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Microcomputed tomography cortical bone evaluation for craniofacial implantology

Процена кортикалне кости микро компјутерском томографијом за краниофацијалну имплантологију

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Процена кортикалне кости микро компјутерском томографијом за краниофацијалну имплантологију

SUMMARY

Introduction/Objective Good implant stability is one of the most important factors for successful implant therapy. This precondition is important to all kind of implants, oral and extra-oral (EO) ie. Craniofacial implants as well. One of the most important factors for satisfactory implant stability is the bone quality, particularly of the cortical bone, which is determined by its microarchitectural parameters.

The aim of this paper was to assess cortical bone microarchitectural parameters in the targeted regions for craniofacial implant placement.

Methods Bone quality on targeted localisations was determined by Micro CT method on cadaver model. The target places for implant placement were: periorbital, perinasal and periauricular region. Microarchitectural parameters included cortical thickness (Ct.Th), cortical porosity (Ct.Po), pore diameter (Po.Dm) and pore separation (Po.Sp).

Results The smallest cortical porosity, (Ct.Po. 4.1 %) and the largest pore separation (Po.Sp. 0.5 mm), were determined in glabella. The maximum cortical thickness was found in the zygomatic region (Ct.Th. 2.7 mm) as well as pore diameter (Po.Dm. 0.2 mm). The mastoid part of the temporal bone showed the smallest cortical thickness (Ct.Th.1.2 mm) and pore separation (Po.Sp. 0.3 mm). Highest cortical porosity was in the perinasal region (Ct.Po. 8.5%).

Conclusion The bone quality measured through microarchitectural parameters was good in all the regions of interest for the disk and screw shape EO implant anchorage.

Keywords: microarchitecture, bone quality, micro ct

САЖЕТАК

Увод/циљ Добра стабилност имплантата један је од најважнијих фактора за успешну имплантолошку терапију. Овај предуслов је применљив на све типове имплантата, оралне и екстра оралне, ЕО краниофацијалне имплантате. Један од најважнијих фактора за задовољавајућу стабилност имплантата је квалитет кости, нарочито кортикалне кости, што је одређено микроархитектонским параметрима.

Циљ је био процена микроархитектонских параметара кортикалне кости на циљаним регијама за постављање краниофацијалних имплантата.

Методе Квалитет кости на циљаним локализацијама одређен је *Micro CT* методом на кадаверичном моделу. Регије од интереса за постављање имплантата биле су: периорбитална, периназална и периаурикуларна регија. Испитани микроархитектонски параметри су: кортикална дебљина (*Ct.Th*), кортикална порозност (*Ct.Po*), пречник пора (*Po.Dm*) и сепарација пора (*Po.Sp*).

Резултати Најмања кортикална порозност (*Ct.Po* 4,1 %) и највећа сепарација пора (*Po.Sp.* 0,5 *mm*) утврђени су у глабели. Највећа дебљина кортекса пронађена је у зимоматичкој регији (*Ct.Th.* 2,7 *mm*) као и пречник пора (*Po.Dm.* 0,2 *mm*). Мастоидни део темпоралне кости показао је најмању кортикалну дебљину (*Ct.Th.*1,2 *mm*) и сепарацију пора (*Po.Sp* 0,3 *mm*). Највећа кортикална порозност била је у периназалној регији (*Ct.Po.* 8,5%).

Закључак Квалитет кости измерен микроархитектонским параметрима био је задовољавајући у свим регијама од интереса за сидрење ЕО диск и имплантата облика шрафа.

Кључне речи: микроархитектура, квалитет кости, микро цт

INTRODUCTION

Patients with different facial defects (orbital, nasal, auricular) are indicated for craniofacial implant therapy and prosthetic rehabilitation. Majority of them have undergone previous tumor resections, which could cause the lack of the bone needed for implant placement. Good implant stability is important for stable maxillofacial prosthesis anchorage [1, 2]. One of the most important factors for successful implant therapy is the bone quality and quantity [3]. For this reason, implant therapy should be well planned and carefully carried out. For craniofacial implant stabilization, microarchitectural parameters of cortical bone in the targeted implant placement points are particularly important. [2, 3]. Periorbital, perinasal and periauricular region which are used for implant anchorage, have different bone microstructure, which could affect the final outcome of the implant therapy [3]. Microtomography (micro-computed-tomography, micro CT) is a method to image and quantify bone tissue. It has the capability to assess the architecture and the mechanical properties of the bone [4].

