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MONITORING OF THE HEALING PROCESS OF ORAL MUCOSA IN THE PERIIMPLANT AREA DURING THE POSTOPERATIVE PERIOD

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Despite high success rates, failures still occur at various observation periods of dental implantation. Therefore, the search for criteria to predict and prevent the risk of complications in dental implantation is naturally increasing. The purpose of this study was to investigate the characteristics of the peri-implant mucosal tissues after dental implant surgery during the healing phase. A total of 67 patients aged between 25 and 45 years were placed single dental implants. Signs of inflammation in the peri-implant area recorded included pain, hyperemia, and swelling on the 3rd, 7th, 10th, 14th, and 20th day. The performed study demonstrated a dependence of the mucosal condition in the operative intervention zone on its duration and a direct impact on the postoperative discomfort period experienced by patients.

Key words: dental implant, oral mucosa, early failure, risk factor, dentition defects, secondary adentia.

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МОНІТОРИНГ ПРОЦЕСУ ЗАГОЄННЯ СЛИЗОВОЇ ОБОЛОНКИ ПЕРІІМПЛАНТНОЇ ЗОНИ В ДИНАМІЦІ ПІСЛЯОПЕРАЦІЙНОГО ПЕРІОДУ

Незважаючи на високі рівні успішності дентальної імплантації, невдачі все ж таки трапляються в різні терміни спостережень. Тому природніми є підвищення пошук критеріїв прогнозування та профілактики ризику розвитку ускладнень дентальної імплантації. Метою роботи було дослідження особливостей стану слизової оболонки періімплантної зони після проведення операції дентальної імплантації на етапі загоєння. До проведення дослідження було залучено 67 пацієнтів у віці від 25 до 45 років, яким було встановлено поодинокі дентальні імплантати. Ознаками запалення періімплантної ділянки, які піддавалися реєстрації, були біль, гіперемія та набряк на 3, 7, 10, 14 та 20 добу. Проведене дослідження продемонструвало залежність стану слизової оболонки в зоні оперативного втручання від його тривалості і безпосередній вплив на період післяопераційного дискомфорту пацієнтів.

Ключові слова: дентальний імплантат, слизова оболонка порожнини рота, раннє відторгнення, фактори ризику, дефекти зубних рядів, вторинна адентія.

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Secondary adentia remains a relevant issue in modern dentistry. Even with the current achievements in dentistry, it is unfortunately impossible to completely prevent tooth loss for any reason. According to Shwetha R. et al., "even with improved access to dental care and a reduction in the prevalence of tooth loss in recent years, the frequency of anterior tooth loss in adults in Western countries remains at 25 %. A significant prevalence level of dentition defects (DD) has also been confirmed by domestic authors [11].

Patients with DD subsequently face a range of negative consequences associated specifically with the absence of teeth – from occlusal and masticatory function disturbances to the presence of digestive system diseases, psychological problems, and a reduced quality of life.

One of the options for modern dental care in such patients is placement of dental implants followed by fabrication of prosthetic constructions. Dental implantation (DI) continues to develop steadily and, as a result, has widespread implementation in practical dentistry (Alghamdi HS, Jansen JA., 2020). Due to DI, a new, more comfortable level of rehabilitation has become possible for patients with complete edentulism, with distally unlimited defects of the dentition, with the loss of anterior teeth, and in the presence of vital teeth adjacent to the missing ones.

The powerful development of materials and technologies for DI has permitted achieving high clinical results. For instance, according to a systematic review by Howe MS et al. (2019), the cumulative assessment of the 10-year survival rate of dental implants was 93.2 % [8]. In a randomized controlled trial by Gadzo N et al. (2023), the survival rate of implants from two leading manufacturers after 10 years was 100 %. But the presence of technical problems was recorded in a mean of 21.3 %, peri-implant mucositis in a mean of 39.9 %, and peri-implantitis was recorded in a mean of 3.2 % of patients [5].

