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Anatomical and radiological approach to pterygoid implants: a cross-sectional study of 202 cone beam computed tomography examinations

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Abstract. The aim of this study was to define the three-dimensional angulation of the pterygomaxillary corridor in which pterygoid implants should ideally be placed. A secondary objective was to study the bone density in the tuberosity area and pterygoid plate. Two hundred and two cone beam computed tomography files of atrophic posterior maxillae were evaluated. Implant placement was guided by the individual anatomy of each patient. The mean implant angulation was $74.19 \pm 3.13^\circ$ in the anteroposterior axis and $81.09 \pm 2.65^\circ$ in the buccopalatal axis, relative to the Frankfort plane. Density in the tuberosity area ranged from 285.8 to 329.1 DV units and density in the pterygoid plate area from 602.9 to 661.2 DV units, with a 95% confidence interval. The density in the pterygoid area was 139.2% greater than in the tuberosity zone. Implant placement should be guided by the individual anatomy of each patient. Statistically significant differences were found between the tuberosity and pterygoid plate in terms of bone density. Based on the results of this study, an implant of at least 15 mm long should be used in order to take advantage of the quantity and quality of the bone in this region.

Key words: atrophic maxilla; CBCT; density; pterygoid implant; tilted implant; tuberosity.

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The posterior atrophic maxilla is one the most common clinical scenarios where implant placement can be challenging.[1] The joint action of pneumatization of the maxillary sinus, resorption of the alveolar bone crest, and the low density of the posterior maxilla can worsen this atrophy.[2–4]

Several techniques have been described for the placement of implants in the posterior atrophic maxilla. Short implants and sinus lift procedures are most commonly used.[5,6] An alternative procedure is to place an implant in the pterygoid area; however the recognition of anatomical and radiological landmarks and safety limits is essential with this procedure.

Tulasne and Tessier were the first to describe the technique for implant placement in the pterygoid plate avoiding grafting procedures.[7] The healing period was shortened and no biomaterials were used. The pterygoid implant goes through the maxillary tuberosity and pyramidal process of the palatine bone, and then engages the pterygoid process of the sphenoid bone.[8] Thus, three bones are involved in this technique, but only one anatomical area. Damage to the palatine artery due to malpositioning of the pterygoid implant represents a major danger.[7] For this reason, this implant technique is not a routine procedure for every dentist.

The placement of pterygoid implants allows improved tissue management, using the remaining pristine bone. Placing the implants in high density bone (type I/II) rather than the low density bone in the posterior maxilla (types III/IV), increases the chance of success.[9]

Each surgeon has to decide where to place the implant and how to place it safely. However, there are some suggested guidelines to help the clinician with the placement of this type of implant in the correct three-dimensional position. Several authors have proposed the insertion of the implant at an inclination of 45° relative to the Frankfort plane,[10–12] however others suggest a 70° angulation.[13,14] In light of such discrepancies it was thought useful to define the ideal corridor that these implants should follow in order to maximize anchorage and achieve an optimal emergence profile. Furthermore, the difference in density between the tuberosity and pterygoid area requires analysis, as this may have an impact on biomechanical stability.

The objectives of this study were to determine the ideal position of the pterygoid implant and dimensions of the pterygomaxillary area, and also to define bone density in the pterygomaxillary region and compare it to the density in the tuberosity area.

Materials and methods

Study protocol

The cone beam computed tomography (CBCT) examinations of 202 consecutive patients in need of rehabilitation of a posterior atrophic maxilla were obtained from the dental school of the study university. These examinations had been performed between January 2008 and February 2014. The local ethics committee approved access to the files; each file retrieved was assigned a number in order to maintain patient confidentiality.

Sample selection

In terms of ethnicity, all of the CBCT scans were from Caucasian patients. Only the cases of adult patients with an atrophic posterior maxillary area were considered. The inclusion criteria were upper molar edentulism and a residual bony ridge of less than 8 mm between the alveolar crest and the sinus floor. The following were exclusion criteria: images that were unclear or incomplete, the presence of a maxillary molar, and more than 8 mm of distance between the alveolar crest and the sinus floor. It was required that all of the implants were 100% covered by bone, as seen three-dimensionally. In the case of bimaxillary atrophy, only one side of the maxilla was measured; the side was selected randomly.

