Influence of crown-to-implant ratio on marginal bone loss in single implant-supported crowns: Five years retrospective clinical study.

Introduction

Restoration of edentulous areas with implant-supported prosthetic restorations is a widely accepted alternative nowadays. One of the successful criteria for implant restorations is the stability of osseointegration and bone-to-implant contact (BIC). It is generally accepted that in physiological functional load it can be expected to have a bone loss of 1 to 1.5 mm within the first year and less than 0.2 mm every successive year (1). This process can be accelerated by mechanical, chemical and biological factors. Due to the onset of bone atrophy after teeth extraction and the limited height of available bone, it often necessitates to use implants with a smaller length than that of the restoration in the distal areas of jaws (2, 3). In such situations, the crown-to-implant (C/I) ratio is increased (Fig 1). Elevated values of this parameter affect the vertical bone loss around the implant (4). There is still no uniform opinion regarding the optimal values of this ratio and its effect on marginal bone loss.

The data of conducted studies are often contradictory. According to Hingsammer L. et al. the ratio between the crown and the implant should not exceed 1.7 in order to avoid increased early bone loss (5). Meijer HJA et al. monitored the frequency of biomechanical complications associated with elevating this indicator. The data of the conducted study showed that there was no significant increase in marginal bone loss at values from 0.86 to 2.14 (6). This is confirmed by recent research carried out by Hämmerle CHF et al., where it was determined that from a biomechanical point of view, it is desirable for a crown-to-implant ratio to be in the range of 0.9 to 2.2 in single restorations (7).

Increasing this marker above certain limits may lead to mechanical complications due to overloading occlusal forces upon the marginal part of the alveolar bone, crest module and implant body. With its increase, the size of the non-axial forces rises, with which the crown acts as a lever arm. This creates a bending moment that carries stress to the marginal bone. Malchiodi L. et al. conducted a prospective study with a follow-up period of three years. The data point out that the ratio of crown height to dental implant length is the main parameter able to influence the clinical survival of dental implants. A critical value of 3.1:1 has been ascertained in which the marginal bone loss was so great that the implant osseointegration was destroyed (8).

Surprisingly, some studies have even reported feedback between the crown-to-implant ratio and marginal bone loss, recording low values at higher ratios (9). In some research, it is suggested that high values of the C/I ratios may provide a protective effect on the marginal bone (10). There are also publications according to which the extent of marginal bone loss is not related to this parameter (11,12,13,14).

It becomes clear that the crown-to-implant ratio should be subject to careful consideration in making the treatment plan in implant recovery. Its increase leads to a proportional rise in the mean stress on the retained screw and peri-implant bone. Heightening the ratio of 1:1 to 1.25:1 leads to intensifying the stress in the crystal module by 30.1%, respectively - in the ratio 1.5: 1 the stress is grown by 51.5% (15).

Material and methods

In the current study, 65 partially edentulous patients of the lower jaw in the area of mandibular molars have been retrospectively traced out. The distribution of the study group is as follows: 35 women and 30 men aged between 20 and 75 years at the time of implantation. The treatment was performed only with single implant-supported cemented crowns. The following indicators have been followed:

- anatomical characteristics in the implantation area - width, height and inclination of the available bone;
- implant characteristics - diameter, length and mesio-distal and vestibulo-lingual inclination;
- crown height space;
- crown-to-implant ratio;
- size of the marginal bone loss after the first and third years of the functional load of implant-supported prosthetic restorations.

We used the following criteria for selection and inclusion in the study:

- cases of one missing tooth in the lower molar region;
- patients with a width of available bone of more than 6.0 mm in the area of implantation and no periodontal diseases;
- patients without para-functional activity;
- non-smokers.

Criteria for exclusion from the study:

- radiotherapy;
- untreated oral pathology or malignant tumors;
- drug or alcohol dependence;
- intravenous bisphosphonate therapy;
- immunosuppression;

- inability to maintain adequate oral hygiene.

All implantations were performed after a preliminary occlusal analysis, including a study of parafunctional activity, occlusal scheme, supra- or infraocclusion, crown height space as well as inter-dental and intermaxillary relations.