Nearly forty years of experience have outlined not only the main advantages of dental implantation but also focused researchers' attention on preventing its early complications, including bleeding, hematoma formation, the development of local inflammatory and neurological conditions, and especially early

rejection or early failure (before physical load, within the next 2–3 months). However, it should be emphasized that the risk factors associated with these complications remain unclear up to this day [1]. Typically, patients find it difficult to assess mucosal inflammation; therefore, control visits are mandatory.

Therefore, a thorough and regular study of various tissues' condition in the peri-implant zone will permit to predict the integration of implants and create conditions for preventing the occurrence of complications not only in the near future, but also in the long term.

The purpose of the study was to investigate the characteristics of peri-implant mucosal tissues in young individuals after dental implant surgery during the healing phase, depending on the duration of the operative intervention.

Materials and methods. A total of 67 patients aged between 25 and 45 years were enrolled in the study, comprising 36 women (53.7 %) and 31 men (46.3 %), with a mean age of 37.7±5.7 years for women and 36.6±4.7 years for men, respectively ($p<0.05$). Patients of both genders were categorized into age groups as follows: 10 women (27.8 %) and 9 men (29.0 %) aged 25 to 34 years; 26 women (72.2 %) and 22 men (71.0 %) aged 34 to 45 years, indicating gender and age homogeneity of the groups ($p<0.05$) (Fig. 1).

All patients underwent the placement of single dental implants using the delayed implantation method in post-extraction sockets without augmentation procedures, involving mucosal flap detachment. The study included patients who attended all scheduled follow-up examinations, were systemically healthy or had controlled medical conditions, consented by signing informed consent, and had comparable indices of oral hygiene and indices of bone density in the jaws [6]. Patients with uncontrolled systemic pathology or bruxism were excluded from the study. Additionally, areas of previous implant failure were not used for operative intervention.

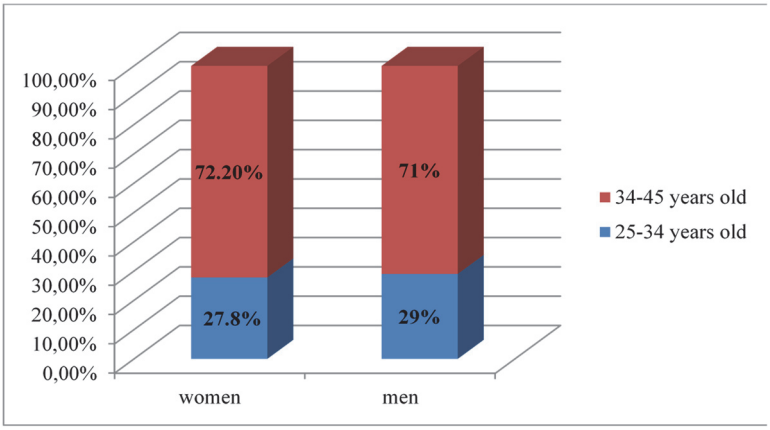

Fig. 1. Distribution diagram of patients by age, %.

All patients were prescribed identical postoperative wound care regimens for 10 days and standard postoperative pharmacological support for 5 days. Furthermore, instructions regarding oral post-surgery hygiene were provided (tooth brushing 24 hours after surgery; rinsing the oral cavity with a 0.12 % chlorhexidine solution after each meal for one week; using a soft toothbrush for six weeks and avoiding chewing or traumatizing the surgical sites for the first six weeks).

Patient management was performed in several stages: The first stage involved a thorough examination of the general condition (clinical and biochemical blood and urine tests) and dental status, including analysis of cone-beam computed tomography (CBCT) results to determine the bone condition in the intervention site, the precise location of the implant, and to assess its dimensions.

The second stage comprised the direct DI operation (short incisions on the alveolar ridge with subsequent mucosal flap detachment, placement of the dental implant, and suturing with polyamide threads 5-0 and 6-0). During this stage, the torque force for implant placement was determined using a torque wrench (35 Hcm)

The third stage involved evaluating the condition of the peri-implant zone. Signs of inflammation recorded included pain, hyperemia, and swelling of the peri-implant area. The condition of the mucosa in the surgical site was examined dynamically on the 3-rd, 7-th, 10-th, 14-th, and 20-th day of the post-operation period. Regarding the duration of the surgical intervention, the distribution was as follows: in 36 patients, the implant placement did not exceed 25 minutes, with a mean duration of 20.66±2.01 minutes ($p<0.01$). In the remaining 31 patients, the operative duration was longer than 25 minutes, with a mean duration of 28.41±2.07 minutes ($p<0.01$).

