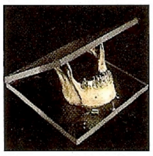
Accuracy of Computerized Tomography for the Evaluation of Mandibular Sites Prior to Implant Placement



*Nicola Marco Sforza, DDS**
*Federico Franchini, DDS***
*Achille Lamma, DDS**
*Susanna Botticelli, DDS****
*Gino Ghigi, DDS, PhD*****

The objective of the present study was to observe the effect of positioning of the mandible on the accuracy of cross-sectional images obtained by reformatting computerized tomographic (CT) scans. An additional aim was to evaluate the ability of a software program (DentalVox, Era Scientific) to reconstruct these measurements on the reformatted images, regardless of the positioning of the mandible, accurately and without distortion. The test was carried out by examining a partially edentulous dry human mandible with an acrylic radiologic template. Through the use of an acrylic glass support, the mandible was positioned at angles of 0, 10, 15, 20, and 30 degrees relative to the scanning gantry, and a series of CT scans was performed that provided five sets of axial images. Each set of original axial images was reformatted by the DentalVox software, used first in its basic function, which is typical of all software for axial CT measurement (control group), and again in its function of site-specific multiplanar reconstruction (test group). The results showed that the position of the mandible in relation to the CT gantry can influence the precision of the linear measurements. The error ranged from 2% to 51%. The DentalVox software allowed the reconstruction of cross-sectional images with very little distortion regardless of the mandibular position. (Int J Periodontics Restorative Dent 2007;27:589–595.)

*Private Practice, Bologna, Italy.
**Private Practice, Pesaro, Italy.
***Resident, Department of Orthodontics, School of Dentistry, University of Aarhus, Denmark.
****Professor, Department of Oral Science, Bologna University, Bologna, Italy.

Correspondence to: Dr Nicola Marco Sforza, Studio Associato Sforza, Piazza Aldrovandi 12, Bologna, Italy; e-mail: nsforza@studiosforza.net.

In dentistry, computerized tomography (CT) is the most widespread radiographic technique for preimplantation diagnosis, because it provides accurate three-dimensional images that can be easily interpreted by clinicians.[1,2] It is well known, however, that there are a number of aspects of the scanning protocol (ie, the movements of the patient, the saturation of the pixels of the images, the position of the mandible in relation to the CT scan) that can influence the quality and accuracy of linear measurements performed on the cross-sectional images. This distortion may produce adverse outcomes following implant surgery, most notably inaccurate positioning of the implant, resulting in biologic, biomechanical, and esthetic side effects.[3–8]

It has previously been shown[6,7,9,10] that an accurate plane of acquisition is crucial to obtain accurate and nondistorted cross-sectional images reformatted by the CT software. In 2003, Kim et al[10] demonstrated on a dry human mandible that the accuracy of linear measurements performed on reformatted cross-sectional images was influenced by the position of the

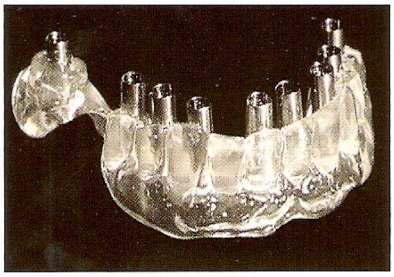
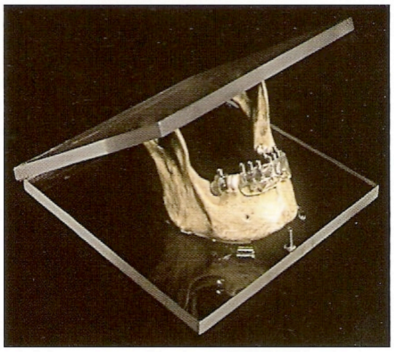


Fig 1 *(left)* *Radiographic template with tubular markers in titanium.*

Fig 2 *(right)* *Oblique view of the dry human mandible showing the mobile bases.*



mandible in relation to the CT scanner. In 2001, a new type of software for CT scans (DentalVox, Era Scientific) was described.[11] According to the authors, it had the same function as other CT software—ie, to reconstruct axial images orthogonally and therefore cross-sectionally parallel to a chosen axis—but it was also able to modify the original scanning surface without a second acquisition, avoiding repeated patient exposure to radiation. The objectives of the present study were to evaluate:

1. The effect of the positioning of the mandible on the scanning plane on the accuracy of the cross-sectional images obtained in the reformatted CT scans.
2. The ability of the DentalVox software to reproduce accurately and without distortions the measurements performed on the reformatted images, regardless of the positioning of the mandible.

