Measurement of Mucosal Thickness in Denture-bearing Area of Edentulous Mandible

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Abstract

Background: The thickness of the alveolar mucosa influences the probability of the occurrence of denture-induced irritations. Thick denture-supporting tissues offer relief from mucosal tenderness and ulcers; however, the uniformity of the thickness across the entire mandibular alveolar mucosa cannot be accurately determined in edentulous patients. This study aimed to assess the mucosal thickness of the denture-bearing area in the edentulous mandible.

Methods: Twenty-seven edentulous patients underwent cone-beam computed tomography scanning, wherein the patients wore a record base to retract soft tissues away from the alveolar mucosa. The measured regions were the central incisor (IC), lateral incisor (IL), canine (Ca), first premolar (P1), second premolar (P2), first molar (M1), and second molar (M2) regions. The thickness was measured in the alveolar ridge crest (T), buccal (B1–B4), and lingual (L1–L4) alveolar ridge mucosa. The average thickness of the mucosa at buccal sides (B) and lingual sides (L) were also assessed.

Results: The differences in the mucosal thickness between the left and right sides were not significant. In the Ca–M2 regions, T was the thickest, and L3 was the thinnest of all the measured points in the same regions. L was significantly less than B in posterior regions (P < 0.01). On the other hand, M2 at L4 was thinnest of all the measured regions from Ca to M2 (P < 0.01), and was thicker than IC, IL, P1, and P2 at B2.

Conclusions: Since the mucosal thickness of denture-bearing area in the edentulous mandible is not uniform; the tissue surface of the denture base or custom tray should be selectively relieved, which may reduce the risk of denture-induced irritations.

Key words: Alveolar Mucosa; Edentulous Jaw; Mandible; Thickness Measurement

Introduction

The alveolar ridge mucosa possesses viscoelastic properties and is, therefore, one of the main supporting tissues for complete dentures in edentulous patients. Deformation of the mucosa can be achieved by compression with impression pressure or mastication, and consequently, the displacement of the mucosal tissue increases when either the thickness of space on the custom tray is reduced, or the viscosity of the impression material is increased. Moreover, the deformation can produce compressive strains, which can result in denture-induced irritations in the alveolar mucosa; occasionally it may even cause resorption in the alveolar bone.

Traumatic ulcers are the most common denture-related mucosal lesions in those using complete dentures. The mandible has less load-bearing area than the maxilla; hence, the denture-induced irritations are higher in the mandible. Within the mandible areas, the most frequently injured sites are the retromylohyoid area (17%), lingual sulcus (14%), and vestibular sulcus (13%), which has been reported in a previous study. It is noteworthy that there was no difference in the pressure pain threshold (PPT) between the left and right sides of the alveolar mucosa, and the PPT was significantly higher at the buccal site than at the lingual site. The PPT of the alveolar ridge crest was the highest when compared with the buccal and lingual sites. The difference in PPT may be ascribed to differences in mucosal thickness that enables the thick mucosa to serve a protective function and free the nerve endings. The thickness of denture-supporting tissue can be an index of the extent by which pain will be relieved. Hence, in order to avoid denture-related mucosal lesions, it is important to understand the distribution of mucosal thickness, which will help in relieving the areas of
the custom tray or denture base corresponding to the thin mucosa. Nevertheless, previous studies were mainly limited to localized areas, and there was a paucity of data on the entire mandibular edentulous alveolar mucosal thickness.\[9\]

In the past, masticatory mucosal thickness was measured using several methods. Physical measurement methods were invasive methods that used needles and periodontal probes after local anesthetic administration.\[10,11\] Ultrasonic devices were non-invasive and easy to use;\[12,13\] however, this method lacked consistency.\[14\] In a recent retrospective study, cone-beam computed tomography (CBCT) with low-dose radiation has been explored as a non-invasive technique,\[15\] which provided an accurate assessment of palatal mucosal tissue thickness.\[15\] The results were very similar to previous reports that employed physical measurements.\[11,16\] This led to the hypothesis that CBCT could be applied for visualizing and measuring soft tissues in the dentogingival unit,\[17,18\] Furthermore, the aspect ratio of the images obtained by CBCT was 1:1,\[17\] and these images could be saved so that repeated measurements were possible, which enabled successive section measurement and analysis of alveolar mucosa thickness in edentulous patients.