To assess the inflammation criterion "pain", a Visual Analog Scale (VAS) was used, designed to assess the dynamics of postoperative pain intensity. The VAS is a standardized, convenient, and simple tool for documenting and interpreting postoperative pain results, presented as a horizontal line with 11 points ranging from 0 to 10. Each point color-coded with varying shades of green, yellow, and red corresponding to increasing pain sensations [9]. VAS scores were interpreted as follows: 0 – no pain, 1-3 – mild pain, 4-6 – moderate pain, 7-9 – severe pain, 10 – unbearable pain.

Objective assessment of inflammation was performed by determining the degree of swelling and hyperemia. For the objective assessment of mucosal inflammation (based on the "hyperemia" criterion) in the postoperative area, the Shiler-Pisarev test was used, which involves treating the mucosa with "Lugol" solution and assessing the intensity of staining on a scale: absence of staining scored 1 point, slight staining – 2 points, pronounced staining – 3 points, and very intense staining – 4 points with color parallels.

Edema assessment (based on the "swelling" criterion) was performed using a scoring system as follows: 1 point – no inflammation (absence of intraoral and extraoral swelling); 2 points – mild degree (intraoral swelling in the surgical area); 3 points – moderate (extraoral swelling in the surgical area); 4 points – intense (extraoral swelling extending beyond the surgical area) [2].

To study the dependence of the selected inflammation parameters ("pain", "hyperemia", and "swelling") on the duration of the operation during different postoperative periods (on the 3-rd, 7-th, 10-th, 14-th, and 20-th day), linear regression coefficients were calculated as follows:

$$y = b_0 + b_1 \cdot t\,,$$

where b_0 – is the regression intercept, b_1 – is the regression coefficient, and t – is the duration R – the operation in minutes. Additionally, the multiple correlation coefficient R between the variations in t and the selected study parameters was evaluated. A correlation R is considered moderate if its value lies between 0.25 and 0.75. A strong correlation is observed when R values exceed 0.75. Calculations were performed using the "Statistica 14" software package by TIBCO Software Inc., "Multiple Regression" module.

The study fully complies with current ethical legislative standards and requirements for performing clinical research.

Results of the study and their discussion. Monitoring the healing process of the mucosa in the dental implant surgical site permitted the identification of specific local characteristics during the postoperative period, depending on the duration of the intervention. Analysis of changes in the inflammation criterion "pain" revealed that in patients with an operative duration of up to 25 minutes, the pain scores were 5.55±0.76, 3.66±1.02, and 1.55±0.89 on the 3-rd, 7-th, and 10-th days, respectively. On the 14-th day of observation, pain was at 0.11±0.39 points, and on the 20-th day, only one patient reported experiencing mild pain after eating.

In patients with longer operative durations, pain scores decreased from 7.74±1.24 points on the 3-rd day to 5.64±1.03 on the 7-th day, 3.64±1.12 on the 10-th day, 1.54±0.94 on the 14-th day, and 0.41±0.49 on the 20-th day. Statistically significant differences ($p<0.05$) in pain levels on the selected days, depending on the duration of the operative intervention, were not observed. However, the dynamics of changes in the inflammation criterion "pain" showed statistically significant differences between the pain levels on the 3-rd day and those in subsequent observation periods (with significance levels ranging from $p<0.001$ to $p<0.05$) in each patient group, regardless of the operative duration. Additionally, it should be noted that all patients, irrespective of the operative duration, reported the highest pain levels six hours post-operation and during the first three days thereafter.

