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Age Dependent Alteration in Bone Surrounding Dental Implant

Zmiany w kości otaczającej wszczep zębowy zależne od wieku

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A – research concept and design, **B** – collection and/or assembly of data, **C** – data analysis and interpretation, **D** – writing the article, **E** – critical revision of the article, **F** – final approval of article

Abstract

Background. Dental implants are versatile solution for the edentulous patients, but implant failure may appear.
Objectives. The aim of this study was to examine the age dependent alterations of microarchitecture in bone surrounding dental implant.
Material and Methods. The study included 249 dental implants in 107 patients. The range of age was 17–67 years old (45.53 ± 12.1). Intra-oral digital X-rays were taken in standardized conditions in all cases: just after implantation, immediately after functional loading, 3, 6, 9, 12, 18, 24 months later. The next step was to geometrically align all radiographs. Two regions of interest were indicated in the bone image [ROI1]: in implant neck region, [ROI2]: in periapical region. Afterwards, the entropy of microarchitecture of bone image was calculated and the analysis of simple regression was performed.
Results. No statistical significance between age and radiological texture in implant surrounding bone was found just after implantation, immediately after functional loading and 3, 6, 12, 18, 24 months after loading (p = 0.201, p = 0.3263, p = 0.0867, p = 0.6844, p = 0.8325, p = 0.4839, p = 0.0677, respectively). Only nine months after loading the implant, the age dependent entropy alteration was found (p = 0.004).
Conclusions. Modern dental implants are as versatile as possible to put to all age patients and entropy is a useful tool for evaluation of bone microarchitecture in standardized radiographs. During remodeling, i.e. 9 months after functional loading in older patients, the authors observed less number of trabeculae than in younger ones (**Dent. Med. Probl. 2014, 51, 1, 27–34**).

Key words: dental implants, radiograph, texture, entropy, age.

Streszczenie

Wprowadzenie. Wszczepy zębowe są odpowiednim rozwiązaniem dla bezzębnych pacjentów, lecz może zdarzyć się, że leczenie implantologiczne nie przyniesie oczekiwanych rezultatów.
Cel pracy. Zbadanie zależnych od wieku zmian w radioteksturze kości wokół wszczepów zębowych.
Materiał i metody. Badaniem objęto 249 implantów zębowych wprowadzonych u 107 pacjentów. Zakres wieku wynosił 17–67 lat (45,53 ± 12,1). We wszystkich przypadkach wewnątrzustne zdjęcia były wykonane techniką standaryzowaną: bezpośrednio po implantacji, od razu po obciążeniu i 3, 6, 9, 12, 18, 24 miesięcy później. Następnym krokiem było geometryczne wyrównanie zdjęć. Na zdjęciach uwidaczniających kość zaznaczano 2 miejsca zainteresowania: ROI1 – w obszarze przyszyjkowym, ROI2 – w obszarze przywierzchołkowym. Następnie obliczano entropię radiotekstury obrazu kostnego i wykonywano analizę regresji.
Wyniki. Nie odnaleziono żadnego znaczącego statystycznie powiązania między wiekiem a radiologiczną teksturą kości otaczającej implant ani bezpośrednio po implantacji, ani od razu po obciążeniu oraz 3, 6, 12, 18, 24 miesięcy później (odpowiednio p = 0,201, p = 0,3263, p = 0,0867, p = 0,6844, p = 0,8325, p = 0,4839, p = 0,0677). Wykazano natomiast zmiany w kości zależne od wieku jedynie 9 miesięcy po implantacji (p = 0,004).
Wnioski. Nowoczesne implanty zębowe są odpowiednim rozwiązaniem dla wszystkich pacjentów niezależnie od wieku, a entropia jest przydatnym narzędziem do oceny radiologicznej tekstury kości w zdjęciach standaryzowa-

nych. Około 9 miesięcy po obciążeniu wszczepów u osób starszych pojawiało się mniej beleczek kostnych niż u osób młodych (**Dent. Med. Probl. 2014, 51, 1, 27–34).**

Słowa kluczowe: wszczepy zębowe, rentgenogram, tekstura, entropia, wiek.

