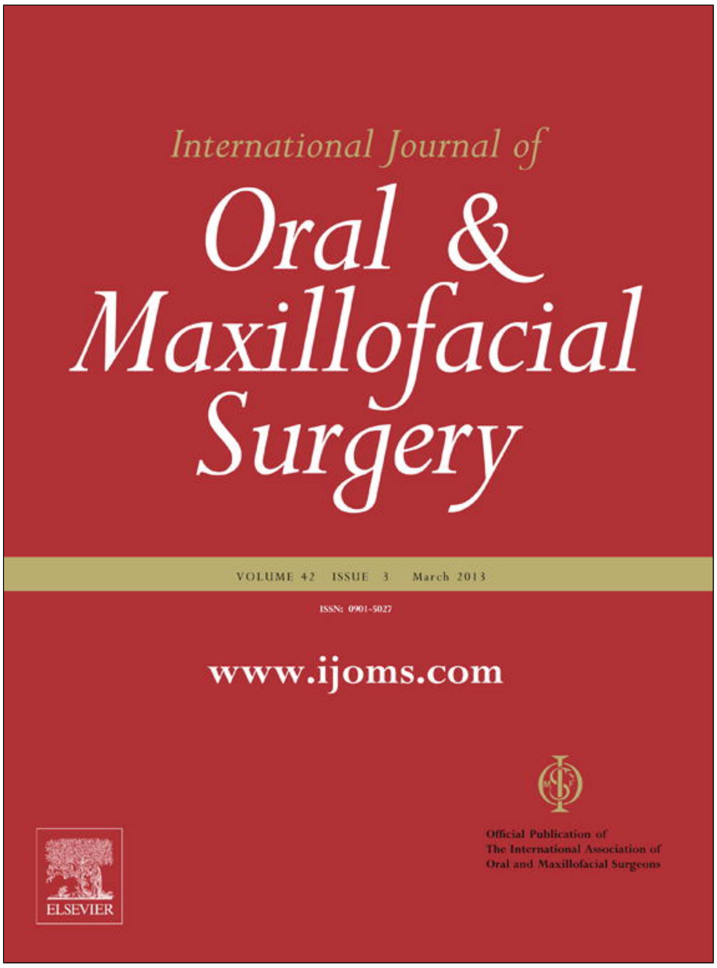
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# Volumetric CBCT analysis of the palatine process of the anterior maxilla: a potential source for bone grafts

**Ramon Bernades-Mayordomo, Ra qu el Guijarro-Martínez, Federico Hernández-Alfaro**
Department of Medicine, Surgery and Oral Implantology, Dental School. International University of Catalonia, Barcelona, Spain

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*Abstract.* The aim of this research was to use cone-beam computerized tomography (CBCT) to analyze the available bone volume in the palatine process of the maxilla (PPM), which is a potential source of bone grafts. 20 CBCT scans were evaluated. From the most caudal axial slice of the PPM, the bony surface was calculated cranially up to the nasal floor. The predetermined thickness of each slice was 0.9 mm. A 2 mm safety margin was established considering the incisive canal and teeth 14–24. A $\pm$0.1 mm error deviation was established for all calculations. By connecting these points and those defined at the posterior bone boundary, a surface was obtained. A three-dimensional (3D) image of the delimited zone was constructed and analyzed using 3D imaging software. The study comprised 6 women and 14 men (mean age 39.4 $\pm$ 11.5 years). Calculated bone volume averaged 2.41 $\pm$ 0.785 $cm^3$. The palatine process of the maxilla contains a considerable bone volume (2.41 $\pm$ 0.785 $cm^3$). This area should be regarded as a potential donor site for the regeneration of maxillary atrophic bones. Further investigation is required before these findings lead to routine clinical application.

Key words: bone graft; palatine process of the maxilla; CBCT; I-CAT®; Simplant®.

