Original article

The most distal palatal ruga for placement of orthodontic mini-implants

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Summary

Objective: To evaluate the stability and bone availability of the most distal (third) palatal ruga, as an anatomical region for safe insertion of orthodontic mini-implants (OMIs) in the anterior palate.

Study design: Orthodontic records of 35 patients were analysed. Initial (T1) and final (T2) study models were bisected and the outline of the palatal contour was marked on the surface. Models were scanned and the palatal contours were superimposed on the palatal structures on the respective initial and final cephalometric images. Cephalometric measurements were used to assess vertical (3rdRug-PP, 2ndRug-PP, and 1stRug-PP), and oblique bone levels (3rdRug-U1, 2ndRug-U1, 1stRug-U1, and 3rdRug-U1(o)). Paired Student’s t-test was used to compare measurements between T1 and T2.

Results: The position of the third palatal ruga remained stable during orthodontic treatment (Δ2ndRug-3rdRug P = 0.1 mm; P = 0.61 and Δ1stRug-3rdRug P = 0.2 mm; P = 0.39). Bone availability also remained adequate (3rdRug-U1(o) = 9.9 mm). Conclusion: The third palatal ruga is a reliable clinical landmark to evaluate bone availability for the placement of OMIs in the anterior palate.

Introduction

The use of mini-implants in orthodontics has been popularized, primarily due to the possibilities they provide in decreasing or eliminating anchorage loss during orthodontic tooth movements (1). In addition, their small dimensions, the ease of insertion and removal as well as their relatively small cost in comparison to regular dental implants are further factors making them an effective tool in the orthodontic practice (2).

However, skeletal anchorage needs to be stable during treatment to be clinically useful. The most important factors associated with stability of orthodontic mini-implants (OMIs) that have been described in the literature are cortical bone thickness (3, 4), insertion torque values (3, 5), and root contact (6, 7). Insertion of OMIs through the buccal attached gingiva into the inter-radicular space is associated with more risks and higher failure rates, primarily due to greater likelihood of root injury and because cortical bone thickness is less than ideal in most anatomical areas (8, 9).

In order to avoid potential implant failure, OMIs can alternatively be placed palatally in the paramedian area of the anterior palate (10, 11). This location is useful for both in adults as well as young patients whose palatal suture has yet not ossified (12). Palatal insertion of mini-implants offers several advantages such as relatively good access, minimal risk of injuring important anatomical structures, favourable mucosal tissues as well as sufficient bone (9). However, there is no obvious anatomical landmark that can be used as a reference to guide clinicians when placing OMIs in the palatal tissues of the anterior palate.

Previous studies utilized computed tomography (CT) imaging to assess the quality and quantity of bone in this region; and found that
the incisal foramen was suitable as anatomical landmark (10, 13–22). However, it is not easy to accurately identify the foramen visually and therefore it cannot be used routinely. In a CT-investigation by Baumgaertel, interproximal tooth contacts were used as reference points to explore the bone of the anterior palate (23). Despite the ease of identifying those landmarks, occlusal–gingival contact points between teeth are highly variable and their location is greatly influenced by tooth morphology and tooth movements. Interproximal contacts are therefore not ideal for identifying reference points reliably.

Previous research proposed that the palatal rugae remain stable over time and can therefore be used as reference points during orthodontic treatment (24). Moreover, numerous studies investigating longitudinal changes in tooth positions have used the palatal rugae as a reference to superimpose consecutive study models (25–27). Christou and Kiliaridis superimposed the median palatal contour of dental casts, taken at different time points, on the corresponding cephalometric X-rays and found that the third palatal ruga remains particularly stable over time (28) and it could hence be used as landmark to guide the clinician when placing mini-implants in the anterior palate.

The aim of this single-centre, retrospective investigation was to evaluate the most distal (third) palatal ruga as an anatomical landmark for the insertion of OMIs in the anterior palate. According to the primary hypothesis, this area remains stable during orthodontic treatment and provides good bone thickness and quality to support the placement of OMIs.

Materials and methods

Study population
All patients’ records of a single orthodontic practice in Traben-Trarbach, Germany were reviewed. In order to be included in the study patients had to fulfill the following criteria:

1. Complete initial (T1) and final (T2) orthodontic records including study models and cephalometric X-rays.
2. No previous history of orthodontic treatment.
3. Complete permanent dentition. No tooth agenesis or previous loss of permanent teeth.
4. Moderate (4–8 mm) of maxillary crowding, enough to ‘block out’ at least one of the permanent canines.
5. Less than ‘full cusp’ Class II (Angle) molar relationship.
6. Mandibular crowding which could be resolved with interproximal enamel size reduction and or non-extraction treatment.
7. Treatment was on a non-extraction basis, using a skeletally anchored K-Pendulum (‘Frog’ appliance) (29) to distalize maxillary teeth for space creation.

