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Computer Evaluation of the Changes of the Vestibular Bone Plate after Classical and Computer-Guided Delayed Implantation in Esthetic Zone

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Abstract

BACKGROUND: The buccal bone plate as one of the key anatomical structures is of great importance for the success of implant therapy in the frontal maxilla and is particularly prone to changes that occur post-extraction. The condition of the buccal bone plate and its dimensions in the horizontal and vertical direction directly affects the method of implantation, the position of the implant, and the long-term results of the implant treatment.

AIM: The aim of the study is to compare the differences and changes of the buccal bone plate in the anterior maxilla, during delayed implantation with and without the use of a surgical guide, which implies the use of different surgical techniques. Furthermore, the aim of this study is to determine their advantages and disadvantages.

MATERIALS AND METHODS: To achieve the set goal, through CBCT images and computer software, changes in 40 patients divided into two groups were analyzed in three time periods: 20 patients who underwent delayed implantation in the anterior maxilla without a surgical guide and the second group of 20 patients who underwent delayed implantation using a surgical guide, which means that in the second group of patients, there was no mucoperiosteal flap elevation.

RESULTS: The analysis of changes in the buccal bone plate showed that the biggest changes were in patients who underwent delayed implantation according to the classical method and approach. The greatest changes in the horizontal dimension in the first group of patients (MI) were in positions 1, 3, and 6. Namely, for position 1, from an average horizontal dimension of 1.54 mm, the dimensions decreased to 0.26 mm during 12 months. On the contrary, in the second group, these dimensions recorded a slight decrease from 2.37 to 2.2 mm on average. At position 3, there was also a more developed resorption in the first group, from 1.54 mm to 0.88 mm, and in the second group, the resorption was insignificant and for the same period of 12 months, the horizontal dimension decreased from 2.27 mm to 2.12 mm, in which, clinically, it was not evident. Regarding the vertical dimension for 12 months in the first group, the resorptive changes ranged from 1.1 to 3.3 mm on average, while in the second group, changes in the vertical dimension were not observed, and they did not exist in the examined patients. The bone density in both groups decreased only in position 0 and much more in the first group where it decreased in a period of 12 months from 742 Hu to 150 Hu, while the decrease in the second group was from 1080.5 Hu to 1080 Hu. For all other dimensions, there is an increase in density in all time periods, higher in the second group.

CONCLUSION: The obtained results showed that the greatest changes in the buccal bone plate in all dimensions occur during delayed implantation with a classical approach. This is mainly due to the position of the implants, as well as the disruption of the blood supply to the bone plate, which follows the creation of the flap.

Introduction

The term “implantation” refers to the surgical implantation of specially shaped and made of appropriate material substitutions that should fuse with the living tissue, in the case of the alveolar ridge of the jawbones.

Modern implants that are used today are made of medical titanium alloys, and the conditions of biocompatibility, bioinertness, or bioactivity must be met [1]. The ultimate goal of implant therapy is to create prosthetic superstructures that are aesthetically and functionally acceptable to the patient [2]. Due to this, it is necessary to precisely plan and determine the position of the implants, with an appropriate soft tissue and bone base as a support for the future prosthetic superstructure [3], [4]. The course of implant therapy has clearly defined phases that allow the transfer of information from one phase to another [4]. Implants must be placed in the correct anatomical position, in the space of the available alveolar bone, which will not violate the surgical and biological principles [5]. Implantation in the anterior maxilla is a complicated surgical challenge that requires a detailed methodological approach and planning [6]. The buccal bone plate, as one of the key anatomical structures, is of great importance for the success of implant therapy in the frontal maxilla

and is particularly prone to changes that occur post-extraction [7]. It is subject to continuous resorption, which lasts up to several years [7]. Previous research shows that the thinner the buccal bone plate, the more pronounced its resorption will be post-extraction, so its presence or absence preoperatively is significant for the choice of the implantation method [8]. However, the changes of the buccal bone plate do not stop even after implantation and are therefore the subject of scientific interest and analysis [9]. Delayed implantation as a therapeutic method for tooth replacement, in the frontal maxilla, due to the physiological resorption of the alveolar ridge is often associated with augmentative techniques locally increase in bone volume [10]. The purpose of the paper is to prove the differences and changes of the buccal bone plate in the anterior maxilla, during delayed implantation with (Figure 1) and without the use of a surgical guide (Figure 2), using different surgical techniques, to simultaneously compare the two implantation techniques and determine their advantages and disadvantages.