Lately, entropy was proposed as objective measure for radiological bone structure monitoring. On the basis of computer assisted radiological research, textural entropy proved to be a potential parameter to assess regeneration of the bone tissue. The calculated entropy increased gradually from bone defect status, through to the new bone formation, up to normal trabecular bone [1].

People who have lost a tooth or teeth due to dental caries, periodontal diseases, injuries or other reasons, may lose their self-confidence, attractiveness and their quality of life may decrease. Masticatory system dysfunctions are the next problem. Then, dental implants can be a comfortable solution. They are an effective solution for the edentulous patients, but implant failure may occur [2]. This is linked to the implant surrounding bone loss [2–4]. It seems interesting if long-term dental implant follow-up reveals their versatility for patients of any age. However, are they age independent?

The aim of this study was to examine the age dependent alterations of microarchitecture in bone surround dental implant.

Material and Methods

The study involved 107 consecutive patients of both genders aged 18–67 years (45.53 ± 12.1). In total, 248 implants have been analyzed.

Inclusion criteria: visualization of the implant in full length on dental X-ray image.

Exclusion criteria: no response to the follow-up examination, diagnose metabolic or bone disease during the investigation, drug affecting bone metabolism. Patients signed the informed consent for the research. Dental intraoral X-rays were performed before the implantation (00M), directly after implantation and control X-rays immediately after loading implants 3, 6, 9, 12, 18, 24 months (03M, 06M, 09M, 12M, 18M, 24M). X-rays straight angle technique was taken. Dental images were taken during a typical clinical follow-up. Ethical Board permission: RNN/27/12/KE. Pictures were taken by Focus X-ray device (Instrumentarium Imaging, Tuusula, Finland). Digora system recording plates was used (Soredex, Orion Corporation, Helsinki, Finland) for digital image acquisition. Dimension of the X-ray point (pixel) was 70 × 70 mm. Pictures were taken by standardized technique. Exposure time – 0.1 s, Intensity – 7 mA. The constant voltage of X-ray tube was 70 kV. After the exposition, recording plates were scanned immediately. The image was sent to database archive [5]. The silicone mass was used to stabilize the recording plate in the same way during the follow-up examination. The plate fixing bracket with silicone mass was set and when the mass got hard, pictures were taken. Next, the block of the mass was removed from the holder, packed, marked with the patient data and stored in the archive until the next appointment. Despite the applied method, pictures had only a slight geometrical inaccuracy. In the next phase of the work, pictures needed to be revised.

The normalization of radiographs was done before image analysis to remove even small geometrical deformations from the image. All X-rays for the same person were aligned to direct post-implantation X-ray (00M). The pairs of topographic markers were used for electronic geometrical alignment. They were placed at the same anatomical points around dental implants (10 points) on both images of the same person. ToothVis 1.6 software was used to correct the geometrical deformation [6]. Dental Studio was used to check the accuracy of the alignment (by means of Flipper and Subtraction tools). The first of them caused the alternate bounded appearance reference and aligned X-ray. When shaking was within landmarks (the tremor of the implant), the correction was possible by the Geometric Alignment function, and subsequent subtraction. If the X-rays were properly aligned, the surface of the implant disappeared (background grey, level 128), only the prosthetic crown was visible. When the X-ray image of the same patient presented several dental implants and it was not possible to align them all together, then each implant was aligned separately. This was done in order to increase the accuracy of the normalization method. By compensating the distortion point around implants on X-ray images of the same patient in subsequent control period, the results were identical.

Two regions of interest were indicated in the bone image [ROI1]: in implant neck region, [ROI2]: in periapical region (Fig. 2). Anatomical structures like alveolar ridge, maxillary sinus, incisive foramen, mental foramen, dental roots, crowns of the teeth etc. were omitted in order to avoid the occurrence in ROI. For this purpose Mazda 4.5 software was used (invented by Electronic Institute of Technical University of Lodz).

