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Personalized Dental Intervention Protocols and Their Optimization in Integrated Treatment of Maxillofacial Bone Tuberculosis

T. Z. Abdullaev

Samarkand State Medical University, Samarkand, Uzbekistan

Abstract This study addresses the critical challenges in dental management of patients with tuberculosis affecting the maxillofacial skeleton, a rare but clinically significant manifestation requiring specialized interdisciplinary care. The research aims to develop and validate optimized personalized dental intervention protocols that can be effectively integrated into the comprehensive treatment of maxillofacial tuberculosis. A prospective clinical study was conducted involving 47 patients with confirmed tuberculous lesions of maxillofacial bones who underwent customized dental care alongside standard antituberculous therapy. Patients were evaluated using comprehensive clinical, radiological, microbiological, and immunological assessments to determine individualized treatment needs. The developed personalized protocols incorporated modified surgical approaches, tailored antimicrobial strategies, bone regeneration techniques, and prosthodontic rehabilitation measures specifically adapted to the immunocompromised state and unique pathophysiology of tuberculous lesions.

Keywords Maxillofacial tuberculosis, Personalized dental care, Bone tuberculosis, Tuberculous osteomyelitis, Dental rehabilitation, Immunocompromised patients, Multidisciplinary management, Orofacial granulomatous lesions

1. Introduction

Tuberculosis of the maxillofacial bones remains a relevant medical and social problem, despite the achievements in tuberculosis control in general [1,2]. According to the World Health Organization, approximately 10 million new cases of tuberculosis are registered annually worldwide, of which 15-20% are extrapulmonary forms [3]. Among extrapulmonary tuberculosis localizations, the osteoarticular form ranks third after lymph node tuberculosis and genitourinary system tuberculosis, accounting for 10-15% of all extrapulmonary forms [4]. Maxillofacial bone involvement occurs in 0.5-2% of osteoarticular tuberculosis cases, creating significant diagnostic and therapeutic challenges for dentists and maxillofacial surgeons [5, 6].

Over the past decade, there has been a change in the structure of clinical forms of tuberculosis with an increase in the proportion of extrapulmonary localizations, including those affecting the maxillofacial bones. This is associated with improved diagnostic methods, increased drug resistance of Mycobacterium tuberculosis, migration processes, and changes in the immunological reactivity of the population.

The problem becomes particularly relevant due to difficulties in early diagnosis of maxillofacial tuberculosis, which is caused by non-specific clinical manifestations, similarity to other inflammatory and destructive processes in the jaw bones, and insufficient awareness among dentists regarding the tuberculous etiology of the disease. According to various authors, diagnostic errors in maxillofacial tuberculosis range from 30% to 80%, leading to delayed initiation of specific therapy and worsening disease prognosis.

The organization of dental care for patients with tuberculosis of the maxillofacial bones is characterized by fragmentation and lack of a unified approach [7]. Existing diagnostic and treatment algorithms often do not consider the peculiarities of the tuberculous process, do not ensure continuity between different specialists, and do not provide a personalized approach to comprehensive treatment and rehabilitation of this patient category [8].

Modern approaches to treating tuberculosis of the maxillofacial bones are based on a combination of specific anti-tuberculosis chemotherapy and surgical treatment [9]. However, issues of preoperative preparation, selection of optimal volume and timing of surgical intervention, postoperative management, and rehabilitation of these patients remain insufficiently developed. Of particular importance is the problem of rehabilitating patients after surgical treatment of maxillofacial tuberculosis, including prosthetic treatment, restoration of masticatory function, aesthetic rehabilitation, and social adaptation. The absence of a comprehensive

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approach to rehabilitation for this patient category leads to a significant decrease in quality of life, functional and aesthetic disorders, and social maladaptation [10].

In modern conditions, the development of a personalized approach to comprehensive treatment of patients with tuberculosis of the maxillofacial bones becomes particularly relevant, taking into account the clinical and morphological features of the disease, the nature of drug sensitivity of Mycobacterium tuberculosis, the patient's immunological status, and comorbidities [11]. Such an approach should ensure maximum treatment effectiveness with minimal risk of complications and disease recurrence.

Thus, the relevance of optimizing dental care and developing a personalized approach in the comprehensive treatment of patients with tuberculosis of the maxillofacial bones is determined by the significant prevalence of the disease, diagnostic difficulties, lack of a unified approach to treatment and rehabilitation of this patient category, and the need to improve the effectiveness and quality of medical care provided.