The search generated a total of 90 patients who had molar distalization. The Frog appliance was used in 53 of those cases. In order to standardize treatment outcomes, only patients treated with this appliance were included in the study. Out of 53 patients, 35 patients (13 males and 22 females) fulfilled all the remaining required criteria and were included in the study (Figure 1).

Figure 1. Sample definition.

Average age at T1 was 11.5 ± 1.6 years for males and 10.9 ± 1.6 years for females. At T2, the respective values were 13.7 ± 1.5 and 13.0 ± 1.5 years. The duration of active treatment was 2.2 ± 1 years in males and 2.1 ± 1 years in females.

Clinical procedures
All patients underwent comprehensive orthodontic treatment with pre torqued and pre angulated fixed appliances (slot dimensions: 0.022” × 0.028”).

For the insertion of the skeletally anchored ‘Frog’ distalizer, two 8 mm long and 1.6 mm in diameter mini-implants (OrthoEasy by Forestadent, Pforzheim, Germany) were placed in the paramedian area (1–2 mm laterally to the suture) of the anterior palate, at the level of the third ruga (9). No implant failures during treatment were observed in subjects included in the study. All clinical procedures were performed by the same orthodontist (B.L.).

Preparation of dental casts and superimposition on cephalometric X-rays
Initial (T1) and final (T2) plaster models of the maxilla were bisected along the maxillary midline, using the midline suture as reference line. The bisection was performed perpendicular to the occlusal plane. In order to obtain a sharp, well-defined edges as well as a flat cut surface, a commercially available plaster trimmer was used. For consistency, the right half of the plaster model was always trimmed off. The cut edge of the plaster models was then outlined in colour with a fine lead pencil. The location of the first, second, and third palatal rugae were marked on the coloured outline, according to the methodology described by Christou and Kiliaridis (28). In addition, a 10 mm long reference mark was also transferred on the model with a caliper.

After models were bisected and marked, they were placed with the flat cut surface on a flatbed scanner (CanoScan 5600F, Canon Inc., Tokyo, Japan) and scanned with an accuracy of 600 dots per inch (dpi). All scans were then imported as images in MS-Powerpoint (Microsoft Corp., Redmond, Washington, USA). The contour of the palate and the three rugae were then traced again in MS-Powerpoint using a 0.5 mm thick tracing tool.
Similarly, all cephalometric X-rays were also imported into MS-Powerpoint. The 10mm reference lines on the models and the ruler on the radiographs were used to scale the model tracings to the cephalometric images. The model tracings were subsequently superimposed on the palatal contour of the corresponding X-rays. In addition, Sella–Nasion (S–N), the long axis and the outline of the maxillary central incisor, as well as the palatal plane—nasal line (NL: ANS-PNS) were also traced on the cephalometric images.

Cephalometric analysis
Tracings were printed in colour (HP Color Laser Jet CP1215, Hewlett Packard, Palo Alto, California, USA), and all cephalometric measurements were performed manually, to a half millimeter. Initial (T1) and final (T2) radiographic images were traced and analysed in one sitting, by a single operator.

Cephalometric measurements were used to quantify
1. The amount of bone in the vertical dimension (bone depth) (Table 1; Figure 2),
2. The anatomical relationship between the three palatal rugae (Table 2; Figure 3),
3. The anatomical relationship of the three rugae to the long axis of the central incisor (Table 3; Figure 4) and
4. The anatomical relationship between the third palatal ruga, the maxillary central incisor and the palatal plane. In addition, the inclination of the maxillary central incisor was also measured, as was the angle between its long axis and the line from Sella to Nasion (SN). According to Jarabak (30), the normative value for this measurement is 102 degrees (±2 degrees).

Statistical analysis
In order to test intra-examiner reliability, the same operator repeated all measurements on 20 randomly selected cases; 3 months after initial measurements had been performed. Intra-examiner reliability was calculated by the coefficient of variation (COV) ($m = 0.04$, range: 0.01–0.08). No statistical significance ($P = 0.979$) was found between

<table>
<thead>
<tr>
<th>Table 1. Bone depth.</th>
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<tbody>
<tr>
<td>Measurement (mm)</td>
</tr>
<tr>
<td>3rdRug-NL</td>
</tr>
<tr>
<td>2ndRug-NL</td>
</tr>
<tr>
<td>1stRug-NL</td>
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</tbody>
</table>

*Parallel to 3rdRugP, perpendicular to NL.

<table>
<thead>
<tr>
<th>Table 2. Anatomical relationship between the rugae.</th>
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<tbody>
<tr>
<td>Measurement (mm)</td>
</tr>
<tr>
<td>2ndRug-3rdRugP</td>
</tr>
<tr>
<td>1stRug-3rdRugP</td>
</tr>
</tbody>
</table>

*Parallel to NL, perpendicular to 3rdRugP.

