Dental Traumatology

Dental Traumatology 2009; **25**: 475–479; doi: 10.1111/j.1600-9657.2009.00824.x

Evaluation of volumetry and density of mandibular symphysis bone grafts by three-dimensional computed tomography

Muhammed Selim Yavuz[1], Mustafa Cemil Buyukkurt[1], Sinan Tozoglu[1], İlhan Metin Dagsuyu[2], Mecit Kantarci[3]

Departments of [1]Oral and Maxillofacial Surgery, [2]Orthodontics, [3]Radiology, Ataturk University, Erzurum, Turkey

Correspondence to: M. Cemil Buyukkurt, Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Ataturk University, Erzurum 25240, Turkey
Tel.: +90 442 2311734
Fax: +90 442 2360945
e-mail: mcbuyukkurt@yahoo.com

Accepted 25 June, 2009

Abstract – *Purpose*: Bone grafting before implant placing can improve the treatment in traumatized or regular implant patients. The aim of this study was to evaluate the density and maximum amount of harvestable bone graft in the mandibular symphysis. *Materials and methods*: Data from 15 CT-scans were obtained from 15 adult patients (10 male/five female) for the purposes of this study. The CT data, in DICOM format, were read into Mimics software from Materialize (Leuven, Belgium), with a slice thickness of 0.5 mm. The volume, density, and dimensions based on Hounsfield units (HU) were measured on the 3D symphyseal bone graft using Mimics software. *Results*: The average bone volume calculated from the mandibular symphysis was 3491.08 $\pm$ 772.12 mm^3. The average sized corticocancellous block that was measured was 38.75 $\times$ 11.05 $\times$ 7.80 mm. The mean bone density was 958.95 $\pm$ 98.11 HU. *Conclusion*: The use of three-dimensional computed tomography (3D CT) in combination with a software program is a reliable means of determining the density of graft, evaluat-ing maximal volume and dimensions of the graft that can be harvested from the mandibular symphysis region.

Trauma is a dominating cause of tooth and bone loss in the jaws. Traumatized patients are thus candidates for implant installation. Bone grafting before implant treatment can improve the placing of implants in areas with bone deficiency where implants cannot be immediately installed. The graft can contribute to improved aesthetics by augmenting the tissues to their original size and volume (1).

Bone is probably the most frequently transplanted tissue in the human body. It can be used to treat or repair defects resulting from atrophy, injury, congenital malformations, or neoplasms. Autogenous bone has been the only source of osteogenic cells to date, and is thus considered the gold standard for oral reconstruction (2).

The bone grafts harvested from the ilium, ribs, calvarium, and intraoral sites have generally been used in maxillofacial surgery (3). The main advantage of using a local donor site is convenient surgical access, which results in reduced operative and anesthesia time. The lateral aspect of the ramus, the anterior mandibular ramus, the buccal aspect of the third molar region, the mandibular lingual cortex, the zygoma, the maxillary tuberosity, the palate, the coronoid process, and the mandibular symphysis have all been used as donor sites in oral and maxillofacial grafting (2–4).

The mandibular symphysis has been used for sinus augmentation, reconstruction of the orbital floor, as an interpositional graft in the treatment of non-union or malunion of maxillary and mandibular fractures, in conjunction with Le Fort I maxillary advancement, in the reconstruction of alveolar clefts and, most popularly, in the reconstruction of alveolar defects and ridge augmentation (3, 4). Compared to other intraoral sites, the symphyseal region can provide higher quantities of bone (2, 5). The quantity of available bone in the donor site can play an important role in adequate grafting and good results.

The success of grafting and surgery can also be affected by bone quality, just as the success of dental implants is influenced by bone quality. Lekholm & Zarb (6) have suggested a bone classification system based on macrostructure, in which the morphology and the distribution of cortical and trabecular bone determine the quality of a given bone. The degree of trabeculation as an indicator of bone density can also be determined using conventional periapical radiographs (7). However, the results obtained from such techniques are often inconclusive, because the images are less able to distinguish between the sites (8). Recently, an image-based bone density classification that utilizes gray-scala values in CT has been suggested (8). The use of preoperative bone density measurement has been advocated as a prognostic indicator with which site-specific, objective, and quantitative results can be obtained on the Hounsfield Unit scala (9).

For a successful operation, surgeons need to know the availability of the desired bone graft to minimize possible risk (10). Several techniques have been described in the literature to measure bone quality and quantity, including radiography (11, 12), calipers (3, 4), and CT (13).