Materials and Method

The bony changes of the buccal bone plate were analyzed in 40 patients divided into two groups:

GROUP 1 (MI) – 20 patients who underwent delayed implantation in the anterior maxilla without a surgical guide.

GROUP 2 (MIG) – 20 patients in whom delayed implantation was performed using a surgical guide.

A detailed medical history was taken from all patients, on the basis of which the patients included in the study were selected. Patients under 18 years of age, patients with acute diseases, patients who are on anticoagulant therapy, who do not maintain oral hygiene, and patients who have bruxism were excluded from the study. All interventions were performed with local anesthetic conduction anesthesia (Artinibsa 4% - Inibsa Dental Spain). A physiodispenser (KaVo Intrasurg 300 – Germany) and a conventional implantological set were used for delayed implantation without a guide, and for delayed implantation with a guide, a special implantological set for computer-guided surgery was used for the preparation of the implant beds.

In the patients of the first group, a crestal incision was made with the raising of a mucoperiosteal flap and the implant bed was made according to the protocol for the preparation of an implant bed in the anterior maxilla, based on the preoperatively determined bone quality (Figure 1). The position of the implants was determined preoperatively through 3D images, and intraoperatively based on previously determined anatomical structures, and the experience of the operator.

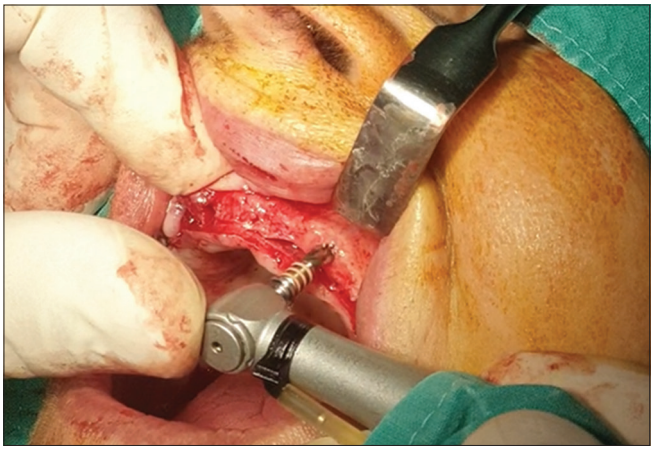

Figure 1: Delayed implantation – classical approach

In the second group of patients in whom the implants were placed with surgical guides, they were properly autoclaved preoperatively. They were fixed intraorally to the maxilla through the retention surfaces of the surrounding teeth and through titanium pins digitally planned in the places with adequate bone through the three-shape software. In these cases, the so-called flapless surgery was performed, that is, no surgical incisions were made (Figure 2). Antibiotic, anti-edematous, and analgesic therapy was prescribed for each patient postoperatively.

Figure 2: Computer-guided delayed implantation

Radiographic examinations

Post-operative radiological examinations and planning of implant therapy were performed on the basis of 3D images recorded with Rotograph Prime 3D – Villa systemi medicali Italy. The exposure time for 3D CBCT images with this device was 21.2 s, with a tube strength of 2–12.5 mA. The nominal tomographic thickness of the sections is 0.175 mm, with a maximum permissible deviation of ± 10%.

The resolution of the images has a size per voxel of 87.5 μm and an image reception area of 144 × 118.6. The 3D analysis of sagittal sections and measurements was made using Villa 3D Planner

software, on the day of implantation, 6 and 12 months postoperatively. Three parameters were analyzed:

Horizontal dimension (HD) is the dimension from the external surface of the implant to the buccal bone plate. It is measured from the platform of the implant starting from position 1 moving apically with positions 3, 6, 9, 12, and 15 position every 3 mm, expressed in millimeters (Figure 3).