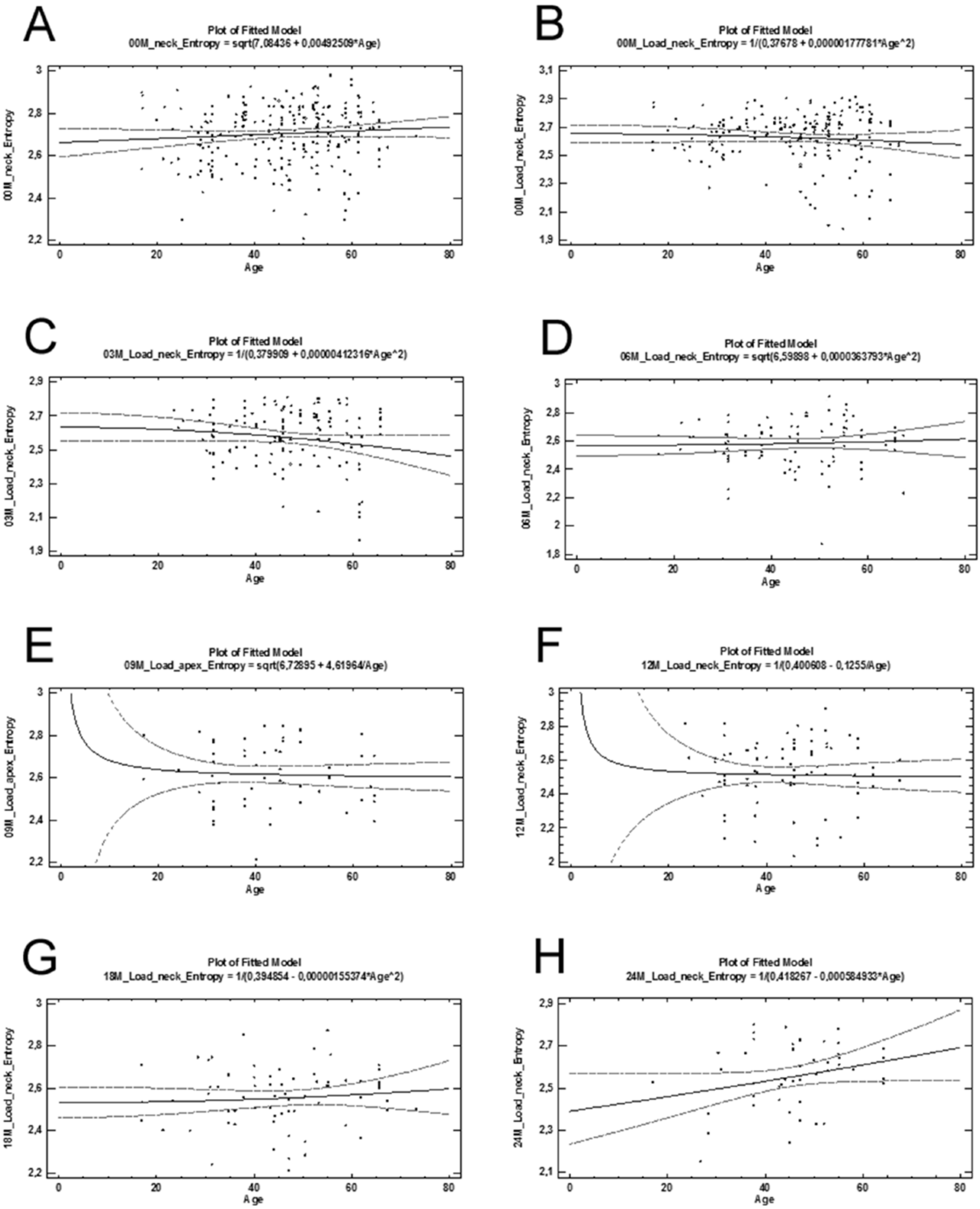

Fig. 1. Textural entropy of bone image in dental implant neck region

Simple regression of textural entropy versus patient age: A – just after implant bone merge and cover the wound ($p = 0.201$), B – immediately after functional loading of the implant ($p = 0.3263$), C – 3 months after functional loading ($p = 0.0867$), D – 6 months after functional loading ($p = 0.6374$), E – 9 months after functional loading ($p = 0.004$), F – 12 months after functional loading ($p = 0.8325$), G – 18 months after functional loading ($p = 0.4839$), H – 24 months after functional loading ($p = 0.0677$).