The aim of this paper was to assess cortical bone microarchitectural parameters in the targeted regions for craniofacial implant placement.

METHODS

The research was performed at the Laboratory for Anthropology, Institute of Anatomy, School of Medicine, University of Belgrade. The study was reviewed and approved by the Committee on Ethics of the School of Dental Medicine, University of Belgrade (No. 36/14).

A young Caucasian adult's dry scull from the collection of the Laboratory for Anthropology, Scholl of Medicine, University of Belgrade was selected in order to perform the micro CT analysis of the targeted implant placement areas and to evaluate the microarchitectural parameters which define the quality of the cortical bone. Sexually demographic characteristics were moderately expressed, thus the skull used, presented an average anatomical sample for the situation.

According to the implant placement points for maxillofacial prosthetic rehabilitation following locations were selected; for nasal implants - glabellar part of the frontal bone and lateral walls of the nasal pyramid; for orbital implants - upper and lower (cranial and caudal) lateral edges of the orbit and the body of the zygomatic bone; for auricular implants – the petrous part of the temporal bone. (Figure 1.)

Based on these targeted implant placement points, the areas for Micro CT scanning were selected: Supraorbital margin - orbit, body of the zygoma, glabella, mastoid process, piriform aperture.

Low Speed Diamond Saw (SYJ-160, MTI) was used to excise bone specimens from the five sites of the skull that correspond to the common implant placement sites in patients (Figure 1).

The specimens were scanned at the Department of Radiology, School of Dental medicine, University of Belgrade.

The scanning was performed in a bone window with a voltage of 120 kV and a tube current of 40 mAs. A total of 179 axial sections were obtained with a single slice thickness of 0.75 mm.

Each bone sample was scanned in dry state at a resolution of 10 μm using microcomputerized tomography (SkyScan 1172 x-Ray Microtomography, SkyScan, Kontich, Belgium). Acquisitions were performed on 85 kV voltages, 118 μA pipe current, 1000 ms time exposure, 0.5 mm thick aluminum and copper filter, and 180 ° rotation. The obtained images were reconstructed using NRecon v.1.6.9.8 software with a beam hardening correction of 25%, a ring artefact with a correction of 18%, and a reduction of 2. The images were then analyzed using CTAn 1.14.4.1 software. 3D reconstructions were made (Figure 2).

The following microarchitectural parameters were evaluated: Cortical thickness, Cortical porosity, Pore diameter and Pore separation. (Table 1.)

RESULTS

The obtained results were based on Micro CT scanning evaluation of the microarchitectural parameters in five different positions (Figure 1).

The smallest cortical porosity (Ct.Po 4.1 %) was determined in the glabella, which suggests that this region has the densest cortical bone. The maximum pore separation (Po.Sp. 0.5mm) and the small pore diameter (Po.Dm 0.1 mm) also speak in favor of dense glabellar cortical bone. Moreover, glabellar cortical thickness showed value of 1.5 mm. The maximum cortical thickness (Ct.Th 2.7 mm) was found in the zygomatic region, as well as the maximum pore diameter (Po.Dm 0.2 mm). In the orbital region, the value of cortical thickness was also high (Ct.Th.1.9 mm), although the porosity was somewhat higher (Ct.Po. 6.7 %), which tells about thick, but porous cortex. The mastoid part of the temporal bone showed the minimum thickness of the cortical bone (Ct.Th.1.2 mm), as well as the smallest pore separation (Po.Sp 0.3 mm). Perinasal region showed the highest porosity values (Ct. Po 8.5%) (Table 2).

