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Simulation of sinus floor augmentation with symphysis bone graft using three-dimensional computerized tomography

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Abstract. The objective of this study was to evaluate the maximum amount of harvestable bone graft in the mandibular symphysis and the augmentation volume needed for different sinus lift levels (from 10 to 18 mm), in addition to calculating which sinus lift level can be acquired using the individual's symphysis bone graft volume with three-dimensional computerized tomography (3D CT) and software. Data from 15 CT scans was obtained from 15 adult patients (10 males, five females). The CT data, in DICOM format, was read into Mimics software from Materialize (Leuven, Belgium), with a slice thickness of 0.5 mm. The mandibular symphysis bone graft volumes and different levels of sinus lift augmentation volumes were calculated on the 3D images using Mimics software. It was determined that the average symphysis bone volume (3491.08 ± 772.12 mm^3) could provide approximately 14 mm of sinus lift height (3167.84 ± 1067.65). 3D CT techniques and software can be used to calculate the required graft volume for sinus floor augmentation and symphysis bone graft volume, and the mandibular symphysis region can provide adequate bone volume for sinus lift augmentation.

Key words: sinus floor augmentation; symphysis bone graft; three-dimensional computerized tomography.

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The lack of vertical bone in the posterior maxilla frequently precludes proper implant placement in this region. Increasing the absolute vertical bone height can be achieved by internal augmentation of the maxillary sinus floor[21]. Sinus floor elevation was first described by Boyne & James[4]. The space created between the maxillary alveolar process, the elevated Schneiderian membrane, and the rotated lateral sinus wall is filled with graft material.

A variety of grafting materials for sinus augmentation have been reported in the literature, but the most frequently used material that has shown the most predictable results is autologous bone material[10,21]. Autogenous bone graft can be harvested from the iliac crest, tibia, calvarium, mandibular symphysis region, mandibular angle or maxillary tuberosity, and it is considered the gold standard as a graft material in sinus grafting procedures[1,3,10,16,21].

As an autogenous bone graft, the mandibular symphysis has been used for sinus augmentation, reconstruction of the orbital

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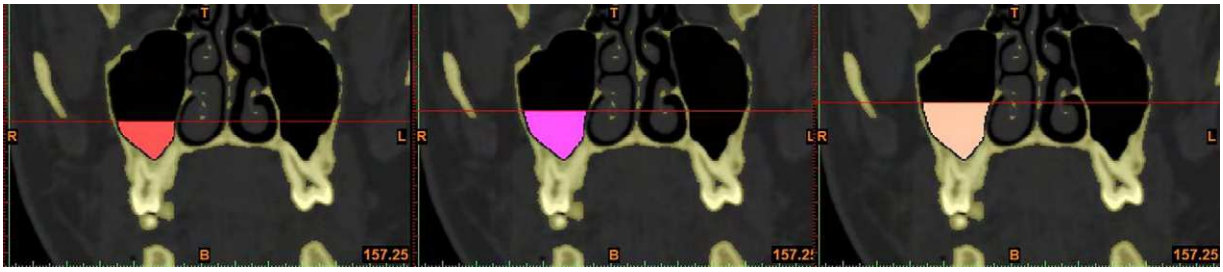

Fig. 1. CT slices show sinus lift augmentation levels 12, 15 and 18 mm, respectively.

floor, as an interpositional graft in the treatment of nonunion 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[6,15]. Compared with other intraoral sites, the symphyseal region can provide higher quantities of bone[1]. The volume of bone available at the donor site can play an important role in achieving adequate grafting and good results.

The procedures for measuring the volume of the maxillary sinus and symphysis bone graft have changed with advances in medical techniques, such as water displacement[6], cadaveric skull measurements[19], plain radiograph, computed tomography (CT)[9], and magnetic resonance imaging. For a precise estimation of the volume change, three-dimensional (3D) CT has recently become a highly used technique[9,12].

The objective of this study was to evaluate the maximum amount of harvestable bone graft in the mandibular symphysis and the augmentation volume needed for different sinus lift levels (from 10 to 18 mm), in addition to calculating which sinus lift level can be acquired using the individual's symphysis bone graft volume with 3D CT and software.

