.98</td>
</tr>
<tr>
<td>Lower 5</td>
<td>4.67±0.27</td>
<td>6.88±0.41</td>
<td>34.68±3.58</td>
</tr>
<tr>
<td>Lower 4</td>
<td>4.58±0.30</td>
<td>6.74±1.15</td>
<td>33.97±3.96</td>
</tr>
<tr>
<td>Lower 3</td>
<td>5.14±0.27</td>
<td>8.04±0.31</td>
<td>38.47±3.32</td>
</tr>
<tr>
<td>Lower 2</td>
<td>3.61±0.24</td>
<td>6.55±0.32</td>
<td>26.19±4.65</td>
</tr>
<tr>
<td>Lower 1</td>
<td>3.28±0.14</td>
<td>6.01±0.57</td>
<td>21.38±3.61</td>
</tr>
</tbody>
</table>

So far, there is no consensus on how to select implant diameter for the tooth implantation and restoration. Clinically, due to the incorrect selection for the implant diameter, it always leads to black triangle from the interproximal clearance after implant restoration, which not only affects the beauty and gives rise to horizontal food impaction [1, 2], but also exerts great influence on the masticatory function, and even speeds up the bone absorption around the implant due to the non-axial force, and reduces the service life of the implant false teeth (Figure 5). In recent years, the experts of the oral implantology and implant manufacturers have already attached great importance to it. Therefore, to select implants with different diameter according to the dental neck of different tooth position presents extremely important clinical significance on the implant restoration. In 1997, in order to select proper implant and basis for realizing good aesthetic restoration effect during the implant restoration, Hebel measured the neck at 2 mm away from the cemento-enamel junction of the extracted tooth [3] and recommended the implant diameter suitable for each tooth position according to the measurement result [4] (Table 1). However, in view of the limitation of insufficient bone mass, the implant diameter recommended is smaller than its measured value. This research result has great reference significance for the clinical doctors to select implants. The clinical research presents that, the defect part of the patients with dentition defect is always accompanied with absorption of alveolar bone, which leads to insufficient bone mass in this part, especially the insufficient thickness of the alveolar process (insufficient cheek and buccolingual bone mass). At that time, the clinical doctor tended to select the implant with small diameter and then implement the implant restoration.

The author holds that, the implant with small diameter has the following disadvantages. ① Low rupture strength. With regard to the implant gingival, and maintain the form of the inter-dental papilla. The implant neck has the same function as the natural dental neck. The ideal implant should be designed into root form, so as to realize the unification of the form and function. However, the current mainstream implant has been designed into conicalness, which greatly differs from the natural tooth root form. To realize the aesthetic restoration of the tooth implantation, it is necessary to make the implant form closer to the natural tooth as possible, and then reach the clinical effect of supporting the radian and fullness of the gingival, and maintaining the form of the inter-dental papilla.
with the same design, the implant with small diameter shows lower rupture strength, and thus it is easy to cause separation of the implant, base rupture, and other complication. ② The crown root diameter ratio between the restoration one and implant is imbalanced. It is easier to cause non-axial torsion when mulling over the food, which will lead to bone absorption [5, 6]. Lvanoff CJ studied the histological characteristics of the implants with different diameter under the effect of yawing force through the animal experiment, and proved that the implants with thick diameter had higher clinical stability [7]. Coelho Goiato M et al studied the stress distribution of the implant under the effect of yawing force through photoelastic experiment, and proved that the stress distribution of the implants with thick diameter is more uniform [8]. ③ The excessive clearance is too large. To adopt the implant with small diameter makes the diastema become larger and makes the gingival papilla unable to fill in the interproximal clearance fully. Especially, as for the patient with thin gingival, it is quite easy to cause black triangle on the dental papilla, which influences the aesthetic restoration effect [9]. The molar teeth easily cause impact of the horizontal food and gathering of dental plaque tartar [2], and induce bone absorption and retrograde peri-implantitis of the implant. Aiming at the above problems, the implant with thick diameter can provide remediation. Meanwhile, with the development of the implant technology, the limitation of the insufficient bone mass on the implantation diameter of the implant becomes smaller: the position conservation technology of the tooth extraction [10] can help to reduce the alveolar absorption, and maintain the bone mass; the application of different bone augmentation [11, 12] (e.g. GBR, bone compressing, bone splitting, bone grafting inlay, onlay bone grafting, distraction osteogenesis) is favorable for implanting the implant with ideal diameter under the condition of different bone augmentation technology. Based on the above factors, using the implant with thick diameter which is closer to that of the natural teeth is recommended.

The vernier caliper is generally adopted for traditional tooth form measurement with manual measurement and X-line image calibration. The manual measurement only can measure the straight line distance, with low accuracy and big error [13]; during x-line image measurement, as the projection plane is different from the dentition curve, the image always causes uncontrollable change, and it is difficult to ensure the measurement accuracy [14]. Besides, the above two methods cannot accurately measure the thickness of the tooth and alveolar bone. In recent years, CBCT and its related software provide scientific and accurate methods for measuring the hard tissue, such as the tooth, which has the incomparable advantage compared with other methods [15, 16]. ① The