In reconstructive surgery, the use of three-dimensional computed tomography (3D CT) imaging has increased the availability of qualitative information for preoperative planning (13). However, there has been very little research into the evaluation of donor sites for bone grafting in real patients. No previous research has measured the quality and quantity of symphysis bone graft using 3D CT techniques. The aim of this study was to evaluate the density and maximum amount of harvestable bone graft in the mandibular symphysis.

Materials and methods

Data from 15 CT-scans were obtained from 15 adult patients (10 male/five female) for the purposes of this study. The CT data, in DICOM format, were read into Mimics software from Materialize (Leuven, Belgium), with a slice thickness of 0.5 mm. In order to reconstruct 3D images based on Hounsfield units (HU), the appropriate voxels were grouped accordingly. To this end, a mask was created containing voxels with the predefined Hounsfield units. Since we were interested in reconstructing the mandible, one mask was created with segmentation and region growing with Mimics Software, and a three-dimensional model of the mandible was constructed. The mandible was defined using masks with HU between 226 and 3071. Symphyseal bone graft boundaries were determined on the mandibular mask. The cortical and cancellous bones were then identified based on the Hounsfield unit on this mask. The mental foramen and lingual cortical plates have been located on axial CT sections and symphysis graft limits have been determined 5 mm anterior from the foramens without lingual cortex (Fig. 1). On sagittal CT sections, the teeth root apexes have been determined, and symphyseal bone graft limits were defined 5 mm below from the apexes and cephalad to the inferior border of the mandible (Fig. 1). A 3D image of the symphyseal corticocancellous bone graft was then constructed and combined with the 3D mandible (Fig. 2). The volume, density, and dimensions based on HU were measured on the 3D symphyseal bone graft using Mimics software (Fig. 3).

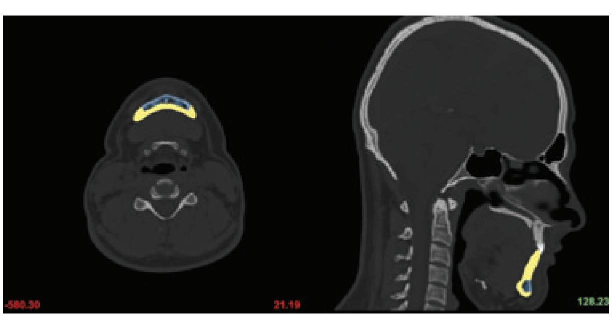

Fig. 1. Symphyseal bone graft boundaries on the axial and sagittal CT slices in respectively.

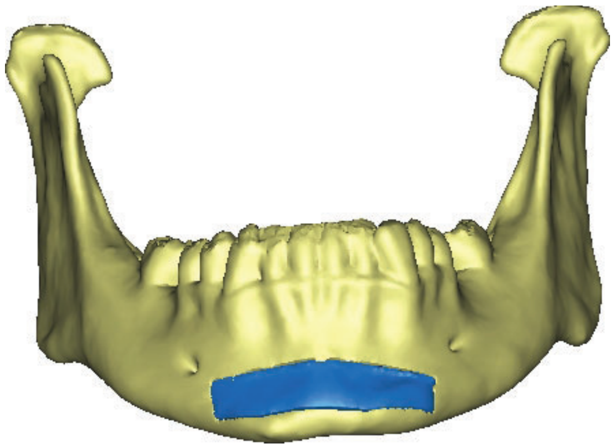

Fig. 2. A 3D image of the symphyseal corticocancellous bone graft and mandibula.

Results

The results are summarized in Table 1. The average bone volume calculated from the mandibular symphysis was 3491.08 ± 772.12 mm^3. The average sized corticocancellous block that was measured was 38.75 × 11.05 × 7.80 mm. The largest block measured 34.08 × 14.91 × 8.73 mm, and the smallest measured 35.61 × 10.08 × 6.54 mm. The length of symphysis graft (LSG) measured from two distal end on the buccal outer side of grafts was 44.16 mm (Fig. 3). The mean bone density was 958.95 ± 98.11 HU.