Method and materials

The study was carried out by examining a partially edentulous dry human mandible; all three left molars and the right second molar remained. To simulate an implant-prosthetic rehabilitation, a diagnostic waxup was performed. Next, a radiographic template was set up in transparent autopolymerizing acrylic resin (Fig 1). This included nine radiopaque reference markers made of type IV titanium alloy; each measured 10 mm and was situated parallel to the longitudinal axis of each tooth to be replaced. In the left canine position, a 16-mm-long cylindric screw implant was placed. The mandible was examined with a high-resolution spiral tomograph (Toshiba Xpress), prepared for the DentalVox software with the following scanning parameters: 135 kVp; 150 mA; scanning time = 1 s per axial acquisition; secondary reconstruction time = 5 min; image reconstruction matrix = 512 × 512 pixels; pixel extension = 1 mm; helix advancement = 1.2 mm; retroreconstruction = 0.8 mm. The format used by DentalVox was original DICOM without viewers.

To allow arbitrary spatial orientations, the mandible was fixed to a support composed of two reciprocally mobile surfaces in acrylic glass that were connected with silicone (Fig 2). In the gantry, the acrylic glass surface, connected to the lower border of the mandible, was oriented at 90, 80, 75, 70, or 60 degrees in relation to the floor. It was therefore possible to obtain five different sets of axial images; one was parallel to the lower border of the mandible and the others had inclinations of 10, 15, 20, or 30 degrees to it. The aim was to evaluate the effect of different positioning of the mandible in relation to the CT scanning surface through consecutive measurements performed on cross-sectional images, reformatted according to each package of axial images (Fig 3).

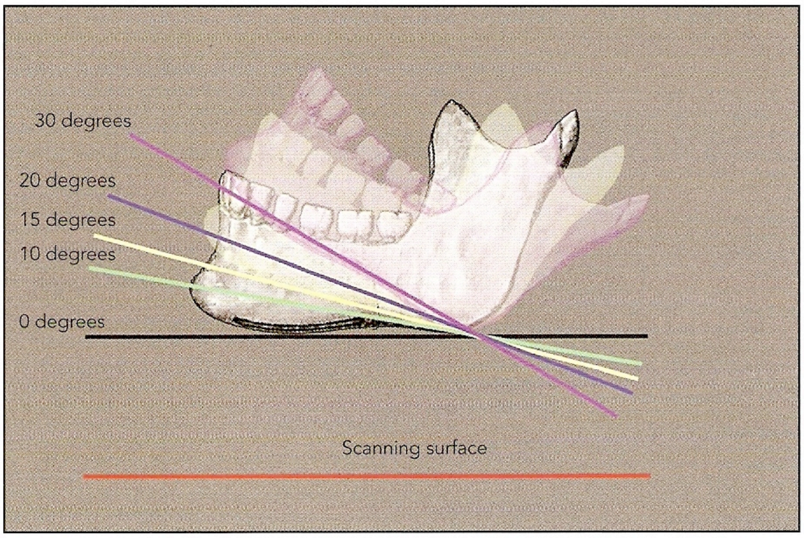


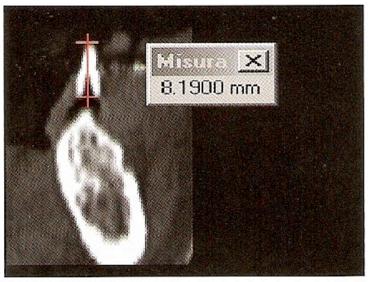
Fig 3 *Scheme of the different positions of the mandible in relation to the scanning surface. At each position, a set of axial images was obtained and reformatted by the DentalVox software, used alternately in the traditional mode (control group) and in its innovative function of site-specific multiplanar reconstruction (test group).*

Each set of images (each included 50 to 90 sections) was reformatted by the DentalVox software according to two different modalities; this allowed us to extract two groups of cross-sectional images for each set of axial images.