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The search for potential bone graft donor sites for use in reconstructing the oral and maxillofacial region has increased steadily during the past years. Although substantial investigation has permitted the incorporation of several allografts, xenografts and alloplastic materials to the routine armamentarium, autologous bone grafting is still considered, in most cases, the gold standard option.

The reconstruction of certain maxillofacial defects requires clinicians to obtain autologous grafts from extraoral sites, such as the iliac crest, tibia and parietal bone. Intraoral donor sites, in the context of an adequate indication, are preferable in order to reduce morbidity, time and costs.[1] However, the intraoral zone often provides a limited source of bone volume. Nevertheless, it is possible that new potential intraoral donor sites can make alternative options available.

Little research has assessed the palatine process of the maxilla (PPM) as a potential intraoral donor site. In one study performed on dry skulls,[2] the authors concluded that the anterior palatal region could be a reliable donor site for routine maxillofacial and oral surgery procedures. Another study provided a correlation between the upper anterior facial height and the hard palate thickness based on craniometric points. In 2005, Hernández-Alfaro et al.,[4] provided the first clinical series of patients treated with palatal core grafts for alveolar reconstruction. Based on their successful clinical outcomes, the authors concluded the palatal region provides a practical, reliable source of intraoral bone grafts with minimum added morbidity. Subsequently, Rodríguez-Recio et al.[5] added two more cases to the scientific literature.

Many authors have highlighted the limited volume of intraoral grafts,[1,6,7] and the great variability that exists between individuals.[3,8] Therefore, a precise analysis for each patient is needed.

Standard diagnostic methods, such as clinical examination, orthopantomography, or cephalograms, do not provide precise information regarding the available bone volume.[8] Computerized tomography (CT) used in conjunction with the correct software can provide the most powerful and reliable technique for pre- and postoperative assessment.[9]

New generation CT devices and improved protocols are diminishing the undesirable effects of ionizing radiation based on the 'as low as reasonably achievable' (ALARA) principle. Nevertheless, conventional CT scanners are often restricted to hospitals or radiological centres, are costly, unergonomic and emit excessive radiation to the patient's head and neck region, when often only a small oral area needs to be studied. The advent of cone-beam computerized tomography (CBCT) has provided a very convenient tool for the evaluation of the hard tissues in the dentomaxillofacial area.[10] Its advantages include its wide accessibility, easy handling, and low radiation doses compared to conventional CT.

Based on the senior author's favourable preliminary clinical results[4] with the palatal core graft, and incorporating the enhanced diagnostic possibilities that CBCT technology and related third-party software provide, the aim of this paper was to assess, in a structured, precise and reproducible way, the available bone volume in the PPM as an alternative source for intraoral grafts.

## Material and methods

This study was conducted according to the principles outlined in the Declaration of Helsinki (first adopted in the 18th WMA General Assembly, Helsinki, Finland, June 1964). Ethical approval was obtained from the Ethical Committee of Clinical Research (CEIC) of the Universitat Internacional de Catalunya (study number: B-16-EFP-10 approved on 3/05/2010).

The studied sample comprised the CBCT scans of 20 patients who had been referred for routine dental analysis to the Dental Clinic of the Universitat Internacional de Catalunya (Sant Cugat del Vallés, Barcelona, Spain). These patients were retrospectively selected from the Clinic's database according to the following inclusion and exclusion criteria. The inclusion criteria were: CBCT scans of the entire maxillary bone; physical growth completed (age $\geq$ 20 years); and dentate (14–24). Exclusion criteria were: developmental malformations of the maxilla; tumours or cysts of the hard palate; severe periodontitis from 14 to 24; and the presence of impacted teeth in the area of study.

Patient confidentiality was safeguarded in accordance with the Organic Law 15/1999. There was no direct or indirect contact with any of the studied subjects, and their personal information was appropriately separated from the study and filed for any possible audits, inspections or confirmation of information veracity. Accordingly, each patient was assigned a number (consecutive from 1 to 20). Each clinical history contained a signed informed consent form for carrying out a CBCT study.