Discussion

Autogenous bone grafts are widely used in the reconstruction of osseous defects in the oral and maxillofacial region. Although allogenic and alloplastic materials can be used in reconstructive surgery, autogenous bone grafts are preferred because of their osteoinductive and osteoconductive properties. For most grafting procedures confined to oral surgery and implantology, it is possible to use another part of the jaw such as the symphysis, as an acceptable donor site. This allows the

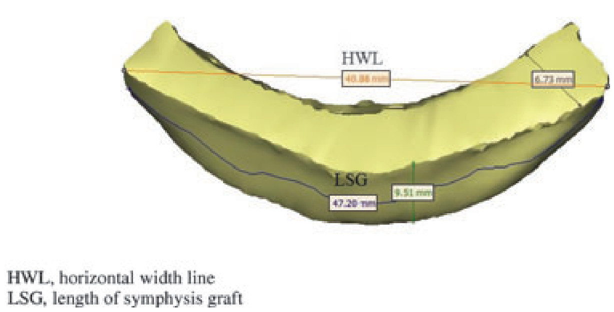

Fig. 3. The dimensions were measured on the 3D symphyseal bone graft.

Table 1. The dimensions, volumetric measurements, and bone densities of symphysis bone grafts

Patients	Volume (mm^3)	Thickness (mm)	Vertical height (mm)	Horizontal width line (mm)	Length of symphysis graft (mm)	Density (HU)	Age
1	3431.01	10.36	11.44	40.84	47.84	988.18	19
2	3123.16	7.27	9.58	44.07	53.51	832.69	58
3	2779.97	9.34	7.43	41.88	47.18	1049.70	43
4	3465.98	7.05	10.02	42.65	46.66	935.67	27
5	3110.47	6.14	11.41	37.03	40.97	949.79	53
6	5232.87	8.73	14.91	34.08	39.16	1013.40	63
7	3553.04	7.70	10.96	39	46.10	950	75
8	2756.08	5.99	9.77	41.76	47.32	942.98	18
9	3033.22	7.37	9.57	41.51	46.18	1016.25	19
10	4701.67	8.93	12.59	37.21	41.66	758.92	75
11	4026.35	9.51	11.04	37.56	43.95	828.91	63
12	2461.41	6.54	10.08	35.61	38.72	1017.91	19
13	4290.46	7.97	12.71	37.93	42.63	916.52	18
14	2927.96	6.80	12.11	37.27	41.89	1041.27	20
15	3472.65	7.37	12.27	32.93	38.67	1142.14	24
Mean	3491.08	7.80	11.05	38.75	44.16	958.95	39
SD	772.12	1.30	1.77	3.26	4.16	98.11	22.55

surgeon to limit surgical procedures to the inside of the mouth and avoids any extra oral wounds or scarring. Other advantages of chin grafts include diminished postoperative morbidity, reduced or eliminated hospital stays with a resulting decrease in costs, minimal postoperative discomfort, no alteration in ambulation, and avoidance of cutaneous scars (2–4).

A review of the literature indicates that little research has attempted to quantify the available symphyseal bone in adult human cadavers. Of the studies available, none provide data regarding the exact quantity and quality of bone available that can be used reliably in decision-making algorithms in actual patients. This study presents that three-dimensional computed tomography (3D CT) provides a reliable predictor of bone volume, maximal block size, and density of the bone that can be harvested from symphysis area without damage of adjacent anatomic structures.

Montazem et al. (4) have suggested that the elevation of the graft from the mandibular symphysis could be difficult because of the concavity of the anterior mandible. They harvested symphysis bone graft as two roughly equivalent blocks and measured the average size of the corticocancellous block as $20.9 \times 9.9 \times 6.9$ mm in dentate human cadavers.

Güngörmüş et al. (3) conducted a study on a cadaverous skull, and reported that the average length of the bone graft obtained from the mandibular symphysis was 45.36 ± 4.82 mm, the average vertical length was 10.31 ± 2.18 mm, and the average thickness was 9.63 ± 1.10 mm. They used calipers to measure the dimensions of the graft materials. In the present study, the horizontal width was measured from both surface (average 44.16 ± 4.16) and line between two distal points (38.75 ± 3.26). We believe that our technique offers a more reliable evaluation of the graft size for patients in clinical practice than that used in previous studies (3, 4).

Because of irregular remodeling of the bone graft, it has only been possible in the past to obtain rough estimates of bone volume, which was calculated as a product of length, width, and thickness, using a caliper in prospective experimental studies (14, 15). Therefore, volumetric studies that use direct measurements have been replaced by studies of en face photographs, where the graft area has been calculated using a digitizing method. To determine the volume, the mean thickness was measured from cross-sectional histological slides at known magnifications (16, 17). Recently, CT technique has been used to evaluate bone volume and density (18). Jensen et al. (13) compared the 3D CT technique with the water displacement technique for the evaluation of bone volume in dry pig mandibles. They found that there was a correlation between the two techniques. However, there has been no previous research to evaluate the volume of symphysis graft using the 3D CT technique. In this study, we calculate close to the exact volume of mandibular symphysis grafts, using 3D CT and Mimics software.