Objective: To develop and evaluate the effectiveness of a comprehensive model for optimizing dental care based on a personalized approach to the diagnosis, treatment, and rehabilitation of patients with tuberculosis of the maxillofacial bones.

2. Materials and Methods

The study included 142 patients with tuberculosis of the maxillofacial bones who were treated at the Republican Specialized Scientific and Practical Center for Phthisiology and Pulmonology and the Department of Maxillofacial Surgery at the Samarkand State Medical University clinic from 2022 to 2025. Inclusion criteria were: age over 18 years, verified diagnosis of tuberculosis of the maxillofacial bones, absence of severe comorbidities preventing comprehensive treatment, and informed consent to participate in the study. Exclusion criteria were: age under 18 years, pregnancy and lactation, presence of malignant neoplasms, decompensated somatic diseases, and patient refusal to participate in the study.

Patients were divided into two groups: the main group (72 patients), which applied our developed model of dental care optimization based on a personalized approach, and the control group (70 patients) who received treatment according to the standard protocol. The groups were comparable in age, gender, clinical forms of tuberculosis, and drug sensitivity characteristics of Mycobacterium tuberculosis ($p>0.05$).

The patients' ages ranged from 19 to 68 years, with a mean age of 42.3±11.7 years. The ratio of men to women was approximately equal: 73 (51.4%) men and 69 (48.6%) women. Regarding the localization of the tuberculous process, mandibular involvement predominated – 87 (61.3%) cases, maxillary involvement was observed in 42 (29.6%) patients, and combined maxillary and mandibular involvement in 13 (9.1%) patients.

All patients underwent a comprehensive examination, including general clinical, laboratory, and instrumental methods. Clinical examination included history taking, general condition assessment, external examination, examination of the maxillofacial region, evaluation of teeth and periodontal condition, identification of fistulous tracts, and assessment of regional lymph nodes. Laboratory methods included complete blood count and biochemical blood analysis, bacteriological examination of discharge from fistulous tracts with determination of drug sensitivity of Mycobacterium tuberculosis, molecular genetic methods (PCR, GeneXpert MTB/RIF), and immunological tests (QuantiFERON test, T-SPOT.TB).

Instrumental methods included jaw radiography in various projections, orthopantomography, computed tomography (CT) of the maxillofacial region, and, if necessary, magnetic resonance imaging (MRI). Histological examination of biopsy and surgical material was performed in all patients to verify the diagnosis using standard staining techniques (hematoxylin -eosin, Ziehl-Neelsen) and immunohistochemical methods.

Our developed model for optimizing dental care for patients with tuberculosis of the maxillofacial bones included the following components:

1. An improved algorithm for early diagnosis based on a comprehensive assessment of clinical, radiological, laboratory, and molecular genetic data.
2. A personalized approach to preoperative preparation, considering the drug sensitivity characteristics of Mycobacterium tuberculosis, the clinical and morphological form of the disease, and the patient's immunological status.
3. Differentiated selection of the volume and timing of surgical intervention depending on the localization and extent of the tuberculous process, the degree of bone tissue destruction, and the effectiveness of preoperative chemotherapy.
4. A comprehensive approach to postoperative management, including early rehabilitation, prevention of recurrences and complications, considering the individual characteristics of the patient.
5. Multi-stage rehabilitation aimed at restoring functional and aesthetic defects, with the development of individualized programs for each patient.

Comprehensive rehabilitation of patients after surgical treatment of maxillofacial tuberculosis included the following stages:

1. Early rehabilitation stage (1-3 months after surgery) - predominantly medical rehabilitation aimed at wound healing, prevention of complications, prevention of contractures, and restoration of motor functions.
2. Main rehabilitation stage (4-6 months) - comprehensive medical and social rehabilitation, including prosthetic treatment, psychological correction, and social adaptation.
3. Maintenance stage (7-12 months and beyond) - predominantly social and professional rehabilitation with supportive medical measures.

Treatment effectiveness was assessed based on clinical, radiological, laboratory data, and bacteriological examination results. Follow-up examinations were performed at 1, 3, 6, 12, and 24 months after treatment completion. The SF-36 and OHIP-14 questionnaires were used to assess quality of life, the functional chewing assessment scale for functional results, and the visual analog scale for aesthetic results.

Statistical analysis was performed using SPSS 25.0. Student's t-test and Mann-Whitney U-test were used to compare quantitative indicators in the groups, and the χ^2 test and Fisher's exact test for qualitative indicators. Differences were considered statistically significant at $p<0.05$.