The dynamics of changes in the mucosal condition based on the criterion "hyperemia" in the postoperative zone were as follows: in patients with shorter interventions, changes were observed on the 3-rd, 7-th, and 10-th days, with scores of 3.38±0.48, 2.28±0.48, and 1.22±0.41 points, respectively. In contrast, patients with longer operative durations exhibited changes in the mucosal condition based on the "hyperemia" criterion up to the 14-th day, with scores of 3.90±0.29, 3.00±0.23, 2.12±0.49, and 1.35±0.47 points on the 3-rd, 7-th, 10-th, and 14-th days, respectively. No statistically significant differences were found for the "hyperemia" criterion based on operative duration ($p<0.05$). Similar to the "pain" criterion, the difference between the scores on the 3-rd day and those in subsequent observation periods was statistically significant (with significance levels ranging from $p<0.001$ to $p<0.05$) in each patient group, regardless of the operative duration.

Finally, the dynamics of changes in the mucosal condition based on the "swelling" criterion in the dental implant surgical area were as follows: in patients with operative durations up to 25 minutes, swelling scores were 3.05±0.22, 2.02±0.16, and 1.05±0.22 points on the 3-rd, 7-th, and 10-th days, respectively. In patients with operative durations exceeding 25 minutes, changes in the mucosal condition based on the "swelling" criterion were observed up to the 14-th day, with scores of 3.67±0.46, 2.70±0.52, 2.29±0.57, and 1.35±0.47 points on the 3-rd, 7-th, 10-th, and 14-th days, respectively. No statistically significant differences were found for the "swelling" criterion based on operative duration ($p<0.05$). However, similar to the previous criteria "pain" and "hyperemia", the difference between the scores on the 3-rd day and those in subsequent observation periods was statistically significant (ranging from $p<0.001$ to $p<0.05$) in each patient group, regardless of the operative duration.

Considering the absence of statistically significant differences in inflammation indices based on operative duration when comparing mean values, we decided to test the hypothesis of the interrelationship between the selected indices and the duration of the operation by calculating linear regression and the multiple correlation coefficient.

As expected, a statistically significant linear dependence exists between the duration of the operation and the values of the parameters “pain”, “hyperemia”, and “swelling”: the longer the operation duration is, the higher are the values of the studied parameters, as it is graphically presented in Figs 2, 3, and 4.

It is noteworthy that the regression coefficient b_1 (slope of the regression line relative to t-axis) reaches a local maximum on the 10th day post-operation for all studied parameters, particularly noticeable for the parameters “hyperemia” and “swelling”. This can be explained by the maximal attenuation of inflammation signs during this period in patients with operative durations of less than 25 minutes. For instance, on the 10-th day, 8.3 % of such patients experienced no pain from the 8th or 9th day onwards, while the remaining 91.7 % reported mild pain associated only with active chewing (Figs. 3, 4).

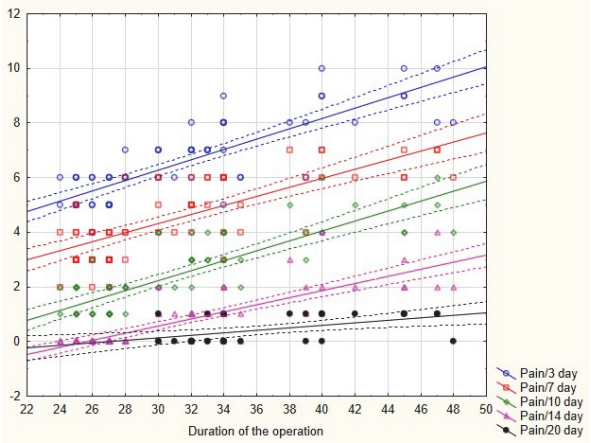

Fig. 2. Regression dependencies of pain scores during different postoperative periods on the duration of the operation. Solid lines represent linear regressions for the corresponding postoperative periods; dashed lines indicate confidence intervals for significance levels $p<0.05$.

