A RADIOGRAPHIC ANALYSIS OF THE ANTERIOR PALATE AS A DONOR SITE FOR BONE HARVESTING

UNIVERSITY *of the*
WESTERN CAPE

Mohamed Farag Abofatira

MSc student in Periodontology

3364551

Supervisor: Prof CJ Nortje

Co-supervisor: Dr MT Peck

A mini-thesis submitted in partial fulfilment of the requirements for the degree of Magister Scientiae in the Department of Oral Medicine and Periodontology, University of the Western Cape

October 2015

A RADIOGRAPHIC ANALYSIS OF THE ANTERIOR PALATE AS A DONOR SITE FOR BONE HARVESTING

Keywords

Alveolar bone

Autogenous bone

Bone augmentation

Dental implants

Cone-beam computed tomography

Palate

ABSTRACT

Autologous bone grafting in conjunction with dental implant therapy is a well-accepted procedure in oral and maxillofacial rehabilitation. A variety of intraoral donor sites, such as the mandibular symphysis, the mandibular ramus and the maxillary tuberosity have been used in oral and maxillofacial reconstruction. However these sites are associated with complications. In order to reduce these complications, the anterior palate has been proposed as a potential donor site. However, the scientific literature in this regard is sparse, and larger studies are required to investigate the clinical potential of this proposed site.

Aim: To determine the volume and density of available bone in the anterior palate that may be used for bone harvesting using cone-beam computed tomography (CBCT) in a select South African population.

Materials and methods: One hundred previously acquired CBCT scans taken at the Diagnostic and Radiology Department of Tygerberg Oral Health Centre were analyzed for the required data. These were all acquired from a single CBCT machine (Newtom VGI®, Verona, Italy). The study sample included 52 females and 48 males ranging from ages 20 years to 80 years. The CBCT scans were divided into 3 different age groups. The first age group was between the ages of 20 and 39 years, the second age group was from 40 to 59 years and the third age group was ≥ 60 years. The volume and density of the anterior palate of the different age groups were analyzed using specific criterion. CBCT specific software (Simplant Pro Crystal®) Dentsply implants, Mannheim, Germany was used to standardize the data collection. All data was stored in a Microsoft Excel spreadsheet (Microsoft Corporation, Washington, USA).

Results: The mean volume of the anterior palate in this study was 2.11 ± 0.55 cm^3, with a minimum volume of 1.04 cm^3 and a maximum volume of 3.82 cm^3. There was no significant difference in the volume and density of the anterior palate between different age groups and no significant difference in the volume between males and females (p value = 0.227). **Conclusions:** The anterior palate affords a considerable amount of bone volume which is similar or even more than other intraoral donor sites. The anterior palate is a potential donor site for bone harvesting and CBCT may be regarded as an ideal tool to analyze the amount of bone available for harvesting.

Declaration

I declare that " A radiographic analysis of the anterior palate as a donor site for bone harvesting" is my own work, that it has not been submitted for any degree or examination in any other university, and that all sources I have used or quoted have been indicated and acknowledged by complete references.

Mohamed Farag Abofatira

October 2015

Signed..................

iii

ACKNOWLEDGMENTS

I would like to express my deep appreciation to my supervisor Prof CJ Nortje and co-supervisor Dr MT Peck who assisted me in this project. Moreover I would like to show my gratitude to my family, friends and colleagues for their moral support throughout the whole process.

CONTENTS

ACRONYM GLOSSARY

CBCT	Cone-Beam Computed Tomography
CT	Computed Tomography
DICOM	Digital Imaging and Communication in Medicine
HU	Hounsfield Unit
PPM	Palatine Process of the Maxilla
STP	Standard Pressure and temperature

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

Literature review

Introduction

A dental implant is a device constructed similar to the root of a tooth. It is surgically inserted into the alveolar ridge *(that part of jaw bone that surrounds and anchors the teeth and runs the entire length, mesiodistally, of both the maxilla and the mandible (Aghaloo and Moy 2008))*, and is used in dentistry to support restorations that substitute a missing tooth or group of teeth (Hernández-Alfaro *et al.* 2005). The alveolar ridge often undergoes physiological horizontal and vertical bone resorption secondary to tooth loss. This leads to a reduction in the amount bone available for implant placement and may compromise the support and the stability of these implants (Szmukler-Moncler *et al*.1998, Aghaloo and Moy 2008).

Besides tooth loss, other factors can lead to alveolar bone loss. These include trauma, periodontal disease, pathology, and disuse atrophy (Hernández-Alfaro *et al.* 2005). Pressure on the alveolar bone is another factor that accelerates the resorption process resulting in edentulous patients with complete dentures experiencing more ridge resorption than edentulous patients who do not wear complete upper and lower dentures.

In order to maximize the amount of bone available for dental implant placement, it is often recommended that areas of severe alveolar bone resorption/loss be surgically reconstructed (Hernández-Alfaro *et al.* 2005). There are many regenerative techniques and materials that have been proposed to stimulate the alveolar bone to form new bone and repair the defects that may be associated with the alveolar bone (Misch 2000). These include harvesting bone directly from the patient, using bone substitutes such as demineralized freeze dried bone, and using alloplastic materials such as hydroxyapatite and tricalcium phosphate (Misch 2000).

Autologous or autogenous bone grafting refers to the procedure of harvesting bone from the same individual who will receive the graft (Jensen *et al.* 2009). Although an additional surgical site is required when using this method, this technique is considered as the gold standard due to the decreased risk of graft rejection and as well as the absence of adverse immunological reactions. These types of grafts also release a large amount of osteogenic growth factors which promote proliferation and differentiation of osteoprogenitor cells i.e osteoinduction. Furthermore they enhance osteoconduction i.e the stimulation of osteoblasts to lay down new bone (Jensen *et al*. 2009).