1. Control group: the DentalVox software was used with its traditional function; it reconstructed in a multiplanar manner each set of original axial images with an axial orientation, an oblique paraxial orientation (cross-sectional images), or a panoramic one ("Panorex").
2. Test group: the DentalVox software was used with its innovative function, which allows a multiplanar site-specific reconstruction, resulting in a three-dimensional reconstruction that is oriented according to the axis of a determined point of reference.

On the computer console, a calibrated observer not involved in the study performed three measurements for the test group and three for the control group for each of the five sets of original axial images, obtaining 30 measurements. These three measurements were:

1. Length of the radiopaque point of reference in the right second molar (known dimensions = 10 mm)
2. Length of the implant in the left canine position (known dimensions = 16 mm)
3. Distance between the upper border of the point of reference (the right central incisor) and the lower cortical mandibular border, measured parallel to the axial inclination of the radiopaque point of reference and compared with a measurement performed with a digital gauge (Mitutoyo) (known measurement = 38.5 mm)



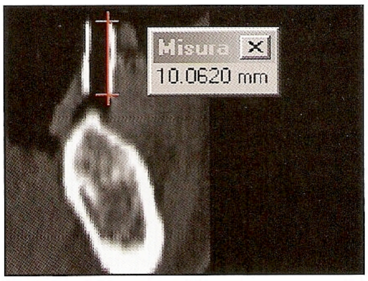


Fig 4 *Example of comparison between the measurement performed on the tubular point of the right second molar on a nonreconstructed volume (control group, left) and using the DentalVox reconstruction (test group, right). The difference in the linear measurement is noticeable.*

Table 1 Linear measurements at the right second molar on nonreconstructed volumes (control group) and after DentalVox reconstruction (test group)

		Control group			Test group		
Actual angle (deg)*	Actual length (mm)	Angle measured (deg)	Length measured (mm)	Error (%)	Angle measured (deg)	Length measured (mm)	Error (%)
0	10	20.2	9.04	–9.6	0	10.06	0.60
10	10	42.6	6.81	–31.9	0	10.06	0.60
15	10	33.9	7.50	–25.0	0	10.07	0.70
20	10	44.9	6.92	–30.8	0	10.00	0.00
30	10	44.2	5.91	–40.9	0	10.08	0.80

*Actual angle = acquisition surface vs lower mandibular border.

Results

At the right second molar, the measurements performed on nonreconstructed volumes with the traditional mode (control group) showed projection errors ranging from 9% to 41%. In contrast, measurements performed on reconstructed volumes with the specific DentalVox software function (test group) showed distortion errors tending toward zero, with a maximum of 0.8% when the angle between the scanning surface and the mandibular angle was at 30 degrees (Fig 4, Table 1). At the left canine, the measurements performed on the reformatted images for each set of original axial images showed 9% to 51% of distortion for the control group and a maximum of 0.9% of distortion for the test group (Table 2). At the right central incisor, the error ranged from 2% to 31% for the control group and from 0.3% to 1.1% for the test group (Table 3).

Discussion and conclusion

CT is an accurate means of planning implant-prosthetic therapy. It is widely known, however, that there are a number of aspects of the scanning protocol that can influence the accuracy of linear measurements performed on the cross-sectional images obtained when reformatting the original axial images.[3–8] In particular, it has been shown[6,7,10] that a correct orientation of the patient's head in relation to the radiation source is sig-

Table 2 Linear measurements at the left canine on nonreconstructed volumes (control group) and after DentalVox reconstruction (test group)

		Control group			Test group		
Actual angle (deg)*	Actual length (mm)	Angle measured (deg)	Length measured (mm)	Error (%)	Angle measured (deg)	Length measured (mm)	Error (%)
0	16	9.4	14.60	–8.8	0	16.18	0.90
10	16	36.7	8.06	–49.6	0	16.14	0.90
15	16	23.8	9.46	–40.9	0	16.15	0.90
20	16	37.7	7.57	–52.7	0	15.97	–0.20
30	16	40.9	6.58	–58.9	0	16.14	0.90

*Actual angle = acquisition surface vs lower mandibular border.