Study design

CBCT standardization

A CBCT scanner with a flat panel detector was used in all cases (i-Cat; Imaging Sciences International, LLC, Hatfield, PA, USA). The exposure volume was set at 102 mm diameter and 102 mm height. The voxel size was 0.2 mm × 0.2 mm × 0.2 mm. The exposure volume was set at 0.4 mm. Manufacturer recommended settings of 80 kV and 5 mA were employed. The Frankfort plane was used rather than the occlusal plane, because an edentulous molar area becomes irregular or inclined to the posterior area of the maxilla, whereas the Frankfort plane remains stable for each patient.

DICOM files of the axial images were imported and analyzed using the planning software Nemo Studio 11.3.0 (Nemotec S.L., Madrid, Spain).

Anatomical and radiological measurements

Two independent investigators (E.L.T. and B.E.) performed the radiological measurements under the supervision of an expert oral and maxillofacial surgeon and researcher (X.R.). Virtual pterygoid implants of 13, 15, or 18 mm in length and 4 mm in diameter were placed in the pterygomaxillary area through the bony corridor, maintaining a safety distance of at least 2 mm between the artery and palatine nerve and the implant (4/3 Certain Prevail implant; Biomet 3i, Palm Beach, FL, USA), (Fig. 1).

All implants were three-dimensionally covered by bone. If an implant thread was exposed, the implant was repositioned or a shorter implant placed. The implant platform was placed at a crestal level on the mesial side and the implant apex was inserted between the pterygoid apophysis and the posterior sinus wall. The inclination of the long axis of the implant was slightly towards the palatine bone in order to follow the cortical area of the palatine bone. The posterior sinus wall, the pterygoid apophysis, and the palatine bone guided the position of the implant. This

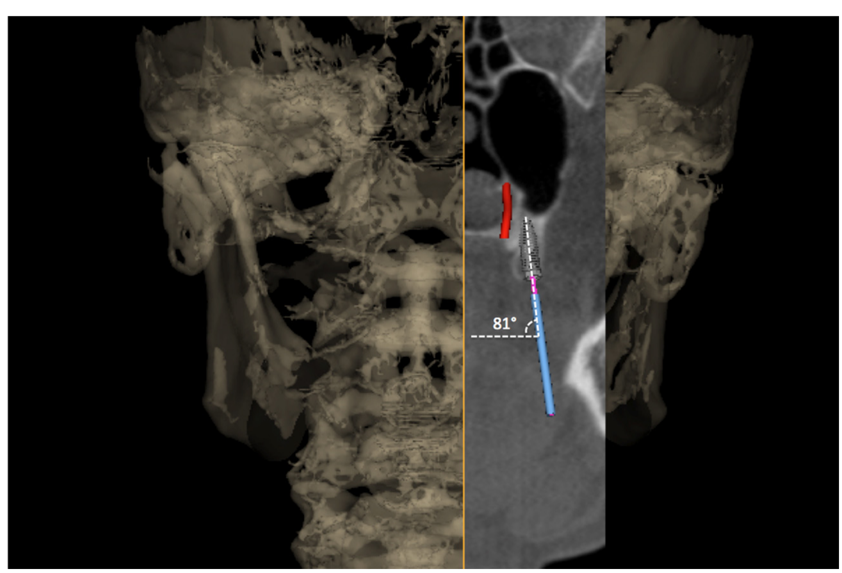

Fig. 1. Image showing virtual implant placement in coronal view; buccopalatal angulation is shown. The safety distance of more than 2 mm between the implant body and the palatine artery should be noted.