Preoperative scanning of the edentulous area in a central occlusion was performed by means of cone-beam computed tomography (CBCT). Used equipment - Planmeca Pro X (Planmeca Oy, Asentajankatu 6, FIN-00880 Helsinki, Finland). The selection of optimal implant sites and measurements of available bone volume were made with Simplant Pro (Dentsply Sirona, Steinzeug Str., 50, 68229 Mannheim Germany). The width of the available bone was measured between the buccal and lingual bone plates along the crest of the alveolar ridge, and the available bone height was recorded from the crest of the alveolar ridge to the mandibular canal (Fig 2-A). The inclination of the planned dental implant position was measured depending on the occlusal plane in vestibulo-lingual direction (Fig 2-B) and in mesio-distal (Fig 2-C). The crown height space was measured from the crestal bone level to the crowns of the teeth-antagonists (Fig 2-D). All placed implants are "bone level" type - TBR Connect and TBR Periosave M (TBR Implants group, Toulouse, France) with a diameter of 4.0 mm - Connect, 3.9 mm - Periosave M and lengths in the range of 8.0 to 13.0 mm.

Resorption of marginal bone was measured by means of periapical radiographs using ImageJ 1.52 (National Institutes of Health, Bethesda, Maryland, USA). Each image was calibrated individually according to the diameter of the implant platform. The distance from the implant shoulder to the level of solid contact with bone, respectively from the medial and distal sides was recorded, by registering the mean value (Fig 3).

The statistical methods we have used are consistent with the nature of data and the nature of followed phenomena. Most of the indicators have no normal distribution, which necessitated using nonparametric methods of analysis. Descriptive methods of categorical and quantitative variables processing (mean, median, mode, standard deviation, minimum and maximum), cross tubulations, correlation analysis, as well as hypothesis testing methods have been applied.

Aim of the study:

The aim of current study was to determine whether the crown-to-implant ratio influences the size of the marginal bone loss around implant-supported single crowns after being functionally loaded.

Results

Most of the followed indicators do not have normal distribution, which necessitated the use of nonparametric analysis methods. In any case covered by the current study, the width of the alveolar bone was greater than or equal to 6.0 mm, i.e. - the condition for a minimum distance of 1.0 mm from the implant periphery by this indicator was strictly observed. In order to determine whether there is a difference in the level of the marginal bone loss compared to the width of the available bone Kruskal-Wallis test was used. The data from the conducted test indicate that there are no statistically significant differences between the mean ranks of the study groups - γ (2) (4) = 7.540, p = 0.110.

Vestibulo-lingual inclinations are reduced to the minimum possible, taking into account the anatomical conditions in the implantation area. The distribution of the cases is as follows: 0^{o} – 40.0%, from 10 to 15^{o} – 30.8%, from 15 to 25^{o} – 26.2% and over 25^{o} – 3.1%. Mesio-distal inclinations are consistent with achieving optimal positioning of the implant platform and with root inclinations of natural teeth. In most cases the inclination size is minimal: 0^{o} – 41.5%, from zero to five degrees – 43.1%, from five to ten degrees -13.8% and between ten and 15 degrees – 1.5%. To trace the influence of the implants inclination on the detected crestal resorption after the third year Kruskal- Wallis test was used. The results of the test showed that there was no statistically significant difference between the study groups - $\gamma^{(2)}$ (4) = 4.749, p < 0.314.

The data for the distribution of the crown-to-implant ratio were combined into five groups: 1.5:1 - 10.8%, 1.25:1 - 15.4%, 1:1 - 18.5%, 1:1.25 - 35.4% and 1:1.5 20.0%. Ratios larger than 1:1 were recorded in only 17 cases (26.2%). The mean value of the followed indicator was 0.871 compared to a standard deviation of 0.279.

After the first year of the functional load, we found low levels of marginal bone loss: 32 cases with 0.0 mm, 32 cases with crestal resorption to 1.0 mm and 1 with 1.2 mm. Mean values of the tracing indicator 0.254 with a standard deviation of 0.299.Сложете глагол в изречението!!! Recording this indicator after the third year, a slight increase in crestal resorption was found out in the following cases: 14 cases with 0.0 mm, 30 with 1.0 mm, 14 from 1.5 to 2.0 mm and one with 2.2 mm. The percentage distribution of these cases is presented in Fig 4.