In this study, CBCT was used to evaluate the edentulous alveolar mucosal thickness in the buccolingual section with varying tooth positions in the mandible for analyzing the mucosal thickness distribution, and to provide an experimental basis for the biomechanical study of complete denture support system.

**Methods**

Retrospective analysis of the CBCT images of 27 edentulous patients (14 men and 13 women) with a mean age of (73.4 ± 9.5) years old (range 56–94 years) was done. The research protocol was approved by the Ethics Committee at Beijing An Zhen Hospital, Capital Medical University, and all patient provided informed consent. CBCT images of the complete denture were taken at Department of Stomatology of Beijing An Zhen Hospital between October 2011 and August 2013. Inclusion criteria were healthy mucosa of the patients, who were not taking any drugs that could influence the volume of mucosa. Exclusion criteria were history or presence of pathology in the mandibular region, bone or mucosa loss seen in the CBCT scans, or having undergone surgery for soft tissue removal in the analyzed area.

**Acquisition of cone-beam computed tomography images**

A mandibular cast was made using pressure-free functional impressions. We adapted the radiopaque visible light-cured (VLC) resin (2 mm thick) over the entire cast to make the record base, cut-off the excess VLC resin sheet, and cured the record base within the cast in the curing unit (light-box) for 15 minutes until the VLC resin was completely cured. We then trimmed the record base and smoothed the base borders. The day prior to CBCT scanning, the patients were instructed to remove dentures overnight and visit the hospital without wearing the dentures. We instructed patients to wear the record base that separated the soft tissue of the lips, cheeks, and tongue away from the surface of alveolar mucosa in the mouth, and ensured that the patients relaxed the facial musculature and tongue while bringing the jaw into a rest position. At the same time, the patients’ mandibular chin was aligned with the middle of the chin care, and ala-tragus line (camper plane) parallel to the horizontal plane, and the facial midline (median sagittal plane) perpendicular to the horizontal plane, before fixing the head with fixtures. CBCT images were obtained using a pulsed short X-ray and a cesium iodide-coated complementary metal oxide semiconductor.

The volumes sizes were Ø140 mm × 90 mm (Planmeca ProMax three-dimensional (3D) CBCT, Planmeca Group, Finland). The total scanning time was about 18 seconds at 90 kV and 10 mA, and the 3D volume consisted of 0.2 mm cubical voxels reconstructed from the bidimensional images by a proprietary 3D algorithm.

**Measurement of the residual ridge mucosa**

The percentage distance between the mesio-distal midpoint of various natural teeth and the mesio-adjacent surface of the central incisor (IC) influences the length of the unilateral dental arch from the IC to the second molar.

The percentage length of the unilateral alveolar ridge crest line from the middle of the alveolar ridge (MA) to the apex of the retromolar pad (ARP) were the mesio-distal midpoint of each tooth position, which could be set in the IC, lateral incisor (IL), canine (Ca), first premolar (P1), second premolar (P2), first molar (M1), and second molar regions (M2) on the alveolar ridge crest. The cross-section CBCT images perpendicular to the alveolar ridge crest lines of the mandible in the buccolingual direction were extracted with the CBCT software (Planmeca Romexis, Planmeca Group, Finland) from 27 adults.