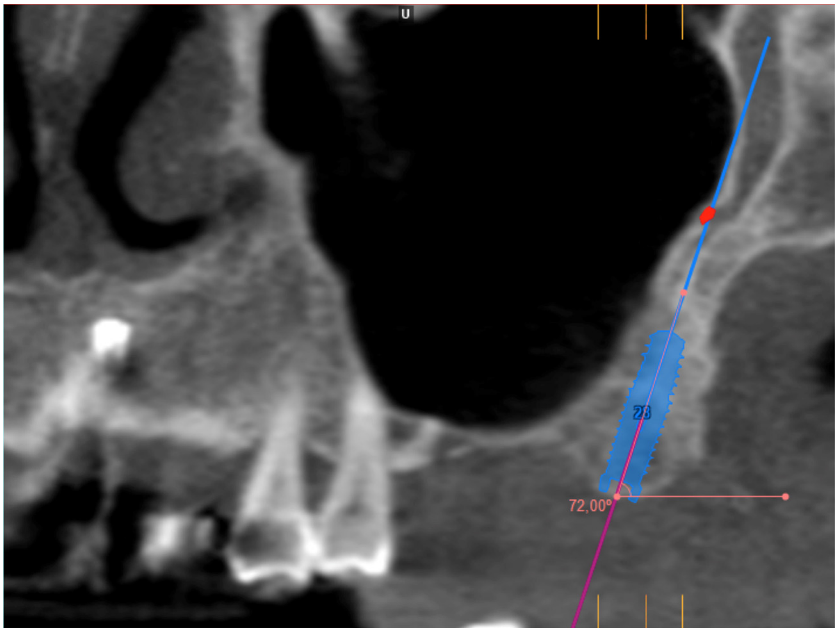

Fig. 2. Virtual implant placement following the pterygoid bone corridor; the mesiodistal inclination (panoramic view) is shown.

procedure resulted in an implant emerging at the distal aspect of the second molar.

The following parameters were measured: (1) implant angulation relative to the Frankfort plane of the anteroposterior axis on reconstructed panoramic view (Fig. 2); (2) the implant angulation relative to the Frankfort plane on the buccopalatal axis (Fig. 1); (3) distance from the tuberosity alveolar ridge to the most apical point of the pterygoid apophysis following the long axis of the virtual implant; (4) bone density, measured as the density value (DV), in the pterygomaxillary region; (5) bone density (DV) in the tuberosity area.

Statistical analysis

Descriptive statistics were used. All data analyses were performed using IBM SPSS Statistics version 21.0 software (IBM Corp., Armonk, NY, USA).

Results

Of 378 available CBCT scans, 202 were eligible for inclusion in this study, giving a rate of 53.4%.

Anatomical and radiological measurements

An 18 mm long virtual implant could be placed in 147 of the cases (72.8%), a 15 mm long virtual implant in 50 cases (24.7%), and a 13 mm long virtual implant in five cases (2.5%). All implants were covered by bone three-dimensionally.

In the anteroposterior axis (sagittal view), the mean implant angulation (± standard deviation) was $74.19 \pm 3.13^\circ$ relative to the Frankfort plane. In the buccopalatal axis (frontal view), the mean implant angulation was $81.09 \pm 2.65^\circ$ relative to the Frankfort plane. The mean bone column length following the long axis of the implant was 22.15 ± 1.56 mm. The relationship between the pterygomaxillary corridor and implant length is shown in Table 1.

Table 1. Bone column length.[a]

	Total	Implant length		
		13 mm	15 mm	18 mm
N	202	5	50	147
Mean	22.15	17.97	21.66	22.46
SD	1.56	1.83	1.78	1.20
Minimum	15.4	15.4	17.5	20.0
Maximum	25.7	19.9	24.7	25.7

SD, standard deviation.

[a] Distance from the tuberosity alveolar ridge to the most apical point of the pterygoid apophysis following the long axis of the virtual implant.

Table 2. Density of the tuberosity and pterygoid areas.

	N	Mean	SD
Tuberosity density units	202	307.43	155.94
Pterygoid density units	202	632.06	209.73
Absolute value	202	324.63	145.71
Percentage value	202	139.23	115.39

SD, standard deviation.

Bone densities

The mean bone density in the tuberosity area was 307.4 ± 155.94 DV, with a coefficient of variation of more than 50% (CV = 50.7%). The mean bone density in the pterygoid region was 632 ± 209.73 DV, with a coefficient of variation of 33.2% (Table 2).