Autogenous bone used for maxillofacial reconstruction, may be harvested from various sites of the body. The selection of the donor site depends on the type and quantity of bone required and the accessibility to the donor site, the time required, and the cost involved (Raghoebar *et al.* 2007). The mandibular symphysis and the anterior mandibular ramus are often selected as favourable harvesting sites.

Previous studies have shown the complications and morbidity of harvesting bone intraorally or extraorally (Pollock *et al.* 2008). All of these harvesting techniques require surgery at two sites, and therefore the morbidity of the various donor sites must be considered. Of the many possible sites, each has its own advantages and disadvantages.

Extraoral bone harvesting

Extraoral bone harvesting refers to the harvesting of autogenous bone grafts outside of the oral region. It often requires hospitalization and general anesthesia, thereby increasing the cost of treatment. In comparison, intraoral bone harvesting, can in most cases be performed in the dental office under local anesthesia (Pollock *et al*. 2008). Common exraoral harvest sites include; the iliac crest, ribs, calvarium and proximal tibia.

The iliac crest

The iliac crest is often used as a donor site of bone harvesting because of the convenient surgical accessibility and quantity of bone available. The occurrence of complications in this region depends on many factors including the quantity of bone harvested, the age of the patient and the technique that has been used to harvest the bone (anterior vs. posterior). The most common complication of harvesting bone from the iliac crest is donor site pain. This may persist for several months after the operation (Pollock *et al.* 2008). Arterial and neural damage may be associated with harvesting bone from the iliac crest. Nerves that may be injured during harvesting of bone from the iliac crest are ilioinguinal, iliohypogastric, lateral femoral cutaneous, superior gluteal, femoral, and the superior gluteal nerves. Infection of the harvesting site is another complication which may result in cosmetic deformity, and hernia formation (Pollock *et al.* 2008).

Ribs

Using the ribs as a donor site of bone harvesting has many disadvantages. This technique always results in a visible scar on the chest resulting in major cosmetic complications. The incision can however be hidden in the submammary area in women. Pain and pulmonary complications such as atelectasis and pneumothorax has also been reported (Pollock *et al*. 2008).

The calvarium

The calvarium (that part of the human skull made up of the superior portions of the frontal bones, occipital bone, and parietal bones) is also used as a donor site for bone grafts. Both cortical and cancellous bone can be harvested from calvarium bone and the graft site is ideal to reconstruct zygomatic or orbital defects. Tulsa in 1999 reported a successful sinus lift using the calvarium as a donor site. A postoperative drain is however necessary to avoid postoperative heamatoma and seroma formation. Intercranial perforation is one of the major complications when using the calvarium as a donor site (Tulsa 1999).

The proximal tibia

The proximal tibia is widely accepted as a donor site for bone harvesting because a large amount of cancellous bone can be harvested from this area. The quality of bone in elderly patients is less predictable due to deposition of fat in the bone marrow (Raghoebar *et al.* 2007). The morbidity of harvesting bone from this site may include temporary gait disturbance, scarring, and fracture of the tibia plateau (Raghoebar *et al.* 2007).

Intraoral bone harvesting

Facial and calvarial bones are of intramembranous origin, while almost all other bones that are used as a donor sites of bone harvesting are of endochondral embryonic origin (ilium, rib, tibia) (Hassani *et al*. 2005). Harvesting the bone from the jaws has many advantages including an increase in bone quality, ease of access, and close proximity to the primary surgical site (Raghoebar *et al.* 2007).

Many studies have also shown however that there is prolonged postoperative pain at intra-oral donor sites (Raghoebar *et al.* 2007, Clavero and Lundgren 2003, Silva *et al.* 2006). This pain remains for a longer time when the bone is taken from mandibular symphysis, with hypoesthesia of the labial gingiva and altered sensation in the incisors often noted (Raghoebar *et al.* 2007). Silva *et al* (2006) showed similar results and noted an increase in the risk of pulp and soft tissue sensitivity changes, which sometimes does not completely resolve.

Clavero and Lundgren (2003) conducted a study to compare the complications between harvesting bone from mandibular symphysis and ramus of the mandible. They found that harvesting bone from the ascending ramus resulted in less pain and for shorter time as compared to using the mandibular symphysis.

Tulsa (1999) published a summary of different intraoral donor site complications. According to the study, the main complication of harvesting of bone from the mandibular symphysis was endodontic problems, mental nerve paresthesia, and wound dehiscence. On the other hand, inferior alveolar nerve paresthesia was the main complication of harvesting bone from the mandibular ramus and retromolar area. He also noted that there was an increased risk of;

- sinus perforation when harvesting bone from the maxillary tuberosity and zygomatic arch
- inferior alveolar nerve paresthesia as a complication of bone harvesting from the coronoid process
- mucosal dehiscence and lingual nerve paresthesia when using the mandibular torus,

Harvesting bone from the retromolar area may also increase the risk of injury to the inferior alveolar neurovascular bundle (Güngörmüş and Yavuz 2002). However, this conclusion was only based on the outcome of a 12-month postsurgery questionnaire. Therefore further studies are needed to evaluate whether an earlier assessment of the subjective experiences of patients will produce similar results (Güngörmüş and Yavuz 2002).