An outline was drawn along the alveolar mucosal surface from the recorded base buccal edge to the lingual edge on a cross-section of the image for each tooth position, and the points were perpendicular to the tangential line at the alveolar ridge crest. Four equal points of the buccal and lingual edges of the outline were drawn to mark measurement sites from the soft tissue surface to the hard tissue. The measuring points at the alveolar ridge crest, buccal, and lingual alveolar ridge surfaces were marked and represented as T, B1–B4, and L1–L4, respectively, to provide a total of nine measurement sites in the cross-section images [Figures 1 and 2]. The mucosal thickness was recorded up to 2 decimal points (0.01 mm) at each site on the images using Image J software (National Institutes of Health, Bethesda, Maryland, USA). These measurements were then repeated 1 week later. Meanwhile, the average thickness of B1–B4 (buccal sides) and L1–L4 (lingual sides) were represented with B and L respectively.

To assess the reliability of measurements, 10 cases were randomly selected, and the measurements were carried out by two dentists who were trained in the use of the Image software. Because the interclass correlation coefficient
showed a high correlation between examiners ($r = 0.966$, $P < 0.0001$), all measurements were carried out by one examiner. An investigator who did not participate in the measurement sessions analyzed the data. The radiographs were reviewed on a personal computer workstation (Thinkpad W530, Lenovo, China). After taking two measurements at each site, average values were calculated.

Statistical analysis
SPSS version 18.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. The paired $t$-test was applied for determining the significance of differences in mucosal thickness between the left and the right side. All numerical data were expressed as mean ± standard deviation (SD), and were analyzed using one-way analysis of variance (ANOVA), followed by the Bonferroni’s test. $P < 0.05$ was considered as statistically significant.

RESULTS
The percentage of the mesio-distal midpoint of each tooth position from the unilateral length of the alveolar ridge crest line was 5% (IC), 15% (IL), 27% (Ca), 39% (P1), 52% (P2), 69% (M1), and 90% (M2). There was no significant difference in the mucosal thickness of the bilateral alveolar ridge at the same measured points from the same measured regions, namely no significant difference was observed between the measurements on the left and right sides ($P > 0.05$). Hence, we merged data of the bilateral measurements at corresponding sites of the same tooth positions in the right and left lower jaw.

Comparison of the mucosal thickness at different measured points in the same measured regions
In the measured regions IC and IL, T did not have a significant difference compared with B4, L1, and L2 ($P > 0.05$), while B2 was thinner than L1 ($P < 0.01$). In the P1–M2 regions, T was the thickest measured point on the buccal sides (B1–B4) and the lingual sides (L1–L4) ($P < 0.01$), and L3 was thinnest among B1–B4 and L1 measurements ($P < 0.01$). In the molar regions (M1 and M2), L2 was thinner compared with B1–B4 ($P < 0.01$) [Table 1].

Comparison of the mucosal thickness among B, L and T in the same measured regions
In all measured regions from IC to M2, T did not have a significant difference compared with B4, L1, and L2 ($P > 0.05$), while B2 was thinner than L1 ($P < 0.01$). In the P1–M2 regions, T was the thickest measured point on the buccal sides (B1–B4) and the lingual sides (L1–L4) ($P < 0.01$), and L3 was thinnest among B1–B4 and L1 measurements ($P < 0.01$). In the molar regions (M1 and M2), L2 was thinner compared with B1–B4 ($P < 0.01$) [Figure 3].

Comparison of the mucosal thickness among the different measured regions at the same measured points
At B4 and B1 points, no significant difference was observed throughout all measured regions ($P > 0.05$). At B3, P2 was thinner than M2 ($P < 0.01$). At B2, M2 was significantly thicker than IC, IL, P1, and P2 ($P < 0.01$). At T, P1 was significantly thinner than M2 ($P < 0.01$). At the L1 and L3 points, P2 and M1 were thinner than IL and IC ($P < 0.01$). At the L2 and L3 points, the posterior regions from P1 to
M2 have thinner mucosa than IC, and were thinner than IL at the L2 point ($P < 0.01$). At L4, P2 was thinner than IC, and M2 was the thinnest among the measured regions from Ca to M1 ($P < 0.01$).