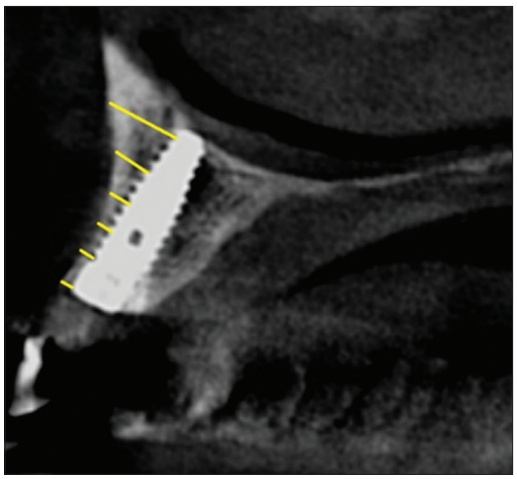

Figure 3: Horizontal dimension (HD), CBCT radiographic presentation

Vertical dimension (VD) – is a dimension that is measured from the platform of the implant (position 0) to the most coronal part of the alveolar bone, during which the loss or resorption of the bone tissue from the buccal and palatal side is measured, expressed in millimeters (Figure 4).

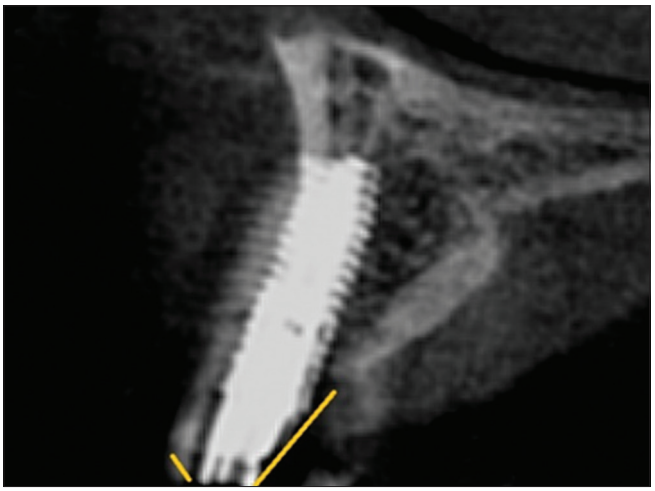

Figure 4: Vertical dimension (VD), CBCT radiographic presentation

Bone density – is measured in three positions:

0 position – bone plate at the level of the implant platform.

One position – bone plate at the level of the middle of the implant.

Two position – bone plate at the apical level of the implant.

The values are expressed in HU (Hounsfield Units), according to the scale of the same name – Hounsfield Scale, for bone density.

Results

The structure of the groups according to the gender variable showed that in both groups, there were more male patients than female patients (Figure 5).

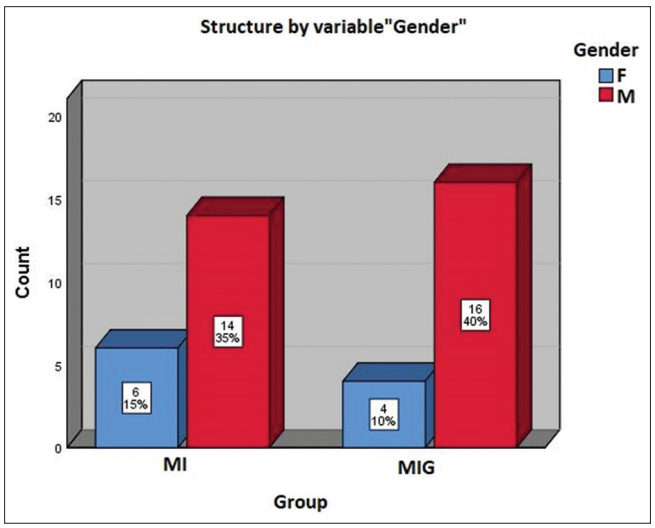

Figure 5: Structure by variable "Gender"

According to the age variable, the average age of the patients in the first group was 54 years, and in the second, it was 46.2 years (Figures 6 and 7).