The anterior palate

Previous studies indicate that the anterior palate may be a potential site for bone harvesting (Hassani *et al.* 2005). Using the anterior palate as a harvesting site may decrease the time and effort of the operation and limit the postoperative pain and edema to one site only. It may also avoid the risk of neural damage associated with harvesting bone from the mandible (Verdugo *et al.* 2010).

In the study carried out by Hassani *et al* (2005), conducted on 21 patients, an osteotomy was performed 2 mm from the bone crest and 3 mm from the incisive foramen at the midline of the maxilla to determine the viability of harvesting bone from the palate. According to the results obtained, the author concluded that the anterior palate of the maxilla is a favourable site for bone harvesting procedures.

Advantages of using the anterior palate as a donor site, include the type of bone obtained from the harvest area. This type of bone develops via intramembranous ossification, and according to experimental evidence, bone that has intramembranous origin undergoes less resorption than bone that has endochondral origin (Oppenheimer *et al.* 2008). The revascularization process also occurs more rapidly in intramembranous bone, thereby enhancing healing (Hassani *et al.* 2005).

Standard diagnostic methods such as clinical examination, pantomography or cephalograms do not provide precise information regarding the amount of available bone at potential intra-oral donor sites (Bernades-Mayordomo *et al.* 2012). Computed tomography (CT) provides detailed and reliable information for pre and postoperative assessment (Bernades-Mayordomo *et al.* 2012). However this is carried out with an increased radiation exposure to the patient. Newer generations of CT devices and improved protocols have sought to reduce this potential problem (Bernades-Mayordomo *et al.* 2012).

Cone-beam computed tomography (CBCT) has provided a convenient tool for the evaluation of the hard tissues in the dentomaxillofacial area and has become increasingly important in the treatment planning of various dental procedures. The advantages include wide accessibility, easy handling and low radiation dose compared to medical CT (Bernades-Mayordomo *et al.* 2012).

Using 20 CBCT scans, Bernades-Mayordomo *et al* (2012) analyzed the available bone volume in the palatine process of the maxilla (PPM). The average bone volume detected in the study was 2.41 ± 0.785 cm^3. This was similar or more in volume when compared to other intra-oral bone harvest sites. Despite the wide use of the mandibular symphysis as a donor site, only limited data is available in the literature. The first paper that analyzed this area was published in 2000 by Montazem *et al*. and according to this study, the mean graft volume was 4.84 cm^3. Two years later, Güngörmüş and Yavuz (2002) published a study analyzing the ascending ramus of the mandible for bone harvesting. They found that the mean volume was 2.36 ± 0.46 cm^3. No CT scans were performed in either of the two papers. Kainulainen *et al* (2004) published a study measuring the zygomatic bone. Although significantly less bone was available, the study was the first study in which medical CT scans were used to study the amount of bone volume that can be harvested from the zygomatic bone.

A summary of previous studies analyzing the volume of bone available for intraoral harvesting is displayed in Table 1 (from Bernades-Mayordomo *et al.* 2012).

Table 1. Summary of previous studies analyzing the volume of bone that can be harvested from various intraoral donor sites (from Bernades-Mayordomo *et al.* 2012).

Authors	Area of study	Total number of cases	Mean volume
Montazem *et al*. (2000)	Mandibular symphysis	16 dry skulls	4.8 cm^3 (3.25-6.5)
Güngörmüş and Yavus (2002)	Mandibular ramus	16 dry skulls	2.36 cm^3
Kainulainen *et al* (2004)	Zygomatic	20 cadavers 40 samples	0.53 cm^3 0.59 cm^3
Hassani *et al* (2005)	Palate	21 dry skulls	2.03 cm^3 Dentulous 2.4 cm^3 Edentulous

Bone density

Bone density is defined as the amount of mineral matter per square centimeter. It is an important factor to consider when placing dental implants, since an area of poor bone density may influence the initial stability of the dental implant. This ultimately affects the long term prognosis of the device.

Bone quality on the other hand, is a poorly defined term often used in implant dentistry. It encompasses a wide range of properties including bone density, shape and orientation of the trabeculae, matrix properties and skeletal size. The quality of bone at the implant site is an important factor in predicting the success of dental implants (Drage *et al*. 2007, Lindh *et al*. 2004).

Measuring maxillofacial bone density using CT and CBCT imaging

Periapical or panoramic radiographs are inconclusive when determining bone density of the alveolar bone because the lateral cortical plates often have a vague trabecular pattern that make density analysis difficult. In addition, the more restrained changes in bone density cannot be quantified using these radiographs. CT and CBCT imaging are currently used to determine information about bone and its density, especially in the field of implant dentistry (Prashant *et al.* 2014).

Hounsfield units (HU) are standard numbers originating from CT imaging. It represents the relative density of body tissues according to a calibrated gray-level scale as determined by the linear transformation of the original linear attenuation coefficient measurement in which the radio-density of distilled water at standard pressure and temperature (STP) is defined as zero, whereas the radio density of air at STP is defined as -1000 HU. It is also referred to as CT number or Hounsfield number. It is used to analyze tissue density associated with CT imaging. CBCT however, cannot be used to determine HUs, therefore software specific algorithms are used to give some indication of bone density.

Shapurian *et al* (2006) studied the bone density of all four quadrants of the mouth. The highest unit/mean density value (559 ± 208 HU) was found in the anterior mandible, followed by 517 ± 177 HU for the anterior maxilla, 333 ± 199 HU for the posterior maxilla, and 321 ± 132 HU for the posterior mandible. There was no association between the Hounsfield value and density, age or gender. When subjective bone quality was correlated to Hounsfield index findings, only the relationship between HU and type 4 bone was found to be significant (Shapurian *et al.* 2006).