Material and methods

Data from 15 head and neck CT scans acquired from 15 adult patients (10 males, five females) taken for various reasons was used in this study. Patients who had maxillary sinus or mandibular symphysis pathology that could prevent size and volume calculations were excluded from the study. CT was performed with a 16-detector-row CT scanner (Aquillon; Toshiba Medical Systems, Tokyo, Japan) during one breath hold (16–24 s). Scans were obtained with 16 × 0.5-mm collimation, 0.5-mm slice thickness, 120 kV and 300 (mAs). The CT data, in DICOM format, was import into Mimics software from Materialize (Leuven, Belgium). 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 the authors were interested in constructing the mandible and maxillary sinus, two masks were created with segmentation and region growing, and a 3D model of the mandible and right maxillary sinus were constructed. The maxillary sinus masks ranged from −485 to −1024 HU. The mandible was defined through the masks with an HU value between 226 and 3071. After maxillary sinus mask construction, the coronal slice in which the bottom level of the sinus was shown was determined. All sinus lift levels from 10 to 18 mm were measured on this coronal slice (Fig. 1). 3D models of sinus lift were obtained for each level and the volume of these models was calculated using Mimics software (Fig. 2). These measurements and calculations were made for all patients. Symphyseal bone graft boundaries were determined on the mandibular mask, from 5 mm below the lower incisal teeth root apex, 5 mm anterior to the position of the mental foramen, and cephalad to the inferior border of the mandible on the axial and sagittal CT slices[6,15] (Fig. 3). The cortical bone and cancellous bone were identified based on the HU on the mask, and the lingual cortex was removed from the mask. A 3D image of the symphyseal corticocancellous bone graft was constructed and combined with the 3D mandibular image (Fig. 4). The volume was measured on the 3D symphyseal bone graft using Mimics software.

Results

The average bone volume calculated from the mandibular symphysis was 3491.08 ± 772.12 mm^3. The average cal-

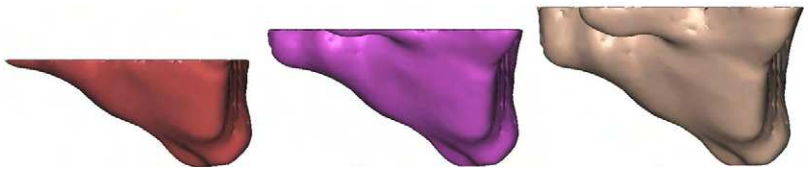

Fig. 2. 3D images of sinus augmented for 12, 15 and 18 mm levels, respectively.

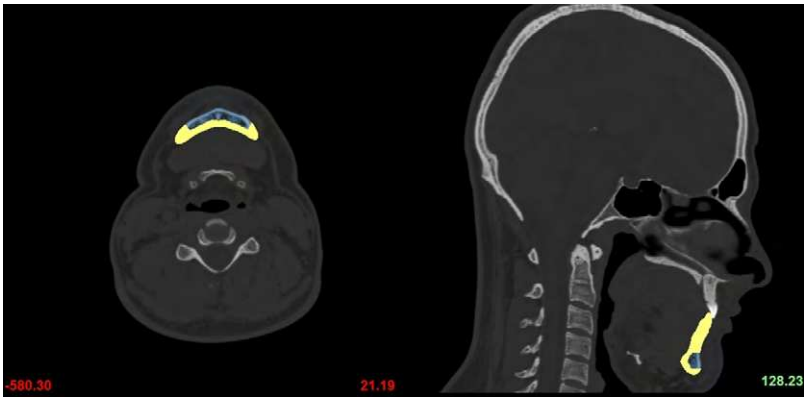

Fig. 3. Symphyseal bone graft boundaries on the axial and sagittal CT slices.

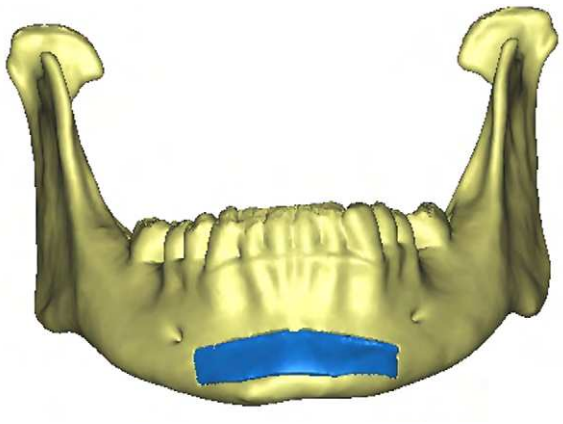

Fig. 4. A 3D image of the symphyseal corticocancellous bone graft and mandible.