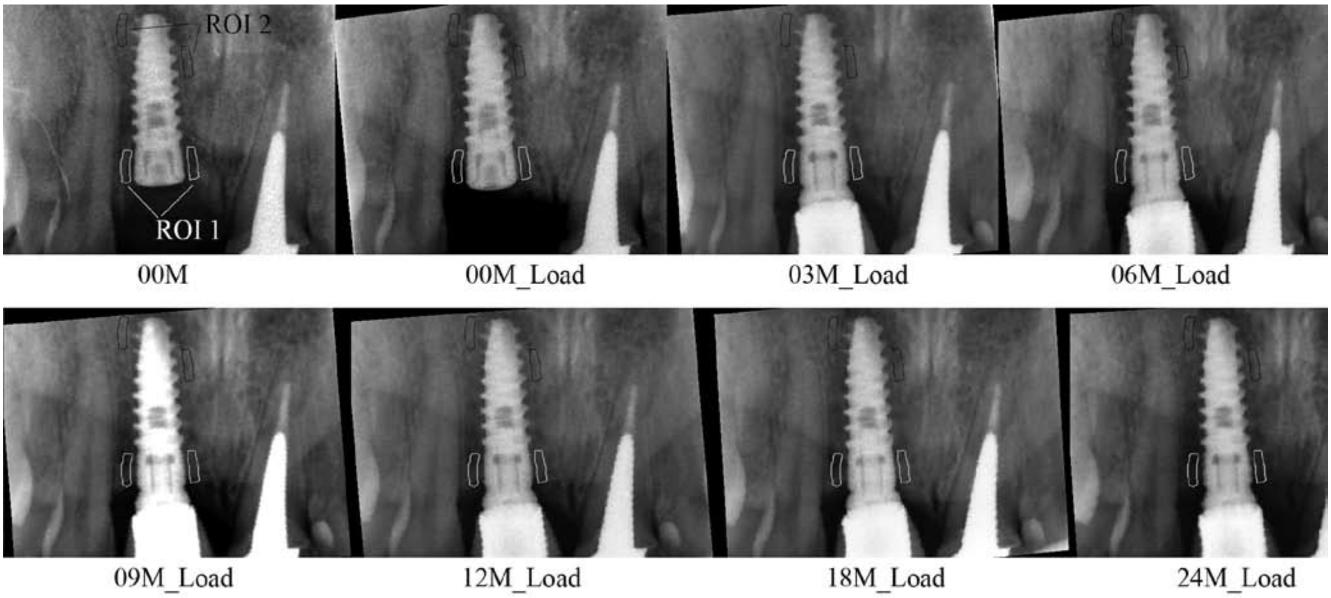

Fig. 2. Series of analyzed radiographs with marked ROI1 [marginal crestal bone] and ROI2 [reference periapical bone]

00M – immediately post-operational, 00M_Load – just before functional loading, 03M_Load – 3 months after functional loading, 06M_Load – 6 months after functional loading, 09M_Load – 9 months after functional loading, 12M_Load – 12 months after functional loading, 18M_Load – 18 months after functional loading, 24M_Load – 24 months after functional loading.

8-bit images were transformed to 7-bit images to reduce initial noise. Pictures had previously aligned analogues ROI to consecutive X-rays of the same patient monitoring ROI marked digital; those images were analyzed and compared. Textural entropy parameter was analyzed as a measure of mature trabecular bone amount [1]. Then, the relation between age and entropy of microarchitecture of bone image was studied by mean of analysis of regression (Statgraphics Centurion XVI, Statsoft, US). The level of significance was $p < 0.05$.

Results

Directly post-implantation there were 249 implants: 142 in women and 107 in men. Age statistical mean was 45.53 ± 12.1. The relation between age and entropy of microarchitecture of bone image measured by means of analysis of regression in 00M directly post-implantation was statistically not significant ($p = 0.20$, $F = 1.64$, correlation coefficient = 0.08, R-squared = 0.66 percent).