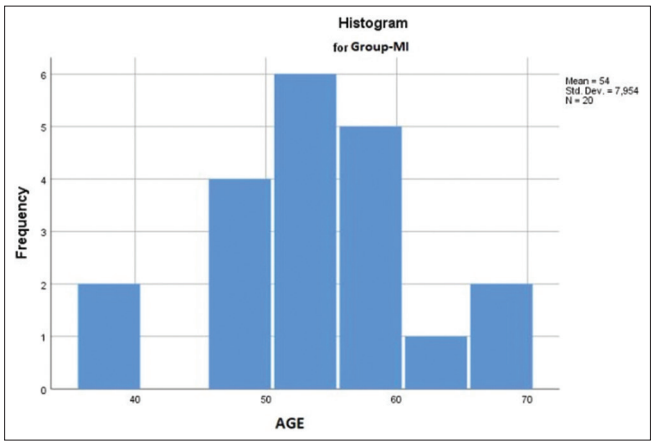

Figure 6: Histogram for Group-MI

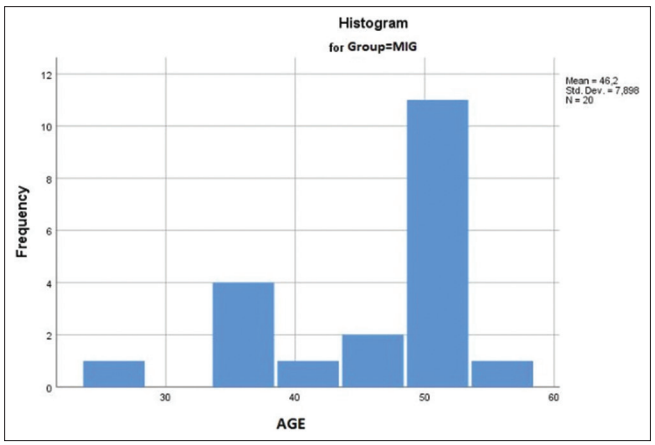

Figure 7: Histogram for Group=MIG

The obtained average results of measuring the horizontal dimension of the buccal bone plate (HD) for different time periods (0.6 and 12 months) showed that changes in the horizontal dimension of the buccal bone plate in both groups took place mostly in position 1.3 and 6 in all time intervals (Table 1).

Table 1: Horizontal dimension results

Position	MI/HD0	MIG/HD0	MI/HD6	MIG/HD6	MI/HD12	MIG/HD12
1	1.54	2.37	0.33	2.26	0.26	2.20
3	1.50	2.27	1.02	2.18	0.88	2.12
6	1.66	2.17	1.47	2.10	1.44	2.08
9	1.90	2.40	1.74	2.39	1.72	2.40
12	2.14	2.86	2.0	2.85	2.00	2.84
15	2.78	3.60	2.74	3.60	2.74	3.59

The results obtained in the first group of patients, in position 1 on the day of implantation (time period 0) have an average value of 1.54 mm, while in the second group, the average value is 2.37 mm, in the same position. Six months later, in the first group of MI, there is a visible decrease in the dimensions of the buccal bone plate, and in the second group of MIH, there is insignificant resorption and the dimensions move within the limits of the initial state. One year later, the obtained results have a decreasing trend in the first MI group, while in the second group, the average values remain the same (Figure 8).The changes in the horizontal dimension in the first group of patients, in position 3 on the day of implantation (time period 0), have an average value of 1.50 mm, while in the second group, the average value is 2.27 mm. Six months later in the first MI group, there is a visible decrease in the dimensions of the buccal bone plate (1.02 mm), and in the second MIH group, there is insignificant resorption and the dimensions move within the limits of the initial state (2.18 mm).

One year later, the horizontal resorption of the buccal bone plate has an increasing trend in the first MI group and the dimensions are visibly reduced (0.88 mm), while in the second group, the horizontal dimension does not change visibly (2.12 mm) (Figure 9).

Changes in the horizontal dimension of the buccal bone plate in position 6, on the day of implantation, have an average value of 1.66 mm in the first MI group, and 2.17 mm in the second MIH group. Six months after the period of osseointegration of the implant, the first group has average values of 1.47 mm, and the second group MIH – 2.10 mm. One year postoperatively, the average values in the first group are 1.44 mm, and in the second 2.08 mm, which indicates stabilization of the dimensions in both groups (Figure 10).

The measured values for the vertical dimension in both groups (MI and MIG) for a time period of 0 months were 0, which means that there was a crestal placement of the implants. Six months after implantation in the first MI group, there is vertical resorption ranging from 1.1 mm to 3.2 mm, while in the second MIH group, no vertical changes were observed in any of the examined patients (Table 2 and Figure 11).