In a study conducted by Prashant *et al* (2014) the author measured the bone density at dental implant sites using CT imaging and Dentascan® software (GE Healthcare, Fairfield, USA). He concluded that there was no significant correlation between bone density and age, sex, jaw, zone of the arch or side of the arch.

According the literature, no studies measuring the bone density of the anterior palate of a South African population sample has yet been carried out.

Study rationale

A limited amount of studies have investigated the anterior palate as a potential donor site for harvesting bone in maxillofacial procedures (Hassani *et al.* 2005, Bernades-Mayordomo *et al.* 2012). In both of these studies the sample size was small and therefore further research that requires a larger sample size to determine the validity of the previous findings is warrented.

CHAPTER 2

AIM AND OBJECTIVES

Aim

- To determine the volume and density of available bone in the anterior palate that may be used for bone harvesting using cone-beam computed tomography (CBCT) in a select South African population.

Objectives

- To determine the volume of bone in the anterior palate of different age groups.
- To determine the density of bone in the anterior palate
- To determine whether there was any significant difference in the volume of bone in the anterior palate between males and females.
- To determine whether there was any significant correlation between palatal bone density and gender.
- To determine whether there was any significant correlation between palatal bone density and age.

Null hypothesis

- Palatal bone density is similar, irrespective of age.
- The amount of bone available for bone harvesting in the anterior palate is significantly different between males and females.

Rationale

- A few previous studies indicate that the anterior bony palate may provide sufficient bone for bone harvesting. These studies included only a few samples each. Larger sample sizes are required to integrate these objectives in a scientifically rigorous study.

CHAPTER 3

MATERIALS AND METHODS

Study design

The study was a cross sectional analytical study of measurements obtained from CBCT images

Study sample

This study was conducted according to the principles outlined in the Declaration of University of Western Cape. Ethical approval was obtained from the ethical committee of clinical research of The University of Western Cape with ethical registration number 14/5/40.

The study sample comprised of 100 CBCT scans that met the selection criteria. The images were obtained from the patient database at the Diagnostic and Radiology Department in Tygerberg Oral Health Centre.

Selection criteria

Inclusion criteria:

- Previously taken CBCT scans of the anterior maxilla of patients above the age of 20 years old (physical growth completed).

Exclusion criteria:

- Developmental malformation of the maxilla
- Tumors or cysts of the hard palate.
- Impacted teeth in the study area.
- Patients with a history of previous maxillofacial surgery in the anterior palate.

Data collection and analysis

Data was collected from CBCT images that were previously taken at the Diagnostic and Radiology Department of Tygerberg Oral Health Centre using the Newtom VGI® (Verona, Italy) 3D imaging machine. The radiology parameters used were (110KV and 5 mA: the axial slice default distance was 0.3 mm and the voxel size was 0.3 mm). The images were stored as DICOM (Digital Imaging and Communication in Medicine) files. These were files opened and analyzed using Simplant Pro Crystal® (Dentsply implants, Mannheim, Germany) software.

In order to create reproducible measurements the same process as described by Bernades-Mayordomo was fallowed ;

1. The dataset of the patient was opened with SimPlant.
2. 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.
3. In Segmentation mode, a mask was created marking the starting point of the bone.
4. All irrelevant areas to the study were again eliminated.
5. Maximum quality was set for 3D.
6. In Planning preparation mode, a panoramic curve was created to facilitate the readings on the different spatial planes.
7. 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).
8. Two mm safety margin was established from tooth 14 to 24 with a margin of error of 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.
9. The same procedure was followed for the mesial and distal views wherever an adjacent tooth was not observed (usually in the longest canine roots) .
10. Two 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).

11. Two mm safety margin was also set wherever the maxillary sinus appeared in the most cranial slices. Once this protocol was implemented, a surface was created by connecting these points plus those created at the posterior bony margin.
12. For the purpose of quantitative volumetric analysis, a three-dimensional (3D) image of the delimited zone was constructed.

***Figure 1**. Axial caudal slice of the palate showing the intended area of analysis.

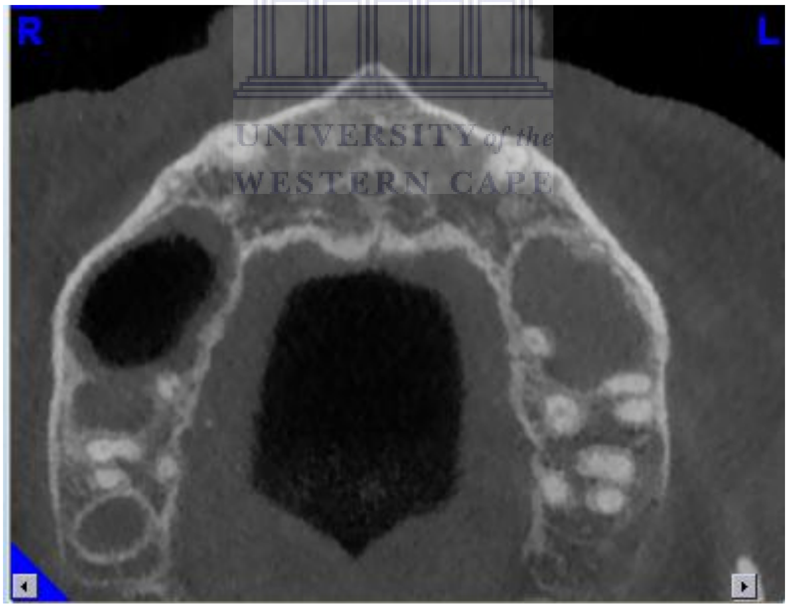


Figure 2. Axial middle slice of the palate.