Table 3 Linear measurements at the right central incisor on nonreconstructed volumes (control group) and after DentalVox reconstruction (test group)

		Control group			Test group		
Actual angle (deg)*	Actual length (mm)	Angle measured (deg)	Length measured (mm)	Error (%)	Angle measured (deg)	Length measured (mm)	Error (%)
0	38.5	22.2	37.19	–3.4	0	38.30	–0.50
10	38.5	44.9	43.60	13.2	0	38.04	–1.10
15	38.5	33.7	36.04	–6.3	0	38.17	–0.90
20	38.5	37.7	26.66	–30.8	0	38.22	–0.70
30	38.5	43.0	39.40	2.3	0	38.63	0.30

*Actual angle = acquisition surface vs lower mandibular border.

nificant because it influences the acquisition surface of the axial images. This defines the scanning plane, which is fundamental to obtain accurate, nondistorted cross-sectional images reformatted by dedicated software. Successive scans obtained parallel to the scanning planes determine a set of axial sections (usually from 20 to 50) thinner than 1 mm. Correctly programmed software is able to reformat every single axial section by reconstructing the images (including the cross-sectional images) lying on several surfaces, which are constantly perpendicular to the axial plane. Obviously, an incorrect orientation of the patient, regardless of the direction of displacement, causes inaccurate acquisition on the scanning plane. This leads to images that are reconstructed according to the incorrect axis and are therefore not reliable.[4,5] To prevent distortions of the images and consequent unreliable evaluations of bone morphology, it is necessary to perform CT acquisitions perpendicular to the ideal axis of the tooth, and, therefore, of the implant.[12] In 2001, a new software that could be applied to CT scans (DentalVox) was reported.[11] According to the authors, DentalVox was able not only to reformat images orthogonal to the initial scanning but also to modify the original scanning plane. This would therefore prevent the need for another acquisition on the patient (minimizing radiation exposure) and allow reconstruction of images oriented according to any plane chosen by the examiner. On the basis of the inclination of the axis of the tooth to be studied/ visualized on the axial images, thanks to the presence of radiopaque references in a radiologic template, the software is able to modify the original scanning plane by reconstructing, for each implant, images that are orthogonal to the axis of the implant itself.

Such a function is not available in traditional axial CT software, which cannot modify distortion errors of the images. Specific software for recent cone-beam CT scanners actually allows the radiologist to choose—after having performed the scan on the patient—the scanning plane from which the axial images (and, later, the multiplanar images[13]) are generated. This is undoubtedly an advantage, since both jaws can be imaged at the same time with only one volumetric scan. However, it is crucial to remember that it is the radiologist who chooses the scanning plane, which can be only on the lateral surface; in contrast, DentalVox allows the clinician to choose the scanning plane not only site by site, but also in the sagittal or lateral planes. Moreover, this operation can be carried out by the clinician while planning implant therapy.

In the present study, a partially edentulous dry human mandible was examined and, according to the studies by Kohavi et al[7] and by Kim et al,[10] the position of the mandible in relation to the CT scanner was modified and the effect of such a modification observed by evaluating the accuracy of linear measurements performed on the cross-sectional images. The major difference between the present work and previous studies is that the linear measurements obtained were not limited to the distance between the edentulous crest and the upper border of the mandibular canal, but standard radiopaque reference markers of known length inserted in a radiologic template were also taken into consideration. In addition, the actual distance between a marker at the left central canine and the inferior mandibular border was measured on the mandibular corpus with a digital gauge. Those measurements were then compared with the measurements obtained from CT images, both reformatted as cross-sectional images but not reoriented (control group) and reconstructed according to the DentalVox method (test group). The results are in agreement with control measurements from the aforementioned studies.[7,10] It has been shown that the position of the mandible in relation to the CT gantry can influence the accuracy of the linear measurements performed on the cross-sectional images, obtained by reformatting the original axial images via the traditional method. Especially in the posterior mandible, changes in mandibular positioning strongly affect vertical measurements of the cross-sectional images; in the present study, distortions of more than 30% in the linear measurements were observed. In contrast, measurements performed on volumes reconstructed with the multiplanar site-specific function of the DentalVox software (test group) provided distortion errors that tended toward zero. On the basis of these results, it is possible to draw the following conclusions:

1. The position of the mandible in relation to the CT gantry can influence the accuracy of the linear measurements performed on cross-sectional images obtained by reformatting the original axial images according to the traditional modality.
2. The DentalVox software provided measurements with very little distortion, regardless of the positioning of the mandible. This represents a great improvement in diagnostic accuracy. Therefore, it can be realistically expected that precision and safety during implant placement surgery can improve.

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