DISCUSSION

Bone tissue is showing organization from smaller (nano, micro) to larger (macro) length scales. However, there is a shortage of qualitative information on cortical bone thickness, porosity, as well as on the distribution and size of pore in mid face region and cranium. Therefore, the essence of the present research was to investigate how cortical bone variates in micro architectural parameters in areas of interest for craniofacial implant placement [5,6]. Extra oral (EO) implants are used for anchoring maxillofacial epithesis. A reliable and clinically verified implant therapy includes production of freestanding implant-supported prosthesis [7]. Generally, EO screw type implants are widely used for this purpose. Due to the anatomical features and thickness of the bone available, the use of conventional EO screw-shaped implants is limited. Good anchoring of enosseal implants requires sufficient bone volume and density [1, 8]. In the case of bone resection, only a small amount of cortical bone is usually left behind. Hence, particularly in the mid face area, anchorage of screw-type implants is compromised. The usual locations for screw implant placement are the glabella, mastoid part of temporal bone and upper ridge of orbit. Vertical or even horizontal bone dimensions are often limited after surgery, for example nasal amputation, thus screw type implants often cannot be used [1, 3]. However, disk implants present an optimal alternative whenever implants-retained craniofacial epithesis are indicated, especially when ‘‘vertical’’ bone substance is limited, because such implants require width rather than height of bone. Since the thickness of the disk implant plate is 0.6 mm, the minimum amount of the cortical bone where the disk implant could be placed is, at least 1 mm, which is far less than minimal requirements for EO screw implants [9, 10]. Disk implants are bi- or multicortically anchored to the cortical bone. The basic premise is that these implants should have absolute primary stability in cortical bone on each side of the disk-plate. The functional load is transferred to the cortical/basal part of the bone [9, 10].

One of the most important factors in the implant therapy is the bone tissue quality. The bone tissue was evaluated and categorized over the years, by different authors. [11-15] However, not a single classification was directly correlated to the implant therapy success. It is not possible to predict the subtle differences in bone quality when applying either the Lekholm and Zarb [11] or Misch [12] classifications, respectively. For this reason, Trisi and Rao [13] and Norton and Gamble [14] demonstrated that subjective methods of evaluating bone quality assessment are useful only when clinically assessing up to three classes of bone quality [15].

In spite of this, the use of CT/CBCT methods to estimate the degree of bone density is not so often implemented by implantologists.

Nevertheless, the microarchitecture of the bone has the impact on the success of the implant therapy. Microarchitectural parameters like Cortical thickness, Pore diameter, Cortical porosity and Pore separation can tell a lot about the bone characteristics, and help to predict the outcome of the EO implant therapy in a certain region of the cranium [3, 16] .

Micro CT evaluation can provide an insight to biomechanical properties of mid facial bones, their thick cortical bone structure, zones of strength, as well as the areas containing thin cortical bone which are considered weak and fragile. However, recent studies revealed that bone of the mid-facial skeleton exhibit remarkable regional variations in structure and elastic properties. These variations have been frequently suggested to result from the different involvement of cortical and trabecular bone in the transfer of forces. Which is why the precise evaluation of the areas intended for implantation was of importance [17, 18, 19].

By examining the microarchitecture of the cortical bone in the orbit, glabella, peripheral region of the aperture piriformis, zygomatic bone, it was understood that the qualitative value of the cortical bone tissue in these localizations was optimal for insertion of disk implants, that are cortically anchored, which is a good alternative for retention of maxillofacial prothesis. This bone area is typically resistant to infection because of its high mineralization. Furthermore, these bone areas are stable to resorption [3, 9, 10]. That's why the cortical bone was of interest for this study.

The maximum cortical bone thickness value was in the zygomatic region (Ct.Th 2.7 mm) and slightly smaller in the orbital region (Ct.Th 1.9 mm). Glabella, piriform aperture (perinasal bone area) showed a smaller cortical thickness, (Ct.Th 1.5 mm; 1.4 mm). Because of relatively dense cortical bone in those areas, disk implants could be used [1,3, 9]. When the microarchitectural parameters were higher (porosity and cortical thickness), as well as, when there is a sufficient amount of bone for triple disk implants it would be justified to use this kind of implants because it is better stability. Single or double disk implants could be used in the limited bone quality and quantity when the cortical thickness is smaller and porosity lower.