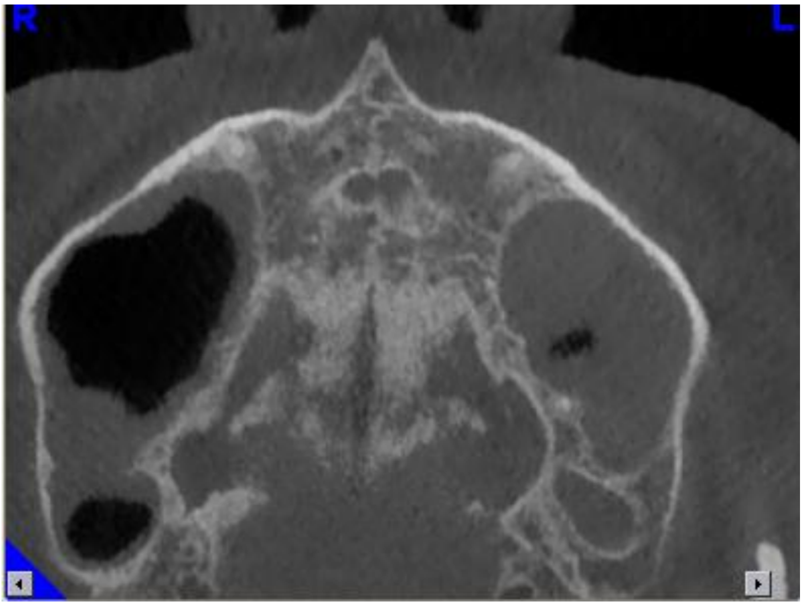
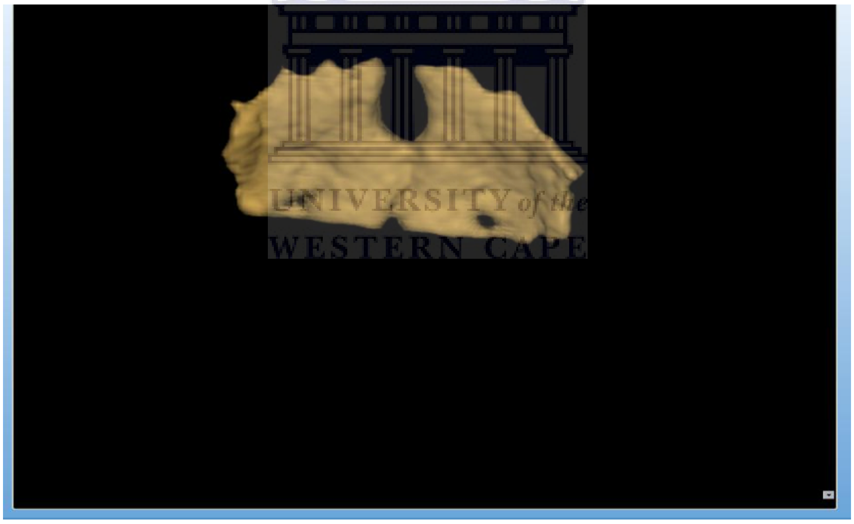


Figure 3. Axial cranial slice of the palatal roof.



! **Figure 4.** 3-dimensional reconstruction of the anterior palate.

* Area of interest defined using Microsoft Word®, (Microsoft Corporation, Washington, USA).

! 3-D reconstruction obtained using the NNT 2.21® software program (Newtom®,Verona,Italy).

CHAPTER 4

RESULTS

One hundred CBCT scans were analyzed. The study sample included 52 females and 48 males (Table 2). The scans were divided into 3 different age groups. The first age group was between the age of 20 and 39 years, the second age group was from 40 to 59 years and the third age group was ≥ 60 years.

Table 2: Study sample

Gender	Frequency
Male	48
Female	52
Total	**100**

The volumetric and density measurements of the anterior palate are displayed in Table 3. The mean graft volume of the anterior palate was 2.11 ± 0.55 cm^3. There was no statistically significant difference in the mean bone volume for the different age groups tested (p = 0.35) (Table 4). The mean bone volume was also not statistically significantly different for the different genders (p = 0.22). The oldest age group however showed the highest amount of bone available (Table 4).

The mean density as measured in HUs of the anterior palate was found to be slightly higher in males (Table 5). However, this was not statistically significant. Although there was no significant difference in bone density between males and females, the age groups showed variable distribution with the bone density found to be slightly higher in youngest age group (Table 6). This was not statistically significant.