<table>
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<tr>
<th>Figure 2. Bone depth.</th>
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<tr>
<th>Figure 3. Anatomical relationship between the rugae.</th>
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<tr>
<th>Table 3. Anatomical relationship of the palatal rugae to the long axis of the central incisor.</th>
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<tr>
<td>Measurement (mm)</td>
</tr>
<tr>
<td>1stRug-U1</td>
</tr>
<tr>
<td>2ndRug-U1</td>
</tr>
<tr>
<td>3rdRug-U1</td>
</tr>
</tbody>
</table>

*Measured on a line perpendicular to the long axis of the central incisor.

| Figure 4. Anatomical relationship of the palatal rugae to the long axis of the central incisor. |
COVs. The Kolmogorov–Smirnov test revealed a normal distribution of the data, therefore the comparison between measurements at T1 and T2 was performed by means of a paired Student t-test. All statistical analyses were conducted at the $P \leq 0.05$ level of statistical significance.

## Results

Descriptive values from cephalometric measurements and results of the statistical analysis are presented in Table 5.

Average bone depth at the level of the third ruga (3rdRug-NL) was 7.6 mm at T1 and 8.1 mm at T2. According to the results, there was approximately 3.5 mm more vertical bone at the level of the second ruga (2ndRug-NL) and 8.5 mm more vertical bone at the level of the first ruga (1stRug-NL).

When measured in an oblique direction, the bone at the level of the third ruga (3rdRug-U1(o)) was significantly less at T2 compared to T1 ($P < 0.01$) (Table 5). And equally when the amount of bone was measured on a line perpendicular to the long axis of the central incisor (3rdRug-U1) ($P < 0.01$).

The distance between the apex of the central incisor and the palatal plane (NL) increased from an average of 5.4 mm before treatment to 6.6 mm post-treatment. This change was statistically significant ($P < 0.01$) and can be attributed to tooth movement during orthodontic treatment.

On the other hand, neither orthodontic treatment nor possible growth between T1 and T2 appeared to affect the anatomic relationship between the three palatal rugae, which remained stable between the time points T1 and T2 (Table 5).

## Discussion

Safe placement of OMIs, without jeopardizing the integrity of adjacent anatomical structures, is strongly dependent on bone availability at the insertion site (18). The purpose of this investigation was to quantitatively evaluate bone availability in the area of the palatal rugae.

Previous studies have used three-dimensional computed tomography to assess bone depth in the anterior palate (10, 13–22). Unfortunately, no direct comparisons are possible between results from these studies and our results, because the above investigations did not use the palatal rugae as anatomical landmarks for bone measurements. However, the values of bone depth at the third ruga (3rdRug-NL) found in this study (7.6 mm at T1 and 8.1 mm at T2), were very similar to previously reported values of 8.7 mm (19, 23).

In order to determine the optimal path of insertion for OMIs in the anterior palate, bone availability in this investigation was not only measured in a vertical (3rdRug-NL), but also in two different oblique directions (3rdRug-U1 and 3rdRug-U1(o)).

Although the most amount of bone was found in the vertical dimension at the first and second rugae (1stRug-NL and 2ndRug-NL), it can be challenging to access this area clinically and achieve a strictly vertical path of insertion for the OMIs. The distance between the first palatal ruga and the long axis of the central incisor ranged between 6.1 and 6.4 mm. The values at the second ruga were 6.5 and 7.3 mm (Table 5). This means that even if a 6 mm OMI were selected, there would be limited clearance between the implant and the root surface.

In order to ensure stability of the implant, Maino et al. (31) have suggested a minimal ‘safety distance’ of 0.5 mm, while others have proposed even larger values of 1 mm (32) or 2 mm (33).

Our findings reveal that the insertion of OMIs at the level of the first and second rugae can be challenging and cannot guarantee safe placement. The findings of our investigation suggest that the third palatal ruga should be used as a landmark for placement of OMIs; the position of this landmark (2ndRug-3rdRugP and 1stRug-3rdRugP) remains stable and is not influenced by tooth movements or growth (Table 5). This finding is in agreement with a previous study by Christou and Kiliaridis (28), who used the same methodology and also revealed that the third palatal ruga remains anatomically stable over time.

In order to determine the appropriate path of insertion for OMIs, the amount of bone in various directions needs to be taken into consideration. The average distance between the third ruga and the central incisor root in this study was 8.9 mm at T1 and 7.6 mm at T2 (Table 5) when measured on a line perpendicular to the long axis of the tooth. This means that in most cases, a 6 mm long OMI could be placed with safety. If however the standard deviation of our measurements is taken into account it becomes apparent that in some patients as little as 5.6 mm of bone was available and this is not enough to guarantee root integrity when using a 6 mm long implant. Therefore a different path of insertion should be considered.