The density in the tuberosity area was 285.8 to 329.1 DV and in pterygoid area was 602.9 to 661.2 DV, with a 95% confidence interval (Fig. 3).

The absolute difference in density between the two areas (tuberosity and pterygoid) was an average of 324.6 ± 145.7 DV. In percentage terms, the density in the pterygoid area was 139.2% higher than in the tuberosity area. The difference in density value between the tuberosity and the pterygoid areas, with a 95% confidence interval, was 304.4 to 344.8 DV (Fig. 4). The *t*-statistic for dependent samples was 31.67 with a *P*-value of <0.001 (statistically significant).

Discussion

Tulasne and Tessier described the pterygoid implant as an option for rehabilitation of the posterior maxilla without a graft, allowing a shortening of the treatment period and decreasing the costs.[7] According to the literature reviews by Bidra and Huynh-Ba[12] and Candel et al.[15] and to some clinical studies,[13,16] the technique is predictable and has success rates and long-term clinical outcomes similar to those obtained with conventional implants. Nevertheless, disadvantages have been described, including severe bleeding, a

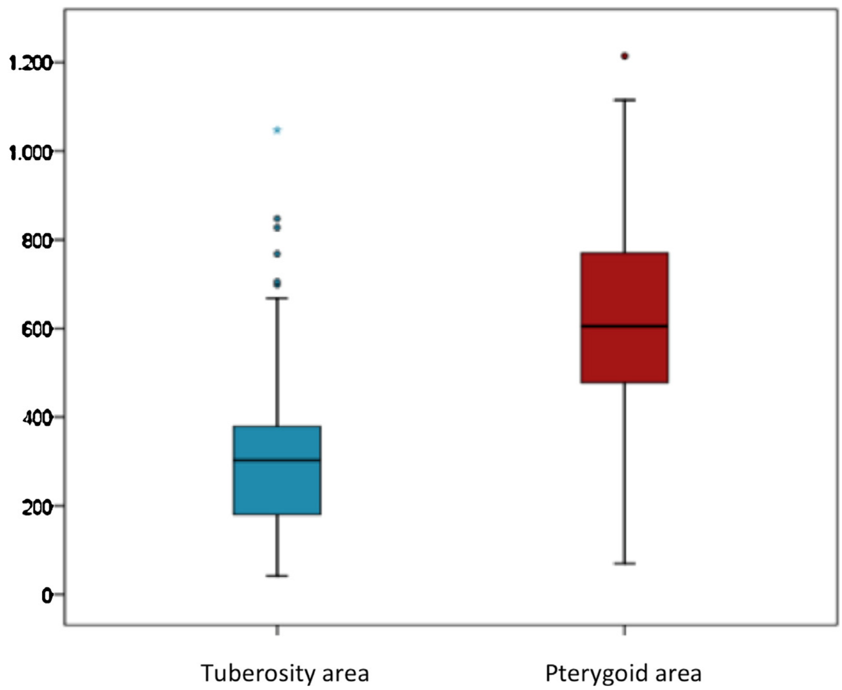

Fig. 3. Density in the tuberosity and pterygoid areas; density value (DV).

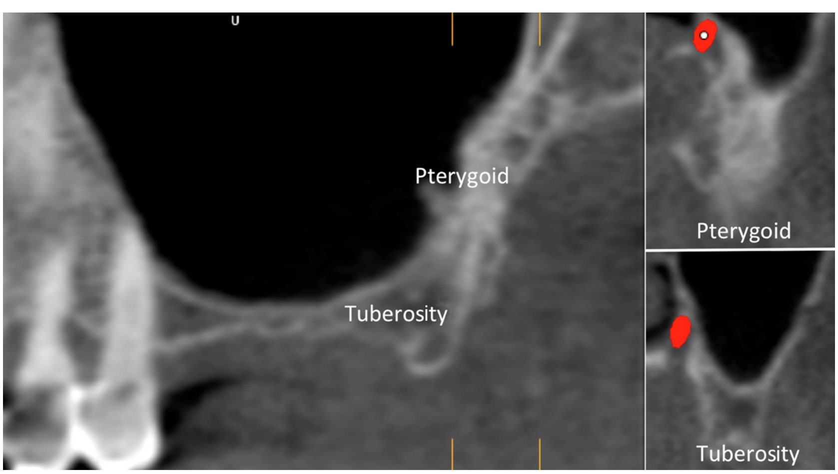

Fig. 4. Left: Pterygoid area in sagittal view. Right: Comparison of the density in the pterygoid area (upper) and tuberosity area (lower).