Table 2: Comparison of groups MI and MIG by variable "VD-6"

Count	VD - 6										Total
	.0	1.1	1.5	1.7	1.9	2.4	2.5	2.7	3.1	3.2	
Group											
MI	8	1	2	2	1	1	1	1	2	1	20
MIG	20	0	0	0	0	0	0	0	0	0	20
Total	28	1	2	2	1	1	1	1	2	1	40

Group * VD - 6 Crosstabulation

Twelve months after implantation, the vertical changes of the buccal bone plate ranged from 1.1 to 3.3 mm in the first MI group, while no resorptive changes of the buccal bone plate in the ventral direction were measured in the second MIH group (Table 3 and Figure 12).

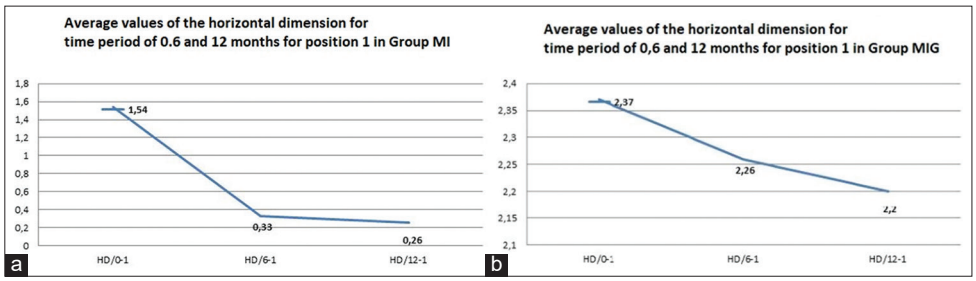

Figure 8: (a) Average values of the horizontal dimension for time period of 0.6 and 12 months for position 1 in group MI. (b) Average values of the horizontal dimension for time period of 0, 6, and 12 months for position 1 in group MIG

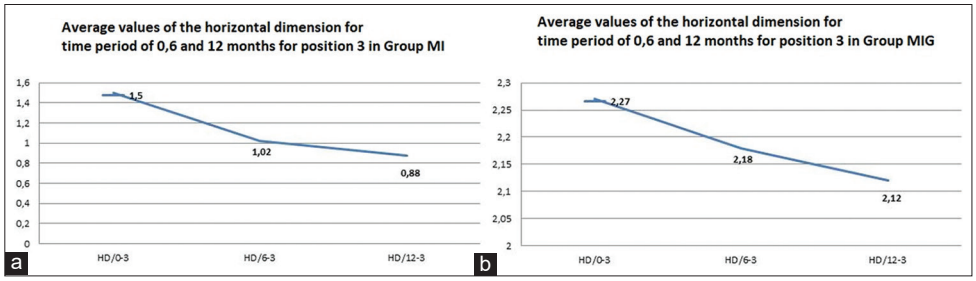

Figure 9: (a) Average values of the horizontal dimension for time period of 0, 6, and 12 months for position 3 in group MI. (b) Average values of the horizontal dimension for time period of 0, 6, and 12 months for position 3 in group MIG

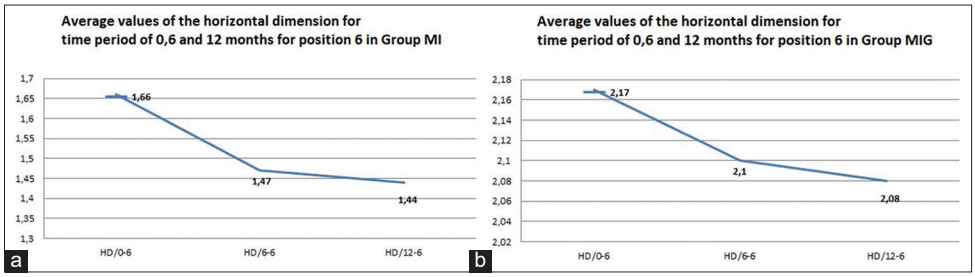

Figure 10: (a) Average values of the horizontal dimension for time period of 0, 6, and 12 months for position 6 in group MI. (b) Average values of the horizontal dimension for time period of 0, 6, and 12 months for position 6 in group MIG

Table 3: GROUP * VD - 12 Crosstabulation

Count	VD - 12											Total
	.0	1.1	1.5	1.7	1.9	2.0	2.5	2.9	3.1	3.2	3.3	
Group												
MI	6	1	2	1	3	1	1	1	1	2	1	20
MIG	20	0	0	0	0	0	0	0	0	0	0	20
Total	26	1	2	1	3	1	1	1	1	2	1	40

At 0 position in the first MI group, there is a decrease in bone density 6 and 12 months after implantation, while in the second MIH group, bone density remains stable for all 3 time periods (Figure 13).