Mastoid part of the temporal bone showed the minimum thickness of the cortical bone (Ct.Th.1.2 mm) as well as small porosity (Ct.Po. 4.3 mm). Anatomically and microarchitecturally this part of the temporal bone is suitable only for screw EO (extraoral) implants. Screw type extraoral implants are similar to short oral (dental) implants, however, there are some differences when it comes to the shape. EO implants have a flange design around their neck to prevent an unwanted drop of the implant, intracranial in the mastoid region. This is justified even more because this region has the smallest cortical thickness, which was shown in this study. For this reason, the implant placement has to be very carefully performed because thin cortex can be easily disrupted [3, 16].

According to the other researches where cortical thickness was higher, the implant stability was more satisfactory. In addition, according to ISQ by resonant frequency analysis, where cortical porosity was the smallest, pore diameter / separation the biggest, the implant stability was the best. This suggests that the cortical bone characteristics and microarchitectural parameters may determine the outcome of the implant therapy [20–25].

Micro CT evaluation of cortical bone on the dry scull cadaver model, on certain implant placement points, can give insight to the cortical bone properties, which can provide valuable guidelines when planning complex implant retained prosthetic restorations.

CONCLUSION

The bone quality measured through microarchitectural parameters was good in all the regions of interest for the disk and screw shape EO implant anchorage.

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Conflict of interest: None declared.

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Table 1. Microarchitectural parameters

Microcomputed tomography parameter	Unit	Description
Cortical thickness (Ct.Th)	mm	Average thickness of the cortical bone
Cortical porosity (Ct.Po)	%	Volume of pores in relation to the total volume of the cortical bone
Pore diameter (Po.Dm)	mm	Average pore diameter
Pore separation (Po.Sp)	mm	Average distance between pores

Microarchitectural parameters of the cortical bone measured by microcomputed tomography

Table 2. Microarchitectural parameters of the cortical bone Micro CT evaluation

Parameter	Position 1 Orbit (supraorbital margin)	Position 2 Glabella	Position 3 Mastoid. Pr.	Position 4 Zygoma.	Position 5 Perinasal (pyriform aperture)
Ct.Th (mm)	1.9	1.5	1.2’	2.7 *	1.4
Ct.Po (%)	6.7	4.1’	4.3	5.7	8.5 *
Po.Dm (mm)	0.1	0.1	0.1	0.2*	0.1
Po.Sp (mm)	0.4	0.5*	0.3’	0.4	0.4

* Highest value for the parameter, ’ Lowest value for the parameter

Figure1. Microcomputed tomography scanning areas

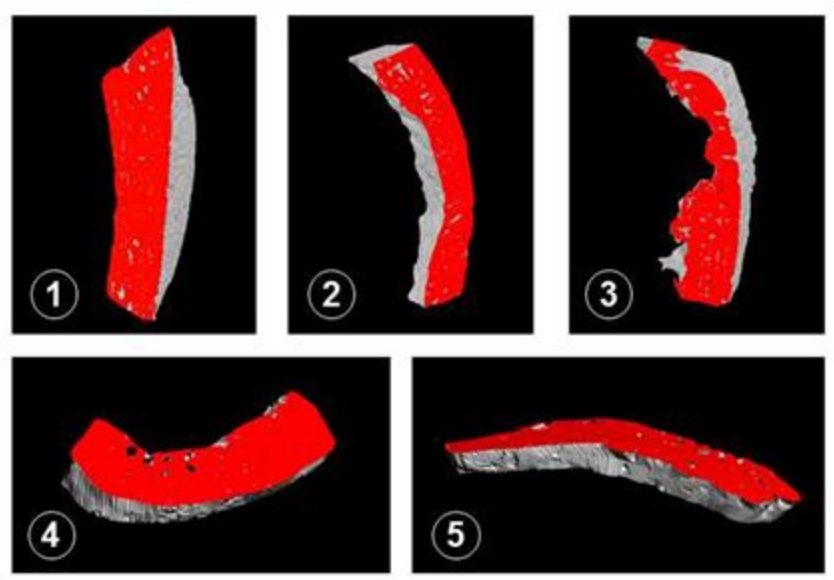

Figure 2. Microcomputed tomography scans 3D reconstruction: 1. supraorbital margin – orbit; 2. glabella; 3. mastoid process; 4. body of the zygoma; 5. pyriform aperture – perinasal