Bone density can be used to evaluate bone qualitatively (10, 19). Bone density is classified into four groups (D1, D2, D3, and D4) based on Hounsfield units (HU) – an X-ray attenuation unit used in computed tomography scan interpretations to characterize the density of a substance. D1 (>1250 HU) is dense cortical bone; D2 (850–1250 HU) is thick (2 mm), porous cortical bone with coarse trabeculae; D3 (350–850 HU) is thin (1 mm), porous cortical bone with fine trabeculae; and D4 (150–350 HU) is fine trabecular bone (10). We found that the average bone density of the mandibular symphysis was 958.95 ± 98.11 HU, which is classified as D2. Bone harvested from the mandibular symphysis is corticocancellous in nature and contains primarily cortical structures (12). Kim et al. (20) have found that cortical bone grafts maintain their volume, width, and projections significantly better than cancellous bone grafts. The primary stability of chin graft may be possible because its corticocancellous structure allows the application of rigid fixation.

Hemmy & Tessier (21) have shown in a visual comparison that 3D CT reconstruction of dry skulls appears to represent skulls accurately, while Matteson et al. (22) have reported on the dimensional accuracy of 3D rendered images. Quirynen et al. (23) found that, using a standard reconstruction based on axial slides, the most reliable cross-sectional images can be obtained with a mean absolute deviation of 0.5 mm. It has been reported that thinner CT slices appear to increase the accuracy of measurements, as would be expected due to the decreased volume-averaging in thinner slices (24). Therefore, in the present study, axial slices of 0.5 mm thickness were used. The systematic and routine use of CT in clinical practice has been limited by concerns about high radiation levels and relatively high costs (19, 25). However, such risks can be reduced considerably by lowering the dose output of the scanner. Cone Beam CT (CBCT) also is now the most commonly used imaging modality for implant assessment (26). A low current and short exposure times for CBCT significantly reduce radiation dose, and images are adequate in diagnostic quality to allow assessment of high-contrast structures in the oral and maxillofacial region (27). However, the diagnostic accuracy of CBCT was low for anterior mandibular region. The buccal and lingual plates are considerably thinner in the anterior region and the bone tapers towards the crest. Apparently, the quality of the CBCT image slices is insufficient to resolve the alveolar crest reliably in this region (28). CBCT systems under evaluation for head and neck imaging are typically described as having soft-tissue contrast discrimination of approximately 10 HU. Modern MDCT scanners have contrast resolution approaching 1 HU (29). Limited contrast resolution continues to impair low-contrast detectability in CBCT images (30). Therefore, we did not prefer CBCT to measure bone density with Mimics in this study.

The mandibular symphysis region has a high quality and quantity of bone, and has frequently been used as a donor site in oral reconstructive surgery and oral implantology. We believe that the use of 3D CT in combination with a software program is a reliable means of determining the density, maximal volume and dimensions of the graft. Doctors which particularly concerned reconstructive surgery and oral implantology can obtain the Mimics software and use it in their clinic practice after a short education.