**Comparison of the average mucosal thickness among the different measured regions at B or L**

At B, M2 was significantly thicker than P1 and P2 ($P < 0.05$) [Table 2]. At L, there were no significant differences between IC and IL, and among the different measured regions from Ca to M2 ($P > 0.05$), but IC and IL were thicker than P1, P2 and M1 ($P < 0.01$) [Table 3]. At B and L, P2 was thinner than other measured regions ($P < 0.01$).

**DISCUSSION**

The CBCT technology provides high-quality diagnostic images, and hence, it is an essential tool for getting an overall anatomic overview, and a painless way to obtain images in dentistry.[19] CBCT is considered as an effective method for visualizing and precisely measuring the dimensions of the palatal masticatory mucosa in dental patients.[15,17,18] In the present study, we developed a method to obtain the CBCT images of the buccolingual section of different regions in the mandibular alveolar ridge, performed successive section measurement analyses, and investigated the thickness distribution of alveolar mucosa in edentulous patients, which may help to relieve the areas of the custom tray or denture base corresponding to thinner mucous and reducing the risk of denture-induced irritations.

Since it is difficult to estimate CT values accurately with partial projection data using CBCT, reconstructed images are based on calculations of relative values.[20] Consequently, differentiation of low-density tissues can be challenging with CBCT, especially in soft tissues,[21,22] and depending on the scan-settings soft tissue dimensions can be considerably underestimated.[17,23] The contrast between soft and hard tissues is higher in the mandibular alveolar ridge, increasing the ability of the segment effectively. However, the density of the alveolar mucosa and the soft tissues surrounding it, such as tongue and buccal mucosa, is so similar that the boundaries between them are difficult to distinguish. In other words, it is not possible to distinguish different types of soft tissues.[17] In the present study, the record base was made by using VLC resin which not only had a lower shrinkage distortion than self-cured resin,[24] but also had a similar radiopacity and density to that of the alveolar ridge bone. The record base

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**Table 1: Thickness (mm) of alveolar mucosa in mandibular edentulous patients (mean ± SD)**

| Regions | B4       | B3       | B2       | B1       | T       | L1      | L2      | L3      | L4      |
|---------|----------|----------|----------|----------|---------|---------|---------|---------|---------|
| IC      | 2.17 ± 0.93 | 1.64 ± 0.51 | 1.48 ± 0.55* | 1.69 ± 0.51 | 2.21 ± 0.67 | 2.00 ± 0.65* | 1.95 ± 0.58 | 1.68 ± 0.54 | 1.81 ± 0.55 |
| IL      | 2.14 ± 0.83 | 1.64 ± 0.76 | 1.54 ± 0.76* | 1.80 ± 0.68 | 2.31 ± 0.84 | 1.96 ± 0.68* | 1.69 ± 0.54 | 1.44 ± 0.41 | 1.63 ± 0.47 |
| Ca      | 2.09 ± 0.78 | 1.69 ± 0.65 | 1.62 ± 0.66 | 1.80 ± 0.66 | 2.33 ± 0.82* | 1.77 ± 0.67 | 1.48 ± 0.52 | 1.36 ± 0.49* | 1.52 ± 0.61 |
| P1      | 1.94 ± 0.57 | 1.58 ± 0.39 | 1.58 ± 0.44 | 1.72 ± 0.49 | 2.07 ± 0.57* | 1.62 ± 0.60 | 1.35 ± 0.41 | 1.20 ± 0.39* | 1.36 ± 0.52 |
| P2      | 1.84 ± 0.61 | 1.46 ± 0.52 | 1.57 ± 0.56 | 1.75 ± 0.65 | 2.25 ± 0.69* | 1.51 ± 0.49 | 1.15 ± 0.40 | 1.05 ± 0.38* | 1.32 ± 0.55 |
| M1      | 1.91 ± 0.49 | 1.60 ± 0.42 | 1.72 ± 0.43 | 1.83 ± 0.57 | 2.36 ± 0.68* | 1.51 ± 0.49 | 1.21 ± 0.46* | 1.08 ± 0.36* | 1.52 ± 0.80 |
| M2      | 2.02 ± 0.68 | 1.86 ± 0.53 | 1.99 ± 0.56 | 2.09 ± 0.63 | 2.57 ± 0.72* | 1.73 ± 0.59 | 1.34 ± 0.53* | 1.30 ± 0.55* | 2.05 ± 1.12 |