culated augmentation volume for an augmentation height of 10 mm was 1665.49 ± 657.18 mm^3; for an augmentation height of 18 mm, the average volume required was 5057.73 ± 1619.36 mm^3. It was determined that the amount of bone volume that can be harvested from each patient's symphysis could be enough to raise the sinus floor height 12 mm in one patient, 13 mm in five patients, 14 mm in two patients, 15 mm in three patients, 17 mm in three patients, and more than 18 mm in one patient. It was determined that the average symphysis bone volume (3491.08 ± 772.12 mm^3) could provide approximately 14 mm of sinus lift height (3167.84 ± 1067.65). The results are summarized in Table 1.

Discussion

Maxillary sinus enlargement and insufficient residual bone often require augmentation procedures before dental implant placement. After the sinus lift operation was introduced in 1980, the technique became widely accepted as a routine method to increase bone volume before implant placement[12]. It should be taken into account that the grafted volumes may adapt considerably in shape and volume due to repneumatisation of the maxillary sinuses[12].

Although allogenic, xenogenic and alloplastic materials can be used in sinus lift surgery, autogenous bone grafts are preferred due to their osteoinductive and osteoconductive properties[5,6,8]. Zerbo et al.[20] determined that osteogenesis occurred at a higher rate on an autogenous bone graft than on the β-TCP used for sinus floor augmentation; they suggested that the difference in bone volume between the two graft sides was because the process of osteoconduction was slower on the β-TCP side. Merkx et al.[13] analysed the two-dimensional change of autogenous bone alone and in combination with hydroxyapatite and bovine bone mineral after maxillary sinus grafting. In their study, the greatest bone height could be achieved without inorganic additives, while hydroxyapatite and bovine bone mineral, used as a bone substitute, showed a greater reduction in bone height in the observation period. Tidwell et al.[18] and Hallman et al.[7] suggested that the addition of bone substitutes to autogenous bone might result in better long-term resistance to resorption.

The buccal aspect of the third molar region, the zygoma, the maxillary tuberosity, the palate, and the mandibular symphysis have been widely used as local donor sites in the oral and maxillofacial region[1,6,15]. The main advantage of using a local donor site is convenient surgical access, which results in reduced operative and anaesthesia time. The choice of graft site depends on the amount of bone graft necessary for the surgical procedure[10]. 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 surgeon to limit surgical procedures to the inside of the mouth and avoids any extraoral 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[1,6,15]. Misch & Dietsh[14] stated that excellent autogenous membranous bone can be obtained intraorally from the mandibular symphysis when smaller dimensions are needed. Crespi et al.[5] claimed that onlay membranous bone grafts resorb less over time because they have a higher proportion of cortical bone than endochondral bone grafts.

In an analysis of the morphological change in the maxillary sinus, the shape changes into an inverted pyramid as the patient grows older[9]. This morphological change increases the necessity for sinus lift for implant placement in the posterior maxilla. Jun et al.[9] reported that the maximum growth period was the third decade in males and the second decade in females, and afterwards, the volume decreases. Uchida et al.[19] did not find statistically significant differences with regard to various factors such as side, sex, and age. According to Ariji et al.[2], the only important parameter was age; maxillary sinus volume tends to decrease after 20 years of age. A specific age period was not chosen because there is no consensus on the relationship between age and sinus volume. Uchida et al.[19] confirmed that the maxillary sinus volume between the dentate and edentulous groups was not significantly different when the maxillary sinus floor was lifted 5, 10, 15 or 20 mm. In the present study, the ages of the patients ranged from 18 to 75 years, and dentate and edentulous individuals were included to represent the general population.

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 of bone available that can be used reliably in decision-making algorithms in patients. Montazem et al.[15] 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 the symphysis bone graft as two roughly equivalent blocks and measured the average volume of the corticocancellous block as 4.71 ml in dentate human cadavers. Güngörmüs et al.[6] conducted a study on a cadaverous skull, and although they reported the average vertical–horizontal lengths and thickness of the bone graft obtained from the mandibular symphysis, bone volume was not evaluated. They also used calipers to measure the dimensions of the graft materials. The authors of the present study believe that their technique offers a more reliable evaluation of the graft volume for patients in clinical practice than that used in previous studies; it also avoids mental nerve or tooth injury, and simultaneously preserves the preoperative facial contour[6,15].