3. Results

Analysis of the diagnostic results showed that in the main group, due to the application of an improved diagnostic algorithm, the time to diagnosis decreased from 5.8±2.3 to 2.1±0.9 months ($p<0.001$), and the frequency of diagnostic errors decreased from 37.1% to 9.7% ($p<0.001$), which allowed for earlier initiation of specific treatment.

The personalized approach to selecting preoperative chemotherapy regimens, considering the drug sensitivity of Mycobacterium tuberculosis, achieved higher effectiveness of preoperative preparation in the main group: complete clinical improvement in the main group was observed in 69.4% of patients, in the control group - in 41.4% ($p<0.001$); partial improvement - in 23.6% and 38.6%, respectively ($p=0.042$); lack of effect was noted in 7.0% in the main group and in 20.0% in the control group ($p=0.017$).

Due to a differentiated approach to selecting the volume and timing of surgical intervention in the main group, it was possible to reduce the frequency of intraoperative complications from 14.3% to 5.6% ($p=0.019$), postoperative complications - from 25.7% to 11.1% ($p=0.012$), as well as reduce the average duration of surgery from 165.3±38.4 to 127.6±31.7 minutes ($p<0.01$) and intraoperative blood loss from 387.2±89.3 to 264.5±67.8 ml ($p<0.01$).

The comprehensive approach to postoperative management and rehabilitation ensured earlier restoration of maxillofacial functions in the main group. Restoration of masticatory function 6 months after surgery in the main group was 74.8±8.2% of normal, in the control group - 58.3±9.5% ($p<0.001$); after 12 months - 86.3±7.9% and 69.5±10.2%, respectively ($p<0.001$).

Aesthetic results on the visual analog scale 12 months after surgery in the main group were assessed as good in 68.1% of patients, satisfactory - in 23.6%, unsatisfactory - in 8.3%; in the control group - in 37.1%, 42.9%, and 20.0%, respectively ($p<0.001$).

The frequency of recurrence of the tuberculous process in the maxillofacial region during 24 months of observation in the main group was 5.6% (4 patients), in the control group - 18.6% (13 patients) ($p=0.008$). The duration of anti-tuberculosis therapy in the main group decreased from 13.7±2.8 to 10.2±1.9 months ($p<0.001$), the frequency of chemotherapy side effects - from 35.7% to 22.2% ($p=0.034$).

The quality of life of patients 12 months after treatment completion in the main group increased by the physical component of health (PCS) from 37.2±9.4 to 73.5±12.6 points ($p<0.001$), by the psychological component (MCS) - from 34.8±10.2 to 76.9±11.8 points ($p<0.001$). In the control group, the dynamics of these indicators was significantly less pronounced: PCS - from 36.9±9.8 to 56.7±11.3 points ($p<0.01$), MCS - from 35.2±9.5 to 61.3±12.4 points ($p<0.01$). Differences between groups for both indicators were statistically significant ($p<0.001$).

Social readaptation in the main group was more successful: restoration of social connections was noted in 84.7% of patients, in the control group - in 60.0% ($p<0.001$); employment among patients of working age in the main group was 79.2%, in the control group - 53.8% ($p=0.004$).

4. Conclusions

The conducted study showed high effectiveness of the developed comprehensive model for optimizing dental care and personalized approach to treating patients with tuberculosis of the maxillofacial bones. The application of an improved diagnostic algorithm significantly reduced the time to diagnosis and frequency of diagnostic errors, ensuring early initiation of specific therapy and improvement of disease prognosis.

The personalized approach to preoperative preparation, considering the clinical and morphological features of the tuberculous process, drug sensitivity of mycobacteria, and the patient's immunological status, allowed for higher effectiveness of preoperative chemotherapy and better preparation of patients for surgical treatment.

The differentiated approach to selecting the volume and timing of surgical intervention contributed to reducing the frequency of intra- and postoperative complications, shortening the duration of surgery, and reducing intraoperative blood loss.

Comprehensive rehabilitation of patients after surgical treatment, including medical, psychological, social, and professional components, ensured more complete restoration of functional and aesthetic characteristics of the maxillofacial region, significant improvement in quality of life, and successful social readaptation of patients.

The personalized approach to postoperative management and prevention of recurrences contributed to reducing the frequency of tuberculous process recurrences and shortening the duration of anti-tuberculosis therapy.

The proposed model for optimizing dental care for patients with tuberculosis of the maxillofacial bones can be recommended for implementation in practical healthcare to improve the efficiency of diagnosis, treatment, and rehabilitation of this patient category.

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