Table 3: Volumetric and density measurements of the anterior palate

Number	Gender	Age	Volume (cm3)	D1	D2	D3	D4	D5	D6
1	2	48	2.42	860	633	443	575	186	1186
2	1	44	1.23	683	554	982	1043	1319	1205
3	2	38	1.56	872	623	1023	923	1200	1466
4	2	26	2.13	785	579	881	748	878	1175
5	1	33	1.79	920	564	765	1042	569	1431
6	2	52	1.04	847	697	958	726	804	1049
7	2	29	1.45	789	881	393	807	207	1514
8	1	31	1.41	1225	1064	847	682	912	976
9	1	67	1.32	804	618	1019	658	725	861
10	2	25	2.34	566	357	569	535	508	987
11	2	42	1.35	1086	434	747	929	994	1120
12	2	47	1.88	1138	660	784	1081	511	967
13	1	57	1.22	1530	1330	934	1200	554	1545
14	2	49	1.52	1204	628	750	630	355	1120
15	1	43	1.47	1118	468	1100	847	1057	1161
16	1	60	3.82	936	257	497	540	398	788
17	1	59	2.63	978	646	849	879	561	1135
18	2	26	1.4	994	813	714	489	239	775
19	2	20	1.8	1062	1001	1093	667	1003	667
20	2	36	2.49	565	456	515	593	450	1034
21	1	46	1.79	846	725	923	749	923	1161
22	1	51	1.88	994	623	358	704	217	1129
23	1	42	2	951	520	1029	901	818	1194
24	2	51	1.32	773	414	941	639	448	468
25	1	44	1.99	845	685	998	823	1136	1203
26	1	52	1.51	824	727	931	888	465	1338
27	1	35	2.34	1043	902	1203	796	1003	963
28	1	48	1.89	1140	635	810	869	723	1164
29	2	50	1.6	942	758	763	833	602	968
30	2	52	1.71	1035	927	959	1012	634	1089
31	2	54	1.32	792	697	341	860	349	913
32	2	35	1.45	990	969	1043	833	1008	1375
33	1	25	1.82	1012	989	1039	986	761	1001
34	1	51	1.47	752	824	760	834	789	1227
35	1	70	1.59	929	781	935	931	734	989
36	2	30	2.04	669	657	264	601	334	1249
37	2	63	1.62	690	329	524	598	893	899
38	2	52	1.13	827	509	552	745	254	1203

Number	Gender	Age	Volume (cm3)	D1	D2	D3	D4	D5	D6
39	1	53	3.31	1237	834	1056	719	707	1396
40	2	58	2.2	857	657	681	894	666	1066
41	1	30	2.34	945	732	874	876	1136	1003
42	2	50	1.48	1179	905	804	739	631	873
43	1	54	1.84	551	374	591	685	260	849
44	1	24	1.09	543	418	852	808	641	999
45	2	28	1.17	653	844	753	695	632	896
46	1	20	1.64	958	1105	1005	1036	846	1139
47	2	25	1.67	926	889	1169	1172	1045	1120
48	2	29	1.58	1085	622	347	843	305	974
49	2	34	1.55	975	952	1011	697	469	976
50	1	72	1.89	1037	989	998	1036	849	1006
51	2	25	1.82	501	725	980	946	901	999
52	1	61	3.1	900	453	587	796	750	987
53	1	78	2.5	620	544	753	707	277	910
54	2	53	2.38	764	700	518	680	363	723
55	1	53	1.22	698	568	599	784	367	946
56	2	74	1.57	616	576	558	844	356	738
57	2	28	1.48	845	847	655	959	1214	1056
58	2	25	1.8	609	498	782	864	1332	1120
59	2	38	1.25	900	713	739	750	369	1556
60	2	38	2.09	850	667	719	825	263	1011
61	2	35	1.32	618	499	252	1093	265	839
62	1	70	1.43	782	569	638	1004	800	936
63	1	36	2.12	706	523	888	794	846	1010
64	2	26	2.93	793	696	473	946	989	1046
65	1	72	2.99	888	569	746	963	749	989
66	1	62	2.24	989	529	343	879	799	1132
67	2	35	1.67	1002	475	510	735	293	864
68	1	38	2.35	1023	869	978	566	844	799
69	2	53	1.19	956	741	729	759	643	776
70	2	80	1.58	635	526	724	738	422	852
71	2	55	1.83	767	688	694	794	707	922
72	2	27	1.44	876	766	611	850	1019	664
73	1	55	1.5	1042	697	797	899	631	874
74	1	35	1.67	1066	987	1011	1233	700	1344
75	2	60	1.22	555	384	481	469	557	579
76	2	34	2.36	665	548	565	1133	463	744
77	1	53	1.95	1023	965	1027	822	539	746

Number	Gender	Age	Volume (cm3)	D1	D2	D3	D4	D5	D6
78	2	25	1.13	1136	1055	850	818	1053	1158
79	1	27	2.43	699	471	725	1003	846	1211
80	2	34	1.66	1002	865	798	988	423	633
81	1	33	2.57	912	765	821	1326	896	1166
82	1	46	2.17	897	759	1006	763	976	1004
83	2	56	1.68	704	527	772	947	409	879
84	1	59	1.43	765	648	693	798	646	1019
85	1	43	1.87	865	698	987	963	1169	1008
86	2	62	2.1	701	469	689	569	501	798
87	1	24	1.33	1027	769	937	857	1124	931
88	1	51	1.69	956	856	1003	899	712	974
89	1	25	1.12	746	694	524	799	720	1011
90	1	56	1.33	1006	987	934	761	760	799
91	2	55	1.78	801	423	399	650	321	703
92	2	66	1.9	703	572	1009	744	962	950
93	1	45	2.33	746	675	963	879	1136	989
94	1	53	2.44	665	384	413	649	601	820
95	2	26	1.32	946	561	679	567	499	677
96	1	54	3.4	1033	770	890	976	788	801
97	2	20	1.54	966	897	787	864	977	1049
98	2	55	1.59	794	569	469	797	455	879
99	2	51	1.6	846	659	749	879	566	788
100	1	62	1.43	985	523	459	879	888	1078

1= male

2= female

D1 = the density of the middle of the palate in caudal slice.

D2 = the density of the bone at the half way between the lower surface and the upper surface of the middle part of anterior palate.

D3 = the density of the roof of the middle of the palate.