* $P < 0.01$, B2 versus L1 at IC and IL regions, T versus B1–B4 and L1–L4 at P1–M2 regions, L3 versus B1–B4 and L1–L4 at P1–M2 regions, L2 versus B1–B4 at M1 and M2 regions. IC: Central incisor; IL: Lateral incisor; Ca: Canine; B: Buccal; L: Lingual; P1: First premolar; P2: Second premolar; M1: First molar; M2: Second molar; SD: Standard deviation.

**Table 2: Comparison of the average mucosal thickness among the different measured regions at B side**

| Regions | IC | IL | Ca | P1 | P2 | M1 | M2 |
|---------|----|----|----|----|----|----|----|
| IC      | -  | -  | *  | ↑  | ↑  | ↑  | ↑  |
| IL      | -  | -  | -  | -  | -  | -  | -  |
| Ca      | -  | -  | -  | -  | -  | -  | -  |
| P1      | ↑  | ↑  | -  | -  | -  | -  | -  |
| P2      | -  | -  | -  | -  | -  | -  | -  |
| M1      | ↑  | ↑  | ↑  | ↑  | -  | -  | -  |
| M2      | ↑  | ↑  | ↑  | ↑  | -  | -  | -  |

* $P < 0.05$.

**Table 3: Comparison of the average mucosal thickness among the different measured regions at L side**

| Regions | IC | IL | Ca | P1 | P2 | M1 | M2 |
|---------|----|----|----|----|----|----|----|
| IC      | -  | -  | -  | -  | -  | -  | -  |
| IL      | -  | -  | -  | -  | -  | -  | -  |
| Ca      | -  | -  | -  | -  | -  | -  | -  |
| P1      | ↑  | ↑  | -  | -  | -  | -  | -  |
| P2      | -  | -  | -  | -  | -  | -  | -  |
| M1      | ↑  | ↑  | ↑  | ↑  | -  | -  | -  |
| M2      | ↑  | ↑  | ↑  | ↑  | -  | -  | -  |

* $P < 0.05$, $P < 0.01$. 

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**Figure 3:** Average thickness of alveolar mucosa in different measured regions ($^* P < 0.05$, $^P < 0.01$).
edge is the actual base edge position of the complete denture, which is easy to identify and helps to set measurement points on the alveolar mucosa. Therefore, by separating the soft tissue of the lips, cheeks, and tongue away from the surface of the alveolar mucosa with the record base, the boundaries between the alveolar mucosa and the record base in the CBCT images can be easily identified. This may increase the effective measurement accuracy. Even if a small space exists between the record base and alveolar mucosa, due to which the record base does not completely fit with the mucosal surface at some positions, such as the undercut areas of alveolar ridge, the boundaries of the mucosal surfaces are easy to identify because the density of the mucosal tissues are significantly different from that of the air or/and saliva, which exists in the small and dark spaces.

Previous studies reported that the decrease in the alveolar mucosal thickness with maximum bite force (9.7 ± 5.0 kg) was about 0.3 mm. In this study, the record base-wearing patients were instructed to relax the masticatory muscle and bring the jaw into a resting position and hence that the bite pressure force on the alveolar mucosa was absent during CBCT scan. Hence, the decrease of mucosal thickness because of bite pressure force might be negligible.

The percentage distance between the mesio-distal midpoint of various natural teeth and the mesio-adjacent surface of the IC accounts for the length of the unilateral dental arch from IC to M2. This was computed from the mesio-distal diameter of each natural tooth. In general, the distal surface of the artificial M2 should be positioned at the ARP in a complete denture; hence, in this study, we measured the length of the unilateral T line from the middle of the alveolar ridge to the ARP, and determined the measured regions on the alveolar ridge according to the percentage.