00M after loading there were 200 implants: 120 in women and 80 in men. Age statistical mean was 46.23 ± 12.53. The relation between age and entropy of microarchitecture of bone image measured by mean of analysis of regression in 00M after loading was statistically not significant ($p = 0.33$, $F = 0.97$, correlation coefficient = 0.07, R-squared = 0.49%).

03M after loading there were 130 implants: 77 in women and 53 in men. Age statistical mean was 46.77 ± 10.90. The relation between age and entropy of microarchitecture of bone image was measured by means of analysis of regression in 03M after loading was statistically not significant ($p = 0.09$, $F = 2.98$, correlation coefficient = 0.15, R-squared = 2.28%).

06M after loading there were 92 implants: 58 in women and 34 in men. Age statistical mean was 44.57 ± 12.64. The relation between age and entropy of microarchitecture of bone image measured by means of analysis of regression in 06M after loading was statistically not significant ($p = 0.64$, $F = 0.22$, correlation coefficient = 0.05, R-squared = 0.25%).

09M after loading there were 57 implants: 35 in women and 22 in men. Age statistical mean was 43.10 ± 12.27. The relation between age and entropy of microarchitecture of bone image measured by mean of analysis of regression in 09M after loading was statistically significant ($p = 0.004$, $F = 9.05$, correlation coefficient = –0.36, R-squared = 14.12%).

12M after loading there were 80 implants: 60 in women and 20 in men. Age statistical mean was 44.04 ± 10.48. The relation between age and entropy of microarchitecture of bone image measured by mean of analysis of regression in 12M after loading was statistically not significant ($p = 0.83$, $F = 0.05$, correlation coefficient = –0.02, R-squared = 0.06%).

18M after loading there were 73 implants: 49 in women and 24 in men. Age statistical mean was 45.79 ± 1.60. The relation between age and entropy of microarchitecture of bone image measured by mean of analysis of regression in 18M after loading was statistically not significant ($p = 0.48$, $F = 0.50$, correlation coefficient = –0.08, R-squared = 0.69%).

24M after loading there were 47 implants: 29 in women and 18 in men. Age statistical mean was 45.03 ± 11.19. The relation between age and entropy of microarchitecture of bone image measured by mean of analysis of regression in 24M after loading was statistically not significant ($p = 0.07$, $F = 3.51$, correlation coefficient = –0.27, R-squared = 7.22%).