D4 = the density of the lower surface of the middle part of the palate in axial slice.

D5 = the density of the half way between the middle part and the lateral side of the lower surface of the palate.

D6 = density of the side of the lower surface of the palate.

Table 4: The mean bone volume for different age groups

Age group in years	Mean volume
20-39	2.06 cm^3
20-59	2.09 cm^3
60 +	2.27 cm^3

Table 5: The mean bone density of the anterior palate of males and females

Gender	Mean density
Male	763.8958 HU
Female	613.9808 HU

Table 6: The mean density of the anterior palate of different age groups

Age group	Mean
20-39	730.6744 HU
40-59	646.7073 HU
60+	666.25 HU

CHAPTER 5

DISCUSSION AND CONCLUSIONS

Previous studies and clinical experience have demonstrated the effectiveness and reliability of the anterior palate as a donor site for bone harvesting. A literature search using Pubmed®, revealed that studies analyzing the anterior palate as a donor site for bone harvesting using CBCT with a sample size of more than 20 has not yet been published.

Hassani *et al* (2005) were the first to report on the volume of bone available from the anterior palate. According to this study the mean volume of bone that can be harvested from the anterior palate is 2.03 ± 0.5 cm^3 in dentate patients and 2.40 ± 0.75 cm^3 in edentulous patients.

In a retrospective study published by Bornstein *et al* (2008), 1817 dental implants that were placed over a 3 years in a specialist clinic were analyzed. Bone augmentation procedures were required for the majority of implants placed (51.7%). Although implant placement in the anterior maxilla in conjunction with bone augmentation is common, only 3 papers making use of the palatal bone graft method have been found in the literature. The first study was conducted by Hernández-Alfaro et al (2005) in which they described a surgical technique for 3D alveolar defects reconstruction in 17 cases. The second study published by Hassani *et al* (2005) on 21 cadavers with slight modifications of Hernández-Alfaro et al technique. The third study was conducted by Rodrı´guez-Recio *et al* (2010), in which they presented 2 cases using the palatal bone graft with an onlay technique in the first case and sinus floor augmentation in the second.

Agbaje *et al* (2007) measured the amount of bone that can be harvested from the socket of the tooth from the maxillary right first premolar to the maxillary left first premolar. The mean volume in that study was 0.23 ± 0.12 cm^3. The mean volume that can be harvested from the anterior palate in this study is 2.11 ± 0.55 cm^3 and is significantly more than that from can be harvested from the socket. The potential amount of bone that can be harvested from the palate therefore appears to be larger than that from other potential intra-oral donor sites. Moreover the anterior palate provides both intramembranous and corticocancellous bone thereby allowing for potentially better healing.

In this study 100 CBCT scans were analyzed. No correlation was observed between gender and volume of bone in the anterior palate of the maxilla. Therefore the amount of bone that can be harvested from the anterior palate of males is similar to that of females. However the density of the younger age group was slightly higher than the other groups which may indicate that bone density decreases with increasing age in this study sample (Table 6).

Although the aim and the primary objectives of the study were achieved, further research is needed in order to answer several questions including; which surgical technique approach is best for bone harvesting from the anterior palate region, as well as a suitable way to define an adequate safety zone for each single case to avoid or minimize risks and complications. More research is required to compare the data between different centers and population groups.

Conclusions

It can be concluded that the anterior palate affords a considerable amount of bone volume which is similar or even superior to that of other intraoral donor sites. The anterior palate should be regarded as a potential donor site for bone harvesting. CBCT may be regarded as an ideal tool to analyse the amount of bone available for harvesting. Further clinical research is required to determine whether the data presented can be translated into any clinically significant results.

REFERENCES

- Agbaje, J.O., Jacobs, R., Maes, F., Michiels, K., & Van Steenberghe, D., 2007. Volumetric analysis of extraction sockets using cone beam computed tomography: a pilot study on ex vivo jaw bone. *J Clin Periodontol*. (34):985–90.
- Aghaloo, T.L., & Moy, P.K., 2008. Which hard tissue augmentation techniques are the most furnishing bony support for implant placement? *Int J Oral Maxillofac Implants.* 22 (3): 192-203.
- Bernades-Mayordomo, R., Guijarro-Martinez, R., & Hernández-Alfaro, F., 2012. Volumertric CBCT analysis of the palatine process of the anterior maxilla: a potential source for bone grafts. *Int J Oral Maxillofac Surg.*(42): 406-410.
- Bornstein, M.M., Halbritter, S., Harnisch, H., Weber, H.P., & Buser, D., 2008. A retrospective analysis of patients referred for implant placement to a specialty clinic: indications, surgical procedures, and early failures. *Int J Oral Maxillofac Implants*. (23):1109–16.
- Clavero, J., & Lundgren, S., 2003. Ramus or chin grafts for maxillary sinus inlay and local onlay augmentation: comparison of donor site morbidity and complications. *Clin Implant Dent Relat Res*. 5 (3): 154- 160.
- Drage, N.A., Palmer, R.M., Blake, G., Wilson, R., Crane, F., & Fogelman, I., 2007. A comparison of bone mineral density in the spine hip and jaws of edentulous subjects. *Clin Oral Implants Res.* (18): 496-500.
- Güngörmüş, M., &Yavuz , M.S., 2002. The ascending ramus of the mandible as a donor site in maxillofacial bone grafting. *J Oral Maxillofac Surg.* (60):1316-6.
- Hassani, A., Khojasteh, A., & Shamsabad, A.N., 2005. The anterior palate as a donor site in maxillofacial bone grafting. *J Oral Maxillofac* Surg. 63 (8): 1196-200.
- Hernández-Alfaro, F., Pages, C.M., García, E., Corchero, G., & Arranz, C., 2005. Palatal core for alveolar reconstruction: a new donor site. *Int J Oral Maxillofac Implants.* 20 (5): 777-782.
- Jensen, S.S., Bosshardt, D.D., & Buser, D., 2009. Bone grafts and Bone fillers for GBR procedures. In: 20 years of guided bone regeneration in implant dentistry. editor. London, UK: Quintessence Publishing: 71-96.