When measured in an oblique direction, along a line crossing the long axis of the central incisor at the level of the palatal plane

<table>
<thead>
<tr>
<th>Measurement</th>
<th>T1</th>
<th>T2</th>
<th>ΔT1–T2</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rdRug-NL (mm)</td>
<td>7.6</td>
<td>8.1</td>
<td>-0.5</td>
<td>0.12**</td>
</tr>
<tr>
<td>2ndRug-NL (mm)</td>
<td>11.1</td>
<td>11.7</td>
<td>-0.7</td>
<td>0.045*</td>
</tr>
<tr>
<td>1stRug-NL (mm)</td>
<td>16.0</td>
<td>16.5</td>
<td>-0.6</td>
<td>0.19**</td>
</tr>
<tr>
<td>2ndRug-3rdRugP (mm)</td>
<td>3.0</td>
<td>2.9</td>
<td>0.1</td>
<td>0.61NS</td>
</tr>
<tr>
<td>1stRug-3rdRugP (mm)</td>
<td>5.6</td>
<td>5.4</td>
<td>0.2</td>
<td>0.39**</td>
</tr>
<tr>
<td>3rdRug-U1 (mm)</td>
<td>8.9</td>
<td>7.6</td>
<td>1.3</td>
<td>0.01**</td>
</tr>
<tr>
<td>2ndRug-U1 (mm)</td>
<td>7.3</td>
<td>6.5</td>
<td>0.7</td>
<td>0.01**</td>
</tr>
<tr>
<td>1stRug-U1 (mm)</td>
<td>6.4</td>
<td>6.1</td>
<td>0.3</td>
<td>0.23**</td>
</tr>
<tr>
<td>3rdRug-U1(o) (mm)</td>
<td>10.8</td>
<td>9.9</td>
<td>0.9</td>
<td>&lt;0.01**</td>
</tr>
<tr>
<td>Isa-NL (o) (mm)</td>
<td>5.4</td>
<td>6.6</td>
<td>-1.3</td>
<td>&lt;0.01**</td>
</tr>
<tr>
<td>U1-SN (degrees)</td>
<td>102.1</td>
<td>106.1</td>
<td>-4.0</td>
<td>0.01*</td>
</tr>
</tbody>
</table>

NS, not significant.

* $P \leq 0.05$, ** $P \leq 0.01$. 

Table 5. Results from cephalometric measurements.
The distance between the third ruga and the apex of the central incisor. The mean distance between the root apex of the central incisor and the palatal plane was 5.4 mm at T1 and 6.6 mm at T2. The lowest recorded value for this measurement was 3.9 mm. The bone depth at the third ruga was 7.6 mm at T1 and 8.1 mm at T2. Hence, the third ruga is anatomically positioned approximately 2 mm dorsally compared to the root apex of the central incisors. Therefore, an oblique path of insertion, pointing towards the palatal plane, should provide adequate clearance from the root apex (Figure 5; Table 4).

The accuracy of the above-mentioned measurements could be compromised due to the difficulty of identifying the exact location of the tooth apex on a cephalometric image. In addition, landmark identification on cephalometric X-rays can be affected by examiner bias (35). The root apex of the central incisor can be a challenging landmark to locate. Various studies have assessed the tracing accuracy of cephalometric images and the range of error in identifying the apex of the maxillary central incisor was between 1 and 1.5 mm (36–38). Even if this tracing error is taken into consideration, there is still a minimum of 2.4 mm of bone between the mini-implant and the root apex. These findings are in agreement with Liu et al. (33) who proposed a minimum of 2 mm of bone between OMs and adjacent anatomic structures for safety reasons.

Figure 5. Anatomical relationship between the third palatal ruga, the maxillary central incisor and the palatal plane.

Table 4. Anatomical relationship between the third palatal ruga, the maxillary central incisor and the palatal plane.

<table>
<thead>
<tr>
<th>Measurement (mm)</th>
<th>Orientation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isa-NL(o)</td>
<td>Oblique</td>
<td>Distance between apex and the palatal plane, measured on the long axis of the central incisor</td>
</tr>
<tr>
<td>3rdRug(o)-U1</td>
<td>Oblique</td>
<td>Distance between the third ruga and the point where the long axis of the central incisor meets the palatal plane</td>
</tr>
</tbody>
</table>

Based on the above-mentioned limitations, future studies utilizing three-dimensional images of the palatal bone could provide more accurate information on the anatomical morphology and bone availability at the level of the third palatal ruga.

Conclusions

The most distal (third) palatal ruga is a stable and easily identifiable anatomical landmark for the insertion of OMs in the anterior palate.

References