CBCT scans were obtained with the IS i-CAT® device version 17–19 (Imaging Sciences International, Hatfield, PA, USA). The radiological parameters used were 120 kV and 5 mA; the axial slice default distance was 0.300 mm and the voxel size was 0.3 mm.

The facial mode with the 23-cm field of view (FOV) was used. Primary images were stored as DICOM (Digital Imaging and Communication in Medicine) files.

In order to create a reproducible measurement system with the SimPlant Pro Crystal® software (Materialise, Leuven, Belgium), the following steps were followed. The dataset of the patient was opened with SimPlant. The region of interest was defined in a sagittal slice view, eliminating all unnecessary areas. By default, slice thickness was 0.300 mm. In order to obtain a thickness per slice of 0.9 mm, two segments from each slice were omitted. In *Segmentation* mode, a mask was created marking the starting point of the bone. All irrelevant areas to the study were again eliminated. Then, maximum quality was set for 3D. Once in *Planning preparation* mode, a panoramic curve was created to facilitate the readings on the different spatial planes. Thereupon the images of the study area in axial view were obtained, working from the base of the hard palate up to the nasal floor (maintaining the latter cortical unspoiled). The next step consisted in establishing a 2 mm safety margin[2] from tooth 14 to 24 with a margin of error of $\pm$0.1 mm for each slice (including teeth 15 and 25 whenever sufficient bone was present). This was done by marking a point in the medial/palatine area of each tooth (Fig. 1). The same procedure was followed for the mesial and distal views wherever an adjacent tooth was not observed (usually in the longest canine roots) (Fig. 2). A 2 mm safety margin was established around the incisive canal. In this case, three peripheral points were marked (one on either side of the paramedials and one on the middle posterior). Similarly, a 2 mm safety margin was also set wherever the maxillary sinus appeared in the most cranial slices (Fig. 3).

Once this protocol was implemented, a surface was created by connecting these points plus those created at the posterior bony margin. For the purpose of quantitative volumetric analysis, a three-dimensional (3D) image of the delimited zone was constructed (Fig. 4).

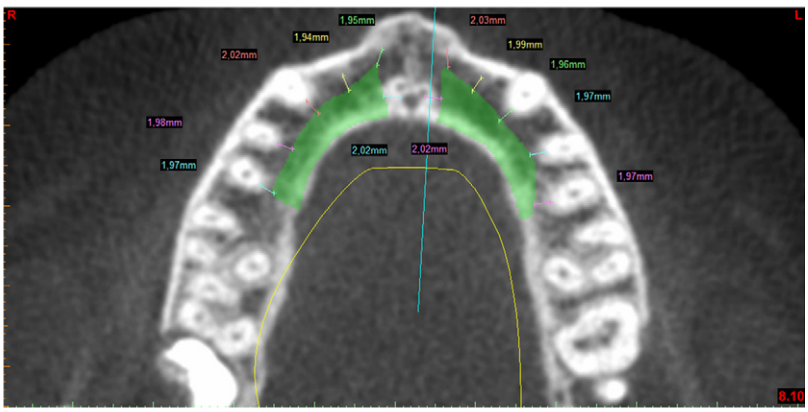


*Fig. 1.* Axial caudal slice.

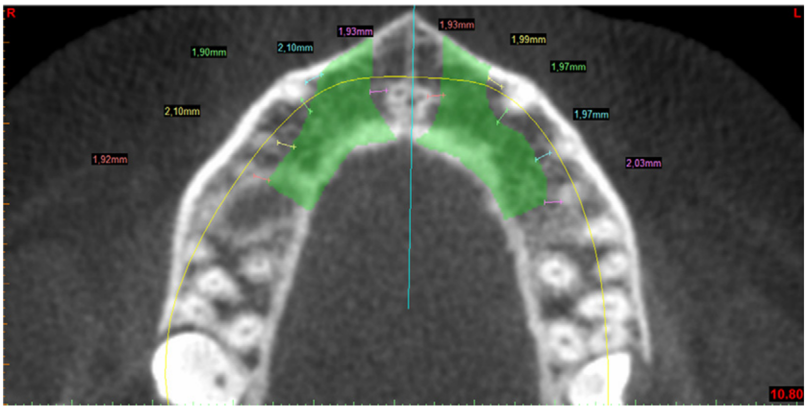


*Fig. 2.* Axial middle slice.