Bone density in 1 position, in all time periods in both groups, shows a tendency for growth and elevation (Figure 14).

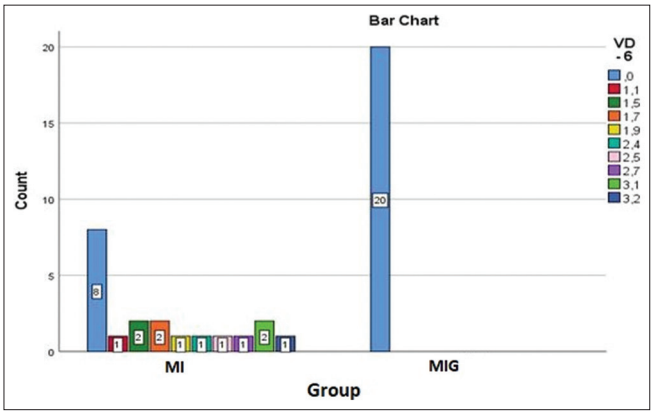

Figure 11: Bar chart

The same trend of bone density growth is observed after 12 months, in both groups in position 2, which is clearly seen in Figure 15.

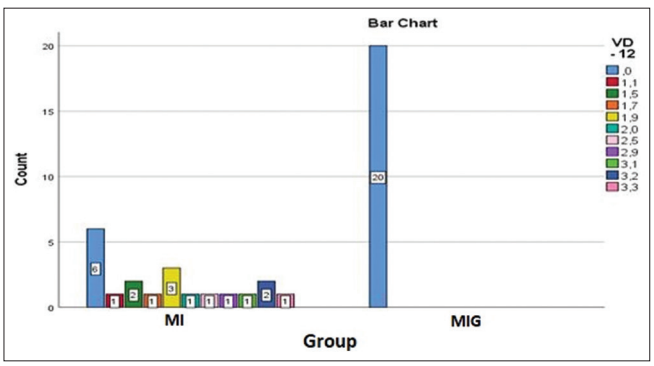

Figure 12: Bar chart

Discussion

Implant therapy in the anterior maxilla is a complex surgical prosthetic process that requires knowledge and experience of the therapist [11]. The buccal bone plate, as part of the anatomical structure of the anterior maxilla, is of great importance for the future success of implant therapy. The changes that occur on the buccal bone plate after tooth extraction dictate the future plan of therapy and the position of the implants [12]. The differences in changes in the horizontal and vertical dimensions of the buccal bone plate clearly indicate which implantation protocol the surgeon should choose The problem of achieving the correct 3D position of the implant in the available bone in the anterior maxilla has been solved in different ways [13]. The revolutionary discovery of 3D computed tomography for the analysis of the bone structures of the lower and middle facial mass allowed the creation of new implantation techniques, such as computer-guided implant surgery. Experimental analyses have proven that the buccal bone plate, due to its structure, is prone to great resorption, and that resorption does not stop even after the placement of the implants [14]. Therefore, the aim of this study was to monitor those changes in each aspect over a longer period of time in patients with different implantation conditions. In addition, this study tried to give an answer regarding the advantages and disadvantages of different implantation techniques in the anterior maxilla.

According to the obtained results for the average values of the horizontal dimension (HD) of the buccal bone plate, it was shown that the lower two-thirds of the buccal bone plate are the most susceptible to resorption, especially in patients in whom the classical implantation technique was used.