Kruskal-Wallis test was applied in order to verify the hypothesis that the mean levels of marginal bone loss after the first year of the functional load of the single crowns is the same in the different ratios between the length of the crown and the implant. The results showed that there were statistically significant differences between the four study groups - $\gamma^{(2)}$ (4) = 19.92, p = 0.006. The same test was applied to the followed cases with crestal resorption after the third year in relation to the different crown-to-implant ratios. In these cases, we found as well statistically significant differences in the mean ranks between the different groups - $\gamma^{(2)}$ (5) = 24.639, $p < 0.001$. It is shown in Fig 5 the distribution of the marginal bone loss compared to the crown-to-implant ratio after the first and third years of the functional load. There is a slight increase in indicators monitored during the third year. This is most pronounced in cases when the crown-to-implant ratio is 1:1 and higher.

In order to investigate the association between the size of crestal resorption after the first and third years compared to the crown-to-implant ratio, Spearman rho rank correlation coefficient was used. The data from the conducted tests point out that there is a statistically significant relationship between the studied parameters - rho (65) = 0.276, p = 0.026 - for the reported values of marginal bone loss after the first year and rho (65) = 0.536, p <0.001 for those after the third year. The correlation signs are positive, which means that the higher the crown-to-implant ratio becomes, the higher the reported values of the marginal bone loss are.

Discussion

The current study results show that increasing the values of the crown-to-implant ratio has a statistically significant positive correlation with marginal bone loss around the implant. They confirm the conclusions of the study by Sotto-Maior BS et al. in which the effect of such indicator on the distribution of occlusal stress in the implant supported prosthetic restorations is being monitored. The data in it show that 22.47% of cortical bone stress is due to increased crown-to-implant ratios. Its values rise with the increase of this indicator (16). This dependence is also described in other prospective clinical studies (2, 17). In studies with the three-dimensional finite element analysis is also indicated that short implants create higher stress in bone around the implant (18, 19). They show that high crown-to-implant ratios affect both cortical and cancellous bone in and load. Therefore, in such situations, cantilevers should be avoided (20).

Our clinical data also confirm the results of Cinar D. and Imirzalioglu P., who determined applying the finite element method that the concentration and distribution of occlusal stress increases with the crown height (21). In a two-fold increase in the crown-to-implant ratio, the stress in von Mises' research increased by 47%, while with ratios close to 2: 1, the highest stress was observed in the implant crest module (21).

The results of the conducted study are in consistence with the data from the systematic review of the literature done by Garaicoa-Pazmiño et al. where it is revealed that the crown-to-implant ratio has an effect on marginal bone loss (10). Similar results are depicted in Malchiodi et al. research in the analysis of 259 short dental implants among 136 patients for a 36-month period of time. The authors ascertained a significant correlation between the clinical crown-to-implant ratio and the peri-implant bone loss, with the highest reported values at 2:1 ratios (8).

According to other studies, these ratios show a direct relationship to peri-implant bone stress, but the absolute height of the restorative space and the implant diameter have a greater influence upon crestal resorption. Lower stress values have been recorded for large-diameter implants, even in clinical cases with a long crown height space (22). It is essential to note that the increased height of the restorative space is directly related to the crown-to-implant ratios due to the anatomical implant length limitations in the distal parts of the jaws.

On the other hand, to determine the effect of this parameter on marginal bone loss, it is necessary to isolate the influence of additional factors such as surgical technique, height of the restorative space, type, length and diameter of the implant, its localization and bone quality (23). These factors also have an effect on marginal bone loss in the implant-supported restorations (24).

Conclusion

Within the current study, higher-ratio C/I implants show greater marginal bone loss in comparison with lower-ratio C/I implants in the posterior areas of the mandible. From a biomechanical point of view, the crown-to-implant ratio is an important parameter that can influence the success of the implant-supported restorations and the marginal bone loss. Therefore, it is of great essence to aim at a low C/I ratio in order to avoid excessive stress in the implant-bone interface, which may lead to increased crestal bone loss or implant failure.

Due to the limited amount of data, further research into the influence of crown-to-implant ratio on the marginal bone loss should be carried out under identical conditions.