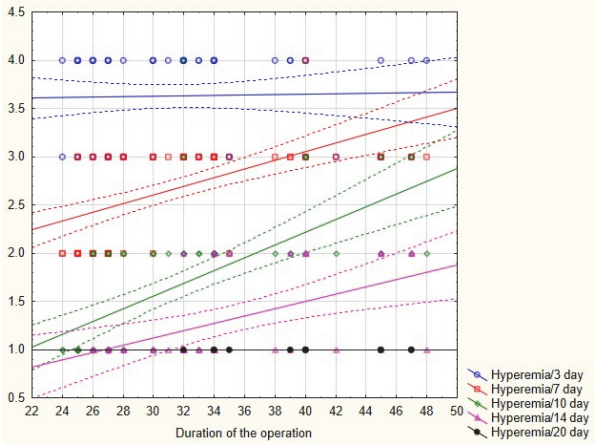

Fig. 3. Regression dependencies of hyperemia scores during different postoperative periods on the duration of the operation. Solid lines represent linear regressions for the corresponding postoperative periods; dashed lines indicate confidence intervals for significance levels $p<0.05$.

The “hyperemia” criterion was absent in 77.8 % of patients, while in the remaining 22.2 %, slight mucosal staining in the surgical area was observed.

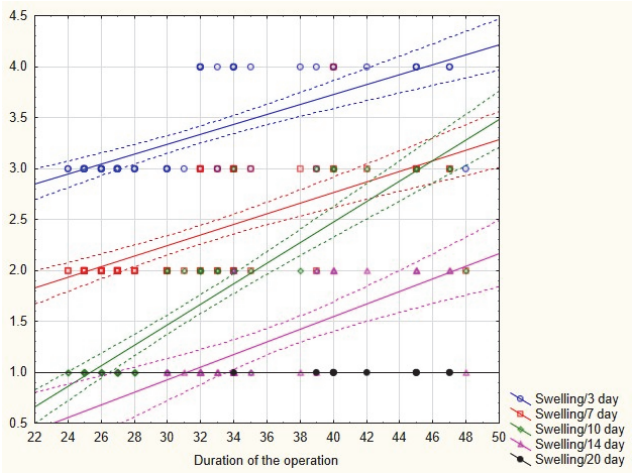

Fig. 4. Regression dependencies of swelling scores during different postoperative periods on the duration of the operation. Solid lines represent linear regressions for the corresponding postoperative periods; dashed lines indicate confidence intervals for significance levels $p<0.05$.

Regarding the “swelling” criterion, signs were absent in 91.7 % of patients whose operative duration was less than 25 minutes. In 51.6 % of patients with longer operative durations, periodic moderate pain persisted on the 10-th day of observation, while in the remaining patients, pain was mild. Signs of hyperemia were completely absent in 6.5 % of patients, present as slight mucosal staining directly around the suturing material in 81.4 %, and pronounced staining of the suturing material areas in only 12.1 %. Finally, regarding the “swelling” criterion, the distribution of patients mirrored that of the “hyperemia” criterion: 6.5 % had no swelling, 80.6 % experienced moderate swelling localized around the suturing material, and only 12.9 % exhibited signs of moderate swelling.

Thus, patients with shorter operative durations exhibited almost complete regression of operative consequences by the 10-th day of observation, whereas in the group with longer operative durations, the 10-th day was the last observation day still demonstrating minor signs of postoperative trauma to the mucosa in the implant placement area.

Statistical dependencies for the "hyperemia" parameter on the 20-th day, as well as for the "swelling" parameter on the 20-th day, could not be obtained because the corresponding values for all examined cases were identical and equal to the value of the regression intercept b_0.

The values of the multiple correlation coefficients R with their respective standard deviations are presented in Table 1.

Table 1

Values of multiple correlation coefficients *R* and their standard deviations for the parameters "Pain", "Hyperemia", and "Swelling"

Parameters	Observation day				
	3th day	7th day	10th day	14th day	20th day
Pain	0.823±0.071	0.753±0.082	0.805±0.074	0.830±0.071	0.515±0.156
Hyperemia	0.031±0.801	0.581±0.101	0.629±0.096	0.502±0.146	–
Swelling	0.682±0.091	0.671±0.092	0.868±0.062	0.711±0.131	–

As shown by the data, the correlation varies from moderate to strong, except for the 20-th day for the parameters "hyperemia" and "swelling", as well as the "hyperemia" parameter on the 3-rd day. This further confirms a significant dependence of the parameters "pain", "hyperemia", and "swelling" on the duration of the operative intervention. Correlation coefficients for the parameters "hyperemia" and "swelling" on the 20-th day of observation could not be obtained because the corresponding values for all cases were identical and equal to the regression intercept b_0. It should also be noted that this is due to the fact that the assessment of the "hyperemia" and "swelling" parameters was performed using a four-point scale, which undoubtedly limits the possibilities for a more detailed study of these indices.