References

1. Andersson L. Patient self-evaluation of intra-oral bone grafting treatment to the maxillary frontal region. Dent Traumatol 2008;24:164–9.
2. Alfaro FH. Bone grafting in oral implantology. Spain: Quintessence Pub.; 2006. p. 9–83.
3. Güngörmüş M, Yilmaz AB, Ertaş U, Akgül HM, Yavuz MS, Harorli A. Evaluation of the mandible as an alternative autogenous bone source for oral and maxillofacial reconstruction. J Int Med Res 2002;30:260–4.
4. Montazem A, Valauri DV, St-Hilaire H, Buchbinder D. The mandibular symphysis as a donor site in maxillofacial bone grafting: a quantitative anatomic study. J Oral Maxillofac Surg 2000;58:1368–71.
5. Raghoebar GM, Louwerse C, Kalk WW, Vissink A. Morbidity of chin bone harvesting. Clin Oral Implants Res 2001;12:503–7.
6. Lekholm U, Zarb GA. Patient selection and preparation. In: Branemark P-I, Zarb GA, Albrektsson T, editors. Tissue-integrated prostheses: osseointegration in clinical dentistry. Chicago: Quintessence Publishing Co.; 1985. p. 199–209.
7. Lindh C, Petersson A, Rohlin M. Assessment of the trabecular pattern before endosseous implant treatment: diagnostic outcome of periapical radiography in the mandible. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1996;82:335–43.
8. Fanuscu MI, Chang TL. Three-dimensional morphometric analysis of human cadaver bone: microstructural data from maxilla and mandible. Clin Oral Implants Res 2004;15:213–8.
9. Kravitz ND, Kusnoto B. Risk and complications of orthodontic miniscrews. Am J Orthod Dentofacial Orthop 2007;131:43–51.
10. Park HS, Lee YJ, Jeong SH, Kwon TG. Density of the alveolar and basal bones of the maxilla and the mandible. Am J Orthod Dentofacial Orthop 2008;133:30–7.
11. Jeffcoat MK, Reddy MS, van den Berg HR, Bertens E. Quantitative digital sutraction radiography for the assessment of periimplant bone change. Clin Oral Implant Res 1992;3:22–7.
12. Hassani A, Khojasteh A, Shamsabad AN. The anterior palate as a donor site in maxillofacial bone grafting: quantitative anatomic study. J Oral Maxillofac Surg 2005;63:1196–200.
13. Jensen J, Kragskov J, Wenzel A, Pedersen SS. In vitro analysis of the accuracy of subtraction radiography and computed tomography scanning for determination of bone graft volume. J Oral Maxillofac Surg 1998;56:743–8.
14. Philips JH, Rahn BA. Fixation effect on membranous and endochondral onlay bone graft resorption. Plast Reconstr Surg 1988;82:891–7.
15. Smith JE, Abramson M. Membranous versus endochondral bone autografts. Arch Otolaryngol 1974;99:203–5.
16. Lin KY, Bartlett SP, Yaremchuk MJ, Fallon M, Grossman RF, Whitaker LA. The effect of rigid fixation on the survival of onlay bone grafts: an experimental study. Plast Reconstr Surg 1990;86:449–56.
17. Chen NT, Glowacki J, Bucky LP, Hong HZ, Kim WK, Yaremchuk MJ. The roles of revascularization and resorption on endurance of craniofacial onlay bone grafts in the rabbit. Plast Reconstr Surg 1994;93:714–22.
18. Turkyilmaz I, Tozum TF, Tumer C, Ozbek EN. Assessment of correlation between computerized tomography values of the bone, maximum torque and resonance frequency values at dental implant placement. J Oral Rehabil 2006;33:881–8.
19. Oliveira RCG, Leles CR, Normanha LM, Lindh C, Rotta RFR. Assessments of trabecular bone density at implant sites on CT images. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:231–8.
20. Kim JH, Kang JS, Park KK. Biological factors influencing the fate of onlay bone graft on the craniofacial skeleton. J Korean Soc Plast Reconstr Surg 1998;25:557–65.
21. Hemmy DC, Tessier PL. CT of dry skulls with craniofacial deformities: accuracy of three dimensional reconstruction. Radiology 1985;157:113–6.
22. Matteson SR, Bechtold W, Phillips C, Staab EB. A method for three dimensional image reformation for quantitative cephalometric analysis. J Oral Maxillofac Surg 1989;47:1053–61.
23. Quirynen M, Lamoral Y, Dkeyser C, Peene P, van Steenberghe D, Bonte J et al. The CT scan standard reconstruction technique for reliable jaw bone determination. Int J Oral Maxillofac Implants 1990;5:384–9.
24. Cowino SW, Mitnick RJ, Shprintzen RJ, Cisneros GJ. The accuracy of measurements of three dimensional computed tomography reconstructions. J Oral Maxillofac Surg 1996;54:982–90.
25. Frederiksen NL. Diagnostic imaging in dental implantology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;80:540–54.
26. Ludlow JB, Ivanovic M. Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:106–14.

27. Palomo JM, Rao PS, Hans MG. Influence of CBCT exposure conditions on radiation dose. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:773–82.
28. Mol A, Balasundaram A. In vitro cone beam computed tomography imaging of periodontal bone. Dentomaxillofacial Radiol 2008;37:319–24.
29. Wiegert J, Bertram M, Schaefer D, Conrads N, Noordhoek N, Jong K et al. Soft tissue contrast resolution within the head of human cadaver by means of flat detector based cone-beam CT. Proc SPIE 2004;5368:330–37.
30. Miracle AC, Mukherji SK. Conebeam CT of the head and neck, part 1: physical principles. Am J Neuroradiol 2009;13:1–8.