Functional 3D visualisation of detailed anatomical structures is being developed

Table 1. Volumes of symphysis bone graft and different levels of sinus lift augmentation.

Patients	Symphysis volume (mm^3)	10 mm height SFAV (mm^3)	11 mm height SFAV (mm^3)	12 mm height SFAV (mm^3)	13 mm height SFAV (mm^3)	14 mm height SFAV (mm^3)	15 mm height SFAV (mm^3)	16 mm height SFAV (mm^3)	17 mm height SFAV (mm^3)	18 mm height SFAV (mm^3)	Age
1	3431.01	2615.63	3013.76	**3430.63**	4307.40	4757.64	5219.48	6185.46	6685.80	7190.03	19
2	3123.16	1344.12	1638.47	1958.21	2668.44	**3052.46**	3450.21	4289.68	4732.42	5191.22	58
3	2779.97	1237.05	1659.93	1985.73	**2527.51**	2921.43	3559.49	4008.63	4699.08	5158.96	43
4	3465.98	2105.69	2407.18	2725.82	**3421.29**	3789.49	4174.40	4568.25	5391.12	5824.64	27
5	3110.47	1130.41	1336.33	1660.53	1883.72	2113.54	2469.00	2711.27	**3082.09**	3333.4	53
6	5232.87	3226.48	3744.77	4562.56	**5125.96**	5705.16	6597.30	7511.49	8130.11	9071.91	63
7	3553.04	651.20	790.77	936.98	1247.81	1411.88	1583.82	1767.59	2177.20	2405.49	75
8	2756.08	1638.93	1933.93	2094.06	**2624.72**	3021.33	3675.65	4391.50	4896.15	5155.35	18
9	3033.22	1260.49	1522.09	2118.06	2457.59	**2829.25**	3230.02	4106.92	4570.83	5054.22	19
10	4701.67	2393.53	2746.04	3293.70	3670.71	4252.13	**4651.88**	5266.46	5681.17	6312.40	75
11	4026.35	1409.88	1679.28	1967.98	2274.13	2590.47	3250.93	3588.78	**3932.82**	4657.16	63
12	2461.41	1530.59	1797.36	2078.08	**2363.11**	2660.43	2968.05	3286.21	3615.33	3965.14	19
13	4290.46	1566.70	1775.13	2212.47	2443.99	2931.63	3184.41	3705.36	**4248.41**	4529.80	18
14	2927.96	1530.23	1796.14	2075.40	2380.86	2657.68	**2965.86**	3286.34	3615.53	3942.93	20
15	3472.65	1341.53	1650.65	1974.41	2478.80	2823.22	**3170.33**	3523.81	3705.37	4073.38	24
Mean	3491.08	1665.49	1966.12	2338.30	2791.73	3167.84	3610.05	4146.51	4610.89	5057.73	39
SD	772.12	657.18	732.75	862.95	970.52	1067.65	1190.22	1391.46	1468.79	1619.36	22.55

SFAV: sinus floor augmentation volume.
Bold values show ''which sinus lift level can be acquired using the individual's symphysis bone graft volume for each patient''.

in accordance with the requirements of current surgical procedures[11]. Despite the accuracy of present imaging modalities for the evaluation of anatomical structures, some limitations with respect to detailed morphology and spatial relationships of oral and maxillofacial structures remain in clinical dentistry, especially in terms of dental implantation procedures[11]. Different techniques for assessing the augmented bone volume have been described. Plain dental or panoramic radiographs allow an estimation of the vertical dimension of grafts, but do not provide information about volume and 3D changes, and images may be different from the actual size[9,12,17]. To overcome the disadvantages of conventional methods, 3D reconstructed CT images of the maxillary sinus should be used[9].

Detailed preoperative knowledge of the sinus lift augmentation volume and donor site for harvesting autogenous bone is helpful as a predictive value in deciding which ratio of bone to bone substitute to use. In the present study, the authors used a 3D CT technique and software to calculate precisely the required graft volume for sinus floor augmentation and symphysis bone graft volume, and it was shown that the mandibular symphysis region provided adequate bone volume for sinus lift augmentation.

Competing interests

None declared.

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None.

Ethical approval

Not required.

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