Therefore, it is crucial to understand all the nuances of the healing process to adequately assess minimal changes that may lead to the development of DI complications. According to Wu X. et al. [14], a successful early healing process has a direct impact on the early survival of implants. This forms the basis for predicting outcomes and managing risks. In other words, thorough analysis of the condition of peri-implant tissues during the healing stages can be used to predict DI results, manage its risks, minimize undesirable consequences of the operative intervention, and importantly, ensure the clinician a satisfactory level of professional achievement.

Our study demonstrated a dependence of the mucosal condition in the operative intervention zone on its duration and a direct impact on the postoperative discomfort period experienced by patients. Objective data from the study indicate that the highest levels of postoperative swelling and pain occurred during the first three days, regardless of the intervention duration. These findings are consistent with results from other researchers. For instance, Wang M. et al., Afrashtehfar KI., and Wu X. et al. [2, 13, 15] reported moderate to severe postoperative pain within the first 24 hours after surgery. We also emphasized the subjective aspects of the study. Specifically, according to patients, criteria such as "pain" and "swelling" reached their highest levels on the day following the operation, aligning with findings from other researchers [2, 7].

Regarding the healing time periods of the peri-implant area, they were observed to range from 7 to 14 days, depending on the duration of the operative intervention, which is consistent with data obtained by Sculean A. et al. (2014). Furthermore, the authors suggested that clinical symptoms of early mucosal healing after dental implant placement may indicate a tendency for the healing of other tissues around the implant.

Today, there is no doubt about the rapid development of dental implantation, which has made significant achievements in both materials and technologies and techniques to achieve the most desirable clinical results for each patient [10]. However, despite high success rates, failures still occur due to various reasons and at different observation periods, including early failures before the fixation of the prosthetic construction. Therefore, there is a natural increase in the demand for tools to prevent and assess the risk of DI complications [4].

An interesting study by S.D. Varzhapetian et al. [12] concluded, based on a retrospective analysis of current literature sources, that the probability of reoperation increases as the number of implants decreases, reaching its maximum when 1–2 implants are placed.

Undoubtedly, the high risk of implant failure is associated with many local, systemic, or iatrogenic factors. These include smoking and alcohol use, somatic pathology, periodontal tissue diseases, inadequate hygiene levels, daytime and nighttime bruxism, infection at the implant site, characteristics of the implant system, insufficient volume or poor quality of the alveolar bone, anatomical localization (e.g., the posterior upper jaw), which are also associated with reduced implant survival rates (Schwarz F., Ramanauskaite A.,

2022; Grigoras RI et al., 2024; Wu X. et al., 2022; Kochar SP et al., 2024). Additionally, the trauma and overheating of the bone bed during the intervention, wound suppuration, and the qualification of the implantologist are considered important by these researchers. Thus, the importance of preventing early implant failure is indisputable and requires in-depth study.

Conclusions

1. The performed study confirmed the presence of a direct linear dependence between the severity of the postoperative period and the duration of the operative intervention. The correlation of the scores for levels of pain, hyperemia, and swelling with the duration of the operative intervention, in the vast majority of cases (in 12 out of 15 cases, or 80 %), ranged from moderate to strong.

2. It was found that in patients with an operative intervention duration of less than 25 minutes, almost complete regression of operative consequences occurred by the 10-th day of observation. For patients with longer operative durations, the 10-th day was the last observation day still demonstrating minor signs of postoperative mucosal trauma.

Prospects for further research involve an in-depth study of various tissue healing aspects in the peri-implant zone and their influence on implant integration.

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