In these patients, although the position of the implants was previously planned based on the CBCT image, the final placement was freehand, based on surgical principles for the preparation of the implant bed in the anterior maxilla. The obtained results showed a slight buccal inclination of the implants, which leads to increased resorption postoperatively, due to the reduced blood supply from the trabecular

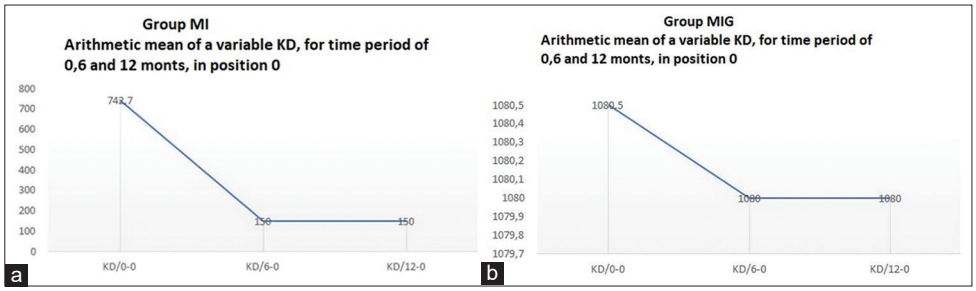

Figure 13: (a) Bone density in groups MI. (b)Group MIG - Arithmetic mean of a variable KD, for time period of 0, 6, and 12 months, in position 0

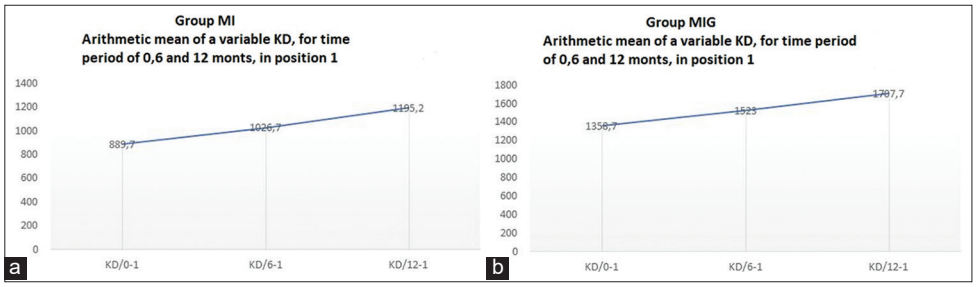

Figure 14: (a) Group MI - Arithmetic mean of a variable KD, for time period of 0, 6, and 12 months, in position 1. (b) Group MIG - Arithmetic mean of a variable KD, for time period of 0, 6, and 12 months, in position 1

bone and the elevation of the mucoperiosteal flap, which disturbs the local circulation and blood supply of the bone plate. These obtained results are correlated with Veltri's trials [8], where in the tested implants, visible buccal bone was present apical from the implant shoulder in ten cases, while two cases showed a bone plate level at the height of the implant shoulder (0 mm). In the particular study of Veltri [8], the buccal bone plate was localized on average 3.8 mm apical from the shoulder of the implant. This is approximately close to other research in this area that provides data that the buccal bone plate is localized at about 2.7 mm from the shoulder of the implant after 10 years of function (Schropp *et al*.) [15]. This trend of resorption was also proven in the study of Benic [9], where after 7 years of functional loading of the implant, the level of soft tissue in implants without a radiologically detectable buccal bone plate was 1 mm apically in contrast to implants with a buccal bone plate present (Benic *et al*.) [9]. Our measurements showed that the greatest changes occurred one year after the placement of the implants, that is, the buccal bone plate was located at a maximum of 3.3 mm from the shoulder of the implant. CBCT buccal bone plate measurements correlate with and depend on bony buccal volume. This means that even if the buccal bone plate is present, and it is thinner than 0.8 mm, it is invisible radiologically (Razavi *et al*.) [16]. Prospective studies of soft and hard tissue in the anterior maxilla after delayed implantation show different values. The soft-tissue recession that develops is no larger than 0.7 mm (Grunder *et al*.) [17]. In some cases, it is higher than 1 mm (Benic *et al*.) [9]. According to Buser *et al*. [2], to avoid this soft-tissue recession and to support the soft tissue, it was measured that the minimum required thickness of the buccal bone plate should be 2 mm, which is difficult to do in practice and was also proven in our research in patients with a classic method of delayed implantation, where the dimensions for different positions in the lower two-thirds of the implants ranged below 2mm.