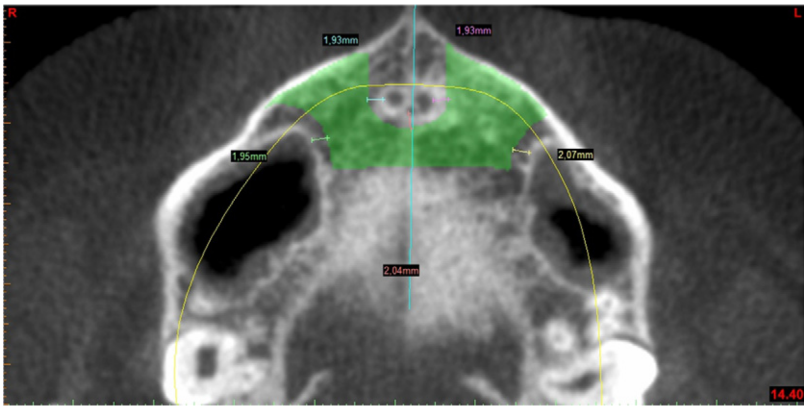


*Fig. 3.* Axial cranial slice, palatal roof.

Subsequently, all measurements were submitted for statistical analysis using StatGraphics Plus® 5.1 (Statistical Graphics, Rockville, MD, USA).

## Results

Table 1 displays the individual demographic characteristics and graft volume for each of the 20 patients analyzed. Each patient's CBCT scan is represented by a consecutive number from 1 to 20. The studied sample comprised 6 women and 14 men with a mean age of 39.4 ± 11.5 years. Mean graft volume of the PPM was 2.41 ± 0.785 $cm^3$. Results are expressed in means and standard deviations because the studied sample showed a normal distribution according to the Shapiro–Wilk test ($p > 0.05$).

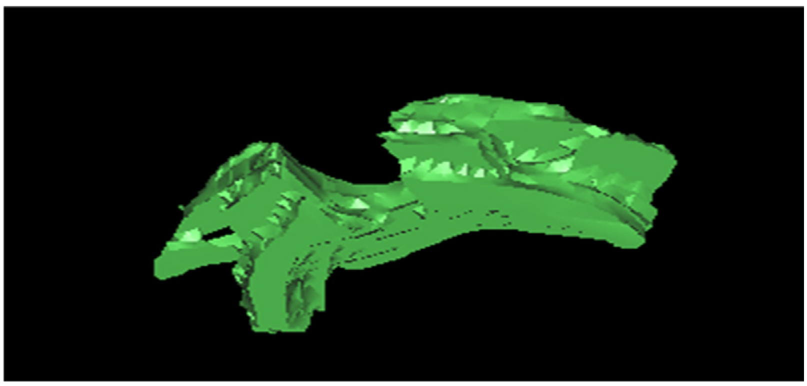

*Fig. 4.* PPM reconstruction in 3D.

*Table 1.* Different variables.

| i-CAT number | Gender | Age | Volume ($cm^3$) |
|---|---|---|---|
| 1 | 1 | 46 | 2.39 |
| 2 | 1 | 69 | 4.12 |
| 3 | 1 | 31 | 2.73 |
| 4 | 2 | 40 | 1.96 |
| 5 | 1 | 50 | 1.60 |
| 6 | 1 | 43 | 2.08 |
| 7 | 1 | 23 | 2.09 |
| 8 | 2 | 42 | 2.98 |
| 9 | 1 | 49 | 1.91 |
| 10 | 1 | 31 | 2.89 |
| 11 | 1 | 54 | 1.34 |
| 12 | 2 | 23 | 2.73 |
| 13 | 2 | 25 | 1.73 |
| 14 | 1 | 34 | 1.96 |
| 15 | 2 | 31 | 4.18 |
| 16 | 1 | 39 | 1.68 |
| 17 | 1 | 39 | 1.80 |
| 18 | 1 | 30 | 2.80 |
| 19 | 1 | 41 | 3.22 |
| 20 | 2 | 48 | 2.17 |