Discussion

Osseointegration can be divided into 3 stages: osteoconduction, *de novo* bone formation, bone remodeling. Older patients suffer for gradual arteriosclerosis in bone also in jaws, blood vessels, reduction in the patency of the maxillary artery [7, 8]. It may be concluded that vascularity and the potential of healing may be jeopardized [9]. The increasing age is strongly related with many disorders like: hypertension, coronary artery diseases, pulmonary diseases, steroid therapy, diabetes, head and neck radiation, osteoporosis and medications taken. Many patients also have bad habits i.e. smoking. There is some research revealing that diabetes, smoking, head and neck radiation and post-menopausal estrogen therapy were correlated significantly with implantation failures. Other scientists mention that diabetes, osteoporosis, steroid therapy, chemotherapy, head and neck radiation are considered as contraindications for implantation [10–14]. Otherwise, the other examination displays that every person is another individual medical problem and is not related to the implant failure. They say that the most important things that may help to achieve medical success are: surgical technique as well as bone quantity and quality [10, 13, 15, 16]. Periodontal disease coexisting with cumulative influence of poor oral hygiene habits results in more failures [9, 17]. Consequently, implant success depends on many factors [18]. Many endocrine, metabolic, physical changes are associated with age [19]. It might be very helpful to know how it may impact implantation. Maximum bone mineral density is at the age between 25–30 years [20]. Until approx. 30 years, the human skeleton accumulates bone. After that age, it gradually loses it [21]. Thus, limitation quantity of the bone tissue, bone becomes attenuated [22]. There are "natural delays" in the healing of older persons. An open wound heals slower. Incised wound strength is also slower. Experimental investigation demonstrates that cellular proliferation wound metabolism, collagen remodeling appear later than in younger animals. Clinical survey shows that surgery could be performed safely in elderly individuals. It is worth mentioning that a major risk factor are medical complications affecting the wound, and are non-wound related [18, 23]. They mentioned that "normal" incisional wounds healed equally well in the older and younger group. Otherwise, in an old animal ischemic wound impaired in 40–65% unlike in the young group [18, 24]. The influence of metabolic and bone diseases were excluded in this study, but other age related factors may affect the bone structure in dental implant surrounding. According to many researches, wound healing could be slower with increasing age [9, 25, 26], jawbone density, osseous healing may be weaker [9]. Consequently, osseointegration could be compromised. In some studies, bone loss is higher in women particularly in post-menopausal period [9, 27, 28]. Our examination does not confirm such conclusions. The research showed that age is not statistically significant – no difference between young and old patients was observed. In the study on rats, Shirota et al. investigated a new trabecular bone formation and implant-bone contact. They showed that the mentioned parameters were achieved more quickly in the younger group. They claim that increasing age is related to the decrease of the rate and the volume of a new bone formation [29]. Moy et al. examined quite large group of patients. The surgery was conducted by an experienced surgeon and revealed that patients older than 60-years are susceptible to twice more failures [2, 18]. Brocard et al. detected that patients over 60 years of age adopted only the small amount of dental implants [3, 18]. On the other hand, Mesa et al. examined a bivariate model and discovered the connection between primary stability failure and smoking, age, gender, periodontal state, bone quality, implant diameter and length. Contrary to our study, they found that age was the confounding factor [18, 30]. Aging has an influence on the quality and quantity of bones. Bone quality is closely connected to osseointegration. Further bone quantity is linked to the implant length (which is responsible for initial stability and long term lifespan) [4, 18, 31]. Benatti et al. studied the group of rats. Unlike to our survey, they reported that age could attenuate but not prevent periodontal healing. There are many articles showing that age influences successful implantation [18, 32]. Noguerol et al. depicted that multiple logistic model, smoking habits, young age, bone quality were related with early implantation failure [18, 31]. Our research did not prove that relationship. Histological studies about aging describe this state as: thinning and diminished keratinization of the epithelium, decrease cell density and synthesized collagen in periodontal ligaments, the decreased number of cells of the osteogenic layer of the alveolar bone [18, 32]. However, older patients have more problems with adaptation, especially after the insertion [18]. Some of them have trouble with general adaptation or muscle control. Very often oral hygiene is also impaired. Consequently, soft tissue inflammation appears in many individuals. Also tongue, lip, cheek biting and other habits are more often observed in elderly patients [18, 33]. Older patients have poorer local bone state – mandibular ridge is close to inferior alveolar canal [9, 34] or floor of the sinus is very close to the ridge crest [9, 35, 36]. The clinician has to take this problem into consideration once planning the implantation. The outcome of our study is similar to Henny J.A. They showed that mean bone loss after 3 years examination was higher in younger group than in older. However, it was not significant. They confirm that implantation could be equally successful for both groups of patients [37]. Furthermore, another study shows the higher percentage of successful implantation in the older group; however, the effect is not significant. Moreover, the prosthetic prescription was also better than in younger patients. [38] They presented that not bone quantity [37], but also quality of bone is stable during a lifetime. Many of the previous surveys indicated that increased age as a single factor is not a contraindication for the implantation [18, 30, 33, 39–43]. Although we did not examine stomatological indexes, our final results are the same. Meijer et al. investigated Plaque Index, Gingival Index, Bleeding Index, bone loss after 3 years and demonstrated no significance between younger and older patients [18, 43]. Also August et al. showed no age influence on successful implantation. In their study, there were no differences between pre-menopausal women and estrogen supplemented post-menopausal women. Additionally, estrogen status was more important than age [18, 44]. Textural entropy of the bone image in implant neck region 09M was the only statistically significant factor (Simple regression) after functional loading. This relationship may be caused by bone remodeling after implantation. Lower entropy may be explained by less number of bone trabeculae visible in radiograph. This may occur from implant's functional loading to 9–12 months after the treatment.

The authors concluded that modern dental implants are as versatile as possible to apply to patients of all ages and entropy is a useful tool to evaluate bone microarchitecture in standardized radiographs. During remodeling i.e. 9 months after functional loading in older patients, less number of trabeculae than in younger ones is observed.

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