The results of this study demonstrated that the mucosal thickness is not uniform, and the mean mucosal thickness of the denture-bearing area varied at different regions of the mandibular alveolar ridge. Among them, the mean mucosa thickness was 1.77 mm at the B side of the anterior region, 2.21 mm at T, and 1.46 mm at L side of IC, P2, and M1 regions. These measurements were similar to the results from a previous study on the mucosa thickness at the same regions using ultrasonography. The mucosa thickness of T was shown to be significantly greater than that of B and L sides throughout the alveolar ridge, and was significantly thinner in P1 region than in M2 region. This suggested that the custom trays corresponding to P1 region of T should be relieved when the alveolar ridge is well rounded, so that the broad and thick mucosa might disperse and cushion the masticatory pressure on T areas. This may serve as the primary stress-bearing area for complete dentures.

However, when the alveolar ridge is atrophied or flabby, the mucosa of the T is easily amenable to compression deformation. Hence, the areas of the custom tray corresponding to T should be relieved, and opened some escape holes that are parallel to the direction of an impression. This can be done using high fluidity impression materials, which are effective in remarkably decreasing the mucosal pressure and deformation during impression. At the same time, the results indicated that the mucosa was thicker in the M region of B side (buccal shelf area) compared with other alveolar ridge regions of B sides. This suggested that the buccal shelf area should be moderately compressed and may be a primary stress-bearing area, and this was in agreement with earlier reports on the complete denture.

On the other hand, in the posterior region, the mucosa was thinner in the lingual middle of the alveolar ridge and a quarter area near the lingual base edge, which were equivalent to the retromylohyoid area (internal oblique line area). Especially, in the lingual middle of P2 and the area near the lingual base edge of the M2, the mucosal thickness was also significantly thinner than in other areas in the posterior region. These thinner areas of mandibular alveolar mucosa were consistent with the most frequently injured mandible areas following placement of complete dentures, and with the distribution features of alveolar mucosal PPT in the mandible; this has been reported in previous studies. The results suggested that the custom tray and denture base corresponding to thinner mucosa areas should be relieved to prevent denture-induced irritations such as traumatic ulcerations. At the same time, moderate compression and relieving treatment in inner areas of the custom tray that correspond to thicker and thinner areas of the alveolar mucosa, should be performed respectively. This might prevent the thinner mucosal sites from becoming a fulcrum of denture movement, and improve the stability of the denture.

In the production process of the custom tray, the mandibular wax spacer, which is used to create space in selected areas of the tray, should cover the anterior labial areas and posterior lingual areas, when sufficient denture space exists extend buccally and lingually from the ridge crest. With the V-shaped ridge, that ridges may be quite narrow buccolingually, the wax spacer should also cover the ridge crest and make buccal shelf stops that will provide stability to the mandibular tray during the final impression making. With severely resorbed mandibular ridges, no spacer wax is placed. Relief space is created by selective recontouring of the internal surface according to the mucosa thickness after border-molding procedures are completed.

A limitation of this study was that CBCT cannot determine the other physical properties such as the hardness of the alveolar mucosa. The CBCT-assisted diagnosis and anatomical knowledge of the thickness of the alveolar mucosa should reduce denture-induced complications, and improve the rationality of the custom tray and denture design. However, the resultant change in mucosal thickness during the denture installation period was not considered. In addition, the morphological characteristics of the alveolar ridge that originate from different degrees of alveolar bone resorption may influence the alveolar mucosa thickness in edentulous subjects. In the future, it will be necessary to examine these influences and differences.
In conclusion, the results of the present study indicated that the buccolingual and mesio-distal distribution of the mucosa thickness were not uniform in the edentulous mandibular alveolar ridge. The tissue surface of the complete denture base or custom tray should be relieved selectively, based on the characteristics of mucosal thickness distribution, which may reduce the risk of denture-induced complications.

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