## Discussion

Clinical experience has proved the efficiency and reliability of the PPM as a potential donor site for the 3D reconstruction of alveolar defects.[4] However, a method for systematically analyzing an intraoral donor site using CBCT with suitable software has not yet been provided, although some studies have demonstrated the accuracy and reliability of this type of equipment, which calculates linear and volumetric measurements.[11,12] Some authors have evaluated the PPM with the combined use of CT and specific software,[5] but a reproducible, systematic methodology has not been provided. The number of studies assessing intraoral donor sites using conventional techniques is quite low. The summarized methodology of these papers together with that of the present study is displayed in Table 2. To the best of the authors' knowledge, this is the first study to quantitatively assess the PPM in a structured, reproducible way combining CBCT technology and related third-party software.

While the use of the mandibular symphysis as a potential donor site is widely acknowledged, the first volumetric analysis of this area was not performed until 2000 by Montazem et al.[6] The authors reported a mean graft volume of 4.84 $cm^3$. Two years later, Gungormus and Yavuz,[13] following a similar protocol to the previous research group, published a volumetric assessment of the ascending ramus of the mandible obtaining a mean volume of 2.36 ± 0.46 $cm^3$. No CT scans were performed in either of the two papers.

*Table 2.* Reports of previous comparisons.

| Authors | Area of study | Graft NN | Graft measurement technique | Mean volume | CT |
|---|---|---|---|---|---|
| Montazem et al. (2000)[6] | Mandibular symphisis | 16 dry skulls | Water displacement | 4.8 $cm^3$ (3.25–6.5) | No |
| Gungormus and Yavuz (2002)[13] | Mandibular ramus | 16 dry skulls | Water displacement | 2.36 $cm^3$ (SD 0.46) | No |
| Kainulainen et al. (2004)[1] | Zygomatic | 20 cadavers (40 samples) | Water displacement Syringe Compression | 0.53 $cm^3$ (SD 0.25) 0.59 $cm^3$ (SD 0.26) | Yes (linear measurements) |
| Hassani et al. (2005)[2] | Palate | 21 dry skulls | Water displacement | 2.03 $cm^3$ (SD 0.5) Dentulous 2.40 $cm^3$ (SD 0.75) Edentulous | Yes (linear measurements) |
| Present study | Palate | 20 i-CAT® | SIMPLANT® | 2.41 (SD 0.785) | Yes (volumetric measurements) |

Kainulainen et al.[1] focused on the zygomatic bone. Even though significantly less bone was available in this area compared to the previously mentioned donor sites, this was the first paper in which conventional CT scans were used; in this case, preoperatively in nine cadavers to take linear measurements and postoperatively to assess possible damage to the neighbouring tissues.

Regarding the anterior palate, although several authors proposed its potential as an intraoral donor site,[4,14] Hassani et al.[2] were the first to analyze it quantitatively for this indication. 21 fixed cadavers (12 dentate and 9 edentulous maxillas) were studied. Osteotomies were performed using fissure and round burs and margins of safety were established to avoid incisive canal or root damage. A 'preoperative' CT scan was taken to perform several linear measurements in order to gauge bur penetration depth, using an inexact radiographic index. The volume of the corticocancellous block was calculated with the displacement volumetric technique. The mean volume obtained was $2.03 \pm 0.5\ cm^3$ in dentate patients and $2.40 \pm 0.75\ cm^3$ in edentulous patients.