The lower two-thirds of the implants were also the most susceptible to horizontal changes, especially in positions 1 and 3, where dimensions decreased over 12 months, double the initial state (from 1.54 mm to 0.26 in position 1, and from 1.5mm to 0.88 for position 2). It is concluded that, as in the previous studies, vertical

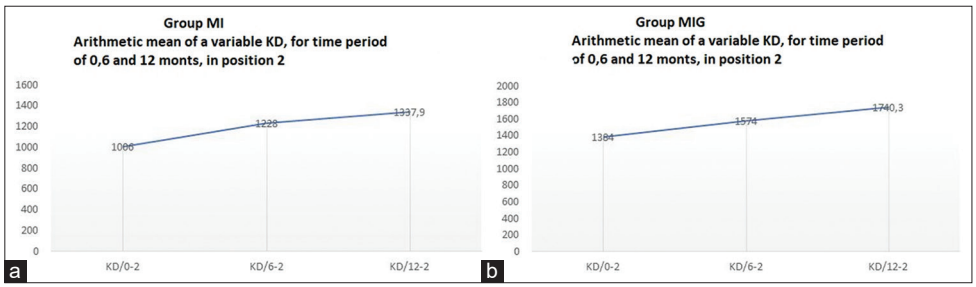

Figure 15: (a) Group MI - Arithmetic mean of a variable KD, for time period of 0, 6, and 12 months, in position 2. (b) Group MIG - Arithmetic mean of a variable KD, for time period of 0, 6, and 12 months, in position 2

resorption goes parallel to horizontal and that they are an inevitable process in classic delayed implantation. In contrast to this group, in patients from the second group (MIG), the obtained results showed two key points: The first is that the planned position of the implants for this technique allowed us to place the implants more poppalatally, without raising a mucoperiosteal flap, resulting in a thick buccal bone plate over 2 mm that was perfused by both the periosteum that remained intact and the trabecular bone that had adequate thickness. The second key moment in the monitoring of the dimensions, especially after 6 and 12 months, showed that the thickness achieved on the day of implantation remained stable and did not vary, and in some situations even increased under the influence of masticatory pressure forces. Regarding the obtained results of the vertical dimension, during the placement of the implants in both groups, there was no loss of vertical bone, because delayed implantation was used and the placement of the implants was crestal at the level of the bone. Six months later, in the first group, resorptive processes begin, which in most patients are within the expected limits (up to 3.3 mm), and in the second group, for the same time period of 6 and 12 months, no resorptive changes in the vertical dimension were observed, which indicates for the superiority of this technique of implant placement, and it correlates with the studies of Komiyana *et al*. [17] where the mean vertical loss with computer-guided surgery ranged from 0 to 1.5 mm for different periods up to 12 months. According to our research, it is due to the correct position and the non-disruption of the local circulation, in the second group of patients with a surgical guide.

Bone density on the day of placement of the implants decreases in both groups of patients with greater emphasis in the MI group, while in the second MIG group, there is a slight decrease. In the patients of the first group, MI decreases on average from 742 Hu to 150 Hu, while in the second group from 1080.5Hu to 1080Hu.

This is perhaps correlated with the stress suffered by the alveolar ridge in the anterior maxilla as a whole during delayed implantation and the loss of vertical dimension. Bone density over the following months never regains the initial values in the patients of the MI group, although it increases over time. In the second group of patients, the changes in density are not evident at the beginning, although they exist, and over time they tend to increase.

Conclusion

The changes that occur on the buccal bone plate during delayed implantation with a classic surgical approach are due to the debatable position of the implant, and the disruption of the blood supply to the implantation zone when raising the mucoperiosteal flap. From the analyzed parameters, although used for a relatively long time, this method proved to be inferior to computer-guided implant surgery, due to the trauma, it causes to the peri-implant tissues, which are more difficult to rehabilitate and return to their initial state. In contrast to this method, computer-guided implant therapy overcomes all these shortcomings and, although a relatively young technique proves to be superior, due to the fact that the emphasis and essence of its creation is the correct position of the implant, with minimal traumatization of the peri-implant tissues. Under such working conditions, the buccal bone plate undergoes the smallest changes, which is crucial for the further fate and success of implant therapy in the anterior maxilla.

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