thick mucosa, and prosthetic complications. Reducing the soft tissue thickness at the tuberosity at the time of implant placement in order to avoid a pocket depth is recommended by some authors.[13]

Implant placement should be guided by the individual anatomy of each patient, but there is no consensus regarding the ideal position of this implant type. Several authors propose implant placement at around 45° in relation to the Frankfort plane,[10,11] while others propose the verticalization of the implant, to around 70° in relation to the same plane.[13,14] The results of the present study agree with the proposed placement of the implant in a more vertical position; the ideal position identified was $74.19 \pm 3.13°$ in the anteroposterior axis (sagittal view) and $81.09 \pm 2.65°$ in the buccopalatal axis (frontal view), in relation to the Frankfort plane.

In order to take clinical advantage of this procedure, the use of surgical splints and models is essential. Several measures should be taken regarding virtual implant placement and clinical angles.

From the biological point of view, the goal of any implant-supported rehabilitation is to imitate the shape and biomechanics of the substituted teeth. The pterygoid implant angulation found in this study follows the axis of the second molar[17]; the placement is more physiological with a vertical angulation.

Another important finding of this study was the average length of the implants used. Most of the implants used were ≥15 mm in length (approx. 97%). Several studies have described the use of implants <15 mm in length in this area[18]; however according to the present results it would be very difficult to engage these implants in the pterygoid plate. Although the present study only demonstrated the virtual placement of implants, several clinical studies do agree with these results.[13,16] A recent case series published by Balshi et al. found that longer implants (15–18 mm) had a higher survival rate (94%) than shorter implants (88%). On analysing the results of the present study, longer implants were usually seen to engage the dense bone area of the pterygomaxillary zone, and thus it could be assumed that better primary stability would be obtained, thereby yielding a better survival rate.[16] From the results of this study, an implant of at least 15 mm in length should be used in this region in order to obtain a better survival rate.[16]

Studies of implants placed in the tuberosity area have described bone types III and IV.[18] Jaffin and Berman reported a 35% failure rate for implants placed in bone quality type IV in contrast to a failure rate of 3% for implants placed in bone of type I, II, and III quality.[4] It is concluded that it is important to obtain primary stability and good anchorage in the posterior atrophic maxilla and that this is closely related to bone density and quality.[19]

Bone density information can be obtained preoperatively by CBCT examination. While Hounsfield units represent the standardized scale for CT scans, there is no consensus regarding the standard unit for CBCT scans because no calibrations have yet been conducted.[20] Several authors have used the terms 'density value' and 'CT number' to define bone density in CBCT scans.[19,21,22] In the present study the term 'density value' was used.

The statistically significant difference in bone density found between the tuberosity and pterygoid plate areas in this study is of importance. It seems logical that engaging the apical part of the implant in the pterygoid plate will increase the probability of success.[9] Nevertheless, an individualized study of the surgical area is necessary in order to determine the bone density of the tuberosity and pterygomaxillary areas and also for the selection of an implant of appropriate length with a view to transferring this information for the clinical benefit of the patient.

Finally, more controlled clinical studies are needed to determine the best angulation for implants in the pterygomaxillary area.

In conclusion, the placement of pterygoid implants should be guided by the individual anatomy of each patient. A statistically significant difference in density value between the tuberosity and pterygoid plate was found in this study. It is concluded that an implant of at least 15 mm in length should be used in this region. Implants should have an angulation of around 74° in anteroposterior axis and 81° in buccopalatal axis in relation to the Frankfort plane in order to take advantage of the greater quantity and better quality of bone in this region.

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Competing interests

The authors declare that there is no conflict of interest in relation to this study.

Ethical approval

Ethical approval was given (reference number CIR-ECL-2014-01).

Patient consent

Not required.

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