- Kainulainen, V.T., Sandor, G.K., Clokie, C.M., Keller, A.M., & Oikarinen K.S., 2004. The zygomatic bone as a potential donor site for alveolar reconstruction- a quantitative anatomic cadaver study. *Int J Oral Maxillofac Surg.* (33):786-91.
- Lindh, C., Obrant, K., & Petersson, A., 2004. Maxillary bone mineral density and its relationship to the bone mineral density of the lumbar spine and hip. *Oral Surg Oral Med Oral Pathol Oral Radiol*. (98): 102-109.
- Misch, CM., 2000. Use of mandibular ramus as a donor site for onlay bone grafting. *J Oral Implantol.* 26 (1): 42-9.
- Montazem, A., Valuari, D.V., St-Hilaire, H., & Buchbinder, D., 2000. The mandibular symphysis as a donor site in maxillofacial bone grafting: a quanitative anatomic study. *J Oral Maxillofac Surg*. (58):1368-71.
- Oppenheimer, A.J., Tong, L., Buchman, S.R., 2008. Craniofacial Bone Grafting: Wolff's Law Revisited. *Craniomaxillofac Trauma Reconstr*. 1(1):49-61. doi: 10.1055/s-0028-1098963.
- Pollock, R., Alcelik, I., Bhatia, C., Chuter, G., Lingutla, K., Budithi, C., & Krishna, M., 2008. Donor site morbidity following iliac crest bone harvesting for cervical fusion: a comparison between minimally invasive and open technique. *Eur Spine J.* 17 (6):845-852.
- Prashant, V., Suvarna., Prashant, P., Jaju1., Arun, V., Subramaniam., Sanjay Jain, D. Y., Patil Dental., Pimpri., Pune ., Nashik., Maharashtra., Reader., & Rangoonwala., 2014. Density evaluation of pre-implant sites by dentascan software. *Int J Clin Dent Res Organization*. IP: 196.(11).235.231.
- Raghoebar, G.M., Meijndert, L., Kalk, W.W., & Vissink, A., 2007. Morbidity of mandibular bone harvesting: a comparative study. *Int J Oral Maxillofac Implants.* 22(3):359-65.
- Rodrı´guez-Recio, O., Rodrı´guez-Recio, C., Gallego, L., & Junquera, L., 2010. Computed tomography and computer-aided design for locating available palatal bone for grafting two cases reports. *Int J Oral Maxillofac Implants.* 25 (1):197-200.
- Shapurian, T., Damoulis, P.D., Reiser, G.M., Griffin, T.J., & Rand, W.M., 2006. Quantitative evaluation of bone density using the Hounsfield index. *Int J Oral Maxillofac Implants.* Mar-Apr; 21(2):290-7.

- Silva, F.M., Cortez, A.L., Moreira, R.W., & Mazzonetto, R., 2006. Complications of intraoral donor site for bone grafting prior to implant placement. *Implant Dent.*15 (4):420- 426.
- Szmukler-Moncler, S., Salama, H., Reingewirtz,Y., & Dubruille, J.H.,1998. Timing of loading and effect of micromotion on bone dental implant interface. *Implant Dent*. 4 (2): 192-203.
- Tulsa, J.F., 1999. A study of 55 cases using autogenous bone graft augmentation .*Rev Stomatol Chir Maxillofac.* 100:265-266.
- Verdugo, F., Simonian, K., Smith, McDonald, R., & Nowzari, H., 2010. Quantitation of mandibular symphysis as a source of bone grafting. *Implant Dent Relat Res.* 12(2): 99-104.

APPENDIX

Office of the Deputy Dean
Postgraduate Studies and Research

Faculty of Dentistry & WHO Collaborating Centre for Oral Health

UNIVERSITY OF THE WESTERN CAPE
Private Bag X1, Tygerberg 7505
Cape Town
SOUTH AFRICA

Date: 6th June 2014

For Attention: Dr MF Abofatira (St. No. 3364551)
Faculty of Dentistry
Tygerberg Campus

Dear Dr Abofatira

STUDY PROJECT: **Radiographic analysis of the anterior palate as a donor site of bone grafting**

PROJECT REGISTRATION NUMBER: 14/5/40

ETHICS: **Approved**

At a meeting of the Senate Research Committee held on Friday 6th June 2014 the above-mentioned project was approved. This project is therefore now registered and you can proceed with the study. Please quote the above-mentioned project title and registration number in all further correspondence. Please carefully read the Standards and Guidance for Researchers below before carrying out your study.

Patients participating in a research project at the Tygerberg and Mitchells Plain Oral Health Centres will not be treated free of charge as the Provincial Administration of the Western Cape does not support research financially.

Due to the heavy workload auxiliary staff of the Oral Health Centres cannot offer assistance with research projects.

Yours sincerely

Professor Sudeshni Naidoo

Tel -27-21-937 3148 (w); Fax -27-21-931 2287 e-mail: suenaidoo@uwc.ac.za