If the methodology of the present study is compared to that of Hassani et al.[2], the anatomical limits of the latter study are unclear, the margin of error and imprecision for obtaining the graft are higher, and their sample is more heterogeneous. However, their results are comparable to those of the present study. The study by Hassani et al.[2] is more clinically comparable to bone harvesting than a radiographic study.

The selection of the ideal intraoral donor site should be based on several variables: location, quantity, quality, graft morphology and possible intra- and postoperative complications.[15] Taking these factors into account, the PPM shows a number of advantages such as location, size, and type of graft. Its gold standard indication is probably the regeneration of the anterior maxilla, because there is only one surgical field required and surgery time and morbidity are significantly decreased.[4]

In their retrospective study of 1817 dental implants placed over a 3 year period in a referral specialty clinic, Bornstein et al.[16] reported that 726 implants (40%) were inserted in the aesthetically demanding region of the anterior maxilla (tooth 14–24) and bone augmentation procedures were required for 939 implants (51.7%). Although implant therapy in the anterior maxilla is common as is the need to regenerate this area, only three papers making use of the PPM graft method have been found in the literature. Hernández-Alfaro et al.[4] were the first to describe a surgical technique for 3D alveolar defect reconstruction in 17 cases. Subsequently, Hassani et al.[17] published a slight modification of that technique in a single case report. Rodríguez-Recio et al.[5] have recently published a two case report using the PPM graft with an onlay technique in the first case, and particulating it for a sinus floor augmentation in the second.

According to Agbaje et al.[18], the mean socket volume from tooth 14 to 24 is $0.23 \pm 0.12\ cm^3$ on average. Considering that the mean PPM graft in the present study measured $2.41 \pm 0.785\ cm^3$, the authors think the reliability of the PPM as a donor site for restoring proximal alveolar defects is quantitatively justified. The amount of bone that can be grafted from the PPM is similar to that from the mandibular ramus, which is a well-established donor site. Moreover, the PPM provides intramembranous and corticocancellous bone. Reduced accessibility and the risk of damaging the neighbouring roots or even nasal and sinus perforation are considered its major drawbacks.[17]

Compared to the study by Rodríguez-Recio et al.,[5] who used CT for the evaluation of the PPM, a strong limitation of the present study is that Hounsfield units (HU) were not calculated.[19] This is due to the inherent incapability of CBCT to provide HU measurements, since scanned regions of the same density in the skull can have a different Grey scale value in the reconstructed CBCT dataset.[19–21] Indeed, the most important disadvantage of CBCT imaging is the low contrast resolution and limited capability of visualizing the internal soft tissues, though some studies have tried to overcome this drawback.[22,23]

Further limitations of this study are grounded in the fact that the purpose of this investigation is basic and not applied. Using a systematized, reproducible procedure, a particular anatomical zone was evaluated as a potential donor site for intraoral bone grafts. However, although the primary objective of the study was achieved, further research is needed to answer the many clinical questions that derive from the application of this technique. These questions include the definition of the best surgical approach, the most suitable means of obtaining the graft according to the type of defect (saw vs. trephine vs. ultrasounds, bone block vs. particulated), and the characterization of an adequate safety zone for each case in order to minimize risks and complications.

In conclusion, the PPM provides considerable bone volume that is similar or even superior to that contained in other previously described intraoral donor sites. Thus, this area should be regarded as a potential donor site for the regeneration of maxillary atrophic regions.


## Funding

None.

## Competing interests

None declared.

## Ethical approval

This study was approved by the ethical committee of clinical research (CEIC) of the Universitat Internacional de Catalunya (study number: B-16-EFP-10 approved on 3/05/2010).

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Corresponding author at: *Department of Medicine*
*Surgery and Oral Implantology Dental School.*
*Universitat Internacional de Catalunya*
*JosepTrueta*
*s/n 08195*
*Sant Cugat del Vallès*
*Barcelona*
*Spain*
*Tel.: +34 935042000*
*fax: +34 935042001*
*E-mails: dr.bernades@hotmail.es*
*themontx@hotmail.com*