![Figure 6. Meticulous implant shape curve.](image-url)
data obtained is integral: CBCT can obtain three-dimensional information of complete dentition and jaw, and compared with relatively scattered extracted tooth measurement, it not only can vertically analyze the information of each tooth position, but also can horizontally analyze the status of dentition and jaw. ② High measurement accuracy: the image can be magnified to 400%, and the measurement accuracy can reach 0.01 mm, which greatly reduces the measurement errors. ③ The measurement content is rich: it can measure different information, such as length, three-dimensional distance, angle, roundness, cross sectional area, superficial area, etc., and it can present the form and feature of the dental neck comprehensively and accurately. ④ The measured object is flexible: measure the image of the dental neck cross section at 1.5 mm away from alveolar ridge crest root. The object measured by Heble is extracted tooth [6]. He could not accurately obtain the position of the alveolar ridge crest, so he selected cemento-enamel junction (CEJ) to balance the position of the alveolar ridge crest. Moreover, in consideration of the factors, e.g. anodontism, age increasing, etc, and atrophy of the alveolar bone in some degree [17], in order to avoid the exposure of the implant and base, he holds that, it is the most suitable to take the dental neck at 2 mm from CEJ as the diameter reference standard of the implant, while actually CEJ is at about 1.07 mm from the alveolar ridge crest root, and the fluctuation range of this distance is relatively great [18], so that it is difficult to accurately assess the bone absorption. Therefore, the author believes, the data of the dental neck at 1.5 mm from the alveolar ridge crest root provide more accurate reference for the selection of the implant diameter.

The horizontal food impaction is the common complication after the implant-supported denture restoration. This problem is usually solved through changing and restoring the neck construction feature clinically. The author believes the horizontal food impaction after the implant-supported denture restoration is generally caused by selecting the relatively thin implant. The natural dental crown is connected with the dental root through the dental neck. The dental crown and the dental root has proper diameter ratio. From the dental crown to the dental root, there is round, slow and smooth external curve (Figure 8A and 8B). On one hand, such curve and the crown-root diameter ratio can transmit the biting force to the dental root evenly, and reduce the non-axial torsion. On the other hand, it is favorable for making interproximal clearance filled with the gingival papilla, which prevents the horizontal food impaction and improves the red aesthetic effect (Figure 6A and 6B). If much thinner implant is selected for the implant surgery (Figure 5), the normal proportional relation between the dental crown and dental root cross section will be damaged. Such abnormal crown-root ratio may give rise to the uneven stress distribution of the implant, generate partial stress concentration (especially the torsion), and lead to partial bone absorp-
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The patient with severe status may suffer some complication, such as the fracture of the central retaining screw, base, and even the implant, which has some impact on the short-term and long-term success rate of the implant-supported denture. Moreover, it more likely leads to the much bigger interproximal clearance between the implant and the adjacent tooth. The normal interdental papilla cannot completely fill the clearance. It can generate black triangle and influence the red aesthetic effect (Figure 5). Besides, it will lead to horizontal food impaction in this area. On the contrary, the above disadvantage can be avoided if selecting relatively thick implant with the similar diameter to the natural tooth (Figure 7). The author suggests that it is necessary to select the implant with the different diameter according to different tooth position, which has great significance on improving the aesthetic restoration effect and the short/long-term success rate of the implant-supported false tooth.

Through the analysis on the section shape and data from the dental neck, it turns out that the cross section of the upper incisor and canine teeth neck is a round triangle; the dentes premolars of the upper jaw is mesio-shrink reniform or oval; the maxillary molar presents the rhombus, the buccolingual diameter is larger than mesiodistal diameter; mandibular anterior tooth is oval; the mandibular canine is round triangle; mandibular premolar is round triangle, close to oval; mandibular molar is square, the mesiodistal diameter is larger than buccolingual diameter. The cross section of the natural dental neck shows different forms, while the cross section of the mainstream implant is round. Such design makes the insufficient bone mass or clearance on any direction of the agomphosis limit the implant diameter. Therefore, with regard to selecting the implant diameter, it is necessary to regard the minimal natural mesiodistal and buccolingual diameter as the reference basis. The data from this research indicates that, the mesiodistal diameter of the first and second molar of the lower jaw is bigger than the buccolingual diameter, so it is necessary to mainly refer to the buccolingual diameter of the dental neck when selecting the diameter of the implant; in addition to this point, the buccolingual diameter of other teeth is larger than the mesiodistal diameter, so it is necessary to mainly refer to the buccolingual diameter of the dental neck when selecting implant diameter (Table 1). To make the implant restoration perform good short and long-term function and aesthetic restoration effect, the author provides the following suggestion according to the measurement on the dental neck and the clinic application: select the implant with the diameter of 4.0-5.0 mm for the maxillary central incisor; select the implant with the diameter of 3.5-4.5 mm for the maxillary lateral incisor; select the implant with the diameter of 3.0-3.5 mm for mandibular incisor; select the implant with the diameter of 4.0-4.5 mm for dentes premolars of the upper and lower jaws; select the implant with the diameter of 6.0-7.0 mm for the molar of the upper and lower jaws (Table 1). It is necessary to note that, to ensure the union of the implant and surrounding sclerotin, the bone thickness surrounding the implant should be ≥ 1.5 mm; Otherwise, the implant with small diameter should be selected. The author suggests that,
the implant with the thick diameter of 6-7 mm should be selected for the molar. However, up to June, 2014, there were only a minority of implantation system produced the implants with the thickness of 6 mm and even thicker diameter, which prompts that each implant manufacturers should produce implants with different types so as to meet the clinical demands.

**Conclusion**

CBCT can effectively collect the information about the tooth and jaw; by virtue of mimics, Photoshop and other software, it is feasible to accurately measure the mesiodistal diameter, buccolingual diameter, roundness, and cross sectional area of the healthy dental neck. According to this data and clinical research, the following suggestion is raised as follows: select the implant with the neck diameter of 4-5 mm for maxillary central incisor; select the implant with the neck diameter of 3.5-4.5 mm for maxillary lateral incisor; select the implant with the neck diameter of 3.0-3.5 mm for the mandibular incisor; select the implant with the neck diameter of 4-4.5 mm for the dentes premolars of the upper and lower jaws; select the plant with the neck diameter of 6-4.5 mm for the molars of the upper and lower jaws (Table 1).

**Disclosure of conflict of interest**

None.

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